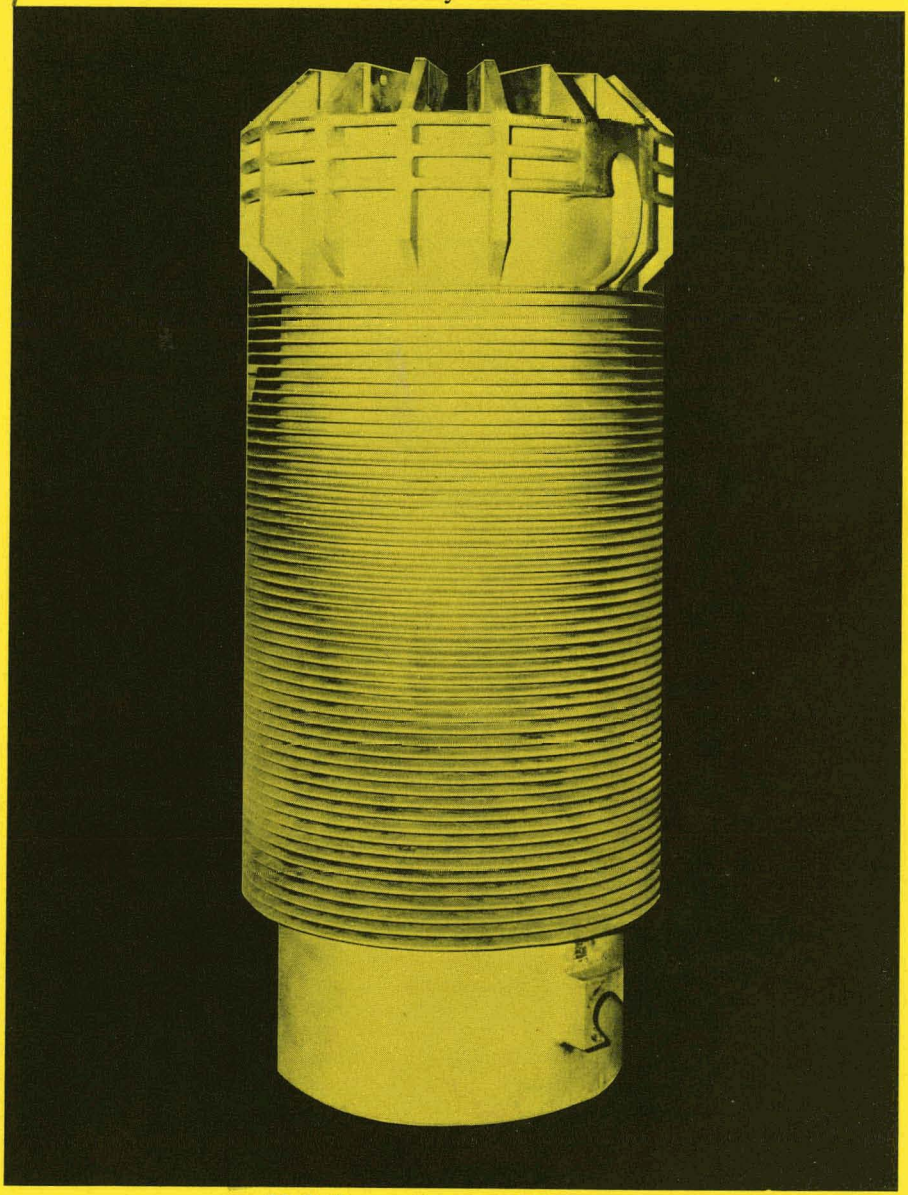
DOE/EV-0003

EVERYTHING YOU ALWAYS WANTED TO KNOW ABOUT SHIPPING HIGH-LEVEL NUCLEAR WASTES

January 1978



U.S. Department of Energy
Assistant Secretary for Environment
Division of Environmental Control Technology

DISCLAIMER

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U.S. Department of Energy
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Washington, D.C. 20545

FOREWORD

During the past few years, the U.S. Energy Research and Development Administration (ERDA), and its predecessor, the U.S. Atomic Energy Commission (AEC), have been asked many different questions about the transportation of high-level nuclear waste. These questions have arisen out of a very real public apprehension about the safety of such shipments. These questions are strickingly similar, which implies that there are a number of things about which the public needs more information on a rather wide scale.

In this document, the U.S. Department of Energy (DOE) has gathered together the "most often asked" questions, and has furnished a detailed answer to each question. Individual answers are not necessarily totally self-contained, and it may be necessary to put several of the answers together in order to obtain a full picture of the various aspects of a particular question. The answers to the questions then serve a dual purpose—to provide specific information on commonly asked questions, in understandable terms, and to present the composite parts of an overall program on just how the wastes will be transported and the many related factors.

No attempt is made here to discuss the basic nature and uses of radioactivity, atomic physics, radiation effects on man, or other primary concepts. The reader is directed to the various pamphlets and booklets published by ERDA and DOE for that information. Several references are made in the answers to regulations and studies. A bibliography following the last question lists these references and how copies may be obtained.

In the future, high-level waste may result from reprocessing spent reactor fuel from nuclear power plants. No reprocessing plants for commercial fuel are approved for operation. High-level waste today is the result of Government reprocessing of national defense materials.

Although the questions and answers are aimed specifically at transportation of high-level nuclear waste, many of them are equally applicable to shipments of other nuclear materials, such as spent nuclear reactor fuel and large amounts of radioisotopes.

Division of Environmental
Control Technology

TABLE OF CONTENTS

EVERYTHING YOU ALWAYS WANTED TO KNOW ABOUT SHIPPING HIGH-LEVEL NUCLEAR WASTES

1 What is high-level nuclear waste?

As nuclear fuel is "burned" in a reactor, the uranium fuel material is slowly converted by nuclear fission into products often referred to as "nuclear ashes." They are not really "ashes" at all, but exist as a contaminant in the individual fuel rods. They may be either solids, dispersed uniformly through the ceramic (sintered uranium oxide) type of fuel material in the fuel rods, or as gases entrapped within the fuel rod. The nuclear fuel itself does not really change its physical form. These fission products are highly radioactive. After the fuel material is partially exhausted and the fission products have built up to a certain level in the fuel, the fuel rods are withdrawn from the reactor, and are shipped either to a fuel storage facility or to a fuel reprocessing plant where the remaining fuel material could be chemically separated from the fission products. The recovered fuel is recycled back into the nuclear power program.

There are no commercial reprocessing plants in operation at present. National defense fuel materials are reprocessed and produce high-level waste.

High-level nuclear wastes are those highly radioactive waste fission products which are stripped out of the fuel elements in the chemical extraction cycles used in the fuel reprocessing plants. The wastes are initially in a liquid (aqueous) form. The liquid wastes may be placed in tanks to "cool," i.e., to lose some of their radioactivity through the process of radioactive decay. In the process of giving off radiation energy, the fission products "decay" and become less radioactive. The loss of radioactivity continues with time. After a period of storage as liquids in the plant (up to five years), they are converted into a dry, stable solid. They are highly radioactive because they contain the fission products from the spent fuel. The solid wastes may be then further stored at the plant for some additional years prior to shipment to a Federal waste repository. Since the future Federal repository will only receive solidified waste, high-level waste will always be transported in solid form.

2 Who owns the wastes?

The wastes will be owned by the producer (the spent fuel processor) of the wastes until they are delivered to a Federal repository, at which time it is planned that the Federal Government will become the owner.

3 How will high-level waste be transported?

In one plan high-level dry solid waste will be placed in steel canisters, between 6 inches and 24 inches in diameter and 10 feet to 15 feet long. Each canister could contain as much as 20 million curies of fission products (a "curie" is a unit of measurement of the amount of radioactivity equivalent to the radioactivity of one gram of radium). One or more canisters will be inserted in a shielded, heavy, reusable cask similar to those now in use to transport spent fuel elements. Rail will be the primary mode used for these heavy shipments, although the lighter casks could also move by truck. In special cases, shipments may be made by barge.

Figure 1 shows a typical high-level waste canister.

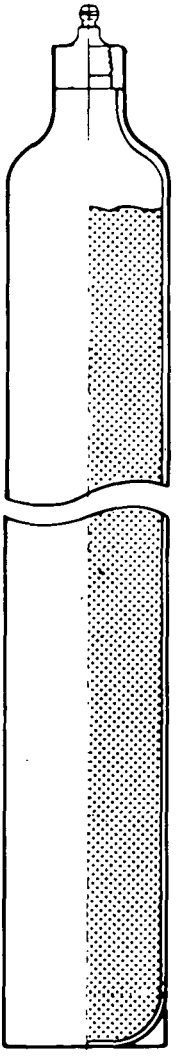
4 How much waste will be shipped and from where?

Government-owned reprocessing plants are in Aiken, South Carolina; Richland, Washington; and Idaho Falls, Idaho. High-level waste originates in reprocessing plants. The high-level waste may be shipped to a Federal repository, perhaps located in deep, stable geologic formations. In the future any spent fuel that is not reprocessed could be shipped directly from the nuclear power plant to the repository.

For each ton of spent reactor fuel processed, high-level liquid wastes will be concentrated to somewhere between 100 and 400 gallons (330 is often used as a "nominal" figure) and then converted to perhaps two or three cubic feet of solidified waste. This quantity of waste will, after 10 years of cooling, contain about 300,000 curies of fission product activity producing about 4,000 Btu per hour (about 1,000 watts) of heat output and may also contain up to 50 grams of plutonium. The high-level solid waste generated from the spent fuel annually discharged from one 1,000 MW(e) reactor would amount to about 90 cubic feet. About one shipment of high-level waste will be made for every 20 shipments of spent reactor fuel. This is about one high-level waste shipment per year per 1,000 MW(e) reactor.

To put these numbers in perspective, if all of our electricity

"TYPICAL" CANISTER



	DIAMETER	LENGTH
TYPICAL	12"	10'

Contents of Typical Canister:

VOLUME: ~ 6.25 CU. FT.
WEIGHT: ~ 4,000 LBS.
HEAT OUTPUT: ~ 5 KILOWATTS
CURIES: ~ 5,000,000

Figure 1.–This "typical" high-level waste canister could be used to ship about 6.25 cubic feet of high-level waste to a Federal repository.

were generated by nuclear power, the total volume of high-level nuclear waste produced from nuclear electric power, per person over his entire lifetime, would just about fill one beer can. Further, this would take 610 shipments a year which may seem like a high number, it must be remembered that there are 1,000,000,000–1 billion–shipments of other hazardous materials every year.

255-223 O - 78 - 2

5 Will foreign countries be shipping high-level waste into the United States?

No, not under current policy and planning.

6 How do you keep the casks from breaking open or leaking in an accident?

Basically, by (1) using casks that are designed to resist the stresses which might occur during accidents; (2) independent review and approval of each cask design by the Nuclear Regulatory Commission (NRC); and (3) assuring that casks have been fabricated, maintained, and prepared for shipment in accordance with the approved design.

7 What do shipping containers look like?

No shipping cask specifically designed for high-level waste has yet been built, because shipments of high-level waste will not begin for an indefinite period. The technology for building safe casks already exists. Containment and shielding requirements for high-level waste canisters are almost identical to many types of spent reactor fuel that ERDA and the nuclear industry have been shipping for years. Therefore, when a high-level waste shipping cask is built to enclose the waste canisters, it will be almost identical to some current spent fuel casks. It will probably be a 75- to 100-ton cylindrical cask with lead or steel shielding and external cooling fins. It will be clad inside and out with stainless steel, perhaps 1½ to 2½ inches thick, and the inner cavity will be large enough to accommodate several high-level waste containers. The exact number will depend on the size of the canisters. The space between the inner and outer steel shells would be filled with a dense shielding material, such as lead, uranium, or tungsten. The 10-foot to 16-foot long cylindrical cask will be mounted on a rail car in a sturdy cradle that will firmly attach the cask to the rail car. The cask diameter will depend on the shielding material used and the cavity size, but will probably be between five and eight feet. It is also possible that smaller casks in the range of 15 to 30 tons will be built for carriage by motor vehicle. Other than size, these casks will be identical with rail casks.

Figures 2 through 6 show typical large shielded casks.

8 Aren't these shipments going to be very dangerous?

The waste to be shipped is in the form of a solid material which is chemically inert, immobile, is nonexplosive, noncombustible, and cannot turn to gaseous form or become easily airborne.

We have had over 25 years' experience with safe transport of thousands of spent fuel elements with high radiation levels. Handling and shipping of the less hazardous solid high-level waste, which has been "cooled" for years in a storage pool, will be a simpler operation. There can be no nuclear reaction with high-level waste shipments. The external radiation is reduced by the thick shielding of the heavy cask. There is a very small possibility that an extremely serious accident could damage the safe shielding of the container or rupture the inner canisters so that the waste material might get outside the packaging. In the event that some of the solid waste particles did get outside of the packaging, the spread of radioactive particles would be limited to the local area. Generally known techniques, such as have been used for many years by ERDA laboratories, could be used to remove the radioactivity.

There is a great difference between potential hazard and actual damage. DOE is determined to prevent the potential hazards from ever becoming a reality. This is the primary reason for the strict safety regulations and extensive research and development programs in transportation—to be sure that the potential hazards are always controlled so that there is no significant public risk. (See also question 68.)

9 What special shipment controls are used?

Special shipment safety controls are not required during the transportation of high-level waste. The principal safety factor in such transportation is the packaging itself. The packaging must meet NRC and Department of Transportation (DOT) regulatory standards for the type and quantity of material involved. These standards provide that the packaging shall prevent loss or dispersal of the radioactive material, retain its shielding efficiency, and provide adequate heat dissipation under either normal or accident damage test conditions. Shippers must also perform certain tests before each shipment, and the shippers and carriers must meet other safety regulations.

