Transporting spent fuel – considerations for safety

From the United States, a review of why the past promotes high standards for the future

by Robert M. Jefferson

In our society today the transportation of radioactive materials, and most particularly spent reactor fuel, is surrounded by considerable emotion and wealth of information, good and bad.

In the United States, transportation of these materials is viewed as unique and distinct from the transportation of other hazardous materials and as a particularly vulnerable component of nuclear power activities. Added to this is the concept, widely held, that almost everyone is an expert on the transportation of radioactive materials.

One significant contribution to this level of emotion is the notion that all roads (rail and highway), on which these goods will be transported, somehow traverse everyone's backyard. The issue of the transportation of spent fuel has thus become a political battleground.

In order that those involved in the discussion of this activity might be able to reach some rational conclusions, this article offers some background information that might be useful to a broad range of individuals in developing their own perspectives. The intent is to address the safety of transporting spent fuel from a technical standpoint without the emotional content frequently a part of this argument.

Classical safety approaches

To address the subject of safety, three classic approaches are available. Obviously one is to look at the past history of transporting any particular commodity and evaluate safety on the basis of experience. Another approach widely used is to analytically approach the subject by combining the various elements of risk involved and assessing them in light of consequences attached to each risk level. A third perspective can be achieved by reviewing available safety research to determine if it might reveal information that would either augment or alter the experience or analysis.

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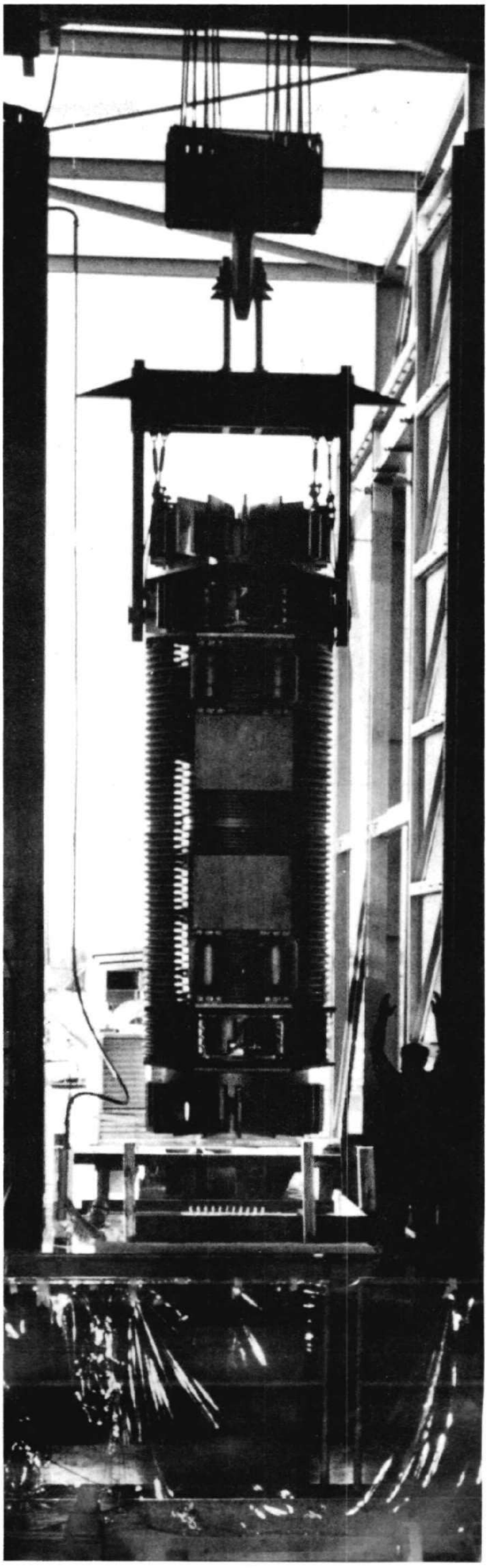

A 70-tonne spent-fuel shipping cask is lowered into an unloading pit. (Credit: Atomic Industrial Forum, Inc.)

Statistical Breakdown

It is interesting to break down radioactive material shipments by categories. Two-thirds of the two million packages involve the shipment of radioisotopes used in the medical industry. These include such things as radiopharmaceuticals, radiodiagnostic sources, and teletherapy sources ranging from the microcurie quantities at one extreme to thousands of curies at the other.

