
Truck and Rail Charges for Shipping Spent Fuel and Nuclear Waste

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PREFACE

Logistics analyses supplied to the nuclear waste management programs of the U.S. Department of Energy (DOE) through the Transportation Technology Center (TTC) at Sandia National Laboratories are used to estimate nuclear waste materials packaging demands, shipping and receiving rates, and various transportation-related costs for alternative strategies. The reference shipping costs for various waste materials are key information used in these analyses. The Pacific Northwest Laboratory, through DOE's defense and commercial nuclear waste management programs, developed techniques that the TTC can use to estimate the costs of shipping irradiated reactor fuel (spent fuel) and nuclear waste materials. This document describes the techniques that were developed and lists representative data required when calculating estimates of the shipping cost for legal-weight truck or general-freight rail shipments of either spent fuel or nuclear waste materials. The scope of the work presented in this document is limited to the costs incurred for shipping and does not include packaging or cask purchase/lease costs.

The units of weights and measures reported in this document are those currently used by the U.S. transportation industry. The use of these units facilitates direct use of existing transportation industry documents.

ABSTRACT

The Pacific Northwest Laboratory developed techniques for calculating estimates of nuclear-waste shipping costs and compiled a listing of representative data that facilitate incorporation of reference shipping costs into various logistics analyses. The formulas that were developed can be used to estimate costs that will be incurred for shipping spent fuel or nuclear waste by either legal-weight truck or general-freight rail.

The basic data for this study were obtained from tariffs of a truck carrier licensed to serve the 48 contiguous states and from various rail freight tariff guides. Also, current transportation regulations as issued by the U.S. Department of Transportation and the Nuclear Regulatory Commission were investigated.

The costs that will be incurred for shipping spent fuel and/or nuclear waste, as addressed by the tariff guides, are based on a complex set of conditions involving the shipment origin, route, destination, weight, size, and volume and the frequency of shipments, existing competition, and the length of contracts. While the complexity of these conditions is an important factor in arriving at a "correct" cost, deregulation of the transportation industry means that costs are much more subject to negotiation and, thus, the actual fee that will be charged will not be determined until a shipping contract is actually signed. This study is designed to provide the baseline data necessary for making comparisons of the estimated costs of shipping spent fuel and/or nuclear wastes by truck and rail transportation modes. The scope of the work presented in this document is limited to the costs incurred for shipping, and does not include packaging, cask purchase/lease costs, or local fees placed on shipments of radioactive materials.

SUMMARY

In this study the Pacific Northwest Laboratory developed techniques that can be used for estimating the costs of shipping spent fuel and/or nuclear waste. Information was collected from a truck carrier licensed to serve the 48 contiguous states and from various rail freight tariff guides. This information was the basis for developing a set of formulas that can be used to estimate legal-weight truck and general-freight rail shipping costs. The cost associated with shipping spent fuel and/or nuclear waste was found to depend on the following variables:

LOADED PORTION OF TRIP

TRUCK

- Distance traveled
- Weight of cask/container and contents
- Special equipment
- Escorts
- Deadhead charges^(a)
- Highway route-controlled surcharges^(b)
- Demurrage
- Overweight fees

RAIL

- Distance traveled
- Weight of cask/container and contents
- Escorts

UNLOADED PORTION OF TRIP (Return of Cask/Container)

TRUCK

- Distance traveled
- Weight of empty cask/container

RAIL

- Distance traveled
- Weight of empty cask/container

(a) Deadhead charges are costs incurred for moving equipment and personnel from their domicile to the shipment origin.

(b) Highway route-controlled materials are determined by their isotopic content (see Appendix B).

In addition to the development of various cost-estimating methodologies, a series of hypothetical shipments for both spent fuel and nuclear waste were evaluated for each of the transport modes. The projected costs obtained from these hypothetical shipments allowed a comparison between the transport modes. However, the actual fee charged by a truck or rail carrier, though based on the variables listed above, cannot be determined until a contract is signed.

When projecting the cost for shipping spent fuel by either legal-weight truck or general-freight rail, which are routine unrestricted modes of commercial transportation, the costs for legal-weight trucks were estimated to average approximately 1.0 to 1.5 times the cost per KgU per one-way mile as compared to general-freight rail. The higher cost associated with shipping by truck arises from the smaller capacities of the truck shipping casks. This cost difference could be offset if slower rail transit times require the purchase or lease of many transportation casks to insure fuel movement at prescribed rates. The inclusion of costs for shipping casks is beyond the scope of this report.

The estimated cost for shipping high-level waste or transuranic (TRU) waste by general-freight rail is approximately 1.5 times greater than the cost per kg of waste of legal-weight truck shipments for highway route controlled (HRC) quantities of these materials and from 2 to 6 times greater than the cost per kg of waste for shipping non-HRC quantities.

A comparison between the cost of legal-weight truck and general-freight rail shipments for a given quantity of low-level waste is not easily obtained. Shipping low-level waste by truck is currently based on a rate charged in dollars per mile rather than dollars per unit weight. The current legal-weight truck rates are based on providing carriage for a minimum of 1,500 cubic feet per truckload. This practice allows the majority of the costs for these shipments to be based on volume rather than weight. Since the rates for shipments of low-level waste by general-freight rail are based on dollars per unit weight (same rate basis used for spent fuel/high-level waste) and the majority of low-level waste shipments have a low weight-to-volume ratio, the majority of low-level waste shipments are expected to occur with legal-weight

truck carriers. This practice is actually observed but it may be based on performance of shipment originators and end-point receivers rather than on cost considerations alone.

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LIST OF ACRONYMS

Ci	curies
cwt	hundred weight (one hundred pounds)
DOE	Department of Energy
DOT	Department of Transportation
ft	feet
GFR	general-freight rail
GVW	gross vehicle weight
HRC	highway route controlled
Kg	kilograms
KgU	kilograms of uranium
lb	pound
LWR	light water reactor
LWT	legal-weight truck
m	meter
NRC	Nuclear Regulatory Commission
NHRC	non-highway route controlled
TRU	transuranic
TTC	Transportation Technology Center

1.0 INTRODUCTION

Basic shipping charge structures for transporting spent fuel and/or nuclear waste exist in various forms in the United States. However, the actual fee charged by a truck or rail carrier cannot be determined under the current transportation deregulation system until an actual contract is negotiated and signed. The charge is based on a complex set of conditions involving the shipment origin, route, destination, weight, size, volume, frequency, and the existing competition and length of contract. The purpose of this report is to compile information on these charges in a manner that will provide baseline data for comparisons between the legal-weight truck and general-freight rail transportation modes. The charges listed in this report are for shipping and do not include charges that may be incurred for lease or purchase of the casks and containers required for transporting the various waste types.

This report also provides an analysis of the problems and contingencies associated with the costs of shipping various radioactive waste types. The costs of shipping radioactive wastes have changed frequently (sometimes monthly) during the past few years because of changes in capital, fuel, and labor costs. The costs and charges reported were derived from November 1984 data that were based on transport cask/container systems existing at that time. These reported costs and charge are intended as relative cost indices only. Actual shipping costs would be negotiable for each waste type and origin/destination combination.

The methods used to estimate the truck and rail shipping costs are discussed in Chapters 2 and 3, respectively. Descriptions of hypothetical shipments for various radioactive waste types are included in these chapters to aid readers in making comparative assessments concerning particular materials shipment. The results of comparing the estimated legal-weight truck and general-freight rail shipping costs for hypothetical shipments of various radioactive waste types are shown in Chapter 4.

2.0 TRUCK SHIPMENTS

All truck shipping charges included in this report were obtained from a single carrier (Tri-State Motor Transit Company 1984). This carrier services the 48 contiguous states in the U.S. and is capable of complying with the Nuclear Regulatory Commission (NRC) and Department of Transportation (DOT) regulations for shipping spent fuel and/or nuclear waste. The use of a single carrier provides a uniform basis for observing changes in truck shipping costs as changes in shipping concepts occur. Other carriers may use different charges.

2.1 DISTANCE AND WEIGHT COSTS

The basic legal-weight vehicle shipping charges used in this study for shipments of spent fuel and/or nuclear waste are, in most cases, used consistently nation-wide. Charges are primarily a function of shipment weight and distance traveled. The charges that were in use as of November 1984 are shown in Tables A.1A and A.1B of Appendix A. The charges shown in Table A.1A are used for materials that would be classified as highway route controlled (HRC) due to the activity levels of the various nuclides contained in the shipment and for non-highway route controlled materials (NHRC) that incur a gross vehicle weight in excess of 85,000 pounds (38,556 kilograms). Appendix B lists the activity levels required for various nuclides to be classed as HRC. Spent fuel, high-level waste, and a significant fraction of TRU shipments will be subject to these charges. Table A.1B is used for NHRC materials. The commodities shipped at NHRC-material rates would include the majority of low-level waste shipments and a portion of the TRU shipments. The rates charged for NHRC materials are expressed as dollars/mile rather than dollars/unit weight as used for HRC materials. Also, the charges for NHRC materials are broken into three categories that are based on the destination and particular type of shipping campaign employed. If the shipper uses a round-trip shipment that requires the return of empty cask/containers, the rates in Column 3 of Table A.1B would apply. If disposable packaging (requiring no return trip) is used, the rates

would be taken from Column 1 of Table A.1B if the point of unloading is located east of the Mississippi River and Column 2 if it is located west of the Mississippi.

In addition to the mileage charges listed in Tables A.1A and A.1B, the shipment may be subject to certain overweight charges imposed by various states along the route. These should not be confused with restrictions on gross vehicle weight or the special permits and procedures required for excess gross-vehicle-weight shipments. These charges are listed in Table A.2. Note that the shipper is subject to overweight charges only as a function of the commodity weight, not the gross vehicle weight. Therefore, the shipper is subject to additional charge only when the commodity shipped exceeds the weights listed in Table A.2.

The truck carrier will also charge, in addition to the charges listed in Table A.2, a fee of \$0.21 per mile for each mile traveled in states that require an overweight permit for shipments of NHRC materials in which the gross vehicle weight is less than 38,556 kilograms (85,000 pounds).

Table A.3 lists additional charges (surcharges), that may be imposed on various shipments. If a shipment requires specially equipped vehicles and specially trained personnel, as specified by the NRC (U.S. Code of Federal Regulations 1985), an additional \$0.92 per loaded mile will be charged for legal-size and legal-weight shipments, and \$1.00 per loaded mile will be charged for over-legal-size or over-legal-weight shipments. Both charges are subject to a \$200.00 minimum per shipment. These shipments must be scheduled, in writing, at least seven days in advance. A fee of \$1000.00 will be charged if a shipment is canceled or rescheduled within the seven days. Special equipment is subject to a deadhead charge of \$2.45 per one-way mile. The mileage for this deadhead charge is computed from the nearest terminal to the point of loading.

Shipments of HRC radioactive material (excluding spent fuel) are subject to a service charge of \$0.45 per mile (\$450.00 minimum). These shipments must be scheduled, in writing, at least 10 days in advance of the pickup date and will be subject to a cancellation charge of \$500.00 if a shipment is canceled or rescheduled within seven days of the scheduled pickup date.

When a shipment is delayed during the hours and/or days of normal travel because of any shipper-imposed or regulatory restrictions, detention penalties will be levied after the first three hours. These penalties can be as high as \$32.50 per hour (Table A.4).