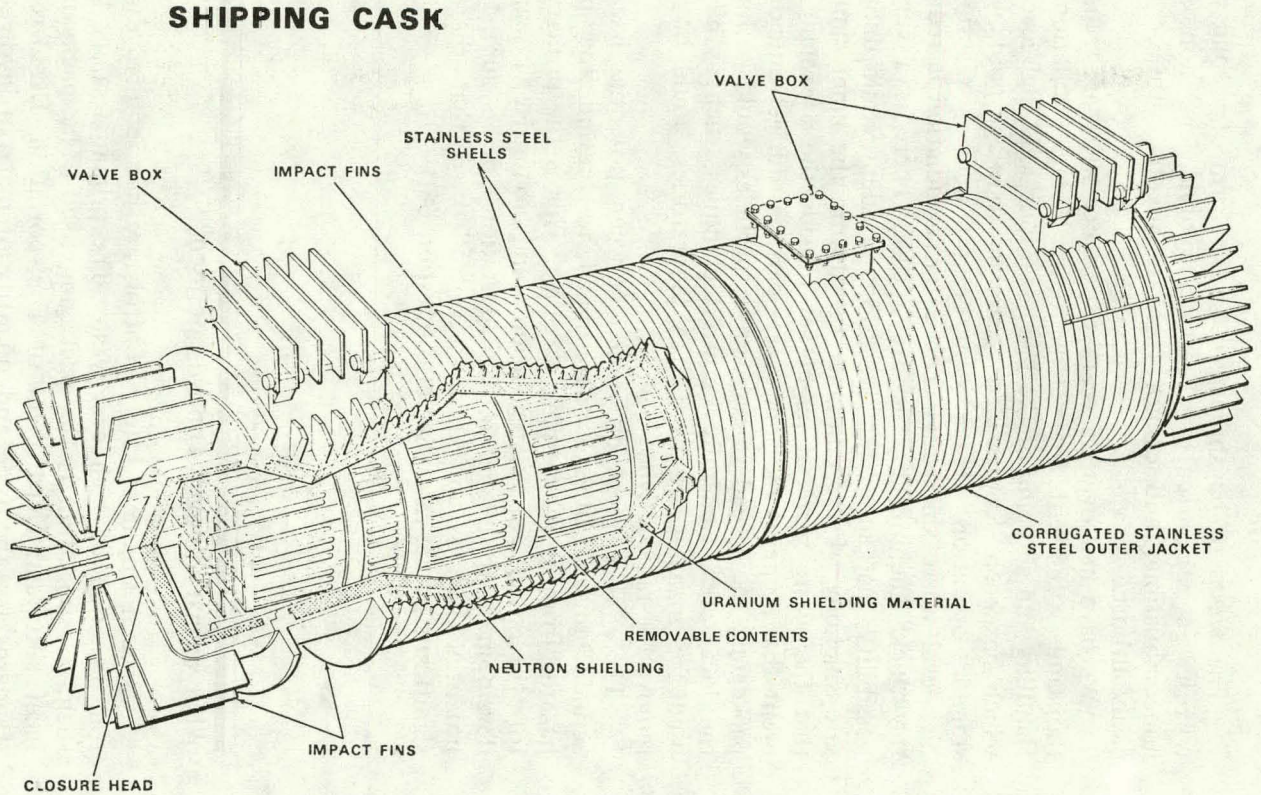


Figure 2.—The IF-300 spent fuel shipping cask was designed by the General Electric Company. It has been licensed for use by the NRC's licensing staff.

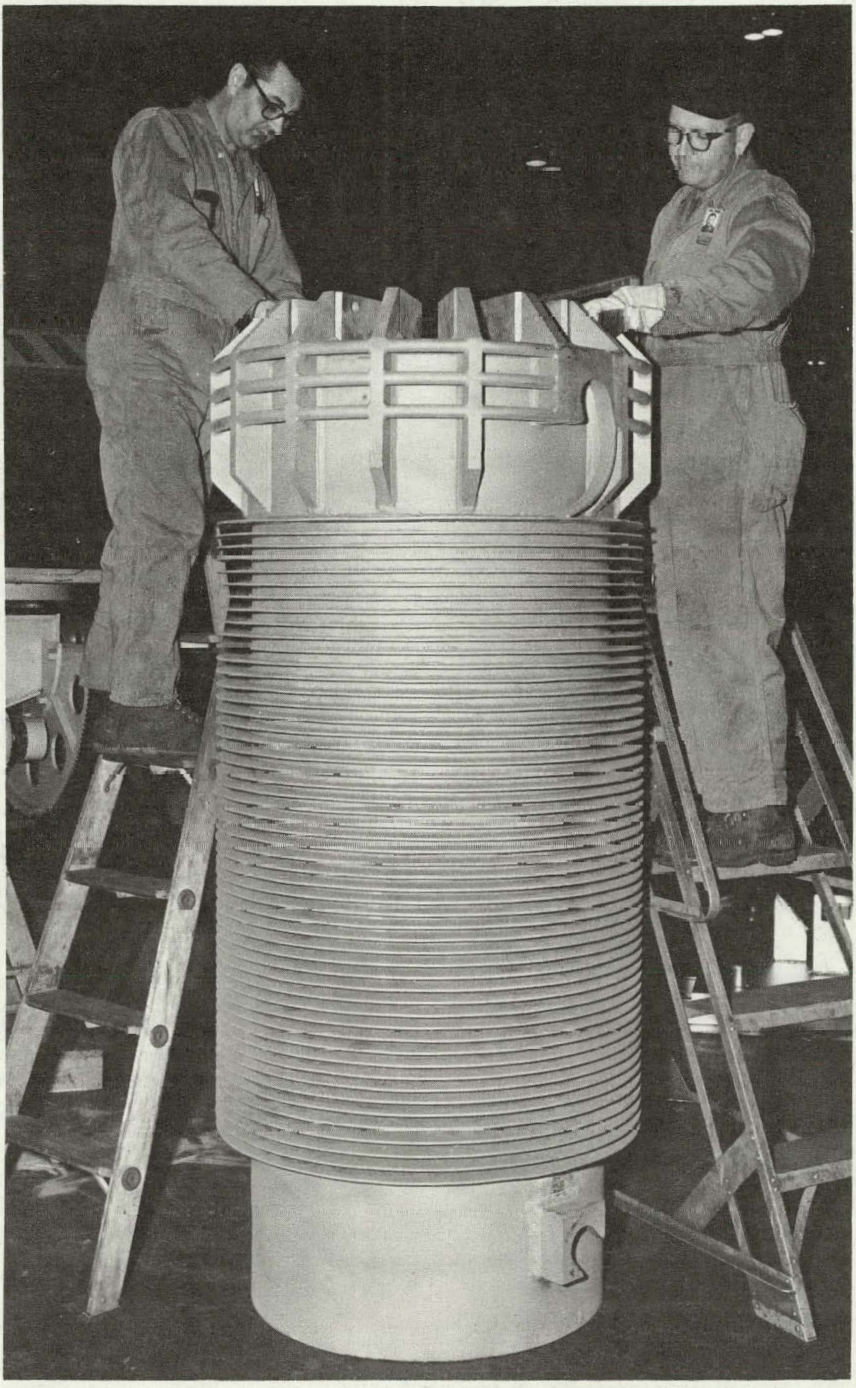


Figure 3.–This is the prototype model of the Demonstration Fuel Element Shipping Cask. It was designed and fabricated by the Union Carbide Corporation, Nuclear Division, in Paducah, Kentucky. It is manufactured from laminated uranium metal.

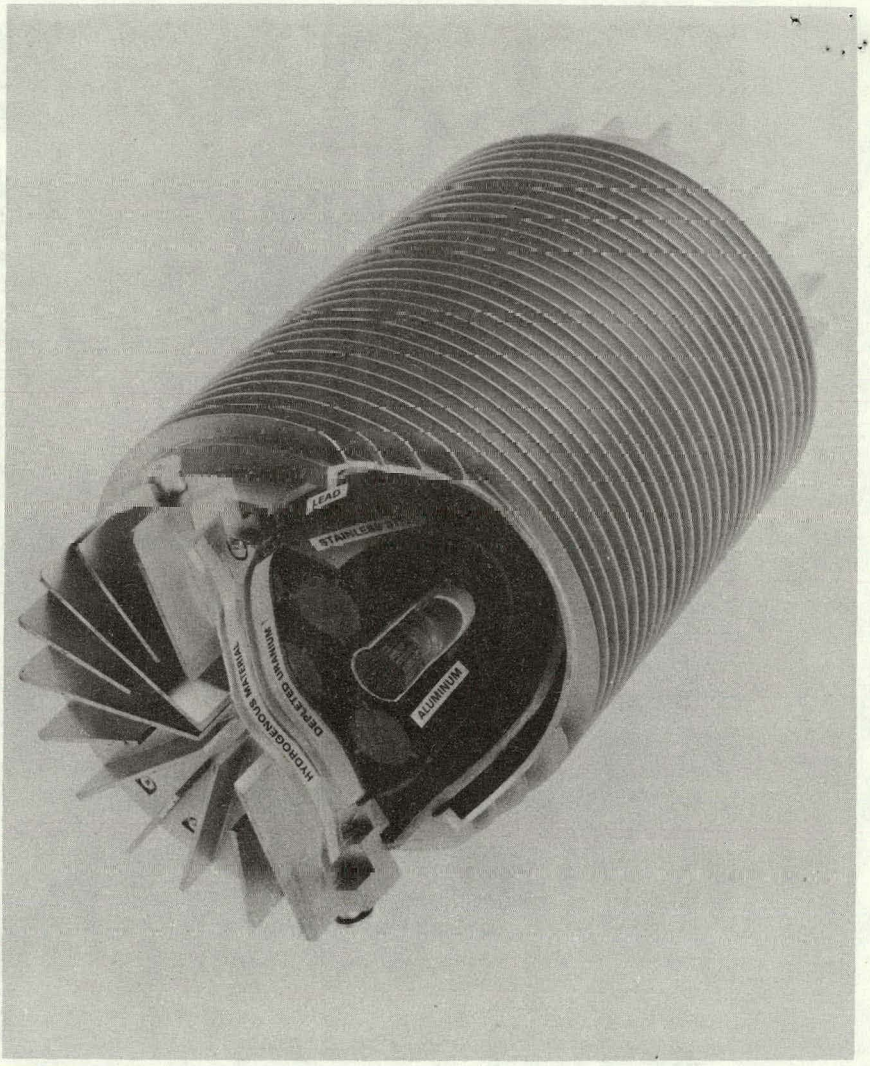


Figure 4.—This is a model of a prototype cask that could be used for the transportation of high-level nuclear wastes.

These regulatory standards contemplate that shipments of radioactive materials, including high-level wastes, would move routinely in commerce without requiring any special shipment controls en route. (See also questions 17, 24, and 36.)

10 Wouldn't it be safer not to ship high-level wastes?

Of course, the ultimate in transportation safety is not to ship at all. If wastes were not shipped, they would have to be stored at the place of production. Since there are several of those, that would mean several long-term storage sites. DOE believes that it would be better to limit the number of storage sites, and that the overall impact on the environment would be less if there were fewer storage sites. The impact of transportation activities themselves on the environment will be so small that transportation should not be a factor in determining the number or location of waste storage sites.

11 What modes of transportation will be used?

Most shipments of high-level waste will be by rail. This is due to the weight of the casks, which will run from 75 to 100 tons. A typical rail shipment would take 4 to 10 days. Highway load limits restrict truck movements to about 25 tons. Truck shipments might take two to five days. Rail shipment offers a significant economic advantage over truck shipment.

Preliminary designs for fuel processing plants near water provide for barge movements. Air shipments seem impractical. (See question 7.)

12 What kind of special trucks or rail cars will be required?

Special trucks or rail cars, in the sense of unique or exotic models, are not needed. Ordinary heavy-duty carrier equipment can be used.

A typical rail car which can be used for high-level waste shipments is a standard heavy-duty flat car about 60 feet long and about 9¾ feet in extreme width. The empty weight of such a car would be about 60 tons, with a nominal carrying capacity of 125 tons. Cars of this general type (with a depressed center) have been used to move spent fuel casks in the 100- to 125-ton range, to the DOE-operated processing plant in Idaho. Figure 7 shows a typical heavy-duty car.

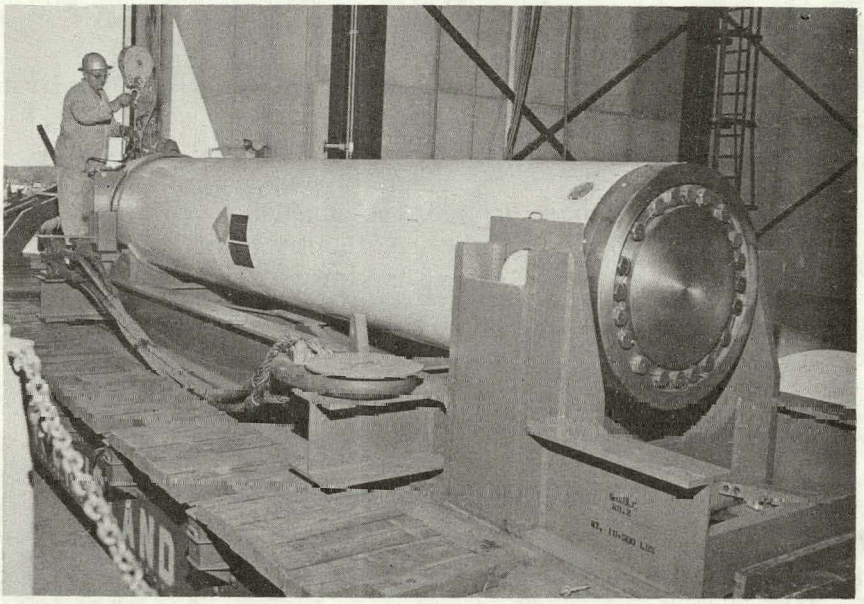


Figure 5.—About 25 shipments were made of spent fuel from the Hallam Nuclear Power Facility (Nebraska) to the Savannah River Plant. It is still being used to ship spent fuel from other reactors.

Heavy-duty truck trailers routinely used to transport heavy machinery can carry spent fuel casks in the 15- to 20-ton range. These trailers are sometimes multiaxled and multiwheeled to spread the load over the roadways. Figure 8 shows a normal heavy-duty low-boy. Figure 9 depicts a typical multiaxled flatbed trailer.

13 Which is safer, truck or rail?

This requires another question: "Safer against what?" A 1972 AEC study regarding the probabilities of different kinds of accidents has shown that rail has fewer minor accidents per mile than truck. On the other hand, highway involves less risk of a more severe accident. Considering the various types of transportation accidents which are of most concern, the overall accident rates, on a per rail car mile or per truck mile basis, are about the same for both. In any event, the differences in accident rates are small enough that the overall public safety probably would not be significantly affected by the choice of one over the other. The objective, after all, is to prevent any serious public hazards even when traffic accidents occur. (See also questions 47 and 48.)

