APPENDIX F
TRANSPORTATION RISK ANALYSIS

F.1 INTRODUCTION

Following in this appendix are more detailed descriptions of the transportation risk analysis methodology and results that are summarized in the main volume of the SWEIS.

Section F.2 includes a description of the types of radioactive material (RAM) packaging required by the regulations of the U.S. Department of Transportation (DOT), the U.S. Nuclear Regulatory Commission (NRC), and DOE, and examples of how packaging is used at LANL. Containers for hazardous materials (HAZMAT) are also described in section F.2. Risk measures are described in section F.3.

The methodology for quantifying the risk measures is described in section F.4. The methodology incorporates truck accident data with an emphasis on routes between Interstate 25 (I–25) and the LANL site; a computer program to determine routes, mileages, and associated population densities; and other computer codes to quantify incident-free exposures and accident doses.

The methodology for determining the numbers and types of shipments for the baseline and the identified SWEIS alternatives (No Action, Expanded Operations, Reduced Operations, and Greener) is described in section F.5.

The risk analysis results are presented in section F.6 for the base case and in section F.7 for the Santa Fe relief route case. To aid in understanding and interpreting the results, specific areas of uncertainty are described in section F.8, with emphasis on how the uncertainties may affect comparison of SWEIS alternatives.

F.1.1 Purpose of the Analysis

Although in DOT regulations (49 CFR 171.8) RAM is a subset of HAZMAT, for this transportation analysis they are addressed separately. The purpose of the transportation risk analysis is to address the human health risks arising from the transport of HAZMAT and RAM associated with the operation of LANL. The human health risks associated with truck traffic arise from exposure to the truck exhaust and the possibility of an accident that could produce injuries or fatalities. These two health risks are independent of the truck cargo and exist for similar shipments of any commodity.

The human health risks associated with the radioactive or hazardous cargo result from the possibility of release of the cargo in an accident. In addition, the radioactive cargo produces a radiation field external to the packaging even for normal conditions. Persons exposed to the external field receive a small level of radiation, referred to as incident-free exposure.

These health risks are characterized in terms of four risk measures: truck-related emissions, which could cause fatalities from latent cancer; fatalities and injuries due to collisions with heavy trucks; incident-free exposures to radiation, which could cause fatalities from latent cancer; and accidental releases of the radioactive or hazardous cargo, which could cause immediate or latent fatalities. These risk measures are described in section F.3, and the methodology used to quantify them is described in section F.4 of this appendix.

F.1.2 Scope of the Analysis

The scope of the analysis includes the transport of RAM or HAZMAT on public roads within the LANL site and off-site shipments of materials by truck or air. Air shipments begin and end with a truck shipment. Rail transport is not addressed in this analysis, because there is no rail service to LANL. The risks to workers or to the public from loading or unloading trucks prior to or after shipment are considered part of normal facility operations and are not addressed as part of the transportation analysis (these are addressed in the analysis of worker health risks due to radiation exposure in sections 5.2.6, 5.3.6, 5.4.6, and 5.5.6); however, handling during shipment is included. Shipments while public roads are temporarily closed are also included in this analysis.

The methods and assumptions described in this appendix were selected to ensure meaningful comparisons among the SWEIS alternatives. A number of generic assumptions appropriate to the overview nature of the SWEIS were made. For example, because a detailed analysis of every type of LANL shipment would be impractical, shipments representative of classes of materials were selected as described in section F.5. Three examples of material class are bulk solid RAM, liquid RAM, and flammable materials. Also, because the different packaging used for RAM are too numerous to analyze individually to determine how severe an accident must be to cause a release, all packaging meeting the same regulatory criteria are assumed to fail at the same accident force magnitude (and hence probability). These parameters are described in subsection F.4.4.

In DOT regulations on the transportation of RAM, packaging is defined in 49 CFR 173.403 as:

> ...the assembly of components necessary to ensure compliance with the packaging requirements of this subpart. It may consist of one or more receptacles, absorbent materials, spacing structures, thermal insulation, radiation shielding, and devices for cooling or absorbing mechanical shock.

A package is defined as "the packaging together with its radioactive contents as presented for transport."

The general rule used in this appendix is that all assumptions should be conservative enough to ensure that the results do not underestimate the level of transportation risk, but not so conservative that the risk calculation is knowingly orders of magnitude too conservative or the differences between alternatives are obscured.

The focus of the transportation accident analysis is on bounding accidents; i.e., the most severe, reasonably foreseeable accidents (DOE 1994a). Transportation accidents that may occur often but that do not involve major consequences are not addressed.

F.2 PACKAGING OVERVIEW

DOT is the lead federal agency for establishing and enforcing regulations regarding safe transportation of HAZMAT and RAM. Procedures to ensure safe packaging for HAZMAT and RAM include categorizing the material and requiring the use of a packaging or container appropriate to the category. In the case of RAM, the categorization is by form, quantity, and concentration of RAM. The premise underlying packaging design for most HAZMAT and RAM is that the packages must maintain their integrity in the normal transportation environment, which includes minor accidents. An exception is that highly RAM and their packaging must survive severe accident conditions without a dangerous release of contents. Because packaging represents the primary barrier between HAZMAT and RAM being transported and exposure of the public and the environment, the regulatory approach for ensuring safety is to specify standards for the packaging of HAZMAT and RAM. These packaging requirements are an important consideration for the transportation risk assessment, and typical packaging used at LANL are described in this section. Packaging and vehicles used for RAM are described first; then chlorine cylinders, propane cargo tanks, and explosives packaging are described.

DOT sets design and performance specifications for packaging that will carry up to Type A quantities of RAM. Under an agreement with DOT, NRC sets the standards for packages of Type A and Type B quantities of RAM (subsections F.2.3 and F.2.4). DOE meets NRC's standards for certain packages and follows DOT's regulations for shipping and packaging or provides equivalent protection for its shipments. Examples of general RAM packages are shown in Figure F.2–1.

F.2.1 Limited Quantity Packaging

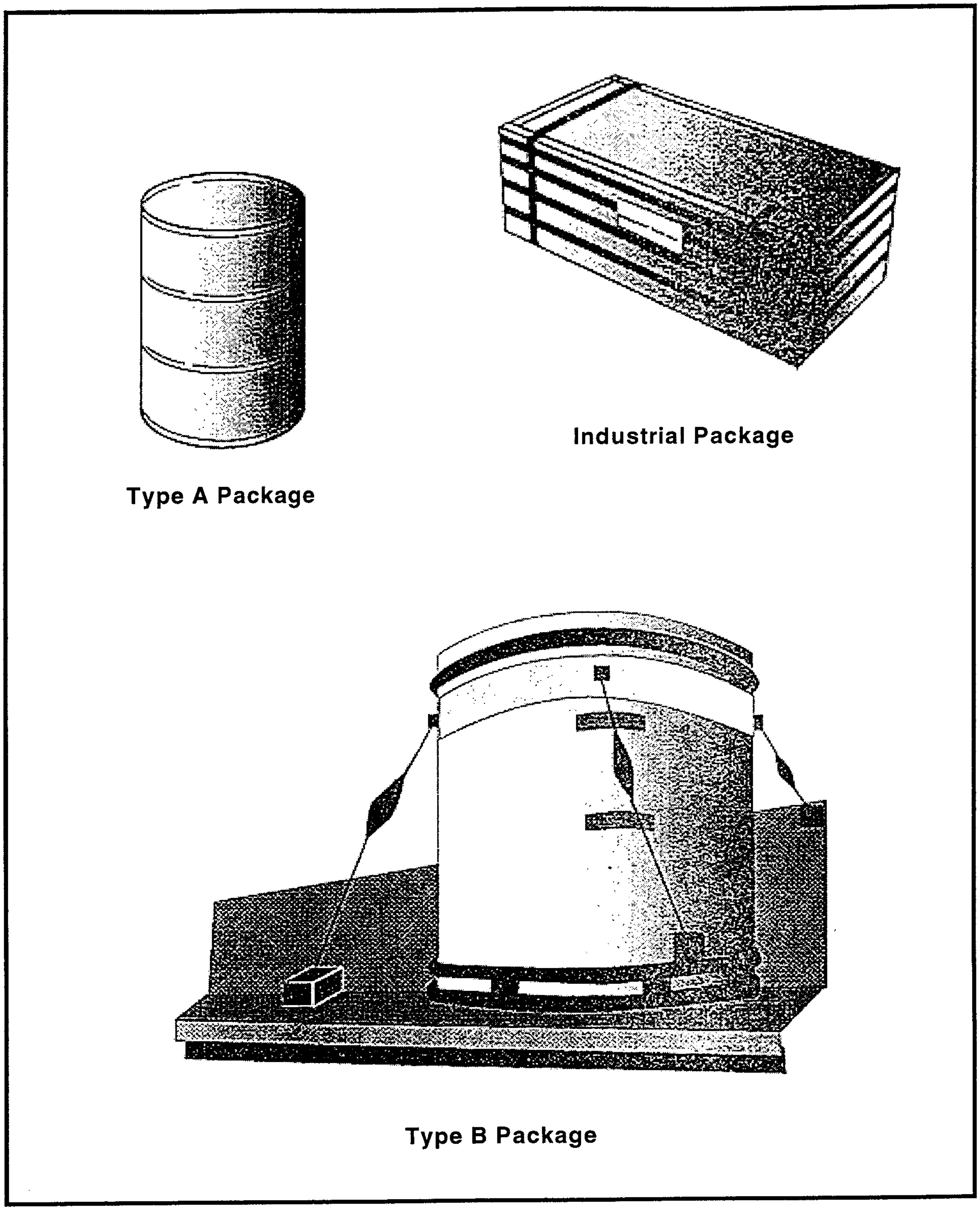
Limited quantities are very small amounts of radioisotopes such as amounts found in smoke detectors, lantern mantles, watches, signs, and measuring devices. The level of radioactivity listed in 49 CFR 173.425 is so low that materials containing that level can be shipped without special packages, shipping papers, markings, and labeling requirements. The materials are packaged in accordance with the general design requirements of 49 CFR 173.410. Such packages must be designed for ease of handling and proper restraint during shipment. They must be free of protuberances, easily decontaminated, and capable of withstanding the effects of vibration during transport. All valves, through which the package contents could escape, must be protected (60 Federal Register [FR] [188] 50297).

F.2.2 Industrial Packaging

Industrial packaging (IP) are authorized as packaging for low-specific-activity (LSA) materials and surface-contaminated objects (SCOs). LSA materials are naturally occurring ores, concentrates, and other materials in which the activity is essentially uniformly distributed at low levels. In contrast, materials classified as SCO are not inherently radioactive; rather, they are objects with radioactive contamination on their surfaces, also at very low levels of activity. At a minimum, each IP must meet the general design requirements of 49 CFR 173.410: it must be designed for ease of handling and proper restraint during shipment; it must be free of protuberances, easily decontaminated, and capable of withstanding the effects of vibration during transport; and valves, through which the contents could escape, must be protected. These are the only requirements that apply to IP Type 1 (IP–1) (60 FR [188] 50297).

IP Type 2 (IP–2) must also survive the Type A free drop and stacking tests. Each IP Type 3 (IP–3) must meet the requirements for IP–1 and IP–2 and the following Type A package requirements (DOT 1995b):

- A seal must be incorporated on the outside of the packaging.
- Temperatures must be within a specified range.
- A containment system that is securely closed by a positive fastening device must be included.
- Any radiolytic decomposition of materials and generation of gas by chemical reaction and radiolysis must be taken into account.
- Radioactive contents must be retained under reduced pressure.
- Each valve (except a pressure-relief device) must have an enclosure to retain any leakage.
- Shielding must remain in place to protect the packaging components.
- The failure of any tie-down attachment must not impair the ability of the package to meet other requirements.
- No loss or dispersal of the radioactive contents or any significant increase in the



SOURCE: DOE 1996a

FIGURE F.2–1.—*Examples of Packaging Types.*

radiation levels at the external surfaces must occur when the IP–3 is evaluated against Type A packaging tests.

Solid depleted uranium is packaged in Type IP–1 packaging. Water with tritium concentrations up to 75.7 curies per gallon (20 curies per liter) is packaged in Type IP–2 packaging for exclusive-use shipments and Type IP–3 packaging for nonexclusive-use shipments. An exclusive-use shipment is one that is for the sole use of the consignor or consignee. SCOs such as decontamination and decommissioning wastes are packaged in Type IP–1 if the fixed alpha contamination is up to 6.45×10^{-7} curies per square inch (10^{-7} curies per square centimeter) and Type IP–2 if the fixed alpha contamination is up to 1.3×10^{-5} curies per square inch (2×10^{-6} curies per square centimeter) (60 FR [188] 50297).

F.2.3 Type A

Type A packaging are used for RAM with specific activities up to limits specified in the regulations. Type A packages must contain RAM under normal transportation conditions and must maintain sufficient shielding to limit exposure of handling personnel. Normal transportation refers to all transportation conditions except those resulting from major accidents or sabotage. Type A packages are generally steel drums or boxes made of steel, wood, or strong fiberboard (see Figure F.2.3–1 for an example of a Type A package). The packaging, with contents, must be capable of withstanding a series of tests (49 CFR 173.465) including: water spray, free drop (as high as 4 feet [1.2 meters], depending upon mass), compression, and penetration.

F.2.4 Type B

Type B containers are very durable packages used to contain and shield more hazardous amounts and forms of RAM than those contained in Type A packages. Type B packages are used to transport materials such as spent fuel and high-level radioactive waste that would present a radiation hazard to the public or the environment if a major release occurred. Type B packages must provide protection under both normal conditions of transport and severe accidents. The certified design and construction methods for Type B packages ensure the production of systems that will contain the packaged radioactive contents even after a series of rigorous accident tests. The tests for hypothetical accident conditions specified in 10 CFR 71.73 include free drop (30 feet [9 meters]), crush, puncture, thermal (exposure to 1,475°F [802°C] for 30 minutes), and immersion. The size of Type B packages can range from 40 pounds (18 kilograms) to over 100 tons (91 metric tons). Examples of Type B packages are presented in the following subsections.

F.2.4.1 *FL-Type Container*

The FL-Type container is currently the only certified container used for pit transport. It is a DOT Type B package with a 16-gage stainless steel outer containment drum surrounding a 12-gage stainless steel inner containment drum (Figure F.2.4.1–1). Fiberboard insulation is present between the inner and outer containment drums. Both the internal and external containment drums are constructed of stainless steel. The inner containment vessel is sealed with dual concentric silicone O-rings (DOE 1996c).

F.2.4.2 *Transuranic Packaging Transporter for Contact-Handled Transuranic Waste*

Contact-handled (CH) transuranic (TRU) waste is contaminated with man-made RAM with atomic numbers greater than uranium, such as plutonium, americium, and curium, which primarily emit alpha radiation. Because this type of radiation cannot penetrate human skin,

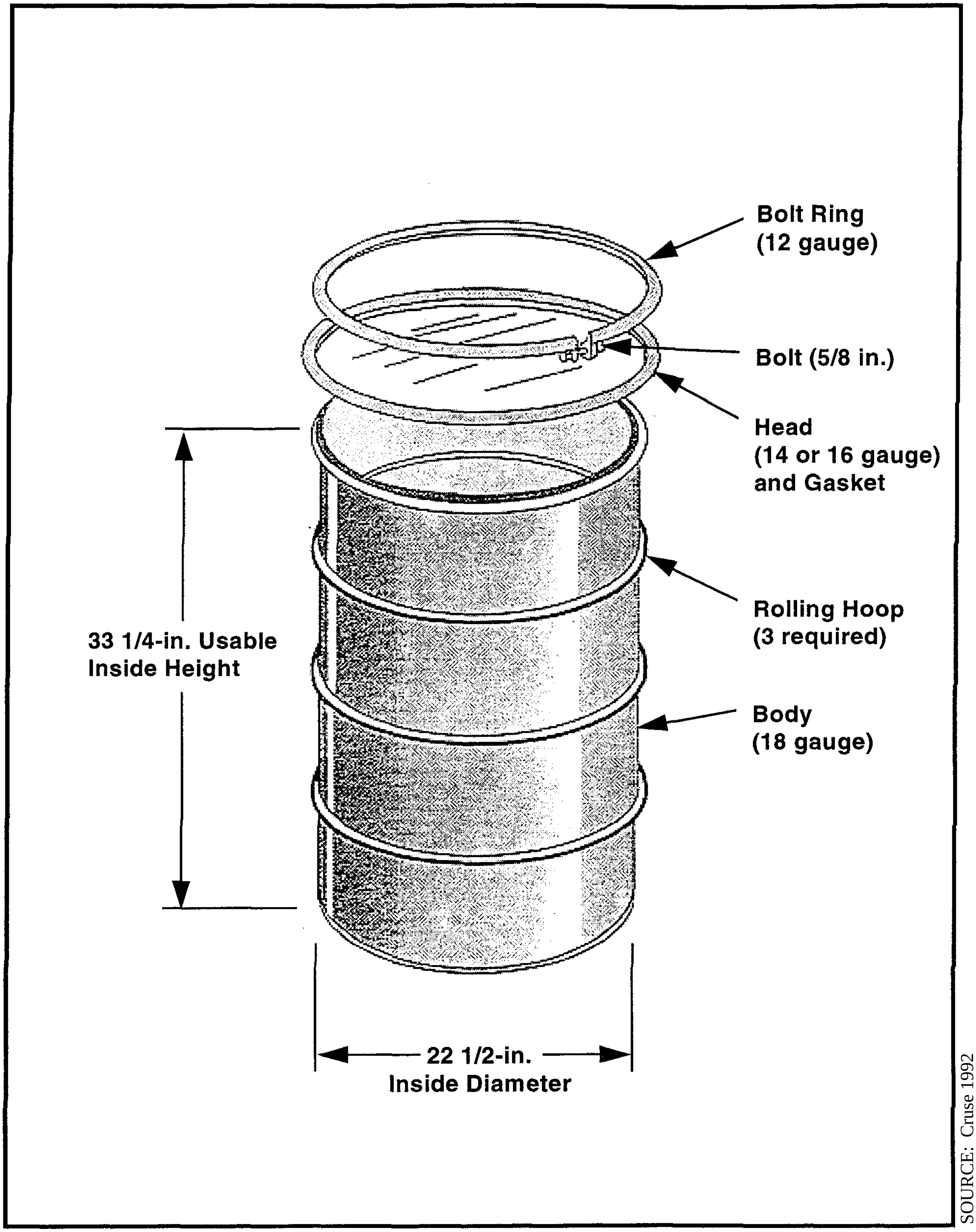


FIGURE F.2.3–1.—*Type A DOT–17H 55-Gallon (208-Liter) Steel Drum.*

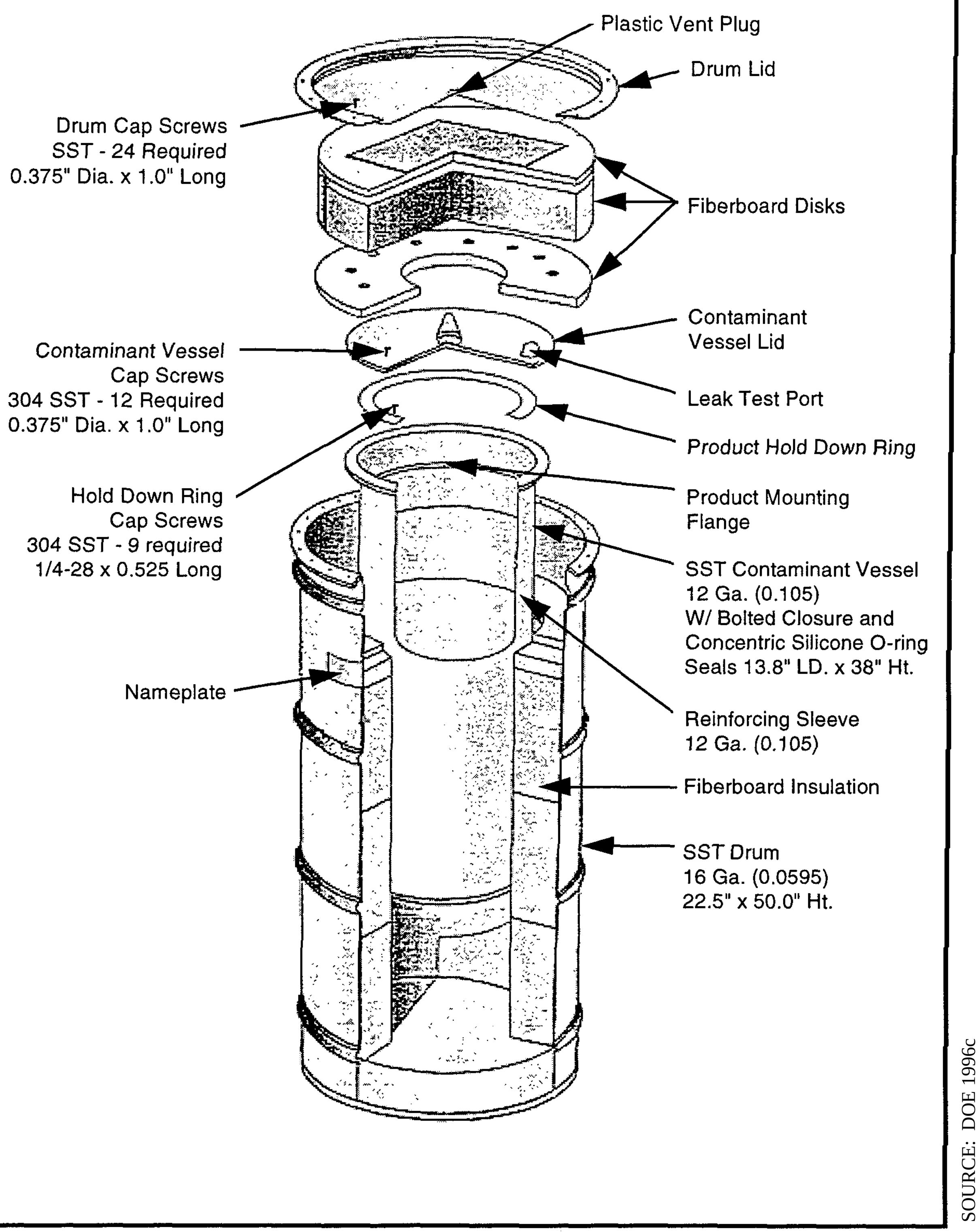


FIGURE F.2.4.1–1.—*Cross Section of an FL-Type Container.*

CH TRU waste is a hazard only if inhaled or ingested. The waste includes such materials as laboratory clothing, tools, glove boxes, plastic, rubber gloves, wood, metals, glassware, and solidified wastewater sludges contaminated with TRU materials. All CH TRU waste will be transported to the Waste Isolation Pilot Plant (WIPP) in the Transuranic Packaging Transporter (TRUPACT-II), a reusable shipping packaging. NRC certified this Type B package according to 10 CFR 71. As part of the certification process, full-scale TRUPACT-II prototypes were subjected to actual drop and fire tests to prove their ability to survive severe accident conditions.

The TRUPACT-II is a cylindrical metal container with a flat bottom and a domed top that is transported in an upright position (Figure F.2.4.2–1). Multi-layered wall design increases the package strength and provides the ability to withstand potential transportation incidents. The CH waste will be sealed in 55-gallon (208-liter) steel drums or waste boxes. Each TRUPACT-II can hold up to fourteen 55-gallon (208-liter) steel drums, or two standard waste boxes (WGA and DOE 1995).

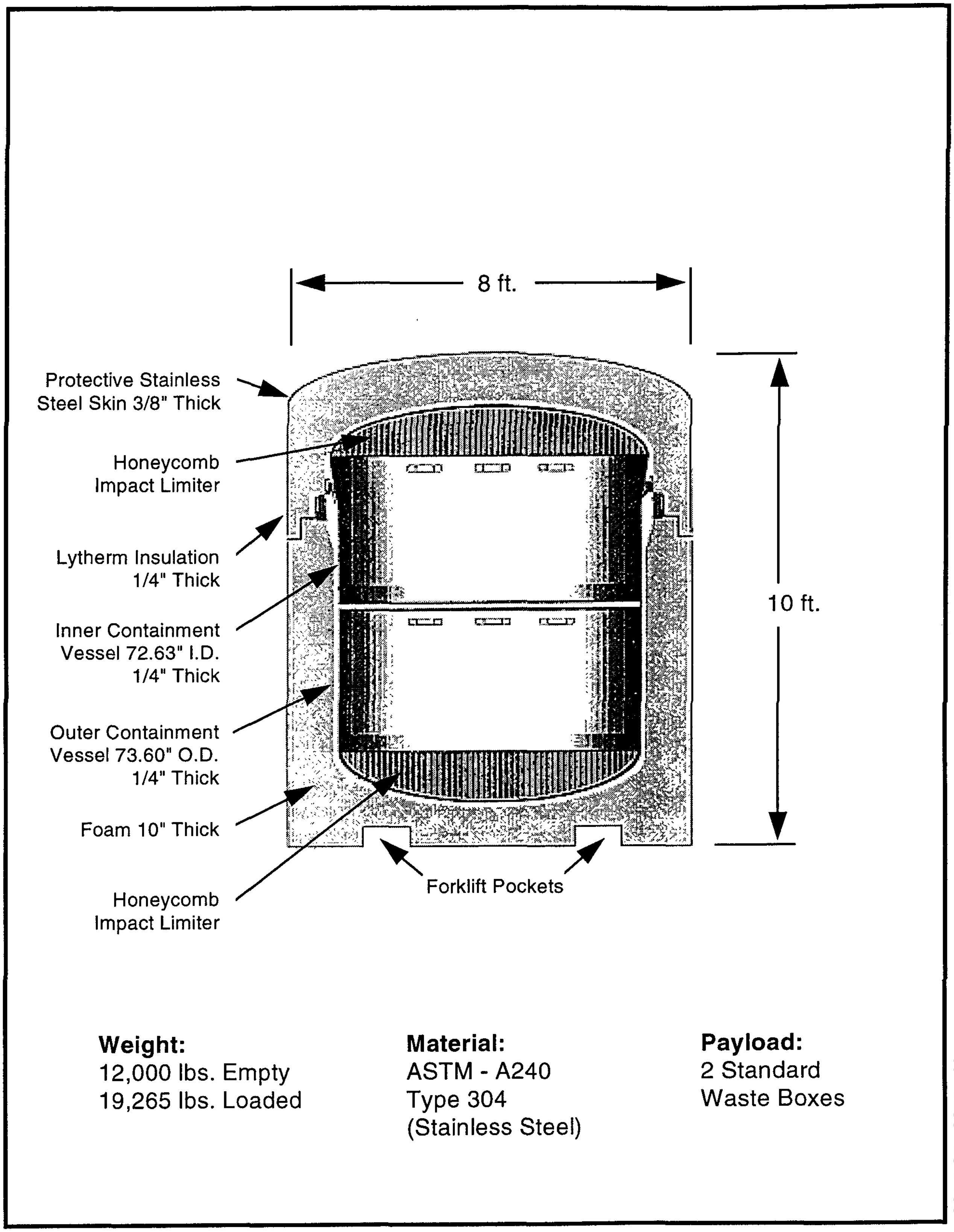
F.2.4.3 *UC–609 for Tritium*

The UC–609 package consists of a containment vessel centered by fiberboard insulation inside a 100-gallon (379-liter) drum (Figure F.2.4.3–1). The tritium contents are carried in a storage vessel inside the containment vessel. The package gross weight is 500 pounds (227 kilograms). The drum is fabricated of 14-gage Type 304 stainless steel. The Type 316 stainless steel containment vessel is 18 inches (45 centimeters) in diameter and 44 inches (112 centimeters) long and is rated for service at 110 pounds per square inch (6.36 kilograms per square centimeter), gage (psig) at 293°F (145°C). To protect the storage vessel from the effects of an accident, the annular space between the storage vessel and the containment vessel wall is filled with aluminum honeycomb to absorb impact.