2.2 PERSONNEL COSTS

When the carrier is required to furnish armed driver(s) or escort(s), an additional \$0.20 per mile per armed driver/escort will be assessed (\$100.00 minimum). If a separate vehicle is necessary for escort services, the fee charged is \$1.48 per mile per vehicle. This fee includes both the vehicle charge and charges for two unarmed escorts. If armed escorts are requested with the vehicle, an additional \$0.20 per mile per armed driver/escort will be assessed. The mileage for this escort vehicle is based on the distance from the domicile of the personnel and equipment to the point of origin of the shipment, then to the shipment destination, and back to the domicile point. The Code of Federal Regulations (1985) states that a vehicle transporting irradiated reactor fuel within a heavily populated area must be occupied by at least two individuals, one of whom serves as escort. The transport vehicle must also be either 1) escorted by an armed member of the local law enforcement agency or 2) led by a separate vehicle occupied by at least one armed escort and trailed by a third vehicle occupied by at least one armed escort. A transport vehicle not within any heavily populated area must be either 1) occupied by at least one driver and one other individual who serves as escort, 2) occupied by a driver and escorted by a separate vehicle occupied by at least two escorts, or 3) provided with armed escorts as required above. The requirements concerning escort services are presently under review by the NRC. In the Federal Register published on June 8, 1984, a proposed rulemaking by the NRC listed the escort requirement for spent fuel shipments (i.e., spent fuel that has cooled 150 days or more) as being only a single escort who may be a shipment vehicle operator who maintains visual surveillance of the shipment during periods when the shipment vehicle is stopped.

2.3 OTHER COSTS

Many other charges can apply if any deviations occur in the original route, schedule, delivery acceptance criteria, or in-transit stops. In addition, charges may be incurred for special services or requirements requested by the shipper (e.g., security clearances). The Code of Federal Regulations does not reference security clearance requirements for drivers or escorts. However, if clearances are required or requested, the following additional charges will be applicable:

Secret or "L" cleared driver - \$0.12 per mile

"Q" cleared driver - \$0.15 per mile

Two "Q" cleared drivers - \$0.15 per mile per driver plus \$200.

2.4 SHIPPING COST CALCULATIONS

The cost to transport spent fuel and/or nuclear waste by truck between two locations can be approximated by using the following formula:

$$\begin{aligned} \text{Shipping Cost} = & (\text{AA} * \text{LOAD}) + (\text{AB} * \text{EMPT}) + (\text{DHC} * \text{DIS2}) + (\text{SVC} * \text{DIS3}) \\ & + (\text{AEC} * \text{DIS4}) + (\text{SEC} * \text{DIS1}) + \text{OWC} + \text{DET} + (\text{HRC} * \text{DIS1}) \end{aligned}$$

where

AA = Value from Table A.1A [Column 1 (\$/cwt^(a))], or Table A.1B [Column 1, 2, or 3 (\$/mile)] for specified distance traveled with a full cask/container

AB = Value from Table A.1A [Column 2 (\$/cwt)], or Table A.1B [Column 1, 2, or 3 (\$/mile)] for specified distance traveled with an empty cask/container

AEC = Charge for each armed escort, \$0.20/man-mile (if required)

DET = Personnel and equipment detention charge, dollars

DHC = Deadhead charge for special equipment, \$2.45/mile (if required)

(a) cwt = hundred weight (100 pounds).

DIS1 = Specified distance traveled with a loaded cask, miles

DIS2 = Specified distance from terminal location of special equipment to point of loading, miles

DIS3 = Total distance traveled by separate escort vehicle(s) from terminal location until subsequent return to terminal, miles

DIS4 = Sum of the number of armed escorts (provided by carrier) times the distance traveled with a loaded cask by each escort, man-miles

EMPT = Weight of empty cask/container, (cwt) for HRC material and spent fuel or distance traveled by return truck for NHRC materials (miles)

LOAD = Weight of full cask/container, (cwt) for HRC material and spent fuel or distance traveled by loaded truck for NHRC materials (miles)

OWC = Applicable overweight charge for each state traversed, dollars (see Table A.2)

SEC = Special equipment charge, \$0.92/mile (if required)

SVC = Charge for each separate escort vehicle (if requested), \$1.48/mile (each vehicle contains 2 escorts)

HRC = Highway route controlled material surcharge, \$0.45/mile (not applicable to spent fuel)

2.5 HYPOTHETICAL TRUCK SHIPMENTS

The use of the above formula may be demonstrated by considering the following 1200-mile hypothetical truck shipments for spent fuel and various classes of nuclear waste.

Spent Fuel

In this example, a spent-fuel shipment is postulated to be part of a long-term shipping campaign requiring frequent shipments. The constant utilization of both equipment and personnel allows the neglect of applicable deadhead charges. One armed escort is assumed to be required during the loaded segment

of the trip and will ride in the truck cab. If the route passes through a heavily populated area, a separate escort vehicle will also be required. It is assumed that this service will be provided at no additional cost by a local law enforcement agency.

Using a loaded cask weight of 50,000 pounds (22,680 kilograms) and an empty cask weight of 48,650 pounds (2,068 kilograms) (see Table A.5), the cost per round trip is calculated using the formula described on page 2.4.

$$(AA * Load) = (6.03 * 500) = \$3015.00$$

$$(AB * EMPT) = (5.05 * 486.50) = 2456.83$$

$$(AEC * OIS4) = (0.20 * 1200) = 240.00$$

$$(SEC * DIS1) = (0.92 * 1200) = \underline{1140.00}$$

Total Estimated Shipping Costs = \$6815.83

For this hypothetical case, the terms of the formula have the following values.

AA = \$6.03/cwt (Table A.1A, Column 1)

LOAD = 500 cwt (50,000/100)

AB = \$5.05/cwt (Table A.1A, Column 2)

EMPT = 486.5 cwt (48,650/100)

AEC = \$0.20/man-mile

OIS4 = 1200 man-miles

DIS1 = 1200 loaded miles

SEC = \$0.92/loaded mile

Remaining variables = 0

Based on a uranium weight of 904 pounds (410 kilograms), the unit cost of this hypothetical shipment is approximately \$7.54 per pound U (\$16.62 per kilogram U). This cost could increase if the separate escort vehicle was not supplied free of charge by a local law enforcement agency or if the shipping campaign was non-routine and required the inclusion of deadhead charges. Conversely, the cost could possibly decrease through the negotiation of a long-term contract involving frequent shipments.

HRC Materials

In this hypothetical case the shipment is postulated to contain remote-handled TRU waste containing HRC quantities of various nuclides. A loaded-cask weight of 50,000 pounds (22,680 kilograms) and an empty-cask weight of 40,000 pounds (18,141 kilograms) (see Table A.5) results in the following trip cost.

$$(AA * LOAD) = (6.03 * 500) = \$3015.00$$

$$(AB * EMPT) = (5.05 * 400) = 2020.00$$

$$(HRC * DIS1) = (0.45 * 1200) = \underline{540.00}$$

$$\text{Total Estimated Shipping Costs} = \$5575.00$$

The applicable terms of the formula have the following values.

AA = \$6.03/cwt (Table A.1A, Column 1)

LOAD = 500 cwt (50,000/100)

AB = \$5.05/cwt (Table A.1A, Column 2)

EMPT = 400 cwt (40,000/100)

HRC = \$0.45/loaded mile

OIS1 = 1200 loaded miles

Remaining variables = 0

Based on a waste weight (waste plus containers) of 10,000 pounds (4356 kilograms), the unit cost of this hypothetical shipment is approximately \$0.56 per pound waste (\$1.23 per kilogram waste). As in the previous case, this cost could possibly decrease through the negotiation of a long-term contract involving frequent shipments.

NHRC Materials

This shipment is postulated to contain non-shielded, low-level waste packaged in disposable containers, with a final destination located west of the Mississippi river. The total cost for this trip, where only two terms of the formula are used, may be calculated as follows:

$$\text{Total Estimated Shipping Cost} = (AA * LOAD) = (1.90 * 1200) = \$2280.00$$

The values for the two required terms are:

AA = \$1.90/mile (Table A.1B, Column 2)

LOAD = 1200 miles

Remaining variables = 0

Based on a volume of approximately 530 cubic feet (15 cubic meters) per truckload of unshielded, low-level waste, the unit cost of this shipment is \$4.30 per cubic foot waste (\$152.00 per cubic meter waste).

If the waste for this hypothetical shipment requires shielding, then the return of the shielded cask must also be accounted for as follows.

(AA * LOAD) = (1.42 * 1200) = \$1704.00

(AB * EMPT) = (1.42 * 1200) = 1704.00

Total Estimated Shipping Cost = \$3408.00

The following values are assigned to the applicable terms in this case.

AA = \$1.42/mile (Table A.1B, Column 3)

AB = \$1.42/mile (Table A.1B, Column 3)

LOAD = 1200 miles

EMPT = 1200 miles

Remaining variables = 0

Based on an assumed volume of 159 cubic feet (4.5 cubic meters) per truckload of shielded low-level waste, the unit cost now becomes \$21.43 per cubic foot waste (\$757.33 per cubic meter waste).

3.0 RAIL SHIPMENTS

Determining rail shipping costs is not as straightforward as determining costs for shipments by truck. Rail charges are not uniformly applied over the distance traveled. Rail shipping costs can be affected by topography, state regulations, the number of carriers servicing the same origin/destination, and the route used. Therefore, to establish uniformity in this study, interregional rates were used.

3.1 DISTANCE AND WEIGHT COSTS

To obtain a reasonable and useful set of charges for spent fuel and/or nuclear waste shipped by rail, the U.S. was divided into four regions. This division was used to isolate any major cost differences that may exist. Fifty-eight light water reactor (LWR) locations (only those having reactors currently operating or under construction and with rail service available) were used as potential shipment origins. Five hypothetical sites were used as destinations. One location in each region was used to simulate regional differences (see Table 3.1), and one location was designated as a national site to simulate transcontinental shipments. Table 3.1 shows which states would ship to each of these final destinations. It should be emphasized that only hypothetical sites were used in this study to establish comparative point-to-point shipping charges.

The rail charges established are for general-freight service of radioactive materials including spent fuel and nuclear waste (Traffic Executive Association--Eastern 1982). Tables A.6 through A.10 list these charges, the reactors serviced, and the location of the closest town used to establish these charges. These tables also show the short-line distances^(a) and the approximate transit times. In some cases, especially in long hauls, the distances and charges quoted may be the same for two different points of origin, although these points can actually be only a few miles apart. These identical charges

(a) Short-line distance is defined as the shortest rail route between two rate-basing areas.

TABLE 3.1. Assumed Origins and Destination

Destination	States from Which Shipments Originate ^(a)	
1. National	All States	
2. Western	Washington Colorado Oregon	California Arizona
3. Southern	Texas Arkansas Florida Georgia Kansas Louisiana	Alabama Mississippi Tennessee South Carolina North Carolina Virginia
4. North Central	Illinois Minnesota Nebraska	Iowa Missouri Wisconsin
5. Northeastern	Indiana Maine Maryland Michigan New York Ohio	Connecticut Massachusetts New Hampshire New Jersey Pennsylvania Vermont

(a) States not shown have no reactors with rail service.

can occur because both points of origin lie in the same rate-basing area.^(a) Shipping charges are established between rate-basing areas regardless of the actual route traveled. The rail transit times are difficult to define with any degree of certainty because too many variables are involved in any origin-destination combination to obtain a precise value. The times quoted in Tables A.6 through A.10 are based on past experience for the areas and/or routes involved.

The charges for general-freight service for radioactive materials are very uniform when based on the short-line distances. Only minor variations are evident between regions (see Figures 3.1 and 3.2). The Western region appears to

(a) Rate-basing areas are areas around major rail points that are grouped together for rate-making purposes.