Industrial applications of radioisotopes account for approximately one-eighth of all the packages moved every year in the United States. These include such things as field radiography sources, so useful to the construction of high-rise buildings and bridges, well logging sources, widely used in the oil and gas industry, and a broad application of what are called DXT gages, or density-time-thickness gages. All of the strip steel, sheet plastic, cigarettes, and most of the paper produced in the USA depend on DXT gaging.

About one-sixth of the total number of packages of radioactive materials moved every year fall into a miscellaneous category. This includes a variety of applications ranging from consumer goods like smoke detectors and watch dials, to items like luminous exit signs, and similar low-level radioactive materials.

The remaining application is nuclear power which accounts for one-twenty-fifth of all the packages of radioactive materials moved in the United States at the present time. These movements include the shipment of low-level radioactive wastes produced in the nuclear industry, radioactive sources used in a variety of applications and, of course, spent reactor fuel.

While the distribution of packages indicates that nuclear power contributes a rather insignificant part of the total activity, (i.e., the number of packages being moved), it is widely believed that the total number of curies shipped by these various activities is almost totally dominated by the nuclear power activity. Recent studies indicate that this is also not the case.

If these same four categories are analysed from the standpoint of the total number of curies shipped, then the medical profession accounts for one-eighth (12.2%) of all the activity, industrial applications account for six-sevenths (85.4%) of the curies, the miscellaneous category covers one-one-hundredth of the radioactivity (1%), leaving nuclear power (including spent fuel movements) to account for only one-seventieth (1.4%) of the curies shipped every year.*

* *Transport of Radioactive Material in the United States: Results of a Survey to Determine the Magnitude and Characteristics of Domestic, Unclassified Shipments of Radioactive Materials*, by H.S. Javits, T.K. Layman, E. Maxwell, E.L. Myers, C.K. Thompson, SRI International, Menlo Park, Calif. (November 1984).

Profile of annual radioactive material shipments in USA

	No. of packages*	Percent of total*	Average curies per package
By end use			
Medical applications	1 640 000	67.4	5.29
Miscellaneous/unspecified	362 700	15.0	0.049
General industrial	219 000	9.0	246.0
Power	95 200	3.9	10.4
Radiography	79 200	3.3	57.9
Waste	18 500	0.8	0.84
Research/academic	17 500	0.7	0.71
Total	2 432 100		
By package type			
Type-A	1 700 000	69.8	0.541
Limited quantity	446 900	18.3	0.044
Low specific activity	191 000	7.8	0.659
Type-B	88 000	3.6	746.0
Unspecified	6 000	0.3	1.16
Type-B/large quantity	2 700	0.1	587.0
Total	2 434 600		
By primary travel mode			
Highway	1 880 000	76.8	35.3
Air	544 000	22.6	3.5
Mail (postal system)	5 900	0.24	0.02
Rail	3 400	0.14	0.15
Other	2 900	0.12	15.8
Total	2 436 200		

* Percentages and totals are rounded and consequently reflect some variances.

Source: Sandia National Laboratories, Report 83-2668, TTC-0542 (September 1984).

Unfortunately, using these approaches individually, or combined, will rarely satisfy all those expressing concern about the transportation of spent fuel. To address those lingering concerns not explicitly covered by these three classic approaches, this article also looks at a class of considerations generically called, "What Ifs." (See accompanying box on page 10.)

Perspective of past experience

A prevalent concept concerning the transportation of spent fuel is that somehow this activity is going to produce a significant increase in the number of hazardous material shipments. It is important, therefore, to look at the enormous scope of the transportation activity in the United States.

It has been estimated that approximately one person in five is employed in some manner or activity involving the transportation of people, goods, and materials. Another reference point might be the fact that there are approximately 500 billion (one-half trillion) packages of all commodities transported in the United States every year.

