US Exhibit 8

Final Environmental Statement on the Transportation of Radioactive Material by Air and Other Modes (NRC 1977)

NUREG-0170
VOL. 1

FINAL ENVIRONMENTAL STATEMENT ON THE TRANSPORTATION OF RADIOACTIVE MATERIAL BY AIR AND OTHER MODES

Docket No. PR-71, 73 (40 FR 23768)

December 1977

Office of Standards Development
U. S. Nuclear Regulatory Commission

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UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

December 1977

Docket No. PR-71, 73 (40FR23768)

TO RECIPIENTS OF THE TRANSPORTATION
FINAL ENVIRONMENTAL STATEMENT (NUREG-0170)

Enclosed for your information is a final environmental statement dealing with the transportation of radioactive material by air and other modes. The document has been prepared in support of the Nuclear Regulatory Commission's advanced notice of rule making proceeding published in the Federal Register on June 2, 1975 (40FR23768), a copy of which is enclosed for your use.

Pursuant to the National Environmental Policy Act of 1969 and the Commission's regulations in 10 CFR Part 51 "Licensing and Regulatory Policy and Procedures for Environmental Protection," the Commission's Office of Standards Development issued a draft environmental statement on Transportation in March, 1976. After consideration of the 28 letters of comment received from the public and from Federal, State and local agencies, a final environmental statement on the Transportation of Radioactive Material by Air and Other Modes has been issued and designated NUREG-0170.

Taking into account the conclusions of the final environmental statement, public comments received on the proceeding, and other information, the Nuclear Regulatory Commission will consider the disposition of the rule making proceeding announced on June 2, 1975. Persons with views on the content or conclusions of the final environmental statement which may be helpful to the Commission in its deliberation should file such comments by March 15, 1978, with the U. S. Nuclear Regulatory Commission, Washington, D. C. 20555, Attention: Director, Office of Standards Development. If sufficient need for clarification of the final environmental statement becomes apparent, the Office of Standards Development will consider holding one or more public meetings for this purpose.

Robert B. Minogue

Robert B. Minogue, Director
Office of Standards Development

Enclosures:
1. Advanced Notice of Rule Making Proceeding
2. Final Environmental Statement

NUCLEAR REGULATORY COMMISSION

[10 CFR Parts 71 and 73]

RADIOACTIVE MATERIAL

Packaging and Transportation by Air

Following its organization under the Energy Reorganization Act of 1974 (Public Law 93-438), the Nuclear Regulatory Commission (NRC) has stated its intention of reviewing those of its regulations and procedures pertaining to the licensing and regulation of nuclear facilities and materials which were originally promulgated by the Atomic Energy Commission, with a view to considering what changes should be made. As part of that effort, the NRC is initiating a rule making proceeding concerning the air transportation of radioactive materials, including packaging, with a view to the possible amendment of its regulations in 10 CFR Parts 71 and 73, adopted pursuant to the Atomic Energy Act of 1954, as amended. The NRC considers the reevaluation of these particular regulations to be especially timely in view of concerns that have been recently expressed by public officials and others as to the safety and security of air shipment of plutonium and other special nuclear materials through highly populated metropolitan areas.

The Department of Transportation (DOT) has overlapping jurisdiction over safety in packaging and transportation by air of radioactive materials under the Transportation of Explosives and Other Dangerous Materials Act (18 U.S.C. 831–835) and the Transportation Safety Act of 1974 (Pub. L. 93–633, 88 Stat. 2156), and the Federal Aviation Administration has similar overlapping jurisdiction under the Federal Aviation Act of 1958 (49 U.S.C. 1421–1430, 1472(b)). It is expected that the expertise of these agencies will be utilized in the subject rule making proceeding.

Background of present regulations. Following a prohibition against shipment of radioactive material by mail in 1936 to protect unexposed film, safety regulations for shipping radioactive material were adopted by the Interstate Commerce Commission in 1948. Those regulations were based on a report of a National Academy of Sciences–National Research Council Subcommittee on Transportation of Radioactive Material. The basic principles reflected in those regulations were reviewed and adopted, with minor modifications and some elaboration, by the International Atomic Energy Agency (IAEA) in 1961 and reflected in recommended International Standards for the Safe Transport of Radioactive Material. In 1964, on the basis of shipping experience up to that date and an analysis of transportation accidents prepared by the United Kingdom Atomic Energy Authority, the IAEA issued revised transport regulations incorporating specific accident damage test standards which were incorporated into the NRC (then AEC) and DOT (then within the jurisdiction of the ICC) regulations by 1968. Except for changes in the regulations to deal with specific problems (e.g., leak testing of packages containing liquids, prompt pickup and monitoring of packages, restrictions on shipments of plutonium on passenger aircraft, opening and closing procedures), the safety regulations have remained essentially the same since that time.

The safety standards for transportation, as set forth in NRC's regulation in 10 CFR Part 71 and DOT regulations in 49 CFR Parts 170–178, are based on two main considerations: (1) Protection of the public from external radiation and (2) assurance that the contents are unlikely to be released during either normal or accident conditions of transport or, if the container is not designed to withstand accidents, that its contents are so limited in quantity as to preclude a significant radiation safety problem if released. These safety standards are applicable to packages used in all models of transport and were developed with the objective of providing an acceptable level of safety for transport of radioactive material by any mode.[1] With respect to air shipments, it was considered that, taking into account the high integrity of the packaging[2] and the low accident probability for air transportation (no more than one accident per 100 million miles, the risk of an air accident resulting in a release of radioactive material from a package was small.

NRC packaging standards are applicable to shipments by NRC licensees, while DOT regulations are applicable to transportation of radioactive material by land in interstate and foreign commerce, on civil aircraft, and on water. DOT regulations in Title 49 of the Code of Federal Regulations and FAA regulations in 14 CFR Part 103 cover labeling and conditions for shipment and carriage as well as certain packaging. NRC regulations exempt carriers from their application in view of the controls exercised over carriers by DOT and its component parts, including FAA.

For the purpose of developing and implementing consistent, comprehensive and effective regulations for the safe transport of radioactive material and to avoid duplication, the DOT (then ICC) and the AEC (NRC's predecessor) entered into a Memorandum of Understanding in 1966 which was superseded by a revised Memorandum of Understanding signed on March 22, 1973. Under the revised memorandum, the AEC (now NRC) develops performance standards for package designs and reviews package designs for Type B[3] fissile and large quantity packages. The DOT develops safety standards governing handling and storage of all radioactive material packages while in possession of a common, contract or private carrier, as well as standards for Type A packages.[4] DOT requires AEC (now NRC) approval prior to use of all Type B, fissile and large quantity package designs. DOT is the National Competent Authority with respect to foreign shipments under the IAEA transport standards. IAEA Certificates of Competent Authority are issued by DOT with technical assistance provided by NRC as requested.

Re-evaluation of present regulations. Consistent with the considerations expressed in the first paragraph of this notice, the NRC has decided that its regulations governing air transportation of radioactive material, including packaging, should be re-evaluated from the standpoint of radiological health safety and prevention of diversion and sabotage as well. In connection with this re-evaluation, the NRC has instructed its staff to commence preparation of a generic environmental impact statement on the air transportation of radioactive materials, including packaging and related ground transportation. The statement will be directed at air transportation. However other transportation modes—land and water transport—will be considered in light of the requirement of the National Environmental Policy Act of 1969 (NEPA) that the relative costs and benefits of alternatives to certain proposed Federal actions be fully considered. It is anticipated that the draft generic environmental impact statement will be available by the time that any proposed changes to the regulations eventuating from this rule making proceeding are published for comment in the FEDERAL REGISTER. While the generic impact statement is in preparation, impact statements or impact appraisals for individual NRC licensing actions related to the transportation of radioactive materials, such as import licenses for significant quantities of plutonium and other special nuclear material, will be prepared as required by NEPA and 10 CFR Part 51.

In order to aid the NRC in this re-evaluation of existing regulations pertaining to radioactive material transported by air, interested persons are invited to submit information, comments and suggestions with respect to those aspects of the above-referenced NRC regulations. The NRC is particularly interested in receiving views on the following:

1. Whether radioactive materials should continue to be transported by air, considering the need for, and the benefits derived from such transportation, the risks to public health and safety and the common defense and security associated with such transportation, and the relative risks and benefits of other modes of transport.

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[1] In contrast to the safety standards described above, NRC's requirements for the physical protection (security) of strategic quantities of special nuclear material, including plutonium, in 10 CFR Part 73, are specific as to the mode of transport.

[2] Container designs required to meet accident conditions are evaluated under current regulations against the following accident test conditions in sequence: 30-foot free drop of the container in the most damaging position onto a flat, essentially unyielding surface, 40-inch drop onto a steel bar to test the ability to withstand puncture, 30-minute fire test at 1475° F and 3-foot water immersion test for eight hours. The puncture test and the drop test are engineering qualification tests. The test conditions were chosen to provide reproducible laboratory conditions representative of severe transportation accident environments. For example, a 30-foot drop onto an unyielding surface produces impact or shock loads which are more severe than drops of several thousand feet onto targets such as land, water, or even city streets which would tend to yield when struck by the package. Because of the conservatism of most designs, packages, when subjected to tests involving free fall from much greater heights than 30-feet, have either remained undamaged or continued to contain their contents. For example, a number of packages which pass the NRC qualification tests have also been tested under extra severe conditions such as a 250-foot free fall onto an essentially unyielding surface. Packages currently approved for bulk shipment of plutonium oxide and nitrate will survive such test conditions. These extra severe tests provide added assurance that containers in much the same manner as aircraft flight recorders, could survive severe air accidents. A description of these tests is set forth in SC-DR-72 0597 (Sept. 1972), "Special Tests for Plutonium Shipping Containers 6M, SP5795, and L-10", a copy of which is available for public inspection at the Commission's Public Document Room, 1717 H Street NW., Washington, D.C.

[3] A Type B package is required for quantities in excess of a few millicuries and up to 20,000–50,000 curies, depending upon the radionuclide. Such packages are required to be designed to withstand accident conditions as well as normal conditions of transport.

[4] A Type A package is required for less than Type B quantities of radioactive material and is required to be designed to withstand normal conditions of transport only.

2. Assuming a justifiable need for air transportation of radioactive materials, to what extent should safety requirements be based on:

(a) Accident probabilities;
(b) Packaging;
(c) Procedural controls;
(d) Combinations of the above?

3. What is the relative risk of transport of radioactive material by air compared to other modes of transport, and to other hazards faced by the public which may or may not be the subject of regulation?

4. Are improvements in applicable regulations necessary, and if so, what improvements should be considered?

Documentation supporting the views expressed by interested persons would be helpful to the NRC in re-evaluation of its regulations relating to air transportation of radioactive materials and consideration of possible changes to such regulations.

It should be noted that there are some related issues which will be, or are presently, the subject of consideration in other rule making proceedings and, therefore, will not be included in this proceeding. They are:

1. Physical security protection requirements for strategic quantities of special nuclear material that would apply to all modes of transport (39 FR 40036).

2. Requirements for advance notice of shipments of strategic quantities of special nuclear material (40 FR 15098).

3. Quality assurance requirements for packages for all special nuclear material (38 FR 35190).

4. Radiation levels from radioactive material transported in passenger aircraft.

If it subsequently appears that additional issues should more properly be treated in a separate proceeding, or proceedings, appropriate notices to that effect will be published in the FEDERAL REGISTER.

Interested persons should send comments and suggestions, with supporting documentation, to the Secretary of the Commission, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555, Attention: Docketing and Service Section by August 1, 1975. Copies of comments received may be examined in the NRC Public Document Room at 1717 H Street NW., Washington, D.C.

After comments have been received and considered, the NRC will publish its views as to NRC rules pertaining to air transportation of radioactive material in the FEDERAL REGISTER. When the aforementioned draft environmental impact statement is prepared, notice of its availability will be published in the FEDERAL REGISTER and opportunity for public comment afforded pursuant to NRC regulations implementing the National Environmental Policy Act of 1969 (10 CFR Part 51). In addition, background information on the subject of regulation of transportation of radioactive materials has been placed in the NRC Public Document Room at 1717 H Street NW., and at its local public document rooms throughout the nation. Copies of such background information are available upon request in writing to the Office of Standards Development, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555.

Interim evaluation. Recently there have been several requests that air shipments of plutonium and other special nuclear materials (and related ground transportation of special nuclear materials incidental thereto) be suspended pending reexamination of presently applicable regulations. In assessing the appropriateness of such action at this time, the NRC has considered the following:

1. In more than 25 years of shipping special nuclear material, including plutonium, in civilian aircraft, there have been no air accidents involving the material.

2. The experience in shipping thousands of packages per year of all forms of radioactive materials by all modes of transport under existing NRC, DOT, and FAA regulations has been very favorable.

3. The requests that have been received do not set forth any significant new information which would indicate that present package or security requirements are inadequate.

4. In view of the physical security measures now required by 10 CFR Part 73, the protection provided against severe accidents by the high integrity packaging required by NRC, DOT, and FAA regulations (summarized supra), the consistency of these requirements with international standards, the low accident probability (supra), and the favorable experience to date, the risk involved in the transportation of radioactive material under currently effective regulations is believed to be small.

Accordingly, it is presently the view of the NRC, subject to consideration of comments to be received, that its currently effective regulations can continue to be applicable during the period in which this rule making proceeding is in progress. More particularly, in light of present information as to the safety and security of air shipments of radioactive material, the Commission finds no sound basis, for the reasons stated above, for requiring the suspension of such shipments.

Notwithstanding the foregoing, in view of the concerns expressed and the fact that requests have been received for the suspension of air shipments of plutonium and other special nuclear materials, comments are specifically invited on the matter of whether suspension or other limitations on the air transportation of plutonium and other special nuclear materials are justified during the period that the subject rule making proceeding is being conducted. Views on this particular matter, together with the supporting basis for these views, should be submitted to the Secretary of the Commission, U.S. Regulatory Commission, Washington, D.C. 20555, Attention: Docketing and Service Section by July 2, 1975. The NRC will decide, after evaluating the views and comments received, whether a different course should be pursued during the pendency of this rule making proceeding and publish its conclusions in the FEDERAL REGISTER. Currently effective regulations will continue to be applied until a decision on this matter is made.

As indicated above, related specific issues will be, or are presently, the subject of consideration in other rule making proceedings, and the NRC will continue to take appropriate action, as justified by the circumstances, to assure that the risk associated with the transportation of radioactive materials remains small.

Dated at Washington, D.C. this 29th day of May 1975.

For the Nuclear Regulatory Commission.

SAMUEL J. CHILK,
Secretary of the Commission.

[FR Doc.75-14519 Filed 5-30-75;8:45 am]

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VOL. 1

FINAL ENVIRONMENTAL STATEMENT ON THE TRANSPORTATION OF RADIOACTIVE MATERIAL BY AIR AND OTHER MODES

Docket No. PR 71, 73 (40 FR 23768)

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Office of Standards Development
U. S. Nuclear Regulatory Commission

SUMMARY AND CONCLUSIONS

This Final Environmental Statement was prepared by the staff of the Office of Standards Development of the U. S. Nuclear Regulatory Commission (NRC), Washington, D.C. 20555. Mr. Donald R. Hopkins is the NRC Task Leader for this statement (telephone: 301-443-6910).

1. This action is administrative.

2. This Final Environmental Statement has been prepared in connection with NRC reevaluation of its present regulations governing air transportation of radioactive materials in order to provide sufficient analysis for determining the effectiveness of the present rules and of possible alternatives to these rules. This statement is not associated with any specific rule change at this time but will be used as a partial basis for determining the adequacy of the present transportation regulations. If a rule change results from consideration of this statement, a separate or supplementary environmental statement will be issued with respect to that action.

When NRC was beginning work on this environmental statement, consideration was given to covering all aspects of the environmental impact resulting from the transport of radioactive material by air. At the Federal level, both the NRC and the Department of Transportation, particularly the Federal Aviation Administration (FAA), are involved in regulating the safety of such transport. Therefore, NRC proposed to the FAA that the statement be cosponsored by both agencies and that both the shipper-packaging aspects and the carrier-transport aspects be covered. In a meeting in early 1975, the FAA declined to actively support the development of such a statement. As a result, the scope of the statement was limited to the shipper-packaging aspects. The statement deals with the carrier-transport area only to the extent necessary to determine the influence of the conditions of transport on the shipper-packaging area, e.g., exposures of personnel from packages of radioactive materials under normal and accident conditions.

Development of the statement began with consideration of transport of radioactive materials by air. However, in order to examine the environmental impact of alternatives, other modes of transport were examined, again primarily from the standpoint of the effect such transport would have on packaging as related to exposure of people under both normal and accident conditions. During the development of the statement, special interest arose in the alternative of transporting irradiated nuclear fuel by special trains. Some detail was added in the section on special trains but the statement scope was not sufficiently broad to deal thoroughly with this subject. A separate statement on the use of special trains for transporting irradiated nuclear fuel has been issued by the Interstate Commerce Commission (ICC) with NRC cooperation. Some of the same methodology used in this generic statement is used in the ICC study.

As a result of the limitations on the scope of this generic statement, only limited study of the conditions of transport, carrier controls, and routing has been undertaken. For example, no evaluation has been made of safety aspects of the vehicles or of items related to carrier controls other than those directly affecting the shipper-packaging area.

Except as noted, this statement does not specifically consider facets unique to the urban environment such as high population densities, diurnal variation in population, convergence of transportation routes, shielding effects of buildings, or the effect of local meteorology on accident consequences. A separate study specific to such considerations is being conducted and will result in a separate environmental statement specific to such an urban environment.

This statement was started in May 1975 and was completed prior to President Carter's April 7, 1977, message on nuclear power policy regarding deferral of commercial reprocessing and recycling of plutonium. Therefore, the 1985 projection of numbers and types of nuclear fuel cycle shipments and their environmental impact that has been used in this study reflects the potential development of plutonium recycle to the extent described in the NRC's generic environmental statement on mixed oxide fuel (GESMO). Since the analysis on non-fuel-cycle shipments remains valid, as does the analysis of all 1975 radioactive material shipments, this statement is issued with the caveat that it does not reflect changes in national energy policy originating with the President's April 7, 1977, message.

Although this statement has not been modified to reflect the President's policy message, it is the NRC staff's judgment, based on related analyses, that the results presented as realistic in this statement would continue to be realistic and the conclusions reached would be essentially the same if changes were made in accordance with the President's message.

3. The environmental impact of radioactive material shipments in all modes of transport under the regulations in effect as of June 30, 1975, is summarized as follows:

a. Radiation exposure of transport workers and of members of the general public along the transportation route occurs from the normal permissible radiation emitted from packages in transport. More than half of the 9800 person-rem exposure resulting from 1975 shipments was received by transport workers associated with the shipments. The remaining 4200 person-rems was divided among approximately ten percent of the U.S. population. None of these exposures would produce short-term fatalities. On a statistical basis, expected values for health effects that may result from this exposure are 1.7 genetic effects per year and 1.2 latent cancer fatalities distributed over the 30 years following each year of transporting radioactive material in the United States at 1975 levels (Chapter 4, Section 4.9). More than half of this effect results from the shipment of medical-use radioactive materials where the corresponding benefit is generally accepted (Chapter 1, Table 1-2).

b. Transportation accidents involving packages of radioactive material present potential for radiological exposure to transport workers and to members of the general public. The expected values of the annual radiological impact from such potential exposure are very small, estimated to be about one latent cancer fatality and one genetic effect for two hundred years of shipping at 1975 rates (Chapter 5, Section 5.9). More than two-thirds of that impact is attributable to nuclear fuel cycle and other industrial shipments (Chapter 1, Table 1-2).

c. Radiological impacts from export and import shipments were evaluated separately and were determined to be negligible compared to impacts from domestic shipments (Chapter 5, Section 5.7).

d. The principal nonradiological impacts from the use of resources for packaging materials and from the use of, and accidents involving, a relatively small number of dedicated transport vehicles were found to be two injuries per year and less than one accidental death per four years (Chapter 5, Section 5.8).

e. Examination of the consequences of a major accident and assumed subsequent release of radioactive material indicates that the potential consequences are not severe for most shipments of radioactive material (Chapter 5, Section 5.6). The consequences are limited by one or more parameters: short half-life, nondispersible form, low radiotoxicity. However, in the unlikely event of a major release of plutonium or polonium in a densely populated area, a few individuals could suffer severe radiological consequences. One early fatality would be expected, and as many as 60 persons would be exposed to radiation dose levels sufficient to produce cardiopulmonary insufficiency and fatalities in some cases. The latent cancer fatalities associated statistically with such a major release are estimated to be as many as 150 over a 30-year period (Chapter 5, Section 5.6). Costs for land reclamation associated with such an unlikely accident could range from 250 million to 800 million dollars for 1975 shipments and up to 1.2 billion dollars for 1985 shipments. The probability of such an event is estimated to be no greater than 3 x 10^{-9} per year for 1975 shipping rates (Chapter 5, Section 5.6). It should be noted that, to obtain the above result, all of the following conditions would have to occur:

(1) A low-probability, extra severe accident would have to involve a vehicle carrying a bulk shipment of plutonium or polonium in an extreme-population-density urban area. There are presently about 20 large-quantity shipments of polonium per year and one of plutonium (Chapter 5, Section 5.2.2);

(2) One or more of the packages of plutonium or polonium that are designed to withstand severe accident conditions would have to be subjected to the highest of the forces developed in the accident so as to cause gross failure of the package and subsequent release of a significant fraction of the radioactive contents from the package (Chapter 5, Section 5.2.3);

(3) The accident would have to create conditions in which plutonium or polonium released from the package would escape from the vehicle in which it was being transported, and a significant amount of material would have to become airborne in respirable form (Appendix A, Section A.4);

(4) The meteorological conditions at the time would have to be such that the plutonium or polonium remains airborne and is dispersed in a way that significant numbers of people would breathe the air containing the material in high concentrations (Chapter 5, Section 5.3); and

(5) Mitigating actions such as evacuation of persons from the area are not taken.