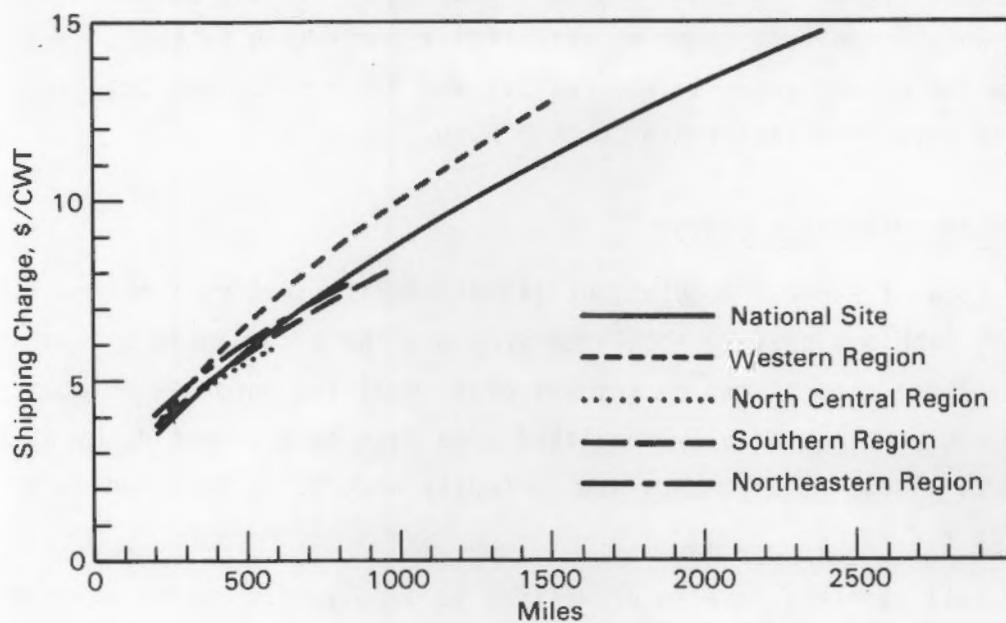


FIGURE 3.1. Regional Comparisons of General-Freight Rail Shipping Charges for Loaded Portion of Trip

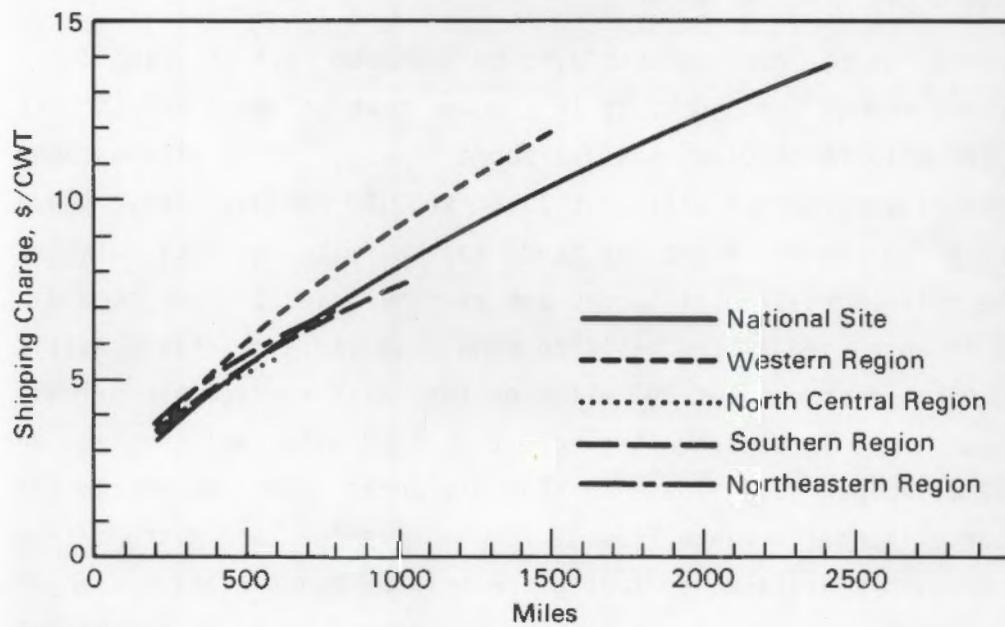


FIGURE 3.2. Regional Comparisons of General-Freight Rail Shipping Charges for Return Portion of Trip

have somewhat higher charges. However, the number of data points available for this region are not sufficient to establish a conclusive pattern. The values that form the curves shown in Figures 3.1 and 3.2 result from regression analysis of the data from Tables A.6 through A.10.

3.2 TIME AND PERSONNEL COSTS

The Code of Federal Regulations (1985) require that rail shipments of spent fuel within a heavily populated area must be accompanied by two armed escorts. These escorts may be members of a local law enforcement agency. A shipment not within a heavily populated area must be accompanied by at least one escort. These requirements are currently undergoing revision as discussed in Section 2.2.

The rail carriers have no provisions to supply this escort service, which typically is expected to be provided by the shipper. However, the rail carriers will supply a car or caboose for the escorts. The only charge for this service is the price of a coach-class passenger ticket. This charge is approximately \$0.08 per mile per escort.

The wages of the escorts must also be added to rail shipping costs. Since trains travel around the clock, it is assumed that at least two escorts will be required per trip to provide constant surveillance. It is also assumed that trained security personnel will cost about \$250.00 per day each. The distance that a train can travel in one day tends to vary with the total distance traveled. The rail short-line distances and average transit times from Tables A.6 through A.10 were used as the basis to show this variance (Table A.11). Trains traveling total distances of 300 miles or less will average approximately 47 miles per day. Those traveling more than 1900 miles will average approximately 182 miles per day. These average distances cause the charge for continuous surveillance to range from \$2.75 per mile for long distances to \$10.64 per mile for short distances. Adding the cost of coach-class passenger ticket causes the total cost for escort service to range from \$2.91 per mile to \$10.80 per mile.

3.3 SHIPPING COST CALCULATIONS

The cost to ship radioactive materials from point to point by general-freight rail can be approximated using the following formula:

$$\text{Shipping Cost} = (\text{CVL} * \text{LOAD}/100) + (\text{CVE} * \text{EMPT}/100) + (\text{ESFGF} * \text{DIS1})$$

where

$$\begin{aligned}\text{CVL} &= \text{Loaded cask/container shipping cost approximation, } \$/\text{cwt} \\ &= 0.1616 * \text{DIS1}^{0.5860} \text{ (National)} \\ &= 0.1565 * \text{DIS1}^{0.6087} \text{ (Western)} \\ &= 0.4025 * \text{DIS1}^{0.4304} \text{ (North Central)} \\ &= 0.2639 * \text{DIS1}^{0.5042} \text{ (Southern)} \\ &= 0.3969 * \text{DIS1}^{0.4469} \text{ (Northeastern)}\end{aligned}$$

$$\begin{aligned}\text{CVE} &= \text{Empty cask/container shipping cost approximation, } \$/\text{cwt} \\ &= 0.1479 * \text{DIS2}^{0.5895} \text{ (National)} \\ &= 0.1477 * \text{DIS2}^{0.6077} \text{ (Western)} \\ &= 0.3796 * \text{DIS2}^{0.4292} \text{ (North Central)} \\ &= 0.2472 * \text{DIS2}^{0.5042} \text{ (Southern)} \\ &= 0.3727 * \text{DIS2}^{0.4468} \text{ (Northeastern)}\end{aligned}$$

DIS1 = Specified distance traveled with a full cask/container, miles

DIS2 = Specified distance traveled with an empty cask/container, miles

EMPT = Weight of empty cask/container, pounds (40,000 pound minimum)

ESFGF = Escort fee general freight, $\$/\text{load mile}$ ($\$2.91 - \10.80)

LOAD = Weight of full cask/container, pounds

3.4 HYPOTHETICAL RAIL SHIPMENTS

The use of the above formula may be demonstrated by considering the following 1200-mile hypothetical rail shipments for spent fuel and radioactive material.

Spent Fuel

For baseline comparison purposes, the parameters detailing the hypothetical rail shipment will remain consistent with those used in Section 2.5

describing truck shipments. The shipment by rail will utilize two escorts riding on the train to maintain a 24-hour surveillance. Having two escorts present will also satisfy the present security requirement while traveling through heavily populated areas. The cost for this service is assumed to be \$3.66 per mile (see Section 3.2).

Applying the formula shown on page 3.5, which was developed from the national average rail cost curve shown in Section 3.1, the roundtrip shipping cost is calculated as follows.

The terms of the formula have the following values.

$$CVL = 0.1616 * DIS1^{0.5860}$$

$$LOAD = 180,000 \text{ pounds}$$

$$CVE = 0.1479 * DIS2^{0.5895}$$

$$EMPT = 169,300 \text{ pounds}$$

$$ESFGF = \$3.66/\text{loaded mile}$$

$$DIS1 = 1200 \text{ miles}$$

$$DIS2 = 1200 \text{ miles}$$

The formula is then used to calculate shipping cost.

$$\begin{aligned} \text{Shipping Cost} &= (0.1616 * 1200^{0.5860}) * 180,000/100 = \$18,540.19 \\ &+ (0.1479 * 1200^{0.5895}) * 169,300/100 = 16,360.72 \\ &+ 3.66 * 1200 = \underline{\underline{4,392.00}} \\ \text{Total Estimated Shipping Cost} &= \$39,292.91 \end{aligned}$$

Based on a uranium weight of 7180 pounds (3256 kilograms), the unit cost for this hypothetical rail shipment is \$5.47 per pound U (\$12.07 per kilogram U). This unit cost is lower than the comparable cost calculated for a shipment by truck (\$7.54 per pound U, Section 2.5, page 2.6). The comparison of these costs is for shipping only. The charges for leasing or purchasing casks have not been included.

As noted in the previous chapter, the shipping cost could increase if the assumed escort requirements were not adequate. Also, negotiation of a long-term contract could possibly result in a decrease in shipment cost.

Nuclear Waste

Shipment costs involving all classes of nuclear waste may be estimated in a manner almost identical to that used for spent-fuel shipments, the only difference being that the security cost imposed for spent fuel shipments can be neglected. The projected shipping cost for shipping a hypothetical shipment of RH-TRU waste by general-freight rail is calculated as follows.

The terms of the formula have the following values.

$$CVL = 0.1616 * DIS1^{0.5860}$$

LOAD = 200,000 pounds

$$CVE = 0.1479 * DIS2^{0.5895}$$

EMPT = 160,000 pounds

DIS1 = 1200 miles

DIS2 = 1200 miles

ESFGF = 0

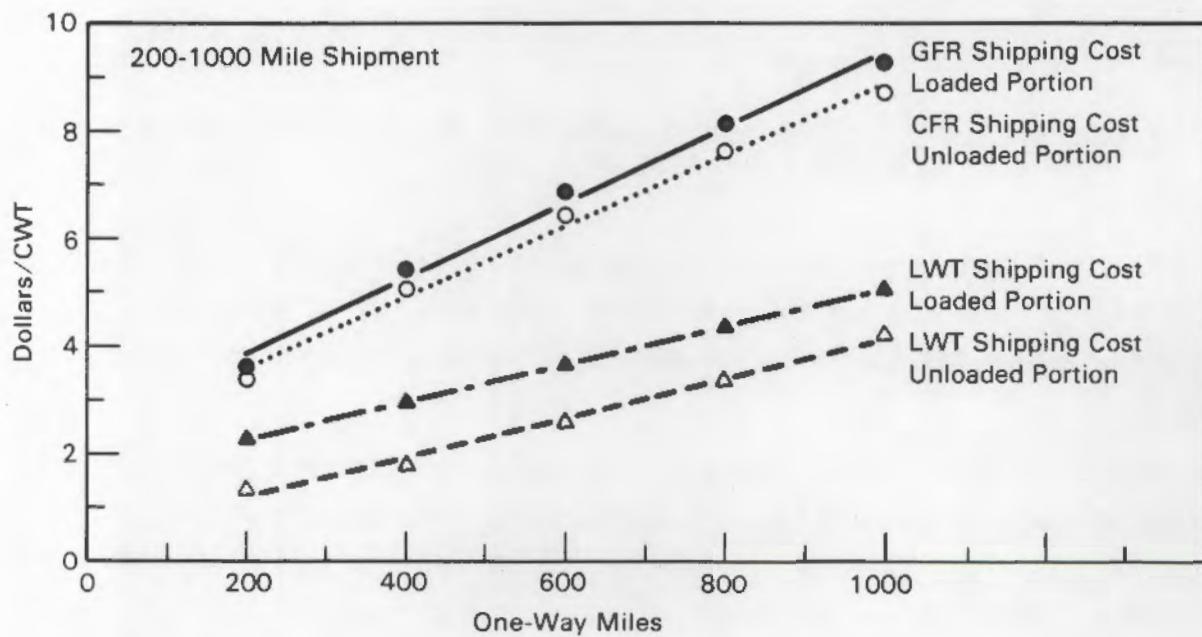
Using the formula again, the shipping cost is calculated

$$\begin{aligned} \text{Shipping Cost} &= (0.1616 * 1200^{0.5860}) * 200,000/100 = \$20,600.21 \\ &+ (0.1479 * 1200^{0.5895}) * 160,000/100 = \underline{15,461.99} \\ &\text{Total Estimated Shipping Cost} = \$36,062.20 \end{aligned}$$

Based on a waste weight (waste plus containers) of 40,000 pound (18,141 kilograms), the unit cost of this hypothetical shipment is approximately \$0.90 per pound waste (\$1.99 per kilogram waste). This unit cost is higher than the comparable cost calculated for a shipment by truck (\$0.56 per pound waste, Section 2.5, page 2.7).