The allowable contents of the UC–609 is tritium in any form (except activated luminous paint) contained in a storage vessel. The maximum quantity of RAM per package is not more than 5.3 ounces (150 grams) of tritium with the decay heat not to exceed 48 watts. The oxygen content must be less than 5 percent by volume of the gas in the containment vessel. The maximum internal pressure of the containment vessel must not exceed 110 psig at 293°F (145°C) (Wangler 1995).

F.2.4.4 *DOT–6M*

The DOT–6M container is a metal packaging conforming to DOT Specification 6M (49 CFR 178.354). The sizes and payloads of DOT–6M containers vary. The rated capacity is not less than 10 gallons (38 liters) and no more than 110 gallons (416 liters) for the outer steel drum. The capacity of the inner containment vessel is not less than 0.33 gallon (1.24 liters). The inner containment vessel must conform to specification 2R or equivalent, with a maximum usable inside diameter of 5.25 inches (13.33 centimeters), a minimum usable inside diameter of 4 inches (10 centimeters), and a minimum height of 6 inches (15 centimeters). The inner containment vessel must be fixed within the outer shell by machined disks and rings made of solid industrial cane fiberboard, hardwood, or plywood. DOT Specification 6M metal packaging is used only for solid or gaseous RAM that will not undergo pressure-generating decomposition at temperatures up to 250°F (121°C) and that do not generate more than 10 watts of radioactive decay heat (49 CFR 173.416). A 55-gallon (208-liter) 6M packaging is shown in Figure F.2.4.4–1.



SOURCE: SSEB 1994

FIGURE F.2.4.2–1.—*TRUPACT-II.*

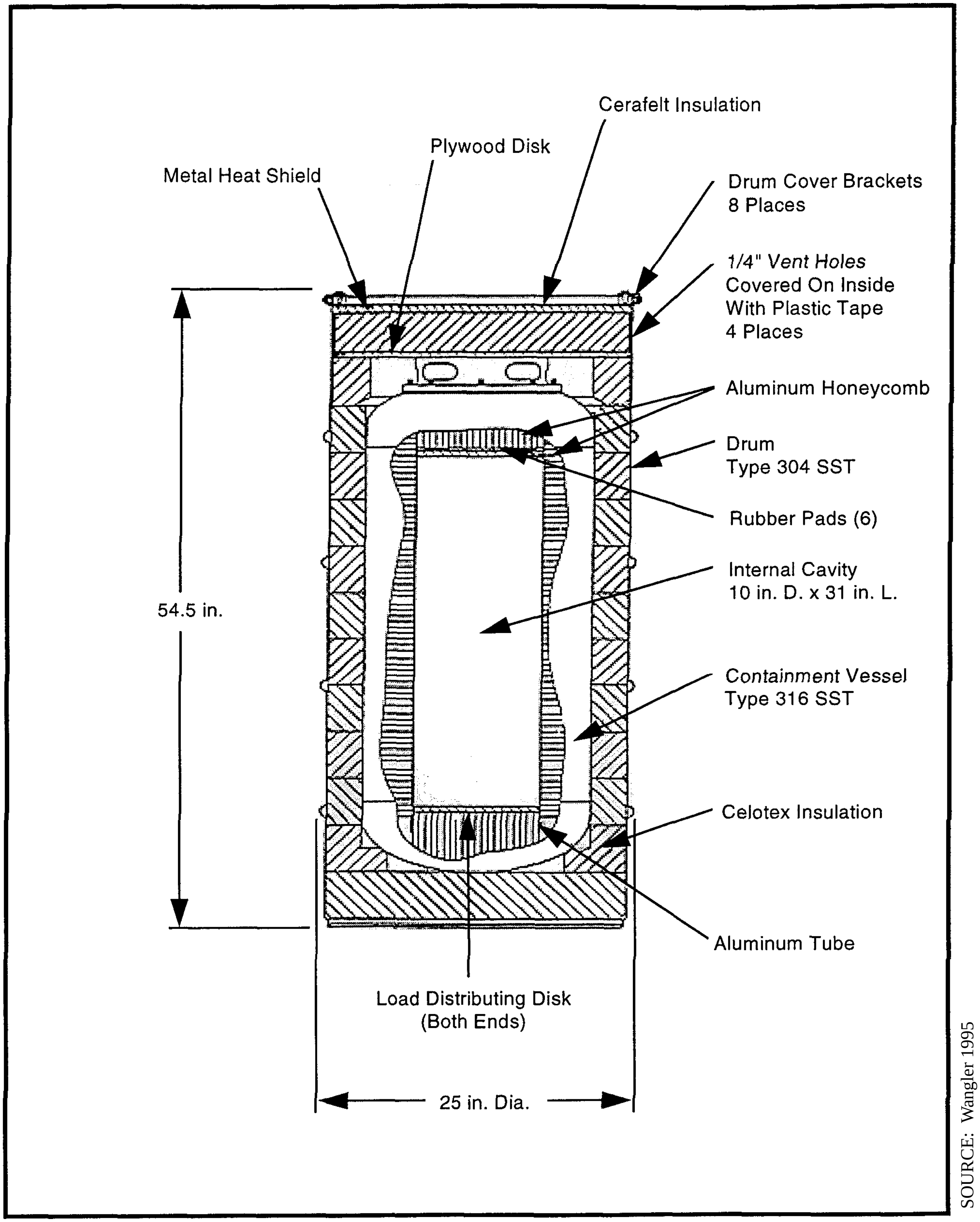
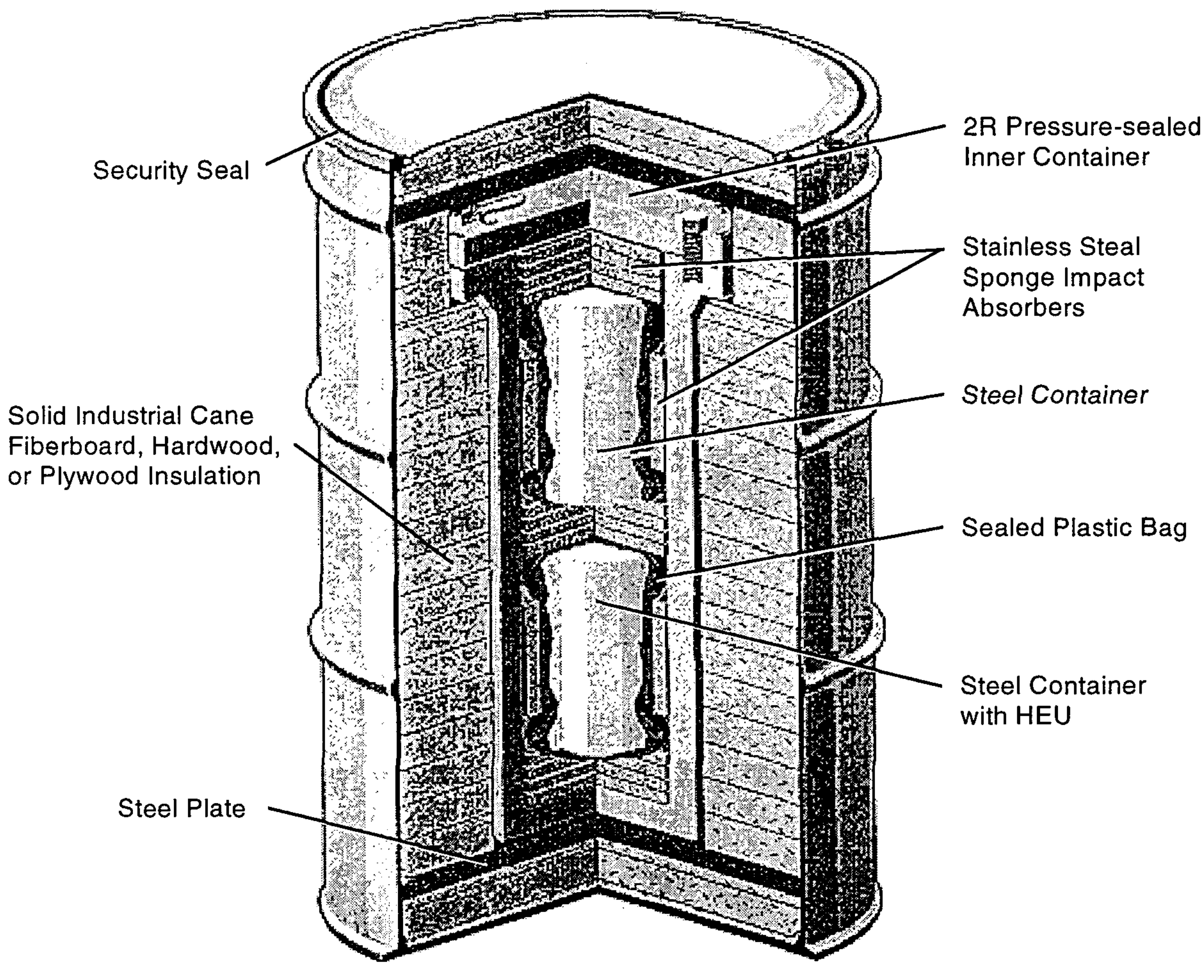


FIGURE F.2.4.3–1.—*Model No. UC–609 Shipping Package.*



SOURCE: DOE 1996b

FIGURE F.2.4.4–1.—*55-Gallon (208-Liter) 6M Packaging.*

F.2.4.5 *5320 for Plutonium Oxide and Americium Oxide*

The basic arrangement of the 5320 shipping cask is an upright cylinder with a domed top (see Figure F.2.4.5–1). The weight of the cask is about 327 pounds (149 kilograms), the overall height is 32 inches (81.3 centimeters), and the diameter is 16.75 inches (42.55 centimeters). The cask cavity has a length of 17.5 inches (44.5 centimeters) and a diameter of 1.73 inches (4.39 centimeters). The nested primary and secondary containment vessels are surrounded by a finned aluminum shield tank filled with water-filled polyester. The containers are retained within the central sleeve of the shield tank by a bolt that holds the bottom of the secondary container against the baseplate. Heat from the package contents is conducted to the outer shell of the shield tank by radial aluminum plates that connect the central sleeve to the outer shell. Axial fins on the outer shell dissipate the heat to the environment. An expanded metal screen encloses and protects the fins. The screen also excludes personnel contact during handling operations.

A thermal shield protects the lid, flanges, flange bolts, and seals of the secondary container during thermal accident conditions. A “top hat” style impact limiter protects all of these components during impact accidents.

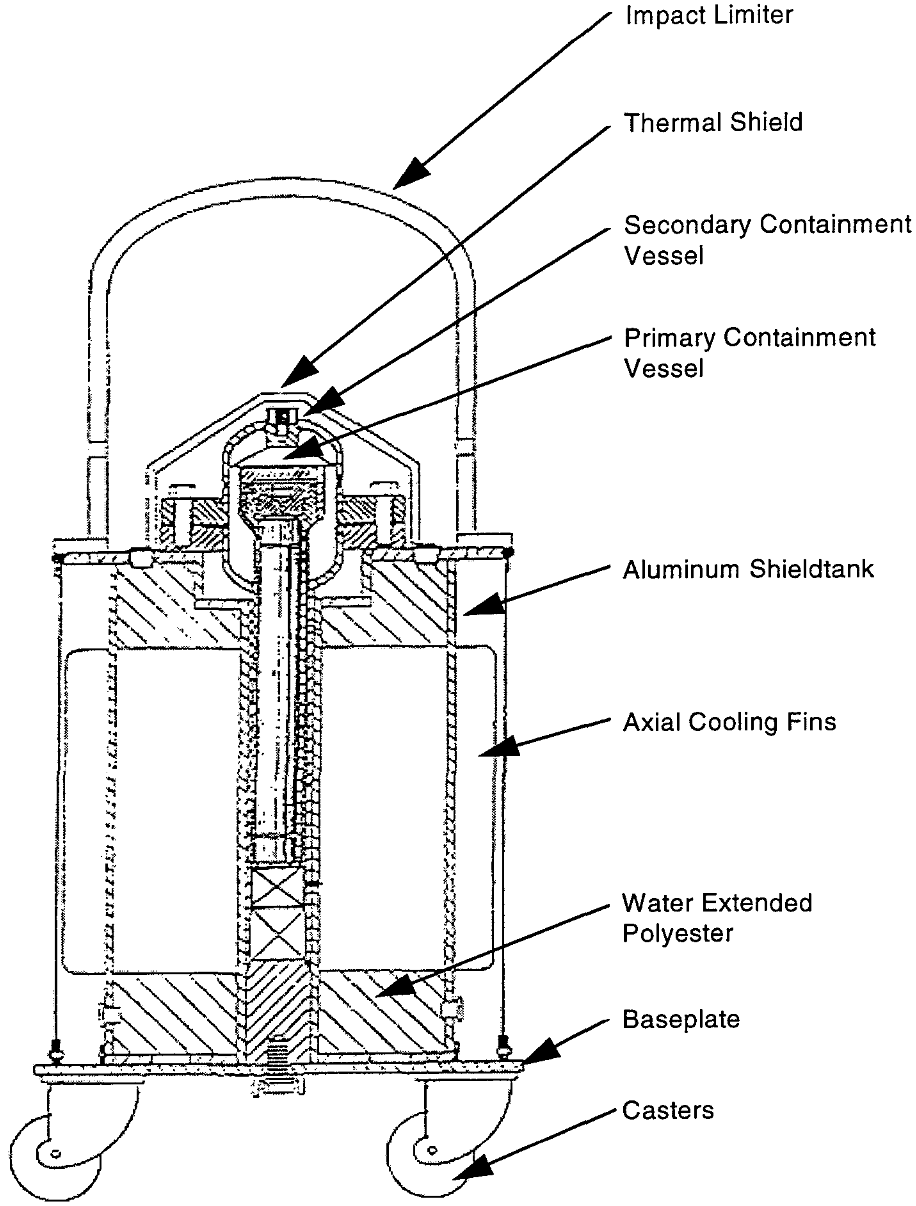
Secondary containment is provided by the EP–62, which is a cylindrical pressure vessel fabricated from Type 304 stainless steel. Primary containment is provided by the EP–61, which is a Type 316 stainless steel pressure vessel with a threaded plug and cap. The containment seal is provided by seal welding the cap to the body. The EP–61 is certified as a one-time-use container. It is opened by removing the welded cap, thus exposing the threaded plug. Energy absorbers are used to center the primary containment vessel inside the secondary containment vessel.

The americium and plutonium products placed inside handling or product canisters are contained in the primary containment vessel. Possible contents include plutonium oxide and its daughter products or americium oxide in any solid form such as granules, scrap, pellets, or powder. The maximum quantity allowed is 12.6 ounces (357 grams) of plutonium of any isotopic composition or 6.2 ounces (176 grams) of americium. The maximum permissible decay heat is 203 watts (Wangler 1996).

F.2.4.6 *Model 72–B for Remote-Handled Transuranic Waste*

Packaging for remote-handled (RH) TRU waste, which produces penetrating gamma radiation, is now going through the certification process. Compliance with the NRC requirements for Type B packaging has to be demonstrated for the 72–B cask by analysis or by combination of analysis and testing. The 72–B cask is a scaled-down version of the 125–B package, which has been certified by the NRC as a Type B package.

The 72–B (Figure F.2.4.6–1) consists of two concentric stainless steel containment vessels protected by impact limiters at each end. A 2-inch (5-centimeter) lead liner between the inner and outer containment vessels provides shielding against gamma radiation. Neither containment vessel is vented, and each is capable of withstanding an internal pressure of 150 psig. The capacity of the 72–B cask is 8,000 pounds (3,632 kilograms) of payload. The payload consists of RH TRU waste packed in 30- or 55-gallon (114- or 208-liter) drums, which are contained in a carbon steel canister. A shipment of RH TRU waste will involve only one 72–B cask, loaded onto a custom-designed trailer, for truck transport to WIPP (SSEB 1994).



SOURCE: Wangler 1996

FIGURE F.2.4.5–1.—*5320 Plutonium Oxide and Americium Oxide Shipping Cask.*

SOURCE: DOE 1990

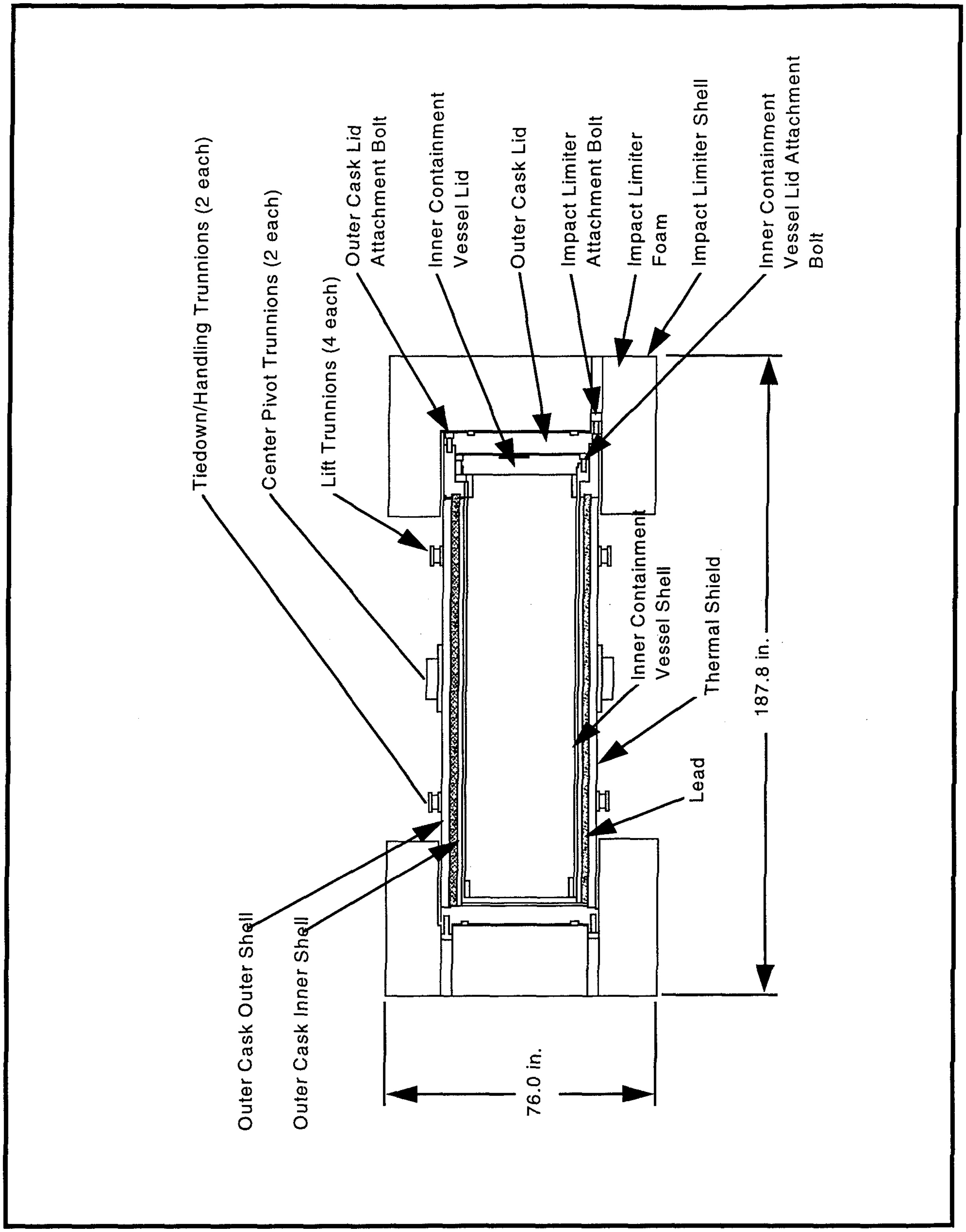


FIGURE F.2.4.6–1.—*Cross Section of Model 72–B Cask.*

F.2.5 Safe Secure Trailers

DOE maintains and operates a special fleet of trucks and trailers used to transport, in a safe and secure manner, SNM, classified configurations of nuclear weapons systems, and other forms and quantities of strategic materials between U.S. Department of Defense (DoD) sites and DOE production sites, laboratories, and test sites. DOE Albuquerque Operations Office, Transportation Safeguards Division, is responsible for the operation and maintenance of safe secure transport (SST) trailers and supporting vehicles. Because DOE exclusively operates and maintains the SST network, DOE is responsible for evaluating and approving the safe and secure use of the SSTs, both within DOE sites and between sites.

An SST trailer is a modified standard closed semi-trailer that includes necessary cargo tie-down equipment and temperature monitoring, fire alarm, and access denial systems. It is essentially a mobile vault that is highly resistant to unauthorized entry and provides a high degree of cargo protection under accident conditions. The SST trailer is pulled by an armored, penetration-resistant tractor.

SST trailers are accompanied by armed couriers in escort vehicles equipped with communications and electronics systems, radiological monitoring equipment, and other equipment to enhance safety and security. The escort vehicles must meet maintenance standards significantly more stringent than those for similar commercial transport equipment. All vehicles undergo an extensive maintenance check prior to every trip, as well as periodic preventive maintenance inspections. In addition, these vehicles are replaced more frequently than the vehicles used by commercial shippers. Every effort is made to ensure that the convoys do not travel during periods of inclement weather. Should the convoys encounter adverse weather, provisions exist for the convoys to seek secure shelter at previously identified facilities (DOE 1996a).

F.2.6 1-Ton Chlorine Containers

Chlorine is categorized as a Division 2.3 material by DOT. This division is composed of gases that are considered poisonous when inhaled (49 CFR 173.115[c]).

Regulations allow transport of chlorine by rail tank car, tank truck, 1-ton (908-kilogram) container, and gas cylinder. Only 1-ton (908-kilogram) containers and smaller gas cylinders have been used at LANL. (One-ton cylinders are no longer used at LANL as they once were; this type of container is retained for analysis because one cannot preclude their future use.) DOT specification classes for the 1-ton (908-kilogram) container are 106A and 110A. The typical chlorine 1-ton (908-kilogram) container is 81.5 inches (207 centimeters) long with an outside diameter of 30.1 inches (76.5 centimeters). The minimum actual wall thickness is usually 0.4375 inch (1.1 centimeters) (the regulatory minimum is 0.406 inch [1.0 centimeter]). The ends of the cylinder are recessed to protect valves, which are also covered by a protective bonnet. Fusible plugs in both ends are designed to open if the temperature exceeds 155°F (68°C). The capacity is 2,000 pounds (908 kilograms) of chlorine.

F.2.7 Liquid Propane Cargo Tank

Liquid propane is transported by rail tank car, tank truck, and cargo tank. The cargo tank is used primarily for local deliveries and will transport up to 2,500 gallons (9,463 liters) of liquid propane. Deliveries to LANL are by cargo truck and are usually in 2,000-gallon (7,570-liter) increments. The cargo tank is 15 feet (4.6 meters) long and 6 feet (1.8 meters) in diameter. Its walls are 0.394 inch (1.0 centimeter) thick. The tank is permanently mounted on a 14-ton (12,712-kilogram) truck body. Valves and piping are located at the rear of the truck. The tank pressure of 250 psi keeps the propane in a liquid state.

F.2.8 Explosives

Explosives are classified as Divisions 1.1 through 1.6 materials:

- *Division 1.1*—Materials that present a mass explosion hazard.
- *Division 1.2*—Materials that present a projection hazard, but not a mass explosion hazard.
- *Division 1.3*—Materials that present a fire hazard and a minor blast or project hazard (or both), but not a mass explosion hazard.
- *Division 1.4*—Materials that present minor explosion hazard.
- *Division 1.5*—Materials that present a mass explosion hazard, but that are also considered insensitive in terms of initiation of explosion.
- *Division 1.6*—Materials that are considered extremely insensitive and do not present a mass explosion hazard.

In the past, shipments to and from LANL have included materials in Divisions 1.1, 1.2, and 1.4.

Typical packages transported to LANL contain 50 pounds (22.7 kilograms) of explosives in a No. 4 fiber carton with a 4-millimeter-thick polyethylene liner. Up to 36 cartons are stacked on a wooden pallet and restrained by stretch netting. Up to 38,800 pounds (17,615 kilograms) of explosives may be transported to LANL in a tractor trailer.

F.3 RISK MEASURES

In this section, basic risk concepts are presented, key features of the transportation quantitative risk analysis are discussed, and the four risk measures used in the transportation risk analysis are described. The transportation risk analysis methodology is illustrated in Figure F.3–1.

F.3.1 Risk Concepts

The terms hazard and risk are synonymous in everyday usage but are quite different in technical language. A hazard is the inherent characteristic of a material, condition, or activity that has the potential to cause harm to people, property, or the environment. A tank pressurized with air has the potential to cause harm to people from flying fragments that would result should the tank fail. An unpressurized tank filled with HAZMAT has the potential to cause harm because of the hazardous nature and quantity of material that could be released.

Risk is the combination of the likelihood and the consequence of a specified hazard becoming uncontrolled. The specified uncontrolled hazard is the result of an accident scenario. A scenario usually consists of a sequence of events. The events are sometimes shown graphically in an event tree (section F.4.5). Likelihood can be expressed as either a frequency or a probability. Frequency is the rate at which events occur (e.g., events per year, accidents per mile). The frequency component of risk often consists of the initiating event frequency multiplied by several conditional probability terms. A probability is a number between 0 and 1 that expresses a degree of belief concerning the possible occurrence of an event. In this appendix, the term probability usually reflects a conditional probability. A conditional probability is a probability for an event that has been preceded by one or more specified events. Consequence is the direct effect, usually undesirable, of the accident scenario. Consequences usually are measured in health effects but may be expressed as cost of property loss or the amount of HAZMAT released.

Risk often is defined as frequency times consequence. However, important information

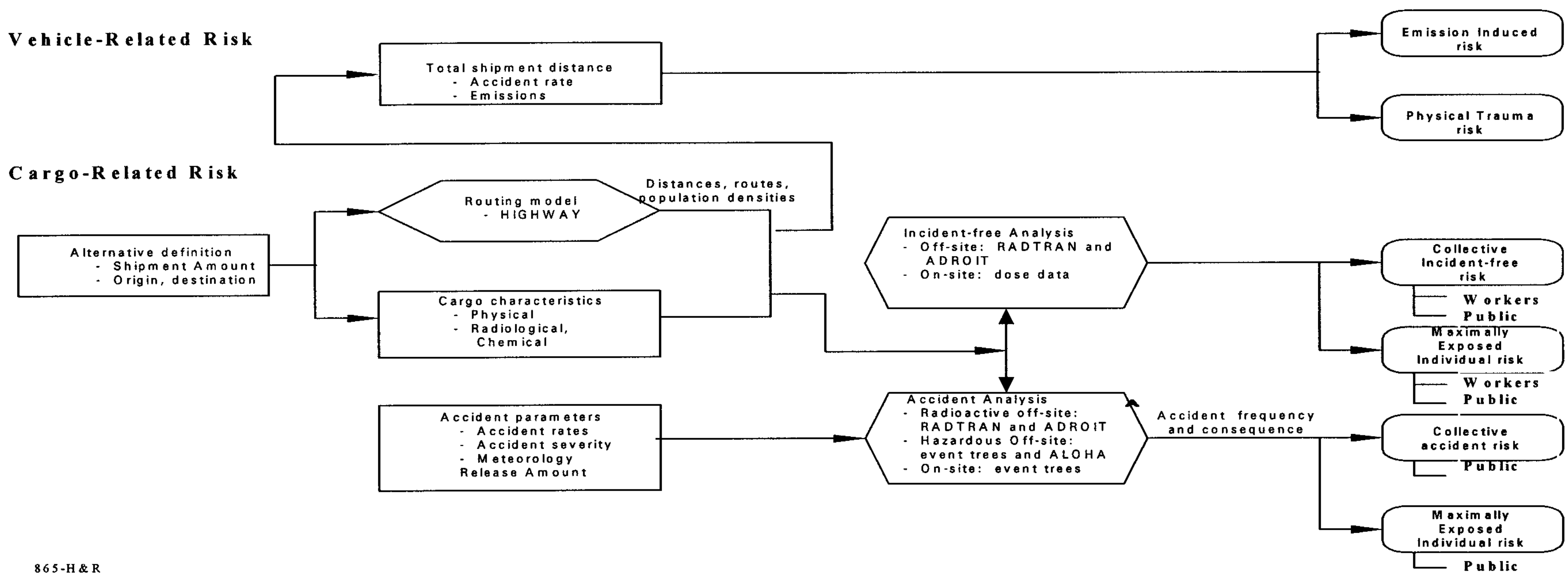


FIGURE F.3–1.—*Transportation Risk Analysis Methodology.*

may be lost when risk is expressed as the product of frequency and consequence. When frequency (or probability) is multiplied by consequence, an accident that is expected to cause one fatality and occur 10 times a year has the same mathematical risk as an accident that is expected to cause 1,000 fatalities and occur once every 100 years. Impact analysis results reported as risk values in sections F.6 and F.7 are the products of frequency and consequence to be consistent with the computer codes used to generate the results.