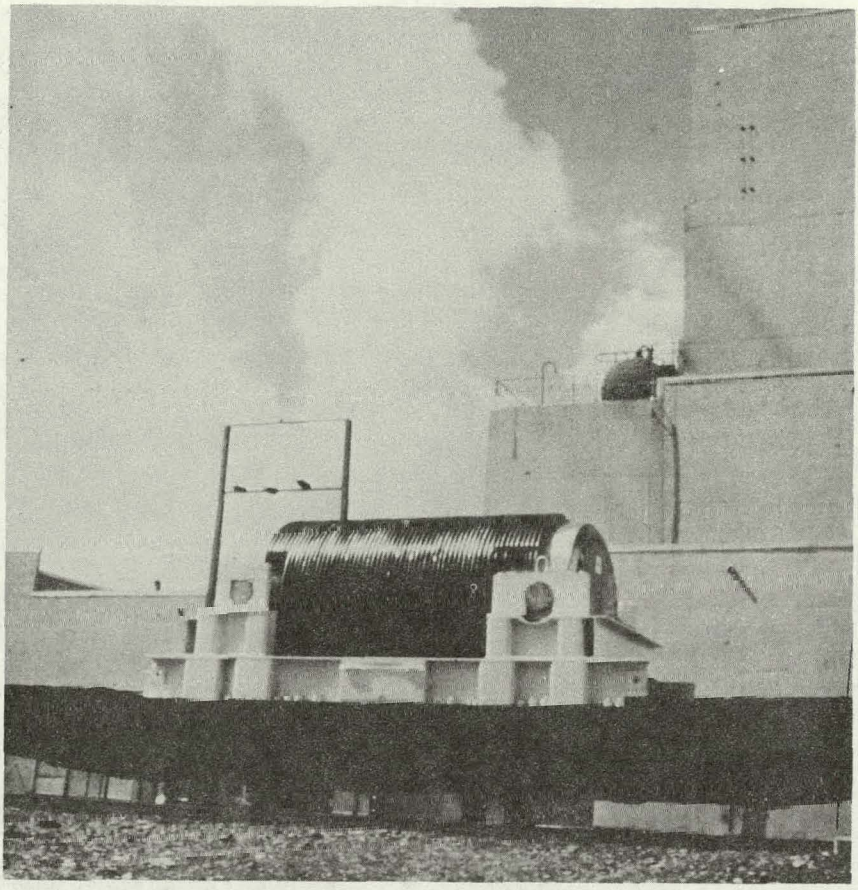


Figure 6.–This cask, NFS-N100, is mounted on a rail car and weighs about 60 tons. It is used to ship spent fuel from nuclear power reactors to a fuel storage site.

Rail is preferred for waste shipments because fewer shipments would be required. If all shipments were made by truck, it would take from 5 to 10 times as many shipments because truck weight restrictions would prevent carrying more than one to three canisters per cask, where rail casks can carry from 8 to 15 canisters (12 canisters is a commonly used "nominal" figure).

14

Wouldn't it be safer to ship the wastes by underground pipeline away from man's environment?

We have considered transporting liquid radioactive waste via pipeline. So far, the only such pipeline transportation is onsite, e.g., from one building to another, or from one building to a storage area onsite. There are two primary reasons why we do not

255-223 O - 78 - 3

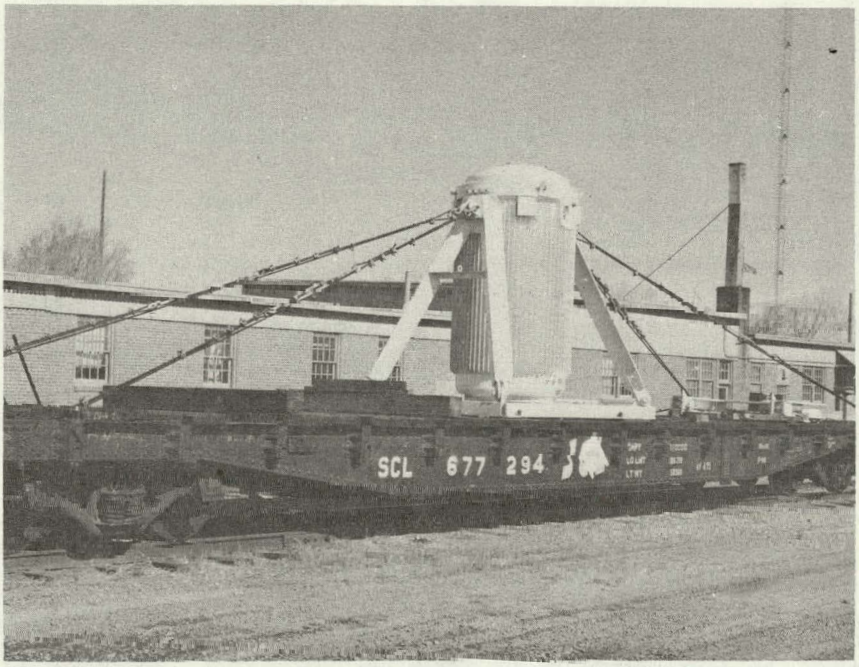


Figure 7.–The Piqua-Elk River Spent Fuel Shipping Cask is a cylindrical lead-filled steel weldment, about 108 inches long by 49 inches in diameter and weights about 30 tons. During shipment, the cask is attached to a shipping skid fabricated from structural steel members, which in turn is attached to a standard rail flatcar.

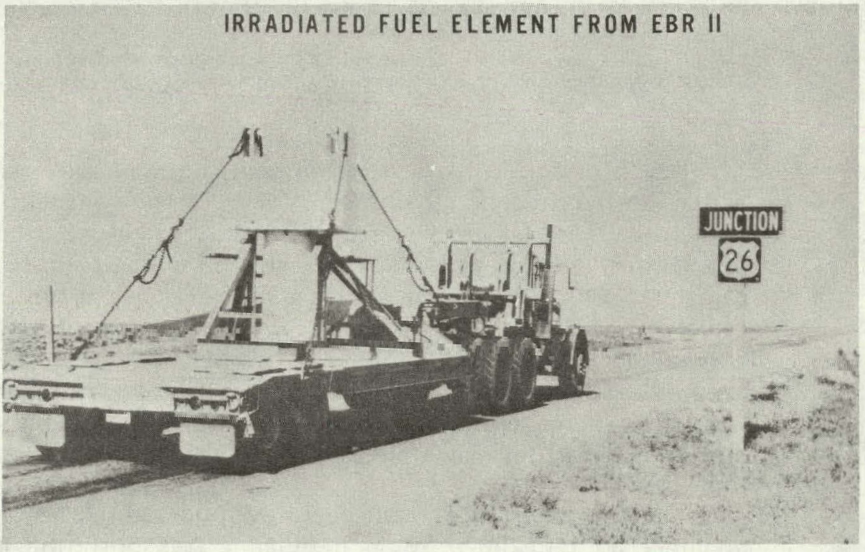


Figure 8.–Spent EBR-II fuel elements are transported onsite at the Idaho facility on low-boy trailers.

consider long-distance transportation of liquid radioactive waste by pipeline to be practical. The first is safety. Pipelines have a history of corrosion and leakage. An entirely different pipeline technology would have to be used in order to provide adequate containment, perhaps involving even a double or triple walled pipeline system.

The second reason is economics. The sophisticated containment system that would be required would be prohibitively expensive. Pipelines would require radiation shielding, remote maintenance, and formidable surveillance and monitoring systems. Additionally, the volume of waste which would be shipped is so small as to preclude any reasonable economic form of dedicated long-distance pipelines between the fuel processors and the storage sites. A typical 24-inch petroleum pipeline carries hundreds of thousands of gallons per hour. That is more than the volume of liquid waste that will be produced in a year in the fuel processing plants.

The technology for shipping packages by pipeline hasn't been sufficiently developed for DOE to give it any serious consideration for use for radioactive materials.

15 What can be done to reduce the risks?

However excellent the engineering, construction, management, and regulation, absolute safety is an unattainable goal in any field of human endeavor. What can be said with great confidence is that the chances of accidents seriously affecting the lives or property of people in the transportation of nuclear materials are very much less than from the other hazards of everyday life.

The risk of radioactive contamination or radiation exposure to the environment from the transportation of high-level waste, although already extremely small, could be further reduced by:

a. Decreasing the number of shipments.
b. Decreasing the distance of each shipment.
c. Making stronger packages.
d. Reducing vehicle speeds.
e. Providing special routing, guards, or escorts.

Adoption of one or more of the alternatives might be justified in special cases. However, the advantages of the alternatives are not great enough to warrant their adoption as general requirements.

The Nuclear Regulatory Commission (NRC) has examined all of these alternatives in terms of relative gain versus loss. For example, shippers could use stronger and heavier casks, but, due

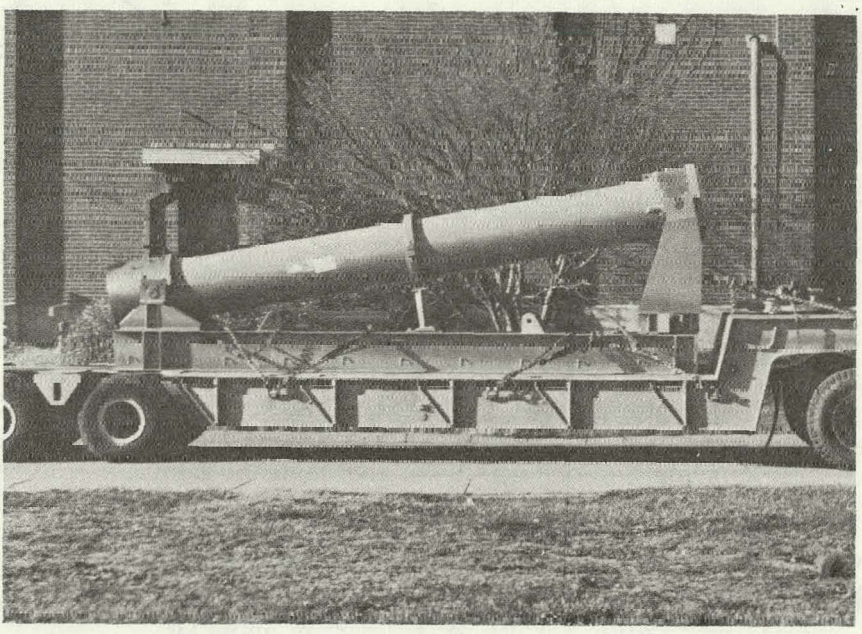


Figure 9.—This Peach Bottom cask owned by the Philadelphia Electric Company, is about 16 feet long by 4 feet in diameter. It weighs a little over 30 tons.

to vehicle load limitations, one would not be able to carry as much waste in each cask. This means that there would have to be more shipments. Similarly, we could route shipments around population centers, large and small, but this might well mean using back roads which would tend to increase the probability of accidents. Super-highways are safer than two-lane roads, according to the Department of Transportation (DOT).

Although some of the alternatives offer apparent advantages in terms of reducing the potential radiological effects on the environment, the NRC believes that, after careful study and analysis, the overall risk from radiological effects is already so small that no significant change would result. Any reduction in the radiological effects of those alternatives would be outweighed to some extent by an increase in adverse nonradiological effects and by a large commitment of additional effort and equipment.

When one multiplies the probable consequences of a nuclear transport accident by the likelihood that the accident might happen, one comes up with a measure of the overall public risk. As shown in the NRC statement on the environmental effects of transportation, these types of calculations led to a conclusion that to go any further in container design integrity or transportation controls would not be worth the effort in terms of gain in public safety. There is no possibility of an explosion of any type. Even

though the levels of radioactivity in the cask are quite high, there is no potential force present to widely disperse the materials outside of the cask. For these reasons, and because the likelihood of a catastrophic nuclear transportation accident is essentially zero, the time and expense required for additional transport controls would far outweigh the possible gains. (See also questions 17, 24, 36, 42, 56, and 68.)

16

At what maximum speeds will the vehicle be permitted to travel?

Both rail and truck shipments for the most part will be made in regular scheduled service at normal speeds, without any specific speed restrictions because of the radioactive nature of the shipments. Any speed restrictions would be due to other reasons—weight, local laws, etc.

17

Should there be special speed limits on shipments of nuclear wastes?

Within reason, lower speeds for trucks or trains carrying nuclear wastes would reduce serious accidents, just as lower speeds would reduce serious automobile accidents. The same would be true of trucks and trains carrying gasoline, lumber, or overalls. However, the frequency of traffic accidents would be independent of the radioactive nature of the cargoes. Considering that nuclear waste casks are already built to withstand high-speed accidents, reduction of the speed limit to, say, 30 mph would not measurably reduce the nuclear hazard. Thus, there is no valid reason to impose reduced speed limits on nuclear loads as long as those loads meet the safety regulations.

It should also be remembered that severe speed restrictions would cause traffic obstruction hazards on expressways and turnpikes, thereby forcing vehicles onto secondary roads where accident rates are higher, according to DOT. The result would be an increased risk of exposure to minor and moderate accident conditions and an increased length of time such shipments would be in public areas. On railroads, speed restrictions would seriously interfere with the flow of traffic due to the scarcity of alternate routings. A slow train presents a hazard to other faster trains. Rear-end collisions are a constant threat on both railroads and highways, and we would like to avoid them.

18 Will the highway be open to other vehicles while radioactive materials are being transported?

Yes. The experience has shown that there is no valid reason why these materials cannot move in routine commerce, just as other radioactive materials have done for many years.

19 How many rail cars of waste would travel on a single train?

The rate of shipment to the storage location will be established and centrally controlled to maintain an orderly flow and receipt of waste at the Federal repository. There will probably be no more than one or two rail cars of waste in a single train moving to the storage location. The extremely high cost of the shipping casks (up to $1 million each) will be a significant economic factor in keeping the number of casks to an absolute minimum, thereby minimizing the likelihood of multiple car shipments. Multiple car shipments will be the exception rather than the rule. (See also question 23.)

20 What does DOE plan to do to assure that the railroad beds en route are in good condition?

Routing of cars between the processing plants and the storage location will generally be handled in railroad main line operations except that branch line service may be necessary for short distances at origin and destination.

The Railroad Safety Act of 1970 gives the Federal Railroad Administration (FRA) increased jurisdiction in the field of railroad safety. The FRA has informed ERDA/DOE that it plans to broaden its safety surveillance program over track and rolling stock. Upon request, FRA will make an inspection of the rail routes to be used and require the railroads to make any corrections in maintenance of tracks, structures, and signals that may be necessary. FRA will also suggest changes to proposed routings, if necessary to provide an adequately maintained track or structure. DOE will work with the FRA to arrange for completion of these inspections sufficiently in advance of the initial shipments.

The Association of American Railroads has analyzed weight clearances via the Nation's railroads (in connection with a different program). The information collected indicates that there would be no clearance problem for these shipments. These data will be updated at an appropriate time.

21

Wouldn't these heavy trains and trucks put too much stress on bridges?

The weights of rail shipments of high-level wastes are within the range of weights of other heavy commodities routinely handled by the railroads, and they offer no unusual loadings or stresses on rail facilities. Proposed routings would be coordinated in advance by the shippers and the railroads, thereby minimizing the possibility of undue stresses being placed on railroad bridges and trestles.

Shipment by truck must meet State restrictions on gross weight of vehicle and load. This ensures against damage to roadways and highway bridges. If shipments exceed that State's weight limitations, they may be transported through the State by special permit issued by the State. Such permits are issued after engineering evaluation of the proposed route to assure that roads, bridges, etc., will safely support the overweight shipment.

22

What position do rail cars carrying nuclear shipments have on the train? Will they be next to cars of other hazardous material?

The placement of cars in trains is subject to the DOT regulations. Those rules prevent "humping" of cars of hazardous materials; prohibit a car of radioactive materials from being coupled next to a car of explosives, poison gases, flammable poison gases, or undeveloped film; and prohibit a rail car of high-level waste from being transported in passenger trains.

23

Will there by many loaded rail cars and trucks lined up at the respository?