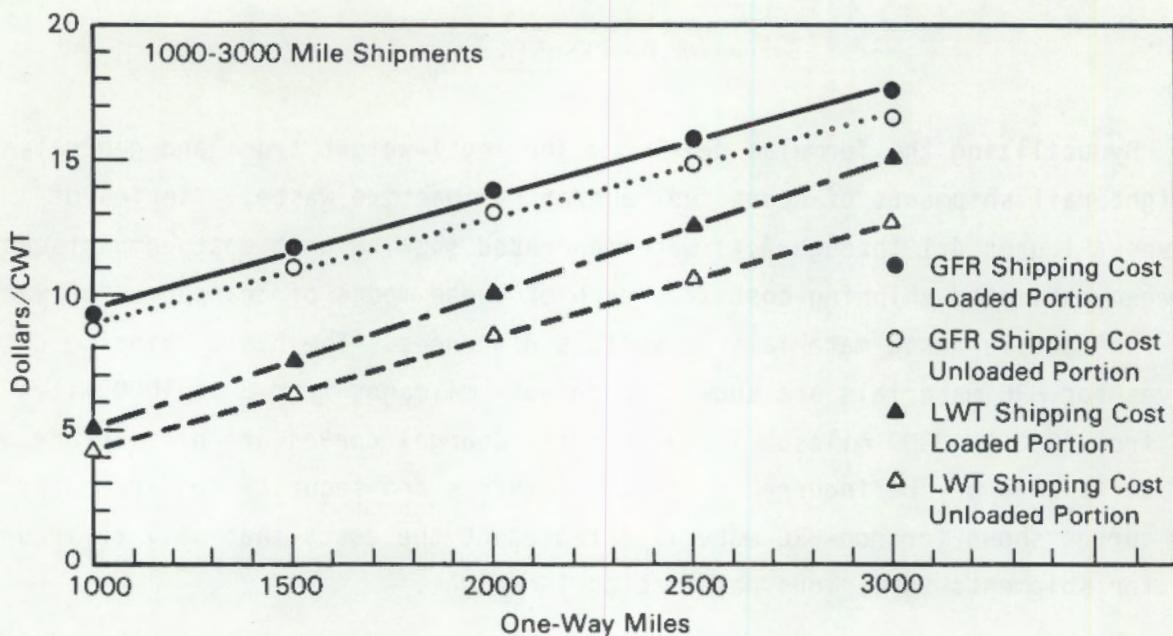
4.0 RESULTS

By utilizing the formulas developed for legal-weight truck and general-freight rail shipments of spent fuel and/or radioactive waste, a series of curves (Figures 4.1 through 4.4) were generated showing unit cost comparisons between estimated shipping costs for each of these modes of transport for various radioactive waste materials at various distances. The basic shipping cost curves for HRC materials are shown for one-way mileages from 0 to 1000 miles and from 1000 to 3000 miles. The adders (surcharge) curves are projections of the costs that may be incurred to meet safeguards and security requirements. The curves shown for non-HRC materials represent the costs that will be incurred for shipments to various destination locations.



LWT = Legal Weight Truck
GFR = General Freight Rail
HRC = Highway Route Controlled

FIGURE 4.1. LWT and GFR Unit Shipping Cost for Spent Fuel and HRC Materials (0-1000 miles)



LWT = Legal Weight Truck

GFR = General Freight Rail

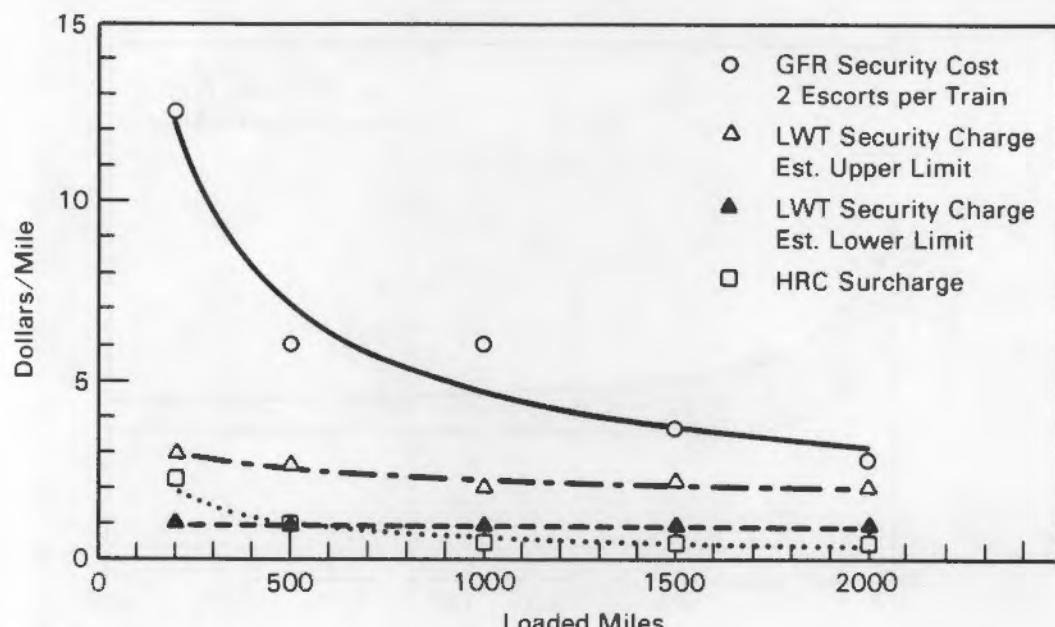
HRC = Highway Route Controlled

FIGURE 4.2. LWT and GFR Unit Shipping Cost for Spent Fuel and HRC Materials (1000-3000 miles)

The unit cost curves may be used by assuming cask/packaging weights and capacities to generate projected shipping costs that may be incurred. Representative values for specific cask and commodity weights are provided in Table A.5.

Utilizing the specific weight and commodity descriptions from Table A.5, a series of comparative shipping cost curves were generated for shipments by either legal-weight truck or general-freight rail for various radioactive waste materials. These curves are shown in Figures 4.5 through 4.8. It is important to note that these curves are representative of the specific cask/packaging specifications listed in Table A.5. The curves will vary if a different cask/packaging is specified.

The unit cost (\$ per kgU) for shipping spent fuel assemblies as a function of miles is shown in Figure 4.5. The legal-weight truck curve utilizes the minimum security charge shown in Figure 4.3. This charge is incurred for

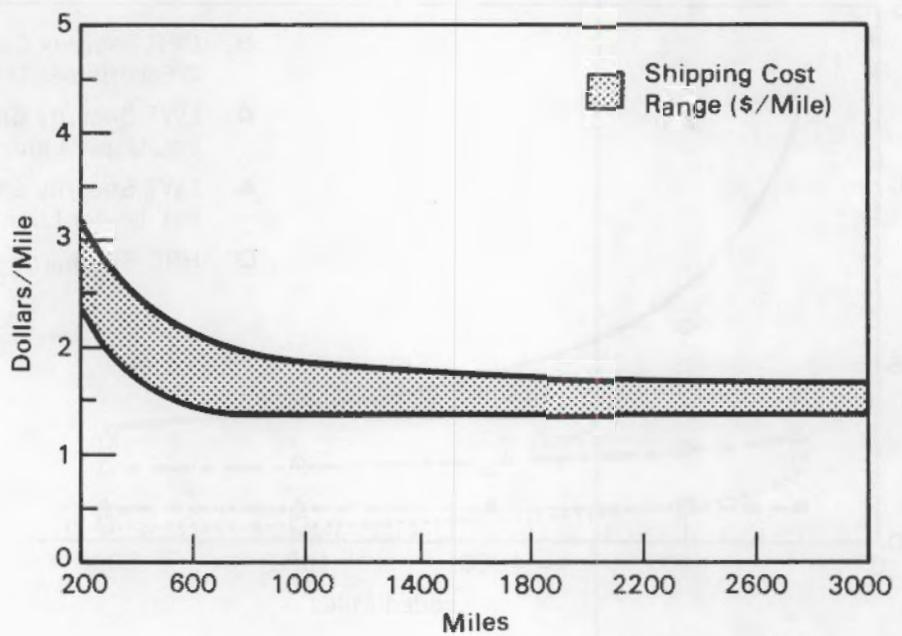


LWT = Legal Weight Truck
 GFR = General Freight Rail
 HRC = Highway Route Controlled

FIGURE 4.3. Shipping Cost Adders (Surcharges) for LWT and GFR Shipments of Spent Fuel and HRC Materials

providing special equipment required for safeguards and security. The general-freight rail curve includes additional charges for armed escorts as shown in Figure 4.3. This figure shows the unit costs for shipping by legal-weight truck to be about 1.0 to 1.5 times greater than that for general-freight rail. These data can be misleading because they represent only one part of the overall cost of transporting spent fuel. The overall cost of transporting spent fuel must also include the cost to purchase or lease shipping casks and the number of casks necessary to handle a prescribed volume. Conceivably, the slow transit speed for rail shipments could cause higher cask lease rates and, therefore, could increase the overall transportation cost by rail. That aspect of the shipping costs was not analyzed in this report.

The comparison of the unit cost for shipping high-level radioactive waste or TRU waste by either legal-weight truck or general-freight rail is shown in Figures 4.6, 4.7, and 4.8. The estimated costs for shipping these commodities by general-freight rail is shown to be approximately 1.5 times the cost of