4. Principal alternatives considered are the following:

   a. Transportation mode shifts for various components of the industry (Chapter 6, Section 6.2).

   b. Operational constraints on transport vehicles to minimize accidents (Chapter 6, Section 6.3).

   c. Changes in packaging requirements to minimize release of radioactive materials in an accident (Chapter 6, Section 6.4).

   d. Changes in the physical properties of radioactive materials to minimize consequences in the event of a release (Chapter 6, Section 6.4.1).

Preliminary analyses were made of a number of alternatives to the present regulations and methods of transport. A few of the alternatives examined were found to be cost effective. However, the cost-effective alternatives dealing with changes in mode of transport did not significantly reduce the radiological impact; the others must be analyzed further to determine whether their adoption would reduce the radiological impact and achieve an impact level as low as is reasonably achievable (Chapter 6).

The alternative of reducing the amount of radioactive material transported, either generally or selectively, was not considered on the assumption that the benefits associated with the use of presently transported materials outweigh the small risk of their transportation.

While future rulemaking may depend in part for its justification on the analysis and conclusions of this statement, no rulemaking is proposed with its present issuance. The primary function of this statement is to establish the NRC staff view of the environmental impact of present transportation of radioactive material and of the projected impact in 1985. This statement provides an overview of a number of alternatives to present transportation requirements and of the changes in impact produced by those alternatives. While this overview serves to limit the number of alternatives worthy of further consideration, any detailed study of alternatives in support of rulemaking activities will be considered separately.

The alternatives considered in this statement are limited to those possible with existing transportation systems. While it might be possible to conceptualize new transportation systems that might reduce environmental impact, it is considered unlikely that any could be justified on a cost-benefit basis because of the present low risk.

5. The following Federal, State, and local agencies commented on the Draft Environmental Statement (NUREG-0034) made available in March 1976. Their comments, along with those from other parties, are in Appendix J.

a. Tennessee Valley Authority
b. Department of Health, Education, and Welfare
c. Environmental Protection Agency
d. Department of the Interior
e. Federal Energy Administration
f. Energy Research and Development Administration
g. Department of Transportation
h. State of New Mexico
i. State of New York
j. State of Georgia
k. City of New York

6. A draft of this Final Environmental Statement was made available to the public in February 1977 at the NRC Public Document Room in Washington, D.C., and at NRC's field offices in King of Prussia, Pennsylvania; Atlanta, Georgia; Glen Ellyn, Illinois; Arlington, Texas; and Walnut Creek, California. Public comments received on that draft are contained in Appendix K.

7. This Final Environmental Statement was made available to the public, to the Council on Environmental Quality, and to the above specified agencies in December 1977.

8. On the basis of the analysis and evaluation set forth in this statement and after weighing the small adverse environmental impact resulting from transportation of radioactive materials and the costs and benefits of the alternatives available for reducing or avoiding the adverse environmental effects, the staff concludes that:

a. Maximum radiation exposure of individuals from normal transportation is generally within recommended limits for members of the general public (Chapter 3, Section 3.5). There are transportation operations at a few locations where some transport workers receive radiation exposures in excess of the recommended limits established for members of the general public. In most cases, these operations employ radiation safety personnel to establish safe procedures and to train and monitor transport workers as though they were radiation workers.

b. The average radiation dose to the population at risk from normal transportation is a small fraction of the limits recommended for members of the general public from all sources of radiation other than natural and medical sources (Chapter 3, Section 3.5) and is a small fraction of natural background dose (Chapter 3, Section 3.3).

c. The radiological risk from accidents in transportation is small, amounting to about one-half percent of the normal transportation risk on an annual basis (Chapter 4, Section 4.9).

d. For the types and numbers of radioactive material shipments now being made or projected for 1985, there is no substantial difference in environmental impact from air transport as opposed to that of other transport modes (Chapter 4, Tables 4-15 and 4-17 and Appendix I, Table I-9).

e. Based on the above conclusions, the NRC staff has determined that the environmental impacts of normal transportation of radioactive material and the risks attendant to accidents involving radioactive material shipments are sufficiently small to allow continued shipments by all modes. Because transportation conducted under present regulations provides adequate safety to the public, the staff concludes that no immediate changes to the regulations are needed at this time. The staff has already upgraded its regulations on transportation quality assurance while this environmental statement was being prepared and has begun studies of transportation through urban areas and of emergency response to transportation accidents and incidents. In addition, the staff is continuing to study other aspects of transportation, such as the accident resistance of packages and the physical/chemical form of the radioactive contents, to maintain the present high level of safety and to determine the cost-effectiveness of changes that could further reduce transportation risk.

9. Based on considerations related to security and safeguards for strategic special nuclear materials (uranium enriched to 20% or more in the U-235 isotope, U-233, and plutonium), spent fuel, and other radioactive materials in transit, the staff concludes that:

a. Existing physical security requirements are adequate to protect at a minimum against theft or sabotage of significant quantities of strategic special nuclear materials in transit by a postulated threat consisting of an internal threat of one employee occupying any position and an external threat of a determined violent assault by several well-armed, well-trained persons who might possess inside knowledge or assistance.

b. The level of protection provided by these requirements reasonably ensures that transportation of strategic special nuclear material does not endanger the public health and safety or common defense and security. However, prudence dictates that safeguards policy be subject to close and continuing review. Thus, the NRC is conducting a public rulemaking proceeding to consider upgraded interim requirements and longer-term upgrading actions. The objective of the forthcoming rulemaking proceeding is to consider additional safeguards measures to counter the hypothetical threats of internal conspiracies among licensee employees and determined violent assaults that would be more severe than those postulated in evaluating the adequacy of current safeguards.

c. The use of the ERDA (now the Department of Energy (DOE)) transport system is not, at this time, considered to be necessary for the protection of significant quantities of privately owned strategic special nuclear material because the present level of transport protection provided by the licensed industry is considered to be comparable to that presently required by ERDA (DOE). Similarly, the use of Department of Defense escorts is not presently needed to protect domestic shipments against the postulated threat because the physical protection deemed necessary to defeat this threat can and is being provided by the private sector.

d. Shipments of radioactive materials not now covered by NRC physical protection requirements, such as spent fuel (containing fission products and irradiated special nuclear materials) and large-source nonfissile radioisotopes, do not constitute a threat to the public health and safety either because of their limited potential for misuse (due in part to the hazardous radiation levels that preclude direct handling) or because of the protection afforded by safety provisions, e.g., shipping containers.

Based on the above conclusions, the NRC staff has determined that the risks of successful theft of a significant quantity of strategic special nuclear material or sabotage of radioactive materials in transit resulting in a significant radiological release are sufficiently small to constitute no major adverse impact on the environment.

10. The validity of the risk assessment has been seriously challenged within the NRC staff. The challenge is with respect to the assessment of the overall level of accident risk and the relative levels of risk of the various types of shipments on which the total accident risk is based. The challenge results from the acknowledged conservative assumptions used in the accident assessment where valid data are not available to support more realistic values for certain parameters. Principal among these are package release fractions (Chapter 5, Table 5-8), particle size (Appendix A, Table A-7), fraction of released materials becoming airborne (Appendix A, Table A-7), and areas contained within dose isopleths (Chapter 5, Figure 5-7). These assumptions are not applied uniformly in the accident analysis over the various types of shipments (e.g., more data is available on plutonium shipment behavior in an accident situation than is available for polonium shipments; therefore, more conservative assumptions were applied to the polonium accident assessment). The resulting challenge is that the assessment is excessively conservative and shows the total accident risk to be greater than a more realistic assessment would show and that the values of risk assessed for different types of shipments may incorrectly show that certain types of shipments are more hazardous than others. However, since the conclusion drawn from the accident assessment is simply that the total accident risk is small compared to the normal transportation risk, the assessment is considered to support that limited conclusion and therefore to be adequate for that purpose, at this time. Nonetheless, further studies to develop additional data and refine the assessments are planned for the future; some are already underway in connection with the generic study on Transport of Radionuclides in Urban Environs and other detailed accident studies. Furthermore, rulemaking actions to reduce the risk in specific areas will not be taken until a more realistic risk assessment has been completed and the specific costs and the benefits have been evaluated.

TABLE OF CONTENTS

TABLE OF CONTENTS (Cont'd)

TABLE OF CONTENTS (Cont'd)

TABLE OF CONTENTS (Cont'd)

LIST OF FIGURES

LIST OF FIGURES (Cont'd)

LIST OF TABLES

LIST OF TABLES (Cont'd)

LIST OF TABLES (Cont'd)

LIST OF TABLES (Cont'd)

DETAILED SUMMARY

INTRODUCTION

This document is an assessment of the environmental impact from transportation of shipments of radioactive material into, within, and out of the United States. It is intended to serve as background material for a review by the United States Nuclear Regulatory Commission (NRC) of regulations dealing with transportation of radioactive materials. The impetus for such a review results not only from a general need to examine regulations to ensure their continuing consistency with the goal of limiting radiological impact to a level that is as low as reasonably achievable, but also from a need to respond to current national discussions of the safety and security aspects of nuclear fuel cycle materials.

The report consists of eight chapters and related appendices. The structure of the report and its content are indicated in the following outline of its chapters:

1. Introduction - The background of the study, uses of radioactive materials, and shipping activities in various major segments of the nuclear industry are discussed.

2. The Regulations Governing the Transportation of Radioactive Materials - The regulations are reviewed together with supporting information indicating the intent and basis for many of the transportation safety regulations.

3. Radiological Effects - The mechanism for radiological impact, the appropriate protection guidelines, and the health effects model used in this assessment are discussed.

4. Transport Impacts Under Normal Conditions - The environmental impacts, both radiological and nonradiological, that result from normal transportation are assessed in terms of a standard shipments model designed to represent current transport conditions.

5. Impacts of Transportation Accidents - The radiological and nonradiological impacts that result from accidents involving vehicles carrying radioactive material shipments are discussed.

6. Alternatives - Assessment is made of differences in radiological impact that would result from modifying the transport mode of certain shipments, adding operational constraints, changing form and quantity restrictions, and raising packaging standards. Cost-benefit tradeoffs are discussed.

7. Security and Safeguards - The need for security of certain radioactive material shipments is discussed together with an assessment of the present physical security requirements applied to various modes of transport.

8. Comments on NUREG-0034 and Major Changes That Have Occurred Since NUREG-0034 was Issued - Major changes from the draft assessment (NUREG-0034) are identified.

DESCRIPTION OF THE ENVIRONMENTAL IMPACT OF EXISTING ACTIVITIES

The environmental impact of radioactive material transport can be described in three distinct parts: the radiological impact from normal transport, the risk of radiological effects from accidents involving vehicles carrying radioactive material shipments, and all nonradiological impacts.

Radiological impacts in normal transport occur continuously as a result of radiation emitted from packages both aboard vehicles in transport and in associated storage. The radiation exposure of specific population groups such as crew, passengers, flight attendants, and bystanders is calculated in the report using a computer model that considers, for the principal radionuclides shipped, radiation exposure rates, shipment information, traffic data, and transport mode splits. Using this computer model, it was estimated that the total annual population exposure resulting from normal transport is about 9790 person-rem. The largest percentage of this population exposure (some 52%) results from the shipment of medical-use radionuclides. The remaining portion results from industrial shipments (about 24%), nuclear fuel cycle shipments (8%), and waste shipments (15%). Shipments by truck produce the largest population exposure, resulting from relatively long exposure times at low radiation levels of truck crew and large numbers of people surrounding transport links.

The individual radiation exposures in all modes are generally at low radiation levels and in most cases take on the character of a slight increase in background radiation. The analysis shows that radiation exposure from normal transportation, averaged over the persons exposed, amounts to 0.5 millirem per year compared to the average natural background exposure of about 100 millirem per year. Based on the conservative linear radiation dose hypothesis, this would result in a total of 1.2 latent cancers distributed statistically over the 30 years following each year of transporting radioactive material in the United States at 1975 levels. This can be compared to the existing rate of more than 300,000 cancer fatalities per year from all causes.

In the accident case, risk to the population from accidents involving vehicles carrying radioactive materials was estimated in terms of the number of latent cancer fatalities and early deaths that might occur on annual and single-accident bases. The analysis resulted in estimates of annual societal risk of 5.4×10^{-3} latent cancer fatalities and 5×10^{-4} early fatalities for each year of shipments at 1975 levels. These values can be compared to the 1100 (in 1969) early fatalities from electrocution each year. The latent cancer fatalities from transport accidents are related principally to industrial and fuel cycle shipments rather than to medical shipments, which are the dominant causes of latent cancer fatalities related to normal transport. This results principally from the larger quantities of more toxic materials associated with industrial and fuel cycle shipments.

In spite of their low annual risk, specific accidents occurring in very-high-density urban population zones can produce as many as one early fatality, 150 latent cancer fatalities, and decontamination costs estimated to range from 250 million to 800 million dollars for 1975 shipments and from 250 million to 1.2 billion dollars for 1985 shipments (1975 dollars). Although such accidents are possible, their probability of occurrence is very small (estimated to be no greater than 3 x 10^{-9} per year based on 1975 shipping rates).

Nonradiological impacts on safety were estimated to be two injuries per year and one fatality every five years from accidents involving vehicles used for the exclusive-use transport of nuclear materials. Accidents involving vehicles carrying radioactive materials in conjunction with carriage of other goods are not considered to be chargeable as radioactive material shipments since the total number of radioactive material packages transported annually is less than 10^{-5} of all goods transported annually in this manner.

RELATIONSHIP OF PROPOSED ACTIVITIES TO OTHER GOVERNMENT ACTIVITIES

Safety and safeguarding of radioactive material shipping is regulated by the NRC and the Department of Transportation in conjunction with cooperating State agencies. The interaction of these agencies is governed by either an agreement or a Memorandum of Understanding that defines the coordination of their activities.

PROBABLE IMPACT OF PROPOSED ACTIONS ON THE ENVIRONMENT

Any rule changes proposed as a result of this environmental assessment will be proposed in a future action. The impact on the environment of those rule changes will be considered separately with that action.

ALTERNATIVES TO EXISTING ACTIVITIES

Alternatives to the existing practices in the shipment of radioactive material are discussed in Chapter 6. Mode shifts, operational constraints, and package standards revisions were found to produce only small changes in the population exposure associated with normal transportation. Although large percentage decreases in the existing risk from transportation accidents result from some of these alternatives, the significance of these decreases is lessened by the following considerations:

1. Because the existing risk (annual early deaths plus latent cancer fatalities) from transportation accidents is a small percentage of the risk from normal transportation, large decreases in accident risk result in insignificant changes in the total (accident plus normal) risk; and

2. Because the existing risk from transportation accidents is so small, large relative decreases are actually small absolute decreases in effects (e.g., reduction in numbers of deaths or illnesses).

Where the cost-benefit ratio for an alternative is adverse, i.e., where the social and economic costs outweigh the decreases in environmental impact, better alternatives should be sought. It has been found, for example, that risk from an accident involving plutonium or polonium-210 is reduced by changing the physical form of these materials. This technique may be capable of producing a decrease in accident risk of 0.005 latent cancer fatalities per year (a 30% reduction) for large shipments of highly toxic materials. Detailed information on the feasibility of this alternative is not yet adequate to permit the determination of its associated costs.

UNAVOIDABLE ADVERSE ENVIRONMENTAL EFFECTS

The principal unavoidable environmental effect was found to be the population exposure resulting from normal transport of radioactive materials. Since the electromagnetic radiation emitted from a package cannot be reduced to zero by any finite quantity of shielding, the transport of radioactive materials will always result in some population exposure.

The much smaller unavoidable risk from accidents that have the potential for releasing radioactive material from packages will always be present but such accidents have a very small probability of occurrence.

The unavoidable nonradiological impact resulting from transport of radioactive material in exclusive-use vehicles amounts to about two injuries and one fatality every five years, mostly from accidents involving transportation of fuel and waste to and from nuclear power plants. This is because exclusive-use vehicles are predominantly used for such shipments. Other nonradiological impacts such as the use of vehicle fuel and other resources were found to be insignificant.

SHORT-TERM USE OF THE ENVIRONMENT VERSUS LONG-TERM POSITIVE EFFECTS

The most obvious and important short-term effect is the population radiation exposure from normal transport, which statistically amounts to 1.2 latent cancer fatalities per year. An additional short-term effect is the small annual accident risk.

Balanced against these risks are long-term positive results from the shipment of radioactive material in such areas as:

1. National Health - The use of radiopharmaceuticals in the diagnosis and treatment of illnesses provides a benefit in lives saved.

2. Oil Exploration - The use of radioactive material in well logging and flow tracing provides technology for intelligent exploitation of our oil resources and aids in optimizing the use of this valuable national energy resource.

3. Quality Control - The use of radionuclides for gauging the thicknesses of metal and paper, measuring product density, and locating levels of contents in small packages and in large holding tanks provides a capability to minimize waste of resources and optimize quality in finished goods.

4. Electricity Generation - The use of nuclear fuels in reactors allows production of electricity for society with lower fuel costs and lower levels of chemical pollutants to the environment than is possible by more conventional methods of generating electricity.

5. Industry - Radionuclides are used in many manufactured devices and consumer products ranging from home smoke detectors to antistatic devices.

IRREVERSIBLE COMMITMENT OF RESOURCES

The only irreversible commitment of resources determined in this assessment was that resulting from use of fuels to operate the transportation network. To the extent that the resources are committed to the transportation of radioactive materials alone, the quantity of fuels used is an infinitesimal quantity, since transportation of radioactive material normally occurs incidental to the movement of general goods in commerce. Only those portions of the fuel and other resources attributable to sole-use shipments are committed directly, and that activity is less than 10^{-5} of the nation's total transportation activity, making this irreversible commitment of resources negligibly small.

CHAPTER 5

IMPACTS OF TRANSPORTATION ACCIDENTS

5.1 INTRODUCTION

Two factors are considered in evaluating the impact of accidents that involve vehicles carrying radioactive shipments: probability and consequence. The probability that an accident releasing radioactive material will occur can be described in terms of the expected number of accidents (of given severity) per year for each transport mode, together with the package response to those accidents and the dispersal that is expected. The consequence of an accident is expressed in terms of the potential effects of the release of a specified quantity of dispersible radioactive material to the environment or the exposure resulting from damaged package shielding.

The product of probability and consequence is called the "annual radiological risk" and is expressed in terms of the expected radiological consequences per year. This risk can be quantified for each shipment type. Summing the risks over all shipments gives the total annual risk resulting from all shipments. Since this method does not distinguish high probability-low consequence risks from low-probability/large-consequence risks, shipments with potentially severe consequences are, in addition, considered separately from the risk calculations.

The actual method by which risk is calculated is outlined in Appendix G and detailed in Reference 5-1. Figure 5-1 outlines the informational flow used in the calculation of impacts due to transportation accidents. It also shows the additional impacts that add to the annual risk discussed above.

This chapter is divided into eight additional sections. Section 5.2, which follows this introduction, includes discussions of accident rates for various transport modes and severities and of package release fractions. Section 5.3 discusses the dispersion/exposure model and the inherent assumptions used in the meteorological calculation. The results of the risk calculations using the 1975 standard shipments and their 1985 projections (see Appendix A) are presented in Section 5.4. Section 5.5 discusses the potential effects and cleanup costs of the radioactive contamination from a transportation accident. In Section 5.6 the "worst-case" shipment scenarios are considered, i.e., those that have the potential for very severe consequences but have a very low occurrence probability. Section 5.7 discusses the impact due to export/import shipments. Section 5.8 discusses the nonradiological impacts of transportation accidents, and Section 5.9 summarizes the results of the accident risk and consequence calculations. A sensitivity analysis for the risk computation is performed in Appendix I.