A quantitative risk analysis incorporates numerical estimates of the frequencies and the consequences in a sophisticated but approximate manner. In practice, few decisions require quantification of both frequency and consequence at equal levels of sophistication. Although risk assessment and risk analysis usually are used interchangeably, risk analysis is defined in the SWEIS as the computation of risks, whereas risk assessment is defined as the determination of risk acceptability. Taking action to mitigate risks is part of risk management.

F.3.2 Transportation Risk Key Parameters

A mathematical formulation specifically for transportation risk will illustrate the important parameters used in this appendix. The risk, R_i, for accident scenario *i* is a function of the scenario frequency, F_i, and the scenario consequence, C_i (Equation F-1).

$$R_i = f(F_i , C_i) \qquad \text{(F–1)}$$

The usual procedure for a quantitative transportation risk analysis is to divide the transport route into segments (also called links), along which the important parameters can be reasonably approximated by a single average value. A detailed expression for risk can then be formulated as follows (Equation F-2) (Rhyne 1994a):

$$R_i = f(F_{1a} \times M_a \times P_{2ab} \times P_{3abc} \times P_{4ad} \times P_{5ae} , N_{ad} \times A_{abc} \times X_{ace}) \qquad \text{(F–2)}$$

Where: F_{1a} = frequency of an accident per mile in transport link *a*, based, in the case of truck transport, primarily on highway type and conditions, vehicle type, and traffic conditions;

M_a = number of miles, or miles per year, in link *a*;

P_{2ab} = probability that the accident in link *a* results in accident forces of type *b* (e.g., mechanical or thermal forces);

P_{3abc} = probability that the magnitude of accident force type *b* in link *a* exceeds the container's capability to resist the force and causes release class *c* to occur;

P_{4ad} = probability that population distribution class *d* occurs in link *a*;

P_{5ae} = probability that meteorological condition *e* occurs in link *a*;

N_{ad} = number of persons per unit area in population class *d* in link *a*;

A_{abc} = release amount for release class *c*, given that force type *b* occurs in link *a*; and

X_{ace} = area that experiences the specified health effects from a unit release of the hazardous material for meteorological condition *e* for release class *c*.

The overall risk is obtained by summing all scenarios for each link or for the entire route (Equation F-3).

$$R = \sum Ri \qquad \text{(F–3)}$$

The risk expression (Equation F-2) shows that risk is directly proportional to nine parameters, the quantification of which is described in section F.4 of this appendix. The key parameters affecting the frequency term are accident rate (subsection F.4.2), mileage (subsection F.4.3), and accident severity and package release probabilities (subsection F.4.4.2). The key parameters affecting the consequence term are population density (subsection F.4.3), release amount (subsection F.4.4.3), and meteorological conditions.

Two of the parameters in Equation F-2 (specific population density and specific meteorology) are not mentioned in section F.4. These conditional probabilities are conservatively valued as 1.0 in this transportation risk analysis.

F.3.3 Truck-Related Risk Measures

Trucks carry cargo as varied as radioactive and HAZMAT, steel girders, and vegetables. Truck traffic on public highways presents two types of health risks independent of the nature of the cargo: the health effect of air pollutants, primarily the diesel fuel combustion products; and the injuries and fatalities caused by truck accidents.

F.3.3.1 *Truck Emissions*

Truck traffic produces air pollution from the diesel engine exhaust, fugitive dust generated by the vehicle wake on the highway surface dust, and particulates from tire wear on the paved surface. The primary health effect of diesel fuel combustion is caused by sulfur oxides and particulates, although nitrogen oxides and hydrocarbons are also produced. The health effect of these pollutants is increased sickness (morbidity) and death, generally occurring after a latency period of several years. The health effect has been evaluated by Rao, et al. (1982) as 1.0 x 10^{-7} fatalities per truck kilometer in urban areas. No analysis was made for morbidity because no data were available. The result is limited to urban areas because the available air pollution mortality data were limited to metropolitan population subgroups.

To evaluate this risk measure, the number of truck miles in urban areas (evaluated as described in subsection F.4.3) associated with RAM and HAZMAT shipments is multiplied by the health effect conversion factor described in the previous paragraph. Given truck travel in an urban area, the frequency of this consequence is 1; i.e., it is certain to occur.

F.3.3.2 *Truck Accident Injuries and Fatalities*

A truck accident can result in only minor property damage (fender bender) or major property damage, an injury to the truck driver or a member of the public, or a fatality. Saricks and Kvitek (1994) give state-by-state truck accident, fatality, and injury rates. The values used in the primary study area, in conjunction with the accident rates given in subsections F.4.2.2 and F.4.2.3, are 0.21 for the conditional probability of an injury in a truck accident, and 0.01 for the conditional probability of a fatality in a truck accident (DOT 1995a). To evaluate this risk, the appropriate truck accident rate (subsection F.4.2) is multiplied by the number of truck miles (subsection F.4.3).

F.3.4 Cargo-Related Risk Measures

The cargo-related health effects are a result of the intrinsic nature of the cargo; i.e., radioactive material and HAZMAT. HAZMAT presents no health risk unless the material is released in an accident. RAM can present a health risk caused by release in an accident as well as by the normally occurring (incident-free) low-level radiation field external to the packaging. The latter is referred to as incident-free risk.

F.3.4.1 *Incident-Free Risk Measure (Radioactive Materials Only)*

The doses to three groups of the public, truck and air crew members, and to the maximally exposed individual (MEI) are quantified separately for the SWEIS. Each of the dose calculations is based on parameters such as the number of shipments and the radiation level of the shipments. Either the RADTRAN or the ADROIT computer codes described in subsection F.4.4 is used to perform the calculations. The collective doses are expressed in person-rem, and the MEI dose is expressed in rem; the conversion from person-rem and rem to human health effects is described in subsection F.4.4.5. The dose calculations are described in the following subsections.

People Along the Truck Route

The dose each person would receive depends on his or her distance from the highway and the speed of the truck as it passed. The already low radiation level at the truck would drop off rapidly as distance from the truck increased. Also, the faster the truck passed, the less time there would be for people to be exposed. The collective doses are calculated for all people living or working within 0.5 mile (0.8 kilometer) on each side of the highway for each route considered.

People Sharing the Truck Route

People in vehicles traveling in the same or the opposite direction as the shipment, as well as people in vehicles passing the shipment, would have the potential for close exposure to the radiation level from the truck. The collective doses are calculated by considering traffic count and vehicle speeds for rural, suburban, and urban areas for each route considered.

People at Truck Stops

Typical truck shipments involve stops for meals, fuel, and rest or driver change. During these stops, the public in the vicinity of the truck would be exposed to a stationary source of radiation. A simple, conservative model is used to calculate the collective doses for each route considered.

Crew Members

Collective doses are calculated for truck and aircraft crew members as well as for handlers transferring the shipment from a truck to an aircraft and vice versa for each route considered. No air shipments from or to LANL use passenger aircraft.

Maximally Exposed Individual

A hypothetical MEI is assumed to live 98 feet (30 meters) from the highway, and all trucks are assumed to pass the MEI at a speed of approximately 15 miles per hour (24 kilometers per hour).

F.3.4.2 *Releases from Accidents*

Given a very severe transportation accident, packaging/containers for radioactive/HAZMAT could fail and release their contents. Except for some shipments with very high radiation levels, such as irradiated targets for production of medical isotopes, subsequent dispersion of the material into the atmosphere would be required to produce a significant exposure to members of the public. Either the RADTRAN or ADROIT computer code described in subsection F.4.4 is used to perform the calculations for RAM. The potential acute dose for an individual is expressed in rem, and the potential latent dose for collective population exposure is expressed in person-rem.

The effects of dispersing toxic materials are expressed as the number of persons who could be exposed to life-threatening or injury-producing concentrations. Detonation effects are expressed as the number of persons who could be killed as a result of a fireball or the number of severe burns that could result.

F.4 TRANSPORTATION RISK METHODOLOGY

F.4.1 Introduction and Overview

The analyses of both radioactive and HAZMAT risks are largely accomplished with standard computer codes; the computer code methodology is documented in more detail elsewhere and will not be repeated here. However, the standard parameters (also called the default values) used in the RADTRAN (Neuhauser and Kanipe 1995) code are presented in this section to ensure the repeatability of the results.

The first key parameter, truck and aircraft accident rates, is discussed in subsection F.4.2. State of New Mexico data are used to determine accident rates from the LANL site to I–25, and a standard state-by-state compilation is used for accident rates elsewhere. On-site truck accident rates and accident rates specific to the SST are presented. Aircraft accident rates are also described.

The second key parameter, truck mileage, is evaluated by using the HIGHWAY code (Johnson et al. 1993) as described in subsection F.4.3. The HIGHWAY code also produces population density values (a key parameter) based on 1990 census data as discussed in subsection F.4.3. State-by-state mileages are quantified by HIGHWAY in each of three population density categories: rural, suburban, and urban. The route between I–25 and Pojoaque and between Pojoaque and LANL is also subdivided by these population density categories.

The RADTRAN or ADROIT codes are used for incident-free dose calculations and for doses from accidents with RAM. An overview of the incident-free methodology and the specific input parameters is presented in subsection F.4.4, as is the accident calculation methodology. Event trees are used for defining HAZMAT and on-site RAM accident scenarios and determining their frequency. The ALOHA™ (NSC 1995) and DEGADIS (Havens and Spicer 1985) codes are used for chlorine accident dispersion calculations.

F.4.2 Accident Rates

Four sets of truck accident rates are used in the analysis: state-specific; route-specific, between I–25 and the LANL site; on-site roads with and without road closure; and the SST.

F.4.2.1 *State-Specific Truck Accident Rates*

Truck accident data for the years 1986, 1987, and 1988, from DOT Office of Motor Carriers, were divided by estimated truck miles data for the same years from DOT Federal Highway Administration (Saricks and Kvitek 1994). The average accident involvement rates for the U.S. and for the State of New Mexico are given in Table F.4.2.1–1. (Note that U.S. 285 to WIPP facility is a federal-aid primary highway.) Saricks and Kvitek point out that the New Mexico urban interstate computed value is more than two standard deviations greater than the national average and indicates decimal place errors in the New Mexico truck mileage data.

F.4.2.2 *Regional Truck Accident Rates*

Truck accident data for U.S. 84/285, NM 502, NM 4, and East Jemez Road were obtained from

TABLE F.4.2.1–1.—*Average Truck Accident Rates*

HIGHWAY TYPE	ACCIDENT RATE			
	ACCIDENTS PER KILOMETER		ACCIDENTS PER MILE	
	U.S.	NM	U.S.	NM
Urban Interstate	3.58×10^{-7}	9.64×10^{-7}	5.76×10^{-7}	1.55×10^{-6}
Rural Interstate	2.03×10^{-7}	1.92×10^{-7}	3.27×10^{-7}	3.09×10^{-7}
Federal-Aid Primary	3.94×10^{-7}	4.77×10^{-7}	6.34×10^{-7}	7.68×10^{-7}

Source: Saricks and Kvitek 1994.

the State of New Mexico (Fenner 1995 and Fenner 1996) for calendar years 1990 through 1994. Truck mileage data were obtained from the State of New Mexico (Vigil 1996) for the calendar years 1992 through 1994. The traffic count for East Jemez Road is assumed to be 65 percent of that on NM 4 on the basis of a different set of traffic counts (BAA 1993). The data and the computed accident rates are given in Table F.4.2.2–1.

Because no accidents occurred on NM 4, the East Jemez Road rate is used for conservatism. The truck accident rates in Table F.4.2.2–1 for primary highways are lower in low population areas and higher in high population areas than the corresponding values in Table F.4.2.1–1 for federal-aid primary highways in New Mexico. This difference is expected because the rate in Table F.4.2.1–1 is an average of rural, suburban, and urban areas.

F.4.2.3 *On-Site Truck Accident Rate*

In previous on-site transportation risk analyses at LANL, values from Harwood and Russell (1990) have been used for accident frequency. These values are the most widely used values for truck transport analysis. Their value for two-lane rural roads, 2.19×10^{-6} accidents per mile (1.36×10^{-6} accidents per kilometer) was considered representative for non-rush-hour traffic on the LANL site (Rhyne 1994b). (An urban rate of 8.66×10^{-6} accidents per mile would be appropriate for Diamond Drive and vicinity.) The representative value used here is a factor of two higher than values for NM 4 and East Jemez Road, but will be conservatively used in the SWEIS for on-site risk analyses. This analysis will also be consistent with the earlier risk analyses that are being incorporated into the SWEIS.

The rates in Tables F.4.2.1–1 and F.4.2.2–1 are averages for trucks traveling in all types of weather, day and night. However, trucking firms that strongly emphasize safety can achieve a factor of 10 reduction in accident rate (Anonymous 1994, Anonymous 1990, Wilson 1990, and OTA 1988). The emphasis on driver safety training and the vehicle maintenance program for RAM shipments on the LANL site are comparable to the safety programs at commercial trucking firms that produced a factor of 10 reduction in accident rate. RAM shipments are made only during daylight, non-rush-hour traffic, and good weather. Drivers work a regular schedule and 8-hour days. These precautions and possibly others lead to an accident rate reduction factor of at least ten for on-site shipments at LANL. As a result, the truck accident rate used in this appendix for on-site transport of RAM and HAZMAT, using DOE trucks and LANL drivers, is 2.19×10^{-7} accidents per mile (1.36×10^{-7} accidents per kilometer). The factor of 10 could also be applied to many off-site shipments. However, because it cannot be applied uniformly, it is conservatively not applied to any off-site shipments.

TABLE F.4.2.2–1.—*Truck Accident Rates in the Santa Fe to Los Alamos Area (1990 Through 1994)*

ROUTE	MILE MARKER RANGE	TOTAL NUMBER OF ACCIDENTS	AVERAGE TRUCK TRAFFIC (VEHICLES PER DAY)	TRUCK ACCIDENT RATE	
				ACCIDENTS PER KILOMETER	ACCIDENTS PER MILE
Route Through Santa Fe	160.7 to 167.6[a]	97[b]	2,104[c]	2.27×10^{-6}	3.66×10^{-6}
U.S. 84/285	167.6 to 180.2[a]	17[b]	1,677[c]	2.74×10^{-7}	4.41×10^{-7}
NM 502	18.5 to 6.3[a]	5[b]	462[c]	3.02×10^{-7}	4.86×10^{-7}
NM 4	67.8 to 66.5[a]	0[a]	520[d]	6.71×10^{-7}	1.08×10^{-6} [a]
East Jemez Road	NA (distance is 6 miles)	4[a]	520[c]	6.71×10^{-7}	1.08×10^{-6}

[a] *Source*: Fenner 1996
[b] *Source*: Fenner 1995
[c] *Source*: Vigil 1996
[d] See text
NA = Not applicable

In conformance with DOT regulations (60 FR [188] 50297), some on-site shipments are made by temporarily closing the affected portions of public roads through the LANL site. Under these conditions, many of the truck accident types can be reduced significantly or even eliminated. According to an analysis of the types of truck accidents and the LANL site administrative controls (Rhyne 1994b), the truck accident rate for closed roads is 1.44×10^{-8} accidents per mile (8.95×10^{-9} accidents per kilometer). This procedure has been used and defended previously (Rhyne 1985) and has compared well with data (Green et al. 1996). The on-site truck accident rates are given in Table F.4.2.3–1.

F.4.2.4 *Safe Secure Tractor Trailer Accident Rate*

The SST accident record is excellent. In the 9-year period between 1988 and 1996, the overall accident rate was 7.7×10^{-8} accidents per mile. The number of SST accidents is too small to support allocating this overall rate among the various types of routes used in the accident analyses (urban interstate, rural interstate, other urban, and other rural). Therefore, data for the relative rates of accidents on these route types for five-axle vans in the appropriate weight range (Phillips et al. 1994) was used to allocate SST rates among these route types. The resulting SST rate for each

TABLE F.4.2.3–1.—*Truck Accident Rates at the LANL Site*

TRANSPORT DESCRIPTION	ACCIDENT RATE	
	ACCIDENTS PER KILOMETER	ACCIDENTS PER MILE
Off-Site Trucks at LANL Site[a]	1.36×10^{-6}	2.19×10^{-6}
DOE Trucks with LANL Drivers[b]	1.36×10^{-7}	2.19×10^{-7}
Trucks with Road Closure[b]	8.95×10^{-9}	1.44×10^{-8}

[a] *Source*: Harwood and Russell 1990
[b] *Source*: Rhyne 1994b

route type is presented in Table F.4.2.4–1. The "other rural" value in Table F.4.2.4–1 corresponds to the "DOE trucks with LANL drivers" value in Table F.4.2.3–1. The first two values of Table F.4.2.4–1 can be compared with the first two values of Table F.4.2.1–1 to see the effect of the strong safety culture described in subsection F.4.2.3.

F.4.2.5 *Aircraft Accident Rate*

Air transport to and from LANL is assumed to be by commercial air-cargo carriers such as Federal Express to and from the Albuquerque International Airport (transport between this airport and LANL is by truck or van). Shipments are picked up in the carrier's van and taken to an airport, flown to the destination city, and taken to the final destination by the carrier's van. Commercial air-cargo carriers are categorized as large certified air carriers and are assumed to fall in the subcategory of "large nonscheduled service" for which the 1992 accident rate was 7.9 x 10^{-9} accidents per mile (DOT 1992). The accident rate has been at or below this value for 4 out of the 5 years between 1988 and 1992. The accident rate is about twice that for large, scheduled service.

Accidents involving air shipments were screened relative to truck shipments. The aircraft accident rate per mile is two orders of magnitude less than the truck accident rate per mile for similar shipments. The probability of a high severity accident is higher for aircraft, but not much higher (section F.4.4.3).

TABLE F.4.2.4–1.—*Safe Secure Trailer Accident Rates*

HIGHWAY TYPE	ACCIDENT RATE	
	ACCIDENTS PER KILOMETER	ACCIDENTS PER MILE
Urban Interstate	3.01×10^{-8}	4.85×10^{-8}
Rural Interstate	4.45×10^{-8}	7.16×10^{-8}
Other Urban	1.87×10^{-7}	3.01×10^{-7}
Other Rural	1.83×10^{-7}	2.95×10^{-7}

Source: Phillips et al. 1994

F.4.3 Route, Mileage, and Population Density Determination

The scope of the SWEIS calls for analysis of LANL shipments of RAM and HAZMAT to and from other DOE sites as well as to and from numerous educational or commercial sites. The calculation approach is to determine the RAM and HAZMAT shipments by alternative (section F.5). The routes between DOE sites are then determined for the shipments unique to those sites, and routes between geographical areas of the U.S. are determined for all other shipments. Five geographical areas are defined for RAM shipments: northeast, southeast, northwest, southwest, and New Mexico. The cities selected as representative of each area are Concord, Massachusetts; Aiken, South Carolina; Richland, Washington; Berkeley, California; and Albuquerque, New Mexico. The cities were chosen as conservatively representative on the basis of the number of shipments to various locations in the geographic area in the 1990 through 1994 baseline (see subsection F.5.2). In the northwest, southeast, and southwest, cities near DOE sites were chosen because they appeared to be reasonable choices for general shipments to and from the region. The routes for each shipment were then used to estimate shipment mileages (see Table F.6.1–1 for distances between LANL and the representative cities for RAM and HAZMAT shipments).

The representative truck routes were determined by using the routing code HIGHWAY, Version 3.3 (Johnson et al. 1993), available to the public and DOE users through the TRANSNET computer system at Sandia National Laboratories (SNL). The HIGHWAY code contains a database of at least 240,000 miles (386,000 kilometers) of roads.

The population densities along a route are derived from 1990 census data from the U.S. Bureau of the Census. Rural, suburban, and urban areas are characterized according to the following breakdown: rural population densities range from 0 to 139 persons per square mile (0 to 54 persons per square kilometer); the suburban range is 140 to 3,326 persons per square mile (55 to 1,284 persons per square kilometer); and urban areas encompass all population densities greater than 3,326 persons per square mile (1,284 persons per square kilometer).

All routes for shipment of radioactive or HAZMAT into or out of LANL are conservatively assumed to pass through Santa Fe for the baseline analysis (the comparative analysis of the proposed bypass route is discussed in section F.7 of this appendix). The route between the LANL site and I–25 in Santa Fe is subdivided into two segments. The corresponding HIGHWAY results are shown in Table F.4.3–1. Similar information was generated from I–25 in Santa Fe to each origin or destination on a state-by-state basis.

Cargo air shipments are also made to and from the LANL site. Air shipments arrive at the Albuquerque Airport and are transported by truck to the LANL site or vice versa. Air shipments are included in incident-free impact analyses, but screened from accident analyses, as discussed in section F.4.2.5.

F.4.4 RADTRAN and ADROIT Analyses for Radioactive Materials

Two of the four risk measures described in section F.3 are modeled by RADTRAN (Neuhauser and Kanipe 1995) (refer to Figure F.3–1). The RADTRAN code is designed to produce conservative estimates of the radiological dose to workers and the public during incident-free transportation and the radiological risks from potential accidents.

The RADTRAN code was originally developed in 1977 in conjunction with the preparation of NUREG–0170, *Final Environmental Statement on the Transportation of RAM by Air and Other Modes* (NRC 1977). Subsequent versions have expanded and refined the analytical capability of the code; the current version is RADTRAN 4 (Neuhauser and Kanipe 1995). RADTRAN is maintained, updated, and improved on a continuing basis by SNL for DOE. RADTRAN is available to the public as well as to DOE users through the TRANSNET computer system at SNL. RADTRAN is widely accepted and used both in the U.S. and internationally.

The ADROIT code was developed in the 1992 through 1994 time frame to replicate the RADTRAN incident-free and accident estimates specific to transport in an SST. The

TABLE F.4.3–1.—*Route Segment Information from I–25 to LANL*

ROUTE SEGMENT	TOTAL DISTANCE		AVERAGE POPULATION DENSITY (PERSONS/km^2)			DISTANCE BREAKDOWN (km)		
	km	MILES	RURAL	SUBURBAN	URBAN	RURAL	SUBURBAN	URBAN
I–25 Exit 282 to U.S. 285/84 Junction with NM 502	32.2	20.0	11	625	2,228	24.0	6.3	1.9
Junction of NM 502 and U.S. 285/84 to NM 4 and Junction of East Jemez Road and Diamond Drive	30.6	19.0	14	312	0	28.5	2.1	0.0

code was developed from first principles; and although the end results are very similar to RADTRAN, the specific models may vary. Significant differences include the use of an event tree rather than an accident severity matrix (subsection F.4.4.2). As used in this analysis, the codes can be considered equivalent.

F.4.4.1 *Incident-Free Risk Parameters*

The most important parameter for evaluation of incident-free risk is the package exterior radiation level. The transport index (TI) is used in RADTRAN to characterize the exterior radiation field. The TI is defined in 49 CFR 173.403(bb) as "the exposure rate in millirems per hour at a distance of 1 meter from the surface of the package," and DOT regulations limit the value of TI to 10 or less for general commerce shipments. The TIs for the LANL baseline shipments discussed in section F.5.0 are based on measurements. The average truck shipment TI is less than 2, and the average air shipment TI is approximately 0.1. During the data-gathering process for the SWEIS alternatives, LANL transportation specialists were asked to place a reasonable upper bound on the average for the entire shipment type being discussed. (An average is appropriate for incident-free risk in contrast to accident risk.) When there is little or no experience with a particular shipment type, the usual procedure is to use the legal limit as a conservative value.

The alternative-specific parameters are given in section F.5.0, and those generic to all alternatives are given in Table F.4.4.1–1. Two exceptions to Table F.4.4.1–1 are used: a value of 1.0 is used for the urban city street fraction in Santa Fe, and the fractions of rural and suburban travel on freeways are 0.347 between I–25 and Pojoaque and 0.525 between Pojoaque and LANL.

F.4.4.2 *Accident Severity Categories*

Accident forces include fire, crush, impact, and puncture, and many accidents involve a combination of thermal and mechanical forces. The severity of accidents is categorized in RADTRAN by up to 20 categories for the magnitudes of accident forces and the associated probabilities. The accident severity category approach seeks to relate the magnitude of an accident force with mode of package response (e.g., small structural strains produce no release; larger strains produce loss of containment function and gross rupture). Ideally, such an analysis is done for each type of package; however, as pointed out earlier, this level of detail is impractical for the SWEIS. Most DOE environmental impact statements (EISs) rely on the accident severity categorization scheme described in an NRC report commonly referred to as NUREG–0170 (NRC 1977). NRC divided the spectrum of accident severities into eight categories that are independent of a specific accident sequence. The eight categories are designed to take into account all credible accidents, including accidents with low probability but high consequence and those with high probability but low consequence. The probabilities that correspond to the accident forces characterizing a particular package response are based on analyses by Dennis et al. (1978) or Clarke et al. (1976) The NUREG–0170 accident severity categories and associated probabilities are given in Table F.4.4.2–1.

Category I accidents are the least severe and the most frequent. Category I is considered to include all those accidents less severe than the normal conditions of transport in which Type A packages are shown by tests to be capable of retaining all their contents (section F.2.0). Category II is considered to include accidents more severe than Category I but less severe than the accident conditions in which Type B packages are shown by tests to be capable of retaining all their contents. The percentage of

TABLE F.4.4.1–1.—*Parameter Values for Incident-Free Risk Quantification*

PARAMETER DESCRIPTION	TRACTOR-TRAILER	CARGO AIR	DELIVERY VAN
Speed in Rural Area, kilometers per hour	88.49	691.90	88.49
Speed in Suburban Area, kilometers per hour	40.25	691.90	56.34
Speed in Urban Area, kilometers per hour	24.16	691.90	24.16
Number of Crew	2	3	1
Average Distance from Radiation Source to Crew, meters	3.10	6.10	2.13
Number of Handlings per Shipment	0	4	6
Time Spent at Rest Stops, hours per kilometer	0.011	0.0016	0.0004
Minimum Rest Stop Time, hour	0.0	1.0	0.15
Number of Persons Exposed During Stops	50	10	100
Average Exposure Distance When Stopped, meters	20	50	10
Storage Time per Shipment, hour	0	0	10
Number of Persons Exposed During Storage	100	100	100
Average Exposure Distance When Stopped, meters	100	100	100
Number of Persons per Vehicle Sharing the Route	2	0	2
Fraction of Urban Travel During Rush Hour	0.08	0	0.08
Fraction of Urban Travel on City Streets	0.05	0	0.65
Fraction of Rural and Suburban Travel on Freeways	0.85	0	0.25
Ratio of Urban Pedestrian to Residential Population Densities	6	0	6
Rural Building Shielding Factor	1	0	1
Suburban Building Shielding Factor	0.87	0	0.87
Urban Building Shielding Factor	0.018	0	0.018

Source: Neuhauser and Kanipe 1992

TABLE F.4.4.2–1.—*Fractional Occurrences for Truck Accidents by Severity Category and Population Density Zone*

SEVERITY CATEGORY	FRACTIONAL OCCURRENCE	FRACTIONAL OCCURRENCE BY POPULATION DENSITY ZONE		
		RURAL	SUBURBAN	URBAN
I	0.55	0.1	0.1	0.8
II	0.36	0.1	0.1	0.8
III	0.07	0.3	0.4	0.3
IV	0.016	0.3	0.4	0.3
V	0.0028	0.5	0.3	0.2
VI	0.0011	0.7	0.2	0.1
VII	8.5×10^{-5}	0.8	0.1	0.1
VIII	1.5×10^{-5}	0.9	0.05	0.05

Source: NRC 1977

truck accidents less severe than Type B test conditions is 91 percent according to the 1977 NRC report. A 1987 NRC study (LLNL 1987) estimated that 99.4 percent of the truck accidents would not cause a release from a Type B package. The more conservative results from the older NRC study are used in the SWEIS transportation risk analyses. Packages for plutonium are required to have both inner and outer containment vessels (10 CFR 71.63). Tests with these packages produced no structural damage to the inner containment vessel after impacts with unyielding targets at speeds typical of a Category V impact accident. Several containment vessels exhibited minor damage for Category VI impacts, but no verified release occurred (NRC 1977).

