RECORDS ADMINISTRATION
AGBY

Acc # 726592

DP-MS-76-48

RADIOACTIVE MATERIALS TRANSPORT EXPERIENCE

J. W. Langhaar

SRL
RECORD COPY

ABSTRACT

The experience described in this paper relates primarily to methods of packaging waste, transport restrictions, and accident record. Only some generalizations can be given here; applicable packaging regulations, and state and local laws must be consulted in any particular case. To define types of packaging, the IAEA classification is used; U. S. limits on amount of activity are somewhat different.

Performance requirements with respect to safety are the same for waste as for useful product. However, as might be expected, waste is more commonly shipped in disposable rather than reusable containers.

Low specific activity material, which for illustration might contain up to about one millicurie of ^{137}Cs per gram, may be shipped in rather common packaging such as drums. If the material is an insoluble solid, the activity may be 20 times as great, but the packaging must be capable of withstanding certain tests to qualify as strong industrial packaging. For such solids, the trend is toward large cylindrical containers of either steel or concrete.

Liquid wastes are often immobilized by mixing them in concrete, absorbing on a solid, or other means. An ANSI standard, N 14.9, now in final draft stage, recommends such immobilization for liquid aqueous waste.

Waste with higher specific activity but with a total generally less than a few millicuries for alpha emitters or a few curies for beta-gamma emitters, requires packaging which will withstand rather harsh normal conditions, including a drop of about a meter. The drums and larger vessels used for low specific activity material are often adequate, although special attention to some features is needed.

Larger amounts of radioactivity, as in high activity waste, require Type B packaging which among other things must withstand a 9 meter drop and a fire. A considerable thickness of gamma shielding is needed. One concept is a cask similar to those used for spent fuel, containing one or more disposable cylindrical steel vessels filled with solidified waste.

Nearly all waste shipment in the U. S. so far has been low level, not requiring Type B packaging. Except for some alpha waste in ATMX railcars, it has nearly all been by truck. The large casks being contemplated for high level waste, with gross weight up to 100 tons, would be shipped by rail or barge. It should be noted that U. S. railroads currently require special train service, with speed restrictions and other special conditions, for spent fuel and radioactive waste. The added cost, estimated at $18 to $20 per mile, is substantial if only a few cars constitute the train.

The U. S. accident record, for which some statistics are given in the paper, has been excellent. There has been no identifiable radiological injury from any shipment of radioactive material, and no detected escape of radioactive material from Type B packaging, as a result of a transport accident. Nevertheless, shipments of the type we are concerned with are prohibited by many bridges, tunnels, toll roads, and by New York City. Some states and localities impose restrictions on time of day, and require such things as advance notice and special escort. Thus any contemplated shipment requires thorough checking of state and local regulations along the route.

DISCUSSION

Introduction

In the broad field of transport experience, this paper presents a brief review of the kinds of packaging suitable for different types of waste, the roles of highway and rail transport, the restrictions imposed by political entities and carriers, and the matter of safety. Types and quantities of waste, and federal regulations for design and performance of packaging, are discussed in other papers of this symposium. Experience described is that in the United States, but with respect to packaging requirements, reference is made to IAEA regulations which may with minor differences be adopted in this country in the near future.

Kinds of Packages

A. Low Specific Activity (LSA)

Much of the waste is sufficiently innocuous to be classified as LSA[1]. If the radioactivity is essentially uniformly distributed with not more than 0.1 microcurie of Group I (such as plutonium) per gram, or 5 microcuries of Group II (such as strontium-90) per gram, or 300 microcuries of Groups III or IV (such as cesium-137) per gram, the material qualifies as LSA. Also included are objects with a small specified amount of external radioactive contamination. (See 49 CFR 173.389c)

For transport by non-exclusive use vehicle, such materials must be in packaging meeting Type A requirements[1]. For exclusive use vehicles, bulk shipment is permitted if the activity is less than a specified small fraction of the LSA limit, or otherwise in strong, tight packages which will not leak in normal transport. (See 49 CFR 173.392). Ordinary drums and boxes generally qualify as strong tight packages. Disposable concrete containers are also used.

If the total number of curies in a package exceeds a Type A quantity, or if there is more than a specified small amount of fissile material, the NRC regulations 10 CFR Part 71 apply[2]. The packages must then withstand the hypothetical accident conditions.

The IAEA limits on concentration of radioactivity to qualify as LSA are somewhat different and more detailed[3], but with the same objective. For exclusive use trucks or railcars, the IAEA regulations require the use of strong, tight packagings, but for LSA solids there is no restriction on the total curies. The rationale is that even if a large amount should escape in an accident, the concentration of activity is so low that there would be no serious hazard to people. There is also a classification called "low level solids", which under certain conditions permits somewhat higher concentrations of activity.