The respository will probably have enough track capacity to store between 10 and 12 rail cars. It is not anticipated that trucks carrying high-level waste will be received at the repository for the first few years of operation. Hauling high-level waste by truck is not very economical because of the extremely low payload weight as compared to the total weight of the cask. The larger the cask, the more economical it is from the standpoint of payload carried. Therefore, almost all high-level waste will move by rail. In any event, DOE will not permit a situation to occur at either the repository or a nearby freight yard where more than a few loaded vehicles (rail or motor freight) are stacked up. The high cost

(about a million dollars each) of shipping casks will preclude their being built in such numbers that industry could afford to have them in storage yards for long periods of time. (See also question 19.)

24 Will the waste shipments be routed around cities and congested areas?

Shipments could be routed so as to avoid major cities and congested areas insofar as it is practicable. It is not intended, however, to restrict the movement of shipments to such circuitous routes only, since the Federal safety standards do not rely on restriction of routes to assure safety during transit.

The regulations of the States impose controls on weights of loads on roadways and bridges. Also, in some cases municipalities and bridge, tunnel, and turnpike authorities place restrictions on cargo movements at specific periods of the day or night and over certain sections of routes. These latter limitations may affect the choice of routes.

Hypothetically, routes for shipping radioactive material could be required to be selected so as to avoid centers of population, special risk areas due to local road or rail conditions, areas of high accident frequency, extremes in ambient conditions such as very cold or very hot weather, high elevations, and delays. Such restrictions could reduce the probability of an accident occurring in many cases. However, if the shipping distances were increased, the accident frequency also might be increased. Examination of local conditions would be required in each case to determine whether such restrictions would be advantageous or not.

The DOT regulations (49 CFR Part 397) require motor carriers of hazardous materials to operate "over routes which do not go through or near heavily populated areas, places where crowds are assembled, tunnels, narrow streets, or alleys," unless there is no practicable alternative. Operating convenience is not a basis for determining practicability. Truck routes usually are chosen to move traffic along, and for that reason they usually avoid congested areas. Carriers use interstate highways whenever possible; these avoid centers of population in most cases. Although the use of divided highways and routes around population centers may reduce the probability of an accident occurring per mile, the severity of those accidents which do occur may be increased because of the higher rate of speed of the vehicle.

There are no specific regulatory requirements with regard to routing of hazardous materials shipments by rail. Severe rail accidents involve high speeds and frequently occur because of

faulty roadbeds or equipment. Roadbeds connecting centers of population are used more frequently than off-the-main-line roadbeds and generally are better maintained for that reason. Further, accidents occurring inside city limits are unlikely to be as severe as those outside the city limits since speeds are restricted. Emergency equipment is more readily available in the city. For these reasons, it appears likely that for rail shipment, the frequency of severe accidents may be greater for shipments made on routes chosen to avoid centers of population than if those same shipments were made on "main line routes" between population centers.

Requiring radioactive material shipments to be shipped over routes which avoid centers of population might reduce the radiological consequences of accidents involving a release of radioactivity or direct radiation exposure of nearby persons. This follows, since the dose would be smaller if the number of people in the affected area was smaller. The risk from accidents, however, involves both frequency and consequences. If the number of miles traveled is increased by the special routing restriction, the frequency of accidents will also be increased unless the probability of an accident is smaller for the "special route," since the number of accidents is proportional to the number of miles traveled. Also, the risk from transportation accidents due to common causes far overshadows the risk due to radiological effects. For instance, nonfatal injuries occur in 33 percent of all truck accidents and fatal injuries in three percent of all truck accidents, whereas the probability of radioactive release is vanishingly small. Experience and statistics show the probability of an accident causing any radiological effects is extremely small. Special routing to avoid centers of population to reduce the radiological effects, which are already small, can be expected to provide very little benefit. This slight reduction in the already very small risk from radiological effects could be outweighed by an increase in the risk from common causes. (See also question 64.)

25

Do truck drivers and train conductors carry Geiger counters?

No. The radiation levels outside of packages and around trucks and rail cars are restricted to very low levels. The experience with monitoring packages before they leave the shipping docks and again when they are received by consignees has been excellent—the levels stay the same in transit. In rare cases where there is suspicion that the levels might have changed,

255-223 O - 78 - 4

the correct procedure is to get knowledgeable personnel with reliable equipment to evaluate any suspected problem. (See also question 54.)

26

Why will private industry be assigned the job of handling the shipping of high-level radioactive waste? Wouldn't it be safer to have the Government do it?

Private industry will have the job of handling the shipping of high-level radioactive waste because it is industry's material. It is generated as a result of normal industrial activity in the processing of spent reactor fuel. The only reason the Government will control the storage and disposal of the waste is because of the need for essentially perpetual control, far beyond the assured life of any private company. The waste shipping will be handled by the spent fuel processor, who will pay for and own the casks, and pay for the shipment. He will also reimburse DOE for the costs of disposing of his wastes.

Regardless of who handles the shipping of high-level radioactive waste, the same safety standards would apply, so, in any case, safety will not be compromised. The NRC and the DOT have very strict regulations for shipping radioactive materials that will apply equally whether private industry or the Government manages the shipments. In fact, then, the shipment of high-level waste is Government-controlled and regulated even though private industry has management responsibility.

27

What is Environmental Protection Agency (EPA) doing about the shipping of waste containers?

DOE, NRC, and DOT have been providing EPA with information and data to allow EPA to make an independent safety evaluation of nuclear waste shipments. Holmes and Narver, Inc., under contract to EPA, has studied the overall environmental risks due to transportation of all types of radioactive materials. This study parallels and extends the NRC's studies on transportation of radioactive materials.

EPA's 1974 report on nuclear transportation risks stated, "the average annual population dose from transportation accidents of the nuclear power industry is insignificant . . . a release, if it should occur, is most likely to result in a relatively small exposure to individuals near the accident . . ."

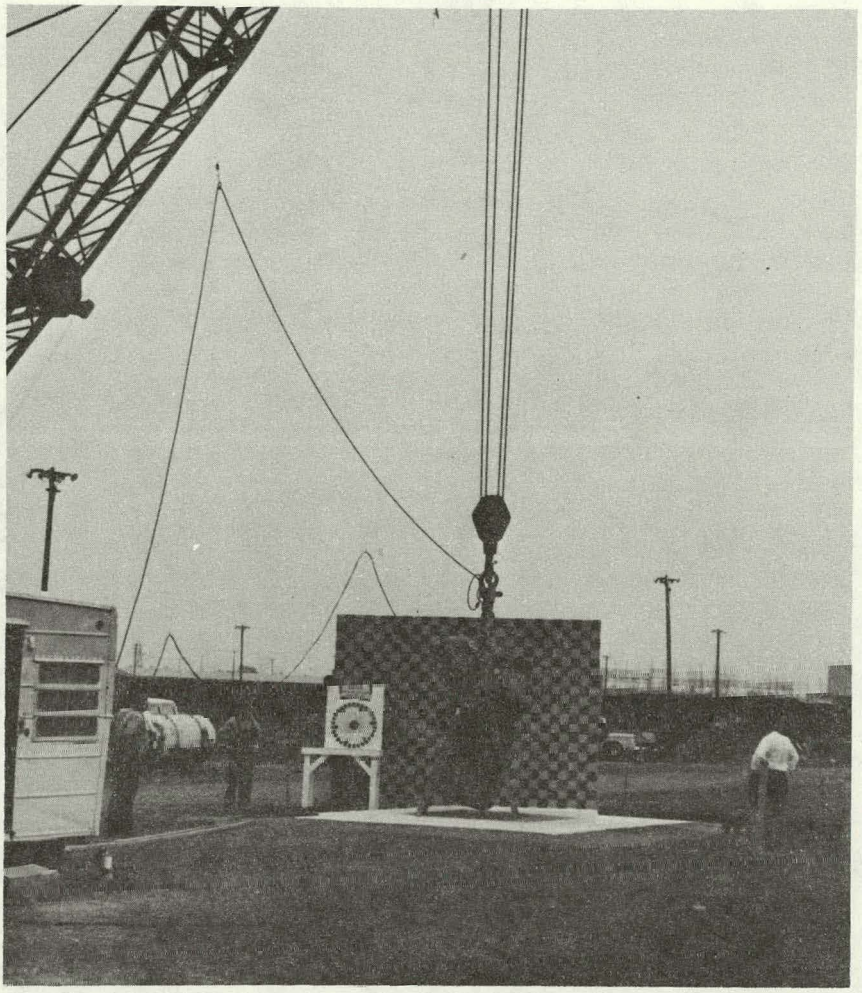


Figure 10.—A cylinder containing a simulated load of UF_6 is being dropped 30 feet onto 4-inch thick armor plate. This drop test was conducted by Union Carbide Corporation, Nuclear Division, at the Oak Ridge Gaseous Diffusion Plant.

28

In setting regulations for shipping high-level waste, isn't there some overlap between NRC and DOT?

Yes, to some extent. Both DOT and the NRC require shippers and carriers to meet strict requirements. But the cross-checking that results provides an added measure of safety. There is no industry in the United States that is more continuously policed, monitored, and inspected, throughout its total operation, than the nuclear power industry is. The transportation of nuclear waste is a part of this entire regulatory control program.

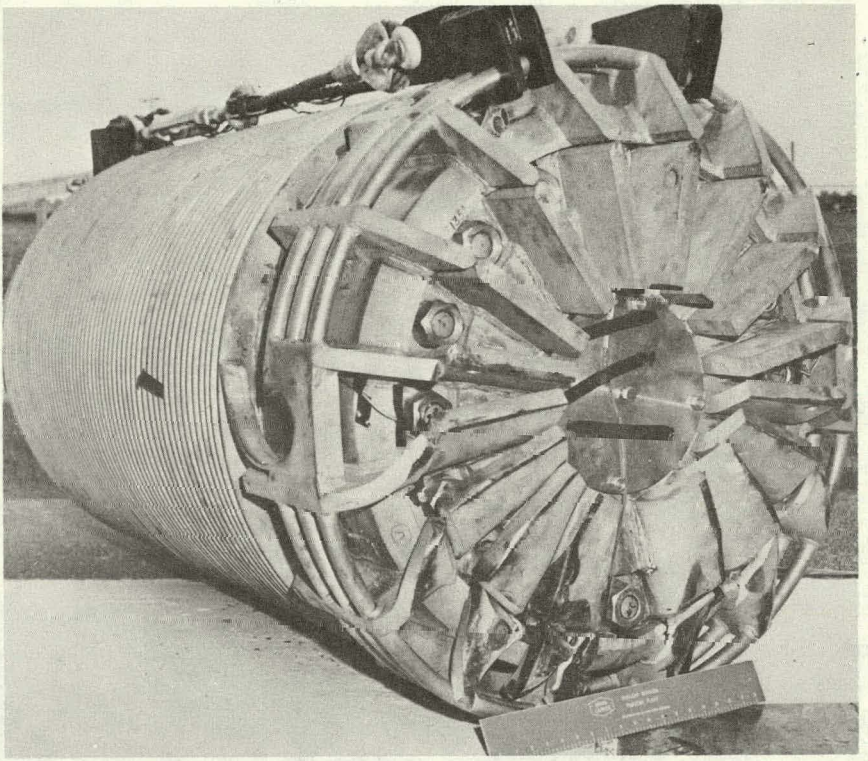


Figure 11.–The impact end of the shipping cask shown in Figure 10 after the 30-foot free-fall shows deformation of some of the fins and other sacrificial members, which prevented any damage of the shielding and cavity, and limited the shock to simulated fuel elements in the cask. The closure plug was easily withdrawn after the bent fins and the closure studs were removed.

The DOT has the regulatory responsibility for safe transportation of radioactive materials, including waste, by all modes (rail, road, air, and water), and by all means of transport (truck, bus, auto, ocean vessel, river barge, rail car, etc.).

All of the technical staff work is performed by the DOT Office of Hazardous Materials Operations (OHMO), which is in the Materials Transportation Bureau and acts as a coordinator and technical focal point in all matters of radioactive materials transport. Both DOE and the NRC act as technical advisors to the DOT. They also assist and advise DOT in establishment of national safety standards and in review and evaluation of packaging designs.

The DOT publishes regulations for the safe packaging and transport by rail or highway of various hazardous materials under 49 CFR 170-189 and 397. Radioactive waste is only one hazardous material covered by these regulations; others are

explosives, flammables, acids, poisons, and unstable chemicals. For shipments of high-level waste, the NRC also publishes additional safety regulations for the packaging of such material for transport in 10 CFR Part 71.

Before a specific type of package is approved by the NRC and the DOT for shipment of high-level radioactive waste, it must be capable of withstanding without leakage, all the normal conditions of transportation as well as a series of accident damage tests which produce damage conditions comparable to the actual damage a package might actually encounter in a severe transportation accident. The accident damage test sequence specified in the DOT and NRC regulations include tests for high speed impact, puncture, fire, and immersion in water. The regulations, therefore, offer a very high degree of assurance that a package will not breach under severe accident conditions.

29 Who approves the shipping casks?

Under the present procedure, the NRC would approve these casks, after a detailed safety evaluation. The standards that the casks must meet are published in both NRC and DOT regulations.

The NRC will evaluate the design and test results of the shielded casks prior to their use. After the design is approved, the casks must be built under carefully controlled procedures, to provide a high degree of quality assurance. (See also question 31.)

30 Who inspects shipments and shippers to be sure that they meet the rules and are safe?

DOE conducts routine inspections and appraisals of its prime operating contractors; the NRC does the same for private nuclear industry licensees. During those inspections, the DOE and the NRC determine whether safe packaging procedures for shipments are being followed.

The commercial carrier's safety practices en route must comply with DOT regulations. The DOT also has a field staff that conducts spot checks of hazardous materials shipments and carrier handling procedures, and investigates accidents. DOT has stated that it is increasing its efforts in this area because of increasing numbers of shipments.

3 **How do you know these casks are really strong enough? Do you test them? How?**

Hundreds of tests have been conducted on shielded shipping casks for highly radioactive materials. These tests have included high speed impact, puncture, fire, and water immersion.

A high-level waste shipping cask must be designed to withstand normal transport conditions without any loss of contents or shielding efficiency, and also without any significant loss of contents (other than small amounts of cooling water) or shielding if subjected to a specified sequence of accident damage test conditions. That damage test sequence includes: (1) a free fall from a height of 30 feet onto an unyielding surface with the package landing in such a position as to do the most damage; (2) a free fall from a height of 4 feet onto a 6-inch-diameter steel plunger long enough to do maximum damage with the package in the most vulnerable orientation; (3) heat input from exposure for 30 minutes to a fire or other radiant environment having a temperature of at least 1475° F.; and (4) total immersion in water for 8 hours. It must also be able to withstand the pressures of 50 feet of water depth without any leakage. Those accident test conditions represent the damage which a package might incur in a severe transportation accident, e.g., if a truck collides with a bridge pier, caroms through a guard rail, rolls down a rocky embankment, and into a river. Or, perhaps, a train derails, rail cars tumble around, several tank cars catch fire, a propane tank car explodes, and firemen pump water into the burning debris. The test conditions have been shown to produce the same kind of damage to the casks that those kinds of accidents will. Package designs which meet the criteria under these test conditions will provide adequate protection to the public and operating personnel in severe transportation accidents. Figures 10-16 show typical test situations.