F.4.4.3 *Package Release Fractions*

The release fraction is defined as the fraction of the RAM in a package that could be released from that package during an accident of a certain severity. Release fractions take into account all mechanisms necessary to create a release of RAM from a damaged package to the environment. Release fractions vary according to the package type. Type B packaging are designed to withstand the forces of severe accidents and, therefore, have smaller release fractions than Type A packaging. Plutonium packages are designed to even higher standards.

In a given accident involving a number of packages transported together, some of the packages could release part of their contents while others could have no release at all. The approach taken in an accident severity categorization scheme is to derive an estimate for the average release fraction for each severity category to support the assumption that all such packages in a shipment respond in the same way.

Release fractions for accidents of each severity category are given in Table F.4.4.3–1 for the package types considered in this appendix.

Note that the release fraction levels out at 100 percent for highest severity accidents. Since 82 percent of aircraft accidents are level III or less, as compared to 98 percent of truck accidents, the probability of a large release due to aircraft accidents is not much higher than that for truck accidents. For this reason, as well as the much higher frequency of truck accidents, aircraft accidents are screened from further analysis (Rhyne 1997).

TABLE F.4.4.3–1.—*Estimated Release Fractions for Shipping Packaging Under Various Accident Severity Categories*

SEVERITY CATEGORY	ESTIMATED RELEASE FRACTION	
	TYPE A	TYPE B
I	0	0
II	0.01	0
III	0.1	0.01
IV	1.0	0.1
V	1.0	1.0
VI	1.0	1.0
VII	1.0	1.0
VIII	1.0	1.0

Source: NRC 1977

F.4.4.4 *Respirable Fractions*

Subsequent to release, dispersion of the material into the atmosphere as an aerosol and, in most cases of interest, inhalation into the respiratory tract (respirable aerosols only) would be required to produce a significant exposure to members of the public. Therefore, in addition to determining the respirable fractions, the portion of that release which is respirable is also determined for risk analysis. Most solid materials are relatively nondispersible. Conversely, gaseous materials are easily dispersed. Liquid dispersibility depends on the liquid volatility. The aerosolization and respirable fractions depend on the physical form of the material.

The bounding off-site shipments described in subsection F.6.5.1 are plutonium powders. (The specific application of this methodology to the bounding shipments is also discussed in section F.6.5.1.) Generally the powder is pressed, reducing its dispersibility, and enclosed within four layers of metal containers: two associated with the plutonium packaging and two associated with handling outside the packaging. Should these four layers of containment fail in an impact accident, the mechanisms for converting the powder to a respirable aerosol would be the impact force itself and the release of gases.

Radioactive decay and solar insulation produce heat that causes gas within containers (including chemically inert gases, such as argon) to expand, thus raising the gas pressure inside the packaging. In addition to producing heat, radioactive decay produces helium, which further increases pressure. The average atmospheric pressure at LANL is 11.3 pounds per square inch absolute (psia), in contrast to 14.7 at sea level. The total pressure difference between the inner powder container and the environment from these factors can be as high as 30.1 psig. Tests with air injected into the bottom of a powder bed in an open-top container produced respirable fractions of 3×10^{-5}, 6.7×10^{-4}, and 6.1×10^{-4} for pressures of 9, 17.5, and 24.5 psig, respectively (DOE 1994b). The highest of the three values was used in this appendix. The fraction of powder aerosolized by depressurization is about a factor of 20 higher than the fraction aerosolized by impact forces (DOE 1994b) and the latter can be ignored in comparison to the former.

The use of the value of 6.7×10^{-4} for the respirable fraction of a release in this appendix is conservative since the four containment vessels would not be expected to completely open up, even in a severe impact accident.

Given an accident involving fire, the release mechanism would also be rapid depressurization since the packaging would contain no combustible material. Once a pathway from the powder cans to the environment is established, some additional powder may be aerosolized by updrafts from the fire. Review of DOE Handbook 3010-94 (DOE 1994b) shows that the depressurization effect is about 400 times larger than the updraft effect and the latter can be ignored in comparison to the former.

Exposure of a plutonium package to a 1,475°F fire for 30 minutes would produce a gas pressure of 64.5 psig in a container that has a rupture pressure of 123 psig (Barklay 1983). Longer fires would produce higher gas pressures and lower rupture pressures; therefore, the gas pressure at rupture would be no higher than 123 psig.

Table 4–12 in DOE Handbook 3010-94 (DOE 1994b) presents respirable fraction estimates from the aforementioned pressurized powder release tests for pressures of 9, 18, 24.5, 250, and 500 psig. For 250 psig, the maximum respirable fraction of a release is 2.5 x 10^{-2}. This value is judged to be conservative for the present case, because the test pressure was a factor of 2 higher than the expected package burst pressure and the tests involved blowing powder out of an open-topped container with a burst of air injected at the bottom of the powder bed.

The impact and fire values are combined for the RADTRAN severity categorization scheme by considering that fires occur in 1.6 percent of all truck accidents. The weighted value of the respirable fraction is then (0.984)(6.7 x 10^{-4}) + (0.016)(2.5 x 10^{-2}) = 1.06 x 10^{-3} for an open-top container. Table F.4.4.4–1 shows the results of combining the open-top container value of 1 x 10^{-3} with the Type B package release factors of Table F.4.4.3–1. The values for WIPP packaging, obtained by a similar analysis (DOE 1990), are also shown in Table F.4.4.4–1.

F.4.4.5 *Health Risk Conversion Factors*

The risk from ionizing radiation consists mostly of some number of excess latent cancer fatalities (LCFs). These are cancers resulting from, and that develop well after, the exposure to ionizing radiation. These represent an increase in the number of fatal cancers that occur from other causes. The excess LCF is the product of the dose and the risk conversion factor. The reader should recognize that these estimates are

TABLE F.4.4.4–1.—*Estimated Respirable Release Fractions for Shipping Packaging Under Various Accident Severity Categories*

SEVERITY CATEGORY	ESTIMATED RESPIRABLE RELEASE FRACTION		
	TYPE B[a]	TRUPACT-II[b]	NUPAC 72B[b]
I	0	0	0
II	0	0	0
III	1×10^{-5}	8×10^{-9}	6×10^{-9}
IV	1×10^{-4}	2×10^{-7}	2×10^{-7}
V	1×10^{-3}	8×10^{-5}	1×10^{-4}
VI	1×10^{-3}	2×10^{-4}	1×10^{-4}
VII	1×10^{-3}	2×10^{-4}	2×10^{-4}
VIII	1×10^{-3}	2×10^{-4}	2×10^{-4}

[a] For package contents of loose powder
[b] *Source:* DOE 1990

intended to provide a conservative measure of the potential impacts to be used in the decision-making process and do not necessarily portray an accurate representation of actual anticipated fatalities. In other words, one could expect that the stated impacts form an upper bound and that actual consequences could be less, but probably would not be worse. Refer to appendix D, section D.1 for further discussion of the determination and application of risk factors for LCFs.

The health risk conversion factors used throughout this appendix to estimate the number of expected cancer-caused fatalities due to radiological exposures are 5.0×10^{-4} cases of expected excess LCFs per person-rem for members of the public, and 4.0×10^{-4} cases per person-rem for workers (ICRP 1991).

F.4.5 Event Tree Analysis

Event trees are used for the analyses of off-site accidents involving HAZMAT transportation and on-site accidents involving RAM transportation.

An event tree is a graphical model for identifying and evaluating potential outcomes from a specific initiating event. The event tree depicts the chronological sequence of events (accident scenario) that could result from the initiating event. The identification of accident scenarios are the first of two key results from the event tree analysis; quantification of the scenario frequencies from the event tree is the second key result.

Figure F.4.5–1 is a graphical representation of five accident scenarios. The frequency of an accident producing a puncture force is designated as the parameter A, which is inserted on the tree as illustrated in Figure F.4.5–1. The conditional probability that puncture force causes package failure designated as the parameter B. Because B is the conditional probability that puncture force causes package failure, then 1-B is the conditional probability that puncture force does not cause package failure. The parameter C designates the conditional probability that a fire occurs, and the parameter D is the conditional probability that the fire duration is sufficient to cause package failure. The frequency of a particular scenario (e.g., puncture failure without fire, which is designated as F_2), is evaluated by multiplying the initiating event frequency and the individual probabilities, [e.g., $F_2 = A \times B \times (1 - C)$].

The parameter A is the product of the accident rate from section F.4.2.3 and the fraction of the accidents producing puncture force. The latter is taken from Dennis et al or Clarke et al., as appropriate. The parameter C and the probabilistic force magnitude distributions needed to evaluate parameters B and D are from the same two references.

Event trees similar to Figure F.4.5–1 are used for impact, crush, puncture, and fire without mechanical forces. This approach is conservative because the failures from other mechanical forces are not excluded for failure from the specific mechanical force. Clearly, the package can fail only once and the mechanical failures are triple counted. The error is generally less than a few percent, but the event trees are greatly simplified. The simple form for each force results from the assumption that all failures for a single accident force can be aggregated for frequency analysis. In frequency analysis, one package failure mode for a particular transportation accident force usually dominates the others. Event trees for fixed facilities are generally more complicated than transportation event trees because there are usually more opportunities for safety systems or operator action to mitigate the accident initiator.

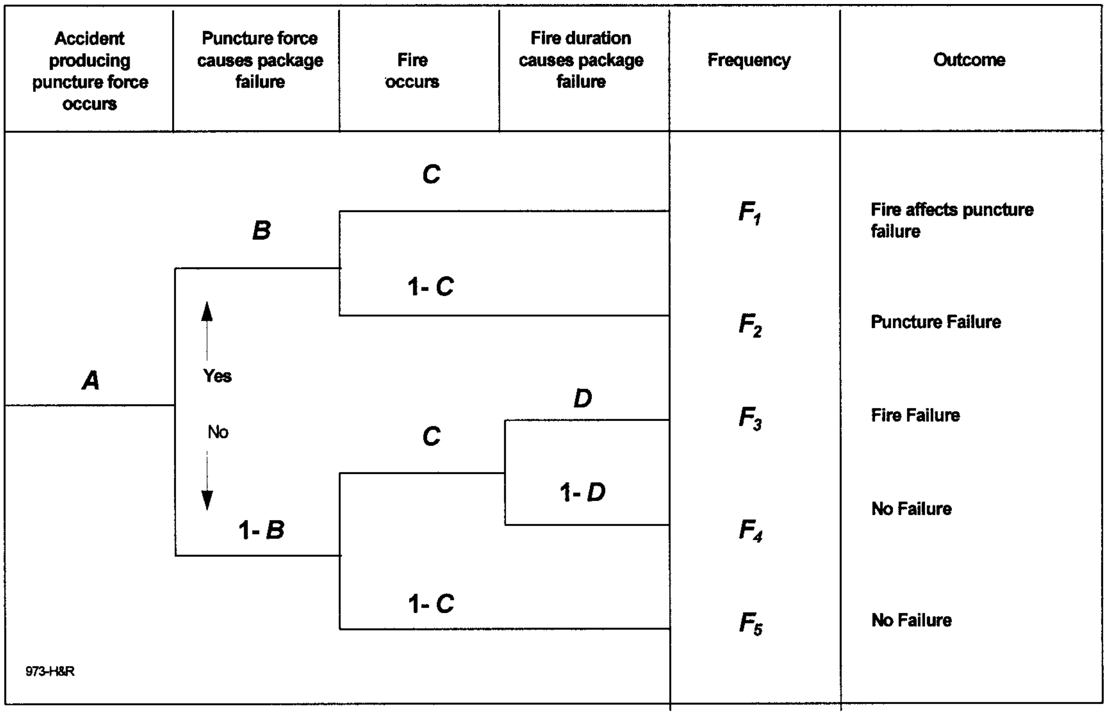


FIGURE F.4.5–1.—*Event Tree Analysis of Puncture Accidents.*

F.5 DETERMINATION OF SHIPMENTS BY ALTERNATIVE

F.5.1 Introduction

The determination of shipments of RAM and HAZMAT proceeded in three steps. First, historical databases were examined to get an overview, focus the subsequent data gathering to the most important risk contributors, and provide an accuracy check for the data-gathering process.

Data gathering, the second step, consisted of both interviews with cognizant persons and reviews of additional databases. The data-gathering process for RAM involved different databases, interviewees, and interviewers than the data-gathering process for HAZMAT.

The last step was the tabulation of results for each SWEIS alternative.

F.5.2 Baseline Shipments

DOE tracks unclassified shipments in a database called the Shipment Mobility/ Accountability Collection (SMAC). The tracking is based on shipping invoices paid by DOE and its contractors. Data on approximately 5,000 RAM and HAZMAT shipments to or from LANL were obtained from the SMAC for fiscal years 1990 through 1994. The shipments were first aggregated into 81 commodity groups, e.g., paint. The least HAZMAT were determined on the basis of the material maximum shipment weight compared with regulatory reporting thresholds in 40 CFR 302, Table 302.4, or 40 CFR 355, appendices A and B. The material was screened from further consideration if the maximum shipping amount was less than the threshold.

The remaining materials were grouped into four categories: radioactive, toxic, flammable, or explosive materials. A bounding material was picked as the most hazardous for each of these four groups on the basis of the toxicity of materials shipped in large amounts to or from LANL. The results are shown in Table F.5.2–1. Also shown in Table F.5.2–1 are the numbers of large and small shipments over the 5-year period. A large shipment is one that is greater than 10 percent of the maximum shipment quantity.

The materials screened from further consideration because of their low hazard are not listed in Table F.5.2–1. Some classified shipments, e.g., SST shipments, are also not included in Table F.5.2–1, since an invoice is not submitted for payment, however, classified shipments are considered in the risk analyses.

A recent annual shipment summary prepared by LANL is shown in Table F.5.2–2. Off-site shipments of RAM and HAZMAT total 3,526 per year in contrast to the SMAC results (Table F.5.2–1) of about 1,000 per year (when the screened shipments are considered). The large difference is due to the classified shipments mentioned previously and to other shipments for which LANL is not billed explicitly for transportation (e.g., contaminated-laundry shipments). Table F.5.2–2 was used to determine the number of HAZMAT shipments used in subsection F.5.3, and Table F.5.2–1 was used to help characterize those shipments

F.5.3 Shipments For SWEIS Alternatives

The determination of shipments by SWEIS alternative focused on ensuring that shipments were identified of both RAM and HAZMAT that could contribute significantly to accident risk. For example, bulk gas shipments were of special interest.

The RAM shipment characteristics were determined by interviewing cognizant LANL staff. Historical shipment data, on-site and off-site, were used to help ensure completeness. On-site shipments of SNM at the gram level were not individually accounted for because their contribution to risk would be minor; however, shipment projections were conservatively high to ensure that the transportation risks were bounded in this analysis. The off-site and on-site RAM shipments for each LANL SWEIS alternative are listed in Tables F.5.3–1 and F.5.3–2, respectively. The number of shipments projected is higher than those reflected in Table F.5.2–2 for a variety of reasons, including: the conservatism applied to shipment projections, the fact that several activities at LANL have been operating below planned levels, and the fact that some programs at LANL are increasing activity levels over recent levels due to DOE decisions made prior to this SWEIS (e.g., stockpile stewardship in the absence of underground testing, demonstration of accelerator production of tritium, and surveillance of stored materials).

The conservatism applied to the shipments is reflected in two ways. First, the number of shipments per year reflected in the table is typically at the high end of a range; this is done to ensure that impacts associated with total mileage are not underestimated. Second, the number of packages in a shipment is at the high end of a range; this is done to ensure that impacts associated with the shipment quantities (e.g., accidents that release cargo and worker and public exposures under no-incident conditions) are not underestimated. These shipments should not be used to estimate material flows/balances because the combination of bounding shipment numbers and bounding packages per shipment would yield overly conservative material flows. For those interested in such balances, the No Action Alternative would result in an average annual plutonium inventory increase of about 130 kilograms. The other alternatives would have slightly different average annual flows, but the inventory growth over the next 10 years can be accommodated in storage facilities, once the NMSF at TA–55 is operational. The enriched uranium inventory at LANL may actually

TABLE F.5.2–1.—*Summary of Radioactive and Hazardous Material Bounding Off-Site Shipments to and from LANL, 1990 Through 1994*

TRANSPORT MODE	MATERIAL CATEGORY	BOUNDING MATERIAL	MAXIMUM SHIPPING QUANTITY	NUMBER OF SMALL[a] SHIPMENTS	NUMBER OF LARGE[b] SHIPMENTS
Truck	Flammable	Hydrogen	50,000 ft^3	320	17
Truck	Toxic	Chlorine	2,000 lb	136	22
Truck	Radiological[c]	Tritium	29,160 Ci	406	11
Truck	Explosive	HMX	13,801 lb	102	24
Air	Toxic	Chlorine	7 lb	160	15
Air	Explosive	HMX	195 lb	21	80
Air	Radiological	Tritium	970,000 Ci	1,185	1

HMX = octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine
[a] About 2,500 shipments screened because of low material toxicity
[b] Large shipments are greater than 10% of the maximum shipping quantity
[c] SST trailer shipments not included

TABLE F.5.2–2.—*Annual LANL On-Site and Off-Site Shipments*

TYPE	NONHAZARDOUS	HAZARDOUS (NONRADIOACTIVE)	RADIOACTIVE
Off-Site	327,939	2,592	934
On-Site	Not available	7,560	1,187

Source: Villa 1996

TABLE F.5.3–1.—*Off-Site Shipments of Radioactive Materials*

PROGRAM/MATERIAL	FORM	ORIGIN	DESTINATION	PACKAGING AND AMOUNT[a]	PACKAGES PER SHIPMENT	SHIPMENTS PER YEAR BY ALTERNATIVE				COMMENT
						NO ACTION	EXPANDED	REDUCED	GREENER	
Stabilization Project 345 for Plutonium-239	Salt	RFETS[c]	TA–55	500 g plutonium-239 in Type B	40 6M	1 (total)[b]	8 (total)[b]	1 (total)[b]	8 (total)[b]	SST
	Oxide	TA–55	RFETS[c]	As above	As above	1 (total)[b]	8 (total)[b]	1 (total)[b]	8 (total)[b]	SST
Pit Fabrication, P362	Plutonium Metal	Pantex	TA–55	FL	10	0	12	0	0	SST
	Plutonium Metal	TA–55	Pantex	FL	10	5	8	5	5	SST
Pit Surveillance, P301	Plutonium Metal	Pantex	TA–55	FL	4 to 6	5	10	5	10	SST
Pit Disassembly[d]	Plutonium Metal	Pantex RFETS SRS LLNL SRS	TA–55 TA–55 TA–55 TA–55 TA–55	FL FL FL FL FL	10 10 2 2 19	1 1 1 1 2	1 1 1 1 2	1 1 1 1 2	1 1 1 1 2	SST
Pit Disassembly	Enriched Uranium Metal	CMR and TA–55	Oak Ridge	Type B or equivalent	22	7	20	7	7	SST
MOX Fuel (Parallex)	Oxide in welded rods	TA–55	Canada	0.3 kg plutonium (weapons grade) 1.2-1.8 kg MOX Type B	1	2	2	2	2	SST
Plutonium-238 Operations	RTG	Pantex	TA–55	500 g plutonium-238 Type B	10	1	1	1	1	SST
	Oxide Powder	TA–55	SRS	500 g 83% plutonium-238 Type B	10	2	2	1	2	SST
Plutonium-238 Heat Source	Oxide Powder	SRS	TA–55	500 g plutonium-238 Type B	15 to 22	4	4	1	4	SST
NASA Plutonium-238 Heat Source	Encapsulated powder	TA–55	Mound	1,800 g Type B	2	10	12	8	12	SST
Actinide Processing & Recovery/ Plutonium (weapons grade)	Plutonium Metal	Pantex RFETS SRS LLNL	TA–55 TA–55 TA–55 TA–55	FL FL FL FL	2 to 8 2 to 8 2 to 4 2 to 4	5 5 1 1	5 5 2 2	0 0 0 0	0 0 0 0	SST
As Above/Uranium	Metal	Oak Ridge	TA–55	Type B	7 to 10	24	60	24	24	SST

TABLE F.5.3–1.—*Off-Site Shipments of Radioactive Materials*-Continued

PROGRAM/MATERIAL	FORM	ORIGIN	DESTINATION	PACKAGING AND AMOUNT[a]	PACKAGES PER SHIPMENT	SHIPMENTS PER YEAR BY ALTERNATIVE				COMMENT
						NO ACTION	EXPANDED	REDUCED	GREENER	
Plutonium (weapons grade) Standards	Oxide	TA–55	Uniform U.S.	4 kg in 9,968 Type B	5	5	5	5	5	SST
	Oxide	Uniform U.S.	TA–55	4 kg in 9,968 Type B	5	5	5	5	5	SST
	Oxide	TA–55	Uniform U.S.	395 g Type B	5	24	24	24	24	
	Oxide	Uniform U.S.	TA–55	395 g Type B	5	24	24	24	24	
Americium-241 Standards Sales	Oxide	TA–55	Houston, TX	28 g in 6M	1	1	2	1	2	
	Oxide	TA–55	England	28 g in 6M	4	3	6	3	6	
	Oxide	TA–55	NY & CA	13 g in 6M	1	2	2	2	2	
Material Disposition	Plutonium Metal	Pantex	TA–55	FL	3 to 19	12	12	0	0	SST
	Plutonium Metal	RFETS	TA–55	FL	14	1 (total)[b]	1 (total)[b]	1 (total)[b]	1 (total)[b]	SST
Bulk Tritium	Solid storage	Mound	TA–16/21	120 g tritium in UC609	1	4 (total)[b]	4 (total)[b]	4 (total)[b]	4 (total)[b]	SST
Plutonium (weapons grade) (Pyrophoric)	Metal powder	Mound	TA–55	< 250 g plutonium in Type B	2	1 (total)[b]	1 (total)[b]	1 (total)[b]	1 (total)[b]	SST
Subcritical Test Program	Test assembly	TA–55	NTS	FL	1	4	6	4	4	SST
Weapons System Evaluation Program Number 301	Secondaries	Oak Ridge	CMR	CSA	1	1	10	1	1	SST
Molybdenum-99 Targets	Metal	CMR	SNL	30 g HEU/target 12 targets/6M	2	45	60	2	45	
Highly Enriched Uranium (HEU) Oxides, Carbides, Nitrides, and Fluorides	Powder	CMR	Oak Ridge	< 300 g HEU in Type A	10	5	5	3	5	SST, yearly values for 1998+2002 only
Secondaries Design Eval	Secondaries	Pantex	CMR	Type B	1	1	10	1	1	SST
	Secondaries	TA–18	Oak Ridge	Type B	--	1	10	1	1	SST
Secondaries	Secondaries	Pantex	TA–18	Type B	3 to 4	1 (total)[b]	2 (total)[b]	1 (total)[b]	1 (total)[b]	Initial receipt at TA–55 in SST, then to TA–18 for storage.
Sealed Sources	Double encapsulated	Uniform U.S.	TA–18	300 Ci iridium-92 shielded cask	1	3 (total)[b]	6 (total)[b]	3 (total)[b]	3 (total)[b]	
	Double encapsulated	Uniform U.S.	TA–18	few mCi	1	20	40	20	20	
Plutonium Objects	Metal	See comment	TA–18	5.85 x 10^3Ci plutonium-239 1.36 x 10^3Ci plutonium-240 in 50-gal. 6M	2	2 (total)[b]	3 (total)[b]	2 (total)[b]	2 (total)[b]	Assume 1 from INEL, 1 from RF, and 1 (Expanded Operations) from Pantex.