B. Type A Quantities

If the concentration exceeds LSA limits and the number of curies is within Type A limits, then Type A packaging is required. Here again, the U. S. and IAEA regulations differ somewhat on the limits, but requirements for Type A packaging are essentially the same and include resistance to water spray and a 1.2 meter drop (or a lesser drop height for very heavy packages). Conventional drums or metal containers usually meet the requirements; concrete containers can also be of acceptable design. In some cases a small amount of gamma shielding is needed; this can be either a permanent or detachable part of the packaging.

Packages with liquid contents have the more stringent requirements of being able to withstand a 9 meter drop and also being provided with enough absorbent material to absorb twice the volume of liquid. As an alternative to the absorbent, the IAEA is considering double containment. These requirements tend to discourage the shipment of liquid waste. The American National Standards Institute is also attempting to discourage it. The proposed standard N 14.9, "Packaging for Transportation of Liquid Aqueous Radioactive Wastes from Nuclear Power Plants" recommends immobilizing liquids whenever practical, by absorption, solidification with cement or other material, or other technique[4]. There is much useful information in the draft of this standard.

C. Type B Quantities

More than 2 millicuries of plutonium-239 is a Type B quantity[3]. That is such a small amount that alpha wastes currently being shipped by ERDA commonly must meet Type B package performance requirements. This is accomplished by shipping disposable containers of moderate cost in ATMX railcars which provide protection against impact and fire[5]. To date, these have been the only important Type B waste shipments; high level wastes from chemical reprocessing have been stored on site.

In the foreseeable future, shipment of solidified high level waste to a disposal site will be undertaken. This waste will very likely be in steel canisters which will be shipped in casks much like the casks being used for spent fuel. The problems of shielding and heat removal are similar. Casks in the past have customarily used 20 to 25 cm of lead for shielding, and dissipated heat by conduction and natural convection. Because of the difficulty of preventing some melting of lead in the hypothetical fire or of otherwise demonstrating adequate retention, there has in recent years been a trend toward the use of depleted uranium in place of part or all of the lead. Uranium shielding has the further advantage of making the cask weigh less, but the disadvantage of making it cost more. Concepts directed specifically to the waste handling problem are currently being developed. The loaded weight of such casks would be up to 25 short tons for truck shipment, and up to about 100 tons for rail or barge shipment.

Mode of Shipment

Truck and rail shipment are given primary consideration here. Air shipment is relatively costly and not needed. Some utilities are on navigable water, but burial grounds are usually not, and a high level waste disposal site will almost certainly not be accessible by water. However, it is possible that shipment part way by boat or barge, and part way by highway or rail, will in some cases be economical.

Shipment of waste so far has been almost exclusively by truck, except for the alpha waste mentioned previously. This will very likely continue to be the case for low level waste. Truck transport has a high degree of versatility, and the only significant potential problem now foreseen from the equipment standpoint is providing adequate tiedown. It has been observed that heavy containers are sometimes not tied down securely enough to withstand bad road

conditions or minor accidents. Although hazard to the public is not appreciably greater than for non-radioactive cargo, the public concern justifies closer attention to this matter. A proposed ANSI standard N 14.2 would require substantially stronger tiedown than has been customary, and would often require the use of bolts through the bed of the truck or trailer to fasten chocks or to transmit the load to the frame by means of underbeams.

For heavily shielded casks, the ratio of payload to gross weight generally increases as the size of the cask increases. Thus if there is enough material to ship and the cost per ton-mile is fixed, the largest practical cask is usually justified. However, the largest practical cask for interstate shipment by truck is about 25 short tons. For short distances, a heavy cask may be transported over highways by lowboy, but for long distances on land, rail transport is required. American railroads are at present requiring special trains with speed restrictions and other restrictions for spent fuel and radioactive waste, including empty containers. The added cost is estimated to be $18 to $20 per train-mile, and the round trip time may be increased. This of course must be taken into account in an economic analysis, and will tend to favor the use of highway and water transport.

Tiedowns apparently must be several times stronger for railcars than for trucks, relative to cask weight, because of the large accelerations imparted to railcars during coupling operations. If present methods of analysis are valid, tiedown by cable or chain will usually not be feasible because of the large forces and the unavailability of suitable attachment points. Attachment directly to the deck is acceptable only if the deck is adequately attached tc the car frame; otherwise, bolts through the deck, and through small underbeams which transmit forces to the car frame, may be used. However, present information is inadequate regarding the relationship between coupler forces and tiedown forces, because of unknown effects of elastic de-

formations and slight relative movements which occur. ERDA and NRC have both indicated interest in developing better information, so that a test program of modest proportions is being planned. Also, with dedicated or special cars, which will no doubt be provided if high level waste is transported by rail to a disposal site, the tiedown difficulties may be overcome by suitable design.