Each high-level waste cask design prototype must be tested to these tests, or be evaluated analytically to assure that the design meets the test requirements. Any package meeting these requirements is a very tough package.

Consider just the 30-foot fall onto an unyielding surface such as a crash pad made of reinforced concrete about five feet thick, supported from bedrock by concrete piles about three feet in diameter, with an impact surface of steel armor plate up to four inches thick.

A free fall of 30 feet onto such an immovable object is a very severe test. Even though the impact velocity is only 30 mph, the fact that the surface is unyielding makes the total energy input to the package equal to a much higher speed accident. The vehicle structure in a severe accident soaks up substantial energy.

Therefore, the 30-foot drop test is equivalent to a transportation accident involving vehicle speeds from well over 50 mph up to 150 mph or more, depending on such variables as the nature of vehicle structure, softness of impact target, and angle of impact.

To guarantee that an industrial shipper has conducted the tests in a proper manner, or correctly performed his analytical study, the NRC requires the applicant to submit the design with detailed test results and/or analysis for a completely independent NRC review. Until NRC has approved this submittal and issued a package design approval, the applicant may not use the package. (See also question 29.)

In developing a safe container for the transportation of radioactive materials, one of the first steps is to look at past experience. Where possible, concepts are used that have proven successful in the past in resisting accidents. When previous experience proves inadequate, new designs are developed and tested as necessary. Once a satisfactory design is developed, it is necessary to assure that production runs are equal in quality to the design prototype. Depending upon the complexity of the particular design in question, quality assurance can be accomplished in several ways. For complex designs, it is often necessary to assign in-plant inspectors to examine the container at each step in the manufacturing sequence. For less involved designs, such as a steel drum, a simple inspection at the time of delivery may be adequate. Occasionally, production samples are tested to the same conditions as the prototype to guarantee that production models meet minimum safety requirements. In early 1974, the AEC proposed some changes to its quality assurance procedures to list in detail the steps that must be taken to improve the transport system. The record has been excellent to date and everybody wants to keep it that way.

In 1975, ERDA began a full-scale crash test program to determine the response of shipping containers to actual accident conditions. Two shielded casks were dropped from a helicopter at a height of 2,000 feet on to the rock-hard desert floor near Albuquerque. Despite an impact velocity of over 240 mph, the casks were practically undamaged and they did not leak. In early 1977, ERDA conducted two truck crash tests at speeds of 60 and 80 mph, with the trucks and casks crashing head on into concrete barriers. Test results were as predicted and fully support the belief that all similarly constructed casks will equally well withstand severe accidents without leakage. In another 1977 test, a locomotive going over 80 mph smashed broadside into a spent fuel cask on a truck trailer. The cask was only slightly dented; the locomotive was demolished. (See figures 17-22.) Other tests, including truck and rail crashes, are scheduled for later in 1977 and in 1978. These tests are open to the public.

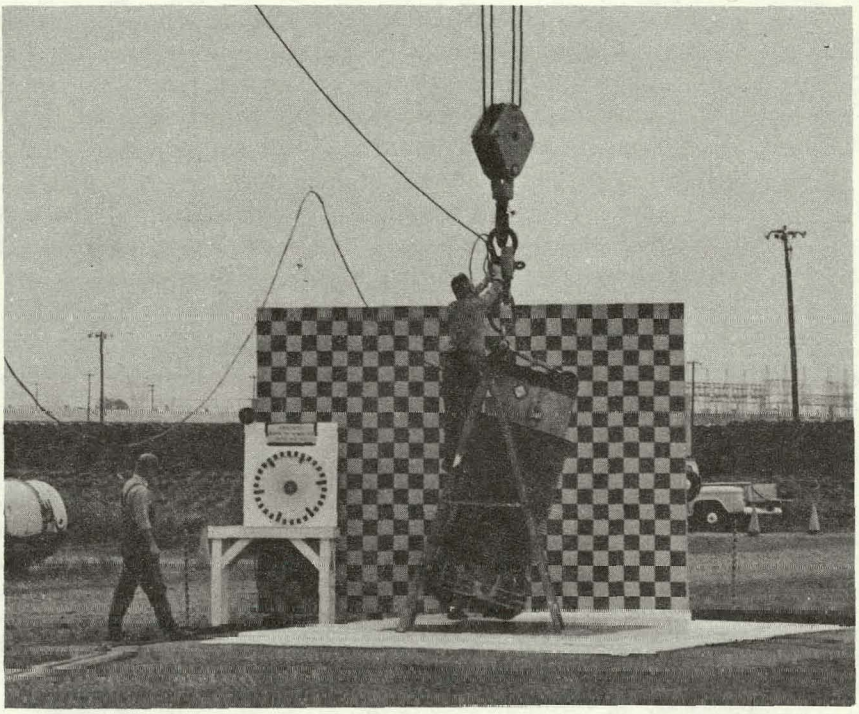


Figure 12.—The cask shown in Figure 10 is being prepared for a drop from a height of 4 feet onto a 6-inch spike at the Paducah, Kentucky plant, operated by Union Carbide Corporation, Nuclear Division. (See Figure 13.)

32

How hot will these casks get?

With respect to heat dissipation, the DOT regulations require the package be designed so that the temperature rise due to the internal heat generation will not cause the accessible surface of the cask to exceed a temperature of 180°F. An accessible surface could be a wire cage surrounding the cask which would limit access. As a practical matter, the temperature of the cask will not approach that level except under the most extreme weather conditions such as a hot summer day in the desert.

The rate of release of heat will not exceed about 100 kilowatts (or about 350,000 Btu/hr.). This might be compared to the heat released from a 200-horsepower truck engine during full-power operation. The amount of heat released is, therefore, too small to have any appreciable effect on the environment.

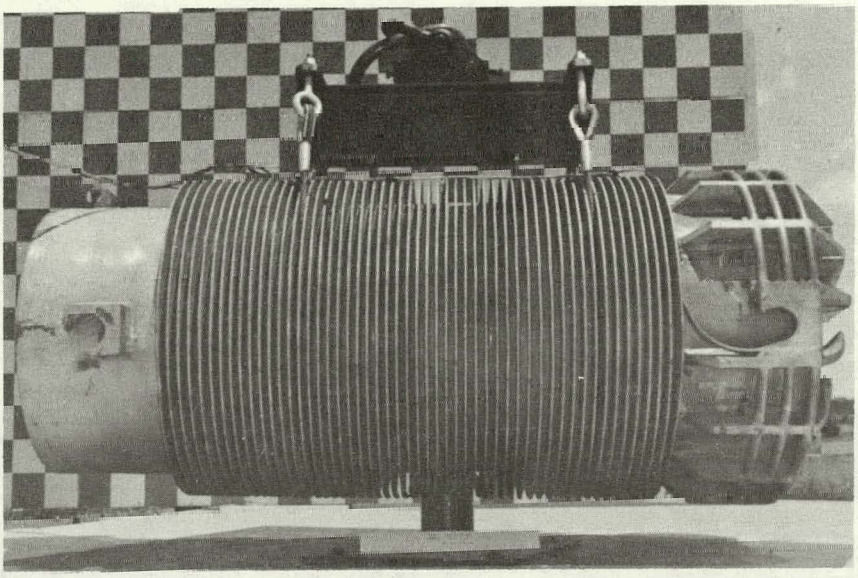


Figure 13.—The cask is resting on the spike after being dropped from a height of 4 feet. Note that there was only a small amount of deformation of the cask fins.

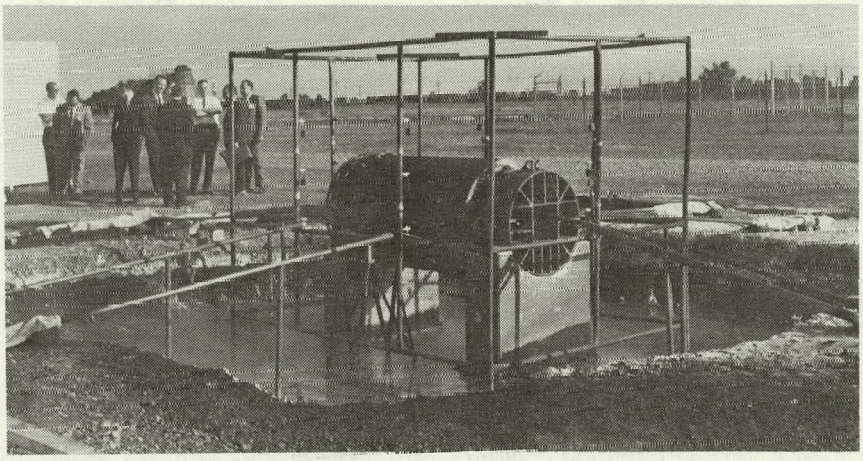


Figure 14.—This shows a cask in position over a pit for the fire test. Jet fuel is used for this test.

33 What happens if one of these hot casks is dropped into a river?

These casks are routinely loaded in water basins 40-50 feet deep, so they are designed for a water environment. If a cask is

accidentally dropped into a river or bay during transport, it is unlikely to be adversely affected unless the water is extremely deep, perhaps 5,000 ft. The water would remove the heat so overheating would not occur. Each cask is required by NRC regulations to be designed to withstand an external pressure equal to the water pressure at a depth of 50 feet, and most designs will withstand external pressure much greater than that. The waste canisters themselves are steel and designed to be stored under water for long periods without leakage of radioactive contamination. The cask could be recovered with normal salvage equipment. There would be no loss of integrity of the cask, and no loss of contents.

34 Are there any liquids in these casks, either as waste or as coolant?

The high-level waste will be shipped as solid material and there will be no liquid inside the canisters. It is unlikely that it will be necessary to use water coolant in the casks as is used for spent fuel shipments, since the amount of heat generated by the waste will not require it. Each canister may generate up to 10 kilowatts of heat during its shipment. There may be some circumstances for experimental purposes where water or other coolants may be used in the cask for shipments of higher temperature canisters which have not been stored for a 10-year period. Shipment of high-level liquid wastes are not permitted, and probably never will be permitted in the future, because the Federal waste repositories to which the wastes will be shipped will not be equipped to receive or handle liquid wastes. (See also question 1.)

35 What is DOE doing to make better casks?

Both industry and DOE have continuing programs to improve the packaging of all types of radioactive materials. Many of these development programs will seek new ways of providing better designs utilizing new materials and concepts. Computer codes are being developed which will permit more comprehensive analysis of packaging designs. DOE is working hard to improve its design review processes to permit greater precision in package analysis. Study programs are under way in DOE to obtain better understanding of transportation accidents and improved methods for assessing risk. DOE has started several new programs to improve package design technology. Every three years AEC, ERDA and now DOE sponsors an international symposium on

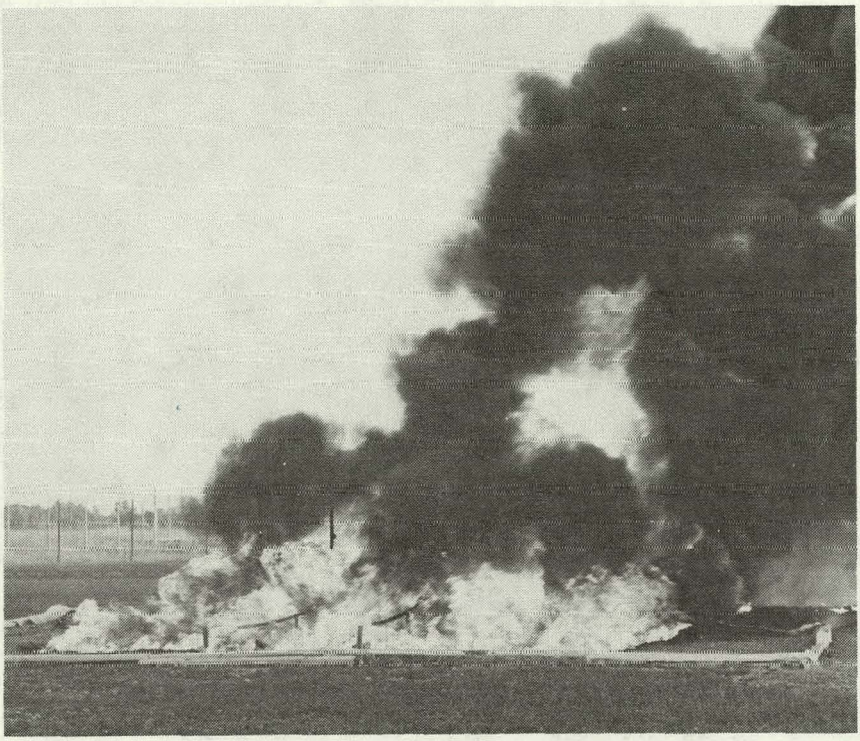


Figure 15.—The jet fuel fire completely engulfs the cask. The fire burned for more than 30 minutes at a temperature of 1475°F.

packaging and transportation of radioactive materials. These symposia were started in 1965 to bring together experts worldwide for an exchange of ideas and to announce improvements in technology.

36

Will guards or mechanics accompany the waste shipments?

A requirement that escorts accompany a shipment is not necessary in view of the low probability of a severe accident occurring in which an escort would be effective. Sending guards or mechanics along as escorts for such shipments would not provide an obvious increase in safety. Experience has shown that it has not been necessary to use safety escorts for shipments of spent fuel elements in the past. High-level waste shipments will be much the same. The casks are capable of being transported without the need for any controls en route. Therefore, there would be nothing for an escort to do.

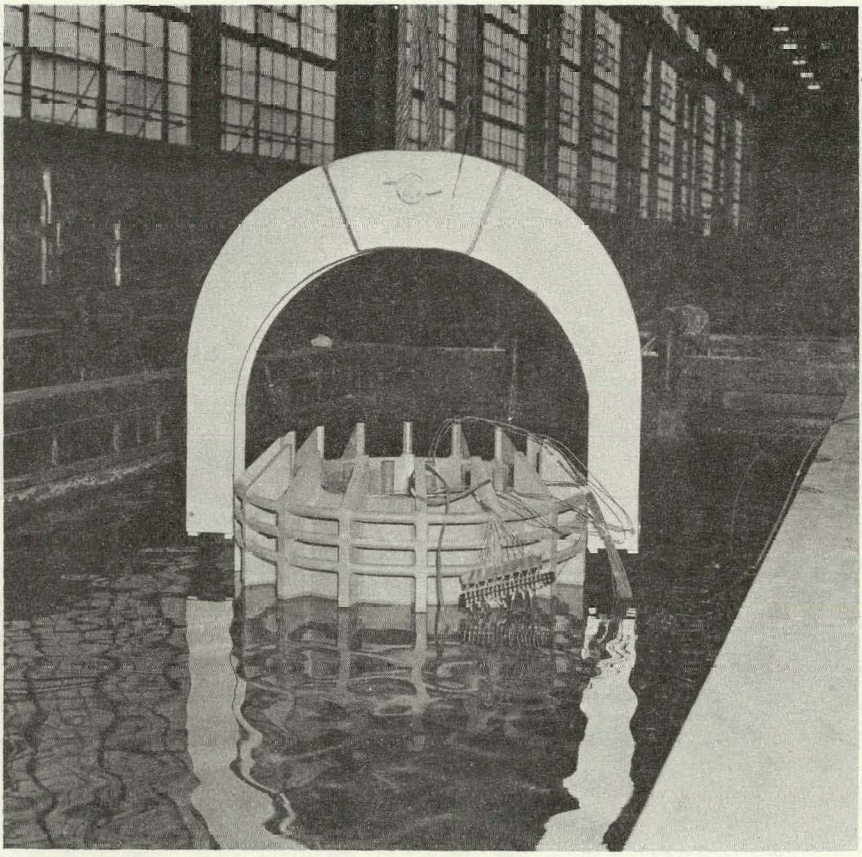


Figure 16.—A cask is lowered into a pool at the Paducah, Kentucky plant. Immersion is the final test of the DOT's accident test series.