TABLE F.5.3–1.—*Off-Site Shipments of Radioactive Materials*-Continued

PROGRAM/MATERIAL	FORM	ORIGIN	DESTINATION	PACKAGING AND AMOUNT[a]	PACKAGES PER SHIPMENT	SHIPMENTS PER YEAR BY ALTERNATIVE				COMMENT
						NO ACTION	EXPANDED	REDUCED	GREENER	
Unirradiated Low Enriched Uranium Fuel	Oxide in Al rods	See comment	TA–18	8.4×10^{-3}Ci uranium-235 2.9×10^{-3}Ci uranium-238 in 50-gal. 6M	10	3 (total)[b]	6 (total)[b]	3 (total)[b]	3 (total)[b]	Assume 1 from Hanford, 2 from SRS; times 2 for Expanded Operations.
Irradiated Highly Enriched Uranium Fuel	Metal or ceramic composite	Oak Ridge	TA–18	2.2×10^{-2}Ci uranium-235 2.6×10^{-4}Ci uranium-238 in 50-gal. 6M	20	4 (total)[b]	8 (total)[b]	4 (total)[b]	4 (total)[b]	SST
Highly Enriched Uranium	Metal or ceramic composite	TA–18	Oak Ridge	2.2×10^{-2}Ci uranium-235 2.6×10^{-4}Ci uranium-238 in 50-gal. 6M	20	1	1	1	1	
Feedstock Depleted Uranium	Bulk metal	SRS	Sigma	2,000 kg uranium total in STCs	25	45	232	45	45	
Depleted Uranium	Bulk metal	Oak Ridge	Sigma	500 kg uranium total in STCs	20	45	171	45	45	
	Bulk metal	Sigma	Oak Ridge	500 kg uranium total in STCs	20	45	171	45	45	
Depleted Uranium Parts	Bulk metal	Oak Ridge	Sigma	75 kg uranium total in STCs	10	60	165	60	60	
	Bulk metal	Sigma	Oak Ridge	75 kg uranium total in STCs	10	60	165	60	60	
	Bulk metal	Concord, MA	Sigma	75 kg uranium total in STCs	10	85	300	85	85	
	Bulk metal	Sigma	Concord, MA	75 kg uranium total in STCs	10	85	300	85	85	
Depleted Uranium Samples	Turnings	Sigma	Oak Ridge	7 vials (20 g uranium each) in STC	1	170	646	170	170	
Highly Enriched Uranium (research and manufacturing technologies)[e]	Bulk metal	Oak Ridge	CMR	250 kg total in Type B	____	25	25	25	25	SST
	Bulk metal	CMR	Oak Ridge	250 kg total in Type B	____	50	50	50	50	SST
Thorium-232 Oxide	Powder	Sigma	Oak Ridge	1,000 kg thorium-232 total in 55-gal. shielded drums	____	1	1	1	1	

TABLE F.5.3–1.—*Off-Site Shipments of Radioactive Materials*-Continued

PROGRAM/MATERIAL	FORM	ORIGIN	DESTINATION	PACKAGING AND AMOUNT[a]	PACKAGES PER SHIPMENT	SHIPMENTS PER YEAR BY ALTERNATIVE				COMMENT
						NO ACTION	EXPANDED	REDUCED	GREENER	
Bulk Tritium	Gas or solid storage	SRS	TA–16/21	120 g tritium in UC609	up to 10	10	20	10	10	
	Gas or solid storage	TA–16/21	SRS	120 g tritium in UC609	up to 5	2	4	2	2	
	Gas or solid storage	SRS	TA–16/21	120 g tritium in H616-2	up to 10	10	20	10	10	
	Gas or solid storage	TA–16/21	Rochester, NY	≤ 1,000 Ci in Type A	up to 10	50	100	50	50	
	Gas or solid storage	Rochester, NY	TA–16/21	≤ 1,000 Ci in Type A	up to 10	100	100	100	100	
Tritiated Water Bound to Zeolite Matrix	Mole sieve	TA–16/21	NTS	10 g tritium in Type A w/ overpack	up to 10	1	2	1	1	
Dispersible Depleted Uranium	Powder	SRS	TA–16/21	6 kg uranium in STC	2	2	4	2	2	
Nondispersible Depleted Uranium	1/8-in. pellets	TA–16/21	Boston	6 kg uranium in STC	2	2	4	2	2	
Neutron Tube Target	Tritium in solid storage	TA–16/21	SNL	≤ 1,000 Ci in Type A	up to 20	50	100	50	50	
Off-Site Samples	Solid	TA–53	DOE Labs (uniform)	Type A	1 by FedEx	50	50	50	50	
Neutron Scattering Research	Pressed powders	TA–53	Uniform U.S.	≤ 0.5 Ci J-L	1 by FedEx	12	12	12	12	
Misc. Nuclear Materials	Double encapsulated	TA–53	Oak Ridge	1.4 mCi californium in 6M	1	1 (total)[b]	1 (total)[b]	1 (total)[b]	1 (total)[b]	
Medical Isotopes	Liquid	TA–48	Uniform U.S.	Bounded by 2 Ci strontium-82 in Type A box by FedEx	1	160	160	160	160	
Irradiated Targets	Nondispersible	TA–48	BNL	Shielded Type B	1	12	12	12	12	The unshielded radiation level is on the order of 10,000 rem/h.
Experimental Samples	Solids	TA–48	Uniform U.S.	Shielded Type A	1	20	40	20	40	
Inertial Confinement Fusion Program	Irradiated Targets	TA–35	Rochester, NY	0.5 Ci by FedEx	1	100	100	100	100	
Beryllium Targets	H_2 and H_3 gas	TA–35	LLNL	1 Ci by FedEx	1	50	50	50	50	
Phosphorus-32 and Sulfur-35 Isotopes	Liquid	Boston	HRL	0.5 mCi by FedEx	3	50	100	16	50	
Neutron Source Recovery	Encapsulated oxide	Uniform U.S.	CMR/TA–55	Type A, special form, 3 Ci plutonium-238	2	10	20	10	10	
Neutron Source Recovery	Encapsulated oxide	Uniform U.S.	CMR/TA–55	6M (Type B) normal form, ≤ 10 g plutonium-238	2	190	380	190	190	

TABLE F.5.3–1.—*Off-Site Shipments of Radioactive Materials*-Continued

PROGRAM/MATERIAL	FORM	ORIGIN	DESTINATION	PACKAGING AND AMOUNT[a]	PACKAGES PER SHIPMENT	SHIPMENTS PER YEAR BY ALTERNATIVE				COMMENT
						NO ACTION	EXPANDED	REDUCED	GREENER	
Neutron Source Recovery	Encapsulated oxide	Uniform U.S.	CMR/TA–55	Heavily shielded Type B, 30 gm plutonium-238	1	2	4	2	2	
Plutonium Research	Powder	SRS	TA–55	Not specified in reference	26	1 (total)[b]	1 (total)[b]	1 (total)[b]	1 (total)[b]	SST
Contaminated Laundry	Particulate-contaminated solid	SM-30	CA	Duffle bag in STC, RAM is near zero	about 200	52	81	52	52	Shipment amount will vary with alternative
Contact-Handled TRU	Solid	TA–54	WIPP	TRUPACT-II	3	157	204	157	166	
TRU and Low-Level Waste	Solid	SNL	TA–54	17H Drum	——	——	——	——	——	Included in contact-handled TRU
Remote-Handled TRU	Solid	TA–54	WIPP	RH-72B	1	33	41	31	34	
Mixed Low-Level Waste	Solid/liquid/gas	TA–54	Various permitted facilities	17H Drum	65	33	33	33	33	Oak Ridge assumed
Low-Level Waste	Solid	TA–54	Utah/Nevada/ Hanford	17H Drum	65	377	0	942	1,050	Primarily soil and debris
Total						2,440	4,244	2,894	3,132	

[a] Refer to the packaging section F.2.0.
[b] The total number of shipments over 10 years is listed. The annual total is the value divided by 10.
[c] This reflects return of recovered plutonium to RFETS. It is possible that this material would remain at LANL, as reflected in the *Final Environmental Impact Statement on Management of Certain Plutonium Residues and Scrub Alloy Stored at the Rocky Flats Environmental Technology Site* (DOE/EIS-0277) (DOE 1998).
[d] This surplus material is expected to leave LANL, eventually; however, without a site selection for the plutonium disposition program, the timing and location for such shipments is unknown. Except for material shipped as MOX fuel (see below), this material is expected to remain at LANL for the period addressed in the SWEIS.
[e] The shipments to Y–12 exceed the receipts from Y–12 because of an excess inventory that currently exists at LANL. This excess inventory of material from a variety of research and development activities is expected to be reduced over the next several years, at which point the HEU received will be approximately equal to the HEU shipped out.
RFETS = Rocky Flats Environmental Technology Site, SRS = Savannah River Site, LLNL = Lawrence Livermore National Laboratory, CMR = Chemistry and Metallurgy Research, HEU = highly enriched uranium, CSA = canned subassembly, STCs = standard transportation containers, NTS = Nevada Test Site, BNL = Brookhaven National Laboratory, HRL = Health Research Laboratory

TABLE F.5.3–2.—*On-Site Shipments of Radioactive Materials*

PROGRAM/MATERIAL	FORM	ORIGIN	DESTINATION	PACKAGING AND AMOUNT[a]	PACKAGES PER SHIPMENT	SHIPMENTS PER YEAR BY ALTERNATIVE				COMMENT
						NO ACTION	EXPANDED	REDUCED	GREENER	
Plutonium (weapons grade) samples	Solid	TA–55	CMR	200 g plutonium (weapons grade) in 6M	10	100	150[b]	100	100	
Plutonium (weapons grade) samples	Liquid	CMR	TA–55	6 L of plutonium (weapons grade) in 15-in. container	4	128	240[b]	128	128	Road closure
Plutonium-238 samples	Solid	TA–55	CMR	20 Ci plutonium-238 in 6M	10	——	——	——	——	Combined with Pu (WG) samples
Plutonium-238 samples	Liquid	CMR	TA–55	6 L of plutonium-238 in 15-in. container	4	——	——	——	——	Combined with Pu (WG) samples
Low-Level Waste	Solid	TA–55	TA–54	2 ft^3 cardboard box	90	52	73	52	52	Compactible and in dumpster
	Solid	TA–55	TA–54	STC, Type A, or plastic wrap	6+12	9	15	9	9	Noncompactible
Contaminated Laundry	Particulate-contaminated solid	TA–55	SM-30	Duffle bag	Up to 40	250	250	250	250	Shipment size will vary with alternative
Radiography	Metal	TA–55	Varies	FL	1	100	500	24	100	Return included
Contact-handled TRU	Particulate-contaminated solid	TA–55	TA–54	17H drum, < 100 g SNM	16+40	78	158	62	78	Road closure
Surveillance	Metal	TA–55	CMR	FL	1	0	200[b]	0	0	Return included
Research and Development	Metal	TA–55	CMR	FL	1	0	100[b]	0	0	Return included
Research and Development	Powder	TA–55	CMR	Type B, 500 g	1	0	100[b]	0	0	Return included
Contact-Handled TRU	Particulate-contaminated solid	CMR	TA–54	17H drum, < 100 g SNM	20+25	4	5	4	4	Road closure
HEU	Powder	TA–55	CMR	17H drum, < 300 g HEU	2	1	1	1	1	
Mixed Low-Level Waste	Liquid	CMR	TA–54	17H drum, 16 mg plutonium (weapons grade)	2	13	13	13	13	
	Particulate-contaminated solid	CMR	TA–54	17H drum, 16 mg plutonium (weapons grade)	2	13	13	13	13	
Mixed TRU	Particulate-contaminated solid	CMR	TA–54	17H drum, < 100 g SNM	1	——	——	——	——	Included in truck with C.12

TABLE F.5.3–2.—*On-Site Shipments of Radioactive Materials*-Continued

PROGRAM/MATERIAL	FORM	ORIGIN	DESTINATION	PACKAGING AND AMOUNT[a]	PACKAGES PER SHIPMENT	SHIPMENTS PER YEAR BY ALTERNATIVE				COMMENT
						NO ACTION	EXPANDED	REDUCED	GREENER	
CSA	Metal	TA–18	CMR	CSA	1	3	10	3	3	Road closure
	Metal	CMR	TA–18	CSA	1	3	10	3	3	Road closure
	Metal	CMR	TA–8	CSA	1	3	10	3	3	Road closure
CSA (continued)	Metal	TA–8	CMR	CSA	1	3	10	3	3	Road closure
TRU Waste Research and Development	Misc. solids	TA–54	TA–50/CMR	≤ 1.8 Ci plutonium-239 and americium-241	10+18	7 (total)[c]	7 (total)[c]	7 (total)[c]	7 (total)[c]	Road closure, 1998, 1999, 2002, Return included
	Cemented	CMR	TA–54	17H drum, mCi level	40	2 (total)[c]	2 (total)[c]	2 (total)[c]	2 (total)[c]	1998, 2002
Neutron Source Recovery	Encapsulated oxide	SM–30	TA–55 (bounds CMR)	6M	2	202	404	202	202	10 g Pu-238 is accident analysis value; see off-site NS.1
	Oxide	CMR	TA–55	Type B, 500 g	4+8	1 (total)[c]	1 (total)[c]	1 (total)[c]	1 (total)[c]	Bounding no action values are 1 kg Pu-238 and 3 kg Am-241
Contaminated Laundry	Particulate-contaminated solid	CMR	SM–30	Duffle bag	Up to 10	250	250	250	250	Shipment amount will vary with alternative
Contingency SNM	Metal	CMR	TA–18	Type B, 20 Ci plutonium-239	10	10	20	10	10	
	Liquid	CMR	TA–18	6 L of Highly Enriched Uranium in 15-in. container	4	1	2	1	1	Road closure
Plutonium Objects	Metal	TA–18	CMR (bounding)	17H, 40 kg plutonium (weapons grade)	2	8	16	8	8	Road closure
Molybdenum-99	Adsorbed	TA–18	TA–48	Shielded Type A	1	0	12	0	0	
Highly Enriched Uranium Samples	Liquid	TA–18	CMR	Type A, 20 g	1	6	18	6	6	Return shipments included
Low-Level Waste	Particulate-contaminated solid	TA–18	CMR/TA–54	17H drum	12	1	1	1	1	Mileage is to/from CMR then to TA–54
Plutonium Parts	Metal	TA–18	CMR	FL	1	84	220	84	96	Most are to TA–55; CMR is used as bounding
	Metal	CMR	TA–18	FL	1	84	220	84	96	
MOX Fuel	Ceramic	TA–55	TA–18	Type B, 20 kg plutonium (weapons grade)	5	2 (total)[c]	2 (total)[c]	2 (total)[c]	2 (total)[c]	Return included
Contaminated Laundry	Particulate-contaminated solid	TA–18	SM–30	Duffle bag	Up to 30	24	48	24	24	Shipment amount will vary with alternative

TABLE F.5.3–2.—*On-Site Shipments of Radioactive Materials*-Continued

PROGRAM/MATERIAL	FORM	ORIGIN	DESTINATION	PACKAGING AND AMOUNT[a]	PACKAGES PER SHIPMENT	SHIPMENTS PER YEAR BY ALTERNATIVE				COMMENT
						NO ACTION	EXPANDED	REDUCED	GREENER	
MC&A Highly Enriched Uranium Measurements	Metals, oxides, or ceramics	TA–18	CMR	20 to 40 kg	Unspecified	24	48	24	24	Return included
Radiography	Solids	TA–8	TA–18	Unspecified	Unspecified	12	24	12	12	Road closure
		TA–18	TA–55	Unspecified	Unspecified	12	24	12	12	Road closure
Tritiated Water Bound to Zeolite Matrix	Mole sieve	TA–21/16	TA–54	≤ 10 g in package	Up to 10	5	10	5	5	Road closure
Sealed Source	Triple encapsulated	TA–55	TA–16	Type A, special form 0.01 g plutonium-238	≤ 4	3	3	3	3	
Dispersible Depleted Uranium	Powder (assumed)	TA–21	TA–16	6 kg uranium in STC	2	4	8	4	4	Return included
Bulk Tritium	Gas or solid storage	TA–16/21	TA–16/21	≤ 120 g per shipment	Up to 10	20	20	20	20	May close roads
	Gas or solid storage	TA–16/21	TA–16/21	≤ 1,000 Ci per package	Up to 10	20	20	20	20	May close roads
Nondispersible Depleted Uranium	1/8-in. pellets	TA–16/21	TA–16/21	≤ 6 kg/STC	Up to 2	2	4	2	2	
Neutron Tube Target	H_3 in solid storage	TA–16/21	TA–16/21	≤ 1,000 Ci per package	Up to 5	50	100	50	50	
Depleted Uranium Materials	Bulk metal	TA–8 (bounds shops)	Sigma	200 kg uranium in STC	1	900	3,780	900	900	Return included
	Pyrophoric metal	Sigma	TA–54	60 kg uranium in 7A drum	7	12	48	12	12	Ash portion is not pyrophoric
Low-Level Waste	Fixed surface contamination	Sigma	TA–54	Low Depleted Uranium in STC	3	13	55	13	13	Noncompactible
Contaminated Laundry	Particulate-contaminated solid	Sigma	SM–30	Duffle bag	30	24	101	24	24	Shipment amount will vary with alternative
Highly Enriched Uranium	Bulk metal	CMR	TA–8 (bounds shops)	20 kg Highly Enriched Uranium in Type A	5	0	240	0	0	Closed roads, return included
Inserts and Beam Stops	Activated components	TA–53	TA–54	Shielded cask	1	12	12	12	12	Unshielded radiation levels from few to 2×10^5 R/h
Irradiated targets	Activated components	TA–53	TA–48	Shielded cask	1	15	17	8	17	Unshielded radiation level up to 5×10^4 R/h
Low-Level Waste	Solid	TA–53	TA–54	2 ft^3 cardboard box	80	5	5	5	5	Compactible and in dumpster
	Solid	TA–53	TA–54	B-25 box	1	2	2	2	2	

TABLE F.5.3–2.—*On-Site Shipments of Radioactive Materials*-Continued

PROGRAM/MATERIAL	FORM	ORIGIN	DESTINATION	PACKAGING AND AMOUNT[a]	PACKAGES PER SHIPMENT	SHIPMENTS PER YEAR BY ALTERNATIVE				COMMENT
						NO ACTION	EXPANDED	REDUCED	GREENER	
Misc. Material	Double encapsulated	TA–53	TA–55	6M, < 5 Ci americium-241	1	2 (total)[c]	2 (total)[c]	2 (total)[c]	2 (total)[c]	One shipment is 4.95 Ci Am-241, other 1.83 Ci Pu-238
	Liquid	TA–53	TA–48	17H drum, 525 kg D_2O	3	1 (total)[c]	1 (total)[c]	1 (total)[c]	1 (total)[c]	
Activated Material	Solid	TA–53	TA–54	Various	2	15	15	15	15	Number of shipments averaged over 10 years
Activated Components	Solid	TA–53	TA–54	Various	1	0	220	0	220	Number of shipments averaged over 10 years, but actually occur 2000 to 2005
Hot Cell Waste	Particulate-contaminated solids or liquids	TA–48	TA–54	Shielded Type A	1	3	3	3	3	Compactible, radiation levels up to 10 R/h
	Activated material	TA–48	TA–54	Shielded cask	1	18	18	18	18	Noncompactible radiation levels up to 300 R/h
	Solids or Tritium in solid storage	Various (TA–3 bounding)	TA–16, TA–15, or similar	Various	1	477	886	471	471	One shipment of DU, H_3, etc. per experiment assumed
	Solids or Tritium in solid storage	TA–16 or similar	TA–15 or similar	Various		477	886	471	471	One shipment per experiment assumed
Low-Level Waste	Solid	TA–3 or similar	TA–54	2 ft^3 cardboard box	90	284	418	271	335	Compactible and in dumpster
Low-Level Waste	Solid	TA–3 or similar	TA–54	B-25 box	2	193	278	181	205	Noncompactible
Low-Level Waste	Solid	TA–3 or similar	TA–54	Dump truck	1	215	269	361	259	Soil and building debris
Low-Level Waste	Solid	TA–3 or similar	TA–54	Various	Unspecified	33	77	105	47	Scrap metal
Low-Level Mixed Waste	Liquid	TA–3 or similar	TA–54	17H Drum	10	20	20	20	20	
Low-Level Mixed Waste	Solid	TA–3 or similar	TA–54	Dump truck	1	53	53	53	53	Soils and debris
Low-Level Mixed Waste	Solid	TA–3 or similar	TA–54	96 ft^3 box	2	18	20	18	18	Contaminated lead and non-RCRA
Total						4,372	10,754	4,454	4,727	

[a] Refer to the packaging section F.2.0.
[b] These shipments constitute the approximately 500-shipment increase discussed in volume II, part II (*PSSC Analysis for the Enhancement of Plutonium Pit Manufacturing*), section II.2.1.1.
[c] The total number of shipments over 10 years is listed. The annual total is the value divided by 10.
CSA = canned subassembly; MC&A = Materials Control and Accountability; STCs = standard transportation containers

decrease over time as the excess material in the current inventory is shipped off site.

The HAZMAT shipments were determined primarily by using LANL databases such as the Automated Chemical Inventory System (ACIS) and STORES as well as by using the SMAC data. Large inventories and bulk shipments were of special interest. When such inventories and bulk shipments were identified, responsible personnel were interviewed. The bounding historical material types and quantities identified in Table F.5.2–1 were validated for the toxic and explosive material categories. The bounding flammable material was changed from hydrogen to propane because the potential consequence of a propane release was determined to be larger as a result of the differing dispersion characteristics of lighter-than-air hydrogen and heavier-than-air propane (subsection F.6.5.4). The maximum future explosive shipment size for truck was determined to be 40,000 pounds (18,000 kilograms). Explosive shipments this large have been received in the past and could be received in the future.

An extensive analysis of on-site HAZMAT shipments determined that the large toxic, flammable, and explosive off-site shipments bound the accident risk both on site and off site.

Off-site shipments of toxic and flammable material classes were assumed to increase from the values in Table F.5.2–2 and vary with the SWEIS alternatives in the same way the off-site RAM shipments increase from the values in Table F.5.2–2 and vary with the SWEIS alternatives as described in Table F.5.3–1.

Although the number of many types of operational shipments associated with the Reduced Operations Alternative are lower than in the other alternatives, the number of low-level waste (LLW) shipments for off-site disposal increases substantially as compared to the number of LLW shipments under the No Action Alternative (since the Reduced Operations Alternative reflects off-site disposal of most LLW). This results in a total for off-site shipment mileage under the Reduced Operations Alternative, which is greater than the total off-site shipment mileage under the No Action Alternative. For this reason, the impacts that depend on the total off-site or radioactive shipment mileage are higher under the Reduced Operations Alternative than under the No Action Alternative.

The baseline value of off-site shipments in Table F.5.2–2 is the starting point for HAZMAT off-site shipments, after it is adjusted upward by the ratio of RAM shipments in Tables F.5.2–2 and F.5.3–1. In the case of toxic and flammable materials, the values are then adjusted for the SWEIS alternatives by the ratio of the number shipments under Expanded Operations, Reduced Operations, and Greener Alternatives to the No Action shipments in Table F.5.3–1. Projections, by alternative, were available for large off-site shipments of explosives. The on-site HAZMAT shipments were assumed to increase from the values in Table F.5.2–2 and vary with SWEIS alternatives in the same way as the on-site RAM shipments increase from Table F.5.2–2 to Table F.5.3–2 and vary with SWEIS alternative.

The resulting annual number of significant HAZMAT shipments for each alternative are given in Table F.5.3–3. The ratio of significant to total shipments is the same as that in Table F.5.2–1. As before, a large shipment is one that is greater than 10 percent of the maximum shipment quantity.

F.6 IMPACT ANALYSIS RESULTS

F.6.1 Introduction

To determine the impacts of the transportation of RAM and HAZMAT, four risk measures are defined in subsections F.3.3 and F.3.4: truck emissions in urban areas, truck accident injuries and fatalities that are independent of the nature

TABLE F.5.3–3.—*Annual Number of Hazardous Material Truck Shipments for SWEIS Alternatives*

SHIPMENT TYPE	ALTERNATIVE							
	NO ACTION		EXPANDED OPERATIONS		REDUCED OPERATIONS		GREENER	
	TOTAL SIGNIFICANT	TOTAL LARGE	TOTAL SIGNIFICANT	TOTAL LARGE	TOTAL SIGNIFICANT	TOTAL LARGE	TOTAL SIGNIFICANT	TOTAL LARGE
Off-Site, Toxic	645	90	1,439	200	606	84	645	90
Off-Site, Flammable	1,382	73	3,081	164	1,299	70	1,382	73
Off-Site, Explosive	518	2	1,155	2	487	1	518	1
On-Site	14,628	NA	34,231	NA	14,189	NA	15,068	NA

of the cargo, incident-free radiation exposure, and accidents resulting in a release of RAM or HAZMAT.

The RAM shipments presented by alternative (as in Tables F.5.3–1 and F.5.3–2) were identified for a specific origin/destination, or were categorized as going to one of five regions: northeast, southeast, northwest, southwest, or New Mexico. A centroid (central location) was picked for each of these regions on the basis of historical and projected shipments: Concord, Massachusetts; Aiken, South Carolina; Richland, Washington; Berkeley, California; and Albuquerque, New Mexico. The distances from LANL to the centroids are given in Table F.6.1–1. The shipment distances for explosives, flammable materials, and toxic materials were based on the corresponding large truck shipments in Table F.5.2–1. The centroids selected were Ft. Smith, Arkansas; Phoenix, Arizona; and Milwaukee, Wisconsin, respectively. All distances given in Table F.6.1–1 were determined from the HIGHWAY code (Johnson et al. 1993) and include the distances between LANL and I–25, as presented in Table F.4.3–1.

F.6.2 Truck Emissions in Urban Areas

The truck emission risk is based on 1.0 x 10^{-7} excess LCF per truck kilometer in urban areas where the number of kilometers is obtained as described in section F.4.3. Because Los Alamos is not an urban area, only off-site shipments were addressed in this analysis (off-site shipments by alternative are presented in Tables F.5.3–1 [RAM] and F.5.3–3 [HAZMAT]). The total distance traveled in urban areas in a year is calculated for these shipments using the distances in Table F.6.1–1, and the corresponding excess LCFs are calculated using the conversion factor presented above. The results are presented in Table F.6.2–1. Approximately 65 percent of the excess LCFs are due to RAM shipments and 35 percent are due to HAZMAT shipments. All shipments are conservatively assumed to result in an empty truck making the return trip. This is appropriate for WIPP shipments and many SST trailer shipments; however, most shipments are in general commerce and would not include the return of an empty truck.

TABLE F.6.1–1.—*Off-Site Shipment Distance per Trip*

ROUTE	MILES (KILOMETERS) IN URBAN AREAS	MILES (KILOMETERS) IN SUBURBAN AREAS	MILES (KILOMETERS) IN RURAL AREAS
Northeast, RAM	63 (102)	511 (823)	1,647 (2,652)
Southeast, RAM	20 (32)	275 (442)	1,312 (2,113)
Northwest, RAM	17 (27)	118 (190)	1,092 (1,759)
Southwest, RAM	20 (32)	75 (120)	1,094 (1,762)
Toxic Material	22 (36)	152 (245)	1,230 (1,981)
Flammable Material	13 (21)	50 (80)	496 (799)
Explosive Material	6 (10)	63 (102)	684 (1,102)

TABLE F.6.2–1.—*Number of Excess Latent Cancer Fatalities Due to Truck Emissions in Urban Areas*

RISK MEASURE	ALTERNATIVE			
	NO ACTION	EXPANDED OPERATIONS	REDUCED OPERATIONS	GREENER
Excess LCF per Year	3.2×10^{-2}	6.6×10^{-2}	3.4×10^{-2}	3.6×10^{-2}

F.6.3 Truck Accident Injuries and Fatalities

The HIGHWAY code (Johnson et al. 1993) was used to determine the distance traveled in each state for each of the centroids described in subsection F.6.1. The truck accident fatality, injury, and total accident rates in each state were taken from Saricks and Kvitek (1994). The rates in Table F.4.2.2–1 were used between Santa Fe and LANL, and the rates in Table F.4.2.3–1 were used on site. The results are given in Tables F.6.3–1 through F.6.3–3 for fatalities, injuries, and total accidents, respectively. Approximately 65 percent of the impacts are due to RAM shipments, and 35 percent are due to HAZMAT shipments. Again, all shipments are assumed to result in a return by an empty truck.

F.6.4 Incident-Free Radiation Exposure

The RADTRAN and ADROIT codes are used with the estimated number of off-site shipments in Tables F.5.3–1 and F.5.3–2 and with the estimated package surface radiation levels to obtain the results shown in Tables F.6.4–1 through F.6.4–4. The aircraft segment is for overnight carrier service; the truck segment to/from the airport is included in the truck results.

MEI dose occurs between LANL and I–25 and is 3.0×10^{-4}, 3.8×10^{-4}, 3.2×10^{-4}, and 3.4×10^{-4} rem for the No Action, Expanded Operations, Reduced Operations, and Greener Alternatives, respectively.

F.6.4.1 *Driver Doses from On-Site Shipments of Radioactive Materials*

The number of on-site shipments of RAM for the baseline year 1994, was 1,187 shipments, (taken from Table F.5.2–2). The baseline number of on-site shipments of RAM for the four SWEIS alternatives was taken from Table F.5.2–3. Table F.6.4.1–1 presents a summary of the total number of on-site shipments for all alternatives.

Dosimetry data for 25 on-site LANL drivers were provided by LANL. For identification purposes, the drivers were assigned numbers 1 through 25. Driver doses for 1994 were extracted from the dosimetry data package and are summarized in Table F.6.4.1–2. Driver number 2 did not have any dosimetry data for years beyond 1992, therefore, it was assumed that this driver is no longer working at LANL. He was dropped from further analysis. The driver doses were, therefore, based on 24 drivers.

To evaluate driver doses for the different SWEIS alternatives, it was assumed that the number of drivers (24) would be the same under each of the alternatives. In calculating the cancer risk associated with these doses, a dose-to-risk conversion factor 4×10^{-4} excess LCFs per person-rem was used (ICRP 1991).

To evaluate doses associated with on-site shipments for the different alternatives, the following procedure was followed:

- A dose per shipment was calculated for the baseline year as follows:
  - Dose (person-rem per shipment) = (total collective dose) per number of shipments.
    $= 9.57 \times 10^{-4}$
  - The baseline total dose of 1.136 person-rem was taken from Table F.6.4.1–2.
  - The total number of shipments for each alternative was then multiplied by 9.57×10^{-4} to obtain the total collective dose per alternative.
  - The total dose per alternative was then divided by 24 (the number of drivers) to obtain the average driver dose for each alternative.