LWT = Legal Weight Truck
 NHRC = Non-Highway Route Controlled

FIGURE 4.4. LWT Unit Shipping Cost for NHRC Materials

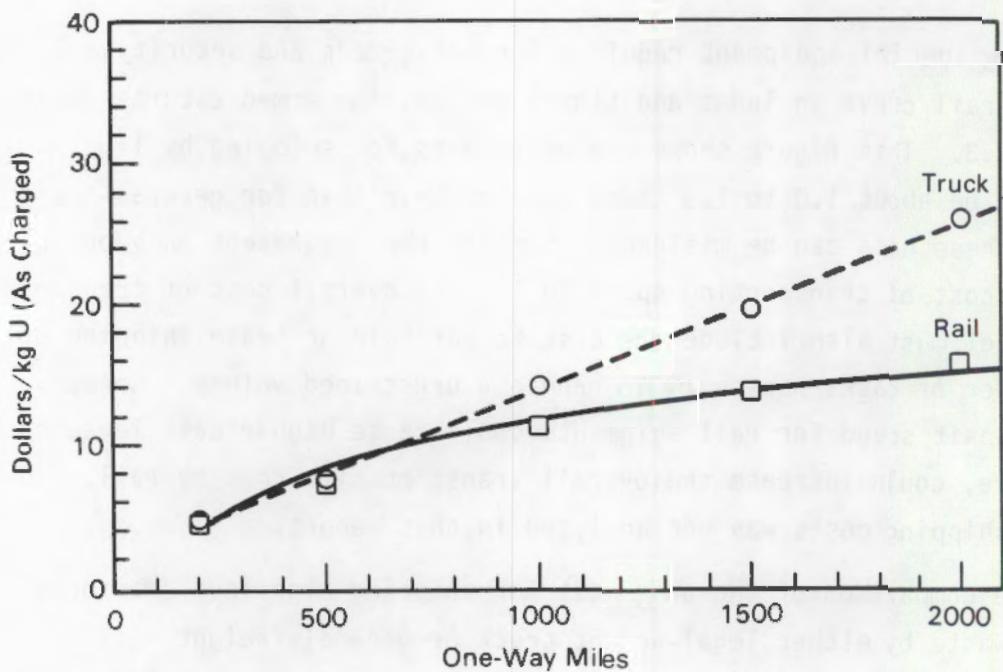


FIGURE 4.5. Comparison of Shipping Cost for Spent Fuel

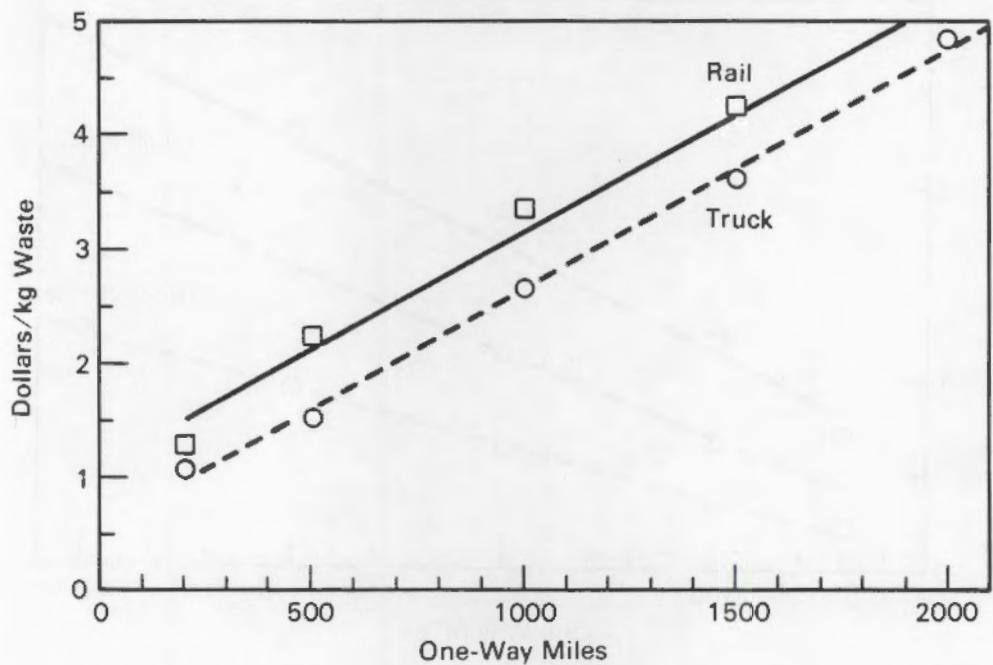
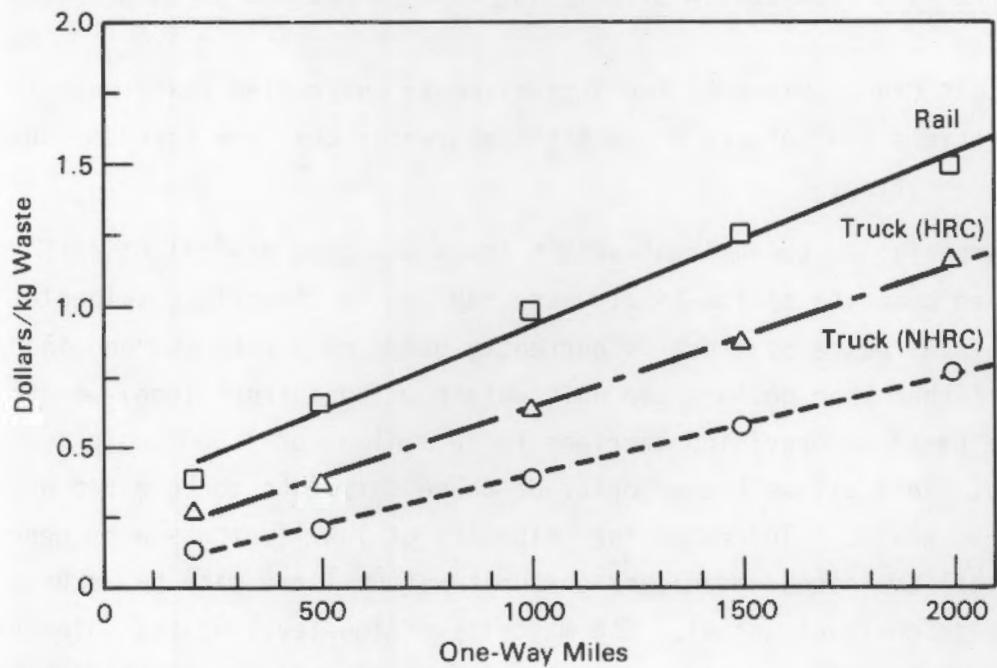
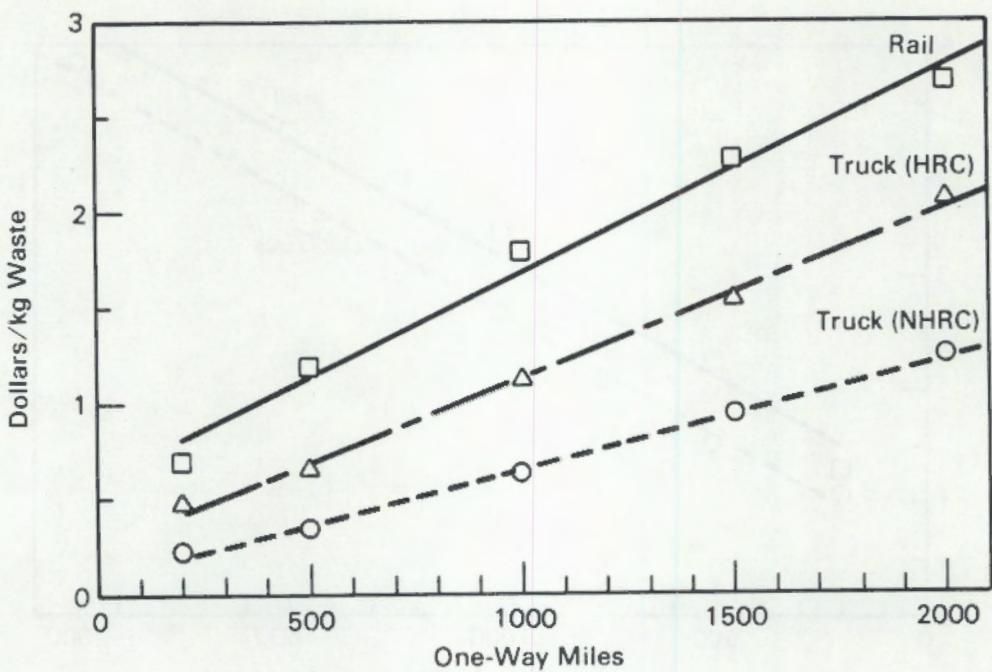


FIGURE 4.6. Comparison of Shipping Cost for High Level Waste



NHRC = Non-Highway Route Controlled
HRC = Highway Route Controlled

FIGURE 4.7. Comparison of Shipping Cost for Contact Handled TRU Waste



NHRC = Non-Highway Route Controlled
 HRC = Highway Route Controlled

FIGURE 4.8. Comparison of Shipping Cost for Remote Handled TRU Waste

legal-weight truck shipments for highway route controlled (HRC) quantities of these materials and between 2 and 6 times greater than the cost for shipping non-HRC quantities.

A comparison between legal-weight truck and general-freight rail shipments for a given quantity of low-level waste may not be directly obtainable. Shipping low-level waste by truck is currently based on a rate charged in dollars per mile rather than dollars per unit weight. The current legal-weight truck rates are based on providing carriage for a minimum of 1,500 cubic feet per truckload. This allows the majority of these shipments to be based on volume rather than weight. The rates for shipments of low-level waste by general freight rail are based on dollars per unit weight (same rate basis used for spent fuel/high-level waste). The majority of low-level wastes shipments have a low weight-to-volume ratio. This low weight-to-volume ratio favors shipments based on volume rather than weight. Thus, the majority of low-level waste shipments are currently being made with legal-weight truck carriers.

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APPENDIX A

LEGAL WEIGHT TRUCK AND GENERAL FREIGHT RAIL FEE SCHEDULES

APPENDIX A - LEGAL WEIGHT TRUCK AND GENERAL FREIGHT RAIL FEE SCHEDULES

TABLE A.1A. Truck Shipping Charges for Highway Route Controlled Materials

Rates in Cents per 100 Pounds					
Miles (Not Over)	Column 1 (a)	Column 2 (b)	Miles (Not Over)	Column 1 (a)	Column 2 (a)
100	158	106	825	443	348
110	166	107	850	448	356
120	167	111	875	462	366
130	172	114	900	467	378
140	178	117	925	475	392
150	184	119	950	487	401
160	191	120	975	495	411
170	198	123	1000	503	420
180	210	126	1025	513	433
190	215	131	1050	530	443
200	225	134	1075	541	450
225	232	141	1100	556	461
250	244	150	1125	568	477
275	252	151	1150	578	484
300	259	157	1175	595	492
325	269	168	1200	603	505
350	279	173	1225	618	514
375	284	174	1250	631	526
400	294	178	1275	644	536
425	306	191	1300	656	547
450	314	197	1325	667	556
475	321	205	1350	683	567
500	332	213	1375	693	579
525	337	229	1400	706	589
550	345	238	1425	719	598
575	358	247	1450	729	608
600	365	258	1475	746	621
625	374	270	1500	756	629
650	382	283	1525	768	643
675	391	287	1550	783	653
700	399	294	1575	794	661
725	409	312	1600	808	671
750	417	322	1625	822	684
775	424	327	1650	830	692
800	433	336	1675	846	704

(a) 36,000 pounds per vehicle minimum charge

(b) 32,000 pounds per vehicle minimum charge

TABLE A.1A. (contd)

Rates in Cents per 100 Pounds					
Miles (Not Over)	Column 1 ^(a)	Column 2 ^(b)	Miles (Not Over)	Column 1 ^(a)	Column 2 ^(a)
1700	857	714	2700	1361	1146
1725	868	733	2750	1387	1163
1750	883	742	2800	1411	1188
1775	893	754	2850	1438	1207
1800	908	768	2900	1461	1230
1825	919	774	2950	1489	1245
1850	932	783	3000	1510	1272
1875	944	796	3050	1538	1292
1900	960	810	3100	1563	1309
1925	971	818	3150	1588	1331
1950	981	825	3200	1615	1355
1975	998	838	3250	1640	1380
2000	1007	847	3300	1666	1395
2025	1022	856	3350	1687	1419
2050	1034	869	3400	1715	1442
2075	1047	881	3450	1741	1461
2100	1060	890	3500	1766	1482
2125	1071	899	3550	1789	1502
2150	1082	912	3600	1815	1525
2175	1093	921	3650	1840	1548
2200	1110	934	3700	1867	1564
2250	1136	953	3750	1891	1592
2300	1161	976	3800	1916	1611
2350	1186	997	3850	1939	1532
2400	1212	942	3900	1968	1651
2450	1239	1039	3950	1993	1674
2500	1258	1062	4000	2019	1695
2550	1284	1080	4050	2042	1719
2600	1310	1103	4100	2066	1738
2650	1336	1122	4150	2090	1759
			4200	2120	1780
			4250	2143	1798
			4300	2167	1822

(a) 36,000 pounds per vehicle minimum charge

(b) 32,000 pounds per vehicle minimum charge

TABLE A.1B. Truck Shipping Charges for Non-Highway Route Controlled Materials

One Way Mileage (Not Over)	Column ^(a)	Column ^(b)	Column ^(c)	One Way Mileage (Not Over)	Column ^(a)	Column ^(b)	Column ^(c)
100	471	495	338	750	173	209	142
125	433	459	313	800	165	203	142
150	396	423	289	850	164	202	142
175	362	389	268	900	162	200	142
200	313	343	245	950	159	197	142
225	296	329	233	1000	156	193	142
250	284	315	217	1100	156	192	142
275	271	304	204	1200	156	190	142
300	259	291	194	1300	156	188	142
325	252	285	183	1400	156	187	142
350	244	278	177	1500	156	186	142
375	235	268	171	1600	156	184	142
400	224	258	165	1700	156	183	142
425	217	252	162	1800	156	182	142
450	207	242	158	1900	156	181	142
475	202	237	155	2000	156	180	142
500	194	230	152	2100	156	179	142
550	190	225	149	2200	156	177	142
600	185	222	142	2300	156	176	142
650	176	211	142	2400	156	175	142
700	169	203	137	2500 & Beyond	156	174	142

(a) Applicable to one-way shipments having a destination east of the Mississippi River.