Of these half-a-trillion packages, approximately 100 million contain hazardous materials of one sort or another. This would include such things as flammables, combustibles, explosives, toxins, and radioactive materials. The radioactive component is made up of approximately two million packages per year; thus, radioactive material transport constitutes only about 2% of the total transportation activity of hazardous materials in the US.*

Spent fuel facts

Since 1964, when the US began shipping spent fuel, there have been an average of 291 shipments per year. The highest number of spent-fuel shipments projected by any analytical base published to date indicates that this would reach a maximum of about 9000 shipments per year when a repository is fully operational, with the equilibrium most likely being approximately one-half of that magnitude, or about 4500 annual shipments.**

This projection, taken in concert with projections based on the increased use of radioactive materials in industry and medicine, would indicate that nuclear power's share of the total number of curies shipped will continue to be relatively small. Further, it is important to realize that spent fuel is being transported at the present time, and has been transported for the past 20 years. Somewhere around 5000 spent fuel elements already have been moved.*

This experience base can be expanded further when you include other radioactive materials that have been moving in the US since 1944. It is this base of experience which allows us to evaluate, at least in one respect, the relative safety of transporting radioactive materials and spent fuel in particular. Further, the Department of Transportation initiated a programme, called the "Hazardous Material Incident Reporting System", at the beginning of 1971. Data from that compilation, augmented by inputs from other sources, provide an accurate evaluation of the accident history involving radioactive material transportation.

Accident experience: packages survive

Between 1971–81 there were a total of 108 accidents involving vehicles carrying radioactive materials. While later data is available, the accident rate has not changed as compared to that 11-year period. These 108 accidents were divided into the following categories. Twenty-six involved low-level wastes generated by all segments of the industry. Twenty-four of these accidents involved industrial radiographic sources being moved to or from job sites. Eighteen of the accidents involved medical sources. Thirty-six involved raw materials such as uranium ore or yellow-cake. The remaining four accidents involved spent-fuel casks (two of which were empty at the time of the accidents).**

There is another way to look at this spectrum of accidents: These 108 accidents involved 1198 packages of radioactive materials. Of these, 861 were in a category called "strong tight", which is the type of container in which low-level materials are shipped, such as yellow-cake and consumer products like smoke detectors. Of these 861 packages, 56 were damaged in the accident to the point where they released some radioactive material. For example, 28 of the 56 were involved in one single accident in Colorado when a truck carrying drums of yellow-cake (U_3O_8) hit a horse and overturned along the side of the highway rupturing the drums. Even so, a total of 56 releases out of 861 packages represents a 93.5% survivability rate for a package type that is used in general commerce.

For materials of a slightly higher activity, it is required to use a type-A package designed to survive the normal rigours of transport. The design conditions for type-A packages specified in the regulations are intended to assure that during accident-free transportation the package does not release any of its contents.

These criteria do not insure that the package will survive accidents. However, of the 286 type-A packages

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* *Transport of Radioactive Material in the United States: Results of a Survey to Determine the Magnitude and Characteristics of Domestic, Unclassified Shipments of Radioactive Materials,* by H.S. Javits, T.K. Layman, E. Maxwell, E.L. Myers, C.K. Thompson, SRI International, Menlo Park, Calif., (November 1984).

** *Social and Economic Aspects of Radioactive Waste Disposal,* National Research Council, National Academy Press, Washington, D.C. (1984) p. 69.

* See "Commercial Experience in the Transportation of Spent Fuel in the United States", by R.M. Jefferson and J.D. McClure, *IAEA Bulletin,* Vol.21, No.6, December 1979.

** *Radioactive Material (RAM) Accident/Incident Data Analysis Program,* by E.L. Emerson and J.D. McClure, SAND82-2156, TTC-0385, Sandia National Laboratories (September 1983).

involved in accidents during the referenced period, only five released radioactive material into the environment, for a survivability of 98.25%. Both the type-A and the "strong tight" packages are used to transport limited quantities of materials, which if released would *not* constitute a significant hazard to the public.

Radioactive releases: none

The remaining 50 packages involved in the 108 accidents were what are called type-B packages. These are packages used to transport higher-level radioactive materials including spent fuel, and are designed to survive accident conditions without release of their contents.

Of the 50 type-B containers involved in accidents, none released radioactive material. While these data apply specifically to the United States, it is important to note that accident experience involving type-B containers is uniform throughout the Western world.