TABLE F.6.3–1.—*Annual Truck Accident Fatalities*

ROUTE SEGMENT	ALTERNATIVE			
	NO ACTION	EXPANDED OPERATIONS	REDUCED OPERATIONS	GREENER
On-Site	1.5×10^{-4}	3.3×10^{-4}	1.4×10^{-4}	1.5×10^{-4}
LANL to U.S. 84/285	1.7×10^{-3}	3.4×10^{-3}	1.8×10^{-3}	1.9×10^{-3}
U.S. 84/285 to I–25	4.1×10^{-3}	8.2×10^{-3}	4.3×10^{-3}	4.6×10^{-3}
Remainder of New Mexico	7.2×10^{-2}	1.5×10^{-1}	7.5×10^{-2}	8.0×10^{-2}
Outside New Mexico	3.0×10^{-1}	6.2×10^{-1}	3.3×10^{-1}	3.5×10^{-1}
Total	3.8×10^{-1}	7.8×10^{-1}	4.1×10^{-1}	4.4×10^{-1}

TABLE F.6.3–2.—*Annual Truck Accident Injuries*

ROUTE SEGMENT	ALTERNATIVE			
	NO ACTION	EXPANDED OPERATIONS	REDUCED OPERATIONS	GREENER
On-Site	3.1×10^{-3}	7.0×10^{-3}	2.9×10^{-3}	3.2×10^{-3}
LANL to U.S. 84/285	3.5×10^{-2}	7.1×10^{-2}	3.7×10^{-2}	4.0×10^{-2}
U.S. 84/285 to I–25	8.6×10^{-2}	1.8×10^{-1}	9.1×10^{-2}	9.7×10^{-2}
Remainder of New Mexico	6.4×10^{-1}	1.3×10^{0}	6.8×10^{-1}	7.2×10^{-1}
Outside New Mexico	3.0×10^{0}	6.0×10^{0}	3.3×10^{0}	3.6×10^{0}
Total	3.8×10^{0}	7.6×10^{0}	4.1×10^{0}	4.5×10^{0}

TABLE F.6.3–3.—*Number of Annual Truck Accidents*

ROUTE SEGMENT	ALTERNATIVE			
	NO ACTION	EXPANDED OPERATIONS	REDUCED OPERATIONS	GREENER
On-Site	1.5×10^{-2}	3.3×10^{-2}	1.4×10^{-2}	1.5×10^{-2}
LANL to U.S. 84/285	1.7×10^{-1}	3.4×10^{-1}	1.8×10^{-1}	1.9×10^{-1}
U.S. 84/285 to I–25	4.1×10^{-1}	8.2×10^{-1}	4.3×10^{-1}	4.6×10^{-1}
Remainder of New Mexico	6.7×10^{-1}	1.4×10^{0}	7.0×10^{-1}	7.6×10^{-1}
Outside New Mexico	3.2×10^{0}	6.4×10^{0}	3.6×10^{0}	3.8×10^{0}
Total	4.5×10^{0}	9.0×10^{0}	4.9×10^{0}	5.2×10^{0}

TABLE F.6.4–1.—*Annual Incident-Free Population Dose and Excess Latent Cancer Fatality for the No Action Alternative*

ROUTE SEGMENT	TRUCK OR AIR CREW		NONOCCUPATIONAL					
			ALONG ROUTE		SHARING ROUTE		STOPS	
	PERSON-REM/ YEAR	EXCESS LCF/ YEAR	PERSON-REM/ YEAR	EXCESS LCF/ YEAR	PERSON-REM/ YEAR	EXCESS LCF/ YEAR	PERSON-REM/ YEAR	EXCESS LCF/ YEAR
LANL to U.S. 84/285	5.9×10^{0}	2.4×10^{-3}	3.2×10^{-2}	1.6×10^{-5}	5.1×10^{-1}	2.6×10^{-4}	3.2×10^{0}	1.6×10^{-3}
U.S. 84/285 to I–25	7.9×10^{0}	3.2×10^{-3}	3.8×10^{-1}	1.9×10^{-4}	3.6×10^{0}	1.8×10^{-3}	3.3×10^{0}	1.6×10^{-3}
Remainder of New Mexico	4.5×10^{1}	1.8×10^{-2}	1.0×10^{-1}	5.0×10^{-5}	1.7×10^{0}	8.5×10^{-4}	2.4×10^{1}	1.2×10^{-2}
Outside New Mexico	4.1×10^{2}	1.6×10^{-1}	2.8×10^{0}	1.4×10^{-3}	2.4×10^{1}	1.2×10^{-2}	1.8×10^{2}	9.0×10^{-2}
Aircraft	2.4×10^{0}	1.2×10^{-3}	NA	NA	NA	NA	NA	NA

NA = Not applicable

TABLE F.6.4–2.—*Annual Incident-Free Population Dose and Excess Latent Cancer Fatality for the Expanded Operations Alternative*

ROUTE SEGMENT	TRUCK OR AIR CREW		NONOCCUPATIONAL					
			ALONG ROUTE		SHARING ROUTE		STOPS	
	PERSON-REM/ YEAR	EXCESS LCF/ YEAR	PERSON-REM/ YEAR	EXCESS LCF/ YEAR	PERSON-REM/ YEAR	EXCESS LCF/ YEAR	PERSON-REM/ YEAR	EXCESS LCF/ YEAR
LANL to U.S. 84/285	7.4×10^{0}	3.0×10^{-3}	4.0×10^{-2}	2.0×10^{-5}	6.5×10^{-1}	3.2×10^{-4}	4.0×10^{0}	2.0×10^{-3}
U.S. 84/285 to I–25	1.0×10^{1}	4.0×10^{-3}	4.9×10^{-1}	2.4×10^{-4}	4.6×10^{0}	2.3×10^{-3}	4.2×10^{0}	2.1×10^{-3}
Remainder of New Mexico	5.5×10^{1}	2.2×10^{-2}	1.2×10^{-1}	6.2×10^{-5}	2.1×10^{0}	1.0×10^{-3}	3.0×10^{1}	1.5×10^{-2}
Outside New Mexico	5.1×10^{2}	2.0×10^{-1}	3.5×10^{0}	1.8×10^{-3}	3.0×10^{1}	1.5×10^{-2}	2.3×10^{2}	1.2×10^{-1}
Aircraft	2.4×10^{0}	1.2×10^{-3}	NA	NA	NA	NA	NA	NA

NA = Not applicable

TABLE F.6.4–3.—*Annual Incident-Free Population Dose and Excess Latent Cancer Fatality for the Reduced Operations Alternative*

ROUTE SEGMENT	TRUCK OR AIR CREW		NONOCCUPATIONAL					
			ALONG ROUTE		SHARING ROUTE		STOPS	
	PERSON-REM/YEAR	EXCESS LCF/YEAR	PERSON-REM/YEAR	EXCESS LCF/YEAR	PERSON-REM/YEAR	EXCESS LCF/YEAR	PERSON-REM/YEAR	EXCESS LCF/YEAR
LANL to U.S. 84/285	6.4×10^{0}	2.6×10^{-3}	3.4×10^{-2}	1.7×10^{-5}	5.6×10^{-1}	2.8×10^{-4}	3.4×10^{0}	1.7×10^{-3}
U.S. 84/285 to I–25	8.7×10^{0}	3.5×10^{-3}	4.2×10^{-1}	2.1×10^{-4}	3.4×10^{0}	1.7×10^{-3}	3.6×10^{0}	1.8×10^{-3}
Remainder of New Mexico	5.0×10^{1}	2.0×10^{-2}	1.2×10^{-1}	6.0×10^{-5}	1.9×10^{0}	9.5×10^{-4}	2.7×10^{1}	1.4×10^{-2}
Outside New Mexico	4.4×10^{2}	1.8×10^{-1}	2.9×10^{0}	1.4×10^{-3}	2.5×10^{1}	1.2×10^{-4}	2.0×10^{2}	1.0×10^{-1}
Aircraft	2.4×10^{0}	1.2×10^{-3}	NA	NA	NA	NA	NA	NA

NA = Not applicable

TABLE F.6.4–4.—*Annual Incident-Free Population Dose and Excess Latent Cancer Fatality for the Greener Alternative*

ROUTE SEGMENT	TRUCK OR AIR CREW		NONOCCUPATIONAL					
			ALONG ROUTE		SHARING ROUTE		STOPS	
	PERSON-REM/YEAR	EXCESS LCF/YEAR	PERSON-REM/YEAR	EXCESS LCF/YEAR	PERSON-REM/YEAR	EXCESS LCF/YEAR	PERSON-REM/YEAR	EXCESS LCF/YEAR
LANL to U.S. 84/285	6.8×10^{0}	2.7×10^{-3}	3.6×10^{-2}	1.8×10^{-5}	5.9×10^{-1}	3.0×10^{-4}	3.6×10^{0}	1.8×10^{-3}
U.S. 84/285 to I–25	9.2×10^{0}	3.7×10^{-3}	4.4×10^{-1}	2.2×10^{-4}	4.2×10^{0}	2.1×10^{-3}	3.8×10^{0}	1.9×10^{-3}
Remainder of New Mexico	5.2×10^{1}	2.1×10^{-2}	1.3×10^{-1}	6.5×10^{-5}	2.0×10^{0}	1.0×10^{-3}	2.8×10^{1}	1.4×10^{-2}
Outside New Mexico	4.6×10^{2}	1.8×10^{-1}	3.0×10^{0}	1.5×10^{-3}	2.6×10^{1}	1.3×10^{-4}	2.1×10^{2}	1.0×10^{-1}
Aircraft	2.4×10^{0}	1.2×10^{-3}	NA	NA	NA	NA	NA	NA

NA = Not applicable

TABLE F.6.4.1–1.—*Annual Doses and Cancer Risks to Drivers from On-Site Shipment of Radioactive Materials*

	BASELINE (1994)	NO ACTION	EXPANDED OPERATIONS	REDUCED OPERATIONS	GREENER
Number of Shipments	1,187	4,372	10,754	4,454	4,728
Collective Driver Dose (person-rem)[a]	1.136	4.184	10.292	4.262	4.525
Average Driver Dose (rem)[b]	0.047	0.174	0.429	0.178	0.189
Cancer Risk[c]	4.54×10^{-4}	1.67×10^{-3}	4.12×10^{-3}	1.70×10^{-3}	1.81×10^{-3}

[a] This is the total collective dose to all 24 drivers working at LANL. This dose was obtained by multiplying the total number of shipments by 9.57×10^{-4}.

[b] This is the annual average dose to each of the 24 drivers, obtained by dividing the total dose by 24.

[c] This is the sum of the excess LCF to all drivers from exposure to low level radiation. A dose-to-risk conversion factor of 4×10^{-4} is used.

TABLE F.6.4.1–2.—*Driver Dose Data for On-Site Shipments in 1994*

DRIVER NUMBER	SKIN DOSE (REM)	DEEP DOSE (REM)	NEUTRON DOSE (REM)	TOTAL DRIVER DOSE (REM)
1	0	0	0	0
2[a]	—	—	—	—
3	0	0	0	0
4	0	0	0	0
5	0	0	0	0
6	0.01	0	0	0.01
7	0	0	0	0
8	0	0	0	0
9	0	0	0	0
10	0	0	0	0
11	0	0	0	0
12	0	0	0	0
13	0	0	0	0
14	0	0	0	0
15	0.031	0	0.008	0.039
16	0.017	0	0	0.017
17	0.212	0.169	0.01	0.391
18	0.216	0.163	0	0.379
19	0.013	0	0	0.013
20	0.116	0.01	0.059	0.185
21	0.029	0	0	0.029
22	0	0	0	0
23	0	0	0	0
24	0.03	0	0.015	0.045
25	0.014	0.014	0	0.028
Total Collective Dose (person-rem/year)	0.688	0.356	0.092	1.136
Average Driver Dose (rem/year)	0.029	0.015	0.004	0.047

[a] No 1994 dosimetry data were available for driver No. 2. It was assumed that the driver left the job prior to 1994, and therefore he was dropped from the analysis.

— The collective driver dose was multiplied by a dose-to-risk conversion factor of 4 x 10^{-4} (cancer deaths per person-rem) to obtain the cancer risk.

The results for driver doses and associated risks are presented in Table F.6.4.1–1. The average driver doses are well below the DOE radiation protection standard of 5 rem per year. The highest collective dose (under the Expanded Operations Alternative) is just over 10 person-rem per year. The cancer risk associated with this dose is 4.12 × 10^{-3} excess LCFs per year.

F.6.5 Accidents

Analyses are conducted for scenarios leading to the release of either RAM or HAZMAT. The materials selected for analysis are those that represent bounding risks. Results are given for off-site shipments of RAM and HAZMAT. This subsection concludes with results for on-site RAM shipment.

F.6.5.1 *Determination of Bounding Materials*

Selection of the bounding material shipments is described in the following subsections.

Radioactive Materials

The shipments described in Tables F.5.3–1 and F.5.3–2 were evaluated as described in this subsection to determine those that would likely present the largest risk. These are referred to as the bounding materials. To determine the transportation risk, the shipment of bounding materials is evaluated in more detail. The bounding materials are those that have the largest value of

$$MAR \times ARF \times RF \times ID, \qquad (F–4)$$

Where:

MAR = material at risk (gram),

ARF = airborne release fraction,

RF = respirable fraction, and

ID = inhalation dose conversion factor (rem per gram).

The ARF values used are the RADTRAN default values, e.g., 1 x 10^{-6} for bulk metal, 1 x 10^{-2} for chunks, 1 x 10^{-1} for powder, and 1.0 for gases and volatile liquids. The RADTRAN default value for RF is 1.0 for gases and volatile liquids and 0.05 otherwise.

The bounding shipments determined by this approach are as follows:

- Off-site in an SST, plutonium-238 oxide powder (Table F.5.3–1, entries for plutonium operations and plutonium-238 heat source shipments to SRS)
- Off-site, americium-241 standards (Table F.5.3–1, americium-241 standard sales entry)
- On-site, plutonium-238 solution samples (Table F.5.3–2, entries for weapons grade plutonium and plutonium-238 liquid samples)

Equation F–4 is for materials that are hazardous due to their dispersion and subsequent exposure of persons to the airborne material. Another hazard is direct radiation from irradiated targets should the packaging fail (entry for irradiated targets in Table F.5.3–2). This hazard is bounding for its type. Some shipments associated with the Dual Axis Radiographic Hydrodynamic Test (DARHT) Facility are explosively configured, and the quoted values for ARF do not apply. DARHT shipments were not considered explicitly as bounding material; instead, the results from the DARHT EIS (DOE 1995) were incorporated into subsection F.6.5.5.

Risk includes both the consequence and the frequency of an event (subsection F.3.2). The bounding shipments were selected to produce the highest calculated consequence. The frequency associated with the calculated bounding consequence is determined by adding together the number of bounding shipments and any other shipment that has a consequence (as estimated by using Equation F–4) that is greater than 10 percent of the bounding consequence. This approach is conservative and is used for both RAM and HAZMAT shipments.

Shipments of CH TRU to WIPP exceed the 10 percent criterion and would be included in the frequency term for off-site shipments of americium-241 standards, but RH TRU shipments do not exceed the 10 percent criterion. Both shipment types are analyzed explicitly in this appendix because of the potential public interest in the results. Off-site shipments of pits in an SST trailer were also analyzed explicitly for the same reason.

Off-site shipments of plutonium-238 oxide powder in an SST trailer were conservatively aggregated with other strategic nuclear material also shipped in SST trailers. (ADROIT analyses of SST shipments were provided by SNL).

On-site shipments of some activated components (e.g., beam stops) as a result of accelerator operations exceed the 10 percent criterion and are included in the frequency term for on-site shipments of irradiated targets, as are DARHT shipments. (Some activated components may exceed the radiation level for irradiated targets, but irradiated targets are judged to pose the greater risk due to the packaging.)

On-site shipments of weapons-grade plutonium solution samples are included in the plutonium-238 solution samples frequency term.

Description of Bounding Radioactive Material Shipments

Pressed plutonium-238 oxide powder is enclosed in a welded capsule that is then enclosed in a welded vessel. The vessel is loaded into the 5320 packaging described in subsection F.2.4.5. Powder is transported to LANL from the Savannah River Site (SRS) in an SST. The 5320 package limit is 12.6 ounces (357 grams) of plutonium, but 15.6 ounces (441 grams) (17.6 ounces [500 grams] as plutonium dioxide) was used in the analysis to allow for possible increases in loading with another package.

The FL-Type container described in subsection F.2.4.1 is used to transport pits in an SST.

Up to 1 ounce (28 grams) americium-241 may be shipped in oxide form in a 30-gallon (114-liter) 6M package (subsection F.2.4.4); up to four packages may be shipped at a time. The oxide is enclosed in a stainless steel vial with a screw top and the vial is enclosed in a crimped can. This assembly is then placed in a 2R container in the 6M package.

Wastes transported to WIPP are enclosed in either the TRUPACT–II packaging described in subsection F.2.4.2 or the 72–B cask described in subsection F.2.4.6. One 72–B cask or three TRUPACT–II packages are transported in a single shipment. The waste parameters are those used in the WIPP Draft Supplemental EIS (DOE 1990c); additional details can be obtained from that document.

Samples of plutonium-238 in solution are transported from the Chemistry and Metallurgy Research (CMR) Facility to TA–55 in an armored vehicle that carries one to four packages. Each package consists of a stainless steel container enclosing three 0.5-gallon (2-liter) bottles. Each bottle is double sealed in plastic bags. The maximum concentration is 0.07 ounce (2 grams) plutonium-238 per 0.5-gallon (2-liter) bottle; all shipments are conservatively assumed to be at the maximum concentration. The LANL roads used are closed to traffic during the shipment.

The irradiated target package is a cylinder measuring 44 inches (112 centimeters) high, with a 26-inch (66-centimeter) diameter. The packaging is constructed of 5.8 tons (5.266 kilograms) of depleted uranium, lead, and stainless steel. The package is equipped with a sliding door on the bottom so that targets can be loaded into the packaging by means of special remote handling tools. The package is transported on a dedicated truck that has a keyhole-shaped receptacle recessed into the bed.

F.6.5.2 *Analysis of Off-Site Accidents Producing Bounding Radioactive Materials Releases*

The RADTRAN and ADROIT codes were used to analyze the bounding off-site RAM shipments described in subsections F.6.5.1. The MEI doses do not vary with route segment or alternative and are given in Table F.6.5.2–1 for each material analyzed with RADTRAN. ADROIT results that are separated into frequency and consequence components are not readily available. The product, MEI dose risk, varies with the number of shipments and the various shipment types. The population dose risks (consequence times frequency) and corresponding excess LCF risks are given in Tables F.6.5.2–2 through F.6.5.2–5 for each alternative.

F.6.5.3 *Analysis of Accidents Producing Chlorine Releases*

An event tree analysis produced the following accident scenarios that could lead to a major chlorine release:

- Release from a small hole caused by a puncture of the cylinder or failure of a valve from puncture or impact accidents
- Opening of a fusible plug as a result of fire
- Catastrophic failure in an impact accident
- Catastrophic failure as a result of a fire

The probability of each of these scenarios was determined from the event trees by using 1-ton (908-kilogram) container failure thresholds (Rhyne 1994a) and force magnitude probabilities (Dennis et al.). (Although LANL is not expected to store or handle chlorine containers this large, they have in the past, and the risks associated with transport of this size container bound the risks of toxic material shipments.) The ALOHA computer model (NSC 1995) was used to estimate release rates from the 1-ton (908-kilogram) container, and the DEGADIS (Havens and Spicer 1985) dense gas dispersion model was used to predict downwind chlorine concentrations following the four postulated releases. (A separate version of DEGADIS is used because the version incorporated in ALOHA does not readily provide time variation of downwind concentrations.)

In this analysis, exposures to toxic chemicals are compared to Emergency Response Planning Guidelines (ERPGs). ERPGs are explained in detail in appendix G, section G.2.2. ERPG–2 is the maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action. ERPG–3 is the maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing life-threatening health effects. The model predicts the length and width of the cloud for which concentrations are greater than those at ERPG–2 and ERPG–3. The area affected, the maximum exposure duration, the maximum downwind distance affected, and the maximum chlorine cloud width are shown in Table F.6.5.3–1 for the bounding release, which is release from a small hole with fire. (Catastrophic releases are of very short duration and a high escape fraction is likely.)

TABLE F.6.5.2–1.—*Maximally Exposed Individual Doses and Associated Frequencies for Off-Site Radioactive Materials Accidents*

ROUTE SEGMENT	SHIPMENT TYPE					
	AMERICIUM-241		CH TRU		RH TRU	
	MEI DOSE (REM)	FREQUENCY PER TRIP	MEI DOSE (REM)	FREQUENCY PER TRIP	MEI DOSE (REM)	FREQUENCY PER TRIP
LANL to U.S. 84/285	59	1.8×10^{-7}	21	6.4×10^{-8}	0.16	6.0×10^{-9}
U.S. 84/285 to I–25	59	2.5×10^{-7}	21	7.4×10^{-8}	0.16	5.6×10^{-9}
Remainder of New Mexico	59	9.9×10^{-7}	21	1.4×10^{-6}	0.16	1.3×10^{-7}
Rest of U.S.	59	1.1×10^{-5}	NA	NA	NA	NA

TABLE F.6.5.2–2.—*Bounding Radioactive Materials Off-Site Accident Population Risk for the No Action Alternative*

ROUTE SEGMENT	ANNUAL POPULATION DOSE RISK AND EXCESS LCF RISK						
	SHIPMENT TYPE						
	AMERICIUM-241	CH TRU	RH TRU	PLUTONIUM-238	PITS	TOTAL	
	PERSON-REM/YEAR	PERSON-REM/YEAR	PERSON-REM/YEAR	PERSON-REM/YEAR	PERSON-REM/YEAR	PERSON-REM/YEAR	EXCESS LCF/YEAR
LANL to U.S. 84/285	1.5×10^{-2}	1.4×10^{-3}	3.1×10^{-6}	4×10^{-7}	2×10^{-6}	1.6×10^{-2}	8.0×10^{-6}
U.S. 84/285 to I–25	2.4×10^{-1}	1.9×10^{-2}	4.2×10^{-5}	1×10^{-6}	1×10^{-5}	2.6×10^{-1}	1.3×10^{-4}
Remainder of New Mexico	3.1×10^{-2}	1.2×10^{-2}	2.6×10^{-5}	4×10^{-7}	4×10^{-6}	4.3×10^{-2}	2.2×10^{-5}
Rest of U.S.	2.5×10^{0}	NA	NA	4×10^{-6}	2×10^{-5}	2.5×10^{0}	1.2×10^{-3}

TABLE F.6.5.2–3.—*Bounding Radioactive Materials Off-Site Accident Population Risk for the Expanded Operations Alternative*

ROUTE SEGMENT	ANNUAL POPULATION DOSE RISK AND EXCESS LCF RISK						
	SHIPMENT TYPE						
	AMERICIUM-241	CH TRU	RH TRU	PLUTONIUM-238	PITS	TOTAL	
	PERSON-REM/YEAR	PERSON-REM/YEAR	PERSON-REM/YEAR	PERSON-REM/YEAR	PERSON-REM/YEAR	PERSON-REM/YEAR	EXCESS LCF/YEAR
LANL to U.S. 84/285	1.6×10^{-2}	1.9×10^{-3}	3.8×10^{-6}	1×10^{-6}	6×10^{-6}	1.8×10^{-2}	9.0×10^{-6}
U.S. 84/285 to I–25	2.5×10^{-1}	2.4×10^{-2}	5.3×10^{-5}	2×10^{-6}	2×10^{-5}	2.7×10^{-1}	1.4×10^{-4}
Remainder of New Mexico	3.3×10^{-2}	1.6×10^{-2}	3.3×10^{-5}	1×10^{-6}	8×10^{-6}	4.9×10^{-2}	2.4×10^{-5}
Rest of U.S.	2.7×10^{0}	NA	NA	8×10^{-6}	4×10^{-5}	2.7×10^{0}	1.4×10^{-3}

TABLE F.6.5.2–4.—*Bounding Radioactive Materials Off-Site Accident Population Risk for the Reduced Operations Alternative*

ROUTE SEGMENT	ANNUAL POPULATION DOSE RISK AND EXCESS LCF RISK						
	SHIPMENT TYPE						
	AMERICIUM-241	CH TRU	RH TRU	PLUTONIUM-238	PITS	TOTAL	
	PERSON-REM/YEAR	PERSON-REM/YEAR	PERSON-REM/YEAR	PERSON-REM/YEAR	PERSON-REM/YEAR	PERSON-REM/YEAR	EXCESS LCF/YEAR
LANL to U.S. 84/285	1.5×10^{-2}	1.4×10^{-3}	2.9×10^{-6}	4×10^{-7}	2×10^{-6}	1.6×10^{-2}	8.0×10^{-6}
U.S. 84/285 to I–25	2.4×10^{-1}	1.9×10^{-2}	4.0×10^{-5}	1×10^{-6}	8×10^{-6}	2.6×10^{-1}	1.3×10^{-4}
Remainder of New Mexico	3.1×10^{-2}	1.2×10^{-2}	2.5×10^{-5}	4×10^{-7}	4×10^{-6}	4.3×10^{-2}	2.2×10^{-5}
Rest of U.S.	2.5×10^{0}	NA	NA	4×10^{-6}	1×10^{-5}	2.5×10^{0}	1.2×10^{-3}

TABLE F.6.5.2–5.—*Bounding Radioactive Materials Off-Site Accident Population Risk for the Greener Alternative*

ROUTE SEGMENT	ANNUAL POPULATION DOSE RISK AND EXCESS LCF RISK						
	SHIPMENT TYPE						
	AMERICIUM-241	CH TRU	RH TRU	PLUTONIUM-238	PITS	TOTAL	
	PERSON-REM/YEAR	PERSON-REM/YEAR	PERSON-REM/YEAR	PERSON-REM/YEAR	PERSON-REM/YEAR	PERSON-REM/YEAR	EXCESS LCF/YEAR
LANL to U.S. 84/285	1.6×10^{-2}	1.5×10^{-3}	3.2×10^{-6}	4×10^{-7}	2×10^{-6}	1.8×10^{-2}	9.0×10^{-6}
U.S. 84/285 to I–25	2.5×10^{-1}	2.0×10^{-2}	4.4×10^{-5}	1×10^{-6}	8×10^{-6}	2.7×10^{-1}	1.4×10^{-4}
Remainder of New Mexico	3.3×10^{-2}	1.3×10^{-2}	2.7×10^{-5}	4×10^{-7}	4×10^{-6}	4.6×10^{-2}	2.3×10^{-5}
Rest of U.S.	2.7×10^{0}	NA	NA	4×10^{-6}	1×10^{-5}	2.7×10^{0}	1.4×10^{-3}

TABLE F.6.5.3–1.—*Exposure Parameters of Bounding Chlorine Accident*

ACCIDENT DESCRIPTION	MAXIMUM EXPOSURE DURATION (MINUTES)	MAXIMUM DOWNWIND DISTANCE (KILOMETERS)		MAXIMUM CLOUD WIDTH (KILOMETERS)	
		EPRG-2	EPRG-3	EPRG-2	EPRG-3
Fire Causes Opening of a Fusible Plug	8.4	4.2	2.1	0.28	0.15

EPRG = Emergency Response Planning Guideline

(NSC 1995) was used to estimate release rates from the 1-ton (908-kilogram) container, and the DEGADIS (Havens and Spicer 1985) dense gas dispersion model was used to predict downwind chlorine concentrations following the four postulated releases. (A separate version of DEGADIS is used because the version incorporated in ALOHA does not readily provide time variation of downwind concentrations.)

In this analysis, exposures to toxic chemicals are compared to Emergency Response Planning Guidelines (ERPGs). ERPGs are explained in detail in appendix G, section G.2.2. ERPG–2 is the maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair their abilities to take protective action. ERPG–3 is the maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing life-threatening health effects. The model predicts the length and width of the cloud for which concentrations are greater than those at ERPG–2 and ERPG–3. The area affected, the maximum exposure duration, the maximum downwind distance affected, and the maximum chlorine cloud width are shown in Table F.6.5.3–1 for the bounding release, which is release from a small hole with fire. (Catastrophic releases are of very short duration and a high escape fraction is likely.)