(b) Applicable to one-way shipments having a destination west of the Mississippi River.

(c) Applicable to continuous excursion moves in which a subsequent shipment is made available to carrier within 24 hours after arrival.

TABLE A.2. Truck Overweight Charges for Traveling Through Each State
Excluding Alaska and Hawaii (a)

State	When Weight of Article Exceeds (lbs)	Overweight Charge Applicable per Vehicles Used (\$)
Alabama	48,000	38.00 up to 65,000 lbs 58.00 from 65,001 to 85,000 lbs 88.00 from 85,001 to 110,000 lbs 128.00 for weight of 110,001 lbs or more
Arizona	48,000	20.00
Arkansas	48,000	17.00 plus a charge per 100 lbs on weight over 43,000 lbs as follows: 0 to 100 miles 25¢ 101 to 150 miles 30¢ 151 to 200 miles 35¢ 201 to 250 miles 40¢ 251 miles and over 45¢
California	48,000	33.00
Colorado	48,000	23.00
Connecticut	48,000	35.00
Delaware	48,000	18.00 plus 2¢ per ton mile traveled in Delaware on the weight over 48,000 lbs
Florida	48,000	35.00 per load on articles weighting 48,001 to 57,000 lbs 40.00 per load on articles weighing between 57,000 lbs and 74,000 lbs 40.00 per load plus 25¢ per 1000 lbs on weight over 74,000 lbs
Georgia	48,000	30.00
Idaho	48,000	30.00

(a) These charges are applicable only when overweight permits are required.

TABLE A.2. (contd)

State	When Weight of Article Exceeds (lbs)	Overweight Charge Applicable per Vehicles Used (\$)
Illinois	43,000	30.00 plus 30¢ per mile traveled in Illinois on shipments over 48,000 to 49,999 lbs plus 50¢ per mile on shipments over 50,000 to 69,999 lbs 65.00 plus 50¢ per mile on shipments weighing over 70,000 lbs
Indiana	48,000	33.00 plus 40¢ per mile traveled in Indiana, subject to a maximum charge of \$75.00
Iowa	48,000	23.00
Kansas	48,000	23.00
Kentucky	48,000	48.00
Louisiana	48,000	30.00 plus 40¢ per mile traveled in Louisiana, up to 68,000 lbs 40.00 plus 80¢ per mile traveled in Louisiana from 68,001 to 88,000 lbs 50.00 plus \$1.20 per mile traveled in Louisiana from 88,000 to 108,000 lbs 60.00 plus \$2.40 per mile traveled in Louisiana from 108,001 or more
Maine	48,000	35.00
Maryland	48,000	45.00 plus \$5.00 per ton, or fraction thereof, on weight in excess of 50,000 lbs
Massachusetts	48,000	18.00
Michigan	48,000	45.00
Minnesota	48,000	28.00

TABLE A.2. (contd)

<u>State</u>	<u>When Weight of Article Exceeds (1bs)</u>	<u>Overweight Charge Applicable per Vehicles Used (\$)</u>
Mississippi	48,000	10.00 plus 15¢ per ton mile traveled only on interstate highways; all other highways 30¢ per ton mile in Mississippi on weight in excess of 48,000 lbs
Missouri	43,000	28.50
Montana	48,000	40.00 on distance of 100 miles or less (in Montana) 60.00 on distance of 101 to 200 miles (in Montana) 80.00 on distance of 201 miles or over (in Montana)
Nebraska	48,000	29.00
Nevada	48,000	25.00
New Hampshire	48,000	44.00 on shipments 48,000 to 58,000 lbs 54.00 on shipments 58,000 to 63,000 lbs 64.00 on shipments 70,000 lbs plus \$2.00 per 100 lbs over 70,000 lbs
New Jersey	48,000	50.00 on articles weighing 48,001 to 53,000 lbs 60.00 on articles weighing 53,001 to 58,000 lbs 75.00 on articles weighing 58,001 to 63,000 lbs 125.00 on articles weighing 63,001 to 68,000 lbs 200.00 on articles weighing over 68,000 lbs
New Mexico	48,000	20.00
New York	48,000	30.000
North Carolina	48,000	23.00

TABLE A.2. (contd)

<u>State</u>	<u>When Weight of Article Exceeds (lbs)</u>	<u>Overweight Charge Applicable per Vehicles Used (\$)</u>
North Dakota	48,000	23.00 plus \$6.00 per ton in excess of 48,000
Ohio	48,000	38.00
Oklahoma	48,000	23.00 plus \$5.00 for each 1,000 lbs or fraction thereof on excess of 48,000 lbs per load
Oregon	48,000	21.00
Pennsylvania	48,000	30.00 plus 3¢ per ton mile on excess of 48,000 lbs per load when weight exceeds 98,000 lbs charge 4¢ per ton
Rhode Island	48,000	18.00
South Carolina	48,000	23.00
South Dakota	48,000	30.00 plus 2¢ per ton mile on excess of 48,000 lbs
Tennessee	48,000	40.00 plus 5¢ per ton mile traveled in TN on weight in excess of 48 M
Texas	48,000	19.00
Utah	48,000	74.00
Vermont	48,000	40.00
Virginia	48,000	28.00 plus 10¢ per mile traveled in Virginia
Washington	48,000	25.00 plus a charge of: 10¢ per mile on 48,000 to 56,999 lbs 20¢ per mile on 57,000 to 62,999 lbs 30¢ per mile on 63,000 to 68,999 lbs 45¢ per mile on 69,000 to 74,999 lbs 75¢ per mile on 75,000 to 80,999 lbs 1.00 per mile on 81,000 to 86,999 lbs 1.50 per mile on 87,000 to 92,999 lbs 1.75 per mile on 93,000 to 98,999 lbs 2.00 per mile on 99,000 lbs or over

TABLE A.2. (contd)

State	When Weight of Article Exceeds (lbs)	Overweight Charge Applicable per Vehicles Used (\$)
West Virginia	48,000	20.00 plus 3¢ per ton mile on excess of 48,000 lbs per load
Wisconsin	48,000	35.00 articles up to 58,000 lbs 5.00 58,001 to 68,000 lbs 60.00 68,001 to 78,000 lbs 70.00 78,001 to 88,000 lbs 80.00 88,001 to 98,000 lbs 90.00 98,001 to 108,000 lbs 100.00 108,000 to 118,000 lbs plus 1.00 per 1000 lbs over 118,000 lbs
Wyoming	48,000	21.00 plus 4¢ per ton mile in excess of 48,000 lbs, subject to maximum charge of \$200.00 (such maximum charge will NOT apply to towaway shipments)

TABLE A.3. Truck Surcharges

<u>Type of Charge</u>	<u>Commodity</u>	<u>Cost</u>	<u>NRC Requirement</u>
Special equipment (legal-size and legal-weight)	Spent fuel	\$0.92 per loaded mile	X
Special equipment (oversize or overweight)	Spent fuel	\$1.00 per loaded mile	X
"L" cleared driver	HRC(a)	\$0.12 per mile	
"Q" cleared driver	HRC(a)	\$0.15 per mile ^(b)	
Armed driver/escort	Spent fuel	\$0.20 per mile	X
Separate escort vehicle	Spent fuel	\$1.48 per mile	X ^(c)
Highway route control surcharge	HRC(d)	\$0.45 per mile ^(e)	

(a) Highway route controlled.

(b) For two "Q" cleared drivers, a fixed charge of \$200.

(c) Required in heavily populated areas.

(d) Is not imposed on spent fuel shipments.

(e) Minimum charge of \$450.

TABLE A.4. Truck Detention Charges

Hours	Rate Per Hour Per Vehicle Used	
	Spent Fuel	Nuclear Waste (a)
First 3	Free	Free
4-8	\$17.50	\$17.50
9-16	\$22.50	\$17.50
17-24	\$27.50	\$17.50
over 24	\$32.50	\$17.50

(a) Maximum detention charge for any one calendar day shall be the charge for ten (10) hours time except, when vehicle is not loaded and/or unloaded and vehicle is not released to carrier within 24 hours after arrival, detention charges thereafter shall be \$17.50 per hour with no exclusions for hours of day, holidays or Sunday.

TABLE A.5. Summary of Loaded and Empty Packaging Weights Used in Analysis of Shipping Costs

Commodity	Legal Weight Truck				General Freight Rail			
	Loaded Weight		Empty Weight		Loaded Weight		Empty Weight	
	lb	kg	lb	kg	lb	kg	lb	kg
Spent Fuel	50,000	22,680	48,650	22,068	180,000	81,648	169,000	76,658
High-Level Waste	50,000	22,680	45,500	20,638	200,000	90,720	177,500	80,514
RH-Tru Waste	50,000	22,680	40,000	18,144	200,000	90,720	160,000	72,576
CH-Tru Waste	50,000	22,680	33,000	14,969	100,000	45,360	66,000	29,938
Low-Level Waste	(a)	(a)	(a)	(a)	(b)	(b)	(c)	(c)

(a) Based on \$/mile (no weight required)

(b) Assumed shipment weight of 150,000 pounds.

(c) Minimum weight assumed (40,000 pounds)

TABLE A.6. Rail General-Freight Shipping Charges, Distances, and Transit Times from All LWRs to National Site

State/Town	Reactor	Dollars		Approximate Rail Miles	Transit Time, Days
		Per 100 Pounds Loaded	Empty		
ALABAMA					
Scottsboro	Bellefonte 1,2	9.67	9.06	1,171	8-11
ARIZONA					
Wintersburg	Palo Verde 1,2,3	9.61	9.01	602	4-6
ARKANSAS					
Russelville	Arkansas Nuclear 1,2	7.51	7.04	749	7-10
CALIFORNIA					
Clay Station	Ranco Seco	13.88	13.02	1346	9-12
Eureka	Humboldt Bay	13.45	12.61	1591	9-12
San Clemente	San Onofre, 1,2,3	13.45	12.61	941	7-10
CONNECTICUT					
Waterford	Millstone 1,2,3	14.90	13.97	2,195	10-13
FLORIDA					
Redlevel	Crystal River 3	11.33	10.62	1,478	10-13
GEORGIA					
Baxley	Hatch 1,2	10.68	10.02	1,371	8-11
Waynesboro	Vogtle 1,2	10.98	10.29	1,425	9-12
ILLINOIS					
Braidwood	Braidwood 1,2	9.93	9.31	1,206	6-8
Byron	Byron 1,2	9.93	9.31	1,221	6-8
Clinton	Clinton 1	9.57	8.97	1,149	6-8
Cordova	Quad Cities 1,2	9.45	8.86	1,125	6-8
Morris	Dresden 1,2,3	9.93	9.31	1,206	6-8
Seneca	LaSalle County 1,2	9.93	9.31	1,206	6-8
Zion	Zion 1,2	10.22	9.58	1,267	6-8
INDIANA					
Madison	Marble Hill 1,2	10.46	9.81	1,315	7-10
IOWA					
Pato	Arnold	9.45	8.86	1,107	8-11
KANSAS					
Burlington	Wolf Creek	7.40	6.94	733	6-8

TABLE A.6. (contd)