5.2 DETAILED ANALYSIS

Direct radiological impacts on man are considered to be the most important component of the environmental impact. Direct impact to man may result from transportation by any mode or

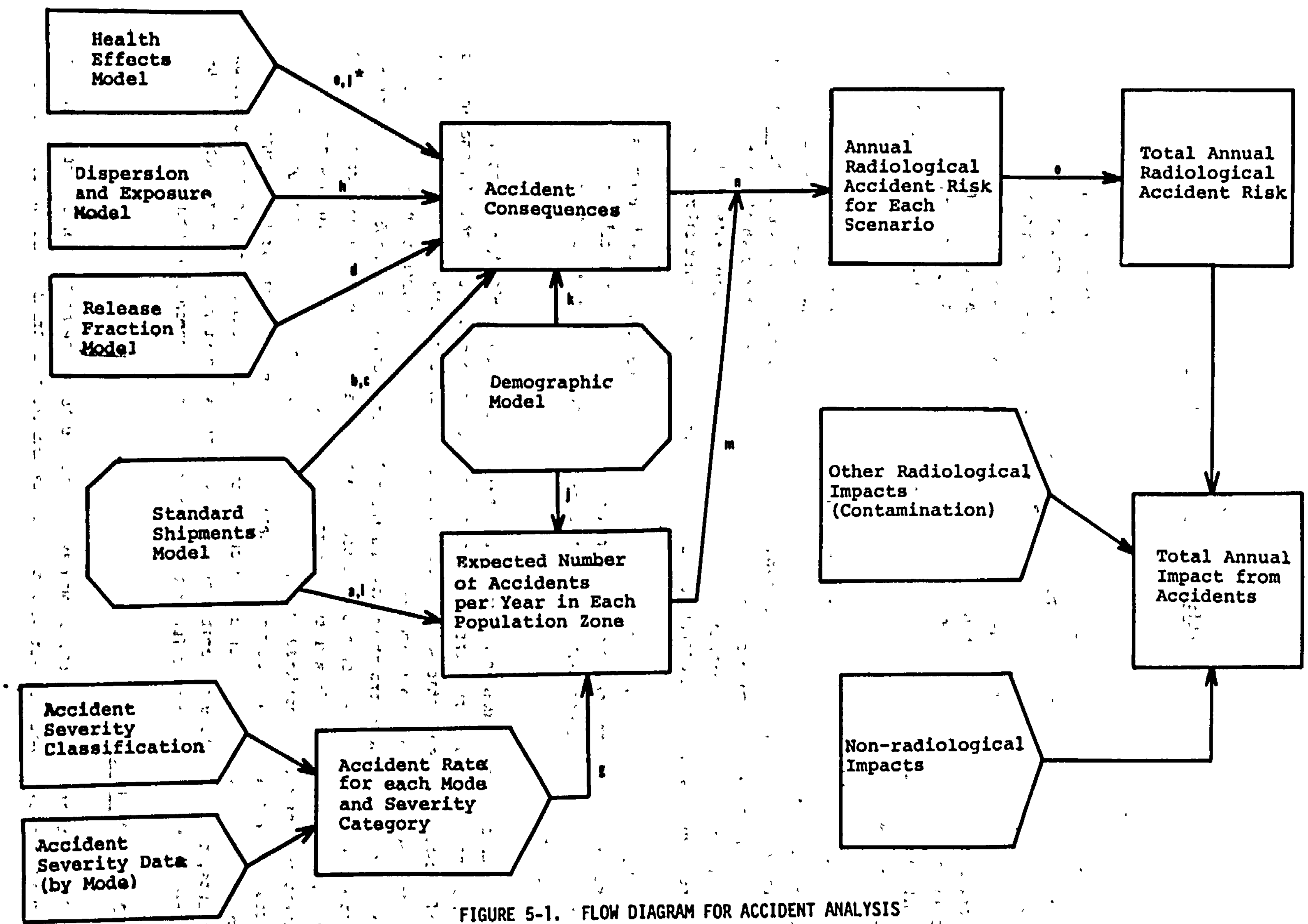


FIGURE 5-1. FLOW DIAGRAM FOR ACCIDENT ANALYSIS

*See notes on following page.

FIGURE 5-1 (continued)

Notes:

a. Shipment mode.

b. Type of packaging.

c. Type of radionuclide; chemical and physical form.

d. Amount of dispersible material released or amount of unshielded material.

e. Dosimetric data for radionuclide.

f. Overall accident rate for each mode.

g. Accident rate for each mode-severity combination.

h. Amount of dispersible material inhaled or external exposure from unshielded material.

i. Number of shipments per year; average distance per shipment.

j. Fractions of accidents expected in each population zone.

k. Population densities.

l. Biological effects of exposure.

m. Average number of accidents per year of each severity.

n. Summation over all severities.

o. Summation over all scenarios.

submode. The probability that a transport vehicle of a particular mode will be involved in an accident of a specific severity depends on the accident rate per vehicle-kilometer, the number of shipments per year by that mode, and the distance traveled by each shipment transported by that mode. The "consequences" of an accident involving a specific mode depend on the quantity and type of radioactive material carried, the fraction of the material that is released in the accident, the population density in the area where the release occurs, the local meteorology at the time of the accident, and the biological effect of the material on the environment.

5.2.1 ACCIDENT RATES

In order to compute the probability of an accident, it is first necessary to know the accident rate for the mode under consideration. The accident rates used in this assessment are specified per vehicle-kilometer and are summarized in Table 5-1, which also lists the sources for the information.

5.2.2 ACCIDENT ENVIRONMENTAL SEVERITY CLASSIFICATION

The amount of radioactive material released to the environment in an accident depends upon the severity of the accident and the package capabilities. Very severe accidents might be expected to release a considerable amount of the radioactive material carried, while minor accidents are unlikely to cause any release. Thus, in addition to the overall accident rate for each mode, the distributions of accidents according to severity must be determined. In this section, the accident severity classification scheme used in this assessment is discussed, and the distributions of accidents according to severity are determined for air, truck, rail, and waterborne transport modes. In addition, estimates of the relative occurrences of accidents of each severity, in each population zone, and for each transport mode are discussed.

5.2.2.1 Aircraft Accidents

The classification scheme devised for aircraft accidents follows that of Clarke, et al. (Ref. 5-2) and is illustrated in Figure 5-2. The ordinate is the speed of impact onto an unyielding surface, and the abscissa is the duration of a 1300°K fire. The results of Clarke et al. indicate that impact speed and fire duration are the most significant parameters with which to categorize aircraft accidents and that crush, puncture, and immersion are lower-order effects (Ref. 5-3). Unyielding surface rather than real surface impacts were chosen in order to make use of the data of Clarke et al. and to facilitate comparison with the regulatory standards. A derating model is introduced into the analysis later to account for the probability of impact on real surfaces rather than on unyielding targets.

The first two scale divisions for impact speed were chosen to correspond to standards for Type A and Type B packagings, respectively. Thus, Category I accidents (with no fire), equivalent to a drop from 4 feet (1.2 m) or less onto an unyielding surface, should not produce a loss of containment or shielding in a Type A package. A 30 foot (9.1 m) equivalent drop was chosen as the division between Category II and Category III impact accidents, corresponding to the Type B container test specification. The remaining impact category divisions were

TABLE 5-1

ACCIDENT RATES

Mode	Accident Rate (per vehicle-kilometer)	Reference
Aircraft	1.44×10^{-8}	5-2*
Truck, Delivery van	1.06×10^{-6}	5-2, 5-5
ICV	$.46 \times 10^{-6}$	5-5, 5-7
Train	$.93 \times 10^{-6}$**	5-2, 5-7, 5-8
Helicopter	$.63 \times 10^{-6}$	5-9
Ship, Barge	6.06×10^{-6}	5-10

*Also see K. A. Soloman, "Estimate of the Probability that an Aircraft Will Impact the PVNGS," NUS-1416, June 1975.

**Rail accidents are given as railcar accidents per railcar-kilometer.

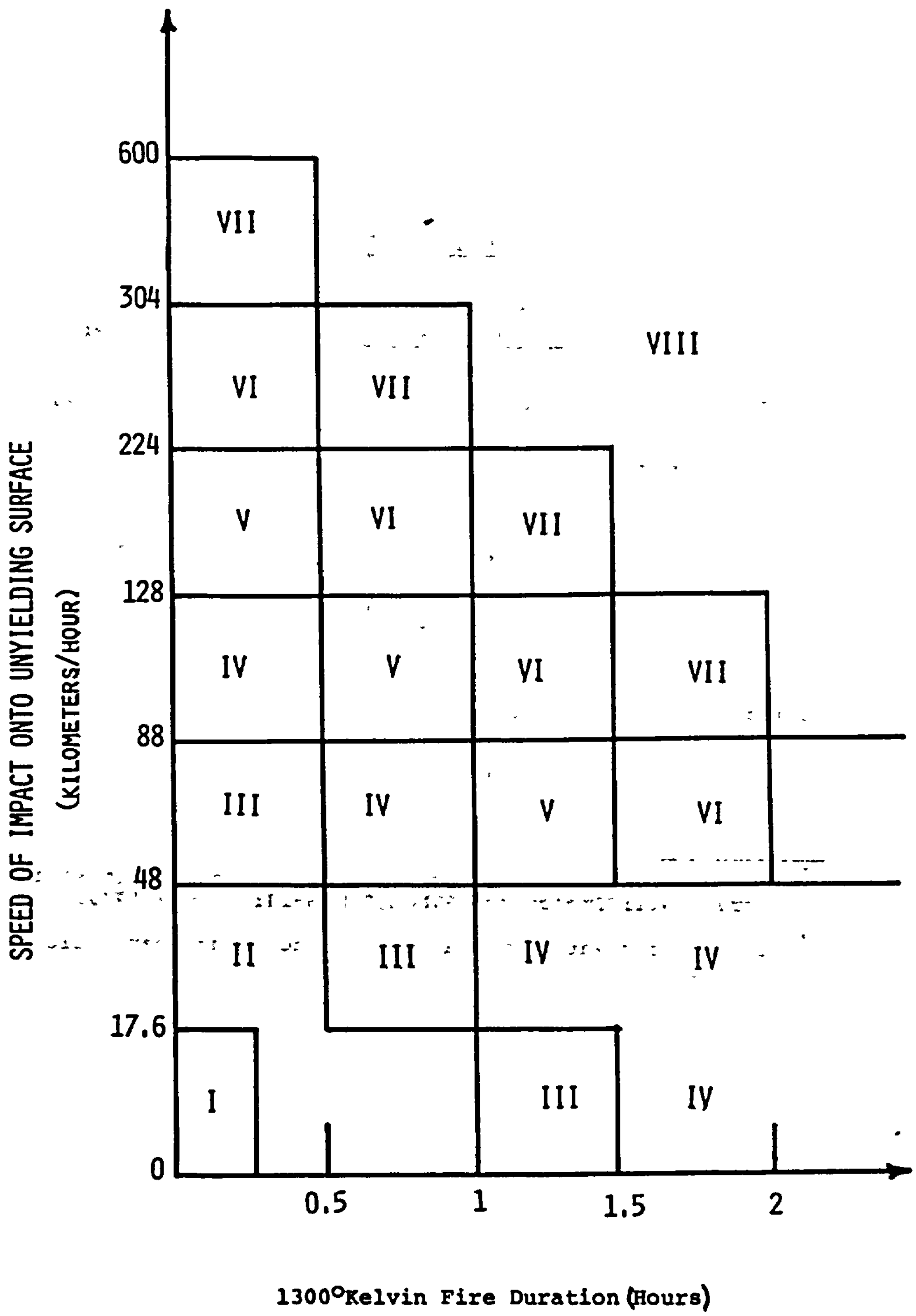


FIGURE 5-2. ACCIDENT SEVERITY CATEGORY CLASSIFICATION SCHEME - AIRCRAFT

chosen more or less arbitrarily from the aircraft accident data compiled by Clarke et al. (Ref. 5-3) in such a way that

1. 95% of the accidents involving impact are severity Category VII or less,

2. 85% of the accidents involving impact are severity Category VI or less,

3. 80% of the accidents involving impact are severity Category V or less,

4. 70% of the accidents involving impact are severity Category IV or less, and

5. 60% of the accidents involving impact are severity Category III or less.

The fire duration category divisions were chosen in such a way that, with the exception of certain Category IV accidents, increasing the fire duration by 30 minutes is equivalent to increasing the impact to the next higher level. Impacts at less than 48 kilometers per hour would not be sufficient to [illegible] an accident of severity Category V or greater regardless of how long the fire burned. The fire temperature was chosen as 1300°K to facilitate comparison with previous data (Ref. 5-2) and to correspond roughly to the temperature of a jet fuel fire.

Note that Category I accidents can involve a fire of as much as 15 minutes' duration. A Type A package involved in a Category I accident in which a fire occurs would not be required by the regulations to survive the accident without loss of shielding or containment.

The fractions of aircraft accidents expected in each of the eight aircraft accident severity categories are given in Table 5-2. The numbers under the column heading "Unyielding Surface" were taken from the accident severity data of Clarke et al. (Ref. 5-3) and were adapted to the accident severity classification scheme used in this study.

The fractional occurrences listed under the heading "Real Surfaces" account for the fact that most aircraft accidents involve impact onto surfaces that yield or deform to provide at least some cushioning effect and result in impact forces that are less severe than would occur on an unyielding surface. These fractional occurrences are obtained by derating those for unyielding surfaces, based upon occurrence statistics for surfaces of varying hardness. The details and rationale for this procedure are discussed in Appendix H. The derating of accident severities was made beginning with Category VIII and working back as far as Category III. No real surface derating is expected for Categories I and II, since these low-severity accidents are expected to occur while the aircraft is on the ground at the airport.

A subclassification within each severity category was made to estimate the fraction of those accidents that occur in a given population density zone. Three zones were used in this assessment: low, medium, and high, characterized by average population densities of 6, 719, and 3861 persons/km^2, respectively (the derivation of these values is discussed in Appendix E). Since accident reports do not generally include the population density of the surrounding areas, the data to determine the accident occurrence fractions in various population zones do

TABLE 5-2

FRACTIONAL OCCURRENCES* FOR AIRCRAFT ACCIDENTS BY ACCIDENT SEVERITY CATEGORY AND POPULATION DENSITY ZONE

Accident Severity Category	Fractional Occurrences f_i Unyielding Surface	Real Surface	Fractional Occurrences According to Population Density Zones Low	Medium	High
I	.57	.447	.05	.9	.05
II	.16	.447	.05	.9	.05
III	.09	.0434	.1	.8	.1
IV	.05	.0107	.1	.8	.1
V	.03	.0279	.3	.6	.1
VI	.03	.0194	.3	.6	.1
VII	.04	.0046	.98	.01	.01
VIII	.03	.0003	.98	.01	.01
TOTAL	1.00	1.00			

*Overall Acident Rate = 1.44×10^{-8} accidents/kilometer for commercial aircraft (K. A. Soloman, "Estimate of the Probability that an Aircraft Will Impact the PVNGS," NUS-1416, June 1975.)

not exist. Thus, estimates were based on the following assumptions relating severity to accident locations:

1. Accidents of severities I and II are assumed to occur at airports. Since most airports are in suburban (or medium) population density zones, 90% of all class I and II accidents were estimated to occur in medium density zones, with 5% each in low- and high-density zones.

2. Accident Categories III-VI were expected to be mainly takeoff and landing accidents and thus were expected to occur near airports.

3. The fractional occurrence of accidents in low-population-density zones was assumed to increase somewhat with accident severity, since a greater percentage of Categories V and VI accidents occur at higher speeds, which implies greater distance from the airport.

4. Accidents of severity Categories VII or VIII are mainly in-flight accidents and are expected to occur at random along the flight path. They are very strongly weighted toward the rural, or low density, areas since about 98% of the land area of the United States is considered rural (Ref. 5-4). The remainder is estimated to be split between medium population density (1.9% of the total land area) and high population density (0.1% of the total land area).

The accident rate for U.S. certified route carriers used in this assessment is 1.44×10^{-8} per kilometer. This accident rate represents an average over all aircraft types for the years 1967-1972, but within those years the range was 1.13×10^{-8} to 2.0×10^{-8} per kilometer. The accident rate for each severity level was obtained by multiplying the overall accident rate by the fractional occurrence for real surfaces for that severity class. For each scenario in the standard shipments model, three risks are computed, assuming the shipments occur entirely in a low-, medium-, or high-population density zone. The actual risk is obtained by forming the sum of these three risk values, weighted by the fractional accident occurrence in each population density zone for that scenario. This same computational technique is used for all transport modes.

5.2.2.2 <u>Truck Accidents</u>

The severity classification scheme for truck accidents is shown in Figure 5-3. In this case the ordinate is crush force rather than impact. Foley <u>et al</u>. (Ref. 5-5) have shown that, in the case of accidents involving motor carriers, the dominant factors in the determination of accident severity are crush force, fire duration, and puncture. The crush force may result from either an inertial load (e.g., container crushed upon impact by other containers in load) or static load (e.g., container crushed beneath vehicle).

The fractional occurrences of truck accidents in each of the eight severity categories are listed in Table 5-3. Since the dominant effect is crush rather than impact, no real-surface derating is involved. The fractional occurrences were taken from the data of Foley <u>et al</u>. (Ref. 5-5). Note that the values for Categories VII and VIII are much lower than for

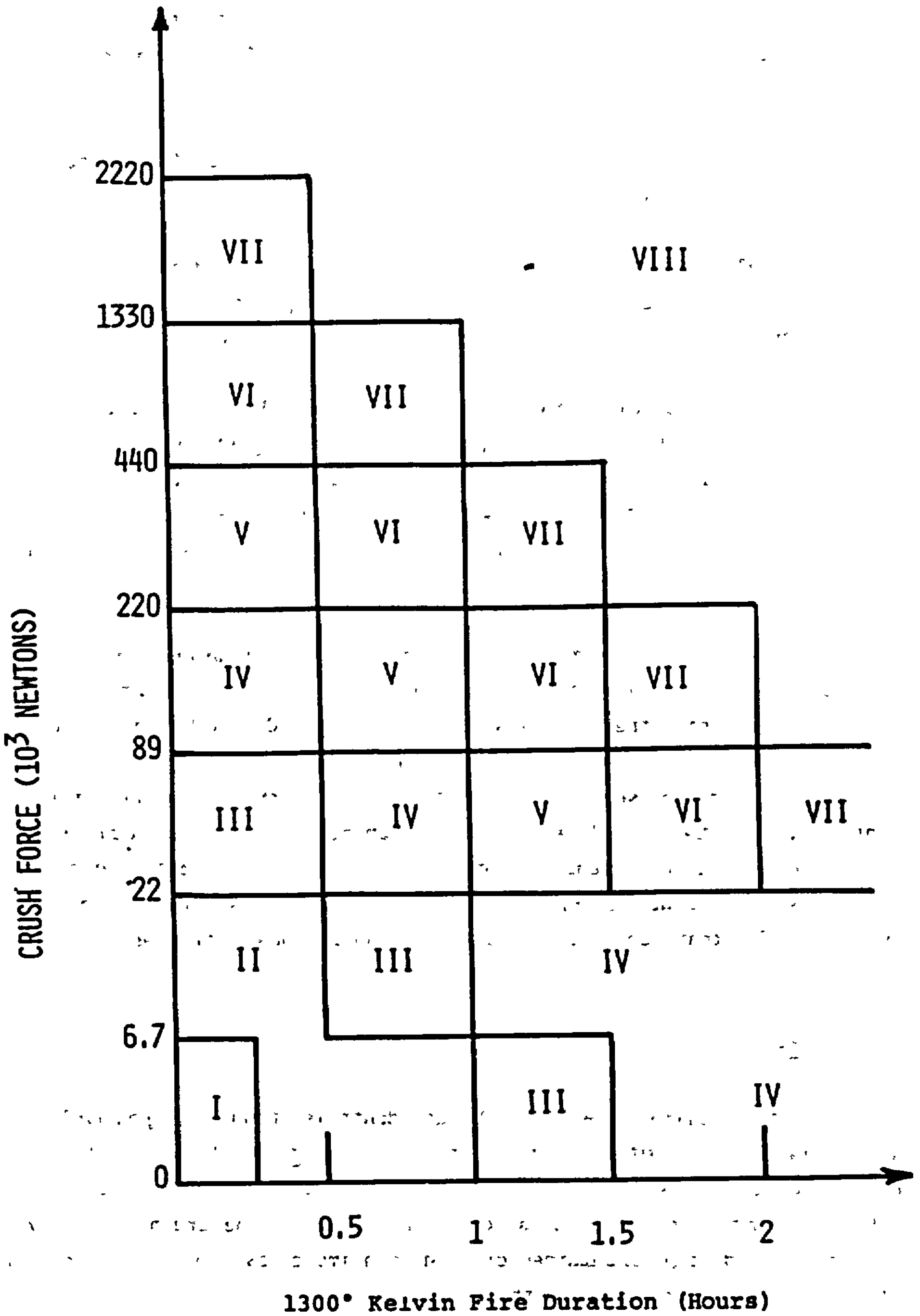


FIGURE 5-3. ACCIDENT SEVERITY CATEGORY CLASSIFICATION SCHEME - MOTOR TRUCKS

TABLE 5-3

FRACTIONAL OCCURRENCES* FOR TRUCK ACCIDENTS BY ACCIDENT SEVERITY CATEGORY AND POPULATION DENSITY ZONE

Accident Severity Category	Fractional Occurrences f	Fractional Occurrences According to Population Density Zones		
		Low	Medium	High
I	.55	.1	.1	.8
II	.36	.1	.1	.8
III	.07	.3	.4	.3
IV	.016	.3	.4	.3
V	.0028	.5	.3	.2
VI	.0011	.7	.2	.1
VII	8.5×10^{-5}	.8	.1	.1
VIII	1.5×10^{-5}	.9	.05	.05

*Overall Accident Rate (Ref. 5-5) = 1.06×10^{-6} accidents/kilometer
(0.46×10^{-6} accidents/kilometer for ICV's)

aircraft accidents. The overall accident rate for motor carriers transporting hazardous materials used for this assessment is 1.06 x 10^{-6} accidents/kilometer.

The estimated fractions of truck accidents in each severity category occurring in each population density zone are also shown in Table 5-3. The very low severity accidents are expected to occur mainly in urban areas. The table reflects a gradual shift of accidents to rural areas with increasing severity as average velocity increases.

Current plans are to require shipment of plutonium in 1985 by Integrated Container Vehicles (ICV) (Ref. 5-6). These are trucks with large vault-like cylinders designed to withstand accident forces and attempted penetration by thieves or saboteurs. Using ERDA nuclear weapons shipment data, the accident rate (which includes the effects of a reduced speed limit, freeway travel, no weekend driving, etc.) is expected to be 0.46 x 10^{-6} accidents/kilometer (Ref. 5-7). The fraction of accidents within each severity category and the fraction of accidents in each population zone are expected to be the same for ICVs as for other trucks.

5.2.2.3 <u>Delivery Van Accidents</u>

The accident severity classification scheme for delivery vans is the same as that for trucks, as shown in Figure 5-3. Fractional occurrences by severity and the overall accident rate are shown in Table 5-4 and were taken to be the same as for trucks. The fractional occurrences in the three population zones, however, are different. In the standard shipments model, delivery vans are used only as a secondary transport mode. There is practically no rural travel since most of the radioactive materials transport in delivery vans is to and from airports, truck terminals, and railroad depots. There are expected to be more low-severity accidents in high-population-density zones and more severe accidents on freeways in medium-population density zones as a result of the higher freeway speeds.