The number of fatalities or injuries would depend on the population density and the ability of people to avoid harmful exposure by going indoors or leaving the affected area. The frequency of occurrence of this accident would depend on the truck accident rate. The accident rate and population density would vary for the different route segments. The ability of people to avoid harmful exposure (to escape) would depend on various factors; an escape fraction of 0.98 is used for all route segments. This fraction is based on analysis of a transportation accident producing fatal releases of ammonia (Glickman and Raj 1992) and should be applicable to chlorine because the same dispersion coefficients apply, resulting in similar plume shapes and gradients of concentration. For both, there will be objectionable odor a short period prior to concentrations that have serious effects. The plumes tend to be visible and of modest transverse dimension, with very objectionable odor and strong respiratory irritation at their edges, permitting recognition and urging prompt escape on foot. The estimated frequency of a major chlorine release and the estimated number of associated fatalities and injuries are given in Table F.6.5.3–2 for different population densities along the routes. The risk values (i.e., annual frequency times consequences analogous to Tables F.6.5.2–2 through F.6.5.2–5) are given for the SWEIS alternatives in Table F.6.5.3–3.

F.6.5.4 *Analysis of Accidents Producing Propane Releases*

The bounding consequence from a propane release would be the generation of a fireball. The fireball would likely occur too soon after the postulated truck accident for evacuation to be effective. The fireball would have a radius of about 148 feet (45 meters) and would burn for about 3 seconds. Many persons would be protected by buildings or automobiles for this short duration. It is assumed that 50 percent of the available population would be shielded from the fireball, 10 percent would be fatalities, and the remainder would be injured (PNL 1980). In addition, fatal second-degree burns might be experienced out to a radius of 620 feet (189 meters). The percentages of available persons that would be exposed to the radiant heat flux are assumed to be 0.16 percent, 12 percent, and 19 percent in urban, suburban, and rural areas, respectively (PNL 1980).

TABLE F.6.5.3–2.—*Frequencies and Consequences of a Major Chlorine Release*

ROUTE SEGMENT	AREA	FREQUENCY PER TRIP	ESTIMATED NUMBER OF FATALITIES	ESTIMATED NUMBER OF INJURIES
LANL to U.S. 84/ 285	Rural	3.1×10^{-7}	6.5×10^{-2}	2.4×10^{-1}
	Suburban	5.1×10^{-8}	1.5×10^{0}	5.6×10^{0}
U.S. 84/285 to I–25	Rural	2.4×10^{-7}	5.3×10^{-2}	2.0×10^{-1}
	Suburban	5.2×10^{-7}	3.0×10^{0}	1.1×10^{1}
	Urban	1.6×10^{-7}	1.1×10^{1}	4.0×10^{1}
Remainder of New Mexico	Rural	1.8×10^{-6}	1.5×10^{-2}	5.6×10^{-2}
	Suburban	1.9×10^{-7}	1.5×10^{0}	5.5×10^{0}
	Urban	3.1×10^{-8}	8.4×10^{0}	3.2×10^{1}
Remainder of U.S.	Rural	1.3×10^{-5}	2.8×10^{-2}	1.0×10^{-1}
	Suburban	3.3×10^{-6}	1.6×10^{0}	6.1×10^{0}
	Urban	7.8×10^{-7}	1.0×10^{1}	3.9×10^{1}

TABLE F.6.5.3–3.—*Major Chlorine Accident Risks*

ROUTE SEGMENT	ALTERNATIVE							
	NO ACTION		EXPANDED OPERATIONS		REDUCED OPERATIONS		GREENER	
	FATALITIES PER YEAR	INJURIES PER YEAR	FATALITIES PER YEAR	INJURIES PER YEAR	FATALITIES PER YEAR	INJURIES PER YEAR	FATALITIES PER YEAR	INJURIES PER YEAR
LANL to U.S. 84/285	8.6×10^{-6}	3.2×10^{-5}	1.9×10^{-5}	7.2×10^{-5}	8.0×10^{-6}	3.0×10^{-5}	8.6×10^{-6}	3.2×10^{-5}
U.S. 84/285 to I–25	2.9×10^{-4}	1.1×10^{-3}	6.4×10^{-4}	2.4×10^{-3}	2.7×10^{-4}	1.0×10^{-3}	2.9×10^{-4}	1.1×10^{-3}
Remainder of New Mexico	5.2×10^{-5}	1.9×10^{-4}	1.1×10^{-4}	4.2×10^{-4}	4.8×10^{-5}	1.8×10^{-4}	5.2×10^{-5}	1.9×10^{-4}
Remainder of U.S.	1.2×10^{-3}	4.7×10^{-3}	2.8×10^{-3}	1.0×10^{-2}	1.2×10^{-3}	4.4×10^{-3}	1.2×10^{-3}	4.7×10^{-3}

The number of fatalities or injuries would depend on the population density and the ability of people to avoid harmful exposure by going indoors or leaving the affected area. The frequency of occurrence of this accident would depend on the truck accident rate. The accident rate and population density would vary for the different route segments. The ability of people to avoid harmful exposure (to escape) would depend on various factors; an escape fraction of 0.98 is used for all route segments. This fraction is based on analysis of a transportation accident producing fatal releases of ammonia (Glickman and Raj 1992) and should be applicable to chlorine because the same dispersion coefficients apply, resulting in similar plume shapes and gradients of concentration. For both, there will be objectionable odor a short period prior to concentrations that have serious effects. The plumes tend to be visible and of modest transverse dimension, with very objectionable odor and strong respiratory irritation at their edges, permitting recognition and urging prompt escape on foot. The estimated frequency of a major chlorine release and the estimated number of associated fatalities and injuries are given in Table F.6.5.3–2 for different population densities along the routes. The risk values (i.e., annual frequency times consequences analogous to Tables F.6.5.2–2 through F.6.5.2–5) are given for the SWEIS alternatives in Table F.6.5.3–3.

F.6.5.4 *Analysis of Accidents Producing Propane Releases*

The bounding consequence from a propane release would be the generation of a fireball. The fireball would likely occur too soon after the postulated truck accident for evacuation to be effective. The fireball would have a radius of about 148 feet (45 meters) and would burn for about 3 seconds. Many persons would be protected by buildings or automobiles for this short duration. It is assumed that 50 percent of the available population would be shielded from the fireball, 10 percent would be fatalities, and the remainder would be injured (PNL 1980). In addition, fatal second-degree burns might be experienced out to a radius of 620 feet (189 meters). The percentages of available persons that would be exposed to the radiant heat flux are assumed to be 0.16 percent, 12 percent, and 19 percent in urban, suburban, and rural areas, respectively (PNL 1980).

The number of persons that would be affected depends on the population density; the frequency of the accident would depend on the truck accident rate. Both of these parameters would vary for the different route segments. The truck accident frequency of a major propane release and the estimated numbers of fatalities and injuries are given in Table F.6.5.4–1 for different population densities along the routes. The fatality and injury risks are given in Table F.6.5.4–2 for the four SWEIS alternatives. The frequency of large explosive shipments was added to the frequency of large flammable shipments.

F.6.5.5 *Analysis of On-Site Accidents Producing Bounding Radioactive Materials Releases*

The bounding on-site shipments involving RAM are the transport of plutonium-238 solution from CMR to TA–55 and the transport of irradiated targets from the LANSCE to TA–48. Both types of shipments are made with the roads closed to all persons except personnel directly involved in the transport. Therefore, no member of the public would be expected to be involved in the postulated truck accident or to be a bystander after the postulated truck accident.

MEI dose is calculated using the following assumptions. In the case of plutonium-238 solution, it is assumed that a person would stand very close to the evaporating liquid for 10 minutes before being warned away. In the case

TABLE F.6.5.4–1.—*Frequencies and Consequences of a Major Propane Release*

ROUTE SEGMENT	AREA	FREQUENCY PER TRIP	ESTIMATED NUMBER OF FATALITIES	ESTIMATED NUMBER OF INJURIES
LANL to U.S. 84/ 285	Rural	1.3×10^{-7}	2.8×10^{-1}	1.1×10^{0}
	Suburban	2.2×10^{-8}	4.2×10^{0}	1.7×10^{1}
U.S. 84/285 to I–25	Rural	1.0×10^{-7}	2.3×10^{-1}	9.2×10^{-1}
	Suburban	2.2×10^{-7}	8.4×10^{0}	3.4×10^{1}
	Urban	6.7×10^{-8}	1.8×10^{0}	7.3×10^{0}
Remainder of New Mexico	Rural	8.7×10^{-7}	1.5×10^{-1}	6.0×10^{-1}
	Suburban	2.8×10^{-7}	5.1×10^{0}	2.0×10^{1}
	Urban	3.5×10^{-8}	1.5×10^{0}	6.1×10^{0}
Remainder of U.S.	Rural	1.1×10^{-6}	9.0×10^{-2}	3.6×10^{-1}
	Suburban	1.4×10^{-7}	4.8×10^{0}	1.9×10^{1}
	Urban	7.2×10^{-8}	1.9×10^{0}	7.5×10^{0}

TABLE F.6.5.4–2.—*Major Propane Accident Risk*

ROUTE SEGMENT	ALTERNATIVE							
	NO ACTION		EXPANDED OPERATIONS		REDUCED OPERATIONS		GREENER	
	FATALITIES PER YEAR	INJURIES PER YEAR	FATALITIES PER YEAR	INJURIES PER YEAR	FATALITIES PER YEAR	INJURIES PER YEAR	FATALITIES PER YEAR	INJURIES PER YEAR
LANL to U.S. 84/285	9.7×10^{-6}	3.9×10^{-5}	2.2×10^{-5}	8.6×10^{-5}	9.2×10^{-6}	3.7×10^{-5}	9.7×10^{-6}	3.9×10^{-5}
U.S. 84/285 to I–25	1.5×10^{-4}	6.0×10^{-4}	3.3×10^{-4}	1.3×10^{-3}	1.4×10^{-4}	5.7×10^{-4}	1.5×10^{-4}	6.0×10^{-4}
Remainder of New Mexico	1.2×10^{-4}	4.8×10^{-4}	2.6×10^{-4}	1.1×10^{-3}	1.1×10^{-4}	4.5×10^{-4}	1.2×10^{-4}	4.8×10^{-4}
Remainder of U.S.	6.7×10^{-5}	2.7×10^{-4}	1.5×10^{-4}	5.9×10^{-4}	6.3×10^{-5}	2.5×10^{-4}	6.7×10^{-5}	2.7×10^{-4}

of the irradiated target cask failure, a narrow radiation beam would be produced that would be lethal after 10 minutes of continuous exposure at a distance of 6 feet (1.8 meters) from the cask, and it is assumed that a person would stand in this beam for 10 minutes.

The resulting MEI doses and frequencies are given in Table F.6.5.5–1, and MEI risk is given in Table F.6.5.5–2 for the four SWEIS alternatives. The plutonium-238 solution sample shipment frequency terms includes weapons-grade plutonium solution sample shipments, and the irradiated target shipment frequency term includes activated inserts and beam stops (Table F.5.3–2) shipments. DARHT shipment accidents could result in an off-site MEI dose of 76 rem and fatalities to LANL truck crews and other individuals within 80 feet (24 meters) of the explosion (DOE 1995). The frequency of DARHT shipments has been added to the frequency of irradiated target shipments.

F.6.6 Transportation of Waste Off Site

Transportation of waste is imbedded in the transportation risk assessment. Because the methodology is directed at identifying the greatest risks associated with shipments of materials, both from the standpoint of incident-free shipments as well as accidents, the lesser quantities of materials per package typically found in wastes (as compared to stock materials) tend to screen them from a detailed analytical presentation in this assessment. Waste shipments have been found to be of public interest; and it is useful, therefore, to discuss the manner in which the impacts of these shipments are considered. This qualitative presentation is also illustrative of the overall methodology.

Numbers of shipments of waste per year in the categories of radioactive and nonradioactive hazardous material were included in the mileage calculations for shipment of other materials in the same class for the purpose of evaluating impacts due to vehicle emissions, direct

TABLE F.6.5.5–1.—*Maximally Exposed Individual Doses and Frequencies for On-Site Radioactive Materials Accidents*

SHIPMENT TYPE	PER TRIP FREQUENCY	MEI DOSE
Plutonium-238 Solution	6.9×10^{-10}	8.7 rem
Irradiated Targets	3.4×10^{-8}	fatal

TABLE F.6.5.5–2.—*On-Site Radioactive Materials Accident Maximally Exposed Individual Risk*

SHIPMENT TYPE	MEI RISK PER ALTERNATIVE			
	NO ACTION	EXPANDED OPERATIONS	REDUCED OPERATIONS	GREENER
Plutonium-238 Solution	7.7×10^{-7} rem/year (3.1×10^{-10} excess LCF/year)	1.4×10^{-6} rem/year (5.8×10^{-10} excess LCF/year)	7.7×10^{-7} rem/year (3.1×10^{-10} excess LCF/year)	7.7×10^{-7} rem/year (3.1×10^{-10} excess LCF/year)
Irradiated Targets	3.1×10^{-6} fatalities/ year	3.2×10^{-6} fatalities/ year	2.9×10^{-6} fatalities/ year	3.2×10^{-6} fatalities/ year

exposure to radiation, and accidents not involving the release of cargo. Specifically, TRU waste shipments to WIPP are less than 10 percent of the total number of shipments under any alternative (and because of the relatively short distance between LANL and WIPP, these shipments would constitute an even smaller percentage contribution to incident-free impacts attributed to radioactive material shipments), LLW shipments for off-site disposal under the Reduced Operations and Greener Alternatives are about 30 percent of the total shipments under these alternatives (LLW constitutes about 15 percent and less than 1 percent of off-site shipments under the No Action and Expanded Operations Alternatives, respectively), and about 10 percent of the total number of hazardous (nonradioactive) shipments would be expected to be waste shipments. (This is based on historical information—hazardous waste shipments were not specifically projected and are not reflected as individual shipments in the off-site shipment projections in this appendix.) Although the numbers of hazardous waste shipments were not individually projected, they are included in the numbers of shipments in Table F.5.3–3 and considered in the total mileage and impacts projected for hazardous material shipments.

Routes for the shipment of waste are typical of, and represented by, the routes chosen for analysis that covered the U.S. by sector in terms of population density as well as the category of road (except that WIPP shipment routes, as noted above, are much shorter than most of the nonwaste radioactive material shipment routes); thus, the contribution of waste shipments to the total risks due to vehicle emissions and accidents without a cargo release could be estimated using the percentages in the previous paragraph (although this would be very conservative for WIPP shipments). The amount of material in a given container is orders of magnitude less for waste shipments than for product shipments (see accidents discussion below), so the incident-free radiation exposure attributable to waste shipments would be a very small percentage of that presented in this appendix and in chapter 5.

Accidents involving the release of cargo were based on factors such as the greatest quantity of the material known to be shipped, the most toxic, and the least protective packaging. Accident risk associated with the transportation of transuranic waste to WIPP was specifically analyzed and presented in this appendix and in chapter 5 due to public interest in such shipments, and they are not discussed further here. LLW and low-level mixed waste (LLMW) shipments involve, at most, from 0.001 percent (for plutonium-238) to 0.01 percent (for americium-241 and plutonium-239) of the total material considered in the off-site radioactive materials accidents specifically presented in this appendix. The mileage associated with LLW waste shipments is conservatively estimated at 30 percent of that used in the radioactive materials accident analyses presented in this appendix. Therefore, the risk associated with waste shipments is conservatively estimated to be 0.003 percent of that analyzed and presented for radioactive materials, as presented in this analysis.

Similarly, shipments of hazardous chemical (nonradioactive) waste contain much less of the hazardous material content than do the shipments of chlorine and propane analyzed and presented in this appendix and in chapter 5. While no estimates of waste contents were available for use in this SWEIS, such shipments would not be likely to exceed 10 percent of the amounts used for chlorine and propane accidents (and would likely be a much smaller fraction of these quantities). On that basis, hazardous chemical waste shipments, which constitute about 10 percent of the total number of hazardous chemical shipments, would not be expected (conservatively) to result in risks that exceed 1 percent of those presented in this SWEIS for hazardous material shipments.

F.7 ANALYSIS OF THE SANTA FE RELIEF ROUTE OPTION

F.7.1 Introduction

The effect of the proposed relief route would be to replace 6.5 miles (10.5 kilometers) on U.S. 84/285 through Santa Fe to exit number 282 of I–25 with 13.8 miles (22.2 kilometers) starting from U.S. 84/285 north of Santa Fe to exit number 276 of I–25, south of Santa Fe. Because of the location where the Relief Route meets I–25, travel on I–25 south of Santa Fe would be reduced by six miles of highway travel, and travel on I–25 north of Santa Fe would be increased by 6 miles of highway travel if the Relief Route were used. The route between exit number 282 of I–25 and the junction of U.S. 84/285 with NM 502 consists of 1.2 miles (1.9 kilometers) of urban, 3.9 miles (1.9 kilometers) of suburban, and 14.9 miles (24 kilometers) of rural highway (Table F.4.3–1). For this analysis, the 6.5 mile (10.5 kilometer) segment replaced is assumed to consist of all of the urban and suburban highway plus 1.4 miles (2.3 kilometers) of rural highway. The 13.8-mile (22.2-kilometer) relief route is assumed to consist of 9.6 miles (15.4 kilometers) of suburban and 4.2 miles (6.8 kilometers) of rural highway.

The four risk measures evaluated in section F.6 are evaluated in this section for the relief route option.

F.7.2 Results

The effect of the proposed relief route on truck emissions in urban areas would be to eliminate 1.2 miles (1.9 kilometers) of urban highway. The overall reduction in excess LCFs would be small, as shown in Table F.7.2–1.

A comparison of the annual number of fatalities and injuries from truck accidents is shown in Tables F.7.2–2 and F.7.2–3, respectively. The variation in truck accidents is shown in Table F.7.2–4.

Only the route segments affected by the relief route option are described. The effect of the relief route on the remainder of New Mexico route segment is negligible, but the effect on the U.S. 84/285 to I–25 route segment is reduced by about one-half for the relief route option. The reason is that the accident rate assumed on the relief route is approximately one order of magnitude less than that for some parts of the route through Santa Fe, in contrast to the distance which increases by 50 percent.

A comparison of the annual incident-free population doses for the No Action, Expanded Operations, Reduced Operations, and Greener Alternatives is given in Tables F.7.2–5 through F.7.2–8, respectively. In general, the changes are small with a few exceptions. The occupational and stops doses are directly proportional to the length and inversely proportional to the truck speed, and they increase for the relief route. The dose to those sharing the route is directly proportional to the traffic density, which is significantly reduced on the relief route. This dose decreases for the relief route.

A comparison of the change in accident frequencies is shown in Tables F.7.2–9 and F.7.2–10 for radioactive and HAZMAT, respectively. The change in the remainder of New Mexico route segment depends on whether the shipment direction is southwest or northeast. Chlorine is the representative material for all toxic materials, whose representative source is the northeast; and propane is the representative material for all flammable materials, whose representative source is the southwest. (The comment in the next paragraph about potential exaggeration applies to Tables F.7.2–9 and F.7.2–10.)

The changes in bounding RAM accident population dose risks are shown in Tables F.7.2–11 through F.7.2–14 for the four SWEIS

TABLE F.7.2–1.—*Comparison of Excess Latent Cancer Fatalities per Year Due to Truck Emissions*

ROUTE OPTION	ALTERNATIVE			
	NO ACTION	EXPANDED OPERATIONS	REDUCED OPERATIONS	GREENER
Route Through Santa Fe	3.2×10^{-2}	6.6×10^{-2}	3.4×10^{-2}	3.6×10^{-2}
Relief Route	3.1×10^{-2}	6.4×10^{-2}	3.3×10^{-2}	3.5×10^{-2}

TABLE F.7.2–2.—*Comparison of Annual Truck Accident Fatalities*

ROUTE OPTION	ROUTE SEGMENT	ALTERNATIVE			
		NO ACTION	EXPANDED OPERATIONS	REDUCED OPERATIONS	GREENER
Route Through Santa Fe	U.S. 84/285 to I–25	4.1×10^{-3}	8.2×10^{-3}	4.3×10^{-3}	4.6×10^{-3}
	Remainder of New Mexico	7.2×10^{-2}	1.5×10^{-1}	7.5×10^{-2}	8.0×10^{-2}
Relief Route	U.S. 84/285 and Relief Route	2.3×10^{-3}	4.7×10^{-3}	2.4×10^{-3}	2.6×10^{-3}
	Remainder of New Mexico	7.2×10^{-2}	1.5×10^{-1}	7.6×10^{-2}	8.1×10^{-2}

TABLE F.7.2–3.—*Comparison of Annual Truck Accident Injuries*

ROUTE OPTION	ROUTE SEGMENT	ALTERNATIVE			
		NO ACTION	EXPANDED OPERATIONS	REDUCED OPERATIONS	GREENER
Route Through Santa Fe	U.S. 84/285 to I–25	8.6×10^{-2}	1.8×10^{-1}	9.1×10^{-2}	9.7×10^{-2}
	Remainder of New Mexico	6.4×10^{-1}	1.3×10^{0}	6.8×10^{-1}	7.2×10^{-1}
Relief Route	U.S. 84/285 to I–25	4.9×10^{-2}	9.8×10^{-2}	5.2×10^{-2}	5.5×10^{-2}
	Remainder of New Mexico	6.5×10^{-1}	1.3×10^{0}	6.8×10^{-1}	7.3×10^{-1}

TABLE F.7.2–4.—*Comparison of Number of Annual Truck Accidents*

ROUTE OPTION	ROUTE SEGMENT	ALTERNATIVE			
		NO ACTION	EXPANDED OPERATIONS	REDUCED OPERATIONS	GREENER
Route Through Santa Fe	U.S. 84/285 to I–25	4.1×10^{-1}	8.2×10^{-1}	4.3×10^{-1}	4.6×10^{-1}
	Remainder of New Mexico	6.7×10^{-1}	1.4×10^{0}	7.0×10^{-1}	7.6×10^{-1}
Relief Route	U.S. 84/285 to I–25	2.3×10^{-1}	4.7×10^{-1}	2.4×10^{-1}	2.6×10^{-1}
	Remainder of New Mexico	6.7×10^{-1}	1.4×10^{0}	7.1×10^{-1}	7.6×10^{-1}

TABLE F.7.2–5.—*Comparison of Annual Incident-Free Population Dose for the No Action Alternative*

ROUTE OPTION	ROUTE SEGMENT	OCCUPATIONAL (PERSON-REM/ YEAR)	NONOCCUPATIONAL (PERSON-REM/YEAR)		
			ALONG ROUTE	SHARING ROUTE	STOPS
Route Through Santa Fe	U.S. 84/285 to I–25	7.9×10^{0}	3.8×10^{-1}	3.6×10^{0}	3.3×10^{0}
	Remainder of New Mexico	4.5×10^{1}	1.0×10^{-1}	1.7×10^{0}	2.4×10^{1}
Relief Route	U.S. 84/285 to I–25	1.1×10^{1}	3.8×10^{-1}	2.2×10^{0}	4.8×10^{0}
	Remainder of New Mexico	4.5×10^{1}	1.2×10^{-1}	1.7×10^{0}	2.4×10^{1}

TABLE F.7.2–6.—*Comparison of Annual Incident-Free Population Dose for the Expanded Operations Alternative*

ROUTE OPTION	ROUTE SEGMENT	OCCUPATIONAL (PERSON-REM/ YEAR)	NONOCCUPATIONAL (PERSON-REM/YEAR)		
			ALONG ROUTE	SHARING ROUTE	STOPS
Route Through Santa Fe	U.S. 84/285 to I–25	1.0×10^{1}	4.9×10^{-1}	4.6×10^{0}	4.2×10^{0}
	Remainder of New Mexico	5.5×10^{1}	1.2×10^{-1}	2.1×10^{0}	3.0×10^{1}
Relief Route	U.S. 84/285 to I–25	1.5×10^{1}	4.8×10^{-1}	2.8×10^{0}	6.1×10^{0}
	Remainder of New Mexico	5.5×10^{1}	1.3×10^{-1}	2.1×10^{1}	3.0×10^{1}

TABLE F.7.2–7.—*Comparison of Annual Incident-Free Population Dose for the Reduced Operations Alternative*

ROUTE OPTION	ROUTE SEGMENT	OCCUPATIONAL (PERSON-REM/ YEAR)	NONOCCUPATIONAL (PERSON-REM/YEAR)		
			ALONG ROUTE	SHARING ROUTE	STOPS
Route Through Santa Fe	U.S. 84/285 to I–25	8.7×10^{0}	4.2×10^{-1}	3.4×10^{0}	3.6×10^{0}
	Remainder of New Mexico	5.0×10^{1}	1.2×10^{-1}	1.9×10^{0}	2.7×10^{1}
Relief Route	U.S. 84/285 to I–25	1.2×10^{1}	4.1×10^{-1}	2.4×10^{0}	5.2×10^{0}
	Remainder of New Mexico	5.1×10^{1}	1.3×10^{-1}	1.9×10^{0}	2.7×10^{1}

TABLE F.7.2–8.—*Comparison of Annual Incident-Free Population Dose for the Greener Alternative*

ROUTE OPTION	ROUTE SEGMENT	OCCUPATIONAL (PERSON-REM/ YEAR)	NONOCCUPATIONAL (PERSON-REM/YEAR)		
			ALONG ROUTE	SHARING ROUTE	STOPS
Route Through Santa Fe	U.S. 84/285 to I–25	9.2×10^{0}	4.4×10^{-1}	4.2×10^{0}	3.8×10^{0}
	Remainder of New Mexico	5.2×10^{1}	1.3×10^{-1}	2.0×10^{0}	2.8×10^{1}
Relief Route	U.S. 84/285 to I–25	1.3×10^{1}	4.8×10^{-1}	2.5×10^{0}	5.5×10^{0}
	Remainder of New Mexico	5.3×10^{1}	1.3×10^{-1}	2.0×10^{0}	2.9×10^{1}

TABLE F.7.2–9.—*Comparison of Off-Site Radioactive Materials Release Frequencies*

ROUTE OPTION	ROUTE SEGMENT	FREQUENCY PER TRIP		
		AMERICIUM-241	CH TRU	RH TRU
Route Through Santa Fe	U.S. 84/285 to I–25	2.5×10^{-7}	7.4×10^{-8}	5.6×10^{-9}
	Remainder of New Mexico	9.9×10^{-7}	1.4×10^{-6}	1.3×10^{-7}
Relief Route	U.S. 84/285 to I–25	2.0×10^{-7}	6.8×10^{-8}	6.1×10^{-9}
	Remainder of New Mexico	1.0×10^{-6}	1.4×10^{-6}	1.3×10^{-7}

TABLE F.7.2–10.—*Comparison of Chlorine and Propane Major Release Frequencies*

ROUTE OPTION	ROUTE SEGMENT	FREQUENCY PER TRIP	
		CHLORINE	PROPANE
Route Through Santa Fe	U.S. 84/285 to I–25	9.1×10^{-7}	3.9×10^{-7}
	Remainder of New Mexico	2.0×10^{-6}	1.2×10^{-6}
Relief Route	U.S. 84/285 to I–25	4.6×10^{-7}	2.0×10^{-7}
	Remainder of New Mexico	2.3×10^{-6}	1.1×10^{-6}

TABLE F.7.2–11.—*Comparison of Bounding Radioactive Material Off-Site Accident Population Risk for the No Action Alternative*

ROUTE OPTION	ROUTE SEGMENT	POPULATION RISK (PERSON-REM/YEAR) FOR SHIPMENT TYPES					TOTAL	
		AMERICIUM -241	CH TRU	RH TRU	PLUTONIUM -238	PITS	PERSON-REM/YEAR	EXCESS LCF/ YEAR
Route Through Santa Fe	U.S. 84/285 to I–25	2.4×10^{-1}	1.9×10^{-2}	4.2×10^{-5}	1×10^{-6}	1×10^{-5}	2.6×10^{-1}	1.3×10^{-4}
	Remainder of New Mexico	3.1×10^{-2}	1.2×10^{-2}	2.6×10^{-5}	4×10^{-7}	4×10^{-6}	4.3×10^{-2}	2.2×10^{-5}
Relief Route	U.S. 84/285 to I–25	6.8×10^{-2}	5.6×10^{-3}	1.2×10^{-5}	4×10^{-7}	4×10^{-6}	7.4×10^{-2}	3.7×10^{-5}
	Remainder of New Mexico	8.4×10^{-2}	1.9×10^{-2}	4.2×10^{-5}	4×10^{-7}	4×10^{-6}	1.0×10^{-1}	5.0×10^{-5}