It is true that escorts in separate vehicles or cars could accompany the shipments to monitor the area and take corrective action in case of an accident. However, escorts may be killed or injured in a severe accident. If they did survive, the most that they could probably do is to keep people away until they could check the cask. If there were, by some chance, a radiation leak, the escorts could do nothing to stop the leak or to reduce the immediate effects, and the police could take care of keeping other people away. The chance that escorts would be needed to reduce radiation exposures is extremely small, due largely to the very low probability of any leakage at all.

Waste shipments are controlled in a safety sense by the nature of the packaging containment. The containment is designed to withstand any likely accident and most unlikely accidents.

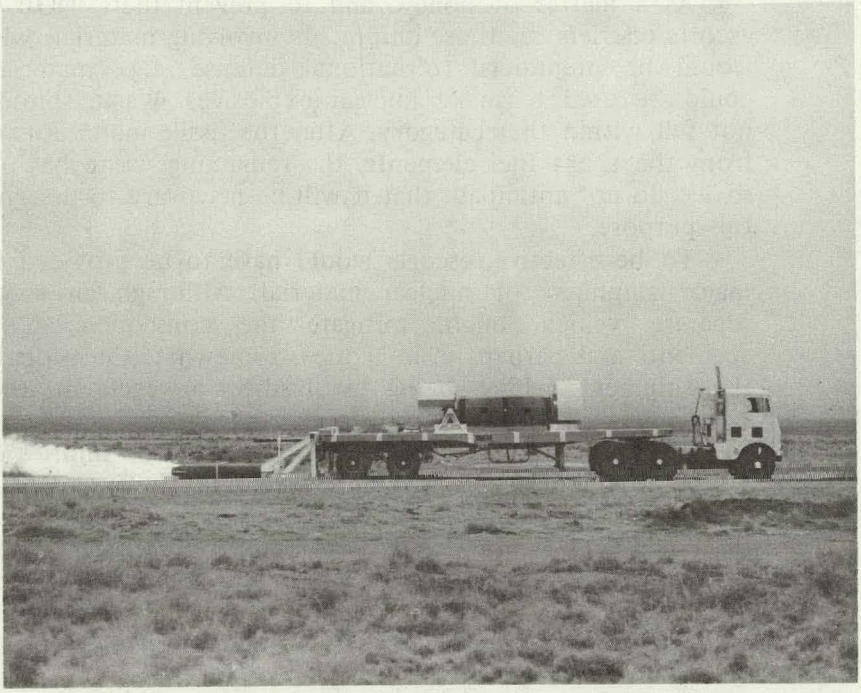


Figure 17.–A truck carrying a spent fuel cask is being fired by rockets into a concrete barrier at over 80 mph.

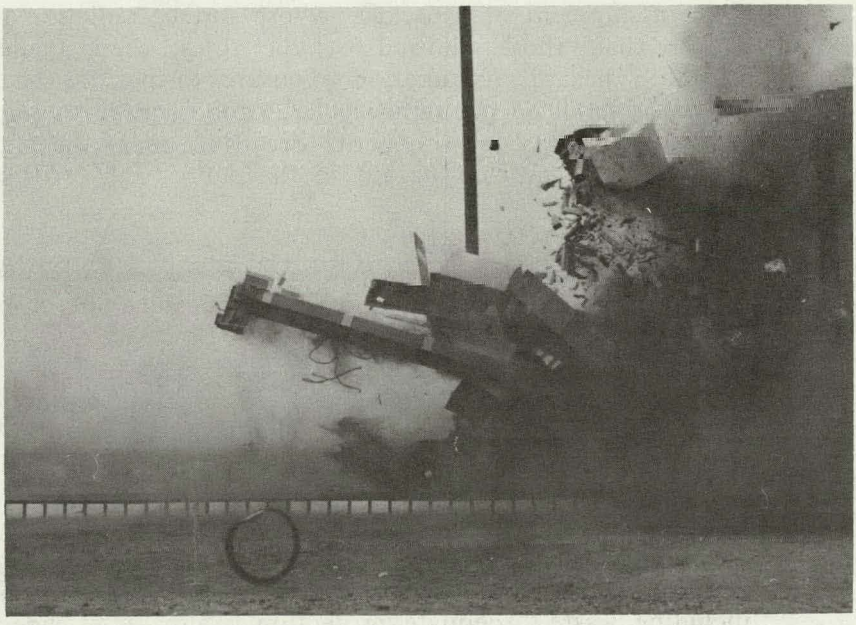


Figure 18.–The moment of impact in the 80 mph truck crash.

As a matter of policy, and to prevent theft, DOE employs escorts/couriers on those shipments involving materials whose loss would be prejudicial to national defense, e.g., material which could be used to make nuclear explosives. Waste shipments do not fall within that category. After the fissile material is removed from the spent fuel elements, the remaining waste has no value, so we do not anticipate that it will be necessary to use guards for this purpose.

To be effective, escorts would have to be provided for each major shipment of nuclear material. Although an escort in a separate vehicle might mitigate the consequences of some accidents and perhaps even reduce, somewhat, the probability of the shipment vehicle being involved in an accident, the escort vehicle has a probability of being involved in an accident at least equal to that of the shipment vehicle. Because injuries occur in 13 percent of all motor vehicle accidents, the increased number of injuries due to accidents involving the escort vehicle outweighs the small probability that escorts could reduce the consequences of a severe traffic accident (less than 0.5 percent of all accidents).

Escorts or attending mechanics might play an important role in those rare shipments which are nonstandard and which have a specific requirement for en route actions. If a shipment does not meet all of the regulatory safety standards, but still has to be made in the public interest, the DOT could require escorts to provide some sort of administrative control to offset the otherwise lower level of safety. For example, if it is necessary to make a shipment of a package whose surface radiation levels are higher than those allowed by the rules, there could be an increased hazard of radiation exposure to persons nearby. An escort could keep people away from the package to reduce that hazard. However, for shipments that fully meet the regulations, there is no significant hazard to the public, and escorts are not needed.

37 What protection from radiation will carrier personnel need to handle high-level waste shipments?

Carrier personnel won't need any special protection. The DOT regulations are very specific about the permissible radiation levels during transport at the surface of a cask, at the surface of a car or vehicle, near the car or vehicle, and for any position in the car or vehicle normally occupied by drivers or crew. Such levels are limited in such a way that transport workers require no additional protection due to carriage of radioactive materials, including waste. Adequate protection is already provided by the packaging itself. The exposures encountered by transport workers

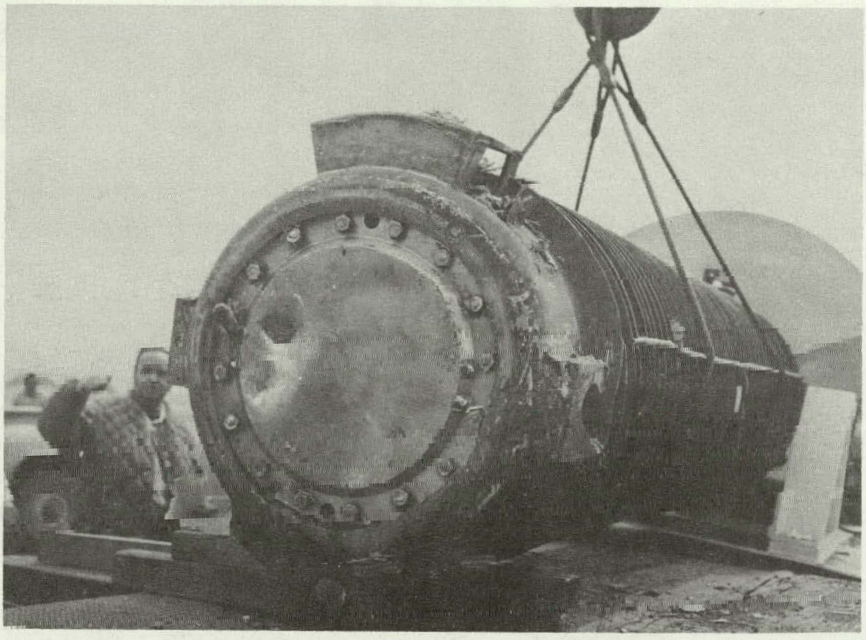


Figure 19.—The aftermath of the truck test—the truck was destroyed, the cask was superficially damaged, but did not break open.

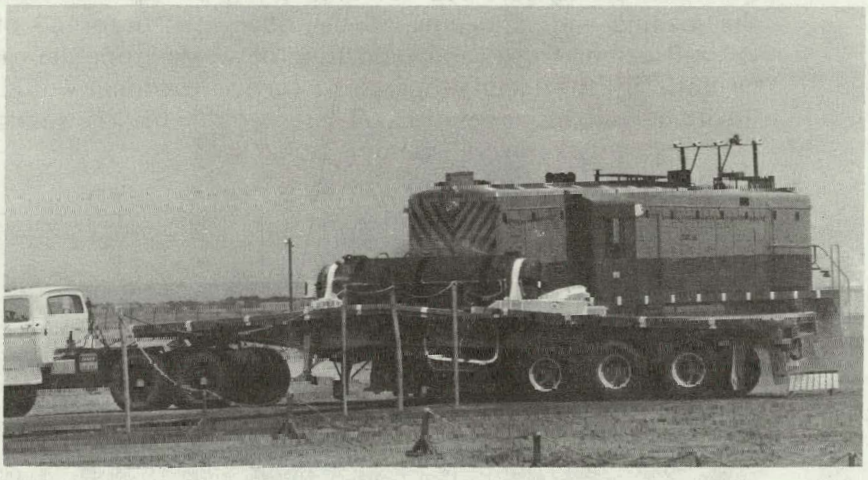


Figure 20. A locomotive, propelled by rockets to over 80 mph, crashing into a spent fuel cask on a truck parked on a grade crossing.

meet exposure limits established by both NRC and the International Commission on Radiological Protection. Experience in previous shipments indicate that even those carrier personnel who routinely handle shipments of various radioactive materials have radiation exposures far less than the allowable limits. Carrier

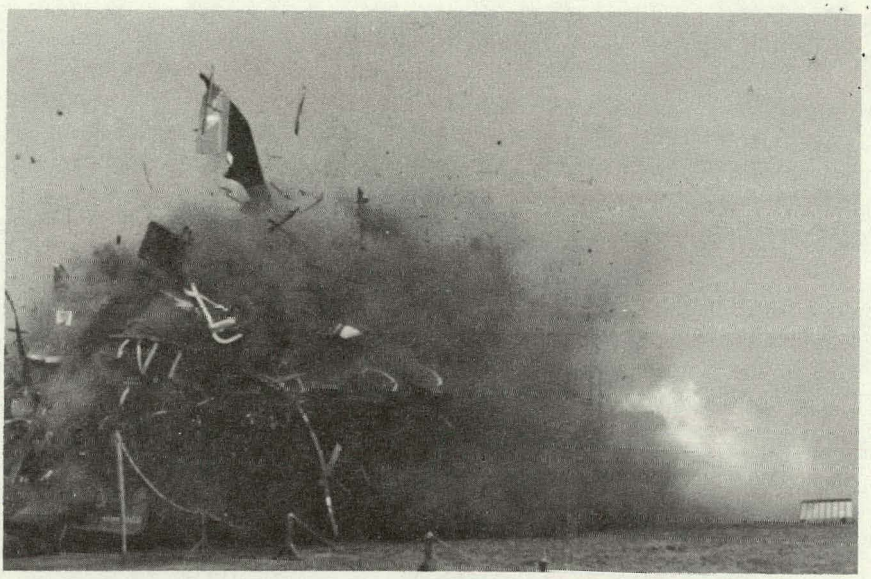


Figure 21. The locomotive smashes into the 25-ton cask.

personnel exposures in the case of high-level waste shipments will be even less because they will not be handling the casks themselves. They will be handling only the vehicles upon which the casks are loaded. The actual handling of waste into the casks, the loading and unloading of the filled cask onto and off from the rail car or truck, and unloading of waste from the casks will be done by the facility operators; carrier personnel would not be involved in this operation. There would be no intermediate handling of casks by vehicle operators.

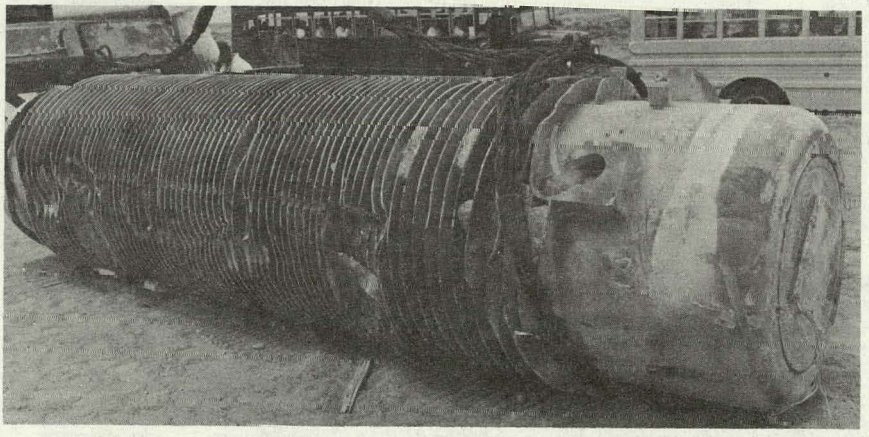


Figure 22.—The cask had some dents in the cooling fins after the locomotive crash, but did not leak.

38 Wouldn't it be better to reduce the amount of radiation the casks give off during normal transportation even further?

Taking into account the costs associated with additional shielding, weight limitations of available transport facilities and equipment, and the present state of the technology, the radiation levels associated with present designs of casks are already as low as reasonably attainable. This might change in the future, of course.

It is certain that there will be very low-level radiation exposure to people along the traveled routes, due to the fact that the casks give off low levels of radiation. Truck drivers, train brakemen, and even passing motorists will receive very low exposures, if they are near the cask. Those exposures would be a very small fraction of the radiation exposures they get due to the natural radioactivity of the earth. For example, the total population exposure of U.S. citizens due to naturally occurring radiation is about 30 million man-rem (a unit of measurement) per year. By 1990, considering the numbers of waste shipments to be made, the total population exposure would be increased by about 500 man-rem per year due to high-level waste shipments. That is a very small fraction of the total.