Transportation Restrictions

Transport of radioactive material, especially by highway, is beset with restrictions imposed by state and local authorities. Among the more common are advance notice and escort, travel at specified time of day or day of week, special routing to avoid congested areas, and restricted speeds. Moreover, transport of the type of material we are concerned with here is prohibited over or through many toll roads, bridges, and tunnels. Such transport has been banned within New York City. Of course there is a continuing effort to convince the authorities that many of the restrictions are unjustified, but transport may nevertheless become more restricted and more costly before any appreciable improvement.

The requirements vary from state to state and city to city, and change from day to day. Companies which provide shipping service for such materials, and also the carriers, must keep abreast of this complex situation, and should be consulted with respect to contemplated movement between any two particular points.

Accident Experience

There have been many studies, investigations, analyses, and parts of environmental impact statements dealing with accident experience and predictions. Packaging regulations in approximately the present form were adopted in 1968, but even before that it was necessary to obtain

certain approvals, and rather stringent design criteria were being applied. We will consider primarily the post-regulatory experience, but it should be noted that to date in the United States, although many packages containing amounts of radioactivity now classified as Type B or large quantity have been involved in accidents, none has as a result released a detected amount of radioactive material. There have, however, been a few cases of partial escape because of faulty packaging procedure rather than accident. Increased emphasis is accordingly being placed on quality assurance in the use and maintenance of packaging. At the same time, attention to design criteria and quality assurance in fabrication has not diminished. Fortunately the very severe accident with a Type B container has not yet occurred, but some day it will, and we want confidence that serious radiological injury will not result.

The number of radioactive material shipments per annum is estimated to be about one million, of which about 50,000 are Type B [6,7]. The number of accidents per vehicle-mile, both for truck and railcar with general cargo, is about 2×10^{-6}, although only about one in 250 is severe[8,9]. We do not have figures for the average travel distance, but arbitrarily taking it to be 500 miles and assuming each shipment to be on a different vehicle, we would then expect about 1000 accidents a year, with 4 of them being severe. Information from DOT[10] shows 25 incident reports per annum for radioactive materials during the period 1971-1974. Information from ERDA[11] shows 10 accidents per annum for AEC shipments during the period 1965-1970. Radiological assistance teams reported being called to 5 to 10 vehicle accidents per annum from 1971 to 1975. The data are admittedly too meager to make any quantitative comparisons of accident frequencies, but it appears that the record for radioactive materials is better than average. The report WASH-1339[7], in reference to the 1972 experience of motor carriers, states that "The accident rate for shipments was about 1.7 accidents per million truck miles, and about 0.53 accidents per truck mile for hazardous materials shipments." This indicates that we may expect considerably fewer accidents per truck mile for radioactive material than for general cargo.

During the past few years there have been many more incidents involving packages damaged in handling or being run over at terminals than incidents involving vehicle accidents. In most cases there was little or no escape of radioactive material. The packages have been mostly quite small, and not representative of the type used for radioactive waste.

Type A packages are not designed to withstand severe accidents, and we should therefore expect occasional accident release. At the same time, the amount of radioactive material is so small that no serious consequence is expected. For AEC shipments during the period 1965-1970, 62 accidents were reported[11], with 8 releases confined to the vehicle and 10 releases which extended beyond the vehicle. For all shipments from 1971 to 1974, 98 incidents involving radioactive material were reported to DOT[10]; of these, 19 had some release, including 10 which were low level waste in drums. These incidents were not necessarily vehicle accidents. The need for careful packaging and procedural control should again be emphasized.

The possibility of a large release from Type B packages in very severe accidents is a matter of primary concern. There have so far been 8 or 10 accidents with Type B packages that might be considered severe, and no release or excessive external radiation level resulted. The first four of those summarized below were described by Grella in a paper at an IAEA meeting[12]. One of the accidents subjected three lead-shielded packages to a 2.5 hour fire. The packages were protected by 10 cm of plywood, which charred to a depth of about 4 cm.

Another accident was a fire which destroyed most of the cargo in a trailer, except a cylinder of uranium hexafluoride in a protective overpack. This packaging required only external cleaning before being returned to service.

A third accident was an overturn of a truck carrying a cylinder of uranium hexafluoride, as the truck was going around a curve on a ramp approach to an interstate highway. The cylinder was only slightly

damaged. The accident was attributed to breaking of a tiedown chain which allowed the cylinder to shift.

A fourth accident was a truck fire which involved five small lead-shielded casks each in a heavy wooden outer box. Only the outer boxes were damaged.

A fifth accident was an overturn of a truck which skidded off the road in a snowstorm. The truck carried three irradiated fuel casks weighing 13,000, 3,500 and 7,400 lb. The cask tiedowns did not fail, and the casks were undamaged. The truck suffered only minor damage.