State/Town	Reactor	Dollars		Approximate Rail Miles	Transit Time, Days
		Per 100 Loaded	Pounds Empty		
<u>LOUISIANA</u>					
St. Francisville	Riverbend 1	8.30	7.79	892	9-12
Taft	Waterford 3	8.52	7.99	936	9-12
<u>MAINE</u>					
Wiscasset	Main Yankee	15.64	14.66	2,349	12-15
<u>MICHIGAN</u>					
Bridgeman	Cook 1,2	10.58	9.92	1,333	9-12
Midland	Midland 1,2	11.47	10.75	1,507	9-12
Newport	Fermi 2	11.33	10.62	1,481	9-12
<u>MINNESOTA</u>					
Monticello	Monticello	10.32	9.68	1,283	9-12
Red Wing	Prairie Isl and 1,2	10.06	9.43	1,249	9-12
<u>MISSISSIPPI</u>					
Iuka	Yellow Creek 1,2	8.92	8.37	1,012	9-12
Port Gibson	Grand Gulf 1,2	8.03	7.53	838	8-11
<u>MISSOURI</u>					
Fulton	Callaway 1,2	8.80	8.25	976	8-11
<u>NEBRASKA</u>					
Brownville	Cooper	8.40	7.88	913	8-11
Ft. Calhoun	Ft. Calhoun 1	8.52	7.99	949	8-11
<u>NEW HAMPSHIRE</u>					
Seabrook	Seabrook 1,2	15.14	14.19	2,239	10-13
<u>NEW YORK</u>					
Scriba	Nine Mile Point 1,2	13.34	12.51	1,880	10-15
Fitzpatrick					
<u>NORTH CAROLINA</u>					
Cornelius	McGuire 1,2	11.56	10.84	1,541	10-13
New Hill	Harris 1,2,3,4	12.06	11.31	1,639	10-13
South Port	Brunswick 1,2	12.35	11.58	1,687	10-13
<u>OHIO</u>					
North Perry	Perry 1,2	11.81	11.07	1,588	12-15
Oak Harbor	Davis-Besse 1	11.47	10.75	1,503	9-12
<u>OREGON</u>					
Ranier	Trojan	16.80	15.75	1,680	8-11

TABLE A.6. (contd)

State/Town	Reactor	Dollars		Approximate Rail Miles	Transit Time, Days
		Per 100 Loaded	Pounds Empty		
<u>PENNSYLVANIA</u>					
Berwick	Susquehanna 1,2	13.62	12.77	1,926	9-12
Goldsboro	Three Mile				
	Island 1,2	13.53	12.68	1,904	9-12
Pottstown	Limerick 1,2	13.88	13.01	1,977	9-12
<u>SOUTH CAROLINA</u>					
Clover	Catawba 1,2	11.47	10.75	1,503	10-13
Gaffney	Cherokee 1,2	11.33	10.62	1,476	10-13
Hartsville	Rabinson 2	11.69	10.96	1,571	10-13
Parr	Summer	11.20	10.50	1,471	10-13
<u>TENNESSEE</u>					
Daisy	Sequoah 1,2	9.93	9.31	1,210	7-10
Spring City	Watts Bar 1,2	10.06	9.43	1,248	7-10
Surgoinsville	Phipps Bend 1,2	10.82	10.15	1,399	7-10
<u>TEXAS</u>					
Glen Rose	Comanche Peak 1,2	5.52	5.18	421	4-6
Palacios	South Texas 1,2	7.00	6.56	674	6-8
<u>VERMONT</u>					
Vernon	Vermont Yankee	14.53	13.62	2,106	10-13
<u>VIRGINIA</u>					
Mineral	North Anna 1,2,3,4	12.87	12.07	1,786	9-12
<u>WASHINGTON</u>					
Hanford	WNP 1,2,4	14.82	13.89	1,960	9-12
Satsop	WNP 3,5	16.80	15.75	2,203	12-15
<u>WISCONSIN</u>					
LaCrosse	LaCrosse	10.22	9.58	1,259	8-11

TABLE A.7. Rail General-Freight Shipping Charges, Distances, and Transit Times from LWRs in the Western Region to Western Site

<u>State/Town</u>	<u>Reactor</u>	<u>Dollars</u>		<u>Approximate</u>	<u>Transit</u>
		<u>Per 100 Pounds</u>	<u>Loaded</u>	<u>Empty</u>	<u>Rail Miles</u>
<u>ARIZONA</u>					
Wintersburg	Palo Verde 1,2,3	13.69	12.83	1,295	8-11
<u>CALIFORNIA</u>					
Clay Station	Rancho Seco	9.10	8.54	926	5-7
Eureka	Humboldt Bay	11.00	10.31	1,207	7-9
San Clemente	San Onofre 1,2,3	12.05	11.30	1,185	6-8
<u>OREGON</u>					
Ranier	Trojan	5.29	4.96	289	3-5
<u>WASHINGTON</u>					
Satsop	WNP 3,5	5.09	4.77	333	4-7

TABLE A.8. Rail General-Freight Shipping Charges, Distances and Transit Time from LWRs in the Southern Region to Southern Site

State/Town	Reactor	Dollars		Approximate Rail Miles	Transit Time, Days
		Per 100 Pounds Loaded	Empty		
<u>ALABAMA</u>					
Scottsboro	Bellefonte 1,2	5.25	4.92	406	5-7
<u>ARKANSAS</u>					
Russellville	Arkansas Nuclear 1,2	5.63	5.28	475	5-7
<u>FLORIDA</u>					
Red Level	Crystal River 3	6.26	5.87	551	7-10
<u>GEORGIA</u>					
Baxley	Hatch 1,2	5.98	5.61	508	6-8
Waynesboro	Vogtle 1,2	6.40	6.00	562	6-8
<u>KANSAS</u>					
Burlington	Wolf Creek	7.64	7.16	779	7-10
<u>LOUISIANA</u>					
St. Francisville	River Bend 1	4.32	4.05	244	4-6
Taft	Waterford 3	4.14	3.89	235	5-7
<u>MISSISSIPPI</u>					
Iuka	Yellow Creek 1,2	4.73	4.43	301	5-7
Port Gibson	Grand Gulf 1,2	3.82	3.59	191	4-6
<u>NORTH CAROLINA</u>					
Cornelius	McGuire 1,2	7.15	6.71	689	5-7
Newhill	Harris 1,2,3,4	7.64	7.16	776	7-9
South Port	Brunswick 1,2	7.89	7.40	824	7-9
<u>SOUTH CAROLINA</u>					
Clover	Catawba 1,2	6.92	6.49	641	5-7
Gaffney	Cherokee 1,2	6.63	6.21	614	5-7
Hartsville	Robinson 2	7.27	6.82	708	6-8
Parr	Summer	6.63	6.21	608	5-7
<u>TENNESSEE</u>					
Daisy	Sequoyah 1,2	5.25	4.92	385	4-6
Spring City	Watts Bar 1,2	5.42	5.08	419	4-6
Surgoinsville	Phipps Bend 1,2	6.40	6.00	570	5-7
<u>TEXAS</u>					
Glen Rose	Comanche Peak 1,2	6.51	6.10	581	5-7
Palacios	South Texas 1,2	6.63	6.21	613	5-7
<u>VIRGINIA</u>					
Mineral	North Anna 1,2,3,4	8.64	8.10	957	9-12

TABLE A.9. Rail General Freight Shipping Charges, Distances and Transit Times from LWRs in the North Central Region to North Central Site

<u>State/Town</u>	<u>Reactor</u>	<u>Dollars</u>		<u>Approximate Rail Miles</u>	<u>Transit Time, Days</u>
		<u>Per 100 Pounds Loaded</u>	<u>Empty</u>		
ILLINOIS					
Braidwood	Braidwood 1,2	4.86	4.56	333	3-5
Byron	Byron 1,2	4.32	4.05	245	3-5
Clinton	Clinton 1	5.42	5.08	419	4-6
Cordova	Quad Cities 1,2	4.73	4.43	315	4-6
Morris	Dresden 1,2,3	4.86	4.56	333	3-5
Seneca	LaSalle County 1,2	4.86	4.56	333	3-5
Zion	Zion 1,2	4.58	4.30	281	2-4
IOWA					
PaTo	Arnold	4.58	4.30	292	4-6
MINNESOTA					
Monticello	Monticello	3.47	3.25	160	3-5
Red Wing	Prairie Island 1,2	2.70	2.54	78	3-5
MISSOURI					
Fulton	Callaway 1,2	6.14	5.75	539	5-7
NEBRASKA					
Brownville	Cooper	5.77	5.41	479	5-7
Ft. Calhoun	Ft. Calhoun 1	5.42	5.08	407	4-6
WISCONSIN					
LaCrosse	LaCrosse	3.03	2.84	109	3-5

TABLE A.10. Rail General-Freight Shipping Charges, Distances, Transit Times from LWRs in the Northeastern Region to Northeastern Site

<u>State/Town</u>	<u>Reactor</u>	<u>Dollars</u>			<u>Approximate Rail Miles</u>	<u>Transit Time, Days</u>
		<u>Per 100 Pounds Loaded</u>	<u>Per 100 Pounds Empty</u>			
<u>CONNECTICUT</u>						
Waterford	Millstone 1,2,3	7.24	6.78		629	7-10
<u>INDIANA</u>						
Madison	Marble Hill 1,2	5.48	5.14		380	3-5
<u>MAINE</u>						
Wiscasset	Maine Yankee	8.32	7.80		783	7-10
<u>MICHIGAN</u>						
Bridgman	Cook 1,2	5.35	5.02		346	4-6
Midland	Midland 1,2	5.06	4.74		308	4-6
Newport	Fermi 2	4.08	3.83		197	3-5
<u>NEW HAMPSHIRE</u>						
Seabrook	Seabrook 1,2	7.49	7.02		673	7-10
<u>NEW YORK</u>						
Scriba	Nine-Mile Point 1,2	5.06	4.74		315	3-5
	Fitzpatrick					
<u>OHIO</u>						
North Perry	Perry 1,2	2.73	2.56		65	2-3
Oak Harbor	Davis-Besse 1	3.43	3.22		126	2-3
<u>PENNSYLVANIA</u>						
Berwick	Susquehanna 1,2	5.20	4.88		323	3-5
Goldsboro	Three-Mile Island 1,2	5.06	4.74		312	3-5
Pottstown	Limerick 1,2	5.62	5.27		396	3-6
<u>VERMONT</u>						
Vernon	Vermont Yankee	6.57	6.16		540	5-7

TABLE A.11. Average Rail Transit Speed

<u>Total Distance Traveled, Miles</u>	<u>General Freight Transit Speed, Miles/Day</u>
0 - 300	47
301 - 1100	88
1101 - 1900	143
1901 - 2400	182

APPENDIX B

ACTIVITY LIMITS FOR HIGHWAY ROUTE CONTROLLED QUANTITIES

APPENDIX B

ACTIVITY LIMITS FOR HIGHWAY ROUTE CONTROLLED QUANTITIESTABLE B.1. Activity Limits for Highway Route Controlled Quantities
(All values in curies [Ci])

Radionuclide Symbol	Normal Form ^(a)	Special Form ^(a)
²²⁷ Ac	9	30K
²²⁸ Ac	12K	30K
¹⁰⁵ Ag	30K	30K
^{110m} Ag	21K	21K
¹¹¹ Ag	30K	30K
²⁴¹ Am	24	24K
²⁴³ Am	24	24K
³⁷ Ar(Comp/Uncomp)	30K	30K
⁴¹ Ar(Uncomp)	30K	30K
⁴¹ Ar(Comp)	3K	3K
⁷³ As	30K	30K
⁷⁴ As	30K	30K
⁷⁶ As	30K	30K
⁷⁷ As	30K	30K
²¹¹ At	21K	30K
¹⁹³ Au	30K	30K
¹⁹⁶ Au	30K	30K
¹⁹⁸ Au	30K	30K
¹⁹⁹ Au	30K	30K
¹³¹ Ba	30K	30K
¹³³ Ba	30K	30K
¹⁴⁰ Ba	30K	30K

(a) As defined in 10 CFR 73 but special form is considered to be nondisposable by virtue of monolithic form or high integrity encapsulation.