In the 40 years of transporting high-level radioactive materials, there have been no deaths or injuries incurred as a result of the radioactive nature of the materials of any kind. Further, there has never been a release from a type-B package as a result of a vehicular accident.*

It is an interesting comparison to note that during the same 40 years in the United States, there have been roughly 1100 deaths directly attributable to the hazardous nature of gasoline being transported.** A large number of similar problems with chlorine, ammonia, PVC, and other hazardous materials can also be cited.

The perception of the safety of transferring high-level radioactive materials suffers by extrapolation from the experience of other hazardous materials, which are not transported in accident-resistant packages. Thus, the safety of transporting spent fuel, from an historical perspective, has proven to be very much greater than the safety of transporting other hazardous materials.

An analytical approach: the hazards

It has become popular in the United States today to analyse the *risk* of any activity based upon statistical information and projections combined with a review of the *consequences* that might develop from activities of various kinds. This same kind of analysis has been done in the field of transporting radioactive material and has produced some rather interesting results.

These studies – based on what are generally believed to be conservative assumptions – would indicate that the accident-free transportation of all radioactive materials throughout the US would, on average, produce radiation exposures of those persons less than one-half millirem per person, per year. This contrasts with an average background radiation from soil, building materials, foods, and cosmic radiation of approximately 160 millirem per year. Even the maximum exposed individual under accident-free conditions would only receive 16 millirem per year.

When accidents are introduced into this analysis, the average exposure level of the population at risk goes up by somewhere between 0.005 millirem to 0.0005 millirem.* In other words, accidents contribute an additional risk to the average individual of only about one-one-thousandth that of the accident-free activity.

It is important to understand that the very same accidents envisioned to threaten the integrity of the package also involve mechanical deaths and injuries. In other words, people are killed and injured in traffic accidents involving radioactive material shipments in which the nature of the cargo has absolutely nothing to do with the consequences of the accident. When one compares the mechanical risk with the radiological risk of transporting radioactive materials, the mechanical risk is on the order of 100 to 1000 times as high as the radiological risk.

It is on this basis that the transportation of high-level materials, such as spent fuel, is carried out under federal regulations that attempt to minimize total distance travelled and thereby to minimize the risk of mechanical death and injuries.** This same approach, not surprisingly, further reduces the already small radiological risk as well.

Thus, the analytical tools used to evaluate risk in this activity, and others as well, indicate that the hazards to which the public is exposed arising from the transportation of radioactive materials, including spent fuel, are considerably below those risks commonly accepted in the transport of people, goods, and services in general.

Safety research: the tests

Since the early 1970s, there has been a growing research effort in the safety area of transporting radioactive materials to evaluate the effectiveness of materials used in the design and construction of packages, to review the adequacy of design tools, to collect data to define risk analysis, and to evaluate the adequacy of existing regulations.

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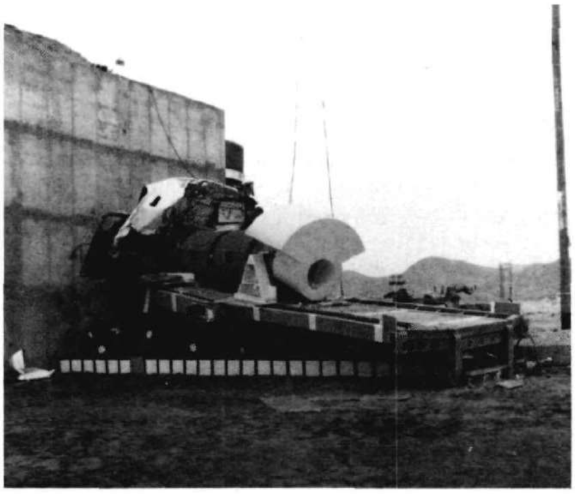
* See "The Role of the International Atomic Energy Agency", by Morris Rosen, and "Design & Safety of Flasks", by R.M. Jefferson in *The Urban Transport of Irradiated Fuel*, MacMillan Press, Long (1984); and *Transportation Accident Scenarios for Commercial Spent Fuel*, by E.L. Wilmot, SAND80-2124, TTC-0156, Sandia National Laboratories (February 1981).