The exposures are now limited by the DOT regulations. The regulations have proved very practical over the years, and no one has been injured or received exposures in excess of the NRC annual limits as a result. The allowable levels could be reduced, as discussed below, but it would not lower the population exposure very much.

It is now possible to design and build heavier packaging with additional shielding or, by reducing the amount of radioactive material in a package, to reduce the radiation levels outside of the package. Additional shielding for most container designs would be added to the outside of the present shielding to avoid reducing the capacity of the container. The fractional increase in the weight of the container due to the added shielding would be more than the fractional increase in shielding thickness. The shipping costs increase as the ratio of weight of container to weight of the contents increases. Additional shielding also increases the initial cost of the container.

The weight of present designs of casks is approaching the limits of the available handling and transport facilities. Extra package weight means a smaller number of packages per vehicle, which would mean more shipments. More shipments would be required if the content of present packages were reduced. Increasing the number of shipments would increase the frequency of accidents and thereby increase the impact on the environment. Therefore, it we have to increase the number of shipments, it could offset the lower radiation levels per shipment.

39 What might happen if a shipping cask carrying high-level waste were involved in a severe truck or train accident?

The cask would probably be damaged to some extent. Severe transportation accidents usually involve high-speed impact, crushing, puncture, or fire forces, or some combination of those forces. The damage to the cask would be limited generally to superficial damage—bending or crushing of cooling fins, warping of attachments, scorching of paint, jamming of bolts and closures so they cannot be easily opened, and loss of any external cooling mechanisms (blowers). The cask might have to be repaired before being put back into routine service. However, it probably could be transported to its destination without repair in most cases.

There have been many thousands of serious nonnuclear transportation accidents over the past years—fires, train wrecks, explosions. Many of these accidents have been studied to see if casks could have withstood the accidents. In each of those cases, the judgment was that the casks would have gone through the accident without failure. (See also question 31.)

40 Suppose they don't screw the lid down tight on the shielded cask. What then?

Lids are normally not "screwed" into place. They are massive (5-15 tons) closure plugs or caps which are usually held in place by many large bolts. A typical bolt might be 2 inches in diameter and 12 inches long. The cover is bolted with a quality-controlled procedure using certain specified forces on torque wrenches, with the readings recorded on checklists. In the event that one or more bolts become loosened, or even broken, there are more than enough other bolts to keep the lid secured. Some casks use two lids in series for extra assurance of closure.

Lids for other types of casks may consist of a heavy plug (weighing several tons) equipped with locking lugs, similar to breech blocks on large cannons. The plugs are inserted into the cask opening, then rotated and locked into place. Then a number of large bolts are fastened to be sure the plug will not rotate. Even if they should all become loosened, there is no way the plug can rotate itself out of place.

In the very unlikely event that a mishap should loosen the lid, the canisters inside the cask will contain the waste and radioisotopes will not be dispersed.

Seals, valves, gaskets, and closures are all checked before shipment.

41 What happens if a cask breaks open, in spite of the assurances?

About the worst credible situation would be a partial failure of the cask closing mechanism, i.e., the lid or the plug. The total removal of the plug or lid is almost impossible, even in a catastrophic accident. Such an accident might produce small gaps in the shielding which would produce some very high radiation levels (hundreds of rems per hour) within a few feet of the gaps, but the nonradiological consequences of such an accident would probably far outweigh any radiological effects.

In other words, an accident bad enough to breach a cask would probably have already killed or injured the drivers or passersby or damaged nearby residences, or caused widespread structural damage, just due to the force of this enormously heavy cask crushing vehicles or striking houses. This is rather like the question sometimes asked about nuclear powerplants: "Would radioactivity be released from the plant if it suffered a direct hit by a nuclear bomb?" The plain answer is: "Yes, but it wouldn't make much difference." (See also question 51.)

42 Can a shipment of waste explode?

No. The high-level waste, as well as the cask itself, is chemically inert. It is nonflammable, nonpoisonous, and nonexplosive (both in the chemical and nuclear sense). (See also question 15.)

43 What if a trainload of explosives blew up next to a cask?

On May 5, 1973, in Roseville, California, several carloads of military ammunition exploded. After examining the results of that accident, and the damage done to adjacent cars, it seems clear that a high-level waste cask would probably not even be knocked off its flatcar, much less damaged to a point where the cask might lose any of its integrity.

A few years ago, terrorists blew up a pickup truck loaded with explosives at the University of Wisconsin. That blast would not have breached the integrity of a cask either. (See also question 64.)

44

How long after an accident will a cask of high-level waste last without cooling before the waste melts or escapes?

All shipping casks for high-level wastes and other large quantities of radioactive materials are designed to remain intact following a severe transportation accident (including a fire) without respect to time after the accident. The typical cooling arrangement in a cask for high-level waste employs a natural convection-conduction principle of heat dissipation, utilizing a finned exterior surface which will permit the cooling system to function indefinitely even after being subjected to a severe accident. Therefore, the cask would last indefinitely without melting or loss of contents. As a practical matter, the likelihood of a severe transportation accident in the U.S. going unnoticed for more than a few hours is remote. (See also questions 50 and 54.)

45

If there were an accident involving a radioactive spill, who would clean it up?

The railroad or trucking company involved, or local emergency authority, would be responsible for cleaning up after an accident, just as it is for spills of nonradioactive hazardous cargo, such as acids or poisons. However, the carrier is not expected to have any expertise in nuclear hazard evaluation. For that reason, and because of the public's general apprehensiveness, radiological assistance is available from DOE and from both state and local health agencies. This assistance consists of advice and emergency action essential for the control of the immediate hazards to health and safety of the public. Responsibility for post-emergency cleanup is assumed by the carrier, or the responsible local governmental authority. (See also questions 58 and 61.)

46

Couldn't you reduce the amount of radioactivity in a cask by storing the waste for a longer period of time before shipping it?

Yes. The amount of radioactivity and decay heat in the high-level waste can be reduced by holding the waste in the storage facility at the fuel processor for longer periods of time. But the whole story is a bit more complicated.

During the first 90 days after removal from the reactor, most of the radioactive iodines decay to low levels, the radioactive gases (krypton, xenon) are reduced, and other short-lived

radionuclides decay so that the amount of heat generated is greatly reduced. As time passes the rate of reduction of radioactivity and heat levels decrease. By the time the waste is put into canisters and shipped, the rate of radioactive decay has become quite low. For purposes of shipment, the difference between storage for 10 years and, say, 20 years is not very significant. (See also question 1.)

47

Is it even possible that there will be any leakage in an accident? Is it a "one-in-a-million" thing?

It is *possible,* but the *probability* is a very remote thing. It is possible for a jetliner to crash into Yankee Stadium during a World Series game. It is possible to be bitten by a rattlesnake in Times Square. It is possible to be struck by a meteorite. The probabilities of these events are so low as to be considered incredible. But they are possible. In contrast, the probability of being hit by a car at a busy intersection is fairly high.

AEC probabilities studies showed the likelihood of a serious release of material from a high-level waste cask to be on the order of one accident for every hundred trillion vehicle miles. With 100 waste shipments per year by 1995, and an average of 1,000 miles per shipment, this means about one accidental serious leakage per billion years. That's a mathematical way of saying that it's incredible, and a psychological way of saying that it's impossible. By comparison, the likelihood of serious injury due to an automobile accident per person is about one in 500 years (400,000 injuries per year).

48

Have you actually made estimates of the frequency with which accidents will happen?

Yes. Several studies are already complete, and others are under way. A recent NRC analysis shows that accidents will occur at a rate of about one per million vehicle miles, or about one in ten years for 100 high-level cask shipments per year. Severe accidents might occur at a rate of one per 120 accidents, and extra-severe accidents about 80,000 times less often.

Projecting these probabilities to the year 2000, with an average distance of 1,000 miles per shipment, one could expect one release of radioactivity of some sort from a cask once every 5,000 years.

49 What might happen in accidents which are even more severe than the accidents you have already considered?

The casks are designed to withstand severe transportation accidents without leakage of contents. It is recognized, as stated in the previous answer, that "catastrophic" or "extreme" accidents also do happen, with some determinable degree of frequency (about 80,000 times less frequent than "severe" accidents, according to an NRC study). Because of the high degree of design integrity in the casks, the casks would probably withstand "catastrophic" accidents without serious leakage. There might be some leakage, but not over a broad area. Any contamination would be essentially local in nature, and would not cause widespread hazards to health or significant risks of injury or death. And in most cases, even in a catastrophic accident (such as a tornado, a head-on collision followed by a long fire, etc.), there would be no leakage at all.

50 Would you have to evacuate a whole city if an accident happens?

In any serious transportation accident, like one involving explosives, propane, or chlorine, the local authorities must consider whether evacuation of the local populace is necessary. This would also be true in the case of a serious accident involving radioactive materials. We can foresee no likely need for evacuation in the case of an accident involving shipments of high-level waste because we are convinced that there will be no release of contents significant enough to warrant such a drastic measure. (See also question 51.)

In 1958, the AEC, along with other Federal agencies established an interagency radiological assistance plan (see also question 53). Since then, the AEC, ERDA, and other Federal and state agencies have been sending radiological assistance teams to help local authorities at the scene of nuclear incidents. It has never been necessary to evacuate people from homes or businesses near transportation incidents because of radiation although evacuation is common in cases of other hazardous material incidents.

It should also be recognized that rapid evacuation of large groups of people often involves injuries and sometimes deaths due to traffic accidents. Such results could be much more serious than the effects of any probable accident involving shipment of high-level waste.

51 How many people might be killed or injured in a serious crash involving nuclear waste?

Serious crashes, either train or truck, often cause death and injury. Truck drivers are not likely to survive an 80 mph impact into another vehicle or a bridge. Multicar, high-speed derailments usually result in death and injury to many persons including both railroad employees and bystanders. People inherently have a low degree of crash survivability. Such details and injuries are independent of the radioactive nature of any nuclear cargoes.

Although nuclear packages will withstand such accidents without leakage, the question always arises, "Yes, but what if? What if there is a leakage, in spite of your assurances? How great a catastrophe will there be?" These are honest questions, and represent real concerns.

First of all, the dangerous effects of a gross leakage, should it occur, would be local, not widespread. If, by some set of highly unlikely circumstances, a canister of high-level waste could be removed from its cask en route and left exposed, it could cause death (400 rem exposure assumed) to people within 100 feet but only if they were to remain there for an hour or more. Shorter exposures would kill fewer people; longer exposures would kill more. Serious injuries (150 rem exposure assumed) could result from one hour exposures out to perhaps 150 feet. Beyond 350 feet, there would probably be no radiation injuries at all. Common fears of thousands of deaths are unfounded, because it is so highly unlikely that there would be many people so close to the waste canister and certainly improbable that they would stay there for long periods of time. Accidents so serious would involve a lot of wreckage, and access would be restricted within a short period of time. Fire would be likely, and the heat from the fire would keep people at a reasonably safe distance. Although serious accidents attract onlookers, it is unlikely that they would be able to remain close enough to the exposed canister long enough to be seriously injured. By comparison, a 1974 rail accident involving an explosion of an LPG tank car in Decatur, Illinois, killed 7, injured 349, and caused $18,000,000 damage to property.

In any event, in a crash serious enough to even threaten the cask's integrity, the number of deaths and injuries from the resultant conventional crash effects would probably be much greater than would be likely from the nuclear effects of an exposed canister. The circumstances which could result in the release of a waste canister from its cask are not credible. (See also questions 27, 41, 47, 48, and 49.)

A more likely, but still highly remote, condition would be where the seal on the cask closure plug fails in an extremely severe accident. In an accident so severe, there is also some

possibility that the stainless steel of the waste canister could be cracked or split, and as much as a handful of fragments or pieces of the solid waste might escape from the cask. This amount of material would not be enough to cause death, even if spread around the immediate vicinity of the cask, and probably would not result in serious injury. (Note: the term "injury" here refers to the conventional industrial use of that term, as defined by the National Safety Council, meaning an injury resulting in lost time from work, hospitalization, or compensation.) Because of the dense and relatively nonsoluble nature of the waste, gross contamination of nearby property or water supplies is not considered likely.

In short, the maximum adverse nuclear effects of a serious transportation accident are: (1) noncatastrophic; (2) manageable from the point of control of public hazard; and (3) small compared to the nonnuclear effects of the same accident.

52 Will the casks be able to be hit by a tornado, hurricane, lightning, or earthquake without spreading radioactivity?

A tornado is the most destructive weather phenomenon known with winds several times stronger than hurricanes. An analysis has been made of the effect of a tornado on the special rail cars now being used for the transport of low-level waste. The analysis indicates that there is a possibility that the 100-ton cars could be rolled over as a result of the high wind velocities, but no radioactive material would be released from the car. The cars are designed to remain intact even if subjected to a rollover or other severe rail accident.

A high-level waste shipping cask will probably weigh 75 to 100 tons with a very low surface area (high density) which means even less susceptability to high winds and more resistance to stress. The flat cars used to carry these large casks also have a very low surface area exposed to tornado winds. About the worst conditions that could be postulated would be that the cars would be turned over and the cask dumped on the ground. In any event, analysis indicates no release of radioactivity would take place.

Hurricanes or earthquakes would not stress the casks beyond their design integrity, either.

Since the casks themselves would be able to withstand a lightning strike with no significant damage to the cask and certainly no release of its contents, there is no need for special lightning protection for the vehicles.

53 **What would happen if a high-speed locomotive smashed into a cask?**

An accident of this type could happen if a train were to strike a truck carrying a cask. Considering the design and construction of casks vs. locomotives, and the relative forces involved, both the cask and the locomotive would probably be damaged beyond economic repair. It is highly unlikely that the integrity of the cask would be threatened, however, or that there would be any loss of contents. Scale model tests have already been conducted which confirm this conclusion and a full-scale test was conducted.

54 **What sort of nuclear emergency procedures do you have in case of an accident?**

DOE operates under an Interagency Radiological Assistance Plan to provide expeditious and effective radiological assistance to anyone requesting it. Under that Plan, DOE coordinates Federal, state, and local radiological incident assistance operations, and encourages the development of local capability to cope with nuclear incidents. Emergency teams are provided by DOE, the armed services, state and local public health agencies and even some police and fire departments.

DOE maintains a nationwide organization for the purpose of responding to radiological emergencies of all kinds on a 24-hour-a-day basis. Under the Plan, the capabilities of the Department of Defense; Department of Health, Education, and Welfare; Environmental Protection Agency; Defense Civil Preparedness Agency; and several additional Federal agencies can be brought to bear on accidents involving nuclear hazards in the unlikely event it might be required. There is close coordination with the state and local police, health, and civil defense organizations and their radiological emergency capabilities. The first objective of these teams is to take the immediate action necessary to save lives, minimize injury, and prevent spread of any nuclear materials that might have been released. The teams remain on the scene until the emergency conditions are under control, and to help the return to normalcy after the incident.