5.2.2.4 <u>Train Accidents</u>

Figure 5-4 illustrates the accident severity classification scheme used for train accidents. The ordinate in this case is impact velocity, taking into account the effects of puncture. In their analysis of train accidents, Larson <u>et al</u>. (Ref. 5-8) considered crush to be an important factor. However, they were concerned with containers shipped in carload lots and with the crush forces resulting from interaction with other cargo in the rail car. Since the principal rail shipment considered is spent fuel, which is not shipped on the same car as other cargo, crush as a severity criterion is not of prime importance.

Table 5-5 lists the fractional occurrences for train accidents by severity class and by population density zone. The f_i-values were taken from the data of Larson <u>et al</u>. (Ref. 5-8). As with truck accidents, no real-surface derating of the fractional occurrences is required, since the predominant mode of damage in severe accidents is puncture. The overall accident rate is 0.93 x 10^{-6} railcar accidents/railcar-kilometer, assuming an average train length of 70 cars and an average of 10 cars involved in each accident (Refs. 5-7 and 5-8). As in the case of motor trucks, the more severe accidents are assumed to occur in lower-population-density zones where velocities are higher.

TABLE 5-4

FRACTIONAL OCCURRENCES* FOR DELIVERY VAN ACCIDENTS BY ACCIDENT SEVERITY CATEGORY AND POPULATION DENSITY ZONE

Accident Severity Category	Fractional Occurrences f	Fractional Occurrences According to Population Density Zones: Low	Medium	High
I	.55	.01	.39	.60
II	.36	.01	.39	.60
III	.07	.01	.39	.60
IV	.016	.01	.50	.49
V	.0028	.01	.50	.48
VI	.0011	.01	.50	.49
VII	8.5×10^{-5}	.01	.60	.39
VIII	1.5×10^{-5}	.01	.60	.39

*Overall Accident Rate = 1.06×10^{-6} accidents/kilometer

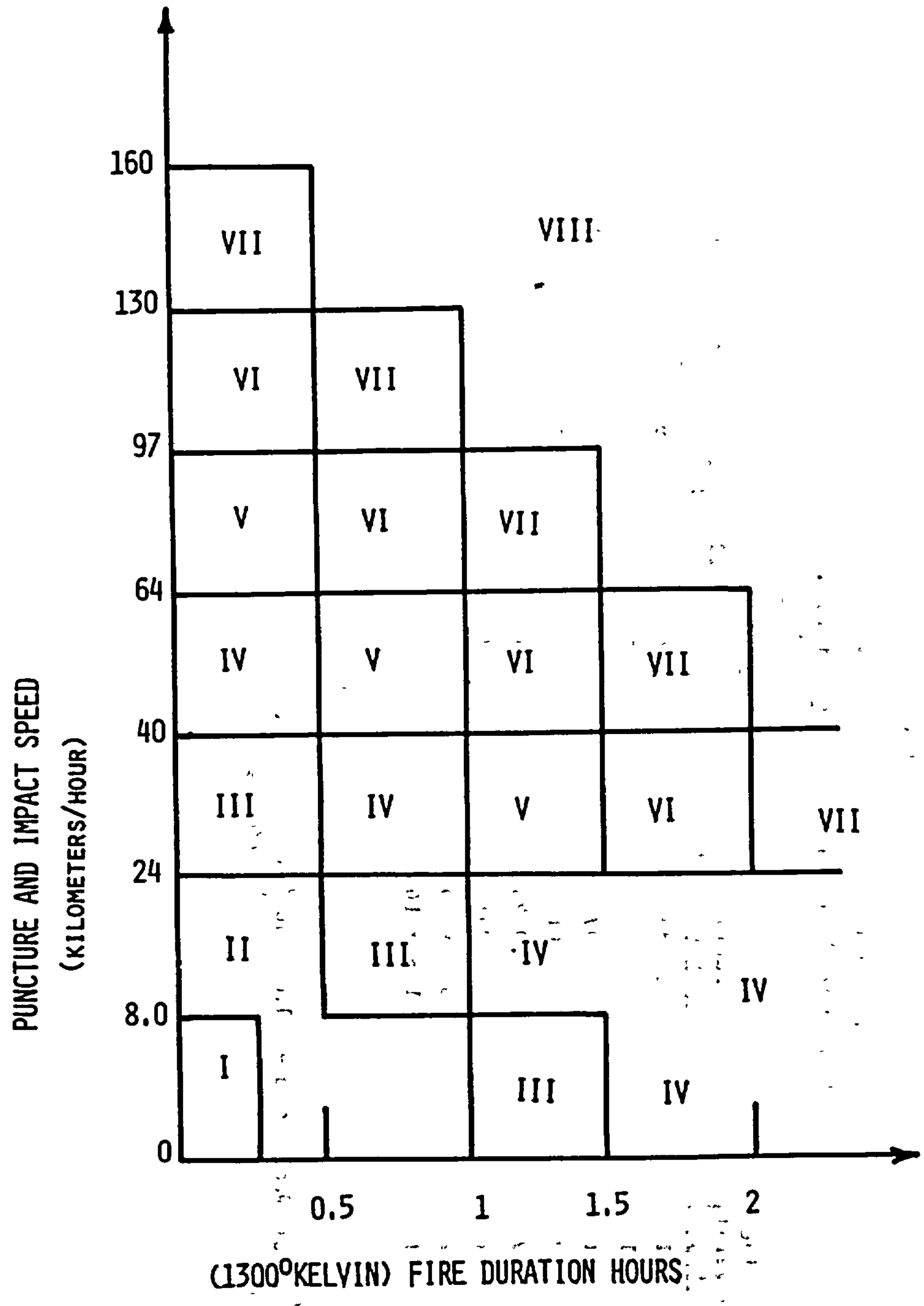


FIGURE 5-4. ACCIDENT SEVERITY CATEGORY CLASSIFICATION SCHEME - TRAIN

TABLE 5-5

FRACTIONAL OCCURRENCES* FOR TRAIN ACCIDENTS BY ACCIDENT SEVERITY CATEGORY AND POPULATION DENSITY ZONE

Accident Severity Category	Fractional Occurrences	Fractional Occurrences According to Population Density Zones		
		Low	Medium	High
I	.50	.1	.1	.8
II	.30	.1	.1	.8
III	.18	.3	.4	.3
IV	.018	.3	.4	.3
V	.0018	.5	.3	.2
VI	1.3×10^{-4}	.7	.2	.1
VII	6.0×10^{-5}	.8	.1	.1
VIII	1.0×10^{-5}	.9	.05	.05

*Overall Accident Rate = 0.93×10^{-6} railcar accidents/railcar-kilometer.

5.2.2.5 Helicopter Accidents

Helicopter accidents are classified in a manner similar to aircraft accidents (Figure 5-2). The overall accident rate is 0.63 x 10^{-6} accidents/kilometer (Ref. 5-9), and the fractional occurrences, shown in Table 5-6, are taken to be the same as for aircraft impacting on real surfaces. However, the fractional occurrences in the three population density zones are different since helicopters are used principally as a secondary transport mode to and from airports.

Accidents represented by the first two severity categories occur while the helicopter is on the ground either at the airport or at a pickup or delivery point, all of which would be located primarily in medium- and low-population density zones. It is anticipated that helicopter flights, particularly those carrying extremely hazardous material, would be routed to avoid flying over high-population-density zones whenever possible. Thus, the takeoff and landing accidents (severity Categories III-VI), as well as the in-flight accidents (Categories VII-VIII), are expected to be concentrated in the medium- and low-population-density zones. Category VII and VIII accidents involving helicopters are considered to be midair collisions and would be expected to occur mainly in the immediate vicinity of an airport; thus most of these accidents should occur in medium-population-density zones.

5.2.2.6 Ship And Barge Accidents (Ref. 5-10)

Records for calendar year 1973 for domestic waterborne traffic show a total of 6.67 x 10^{11} ton-miles. Precise data are not available to indicate what fraction of those ton-miles was barge traffic; however, a reasonable estimate seems to be 1.73 x 10^{11} ton-miles of barge traffic. According to the Coast Guard's annual statistics of casualties, there were an estimated 1395 barge accidents in 1973, of which about 60% involved cargo barges.

The available data cannot be analyzed in the same way as the data for rail or truck transport. On the basis of discussions with the U.S. Coast Guard, it is estimated that the average net cargo weight of a typical barge is about 1200 tons. The total number of barge miles would then be about 1.44 x 10^{8}. This yields an accident rate of about 6.0 accidents per million barge kilometers.

Very little data are available on the severity of accidents involving barges. Since barges travel only a few miles per hour, the velocity of impacts in accidents is small. However, because of the large mass of the vehicle and cargo, large forces could be encountered by packages, for instance, spent fuel casks aboard barges. A forward barge could impact on a bridge pier and suffer crushing forces as other barges are pushed into it. A coastal or river ship could knife into a barge. Fires could result in either case. An extreme accident, i.e., an extreme impact plus a long fire, is considered to be of such low probability that it is not considered a design-basis accident. The likelihood of a long fire in barge accidents is small because of the availability of water at all times. Also, since casks could be kept cool by sprays or submergence in water, there is compensation for loss of mechanical cooling.

TABLE 5-6

FRACTIONAL OCCURRENCES* FOR HELICOPTER ACCIDENTS BY ACCIDENT SEVERITY CATEGORY AND POPULATION DENSITY ZONE

Accident Severity Category	Fractional Occurrences (Real Surfaces)	Fractional Occurrences According to Population Density Zones		
		Low	Medium	High
I	.447	.35	.60	.05
II	.447	.35	.60	.05
III	.0434	.45	.45	.10
IV	.0107	.45	.45	.10
V	.0279	.45	.45	.10
VI	.0194	.45	.45	.10
VII	.0046	.19	.80	.01
VIII	.0003	.19	.80	.01

*Overall Accident Rate = 0.63×10^{-6} accidents/kilometer

The likelihood of cargo damage occurring in barge accidents is much less than in the case of rail accidents. The accident severity breakdown for ship and barge is shown in Table 5-7.

If a cask were accidentally dropped into water during barge transport, it is unlikely that it would be adversely affected unless the water was very deep. Most fuel is loaded into casks under water, so immersion would have no immediate effects. The water would remove the heat, so overheating would not occur. Each cask is required by NRC regulations (10 CFR § 71.32(b)) to be designed to withstand an external pressure equal to the water pressure at a depth of 15 m (50 ft), and most designs will withstand external pressure at much greater depths. If a cask seal were to fail due to excessive pressure in deep water, only the small amount of radioactivity in the cask coolant and gases from perforated elements in the cask cavity would be likely to be released. Even if the cask shielding were ruptured as a result of excessive pressure, the direct radiation would be shielded by the water. About 10 m of water, which is the depth of most storage pools, would be ample shielding for radiation, even from fully exposed fuel elements.

In a recent study (Ref. 5-11) it was concluded that the pressure seals on a spent fuel cask that is dropped into the ocean might begin to fail at a depth of 200 meters, a typical depth at the edge of the continental shelf, and release contaminated coolant. The fuel elements, which contain most of the radioactive material, provide excellent containment. In an operating reactor, the fuel elements are under water at elevated temperatures and at pressures on the order of 1000 to 2000 psi. Thus exposure to water pressures at depths of 600 to 1200 m should have no substantial effect on the fuel elements themselves. The study concluded that they would not fail until they reached a depth of approximately 3000 meters. Once they failed, the fuel pins would release fission products into the ocean, but these would be dispersed into such a large volume of the ocean that the concentrations would be very small. Certain nuclides such as cesium and plutonium could be reconcentrated through the food chain to fish and invertebrates that could be eaten by man; but, as pointed out in the study, the possibilities of a single person consuming large quantities of seafood, all of which was harvested from the immediate vicinity of the release, is very remote, especially since most seafood is harvested in areas over the continental shelves.

In virtually all cases, except those in which the cask was submerged to extreme depths, recovery would be possible with normal salvage equipment. If the cask and elements could not be recovered, corrosion could open limited numbers of weld areas within about 2000 years (Ref. 5-11), with possible localized failures occurring sooner. However, by that time most of the radioactivity would have decayed. Subsequent release would be gradual, and the total amount of radioactivity released at any one time and over the total period would be relatively small. Considering the extremely low probability of occurrence, the major reduction in radioactivity due to radioactive decay, and the dilution that would be available, there would be little environmental impact from single events of this kind.

Should a shipment be accidentally dropped during transfer to a barge, the main effect will likely be limited to that of rather severe damage to the barge. It is possible that a fuel cask could penetrate the barge decks and fall into the relatively shallow water of the breakwater basin. As previously discussed, there would be at most only minor radiological

TABLE 5-7

FRACTIONAL OCCURRENCES* FOR SHIP AND BARGE ACCIDENTS BY SEVERITY CATEGORY AND POPULATION DENSITY ZONE

Accident Severity Category**	Fractional Occurrences**	Accident Severity Category	Fractional Occurrences (this assessment)	Fractional Occurrences According to population density zone: Low	Medium	High
minor-2	.897	I	.897	0	.5	.5
minor-3	.0794	II	.0798	0	.5	.5
moderate-2	.00044					
moderate-3	.00113	III	.00113	0	.9	.1
moderate-4	.0186	IV	.0186	0	.9	.1
severe-2	.0000052	V	.0000052	.1	.9	0
severe-3	.000072	VI	.000072	.1	.9	0
severe-4	.000195	VII	.000195	.1	.9	0
extra severe-1	.000013	VIII	.000013	.1	.9	0

*Overall accident rate = 6.06×10^{-6} accidents/kilometer

**From Ref. 5-10.

consequences, since the cask (or drums) could be recovered easily and rather quickly. The environmental impact resulting from damage to the barge (including its sinking) would also be minor, since salvage could readily be started. The most significant effect would be the economic loss from recovery operations.

Waterborne traffic spends a very small fraction of its travel in high-population-density regions. The highest traffic density will probably occur in the port areas and, as a result, be associated with lower speed. Categories VI, VII, and VIII accidents probably require relatively large forces, a long-term fire, or an explosion, which are more likely to occur in open water. Categories III through V are more likely to be the result of a lower speed collision in a dock area, either with another vessel or a pier. The population density of dock areas of most cities was considered to be representative of a medium-population zone. Hence, Class III-V accidents are assumed to occur in a medium-population zone. Categories I and II accidents are not likely to involve another vessel, since they are very minor in nature. Hence, they are considered to occur either in open waters or while securely moored. These assumptions are reflected in Table 5-7.

5.2.3 RELEASE FRACTIONS

In order to assess the risk of a transportation accident, one must be able to predict the package response to an accident of given severity. In particular, one needs to know the fraction of the total package contents that would be released for an accident of given severity. The actual releases for a given package type would not necessarily be the same for a number of accidents of the same severity class. In some cases there may be no release, while in others there may be, for example, a 10% release. Indeed, in a given accident involving a number of radioactive material packages transported together, some of the packages may release part of their contents while others have no release at all. The approach taken in this assessment is to derive a point estimate for the average release fraction for each severity category and package type and assume <u>all</u> such packages, including each package in a multipackage shipment, respond to such an accident in the same way without regard to the type or form of the contents.

The paucity of data on package responses to severe accidents makes it difficult to predict even the average release fraction, much less a distribution. Since the packaging standards do not require tests to failure there has been, until recently, little information relating the response of packages to accident environments.

Recently, a series of severe impact tests was carried out at Sandia Laboratories using several types of containers commonly used to ship plutonium (Refs. 5-12 and 5-13). All container types survived tests with no structural damage to the inner container after impacts onto unyielding targets occurred at speeds up to those typical of a Category V impact accident. Several containers exhibited some minor structural damages and cracking in Category VI impacts, but no verified release occurred. Tests of containers typical of those in commerce resulted in failure of a nonspecification cast iron plug and allowed material loss and also compromised the overall integrity of the inner containers. In one test a container lost 6% of its contents (magnesium oxide powder) in a Category VII impact; others survived Category VIII impacts with no loss of contents. Although none of the containers in this test series was subjected to fire, others of the same type survived less severe impacts followed by a 1300°K environment lasting for a half-hour with no release. Using this test information or assuming that packagings begin to fail at severities just above those that they are required to survive, the responses of packages are estimated by the methods detailed below. The release fraction estimates for all packagings evaluated are shown in Table 5-8.

Two specific release fraction models are considered. Model I specifies total release of package contents for all accident severities exceeding that specified by Federal regulations. This somewhat unrealistic model assumes that zero release occurs up to the regulatory test level and that the packaging fails catastrophically in all environments that exceed that level. Clearly, packagings do not behave in this fashion, but this approach does present a simplistic evaluation of present regulations. Model II is considered to be a more realistic model, although it too has inherent conservatism as is discussed later. Models I and II are used for the 1975 and 1985 risk assessment, and Model II is used for consideration of transportation alternatives in Chapter 6.

5.2.3.1 Release Fractions For Plutonium Shipping Containers

Two sets of release fractions for Type B plutonium shipping containers are listed for Model II; both are derived from the container impact test data described earlier (Refs. 5-12 and 5-13). Those release fractions listed under the heading 1975 Pu show a small release (1%) in a Category VI accident. This accounts for the possibility that small amounts of material might be forced through the cracks observed in the inner container. The 5% release in Category VII reflects the results of the one test in which a measurable amount of material escaped. The Category VIII release fraction of 10% is an estimate of the upper limit to the release fraction based upon analysis of all test data.

The 1985 Pu release fractions acknowledge that in the interim period from 1975 to 1985, package development programs currently underway are likely to produce packages that will have higher integrity. As a result only a 1% release is expected in Category VII and 10% in Category VIII. Even lower release fractions are likely to be justifiable for containers currently under development, but no lower values were shown without complete test data and assurance that older containers will be out of use.

The Integrated Container Vehicle (ICV) is currently being discussed as the principal transport vehicle for plutonium shipments in 1985 and is expected to change the release fractions associated with plutonium shipments appreciably. The massive vault-like containers will be highly accident resistant. The release fractions assumed for these containers are also shown in Table 5-8.

5.2.3.2. Other Type B Containers

Federal regulations require that Type B packagings be able to withstand tests designed to simulate certain accident conditions (Ref. 5-14). In the absence of test data on safety margins for Type B packages, the assumption is made that most containers begin to fail just beyond the accident conditions at which they were tested, although not in the catastrophic

TABLE 5-8

RELEASE FRACTIONS

Model I

Severity Category	LSA Drums	Type A	Type B	Cask (Exposure)	Cask (Release)
I	0	0	0	0	0
II	1.0	1.0	0	0	0
III	1.0	1.0	1.0	1.0	1.0
IV	1.0	1.0	1.0	1.0	1.0
V	1.0	1.0	1.0	1.0	1.0
VI	1.0	1.0	1.0	1.0	1.0
VII	1.0	1.0	1.0	1.0	1.0
VIII	1.0	1.0	1.0	1.0	1.0

TABLE 5-8 (continued)

RELEASE FRACTIONS

Model II

Severity Category	LSA Drum	Type A	Type B No Pu	Type B 1975 Pu	Type B 1985 Pu	Cask (exposure)	Cask (release)	ICV
I	0	0	0	0	0	0	0	0
II	.01	.01	0	0	0	0	0	0
III	.1	.1	.01	0	0	0	.01	0
IV	1.0	1.0	.1	0	0	0	.1	0
V	1.0	1.0	1.0	0	0	0	1.0	0
VI	1.0	1.0	1.0	.01	0	$3.18x10^{-7}$	1.0	0
VII	1.0	1.0	1.0	.05	.01	$3.18x10^{-5}$	1.0	0
VIII	1.0	1.0	1.0	.1	.1	$3.12x10^{-3}$	1.0	.1

manner assumed with Model I. Above the threshold test at which release occurs, the release fractions are assumed to increase with increasing accident severity as assumed for plutonium containers. Note that catastrophic failure (i.e., complete release) is assumed for accident severity categories above IV. This is a conservative assumption in the absence of tests to failure.

5.2.3.3. Type A And Low Specific Activity Containers

The same rationale used for Type B containers is used for Type A containers. A small release is assumed for Category II with progressively greater releases with increasing severity in the same way as for Type B containers. An independent test carried out at Sandia Laboratories on a single Type A (Mo-99 generator) container under Category IV impact conditions resulted in extensive packaging damage but zero release. Thus, the release fractions assumed for this type of packaging are believed to be conservative.