** Private communication with R. Rawl, US Department of Transportation.

* See *A Nuclear Waste Primer*, League of Women Voters, Publication No.391, Washington, D.C. (1980); and *A Preliminary Cost and Risk Analysis for Transporting Spent Fuel and High-level Wastes to Candidate Repository Sites*, by K.S. Neuhauser, J.W. Cashwell, P.C. Reardon, and G.W. McNair, SAND84-1795, TTC-0506, Sandia National Laboratories (October 1984), for discussion of radiation exposures.

** *Federal Register*, Docket No. HM 164, Vol.46, No.12, January 19 (1981) pp. 5298–5318.



Crash, burn, and drop tests more demanding than actual transportation environments are among the torture trials spent-fuel casks have survived, with essentially no loss of containment and no significant reduction in shielding. (Credit: Atomic Industrial Forum, Inc.)

Since the adequacy of regulations frequently come into question, there has been a substantial effort to explore that area. For instance, one frequently voiced complaint about the regulations is that the design criteria intended to encompass accident conditions specifies a 30-foot drop (about 9 metres) onto an unyielding surface. A very simple calculation quickly reveals that a 30-foot drop translates into a 30 mile-per-hour (mph) impact.

Obviously there are a large number of potential accidents occurring at speeds above 30 mph (about 50 kilometres per hour); even with the 55 mph speed limits in the USA, everyone has the occasional experience of being passed by a truck going 60 or 70 mph (even occasionally 80 mph). The key to this design criterion is the unyielding target.

The unyielding surface: how tough?

The regulations define an unyielding target as a concrete body that weighs a minimum of ten times the weight of the package being dropped on it and is surfaced with a minimum of two inches (about 5 centimetres) of steel emplaced when the concrete is still wet and vibrated to eliminate air pockets between the two.* Those tests conducted in the US on unyielding targets are most frequently performed at a facility at the Oak Ridge National Laboratories in Oak Ridge, Tennessee. The target at this location consists of 1.2 million pounds (about 545 000 kilos) of concrete poured into a pit in the ground and topped with 12 inches (30 centimetres) of steel. Even this target is not infinitely rigid, but it is considerably more rigid than those man-made or naturally occurring targets available along the rail or highway right-of-ways.

Thus, while the regulatory requirements involve a velocity that is seen as unrealistically low, they also involve a target that is truly unrealistically rigid. The question becomes whether these two conditions encompass the environment that one would find in a real accident.

To explore this concern, a number of research programmes have been conducted. The earliest of these involved dropping two identical casks on two targets of different hardness. In the first of these, a 16 000-pound research reactor spent-fuel cask was dropped 30 feet

* *Advisory Material for the Application of the IAEA Transport Regulations*, Safety Series 37, IAEA (1973).

What if?

In spite of historical experience, risk analysis techniques, and safety research, there still lurks in some people's minds the question: What if? What if a cask were to leak following some extremely severe accident? Or, what if a terrorist were to attack one of these with explosives — what would happen then?

During 1981—82 a series of tests were conducted on spent-fuel casks to evaluate the consequences of an explosive attack. After employing eight different explosive attack methodologies, one methodology was chosen as the standard for further testing. This choice was made on the basis of the availability of the munitions involved, the likelihood of expertise to use that munition, and the probability of success should that munition be utilized. A series of tests was then conducted utilizing an explosive attack on a spent-fuel shipping cask.

Prior to beginning this research, it was estimated that approximately 0.7% of the total contents of a spent-fuel cask might be released as respirable particles as the result of a successful sabotage attack. This research programme reached its culmination in an explosive attack on a full-scale shipping cask conducted inside a very large chamber.

After all the debris was collected and analysed it was concluded that instead of 0.7% of the contents being released in respirable form, the value was only 0.0006%. While the consequence analysis based on 0.7% release indicated the possibility of hundreds of early fatalities and thousands of latent cancers, the same consequence analysis using the measured release indicates that there would be *no* early fatalities and the expectation that about two-tenths of one cancer would occur in the exposed population over the next 30 years. If all uncertainties are pushed to their extreme limits, it might be possible to predict approximately 14 cancers in the affected population over the same time.

The population chosen for this analysis consisted of a very densely populated urban area in which the normal expectation of cancer incidence would be about 250 000 cancers during the same time period. Thus, while the successful explosive attack on a spent-fuel cask would create an ugly situation, it would not be impossible to handle, nor would it create a significant public health impact.