In a sixth accident, a truck with a cask of waste overturned near Morgantown, West Virginia. The cask remained intact.

In a seventh accident, a truck with empty fuel casks overturned near Blackfoot, Idaho. Again, the casks remained intact.

In 1971, a truck with a cask overturned near Oak Ridge, Tennessee, killing the driver. The cask was only superficially damaged.

There have been numerous collisions of trucks with private autos, and derailments of railcars, which as it turned out posed no threat to the cargo. There has apparently been no accident which subjected a Type B container to the most severe impact which it is designed to resist, but there have been one or two fires approaching the design value.

One may wonder whether or not we have just been lucky. That question cannot be answered readily, because there is not a clearcut relationship between the regulatory hypothetical accident and the myriad of conditions in real accidents. Reference 9 estimates the frequency of accidents which would cause a large release from a cask of spent fuel to be less than 2×10^{-12} per vehicle-mile. Reference 13 suggests that small Type B containers (not casks) might be subjected to a mechanical or thermal stress exceeding the minimum regulatory design value with a frequency of 7×10^{-9} per truck mile or 1×10^{-7} per rail mile. However, destructive tests of several containers showed that they

survived conditions well in excess of minimum requirements[14]; also, breach of the closure or containment vessel does not necessarily result in release of radioactive material[7].

In order to make some judgment about whether or not we have been lucky, let us take 10^{-10} as the probability per vehicle-mile of some release from a Type B container, an average of 10,000 shipments per annum during the past 15 years, and 500 miles per shipment. Then the expected number of releases during this 15 years would be 0.0075, so that the fact that we have had no release does not seem unusual. Another way of putting it is that for 50,000 shipments per annum, at 500 miles per shipment and with the probability of 10^{-10}, we would expect a release, on the average, once every 400 years. The probability depends to some extent on the nature of the package contents, and particularly on whether gaseous or volatile radioisotopes are present. For high level waste that has decayed for many years, the probability should be lower than the average for Type B shipments.

SUMMARY

Containers commonly used for low level wastes include drums, and metal or concrete boxes. These must be sturdy enough to withstand normal rough handing without permitting any escape of radioactive material. Shipment of waste in liquid form is being discouraged.

High level waste will be solidifed and contained in steel canisters which will be shipped in casks generally of the type used for irradiated fuel.

The mode of shipment in any particular case will depend on available facilities at shipping and receiving sites, on several cost factors, and on transport restrictions imposed by regulatory authorities or by carriers. Rail and barge will accommodate casks of 100 tons or more. Truck transport is generally faster and more versatile. Account

must be taken of the present railroad requirement for special trains.

Accident experience with low level waste will probably be about the same as for other Type A packages, with occasional small release of radioactivity but no significant hazard to the public. Assurance that material is actually packaged as intended is very important. For high level waste, the required integrity of casks and canisters is such that the risk of excessive exposure of individuals due to transport accidents is very small, probably in the range of 10^{-10} per vehicle mile. Concepts of casks specifically for waste are currently being developed.

REFERENCES

1. DOT Regulations, 49 CFR Parts 170-189.

2. NRC Regulations, 10 CFR Part 71.

3. IAEA Safety Series No. 6. 1973 Edition.

4. Draft American National Standard N 14.9, Edmund C. Tarnuzzer, Chairman.

5. J. E. Griffin, et al, Safety Analysis Report for Packaging: ATMX-500 Railcar Nuclear Packaging, MLM-2145, May 31, 1974.

6. W. C. McCluggage, Emergency Actions During Fires Involving Radioactive Materials in Transit, unpublished paper, USERDA

7. WASH-1339, Shipments of Nuclear Fuel and Waste, August 1974.

8. WASH-1238, Environmental Survey of Transportation of Radioactive Materials to and from Nuclear Power Plants, December 1972.

9. L. B. Shappert, et al, Probability and Consequences of Transportation Accidents Involving Radioactive Material Shipments in the Nuclear Fuel Cycle, Nuclear Safety, Vol. 14, No. 6.

10. A. W. Grella, private communication.

11. W. C. McCluggage, The AEC Accident Record and Recent Changes in AEC Manual Chapter 0529, Proceedings, Third International Symposium, Packaging and Transportation of Radioactive Materials, BNWL-SA-3906, p. 108.

12. A. W. Grella, Accident Experience with Type B Packaging in the United States of America, IAEA-SM-147/19, Vienna, 1971.

13. Clarke et al, Severities of Transportation Accidents, SLA-74-0001, September 1975.

14. L. F. Stravasnik, Special Tests for Plutonium Shipping Containers 6M, SP-5795, and L-10, SC-DR-720597, September 1972.