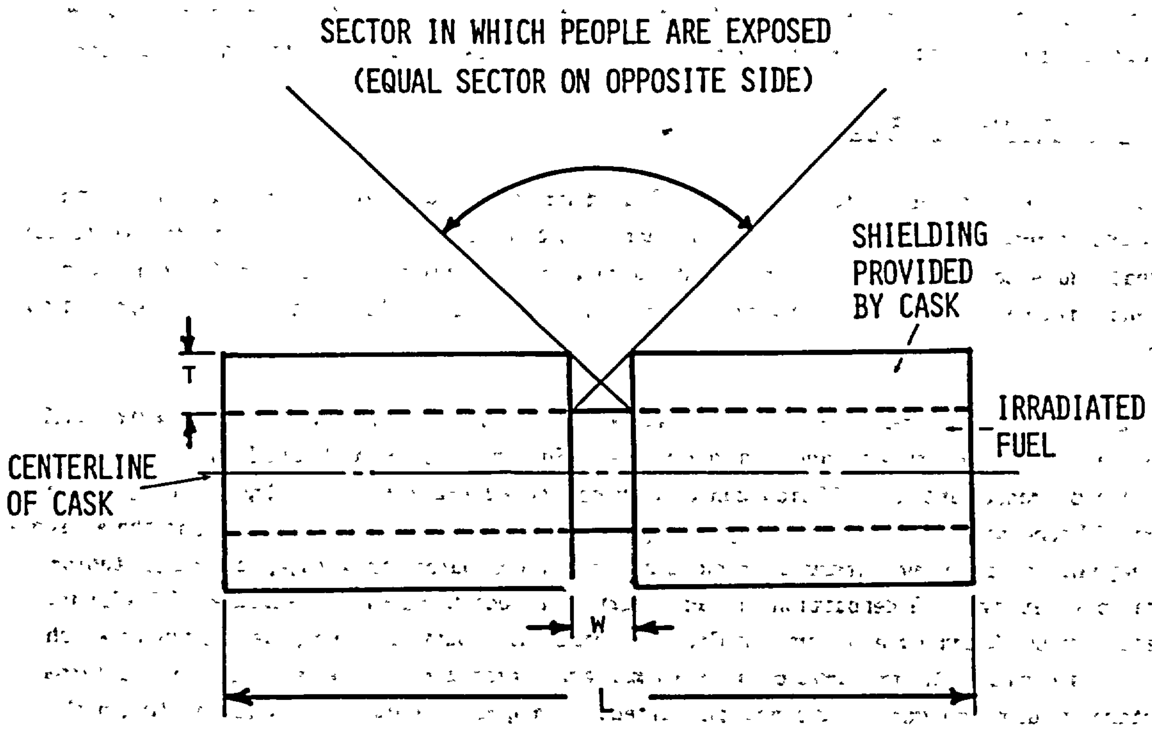
5.2.3.4 Casks

Large casks are used for shipments of large irradiator or teletherapy sources, irradiated fuel, and high-level fuel cycle waste. In analyzing release fractions, therefore, two types of releases must be considered: direct release of contents to the environment and exposure of the surrounding environment to neutron or gamma radiation through a breach in shielding. These two problems must be addressed separately.

Spent fuel can be thought of as a combination of two components: gaseous and volatile materials in the coolant, plenums, and void spaces in fuel rods and non-volatile fission products and activated material held in the matrix of the fuel pellets. Since packagings for large-quantity shipments such as spent fuel must meet Type B standards, the Type B packaging release fractions discussed previously are used to evaluate the release of available gaseous and volatile materials (Ref. 5-14). Drop tests using spent fuel shipping containers were conducted at Sandia Laboratories (Ref. 5-15). There were no releases at impact velocities up to 394 kilometers per hour onto hard soil.

The effect of loss of shielding is modeled by assuming that a circumferential crack is produced in the cask by the accident forces (see Figure 5-5). Using probabilities and descriptions of breaches suggested in Reference 5-16, a Category VI accident was considered the minimum accident with forces sufficient to cause a crack through the entire cask. This was modeled as a circumferential crack 0.1 cm wide around the entire cask. In a Category VII accident this crack is assumed to be 1 cm in width; in a Category VIII accident, it is assumed to be 10 cm in width.

The "release fraction" for the loss of shielding case is not really a release fraction at all, but is the product of the fraction (W/L) of the source length that is exposing the surrounding population and the fraction $[1 - 2/\pi \tan^{-1}(T/W)]$ of the surrounding area that lies within the sector being exposed (see Figure 5-5). The computation of the integrated population dose is then carried out assuming a fictitious point source whose strength is the total



W = WIDTH OF CRACK

T = THICKNESS OF CASK SHIELDING

$$\text{FRACTION OF SURROUNDING POPULATION EXPOSED} = 1 - \frac{2}{\pi}\,\text{TAN}^{-1}\left(\frac{T}{W}\right)$$

FIGURE 5-5. RELEASE FRACTION MODEL FOR EXPOSURE-TYPE SOURCES SHIPPED IN CASKS

number of curies contained multiplied by the "release fraction," with the integration extending over the entire area. The values in Table 5-8 were determined for a cask length, L, of 2.54 meters and a shielding thickness, T, of 0.4 meter.

5.2.4 SHIPMENT PARAMETERS

The shipment parameters that contribute to the accident impact calculation include the number of curies per package, the number of packages per shipment, the physical/chemical form of the material, the dosimetric aspects of the material, the number of shipments per year by each mode, and the distance traveled by each shipment. These data are presented in Appendix A.

5.3 DISPERSION/EXPOSURE MODEL

Once a release has occurred, the released material is assumed to drift downwind and disperse according to a Gaussian diffusion model and can produce such environmental effects as internal and external radiation doses, contamination, or buildup in the food chain. If the accident involves a material in special form, only external radiation exposure is assumed to occur.

Environmental impacts result both from a release to the atmosphere and from external radiation exposure from a large source whose shielding has been damaged in an accident. Atmospheric transport and diffusion can disperse released material over large areas, but the degree of dispersion is determined by atmospheric turbulence, which is a function of the season of the year, time of day, amount of cloud cover, surface characteristics, and other meteorological parameters. The deposition of radionuclides associated with the passage of a cloud of released material can have a very complex environmental impact. Some possible ways in which the dispersed material can produce a dose to man are summarized in Figure 5-6. Direct external or internal dose to man is the principal effect from gamma emitters. Material that emits alpha or beta radiation produces the largest radiological consequence when aerosolized and inhaled by man. Figure 5-6 shows that deposited radionuclides can also be taken into the food chain. They can be transferred from soil to vegetation to animals and eventually to man. However, radiation doses to man through the food-chain pathway are usually more significant (relative to doses through inhalation, for example) if there exists a continuous source of release to the environment.

5.3.1 ATMOSPHERIC DISPERSION MODEL

The dispersion model is based on Gaussian diffusion, a technique widely used in analysis of atmospheric transport and diffusion. Accidents that involve a release of dispersible material are assumed to produce a cloud of aerosolized debris instantaneously at the accident site. The initial distribution of aerosol mass with height is assumed to be a line source extending from the ground to a height of 10 meters. The initial concentration increases with height in a manner consistent with data obtained in experimental detonations of simulated weapons (Ref. 5-17). The use of such an initial distribution is justified for accidents in which fires or residual energy provide an aerosol cloud to be released from the accident site. Since the dose from a 10-meter-high line source is indistinguishable from that of a point

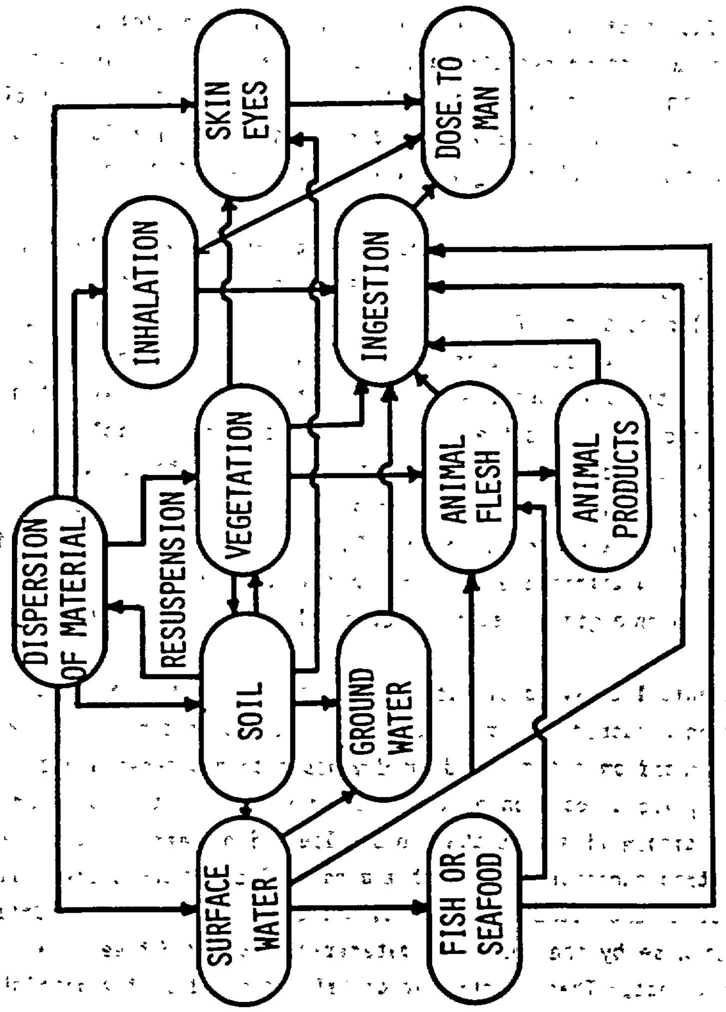


FIGURE 5-6. POSSIBLE ROUTES TO MAN FROM RADIONUCLIDE RELEASE

source at downwind distances greater than about 100 meters, the initial distribution with height is unimportant. Doses calculated using this model are conservative, since most potential accidents involve energy releases that may carry aerosolized materials to heights greater than 10 meters. The degree of conservatism increases as the height of release increases and is especially conservative for elevated sources such as a release that might result from midair aircraft collisons.

Transport and diffusion of the aerosol cloud (composed of particles so small that gravitational settling is minimal) occur symmetrically about the mean wind velocity vector. This process is described using climatological distributions of horizontal and vertical components of turbulence intensities and wind speed. The aerosolized material is allowed to diffuse horizontally without constraint and vertically to an altitude of 1400 meters (Ref. 5-18).

A year or more of meteorological data recorded at sites near White Sands, New Mexico, and Aiken, South Carolina, is used in the model. These data are used to generate values for the lateral and vertical dimensions of the aerosol cloud, which are expressed in terms of the measured lateral and vertical turbulence intensities (Ref. 5-19). These values are calculated for various downwind locations to provide estimates of the dilution that has occurred as a function of the downwind distance and the amount of aerosolized material involved. The results obtained for each of the meteorological data sets are examined to determine the area within which a given dilution factor is not exceeded (this is an area in which a given concentration is exceeded). A curve of area exceeded in only 5% of all meterological conditions versus dilution factor not exceeded within the area is shown in Figure 5-7. This area is taken as a credible upper limit in which a given dilution factor will not be exceeded.

In order to make a full analysis of actual inhalation hazard, the phenomena of deposition and resuspension must be considered. As the cloud of aerosolized material is transported by the wind, material is scavenged from the cloud by dry deposition processes and deposited on the ground. Wet deposition, i.e., deposition by rain and snowfall, is not considered in this model; the neglect of wet deposition will mean that this calculation overestimates the population dose in areas where precipitation can interact with the aerosol cloud. Dry deposition occurs continuously, and its effect is estimated by depleting the total quantity of material that would contribute to inhalation dose by the amount of material deposited between the source release point and a point of interest. The amount of material deposited at any point is calculated using a deposition velocity, V_d (m/sec), which, when multiplied by the time-integrated concentration (Ci-sec/m^3), yields the amount deposited, D (Ci/m^2). A value of 0.01 m/sec is used for V_d based on a previous analysis (Ref. 5-20) and for consistency with the resuspension model used in this document. Dry deposition removes material from the cloud and reduces the downwind concentration, as shown in the lower curve on Figure 5-7.

Resuspension occurs when deposited particle material on a surface is made airborne as a result of mechanical forces (walking, vehicle traffic, plowing, etc.) and wind stress on the deposition surface (as in sandstorms or blowing snow). The resuspended material becomes available for inhalation by people in the contaminated area and can cause an additional component of body burden and radiation dose accumulating with time. Methods used to calculate

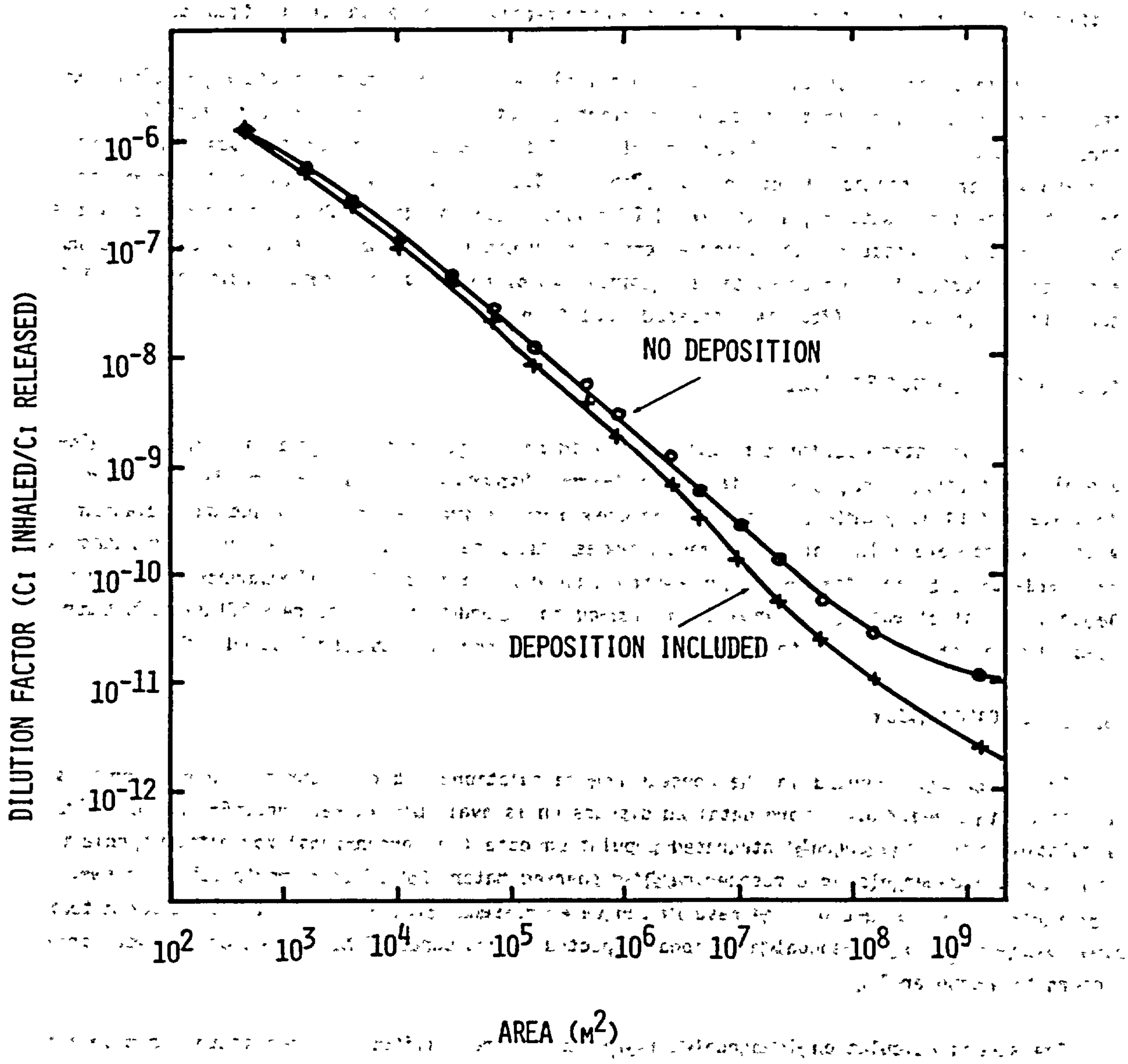


FIGURE 5-7. DOWNWIND DILUTION FACTOR AS A FUNCTION OF AREA

resuspension involve an empirical "resuspension factor," K/m, which is the ratio of the air concentration at a point to the surface concentration just below that point in the contaminated area. An initial value of 10^{-5}/m decreasing exponentially with a 50-day half-life to a constant value of 10^{-9}/m is used in this study to evaluate the dose contributed by resuspension (Ref. 5-20). Because of radioactive decay, short-half-life materials such as Tc-99m provide little resuspension dose, whereas long-half-life nuclides such as Pu-239 increase the initial dose by a factor of up to 1.6 over the dose received during actual cloud passage.

Two effects can be calculated once the actual downwind concentration and deposition patterns are known. The first and most important effect is the inhalation dose received by persons in the downwind area. The calculation of this dose is discussed in Appendix G, and the results are presented later in this chapter. The second effect, which can be determined from the deposition pattern, is the level of surface contamination. Contamination on surfaces has two principal effects: the material can be resuspended and inhaled (as previously discussed), and affected land or crops can be quarantined or condemned if the contamination level is sufficient. The latter effect is discussed in Section 5.5.

5.3.2 EXTERNAL EXPOSURE MODEL

If the postulated accident results in shielding damage to a package containing a nondispersible material, e.g., one of the special-form shipments such as Co-60 or Ir-192, or an irradiated fuel cask, direct external exposure results from the gamma or neutron radiation emitted by the material. This assessment assumes that after an accident the source remains at the accident site for 1 hour with no evacuation and no introduction of temporary shielding The area in which people are exposed is assumed to extend for a distance of 0.8 kilometer radially from the location of the source. This calculation is discussed in Appendix G.

5.3.3 DOSE CALCULATION

Two doses are computed in the consequence calculation, and the computation of each is discussed in Appendix G. A more detailed discussion is available in Reference 5-1. The first calculation is of the annual integrated population dose (in person-rems) for either special form exposure materials or atmospherically dispersed materials. This computation is shown schematically in Figure 5-8. The results can be expressed either as person-rems delivered to particular organs or as annual additional expected latent cancer fatalities using conversion factors from Chapter 3.

The second calculation is annual early fatality probability. If an isotope can give a sufficient dose to cause an early fatality, either from external exposure or excessive pulmonary exposure, the annual probability of this occurrence is computed as shown in Figure 5-9.

5.4 APPLICATION OF THE MODEL TO 1975 AND 1985 STANDARD SHIPMENTS

The annual population dose calculations were carried out for the standard shipment scenarios discussed in Appendix A using the methods discussed previously. The results are presented