Emergency response

In spite of this, there is still concern over how municipalities and states might respond to an accident involving radioactive materials, and most particularly to a severe accident involving spent fuel. There is a widespread belief that there are no emergency response capabilities in existence. Nothing could be further from the truth.

There already is in existence, as a result of the daily transport of many, many other hazardous materials, a well-established emergency response capability throughout the United States. This emergency response takes place at three distinct levels and in three distinct phases.

The first responder to an accident involving hazardous materials is almost always a state policeman, a local policeman, or a fire department. In each case these people are trained to conduct first-response type activities under all sorts of emergency conditions. This first responder is responsible for those activities necessary to achieve two objectives. First, the initial responder is to isolate the situation. That is accomplished by establishing exclusion areas, keeping people away at the discretion of the first responder, and attempting to save lives in imminent danger (such as pulling the driver from a burning gasoline truck). A second responsibility of the initial responder is to notify the state emergency personnel, be it the Office of Civil Defense, the Office of Emergency Government, the State Police or whatever other duly constituted authority is in effect in each state.

This notification brings on the second phase of response. These second responders have the responsibility for stabilizing the situation to prevent whatever hazards exist from getting worse, and to take whatever measures are possible to reduce the hazards involved. This would include fighting fires, neutralizing chemicals, preventing winds or water from further distributing the hazardous material, or other such activities.

In this second phase there is available from private industry and the US Government a substantial amount of aid and assistance. The Chemical Manufacturers Association operates a hot-line system called "Chemtrec" which acts as an information resource to provide local responders with data on the materials involved in accidents and to provide advice on response methodologies. In addition, the US Department of Energy, in co-operation with several other federal agencies, operates a similar response capability for defense-related nuclear accidents called "JNACC" (Joint Nuclear Accident Co-ordinating Center). These people not only provide advice, but within a reasonable time provide physical assistance as well.

The third phase of the accident response is the recovery phase which is handled by commercial organizations whose task it is to clean up the accident site and remove all the hazardous materials.

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An Assessment of the Safety of Spent Fuel Transportation in Urban Environs, by R.P. Sandoval, J.P. Weber, H.S. Levine, A.D. Romig, J.D. Johnson, R.E. Luna, G.J. Newton, B.A. Wong, R.W. Marshall, Jr., J.L. Alvarez, and F. Gelbard, SAND82-2365, TTC-0398 (June 1983).

A Safety Assessment of Spent Fuel Transportation Through Urban Regions, by R.P. Sandoval, and G.J. Newton, in Proceedings of Waste Management '82, University of Arizona (1982).

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Preparedness and Response in Radiation Accidents, US Department of Health, FDA83-8211 (August 1983).

Emergency Response Capabilities Developed in the United States to Deal With Nuclear Materials Transportation Accidents, by S.G. Vandevender, R.T. Reese, and A.H. Shilling, in Proceedings of GTA International Symposium on Packaging and Transportation of Radioactive Materials, Berlin (1980).

The patient survived: To further publicly demonstrate the structural integrity of shipping casks, the United Kingdom's Central Electricity Generating Board (CEGB) held a US $2.1 million test in July 1984 — a shipping cask was hit head-on by a diesel locomotive weighing 140 tonnes, coupled to three 35-tonne coaches and moving about 160 kilometres per hour. Despite the impact and being hurled 60 metres, the cask suffered only minor scratches and totally protected its contents, simulated nuclear waste, which were not affected. The train was demolished. (Credit: CEGB)

onto the unyielding target described earlier. While the cask did not fail in any way, there was visible damage in the form of deformation of the outer shell and some movement of the lead shielding between the two shells. An identical cask was subsequently dropped from a height of 2000 feet onto hard pan desert soil. This cask hit the target at a speed of 235mph penetrating the soil about 52 inches. Damage to this second cask consisted entirely of paint scratches.*

In recent tests performed to evaluate the same relationship between target hardness and package damage, a series of steel bodies was dropped from various heights onto three different targets. The targets were compacted soil, two feet of reinforced concrete, and an unyielding target. Data from those tests indicate that a 30mph impact into an unyielding target is equivalent to an impact at about 90mph into two feet of reinforced concrete and about 120mph into one foot of reinforced concrete (roughly equivalent to a bridge abutment).** To achieve such impact velocities on realistic targets, casks would have to be dropped from altitudes varying from 270 feet (90mph) to 480 feet (120mph).