55 **Some scientists at DOE's Hanford plant have been quoted in the press as saying they did not want to ship their own wastes because they didn't like the chances of a transportation accident. Wouldn't the commercial waste be a lot worse?**

The Hanford scientists were considering the cost and problems of storing or disposing of 250,000 tons of nuclear wastes from 25 years of operation in the nuclear weapons program. These existing stockpiles of both liquid and solid wastes are of a completely different physical and chemical composition than solidified high-level wastes. A few of those scientists were, in fact, concerned about potential radiation hazards, but they were wrong as far as the magnitude of the problem was concerned. Most of the scientists recognized the situation as a logistics problem rather than a nuclear one. The size of the fleet movement of that much waste could have made potential deaths and injuries from common traffic accident causes a definite disadvantage. The confusion came from misquoting or misinterpreting the scientists as to the reasons for their concern. In any event, it is expected to be easier to treat the commerical waste problems, which can be planned for in advance, than to try to look back to past accumulations of waste materials.

56 Why can't we require stricter safety rules to be even more safe?

We could. We could even go so far as to prohibit shipments entirely—that would be the ultimate in transportation safety.

But how about something in between? Surely, the potential radiation exposures due to nuclear transportation accidents would be reduced by imposing more strict accident damage tests on casks. But reduced from what? Studies of probabilities and consequences of nuclear transport accidents involving casks meeting the present standards show that the radiological risk is already very small. Increasing the severity of the test conditions would require heavier or larger casks, which would, in turn, mean a lower payload per vehicle and a resultant increase in the number of shipments. More shipments mean more accidents, and any potential gain in nuclear safety would be largely negated by a lesser degree of non-nuclear safety.

The National Academy of Sciences recently stated, "The public must be protected from radiation, but not to the extent that the degree of protection provided results in the substitution of a worse hazard for the radiation avoided. Additionally, there should not be attempted the reduction of small risks even further at the cost of large sums of money that, spent otherwise, would clearly produce greater benefit." (See also questions 15 and 68.)

57 Have policemen and firemen been briefed in the basics of radiation?

Appropriate training has been given to firemen, policemen, and other emergency groups who may be called upon for emergency action in the event of an accident in transit. Various pamphlets, films, and other materials have been prepared by DOE. These are useful to local authorities in developing their own training capabilities.

58 Who is responsible—the Government or industry—if an accident results in damage?

Basically, there is no difference in who is responsible for an accident just because nuclear materials are involved. In a transportation accident, the carrier may be held liable for damages to persons or property resulting from the accident. If the carrier can show that the shipper or another vehicle operator was at fault, or at least contributed to the losses, that other person may be held coresponsible to some extent and may even end up shouldering the full liability.

Although the carrier has a liability responsibility for damages, the local authority (sheriff, police chief, constable) would be in charge of activities at the scene of an accident, just as if it involved chemicals, flammables, or explosives. (See also question 45.)

59 What insurance coverage is available for nuclear shipments?

Following enactment of the Atomic Energy Act of 1954, the private nuclear industry expressed a need for a substantial amount of public liability insurance for injury or property damage to protect against the unknown and potentially catastrophic risks of nuclear energy. The industry indicated that lack of adequate insurance could be a major obstacle to the commercial development of nuclear technology. The Price-Anderson Act of 1957, which amended the Atomic Energy Act of 1954 (principally Section 170), provides Governmental indemnity to complement available private financial protection for the payment of public liability claims for personal injury and property damage resulting from a nuclear incident. In 1957, two nuclear liability insurance pools were formed by the insurance industry with a combined insurance capacity of $60 million applicable to any one nuclear incident. This has been increased several times, and currently is $110 million.

The Price-Anderson Act of 1957 provided Government indemnity in the maximum amount of $500 million. The statute further provides that this $500 million shall be reduced by the amount by which the "financial protection required" exceeds $60 million. Thus, the total at any given time is determined by adding the amount of insurance available from the industry (currently $110 million) to the $500 million maximum Government indemnity, and then subtracting the amount by which the available insurance exceeds $60 million. A major purpose of the Congress in enacting this legislation was to assure that in the unlikely event of such an incident, funds would be available to compensate members of the public for injury or property damage.

Price-Anderson coverage is provided to certain contractors and licensees of the NRC and would be available for payment of public claims for personal injury and property damage in the event a nuclear incident occurred in the performance of activities under the contract or license. This coverage is also available to carriers transporting radioactive waste to and from indemnified facilities.

60

If transportation of waste is so safe, how come you have Price-Anderson indemnity coverage for transportation accidents?

Several studies have shown that potential losses during transportation accidents would be far less than the regularly available insurance coverage, and so Price-Anderson coverage normally would not be necessary for transportation accidents. Even so, it is available under appropriate circumstances.

Shipment procedures regarding transportation of radioactive materials provide a very high degree of safety. Nevertheless, a radioactive release during a transportation accident theoretically could happen, however remote that possibility might be. In order to satisfy the concern of the carriers, and to assure the public of adequate coverage in the event of the occurrence of even such a remote possibility, Price-Anderson is available to cover transportation of nuclear waste.

61

How do you clean up after an accident?

Procedures for cleaning up the site of a radiological incident are essentially the same as for cleaning up the site of an accident involving other hazardous materials. Because of the nature of radiation and radioactive contamination, protective clothing, radiation detectors, and other special equipment may need to be

used. The levels of radiation and contamination would be sufficiently low in any credible accident as to make the recovery and cleanup a manageable operation, not unlike the cleanup of a ruptured tank truck of acid or pesticides.

These procedures are written into pamphlets issued by DOE, the Department of Transportation, the American Trucking Associations, and the Association of American Railroads, as well as numerous public health, civic, and technical groups. (See also question 45.)

62 How much might a serious accident cost in damages?

At least two reports (WASH 1238 and NUREG-0034 (see Bibliography in the back of this booklet) estimate the damage and cleanup costs resulting from an accident. It is difficult to project credible radiological costs in excess of a million dollars in the case of high-level waste cask accidents. Severe rail accidents (not involving any radioactive materials) routinely result in losses of that magnitude, due to fire, explosion, impact damage, injury, and death. Shipments of high-level waste would have even a lower potential for accident losses than spent fuel shipments, due to the nondispersibility of the solidified contents, with no radioactive gases or liquids. The AEC and NRC studies show that the radiological consequences of an accident would always be manageable, and that they would be small compared to the nonradiological consequences.

63 What are you doing to protect the casks from sabotage and terrorist attacks?

The casks will successfully withstand the types of assault one might expect in that regard. The casks will withstand high-power rifle or machinegun fire, even with armor-piercing bullets, without penetration. Such bullets will not penetrate two inches of steel shell, much less the thick lead and steel inner shell. The casks would also withstand explosive attacks, such as one might expect with a satchel charge (several sticks of dynamite) or small bombs or plastic explosive charges that might be surreptitiously placed on the vehicle or dropped from an overpass. Even small thermite bombs would have no serious effects. (See also question 52.)

With lids and closure plugs weighing as much as 5 to 10 tons, it is not likely that anyone will be peeking in to see what is inside. With the casks themselves weighing between 20 and 100 tons, theft of an entire cask is highly unlikely.

64 What do you do to prevent transportation accidents involving high-level waste?

There is very little that DOE can do to prevent accidents to trains, trucks, airplanes, or ships. The Department of Transportation has regulatory responsibility for safety in the transportation of radioactive materials by all modes of transport in interstate and foreign commerce. However, DOE, NRC, and DOT do work closely together both in research and development and in regulatory actions to try to reduce accident rates.

Protection of the public and transportation workers from radiation during shipments of high-level waste is achieved by a combination of limitations on both the contents of the packaging (according to the quantities and types of radioactivity) and the packaging design. Shipments will move in routine commerce, and on conventional transportation equipment. Shipments are, therefore, subject to normal transportation accident environments, just like other nonradioactive cargo. The shipper has little control over carrier operations or over the likelihood of an accident involving his shipment. He does have control over the consequences of accidents by controlling the package design, contents, and external radiation levels. Safety during transportation does not depend upon special handling or special routing.

DOE has an agreement with the Federal Railroad Administration which may reduce the rate of accidents. The FRA has agreed to handle track inspections on a priority basis on request, for those routes over which the waste casks will travel. (See also questions 9, 16, and 21.)

65 What kind of leak tests do you conduct prior to shipment, both on the cask and on the waste canisters inside?

Even though the likelihood of any leaks of radioactive material from a canister containing encapsulated dry solid waste is rather remote, there are monitoring procedures to detect leaks if any should occur. The water in the storage and loading basins where the waste canisters are stored prior to shipment is monitored to detect any increase in radioactive contamination. If any increase is detected, the offending canisters are removed and resealed. This is a sensitive measurement and will detect small increases in contamination levels. The waste canisters are loaded into the cask with the cask submerged in the basin, permitting any leaking canisters to be detected right up to the time the cask is sealed. The procedures just described are in-plant safety

precautions normally required by the terms of the NRC license for reactors and processing facilities.

Once the waste shipping cask is ready for shipment, Department of Transportation regulations require, among other things, that the shipper ensure by examination or appropriate test that: ". . . each closure device of the packaging, including any required gasket, is properly installed and secured and free of defects; . . . and that each closure, valve, and any other opening of the containment system through which the radioactive content might escape is properly closed and sealed."

One often-used technique for testing a cask for leaks is a helium leak test system. The shipper is free to use his own leak test techniques as long as he meets the regulatory requirements that the cask be sealed and will cause no significant release of radioactivity to the environment. Another standard technique is to monitor the radiation level of the cask after it is sealed to ensure that no voids exist in the shielding. Tests are also performed just before shipment to ensure that the external surface of the cask is clean and free of radioactive contamination. This is an additional means of detecting any possible means of cask leakage and provides assurance that a leaking cask is not shipped. (See also question 40.)

66 What happened to the radium shipments that disappeared in 1966? Would the waste shipments be more dangerous?

There were several cases of medical radium shipments that disappeared. Sometimes the packages would arrive empty, with the tops missing. These resulted from faulty packaging which allowed the radium capsules to fall out or perhaps to be removed from the lead pot inside. Where they went, no one knows. The major DOT and AEC regulatory changes made in 1968 tightened the packaging standards to preclude recurrence of that sort of problem. In other cases, the shipments may have been stolen, either intentionally or inadvertently (along with other cargo). The radium itself has not been found.

In the case of waste shipments, there is much more radioactivity per cask, but the casks are also much heavier and stronger, and virtually theft-proof. The radium packages were not "accident-proof," but the casks are. External radiation levels around the radium packages and the casks during normal transport are limited by the same regulatory levels. Because of restricted access to the waste casks and the accident-proof design, the overall risks to the public from the high-level waste shipments are likely to be far less than those radium shipments.

67

I've heard that there were increases in infant mortality along routes heavily traveled by radioactive materials shipments. Is that true?

No. None can be detected or even meaningfully calculated. The radiation dose to persons near (100 feet to 2,500 feet) the route of a vehicle carrying spent fuel would be from 0.0006 to 0.000001 millirem per shipment. The situation of high-level waste would be about the same. Even if 1,000 of these casks went past a certain house very year, the increase in radiation exposure to the inhabitants would be less than one percent of the dose due to natural background radiation (about 100-150 millirem per year). Actually, it is not likely that any one person would be exposed to as many as 100 cask loads per year. These radiation levels cannot be practically considered to be injurious. (See also questions 47, 48, and 49.)

68

Who else besides DOE says that waste transportation is safe?

For one, the National Academy of Sciences (NAS). The NAS Panel on Transportation of Radioactive Waste, with no AEC employees as members, has studied waste transportation safety in depth since 1970. That Panel concluded in 1974 that "... it seems likely that the overwhelming risk in transportation (of nuclear wastes) is that of direct death and injury and damage to property from conventional traffic accidents totally unrelated to radiation." Further, "... the total adverse effect of that transportation (of nuclear wastes) is still acceptably small."

For another, the Environmental Protection Agency (EPA) agreed with the AEC's assessment of the public risk on shipment of spent fuel. The EPA found the risk to the environment due to the radiological effects from transportation accidents is small. The same would apply to high-level waste shipments, where the potential public hazard is even smaller. EPA has performed additional studies on waste since then, with the same conclusion.

Even more recently, in 1976, the NRC published its generic environmental impact statement on the shipment of nuclear materials, including nuclear waste. NRC came to the same conclusion.

69

What criteria do you use in saying that the public risk from the transportation of nuclear waste is "acceptable"?

Modern life confronts people with a multitude of risks. Each person has his own idea of what risks are acceptable to him.

Some people are afraid of airplanes but ride motorcycles. Others smoke heavily but take a vitamin pill every day to stay healthy. Many people are afraid of the potential hazards of nuclear power, but risk their necks every day in the hazardous reality of highway travel. Some say that risks which they choose to accept are acceptable, but risks which others force on them are not. In each case, the acceptability is most likely to be based on subjective emotional reactions—"gut" feelings—rather than a logical analysis of accident data or other actual experience.

Certainly laws and regulations themselves will not guarantee risk-free transportation. We do not live in a riskless society, nor could modern technological societies exist on that basis. We are all aware of the potential risks in nuclear matters if safety is not given the very close attention it deserves. Transportation accidents and their potential effects on shipping containers have been well studied. These studies continue. It is precisely because of this perceived risk that ERDA (now DOE) and NRC have always imposed stringent and overlapping protective measures in their concept of "defense in depth." However, one cannot claim "assurance" as an absolute.

We tend to react to the problem of risk by making choices based on the magnitude of the risk, as we perceive it, and the benefits to be gained from accepting the risk. The public apparently judges the convenience of air travel to be worth the risk that results in 200 fatalities per year; the convenience of driving an automobile is considered worth much higher levels of risk. Sometimes the public judgments are not especially rational. About 49 million Americans continue to smoke cigarettes despite the clear warning of risk to their health printed on each package.

The National Academy of Sciences has stated, "Whether we regard a risk as acceptable or not depends on how avoidable it is, and how it compares with the risks of alternative options and those normally accepted by industry." As a result of the studies which have been done, it is evident that, with regard to nuclear waste transportation:

a. We have enough facts and figures on the hazards to allow a more objective evaluation of the risk acceptability than we might derive solely from "gut" feelings.

b. The risk of public catastrophe has been eliminated by strict standards, engineering design safety, and operational care. Whatever the consequences of an accident are, the public hazard will be manageable, and the nuclear effects will be small compared to the nonnuclear effects.

c. The long-term public burden of not transporting wastes is likely to be higher than the risks of carefully

controlled transportation, considering the various options available.

d. The likelihood of death, injury, or serious property damage from the nuclear aspects of waste transportation is thousands of times less than the likelihood of death, injury, or serious property damage from more common hazards, such as automobile accidents, boating accidents, accidental poisoning, gunshot wounds, fires, or even falls—all things which we can control, but apparently have accepted as a way of life without much public support for reduction of risk.

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