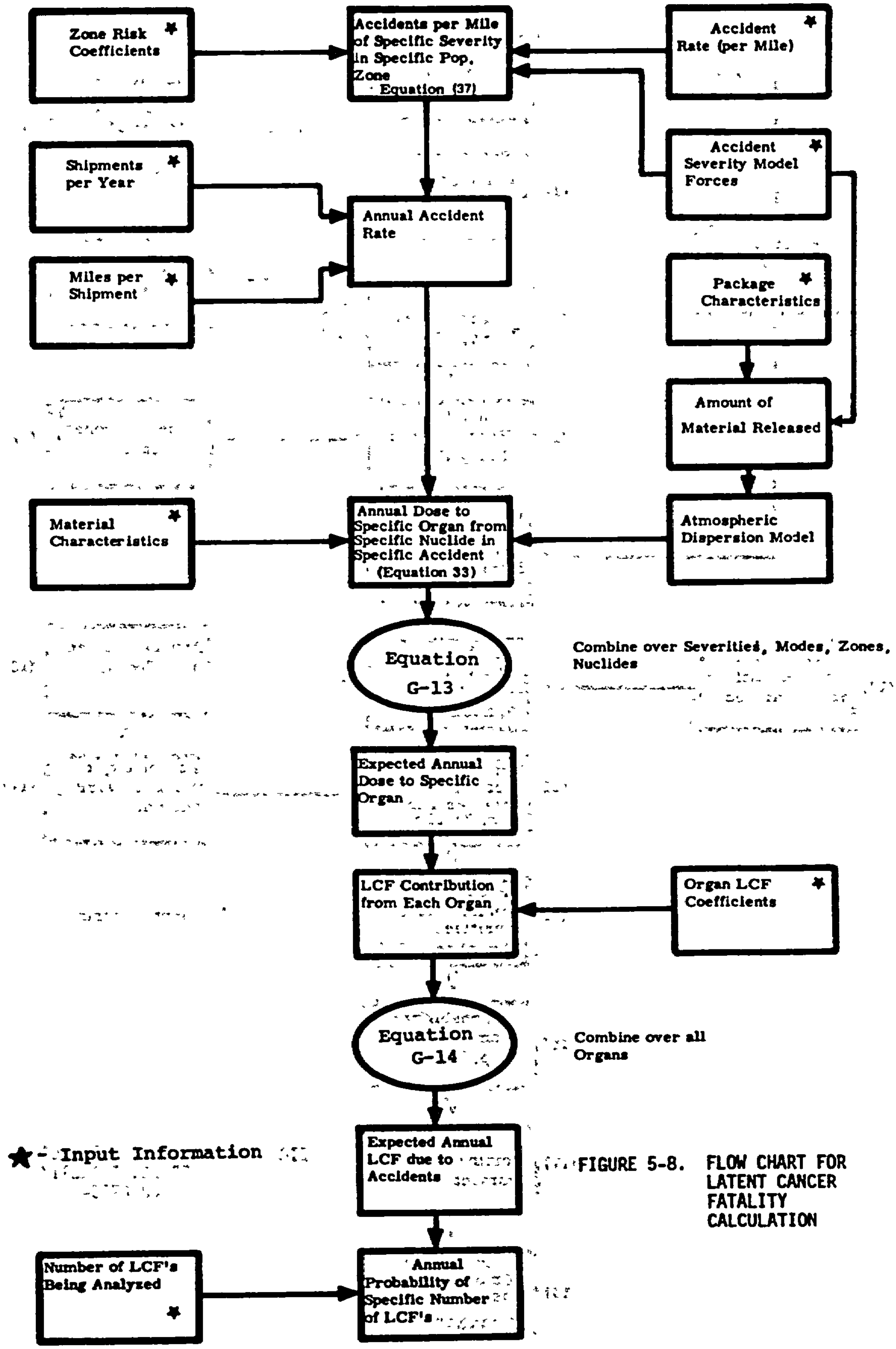


FIGURE 5-8. FLOW CHART FOR LATENT CANCER FATALITY CALCULATION

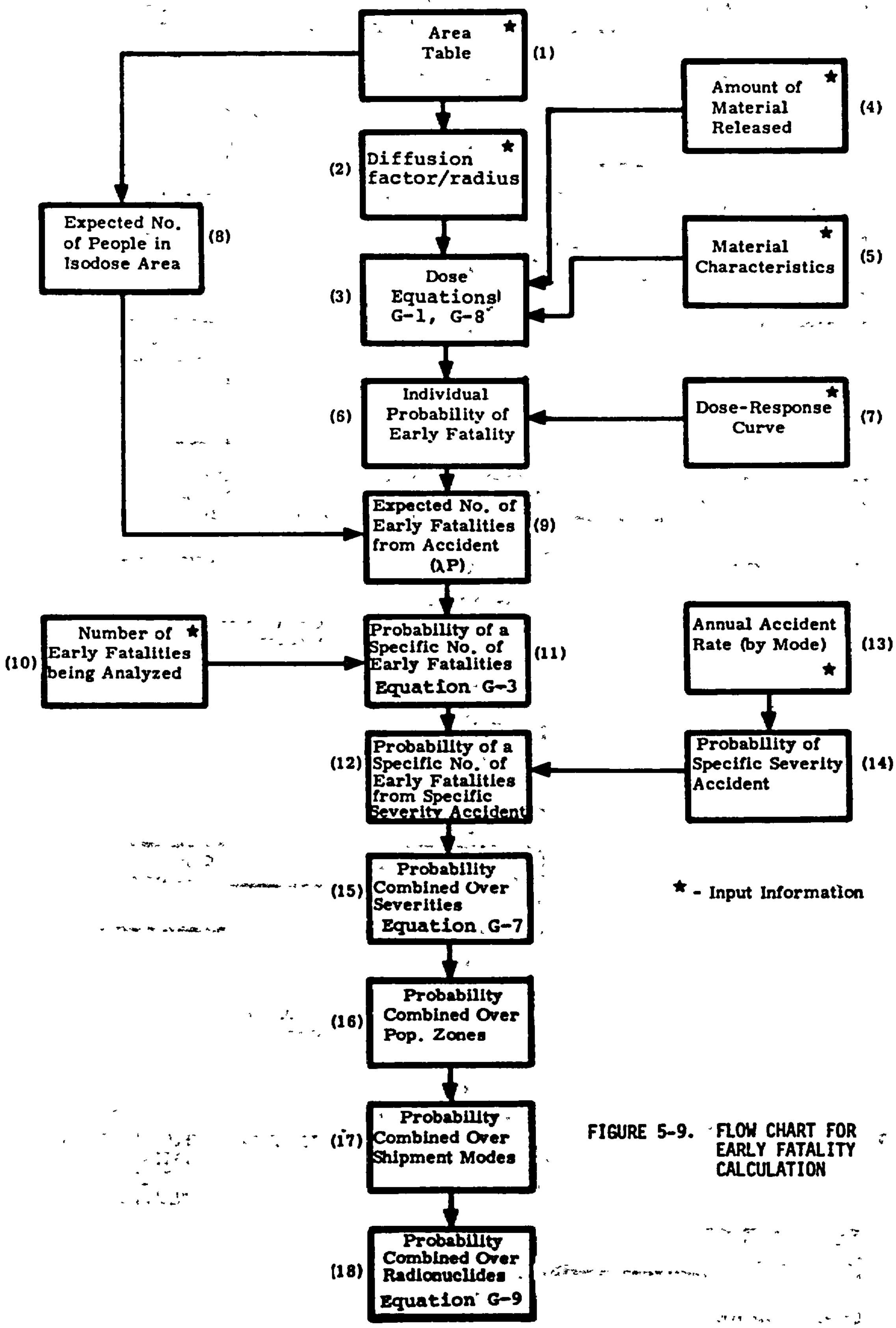


FIGURE 5-9. FLOW CHART FOR EARLY FATALITY CALCULATION

in Table 5-9 for both 1975 and 1985 standard shipments. The annual probability of more than a given number of early fatalities is plotted on Figure 5-10 for 1975 and 1985. Note that a total of 5.37×10^{-3} latent cancer fatalities were expected to result in 1975 from all radioactive material shipments, with the principal contributor being the 144-curie Po-210 shipment scenario with 24% of the 1975 LCFs.* The mixed fission product/corrosion product shipments taken together are of similar importance to Po-210, and the shipments of uranium-plutonium mixtures are third, representing 10.7% of the total LCFs in 1975.

The picture in 1985 is similar, except that the plutonium shipments become much less important. This results from the expected improvement in packaging release fractions in plutonium containers.

The data plotted in Figure 5-10 indicate an annual probability of one or more early fatalities (within 1 year of an accident) of approximately 3.5×10^{-4}, while the probability of 10 or more is 2.5×10^{-6}. This implies that an accident serious enough to kill one person from acute radiological effects would occur only once in 2000 years at 1975 shipping levels.

Results using Model I release fractions for 1975 and 1985 data are presented in Table 5-10 and Figure 5-11. The results shown in Table 5-10 show clearly the impact of the Model I release fractions, which imply that the containment capability of the containers is no better than the regulations require. The most important shipments in this analysis are those with the large quantities of very hazardous materials. The expected LCFs in this case are 9.8 per year in 1975, more than 1000 times that for Model II. The data plotted in Figure 5-11 for the probability of early fatalities using Model I release fractions are also very different from the Model II results. They indicate a probability of less than 0.1 of having one or more early fatalities per year for 1975 using this unrealistic, but legally possible, release fraction model.

5.5 CONSEQUENCES OF CONTAMINATION FROM ACCIDENTS

In addition to direct radiological impacts to man, an accident involving radioactive material may result in environmental contamination leading to loss of crops or contamination of buildings and necessitating evacuation of residents. Analysis of these impacts has been addressed in some detail for the case of a reactor accident in Reference 5-20, and a similar methodology has been adopted for this report.

The potential contamination consequences of a transportation accident involving radioactive materials are, in general, several orders of magnitude smaller than those for a reactor accident. The potential for ingestion of radioactive materials is reduced considerably by the

*There are many factors that can modify the risks identified in Table 5-9. One of these factors is the accident resistance of the package used to ship particular radionuclides. Not included in this analytical model, and thus not reflected in the results, is the fact that all large-quantity shipments of polonium were made in the same accident-resistant packages used to ship plutonium. If considered, this would result in much smaller releases in many of the accident severity categories, and in a smaller total risk attributed to polonium.

TABLE 5-9

ACCIDENT RISK ANALYSIS RESULTS - EXPECTED LATENT CANCER FATALITIES

1975 AND 1985 - MODEL II RELEASE FRACTIONS

Standard Shipment	Expected Latent Cancer Fatalities 1975	Percent of Total Risk	Expected Latent Cancer Fatalities 1985	Percent of Total Risk
Po-210 (144 ci)	.00131	24.4	.00373	22.4
MF+MC (LSA)	.000709	13.2	.00294	17.7
U-Pu Mix	.000514	10.7	.00022	1.3
MF+MC (A)	.000478	8.9	.00198	11.9
Waste (A)	.000388	7.2	.00160	9.6
UF_6 (natural)	.000328	6.1	.00135	8.2
Waste (B)	.000182	3.4	.000752	4.5
Co-60 (40,000 ci)	.00013	2.4	.000336	2.0
Pu-239 (B)	.000129	2.4	.0000122	0.0
Mixed (A)	.00011	2.1	.000286	1.7
U_3O_8	.0000817	1.5	.000338	2.0
MF+MC (392 ci)	.0000800	1.5	.000334	2.0
Mo-99 (A)	.0000708	1.3	.000184	1.1
UF_6 (enriched)	.0000594	1.1	.000246	1.5
Limited	.0000579	1.1	.000151	0.9
Mo-99 (B)	.0000573	1.1	.000149	0.9
Co-60 (LSA)	.0000478	0.9	.000126	0.8
I-131 (A)	.0000384	0.7	.0000384	0.2
Mixed (B)	.0000383	0.7	.0000997	0.6
Spent fuel	.0000356	0.7	.000422	2.5
All others	.000482	9.0	.00136	8.2
TOTAL	.00537		.0166	

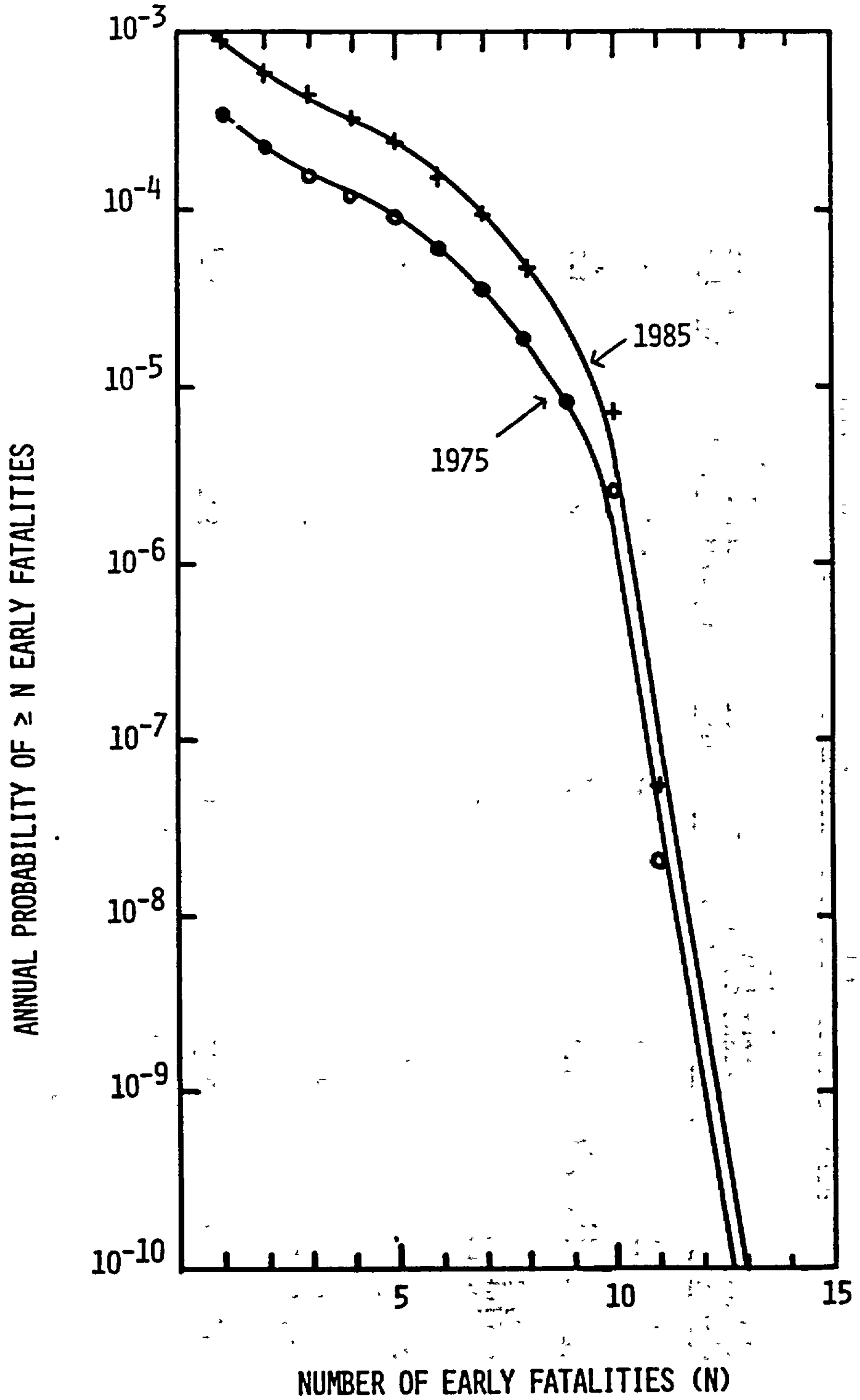


FIGURE 5-10. CUMULATIVE ANNUAL EARLY FATALITY PROBABILITY - 1975, 1985 - MODEL II

TABLE 5-10

ACCIDENT RISK ANALYSIS RESULTS - 1975, 1985 - MODEL I RELEASE FRACTIONS

Standard Shipment	Expected Latent Cancer Fatalities -1975	Percent of Total Risk	Expected Latent Cancer Fatalities - 1985	Percent of Total Risk
U-Pu Mixture	7.9	80.2	32.8	86.6
Pu-239 (1169 ci)	1.78	18.0	1.78	4.7
Recycle plutonium	-	-	1.83	4.8
Spent fuel (rail)	0.021	0.2	0.8	2.1
Spent fuel (truck)	0.047	0.5	0.29	0.8
All others	0.11	1.1	0.038	0.1
	9.86	100	37.9	100

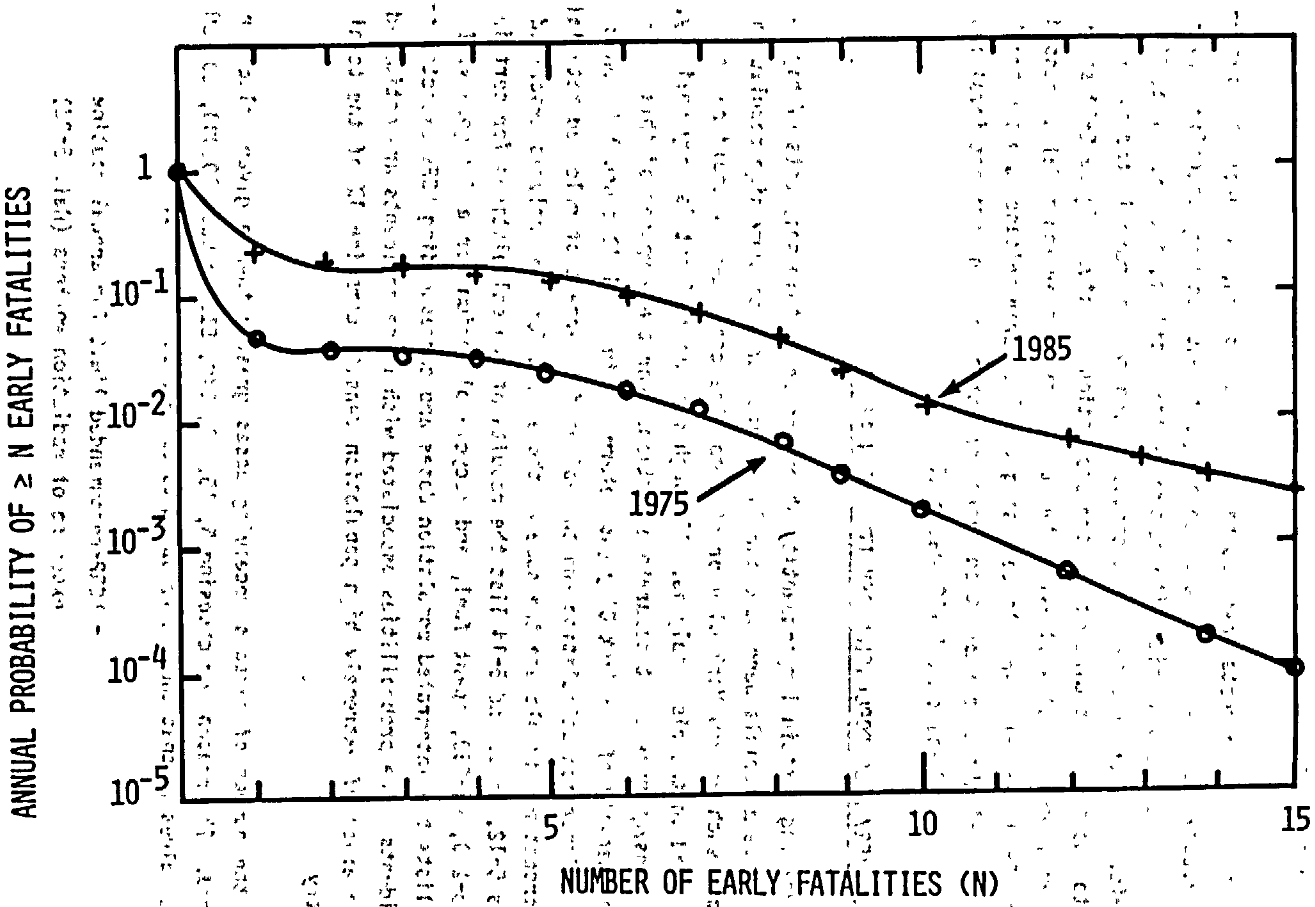


FIGURE 5-11. CUMULATIVE ANNUAL EARLY FATALITY PROBABILITY - 1975, 1985 - MODEL I

fact that contaminated areas are smaller and could be cordoned off. Contaminated crops, milk, and possibly even animals might have to be condemned and destroyed.

A detailed analysis of decontamination costs for four land-use situations for contamination by both a long-lived and a short-lived isotope is presented in this Section. A cleanup level of 0.65 $\mu Ci/m^2$ was used, based on the Palomares, Spain, nuclear weapons incident (Ref. 5-21). The assumptions and results are shown in Table 5-11. Values associated with Table 5-11 were extracted from Reference 5-20.

The analysis of decontamination costs involves many assumptions and, of necessity, represents only order-of-magnitude accuracy. More accurate analysis requires very specific information about land use near the accident site, the nature of the accident, the weather at the time of the accident, etc. However, the cost of decontamination may be approximated as being directly proportional to the area contaminated and the population density. Figure 5-12 shows the area contaminated versus curies released using the atmospheric dispersion model discussed in Section 5.3. Figures 5-13 and 5-14 were plotted using the 600-curie release as a benchmark. These figures show the approximate decontamination costs resulting from an accident involving a given size shipment of long- and short-half-life material.

5.6 SEVERE ACCIDENTS IN VERY HIGH POPULATION DENSITY URBAN AREAS

If an accident involving certain large-quantity shipments or certain shipments of highly toxic or highly radioactive materials were to occur in an urban area of very high population density (i.e., $>10^4/km^2$) such as New York City or Chicago, the consequences could be more serious than any considered in the risk analysis. Although such an accident is very unlikely, its potentially severe consequences merit separate attention. For the purposes of this analysis, the average urban density of New York City (as determined in the 1970 census) is used: 15,444 people/km^2. The dispersion calculation and the values for percent of released material aerosolized and the percent respirable are the same as those used for the analysis described in Section 5.3. Tables 5-12, 5-13, and 5-14 list the results of the calculations for certain shipments of Co-60, Po-210, Pu-239, spent fuel, and recycle plutonium for a Category VIII accident. Table 5-12 lists the integrated population doses and corresponding LCFs expected to result from these accidents. The probabilities associated with these accidents are estimated by assuming that urban areas of extremely high population density comprise 1% of the total urban area in the country.

Table 5-13 shows the number of persons receiving doses greater than a given value for each accident considered. The reason for choosing 5, 15, 50, 340, 510, 3,000, 10,000, 20,000 and 70,000 rems as dose values is that these correspond to certain benchmark values:

15 rems to lungs - NCRP-recommended limit for annual routine exposure of radiation workers (Ref. 5-22)

3000 rems to lungs - threshold for pulmonary morbidity from short-lived gamma and beta emitters (Ref. 5-20)

TABLE 5-11

ESTIMATED DECONTAMINATION COST FOR 600 CURIE RELEASE OF VARIOUS MATERIALS [a]*

		Long-Lived Contaminant		Short-Lived Contaminant [b]	
Population Zone	Land Use	Decont. Technique	Estimated Cost ($)	Decont. Technique	Estimated Cost ($)
Rural (6 person/km^2)	undeveloped/ uninhabited	(1) DF<20- bury by deep plowing [c]	7.8×10^5	(1) cordon off for 60 days [e]	$29,000
		(2) DF ≥ 20- scrape and bury [d]	3.04×10^5		
			Total = 1.08×10^6		Total = $29,000
	farmland/ dairyland	(1) DF < 20 bury by deep plowing	7.8×10^5	(1) cordon off for 60 days	$29,000
		(2) DF ≥ 20 scrape and bury	3.04×10^5	(2) 270 evacuees for 60 days	3.65×10^4
		(3) decon. homes/barns a. DF<20 [f]	6.22×10^5	(3) purchase & dispose of crops, forage, milk [k]	9.77×10^5
		b. DF≥20 [g]	7.42×10^4		
		(4) 270 evacuees [h]	3.65×10^4		
		(5) purchase & dispose of crops, forage, and milk [i]	1.15×10^6 [j]		
			Total = $2.97 \times 10^6		Total = 1.04×10^6

*See notes at end of table.