TABLE F.7.2–12.—*Comparison of Bounding Radioactive Materials Off-Site Accident Population Risk for the Expanded Operations Alternative*

ROUTE OPTION	ROUTE SEGMENT	POPULATION RISK (PERSON-REM/YEAR) FOR SHIPMENT TYPES					TOTAL	
		AMERICIUM -241	CH TRU	RH TRU	PLUTONIUM-238	PITS	PERSON-REM/YEAR	EXCESS LCF/ YEAR
Route Through Santa Fe	U.S. 84/285 to I–25	2.5×10^{-1}	2.4×10^{-2}	5.3×10^{-5}	2×10^{-6}	2×10^{-5}	2.7×10^{-1}	1.4×10^{-4}
	Remainder of New Mexico	3.3×10^{-2}	1.6×10^{-2}	3.3×10^{-5}	1×10^{-6}	8×10^{-6}	4.9×10^{-2}	2.4×10^{-5}
Relief Route	U.S. 84/285 to I–25	7.3×10^{-2}	7.3×10^{-3}	1.5×10^{-5}	1×10^{-6}	8×10^{-6}	8.0×10^{-2}	4.0×10^{-5}
	Remainder of New Mexico	9.0×10^{-2}	2.5×10^{-2}	4.9×10^{-5}	1×10^{-6}	8×10^{-6}	1.2×10^{-1}	6.0×10^{-5}

TABLE F.7.2–13.—*Comparison of Bounding Radioactive Materials Off-Site Accident Population Risk for the Reduced Operations Alternative*

ROUTE OPTION	ROUTE SEGMENT	POPULATION RISK (PERSON-REM/YEAR) FOR SHIPMENT TYPES					TOTAL	
		AMERICIUM -241	CH TRU	RH TRU	PLUTONIUM -238	PITS	PERSON-REM/YEAR	EXCESS LCF/ YEAR
Route Through Santa Fe	U.S. 84/285 to I–25	2.4×10^{-1}	1.9×10^{-2}	4.0×10^{-5}	1×10^{-6}	8×10^{-6}	2.6×10^{-1}	1.3×10^{-4}
	Remainder of New Mexico	3.1×10^{-2}	1.2×10^{-2}	2.5×10^{-5}	4×10^{-7}	4×10^{-6}	4.3×10^{-2}	2.2×10^{-5}
Relief Route	U.S. 84/285 to I–25	6.8×10^{-2}	5.6×10^{-3}	1.2×10^{-5}	4×10^{-7}	2×10^{-6}	7.4×10^{-2}	3.7×10^{-5}
	Remainder of New Mexico	8.4×10^{-2}	1.9×10^{-2}	4.0×10^{-5}	4×10^{-7}	4×10^{-6}	1.0×10^{-1}	5.0×10^{-5}

TABLE F.7.2–14.—*Comparison of Bounding Radioactive Materials Off-Site Accident Population Risk for the Greener Alternative*

ROUTE OPTION	ROUTE SEGMENT	POPULATION RISK (PERSON-REM/YEAR) FOR SHIPMENT TYPES					TOTAL	
		AMERICIUM-241	CH TRU	RH TRU	PLUTONIUM-238	PITS	PERSON-REM/YEAR	EXCESS LCF/ YEAR
St. Francis Drive	U.S. 84/285 to I–25	2.5×10^{-1}	2.0×10^{-2}	4.4×10^{-5}	1×10^{-6}	8×10^{-6}	2.7×10^{-1}	1.4×10^{-4}
	Remainder of New Mexico	3.3×10^{-2}	1.3×10^{-2}	2.7×10^{-5}	4×10^{-7}	4×10^{-6}	4.6×10^{-2}	2.3×10^{-5}
Relief Route	U.S. 84/285 to I–25	7.3×10^{-2}	5.9×10^{-3}	1.3×10^{-5}	4×10^{-7}	2×10^{-6}	7.9×10^{-2}	4.0×10^{-5}
	Remainder of New Mexico	9.0×10^{-2}	2.0×10^{-2}	4.3×10^{-5}	4×10^{-7}	4×10^{-6}	1.1×10^{-1}	5.5×10^{-5}

alternatives. The change in injury and fatality risks of major releases of chlorine and propane is shown in Tables F.7.2–15 through F.7.2–18 for the four SWEIS alternatives. The RADTRAN results in Tables F.7.2–11 through F.7.2–14 show a major increase for the remainder of New Mexico route segment, but the ADROIT results show no change. The difference in these sets of results is due to the difference in the way the portion of I–25 between exits 276 and 282 was modeled in the two computer programs. All of the RAM shipments analyzed in Tables F.7.2–11 through F.7.2–14, as well as chlorine shipments in Tables F.7.2–15 through F.7.2–18, are expected to follow I–25 north for 6 miles further with the relief route option than for the route through Santa Fe, in contrast to propane shipments that would go south on I–25 and experience 6 miles less travel on I–25. The RADTRAN, chlorine, and propane analyses are based on the conservative assumption that the 6 miles on I–25 are in an area with a population density characteristic of suburban areas. The changes in the remainder of New Mexico values for americium-241, CH TRU, RH TRU, chlorine, and propane are therefore somewhat exaggerated. The changes for the 6 miles on I–25 are accurately computed in the ADROIT analysis of plutonium-238 and pits, but are tabulated in the U.S. 84/285 to I–25 route segment rather than the remainder of New Mexico route segment. The ADROIT computer code has the capability to access population data at the census block level.

F.8 UNCERTAINTY AND CONSERVATISM IN THE ANALYSIS

The major steps in the transportation risk analysis are as follows:

- Determination of the amount and characteristics of materials that will be needed or generated and thus moved to or from the LANL site.
- Estimation of the amount per shipment (e.g., packaging requirements and efficiency of truck capacity utilization, which may conflict with other logistics considerations such as storage requirements until a truck can be filled).
- Determination of the bounding material in a category and the number of shipments of this and similar materials that should be aggregated for frequency analysis.
- Selection of appropriate origin and destination and determination of the route and its characteristic population, accident rate, etc.
- Estimation of package release probabilities.
- Estimation of the amount released from the packaging and the fraction airborne that is respirable.
- Calculation of dispersion, exposure, and health effect.

Uncertainties are associated with each step. The overall approach to dealing with uncertainty is to estimate conservative values for parameters and to estimate consistently. On the other hand, estimates are not knowingly chosen to be conservative by orders of magnitude because that approach could obscure differences between alternatives. The focus of this analysis was on shipments that could contribute significantly to the transportation risk. The total number of shipments is important, as are the shipments of large amounts of dispersible and toxic material. The following subsections contain descriptions of sources of uncertainty and the resulting conservatism for each of the major analysis steps. Emphasis is placed on uncertainty unique to the SWEIS.

F.8.1 Material Amount and Characterization

Because a detailed analysis of every type of LANL shipment would be impractical, shipments of similar types were aggregated on the basis of the most hazardous material.

TABLE F.7.2–15.—*Comparison of Major Chlorine and Propane Accident Risks for the No Action Alternative*

ROUTE OPTION	ROUTE SEGMENT	CHLORINE		PROPANE	
		FATALITIES PER YEAR	INJURIES PER YEAR	FATALITIES PER YEAR	INJURIES PER YEAR
Route Through Santa Fe	U.S. 84/285 to I–25	2.9×10^{-4}	1.1×10^{-3}	1.5×10^{-4}	6.0×10^{-4}
	Remainder of New Mexico	5.2×10^{-5}	1.9×10^{-4}	1.2×10^{-4}	4.8×10^{-4}
Relief Route	U.S. 84/285 to I–25	4.2×10^{-5}	1.6×10^{-4}	4.4×10^{-5}	1.7×10^{-4}
	Remainder of New Mexico	8.4×10^{-5}	3.2×10^{-4}	7.4×10^{-5}	3.0×10^{-4}

TABLE F.7.2–16.—*Comparison of Major Chlorine and Propane Accident Risks for the Expanded Operations Alternative*

ROUTE OPTION	ROUTE SEGMENT	CHLORINE		PROPANE	
		FATALITIES PER YEAR	INJURIES PER YEAR	FATALITIES PER YEAR	INJURIES PER YEAR
Route Through Santa Fe	U.S. 84/285 to I–25	6.4×10^{-4}	2.4×10^{-3}	3.3×10^{-4}	1.3×10^{-3}
	Remainder of New Mexico	1.1×10^{-4}	4.2×10^{-4}	2.6×10^{-4}	1.1×10^{-3}
Relief Route	U.S. 84/285 to I–25	9.4×10^{-5}	3.6×10^{-4}	9.6×10^{-5}	3.8×10^{-4}
	Remainder of New Mexico	1.9×10^{-4}	7.0×10^{-4}	1.6×10^{-4}	6.6×10^{-4}

TABLE F.7.2–17.—*Comparison of Major Chlorine and Propane Accident Risks for the Reduced Operations Alternative*

ROUTE OPTION	ROUTE SEGMENT	CHLORINE		PROPANE	
		FATALITIES PER YEAR	INJURIES PER YEAR	FATALITIES PER YEAR	INJURIES PER YEAR
Route Through Santa Fe	U.S. 84/285 to I–25	2.7×10^{-4}	1.0×10^{-3}	1.4×10^{-4}	5.7×10^{-4}
	Remainder of New Mexico	4.8×10^{-5}	1.8×10^{-4}	1.1×10^{-4}	4.5×10^{-4}
Relief Route	U.S. 84/285 to I–25	3.9×10^{-5}	1.5×10^{-4}	4.1×10^{-5}	1.6×10^{-4}
	Remainder of New Mexico	7.8×10^{-5}	3.0×10^{-4}	7.1×10^{-5}	2.8×10^{-4}

TABLE F.7.2–18.—*Comparison of Major Chlorine and Propane Accident Risks for the Greener Alternative*

ROUTE OPTION	ROUTE SEGMENT	CHLORINE		PROPANE	
		FATALITIES PER YEAR	INJURIES PER YEAR	FATALITIES PER YEAR	INJURIES PER YEAR
Route Through Santa Fe	U.S. 84/285 to I–25	2.9×10^{-4}	1.1×10^{-3}	1.5×10^{-4}	6.0×10^{-4}
	Remainder of New Mexico	5.2×10^{-5}	1.9×10^{-4}	1.2×10^{-4}	4.8×10^{-4}
Relief Route	U.S. 84/285 to I–25	4.2×10^{-5}	1.6×10^{-4}	4.4×10^{-5}	1.7×10^{-4}
	Remainder of New Mexico	8.4×10^{-5}	3.2×10^{-4}	7.5×10^{-5}	3.0×10^{-4}

Chemicals were grouped in classes of materials such as flammable materials. RAMs were grouped in many more categories. First, general categories such as LLW, pits, samples, and irradiated targets were used. Then the general categories were divided into groups within which significant packaging differences could occur. For example, LLMW transported on site was aggregated into three groups: materials likely to be packaged in 55-gallon drums, materials likely to be transported in bulk, such as in covered dump trucks (soil and debris), and materials likely to be transported in 96-cubic foot boxes (contaminated lead and non-RCRA waste).

The incident-free risk is proportional to the TI value. The maximum legal value of 10 millirem was used unless there were data to the contrary. The conservatism in TI estimation is significant because most shipments are much less than the regulatory maximum.

Some small shipments are likely to have been missed. For example, on-site shipment of small quantities of special nuclear materials and chemicals are thought to have been overlooked in the data-gathering activity. These small shipments have no effect on the risk of bounding accidents and would contribute little to the incident-free and truck-related risk measures. The net effect is a significantly conservative estimate.

F.8.2 Amount per Shipment

In almost all cases, the number of packages per shipment was selected as less than full use of the truck capacity. In the case of contaminated laundry, for example, the current one truckload per week (sometimes with less than full capacity) is assumed to continue and the number of laundry bags is assumed to vary with alternative and with week-to-week and year-to-year variability in operations. The only exception to weekly shipments is that the increase for the expanded alternative was large enough to change the projection from a shipment every five working days to one every three working days.

Another example of less than full truck capacity is the case of LLW transported off-site. A waste volume equivalent to 65, 55-gallon drums, with an 80 percent volume utilization, was used for both LLMW and for LLW consisting of soil and debris. A tractor-trailer can hold 80 drums if weight limits are not exceeded. The volume per shipment, 389 cubic feet (10.9 cubic meters), also corresponds to that of a standard covered dump truck, but larger trucks could also be used. LLMW would likely go to several facilities, and full truck loads could be impractical. On the other hand, soil and debris would likely go to the same facility (in a given time frame), and full shipments would be a realistic expectation.

The objectives were to be conservative, but not overly so, in estimating amounts per shipment and to be consistent across alternatives.

F.8.3 Bounding Materials

It is impractical to compute the accident risk from every shipment. As described in subsection F.6.5.1, the approach is to select bounding materials for consequence analysis. Selection of the bounding materials was based on quantity, dispersibility, and health effects. Selection of bounding chemicals was straightforward: the toxic or flammable bulk gases are the obvious primary candidates. Highly dispersible actinides are the primary candidates for RAM; dispersion is enhanced by the physical form; e.g., powder, or by the presence of another dispersion-causing material; e.g., explosives. Highly irradiated materials are in a separate category, as are fissile materials.

Estimates of the number of bounding shipments are less straightforward because the frequency of shipments of similar materials should also be included. Obviously, shipments of materials that are slightly less dangerous than the bounding material should contribute to the frequency component of risk. The question is, how much less dangerous? As described in subsection F.6.5.1, the measure of danger chosen was the amount of material, and if the amount exceeded 10 percent of the bounding amount, then the shipment was counted in the frequency term. This is a conservative approach. The term “amount” for RAM was considered as the product of the weight in grams, the respirable airborne release fraction, and the health risk conversion factor of rem per gram.

F.8.4 Origin and Destination

A major simplification was the aggregation of the numerous origin and destination cities (other than the LANL site) to only a few cities. Doing otherwise would have been impractical. The methodology introduced major conservatism in the route length of most shipments. The centroid city of each of the five regions was chosen so that the great majority of shipments were going to a city no farther away than the one chosen. First, the average HAZMAT shipping distance was determined for historical large shipments. Then a city in the northeast (toxic), southeast (explosives), and southwest (flammable) that was at that average shipping distance or farther from LANL was chosen. The conservatism introduced for HAZMAT shipments is likely much less than that for RAM shipments, because an average distance was computed for HAZMAT shipments, and a near-upper-bound distance was chosen on the basis of historical shipments for the RAM shipments.

The choice of SRS for the southeast centroid, when material has historically also been shipped to Florida, illustrates the logic underlying the choice of a near-upper-bound distance. Portions of Florida are farther from LANL than is SRS. However, approximately 94 percent of the historical ground shipments are to destinations no farther from LANL than is the SRS, and approximately 80 percent are to destinations significantly closer than the SRS. Therefore, choosing the upper bound distance (Florida) would be overly conservative because only about 6 percent of the shipments actually go to Florida. The logical choice is the near-upper-bound distance to the SRS.

Given the chosen city, no special conservatism was introduced when choosing other factors such as route, population density, or accident rate.

F.8.5 Package Release Probability

The package release probability is based on performance requirements for all packages of a given type (e.g., Type B). The package release probability used in this analysis would correspond to the release probability of a package meeting the minimum performance requirements for its type. The conservatism would have to be quantified on a package-specific basis and such quantification would require substantial analyses.

F.8.6 Package Release Fractions and Respirable Airborne Release Fractions

The package release fraction is also based on performance for all packages of a given type, and the conservatism would have to be quantified for a specific package and contents.

The respirable airborne release fraction used for analysis for general commerce shipments corresponds to that for a loose, noncombustible powder that suddenly loses all barriers preventing its release (i.e., its packaging suddenly becomes equivalent to an open-top container). In fact, the actual powder is not loose, but compressed, and the packaging is unlikely to fail such that a line-of-sight opening develops. Rather, realistic package failures are more likely to produce an indirect path to the environment that would significantly reduce the fraction that could be made airborne and respirable in the environment. The respirable airborne release fraction used is estimated to be conservative by several orders of magnitude. Further definite quantitative refinement of the value used is not practical given the variety of packaging and release mechanisms considered.

F.8.7 Dispersion and Exposure

Standard dispersion computer programs (RADTRAN, ADROIT, DEGADIS, and ALOHA™) were used with the programs' default or recommended meteorological input. To establish population densities, most exposure calculations were based on census data; time-of-day variation could increase or decrease these values. The chlorine accident escape fraction and propane accident shielding fractions are intended to be average values, but few data are available to support the values used. The MEI doses are intended to be upper bounds for the default meteorological conditions.

F.8.8 Summary

Four risk measures (section F.3) are used in this appendix and each has a consequence and a frequency component. Although the uncertainties described previously do not apply uniformly to the eight risk components, a general statement can be made that each risk component is much more likely to be significantly conservative than to be slightly not conservative enough. This statement applies to all alternatives. A major ramification of the conservatism is that shipments in addition to those described in Tables F.5.3–1 and F.5.3.2–3 are enveloped by the present analysis.

REFERENCES

Anonymous 1990 "Usher Transport Includes Customers, Others in Overall Safety Programs." *Modern Bulk Transporter*. Vol. 52, No. 12, pp. 36-43. June 1990.

Anonymous 1994 "Manfredi Motor Transit Company Wins Back-To-Back Safety Awards." *Modern Bulk Transporter*. Vol. 56, No. 11, pp. 92-98. May 1994.

BAA 1993 *Emergency Evacuation/Transportation Plan Update: Traffic Model Development and Evaluation of Early Closure Procedures*. Barton-Aschman Associates, Inc. Albuquerque, New Mexico. October 28, 1993.

Barklay 1983 *Safety Analysis Report for Packaging (SARP) for the Mound 1-kW Package*, Revision 5. C. D. Barklay. EG&G Mound Applied Technologies. MLM-MU-91-64-001. Miamisburg, Ohio. 1983.

Clarke et al. 1976 *Severities of Transportation Accidents*. R. K. Clarke et al. Sandia National Laboratories. SLA-74-0001. Albuquerque, New Mexico. July 1976.

Cruse 1992 *Test and Evaluation Document for DOT Specification 7A Type A Packaging.* J. M. Cruse. Westinghouse Hanford Company. WHC-EP-0558. Richland, Washington. June 1992.

Dennis et al. 1978 *Severities of Transportation Accidents Involving Large Packages*. A. W. Dennis et al. Sandia National Laboratories. SAND-77-0001. Albuquerque, New Mexico. 1978.

DOE 1990 *Waste Isolation Pilot Plant Disposal Phase Supplemental Environmental Impact Statement.* U.S. Department of Energy, Albuquerque Operations Office. DOE/EIS-0026-S1. Albuquerque, New Mexico. 1990.

DOE 1994a *Framework for Assessing the Effects of Radioactive Materials Transportation in Defense Programs NEPA Documents*, Revised Draft. U.S. Department of Energy, Office of Defense Programs. Washington, D.C. June 1994.

DOE 1994b *Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities.* U.S. Department of Energy. DOE Handbook 3010-94. Washington, D.C. October 1994.

DOE 1995 *Dual Axis Radiographic Hydrodynamic Test Facility Final Environmental Impact Statement*. U.S. Department of Energy, Albuquerque Operations Office and Los Alamos Area Office. DOE/EIS-0228. Albuquerque, New Mexico. August 1995.

DOE 1996a — *The Environmental Impact Statement for the Nevada Test Site and Off-Site Locations in the State of Nevada*, Draft. Vol. I, Appendix I, "Transportation Study." U.S. Department of Energy, Nevada Operations Office. DOE/EIS-0243. Las Vegas, Nevada. January 1996.

DOE 1996b — *Final Programmatic Environmental Impact Statement for Stockpile Stewardship and Management.* U.S. Department of Energy. DOE/EIS-0236. Washington, D.C. September 1996.

DOE 1996c — *Final Environmental Impact Statement for the Continued Operation of the Pantex Plant and Associated Storage of Nuclear Weapon Components.* Appendix F, "Transportation Risk Analysis." U.S. Department of Energy. DOE/EIS-0225. Washington, D.C. November 1996.

DOE 1998 — *Final Environmental Impact Statement on Management of Certain Plutonium Residues and Scrub Alloy Stored at the Rocky Flats Environmental Technology Site.* U.S. Department of Energy. DOE/EIS-0277. August 1998.

DOT 1992 — *FAA Statistical Handbook of Aviation: Calendar Year 1992.* U.S. Department of Transportation, Federal Aviation Administration. FAA APO-94-5. Washington, D.C. 1992.

DOT 1995a — *Traffic Safety Facts 1994: A Compilation of Motor Vehicle Crash Data from the Fatal Accident Reporting System and the General Estimates System.* U.S. Department of Transportation, National Highway Traffic Safety Administration. DOT HS 808 292. Washington, D.C. August 1995.

DOT 1995b — *Hazardous Materials, Transportation Regulations: Compatibility with Regulations of the International Atomic Energy Agency, Final Rule.* 60 FR (188) 50297. 1995.

Fenner 1995 — Letter from H. Allen Fenner, Transportation Planning Division, New Mexico Highway and Transportation Department, to Joe Matlock. Santa Fe, New Mexico. November 13, 1995.

Fenner 1996 — Letter from H. Allen Fenner, Transportation Planning Division, New Mexico State Highway Department, to W. R. Rhyne. Santa Fe, New Mexico. January 17, 1996

Glickman and Raj 1992 — "A Comparison of Theoretical and Actual Consequences in Two Fatal Ammonia Accidents." T. A. Glickman and P. K. Raj. *Transportation of Dangerous Goods: Assessing the Risks.* F. Frank Saccomanno and Keith Cassidy, eds. Institute for Risk Research, University of Waterloo. Ontario, Canada. 1992.

Green et al. 1996	*Hanford Site Truck Accident Rate, 1990–1995*. J. R. Green, B. D. Flanagan, and H. W. Harris. Westinghouse Hanford Company. WHC-SD-TP-RPT-021. Richland, Washington. March 1996.
Harwood and Russell 1990	*Present Practices of Highway Transportation of Hazardous Materials*. D. W. Harwood and E. R. Russell. U.S. Department of Transportation. FHWA-RD-89-0134. Washington, D.C. 1990.
Havens and Spicer 1985	*Development of an Atmospheric Dispersion Model for Heavier-than-Air Gas Mixtures*. J. A. Havens and T. O. Spicer. U.S. Coast Guard. CG-D-22-85. Washington, D.C. 1985.
ICRP 1991	*Recommendations of the International Commission on Radiological Protection*. International Commission on Radiological Protection. ICRP Publication No. 60. Pergamon Press. New York. 1991.
Johnson et al. 1993	*HIGHWAY 3.1 + An Enhanced Highway Routing Model: Program Description, Methodology, and Revised User's Manual.* P. E. Johnson, D. S. Joy, D. B. Clarke, and J. M. Jacobi. Oak Ridge National Laboratory. ORNL/TM-12124. Oak Ridge, Tennessee. March 1993.
LLNL 1987	*Shipping Container Response to Severe Highway and Railway Accident Conditions*. L. E. Fischer et al. Lawrence Livermore National Laboratory. NUREG/CR-4829. Livermore, California. 1987.
Neuhauser and Kanipe 1992	*RADTRAN 4, Volume III: User Guide.* K. S. Neuhauser and F. L. Kanipe. Sandia National Laboratories. SAND89-2370. Albuquerque, New Mexico. January 1992.
Neuhauser and Kanipe 1995	*RADTRAN 4, Volume II: Technical Manual.* K. S. Neuhauser and F. L. Kanipe. Sandia National Laboratories. SAND89-2370. Albuquerque, New Mexico. 1995.
NRC 1977	*Final Environmental Statement on the Transportation of Radioactive Materials by Air and Other Modes.* U.S. Nuclear Regulatory Commission. NUREG-0170. Washington, D.C. December 1977.
NSC 1995	*ALOHA™ + Areal Locations of Hazardous Atmospheres, User's Manual.* National Safety Council. Itasca, Illinois. 1995.
OTA 1988	*Gearing Up for Safety: Motor Carrier Safety in a Competitive Environment.* Congress of the United States of America, Office of Technology Assessment. OTA-SET-382. Washington, D.C. 1988.

Phillips et al. 1994 *Determination of Influence Factors and Accident Rates for the Armored Tractor/ Safe Secure Trailer.* J. S. Phillips, D. B. Clauss, and D. F. Blower. Sandia National Laboratories. SAND93-0111. Albuquerque, New Mexico. 1994.

PNL 1980 *An Assessment of the Risk of Transporting Propane by Truck and Train*. C. A. Geffen et. al. Pacific Northwest Laboratory. PNL-3308. Richland, Washington. 1980.

Rao et al. 1982 *Non-Radiological Impacts of Transporting Radioactive Material*. R. K. Rao, E. L. Wilmot, and R. E. Luna. Sandia National Laboratories. DE8-2012844. Albuquerque, New Mexico. February 1982.

Rhyne 1985 *Probabilistic Analysis of Chemical Agent Release During Transport of M55 Rockets*. W. R. Rhyne. U.S. Department of the Army. M55-CD-4. Available from the Defense Technical Information Center. Washington, D.C. 1985.

Rhyne 1994a *Hazardous Materials Transportation Risk Analysis: Quantitative Approaches for Truck and Train*. W. R. Rhyne. Van Nostrand Reinhold. New York, New York. 1994.

Rhyne 1994b *Risk Management of the Transport of Irradiated Targets from LAMPF to TA-48.* W. R. Rhyne. H&R Technical Associates. SM-BUS-6-TQC-53.0. Oak Ridge, Tennessee. July 1994

Rhyne 1997 Correspondence from W. R. Rhyne, H&R Technical Associates, to C. A. Cruz, U.S. Department of Energy. September 11, 1997.

Saricks and Kvitek 1994 *Longitudinal Review of State-Level Accident Statistics for Carriers of Interstate Freight.* C. Saricks and T. Kvitek. Argonne National Laboratory. ANL/ESD/ TM-68 (DE94-016625). Argonne, Illinois. March 1994.

SSEB 1994 *Transuranic Waste Transportation Handbook.* Southern States Energy Board. Prepared under U.S. Department of Energy Cooperation Agreement DE-FC04-93AL82966. Norcross, Georgia. 1994.

Vigil 1996 Letter from Alvaro Vigil, Transportation Planning Division, New Mexico State Highway and Transportation Department, to W. R. Rhyne, H&R Technical Associates. Santa Fe, New Mexico. January 25, 1996.

Villa 1996 Presentation Viewgraph from SWEIS Transportation Workshop. Sandra A. Villa. Los Alamos National Laboratory. Los Alamos, New Mexico. September 24, 1996.

Wangler 1995	*U.S. Department of Energy Certificate of Compliance for Radioactive Materials Packages*. M. E. Wangler. U.S. Department of Energy. Certificate No. 9932. Washington, D.C. December 1, 1995.
Wangler 1996	*U.S. Department of Energy Certificate of Compliance for Radioactive Materials Packages.* M. E. Wangler. U.S. Department of Energy. Certificate No. 5320. Washington, D.C. March 25, 1996.
WGA and DOE 1995	*WIPP Transportation Safety Program Implementation Guide.* Western Governors' Association Technical Advisory Group for WIPP Transport and the U.S. Department of Energy, Carlsbad Area Office. Carlsbad, New Mexico. November 1995.
Wilson 1990	"Enterprise Transportation Wins Big with Daily Focus on Fleet Safety." C. E. Wilson. *Modern Bulk Transporter.* Vol. 52, No. 12, pp. 24-34. 1990.