Thus, while the 30-foot drop test appears to be nonthreatening, the unyielding target boosts the effective impact velocity to values well above the range of speeds encountered in surface transportation.

* *Air Drop Test of Shielded Radioactive Material Containers,* by I.G. Waddoups, SAND75-0276, Sandia National Laboratories (September 1975).

** *Relative Response of Type-B Packagings to Regulatory and Other Impact Test Environments,* by J.D. McClure, H.R. Yoshimura, R.B. Pope, R.M. Jefferson, R.D. Seagren, and L.B. Shapper, in Proceedings of PATRAM-80 (November 1980).

Cask burn and crash tests

Still the question persists as to whether an accident involving a complex set of environments is actually encompassed by these tests. In addition, there are questions about the capability of analytical tools to predict the damage produced by such "real accident" environments.

In order to evaluate these analytical tools, and to gather data on the accident environment, a series of tests was staged in 1977 and 1978 involving full-scale crashes of spent-fuel casks mounted on railcars and tractor-trailer rigs.* The casks used had been retired from service because they could no longer meet the quality assurance requirements in effect at that time. Using these casks, a series of five tests was conducted, including two crashes of a tractor-trailer rig carrying a spent-fuel cask.

The vehicle was propelled into a 690-tonne concrete block at speeds of 60mph in the first case, and 84mph in the second case. In these two tests, the same cask was used because in the first accident the cask received only superficial damage. In the second (84mph) crash the cask was permanently deformed but that deformation was well within the limits predicted by analysis.

In the third test, another truck-type spent-fuel cask mounted on a tractor-trailer rig was struck by a 120-ton locomotive going 81mph. As a result of the crash, the cask was thrown up over the top of the locomotive and

* *Analysis, Scale Modeling, and Full-Scale Testing of Shipping Containers for Radioactive Materials,* by H.R. Yoshimura and M. Huerta, US Department of Commerce, National Bureau of Standards, NBS Special Publication 652.

tumbled end-over-end coming to rest between the tracks. The locomotive was demolished, but the cask suffered only minor damage: again as predicted by the analysis.

The fourth test consisted of a rail-type spent-fuel cask hitting the same 690-tonne target at a speed of 81mph. Here again the behaviour of the cask was as predicted. In all four cases, it was important to note that the environments produced by the accident event were consistent with those predicted by the analyses and calculations employed.

The fifth of the test series involved placing the rail-mounted spent-fuel cask and its rail car in a 30-by-60 foot concrete-lined pool of JP4 (jet aviation fuel), and burning the cask for a period of two hours and three minutes. This burn test was conducted for a protracted period of time in order to evaluate the total behaviour of the cask and not to simulate some real accident.

To provide an event lasting this long, it was necessary to burn approximately 65 000 gallons of fuel within a well-contained pool. As a result of this extended burn, all lead in the cask was melted and the internal temperature was raised to a point where the relief valve opened and steam was ejected. Once again, the behaviour of the cask was as predicted by the thermal analysis conducted in advance of the test.

In none of these five tests would there have been any significant release of radioactive material to the atmosphere as the result of the event, had the cask been carrying spent fuel. The conduct of these tests provided information on the accident environment to support the conclusion that regulatory requirements are indeed more severe than those encountered in highway and railway crashes. In addition, these tests showed that analysis is an accurate method of predicting damage, making it possible to rely on proven design techniques to produce competent shipping casks.

Risks in perspective

The purpose of this article has not been to insist that problems of transporting spent fuel do not exist. Rather, it presents a synopsis of factual information individuals can use to establish a rational perspective toward the safety of this activity.

It is the considered view of the author that society should spend its limited risk-reduction resources (which in every case ultimately come from the taxpayer) where they can produce the greatest payoffs in the health and well-being of citizens. Since the transportation of spent fuel and other radioactive materials has such a good historical record, is accompanied by a very low risk to the public, and is currently being conservatively regulated, it appears that this is not the place to argue for higher levels of risk reduction. Indeed, in a global view of all the risks routinely accepted by the public at large, it appears to be almost imperceptible.