TABLE 5-11 (continued)

Population Zone	Land Use	Long-Lived Contaminant: Decont. Technique	Long-Lived Contaminant: Estimated Cost ($)	Short-Lived Contaminant [b]: Decont. Technique	Short-Lived Contaminant [b]: Estimated Cost ($)
Suburban (719 persons/km^2)	98.5% single family dwellings	(1) Decon. homes		(1) cordon off all residential areas with DF ≥ 20 [t]	$7.2x10^4$
		a. DF < 20[l]	$56.1x10^6$		
		b. DF ≥ 20[m]	$12.1x10^6$		
	0.8% public areas (schools, etc.)	(2) $3.24x10^4$ evacuees	$4.4x10^6$	(2) Decon. homes DF>20	$12.3x10^6$
	0.4% commercial & industrial areas	(3) Decon. public areas		(3) cordon off all parks [u]	$2.84x10^5$
		a. DF < 20[n]	$1.83x10^5$		
		b. DF ≥ 20[o]	$1.0x10^5$		
	0.3% parks, cemeteries, etc.	(4) Decon. commercial & industrial areas		(4) Decon. public areas	$2.84x10^5$
		a. DF < 20[p]	$9.15x10^4$	(5) Decon. commercial & industrial, areas	$1.89x10^5$
		b. DF ≥ 20[q]	$9.77x10^4$		
		(5) Decon. parks by replacing lawn [r]	$1.12x10^6$	(6) 2035 evacuees for 60 days. 30,320 evacuees for 10 days	$5.74x10^6$
		(6) indiv. and corporate income loss[s]	$7.33x10^6$	(7) income loss	$9.64x10^6$
			Total = $82x10^6		Total = $28.5x10^6

TABLE 5-11 (continued)

Population Zone	Land Use [w]	Long-Lived Contaminant: Decont. Technique	Long-Lived Contaminant: Estimated Cost ($)	Short-Lived Contaminant: Decont. Technique	Short-Lived Contaminant: Estimated Cost ($)
Urban (3861 persons/ km^2)	20% high density resid. (6 story apts) [cc]	(1) Decon. apartment buildings a. DF<20[x] b. DF≥20[y]	$1.7x10^6$ $1.06x10^6$	(1) cordon off resid. areas with DF≥20 [t]	$7.2x10^4$
	20% single fam. resid[cc]	(2) Decon. single fam. residences a. DF<20[l] b. DF≥20[m]	$11.4x10^6$ $2.45x10^6$	(2) cordon off all parks and vacant areas	$3.2x10^6$
	20% public land			(3) Decon. resid. with DF ≥ 20	$3.5x10^6$
	20% Ind. & commercial	(3) Decon. public land a. DF<20 b. DF≥20	$4.6x10^6$ $2.5x10^6$	(4) Decon. commercial & industrial areas	$9.5x10^6$
	10% parks				
	10% undevel. or vacant land	(4) Decon. commercial & industrial area a. DF<20 b. DF≥20	$4.6x10^6$ $4.9x10^6$	(5) 10,900 evacuees for 60 days; $1.63x10^5$ for 10 days	$30.8x10^6$
		(5) Decon parks	$5.67x10^6$	(6) Decon. public areas	$7.1x10^6$
		(6) Decon vacant areas (scrape and bury)	$4.83x10^5$	(7) income loss	$51.8x10^6$
		(7) $1.64x10^5$ evacuees	$22x10^6$		
		(8) income loss	$37.2x10^6$		
			Total = $98.6x10^6$		Total = $106x10^6$ [aa,v]

Notes for Table 5-11

a. $4.5 \times 10^7 m^2$ (1.11×10^4 acres) require decontamination; $2.82 \times 10^6 m^2$ (698 acres) require a DF ≥ 20. 400 cpm/m^2 (.65 µci/m^2).

b. I-131 is used as an example/$t_{1/2}$ = 8 days/7 x $t_{1/2}$ = 60 days.

c. $75 per acre.

d. $435 per acre - includes costs of reburial.

e. $5 per hour per guard/4 guards per shift (based on conversations with private security agencies). This could be reduced if National Guard or active duty military were used.

f. $4915 per building/2 buildings per 4-person family (home and barn).

g. $8725 per building/2 buildings per 4-person family (home and barn).

h. $13.5 per day per evacuee; 10 day evacuation required.

i. $104 per acre (based on 48-state average - less Alaska and Hawaii).

j. If orchards are involved, the cost could be considerably higher (up to $5000 per acre) to account for the loss of crops in subsequent years.

k. The entire year's crops are purchased/60-days of milk products are purchased/the average dairy yield per acre is $16 per year.

l. 5 houses per acre/$1095 per house (includes street cleanup).

m. 5 houses per acre/$3510 per house (includes street cleanup).

n. $2200 per acre.

o. $18,000 per acre.

p. $2200 per acre.

q. $35,000 per acre.

r. $0.13 per ft^2 to replace lawns/0.61 acres of parks per 100 persons.

s. $1100 per capita per quarter - individual/$940 per capita per quarter - corporate/10 days of lost income.

t. 10 guards on patrol per shift.

u. 1 guard per 5 acre park per shift.

v. If total evacuation for 60 days with no decontamination were used, the approximate cost would be $261 x 10^6 for suburban and $1.4 x 10^9 for urban. However, this approach would probably not be socially acceptable.

w. Based on approximate values for an average U.S. city (New York City Planning Commission, "Plan for New York City - Volume 1 (initial issue)," 1969)- streets are included with appropriate categories.

x. $15 per occupant for 6-story apartment building } all residents assumed to

y. $140 per occupant for 6-story apartment building } live in multi-story buildings

z. 20 guards on patrol per shift.

aa. Clearly, the method used to deal with a spill of this sort would be the least expensive method - probably outright cleanup rather than long-term evacuation.

bb. Single family units.

cc. The single family units are assumed to have 4 persons per unit, 5 units per acre. The remaining people are assumed to live in multi-story buildings.

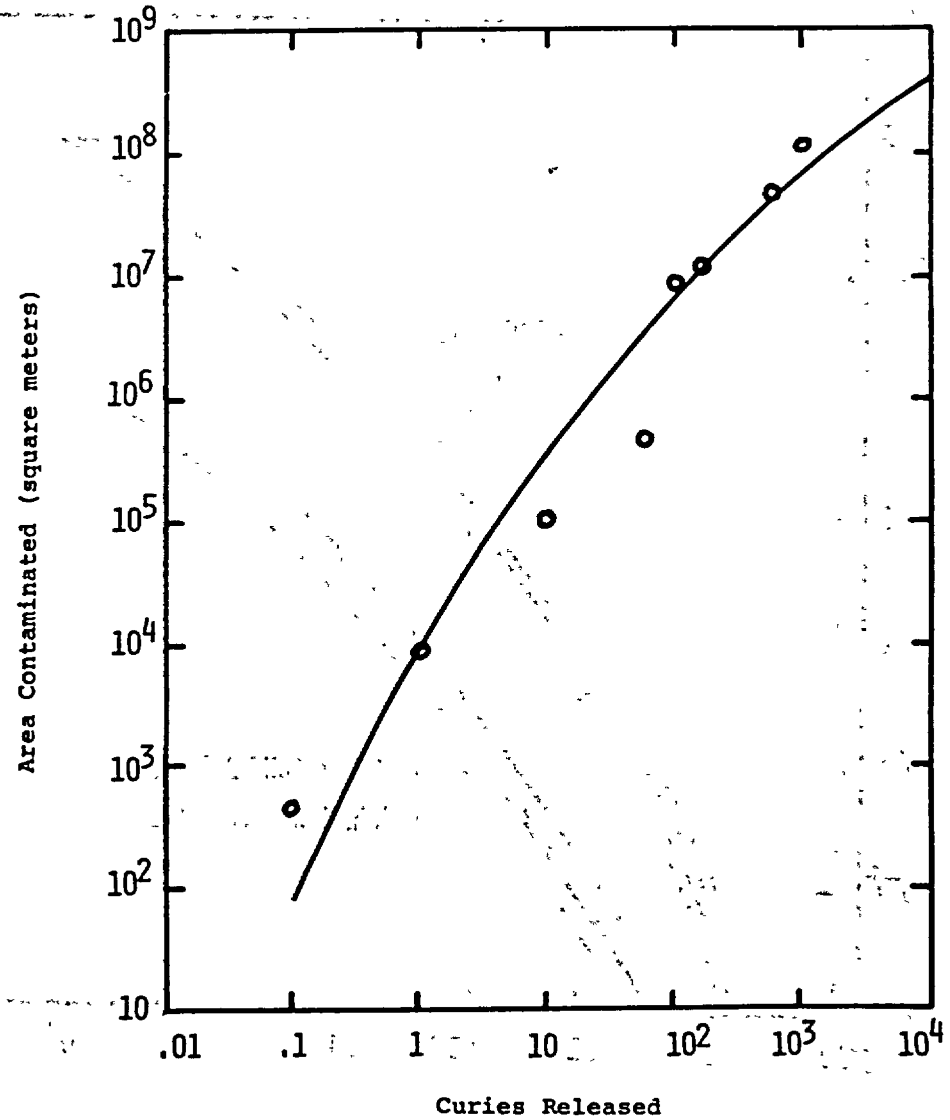


FIGURE 5-12. AREA CONTAMINATED TO A LEVEL OF 0.65 μCi/m^2 FOR A GIVEN RELEASE

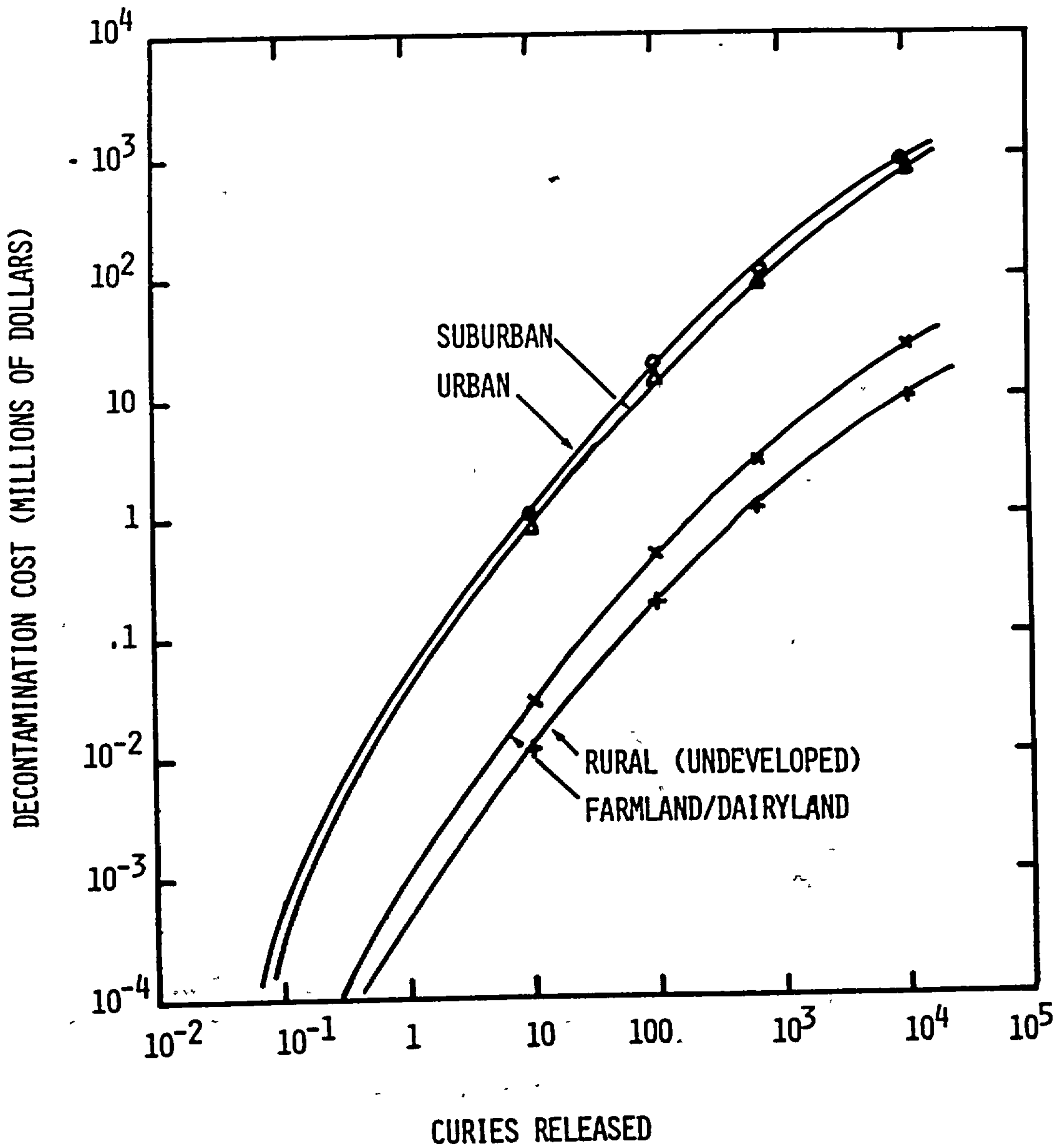


FIGURE 5-13. DECONTAMINATION COSTS FOR RELEASES OF LONG-LIVED ISOTOPES

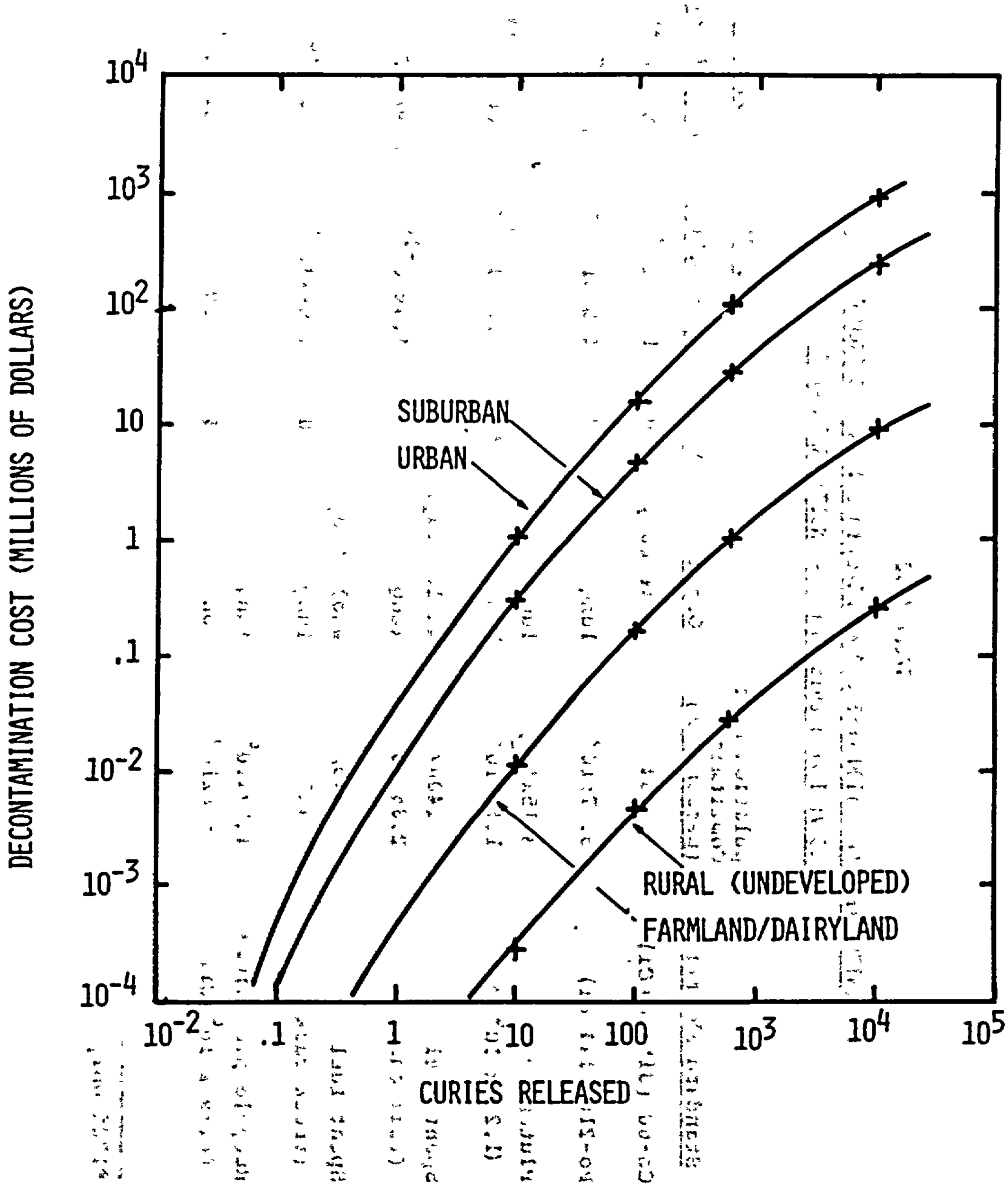


FIGURE 5-14. DECONTAMINATION COSTS FOR RELEASES OF SHORT-LIVED ISOTOPES

TABLE 5-12

INTEGRATED POPULATION DOSE AND EXPECTED LATENT CANCERS FROM CERTAIN CLASS VIII ACCIDENTS IN HIGH-DENSITY URBAN AREAS

Standard Shipment	Population Dose Commitment (person-rem)	Organ	LCF	1975 Probability	1985 Probability
Co-60 (315,000 Ci)	284	whole body	0	1.02×10^{-10}	2.55×10^{-10}
Po-210 (144 Ci)	5.27×10^{6}	lung	117	2.57×10^{-10}	8.2×10^{-10}
Plutonium (1.23×10^{6} Ci)	3.15×10^{6}/ 1.11×10^{7}	lung/ bone	147	1.06×11^{-11}	1.06×10^{-11}
Spent fuel (rail cask)	1400/ 2.85×10^{4}	whole body/ lung	1	1.8×10^{-10}	6.91×10^{-9}
Spent fuel (truck cask)	215/ 4450	whole body/ lung	0	2.99×10^{-9}	1.8×10^{-8}
Recycle plutonium* (6.19×10^{6} Ci)	1.59×10^{6}/ 5.6×10^{6}	lung/ bone	74*	0.0	2.24×10^{-10}

*1985 only.

TABLE 5-13

NUMBER OF PEOPLE RECEIVING DOSES GREATER THAN OR EQUAL TO VARIOUS SPECIFIED ACUTE DOSES (IN REMS) OF INTEREST IN CERTAIN CLASS VIII ACCIDENTS IN HIGH-DENSITY URBAN AREAS

Shipment	Organ	Time Period for Dose	5	15	50	340	510	3000	10,000	20,000	70,000
Co-60 (315,000 Ci)	Whole Body	1 hr	75	-	12	0	0	-	-	-	-
Po-210 (144 Ci)	Lung	1 yr	-	$3.42x10^4$	-	-	-	59	-	2	-
Plutonium ($1.23x10^6$ Ci)	Lung	1 yr	-	2337	-	-	-	-	0	-	0
Spent Fuel (truck cask)	Whole Body	1 hr	61	-	8	0	0	-	-	-	-
	Lung	1 yr	-	0	-	-	-	0	-	0	-
Spent Fuel (rail cask)	Whole Body	1 hr	440	-	40	7	0	-	-	-	-
	Lung	1 yr	-	48	-	-	-	0	-	0	-
Recycle Pu ($6.19x10^6$ Ci)	Lung	1 yr	-	2475	-	-	-	-	0	-	0

TABLE 5-14

EARLY FATALITIES AND DECONTAMINATION COSTS

CLASS VIII ACCIDENTS - EXTREME DENSITY URBAN AREAS

Isotope	Total Curies	Percent Released	Percent Aerosolized	Early Fatalities	Decontamination Cost*
Co-60	315,000	0	0	0	NA
Po-210	144	100	100	1	$\$300 \times 10^6$
Plutonium	1.2×10^6	10	5	0	$\$800 \times 10^6$
Recycle Pu (1985 only)	6.2×10^6	10	5	0	$\$1200 \times 10^6$
Spent fuel	9.1×10^6	100**	100**	0	$\$400 \times 10^6$
Spent fuel	1.4×10^6	100**	100**	0	$\$200 \times 10^6$

*Adjusted for increased evacuation and income loss costs resulting from higher population density.

**Of available gaseous and volatile fission products only.

10,000 rems to lungs	- threshold for pulmonary morbidity from long-lived alpha emitters when received as an acute dose (Refs. 5-20 and 5-23)
20,000 rems to lungs*	- produces early fatality from pulmonary morbidity resulting from short-lived beta-gamma emitters when received as an acute dose (Ref. 5-23)
70,000 rems to lungs*	- produces early fatality from pulmonary morbidity resulting from long-lived alpha emitters when received as an acute dose (Ref. 5-23)
5 rems to whole body	- NCRP-recommended limit for annual whole-body radiation for radiation workers (Ref. 5-22)
50 rems to whole body	- threshold for noticeable physiological effects from acute exposure to whole-body radiation (Ref. 5-22)
340 rems to whole body**	- produces early fatality from bone marrow destruction from acute exposure with minimal medical treatment (Ref. 5-20)
510 rems to whole body**	- produces early fatality from bone marrow destruction from acute exposure with supportive medical treatment (Ref. 5-20)

5.7 EXPORT AND IMPORT SHIPMENTS

The annual radiological risk calculation for accidents involving import and export shipments was done in the same way as for the 1975 and 1985 standard shipments models. A separate standard shipments model was devised for 1975 export shipments only and is discussed in Appendix A.

The total annual radiological risk computed for export shipments in 1975 is 1.57×10^{-5} LCF per year, or 0.3% of the total accident risk. Table 5-15 shows a breakdown of the annual accident risk by material and major transport modes. Over half of the risk results from enriched uranium shipments because this is the dominant exported material. Since most exported enriched uranium shipments are transported by ship, these dominate the risk; shipments by aircraft and truck are of lesser importance. It is not anticipated that export shipments would contribute a significantly greater percentage of the annual risk in 1985 than they did in 1975. A detailed analysis of the environmental effects of U.S. nuclear power export activities is given in Reference 5-24.

*LD 50/360 value (lethal dose within 360 days for 50% of a population so exposed).