TABLE B.1. (contd)

Radionuclide Symbol	Normal Form ^(a)	Special Form ^(a)
⁷ Be	30K	30K
²⁰⁶ Bi	15K	15K
²⁰⁷ Bi	30K	30K
²¹⁰ Bi(RaE)	12K	30K
²¹² Bi	18K	18K
²⁴⁹ Bk	3K	30K
⁷⁷ Br	30K	30K
⁸² Br	18K	18K
¹¹ C	30K	30K
¹⁴ C	30K	30K
⁴⁵ Ca	30K	30K
⁴⁷ Ca	30K	30K
¹⁰⁹ Cd	30K	30K
^{115m} Cd	30K	30K
¹¹⁵ Cd	30K	30K
¹³⁹ Ce	30K	30K
¹⁴¹ Ce	30K	30K
¹⁴³ Ce	30K	30K
¹⁴⁴ Ce	21K	30K
²⁴⁹ Cf	6	6K
²⁵⁰ Cf	21	21K
²⁵² Cf	27	6K
³⁶ Cl	30K	30K
³⁸ Cl	30K	30K
²⁴² Cm	600	30K
²⁴³ Cm	27	27K
²⁴⁴ Cm	30	30K
²⁴⁵ Cm	18	18K

(a) As defined in 10 CFR 73 but special form is considered to be nondisposable by virtue of monolithic form or high integrity encapsulation.

TABLE B.1. (contd)

Radionuclide Symbol	Normal Form ^(a)	Special Form ^(a)
²⁴⁶ Cm	18	18K
⁵⁶ Co	15K	15K
⁵⁷ Co	30K	30K
^{58m} Co	30K	30K
⁵⁸ Co	30K	30K
⁶⁰ Co	21K	21K
⁵¹ Cr	30K	30K
¹²⁹ Cs	30K	30K
¹³¹ Cs	30K	30K
^{134m} Cs	30K	30K
¹³⁴ Cs	30K	30K
¹³⁵ Cs	30K	30K
¹³⁶ Cs	21K	21K
¹³⁷ Cs	30K	30K
⁶⁴ Cu	30K	30K
⁶⁷ Cu	30K	30K
¹⁶⁵ Y	30K	30K
¹⁶⁶ Dy	30K	30K
¹⁶⁹ Er	30K	30K
¹⁷¹ Er	30K	30K
^{152m} Er	30K	30K
¹⁵² Er	30K	30K
¹⁵⁴ Er	15K	30K
¹⁵⁵ Er	30K	30K
¹⁸ F	30K	30K
⁵² Fe	15K	15K
⁵⁵ Fe	30K	30K
⁵⁹ Fe	30K	30K

(a) As defined in 10 CFR 73 but special form is considered to be nondisposable by virtue of monolithic form or high integrity encapsulation.

TABLE B.1. (contd)

Radionuclide Symbol	Normal Form ^(a)	Special Form ^(a)
⁶⁷ Ga	30K	30K
⁶⁸ Ga	30K	30K
⁷² Ga	21K	21K
¹⁵³ Gd	30K	30K
¹⁵⁹ Gd	30K	30K
⁶⁸ Ge	30K	30K
⁷¹ Ge	30K	30K
³ H	†	†
¹⁸¹ Hf	30K	30K
^{197m} Hg	30K	30K
¹⁹⁷ Hg	30K	30K
²⁰³ Hg	30K	30K
¹⁶⁶ Ho	30K	30K
¹²³ I	30K	30K
¹²⁵ I	30K	30K
¹²⁶ I	30K	30K
¹²⁹ I	6K	30K
¹³¹ I	30K	30K
¹³² I	21K	21K
¹³³ I	30K	30K
¹³⁴ I	24K	24K
¹³⁵ I	30K	30K
¹¹¹ In	30K	30K
^{113m} In	30K	30K
^{114m} In	30K	30K
^{115m} In	30K	30K
¹⁹⁰ Ir	30K	30K

(a) As defined in 10 CFR 73 but special form is considered to be nondisposable by virtue of monolithic form or high integrity encapsulation.

TABLE B.1. (contd)

Radionuclide Symbol	Normal Form ^(a)	Special Form ^(a)
¹⁹² Ir	30K	30K
¹⁹⁴ Ir	30K	30K
⁴² K	30K	30K
⁴³ K	30K	30K
^{85m} Kr(Uncomp)	30K	30K
^{85m} Kr(Comp)	9K	9K
⁸⁵ Kr(Uncomp)	30K	30K
⁸⁵ Kr(Comp)	15K	15K
⁸⁷ Kr(Uncomp)	30K	30K
⁸⁷ Kr(Comp)	1800	1800
¹⁴⁰ La	30K	30K
¹⁷⁷ Lu	30K	30K
MFP	1200	30K
²⁸ Mg	18K	18K
⁵² Mn	15K	15K
⁵⁴ Mn	30K	30K
⁵⁶ Mn	15K	15K
⁹⁹ Mo	30K	30K
¹³ N	30K	30K
²² Na	24K	24K
²⁴ Na	15K	15K
^{93m} Nb	30K	30K
⁹⁵ Nb	30K	30K
⁹⁷ Nb	30K	30K
¹⁴⁷ Nd	30K	30K
¹⁴⁹ Nd	30K	30K
⁵⁹ Ni	30K	30K

(a) As defined in 10 CFR 73 but special form is considered to be nondisposable by virtue of monolithic form or high integrity encapsulation.

TABLE B.1. (contd)

Radionuclide Symbol	Normal Form ^(a)	Special Form ^(a)
⁶³ Ni	30K	30K
⁶⁵ Ni	30K	30K
²³⁷ Np	15	15K
²³⁹ Np	30K	30K
¹⁸⁵ Os	30K	30K
¹⁹¹ Os	30K	30K
^{191m} Os	30K	30K
¹⁹³ Os	30K	30K
³² P	30K	30K
²³⁰ Pa	2400	30K
²³¹ Pa	6	6K
²³³ Pa	30K	30K
²⁰¹ Pb	30K	30K
²¹⁰ Pb	600	30K
²¹² Pb	18K	18K
¹⁰³ Pd	30K	30K
¹⁰⁹ Pd	30K	30K
¹⁴⁷ Pm	30K	30K
¹⁴⁹ Pm	30K	30K
²¹⁰ Po	600	30K
¹⁴² Pr	30K	30K
¹⁴³ Pr	30K	30K
¹⁹¹ Pt	30K	30K
^{193m} Pt	30K	30K
^{197m} Pt	30K	30K
¹⁹⁷ Pt	30K	30K
²³⁸ Pu	9	9K
²³⁹ Pu	6	6K

(a) As defined in 10 CFR 73 but special form is considered to be nondisposable by virtue of monolithic form or high integrity encapsulation.

TABLE B.1. (contd)

Radionuclide Symbol	Normal Form ^(a)	Special Form ^(a)
²⁴⁰ Pu	6	6K
²⁴¹ Pu	300	30K
²⁴² Pu	9	9K
²²³ Ra	600	30K
²²⁴ Ra	1500	18K
²²⁶ Ra	150	30K
²²⁸ Ra	150	30K
⁸¹ Rb	30K	30K
⁸⁶ Rb	30K	30K
⁸⁷ Rb	30K	30K
Rb(Nat)	30K	30K
¹⁸⁶ Re	30K	30K
¹⁸⁷ Re	30K	30K
¹⁸⁸ Re	30K	30K
Re(Nat)	30K	30K
^{103m} Rh	30K	30K
¹⁰⁵ Rh	30K	30K
²²² Rn	6K	30K
⁹⁷ Ru	30K	30K
¹⁰³ Ru	30K	30K
¹⁰⁵ Ru	30K	30K
¹⁰⁶ Ru	21K	30K
³⁵ S	30K	30K
¹²² Sb	30K	30K
¹²⁴ Sb	15K	15K
¹²⁵ Sb	30K	30K
⁴⁶ Sc	24K	24K
⁴⁷ Sc	30K	30K

(a) As defined in 10 CFR 73 but special form is considered to be nondisposable by virtue of monolithic form or high integrity encapsulation.

TABLE B.1. (contd)

Radionuclide Symbol	Normal Form ^(a)	Special Form ^(a)
⁴⁸ Sc	15K	15K
⁷⁵ Se	30K	30K
³¹ Si	30K	30K
¹⁴⁷ Sm	30K	30K
¹⁵¹ Sm	30K	30K
¹⁵³ Sm	30K	30K
¹¹³ Sn	30K	30K
^{119m} Sn	30K	30K
¹²⁵ Sn	30K	30K
^{85m} Sr	30K	30K
⁸⁵ Sr	30K	30K
^{87m} Sr	30K	30K
⁸⁹ Sr	30K	30K
⁹⁰ Sr	1200	30K
⁹¹ Sr	30K	30K
⁹² Sr	30K	30K
T(Uncomp)	30K	30K
T(Comp)	30K	30K
T(Actuated luminous paint)	30K	30K
T(Absorbed on solid)	30K	30K
T(Tritiated water)	30K	30K
T(Other forms)	30K	30K
¹⁸² Ta	30K	30K
¹⁶⁰ Tb	30K	30K
^{96m} Tc	30K	30K
⁹⁶ Tc	18K	18K

(a) As defined in 10 CFR 73 but special form is considered to be nondisposable by virtue of monolithic form or high integrity encapsulation.

TABLE B.1. (contd)

Radionuclide Symbol	Normal Form ^(a)	Special Form ^(a)
^{97m}Tc	30K	30K
^{97}Tc	30K	30K
^{99m}Tc	30K	30K
^{99}Tc	30K	30K
^{125m}Te	30K	30K
^{127m}Te	30K	30K
^{127}Te	30K	30K
^{129m}Te	30K	30K
^{129}Te	30K	30K
^{131m}Te	30K	30K
^{132}Te	21K	21K
^{227}Th	600	30K
^{228}Th	24	18K
^{230}Th	9	9K
^{231}Th	30K	30K
^{232}Th	30K	30K
^{234}Th	30K	30K
Th(Nat)	30K	30K
Th(Irrad)	30K	30K
^{200}Tl	30K	30K
^{201}Tl	30K	30K
^{202}Tl	30K	30K
^{204}Tl	30K	30K
^{170}Tm	30K	30K
^{171}Tm	30K	30K
^{230}U	300	30K
^{232}U	90	30K
^{233}U	300	30K

(a) As defined in 10 CFR 73 but special form is considered to be nondisposable by virtue of monolithic form or high integrity encapsulation.

TABLE B.1. (contd)

Radionuclide Symbol	Normal Form ^(a)	Special Form ^(a)
^{234}U	300	30K
^{235}U	600	30K
^{236}U	600	30K
^{238}U	30K	30K
$\text{U}(\text{Nat})$	30K	30K
$\text{U}(\text{Enr} < 20\%)$	30K	30K
$\text{U}(\text{Enr} > 20\%)$	300	30K
$\text{U}(\text{Depl})$	30K	30K
$\text{U}(\text{Irrad})$	30K	30K
$^{48}\gamma$	18K	18K
^{181}W	30K	30K
^{185}W	30K	30K
^{187}W	30K	30K
$^{127}\text{Xe}(\text{Uncomp})$	30K	30K
$^{127}\text{Xe}(\text{Comp})$	15K	15K
$^{131}\text{mXe}(\text{Comp})$	30K	30K
$^{131}\text{mXe}(\text{Uncomp})$	30K	30K
$^{133}\text{Xe}(\text{Uncomp})$	30K	30K
$^{133}\text{Xe}(\text{Comp})$	15K	15K
$^{135}\text{Xe}(\text{Uncomp})$	30K	30K
$^{135}\text{Xe}(\text{Comp})$	6K	6K
$^{87}\gamma$	30K	30K
$^{90}\gamma$	30K	30K
$^{91}\text{m}\gamma$	30K	30K
$^{91}\gamma$	30K	30K
$^{92}\gamma$	30K	30K
$^{93}\gamma$	30K	30K

(a) As defined in 10 CFR 73 but special form is considered to be nondisposable by virtue of monolithic form or high integrity encapsulation.

TABLE B.1. (contd)

Radionuclide Symbol	Normal Form ^(a)	Special Form ^(a)
^{169}Yb	30K	30K
^{175}Yb	30K	30K
^{65}Zn	30K	30K
$^{69\text{m}}\text{Zn}$	30K	30K
^{67}Zn	30K	30K
^{93}Zr	30K	30K
^{95}Zr	30K	30K
^{97}Zr	30K	30K

(a) As defined in 10 CFR 73 but special form is considered to be nondisposable by virtue of monolithic form or high integrity encapsulation.

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