**LD 50/30 value (lethal dose within 30 days for 50% of a population so exposed).

TABLE 5-15

ANNUAL EXPECTED LATENT CANCER FATALITIES RESULTING FROM ACCIDENTS INVOLVING EXPORT SHIPMENTS OF RADIOACTIVE MATERIALS - 1975 EXPORT SHIPMENTS MODEL

Material	Major Transport Mode(s)	Annual Expected Latent Cancer Fatalities	Percent of Total Export Shipment Risk
Enriched UO_2	Ship	5.5×10^{-6}	35.1%
Enriched UF_6	Ship	4.4×10^{-6}	28.1%
MF+MC - Type A	Cargo Air	3.3×10^{-6}	21.1%
Co-60 - Type B	Truck	1.4×10^{-6}	8.9%
Enriched UF_6	Cargo Air, Truck	7.5×10^{-7}	4.6%
Mo-99 - Types A,B	Pass Air, Cargo Air	1.4×10^{-7}	0.9%
All Other Exports	Ship, Truck Pass. Air, Cargo Air	1.9×10^{-7}	1.3%
TOTAL		1.57×10^{-5}	100%

According to the 1975 Survey (see Appendix A), virtually all of the curies imported in 1975 were contained in four Type B Co-60 shipments, each containing only one package with an average of 1.8×10^5 curies per package. The average distance per shipment was 670 km, and the shipments were all transported by truck. One of the scenarios considered in the 1975 standard shipments model, Co-60-LQ2, involved four Co-60 shipments by truck, 3.2×10^5 curies per shipment and 3200 km per shipment. These four shipments result in an annual risk of 1.2×10^{-10} LCF per year. The risk for the four import shipments can be determined from this figure, reduced in proportion to the curies transported and the shipment distance. The result is 1.4×10^{-11} LCF per year.

5.8 NONRADIOLOGICAL RISKS IN TRANSPORTATION ACCIDENTS

Most radioactive materials are shipped incidental to other freight shipments, i.e., the shipment would take place whether or not the radioactive material were on board. For these shipments the only impacts chargeable to the radioactive material are the normal population dose discussed in Chapter 4 and the radiological accident risk discussed earlier in this chapter.

However, for exclusive-use shipments, i.e., those that require the exclusive use of the transport vehicle, there are certain nonradiological risks that must also be considered, e.g., the risk that the driver of a exclusive-use vehicle will be injured or killed in an accident, not from radiological causes, but from the accident itself. In addition to fatalities, nonradiological injuries and property damage must be considered as part of the environmental impact of radioactive materials transport along with the radiological effects.

It has been estimated (Ref. 5-25) that transport of cold fuel to nuclear power plants and shipments of irradiated fuel and solid wastes from the plants by exclusive-use vehicles could result in 0.03 injuries and 0.003 fatalities per reactor year if all fuel and solid waste transport were by truck and irradiated fuel transport were by rail or barge. For the approximately 60 power reactors in operation in 1975, this translates into 2 injuries and 0.2 fatalities per year.

Probably the greatest use of exclusive-use trucks for other than fuel cycle materials is in the transport of radiopharmaceuticals, primarily Mo-99/Tc-99m generators. If it is estimated that 10% of the generators that were transported by truck in the 1975 standard shipments model are transported by exclusive-use trucks in average aggregate quantities of 80 TI per shipment, about 130 such shipments per year would be expected. For an average shipment distance of 960 kilometers, the total distance traveled would be 1.25×10^5 kilometers per year. Utilizing the accident statistics and injury and fatality data that were used to estimate the nonradiological impact for shipments to and from power plants (Ref. 5-25), the transport of Mo-99/Tc-99m generators by exclusive-use trucks would produce about 0.07 injuries and about 0.004 fatalities per year.

Finally, certain all-cargo airlines make routine flights exclusively for shipment of radioactive materials, primarily Mo-99/Tc-99m generators. It is estimated that these flights cover 320,000 kilometers per year. Using the commercial aircraft accident rates of

1.44×10^{-8} accidents per kilometer, these flights would be expected to result in about 0.005 accidents per year. Assuming that a crew of two would be killed in each accident, an average of 0.01 fatalities per year would be expected.

Thus, the estimated nonradiological impacts resulting from transport in vehicles used exclusively for radioactive material shipments is 2.05 injuries and 0.213 fatalities per year. The major contribution is made by transport of cold and spent fuel to and from nuclear power plants.

5.9 SUMMARY OF RESULTS

The results of the calculations of the risk resulting from potential transportation accidents involving radioactive materials shipments may be summarized as follows:

1. The accident risk for the 1975 level of shipping activity, as determined from the 1975 shipping survey, is very small: roughly 0.005 additional LCF per year, or one additional LCF every 200 years, plus an equal number of genetic effects. This number of LCFs is only 0.3% of those resulting from normal transport population exposures.

2. Over 70% of the accident risk is attributable to shipments of Po-210, plutonium, waste, mixed fission and corrosion products, and UF_6 (Table 5-9).

3. The projected accident risk in 1985 is 0.0166 LCF per year, or about 3.5 times the 1975 risk, but is still very small in comparison to the LCFs resulting from normal transport. Even though the 1985 calculation takes into account a modest amount of plutonium recycle, the risk from plutonium (U-Pu mix) is 1.3% of the total risk.

4. Using Model II release fractions, the annual probability of one or more early fatalities from radiological causes in a transportation accident is about 5×10^{-4} in 1975 and about 10^{-3} in 1985.

5. Costs of decontamination following a transportation accident involving a 600-curie release can be as much as 100×10^6 dollars in an urban population zone.

6. In spite of their low annual risk, specific accidents occurring in very-high-density urban population zones can produce as many as 1 early fatality, 150 LCFs, and large decontamination costs. Although such accidents are possible, their probability of occurrence is very small.

7. The contribution to the annual accident risk from export and import shipments is less than 0.01 times the domestic transport risk and is likely to remain so in 1985.

8. The principal nonradiological impacts are those injuries and fatalities resulting from accidents involving vehicles used exclusively for the transport of radioactive materials. The number of expected annual nonradiological fatalities is almost 50 times greater than the

expected number of additional LCFs resulting from radiological causes but is less than one fatality every five years.

The annual individual probability of an early (radiological) fatality resulting from a transportation accident involving a radioactive materials shipment is presented in Table 5-16 together with annual individual probabilities of an early fatality from other types of accidents. The numbers listed in the table are based on the assumptions that all accidents occur randomly throughout the population and that the number of persons at risk for early fatalities resulting from radiological causes following a transportation accident is 75 x 10^6 (estimating that approximately one-third of the population lives along major transport routes). The table shows, for example, that an individual is 10^5 times as likely to be killed as a result of being struck by lightning as he is to die from radiological causes within one year following a transportation accident involving a shipment of radioactive materials. The table shows that there are many commonly accepted accident risks that are very much greater than the accident risk of transporting radioactive materials.

TABLE 5-16

INDIVIDUAL RISK OF EARLY FATALITY BY VARIOUS CAUSES (Ref. 5-20)

Accident Type	Number per Year	Individual Risk per Year
Motor Vehicle	5.5×10^4	1 in 4,000
Falls	1.8×10^4	1 in 10,000
Fires	7.5×10^3	1 in 25,000
Drowning	6.2×10^3	1 in 30,000
Air Travel	1.8×10^3	1 in 100,000
Falling Objects	1.3×10^3	1 in 160,000
Electrocution	1.1×10^3	1 in 160,000
Lightning	160	1 in 2,000,000
Tornadoes	91	1 in 2,500,000
Hurricanes	93	1 in 2,500,000
100 Nuclear Reactors	3×10^{-3}*	1 in 5,000,000,000
Transportation of Radioactive Material (from Radioactive causes)	3.5×10^{-4}**	1 in 200,000,000,000***

*Statistical estimate.
**Statistical estimate for 1975.
***Using a population at risk of 75 million people.

CHAPTER 7
SECURITY AND SAFEGUARDS

7.1 INTRODUCTION

The rapid growth of the nuclear power industry coupled with an increase in terrorist activities have increased concern over theft of nuclear materials, sabotage of nuclear facilities, and other associated acts of terrorism. The possibilities of illegal acts and the nature and extent of potential threats have been and are continuing to be examined by the NRC as part of the overall safeguards program described in Section 7.3. Countermeasures have been established to protect both fixed sites and nuclear material in transit.*

Two categories of material have been examined relative to the in-transit protection of the material against theft and sabotage: (1) special nuclear material (SNM) such as enriched uranium and plutonium and (2) radioactive isotopes and wastes such as cobalt-60 and spent fuel.

7.2 RADIOACTIVE MATERIALS - POTENTIAL FOR MISUSE

7.2.1 LOW ENRICHED URANIUM

Low enriched uranium, the fuel used in light-water-cooled power reactors, cannot be used directly to fabricate a nuclear explosive. Furthermore, the radioactivity of this material is so low that dispersal by manual means or acts of sabotage would not produce a significant radiological hazard.

Requirements for physical protection of shipments of low enriched uranium in transit are not specified in NRC regulations.

7.2.2 IRRADIATED (SPENT) FUEL

Irradiated fuel removed from light-water-cooled power reactors contains low enriched uranium, fission products, and plutonium and other transuranics. It is highly radioactive and requires heavy shielding for safe handling. Massive, durable containers (casks) weighing 25 to 100 tons are used for transport of the spent fuel assemblies (both by road and rail). The contained plutonium is not readily separable from the other radioactive materials.

*In March of 1974, specific requirements for the protection of significant quantities of strategic special nuclear material (SSNM) in transit in 10 CFR Part 73 became effective. In May of 1976, licensees were directed to provide additional protection for road shipments through the use of a separate escort vehicle and improved communications. In February of 1977, in order to formalize security measures currently being employed, license conditions were issued requiring the use of an armored transporter plus an escort vehicle and a minimum of five armed guards for the protection of road shipments.

The design features that enable the shipping container to withstand severe transportation accidents (e.g., multiplicity of heavy steel shells, thick dense shields, and neutron-absorbing jackets) also enable the containers to withstand attack by small arms fire and explosives. A massive rupture of the containers by mechanical means or high explosives that would result in the radioactive contents being ejected or removed is considered to be essentially impossible. Although unlikely, the possibility exists that the container could be breached to the extent that the gaseous inventory and a small portion of the solids would be dispersed into the atmosphere. For a release from a truck cask containing three PWR elements, the effects in a population density of 2000 people per square mile are calculated to be about 1 early death and about 220 latent cancer fatalities (Ref. 7-1).*

Spent fuel in transit is considered to be neither an attractive nor a practical target for theft or sabotage and is specifically exempt from the physical protection requirements of 10 CFR Part 73.

7.2.3 LOW-LEVEL WASTES

Soft waste material generated at nuclear reactors and associated fuel cycle facilities, e.g., contaminated paper and clothing, are compacted and placed (typically) in 55-gallon drums for shipment. Each drum may contain 500 pounds of compacted material with up to one curie of activation and fission products.

The low specific activity and low radiation levels allow the contaminated trash to be shipped without shielding. Because the radioactive contamination is bound on the compacted material, it is unlikely to be released in the event the drums are broken open by accident or criminal acts. Even if an entire truckload of 50 drums were to be consumed by fire, the amount of radionuclides that would become widely dispersed would be quite small. It has been estimated that as much as 99 percent of the 50-curie inventory would remain in the ashes, and only 1 percent or 0.5 curie (primarily cesium-137) would become airborne (Ref. 7-2).

Liquid fuel cycle and reactor wastes such as contaminated resins and sludges are dewatered, consolidated by mixing with concrete (or other solidifying agents), and placed (typically) in 55-gallon drums.

The majority of these drums contain less than 20 curies and are shipped as Type A packages. A small percentage contain up to 100 curies (average of 20 curies) and are shipped as Type B packages. The cemented, solidified form of the waste materials contributes significantly to the retention of the radioactive inventory in case of container failure.

If each container of a 50-drum Type A shipment of cemented wastes were broken open by acts of sabotage, the total activity released to the atmosphere would be quite small. (Reference 7-2 indicates that approximately 2×10^{-3} curies of gaseous and volatile fission products would become airborne.)

*For different population densities the effects would vary proportionately. However, no credit is given in the calculations to evacuation of downwind areas that could reduce these consequences by a factor of 10.

It would be extremely difficult to breach the Type B package to the extent of breaking open the inner container and exposing the solidified wastes. In the unlikely event this were to occur, approximately 0.2 curie of fission products (primarily cesium-134 and -137) would be released to the atmosphere for each 55-gallon drum ruptured (Ref. 7-2). For a 42-drum load, which would probably be the limit for a Type B truck shipment, the total activity released would be 8.4 curies. Because of the form of the material, it is unlikely that the presence of an open fire would significantly increase the activity that would become airborne.

The breach of the Type B package and the exposure of the cemented wastes would contaminate the transport vehicle and nearby ground and produce a radiation field. However, the hazard would be limited to the vicinity of the vehicle.

Because of the form of the materials and the relatively low levels of radioactivity, low-level wastes are considered unlikely targets for sabotage. Even if subjected to criminal acts, no major hazard would result.

7.2.4 HIGH-LEVEL WASTES

High-level wastes (HLW) generated from the reprocessing of spent reactor fuel, even though cooled for many years before shipment, have many of the same fission products found in the spent fuel but little plutonium. These wastes are intended to be solidified (e.g., in the form of a dense glass) for shipment and storage. They are highly radioactive and will require heavy shielding for safe handling.

HLW shipping casks would be similar in design to a spent fuel shipping cask and would have many of the same features (steel liners, lead or depleted uranium gamma shielding, a cooling system, neutron shields, and sacrificial impact limiters). The resistance to sabotage would be essentially the same as for a spent fuel cask; if either were breached by criminal acts, the consequences are estimated to be of the same order of magnitude.

High-level waste shipments are considered to be neither an attractive nor a practical target for theft or sabotage. (There are currently no HLW shipments and few if any are anticipated by 1985.)

7.2.5 NON-FISSILE RADIOISOTOPES (SMALL SOURCE)

Small-quantity shipments (less than 20 curies) have little potential for harm to the general public through misuse. Dispersal of the contents of a shipping container following a theft or by sabotage would result in a relatively minor localized contamination. (The radiation from an unshielded 20-curie source of cobalt-60 would be only about 25 R/hr at 1 meter. On the other hand, the radiation would be extemely hazardous to a terrorist who directly handled the source without intervening shielding.)

7.2.6 NON-FISSILE RADIOISOTOPES (LARGE SOURCE)

Large-quantity shipments (10 to 10^6 curies) may have a limited potential for endangering the public health and safety through misuse.

Containers used for the shipment of these amounts of material must meet DOT and NRC regulatory requirements for Type B or large-quantity packages. These packages are designed to prevent the loss or dispersal of the contents, to retain shielding efficiency, and to provide for heat dissipation under both normal transport conditions and specific accident damage test conditions.

The size, weight (which varies from hundreds of pounds to forty tons for a 500,000-Ci Co-60 source), and construction of these containers make theft a difficult endeavor and dispersal of the contents an impractical event. In addition, the high level of radiation associated with the isotopes prevents handling without mass shielding. If a shipping container were diverted, it would be almost impossible to use the contents to cause any significant harm other than through explosive breaching and subsequent dispersal of the contents.

If sufficient amounts of explosives are used, the possibility exists that the radioisotopes could be dispersed to the atmosphere (for gases or volatiles) or locally dispersed on the ground (for solids). Tables 5-12, 5-13, and 5-14 show the consequences of worst-case accidents for several large-quantity shipments of Po-210 and Co-60. It is believed that these results are representative of the possible effects of worst-case credible criminal acts during transport.

Although terrorists might perceive large-quantity shipments of non-fissile radioisotopes to be attractive weapons, the protection afforded by the shipping container and the high level of radioactivity of the contents make theft and dispersal difficult and deliberate manipulation very difficult. The consequences associated with worst-case acts of sabotage would not constitute a significant radiological hazard.

7.2.7 URANIUM HIGHLY ENRICHED IN U-235

Highly enriched uranium (uranium enriched to 20 percent or more in the U-235 isotope) could be used to fabricate a nuclear explosive and therefore has significant potential for misuse. Depending on their form, these materials could be used directly (e.g., U metal) or after processing (e.g., HTGR fuel).

Because of its low radioactivity, sabotage of U-235 would not, in general, constitute a threat to the general public. Conceivably, it might be possible to bring about criticality by actions involving both removal of neutron absorbers and rearrangement of the uranium materials. It certainly would be a dangerous task and probably would irradiate the perpetrator. If successful, the hazard, although dangerous, would be restricted to the general vicinity of the nuclear materials.

NRC regulations require that highly enriched uranium in quantities of 5 kilograms or more be protected against theft and sabotage in accordance with the physical security requirements of 10 CFR Part 73. Additional requirements have been established for fixed site and transport protection by license conditions. (These include requirements for the use of an armored transport vehicle that has a cargo compartment with barriers or containers that deter or delay penetration, a separate escort vehicle, and a minimum of five armed guards for road shipments.) Physical security requirements are not specified for quantities smaller than this amount.

7.2.8 PLUTONIUM AND URANIUM-233

Reactor grade plutonium and U-233* (like U-235) could be used to fabricate a crude nuclear explosive. Depending on their form, the plutonium or U-233 could be used directly (e.g., Pu or U metal) or after processing (e.g., Pu nitrate). In addition, because of their radioactivity, plutonium and U-233 are potentially hazardous, particularly when in the form of respirable aerosols. Therefore, for significant quantities of these materials, the potential exists for misuse both as illicit explosives and as dispersal weapons.

Plutonium and U-233 in quantities of 2 kilograms or more are protected against theft and sabotage in accordance with the physical security requirements of 10 CFR Part 73. Additional protection has been required at both fixed sites and in transit by specific license conditions as in the case of highly enriched uranium discussed earlier.

7.3 SAFEGUARDS OBJECTIVES AND PROGRAM

Safeguards are defined as those measures employed to deter, prevent, or respond to (1) the unauthorized possession or use of significant quantities of nuclear materials through theft of diversion and (2) the sabotage of nuclear materials and facilities. The NRC safeguards program has the general objective of providing a level of protection against such acts that will ensure against significant increase in the overall risk of death, injury, and property damage to the public from other causes beyond the control of the individual. To be acceptable, safeguards must take realistic account of the risks involved and of burdens on the public in terms of impacts on civil liberties, institutions, the economy, and the environment.

The following functional elements are utilized by the NRC to ensure effective protection of the radiological health and safety of the public and protection of the environment:

1. Consideration of the nature and dimensions of the postulated threat in the development of regulatory requirements.

2. Imposition of safeguards requirements on the industry directed toward countering the postulated threat.

3. Licensing activities, including review of safeguards procedures proposed by industry, as required by regulations.

4. Inspection of safeguards implementation to ensure adequacy.

5. Enforcement of requirements through administrative, civil, or criminal penalties.

6. Administrative and technical support for response and recovery.

*There are currently no strategic quantities of privately owned U-233, and no shipments are expected in the next several years.

7. Confirmatory research related to the development and testing of methods, techniques, and equipment necessary to the effective implementation of safeguards.

8. Frequent program review in the light of industrial/technical or social/political changes to ensure that any needed revisions are made to the elements above.

Current programs are directed at protecting against theft or diversion of certain types and quantities of nuclear materials that could be used for nuclear explosives or contaminants and protecting against the sabotage of nuclear facilities and materials.

The Commission's regulations in 10 CFR Part 70 require a license in order to own, acquire, deliver, receive, possess, use, transport, import, or export special nuclear materials. The NRC publishes specific safeguards requirements for materials and plant protection in 10 CFR Parts 70 and 73 and carries out the following activities to ensure compliance:

1. Prelicensing evaluation of applicants' proposed nuclear activities, including safeguards procedures in the case of applicants for significant quantities of special nuclear material;

2. Issuance of a license to authorize activities subject to specific safeguards requirements; and

3. Inspection and enforcement to ensure that applicable safeguards requirements are met by implementation of approved plans.

The provisions in 10 CFR Part 73 include specific physical protection requirements that apply to licensees who ship 5 kilograms of U-235 (contained in uranium enriched to 20% or more), 2 kilograms of plutonium or U-233, or a weighted combination of these.

The NRC conducts inspections of a licensed plant and its related transportation links to ensure continued effective implementation of material control and physical protection requirements. Each licensee is required to afford the NRC opportunity to inspect the nuclear materials, to perform or permit the NRC to perform necessary tests of materials and equipment, and to make available any records pertaining to possession, use, or transfer of nuclear material.

If items of noncompliance or deficiencies are found in the implementation of safeguards requirements by the licensee, the licensee is instructed to take prompt corrective action and to inform the NRC of the results. The NRC has the authority to modify, suspend, or revoke licenses and to impose civil penalties on licensees for noncompliance with the items and conditions of the license.

Early in 1976, the NRC established an Information Assessment Team (IAT) for the purpose of determining in a timely fashion the credibility, seriousness, and immediacy of hazards associated with threats to nuclear facilities or transportation. This team is charged with the responsibility for receiving and reviewing all incoming threat notifications, performing multi-source correlation, assessing the validity of sources and data, judging the degree of seriousness, and recommending options for alternative courses of action. In the event that a threat escalates into an attempt to steal SNM or sabotage nuclear facilities or transportation, the IAT forms the nucleus of the NRC Incident Response Action Coordination Team (IRACT). This team is responsible for initiating, planning, and coordinating incident response actions.

7.4 PHYSICAL PROTECTION OF HIGHLY ENRICHED URANIUM AND PLUTONIUM DURING TRANSIT

7.4.1 INTRODUCTION

As noted in Section 7.2, the only radioactive materials that require physical protection against theft and sabotage during transit are strategically significant quantities of uranium enriched to 20% or more in the U-235 isotope, U-233, and plutonium. The potential for misuse of shipments of other radioisotopes is sufficiently low that no additional protection is presently believed necessary.

It is estimated that during calendar years 1977 and 1978 there will be less than 30 shipments per year of strategic quantities of uranium and plutonium in the commercial sector. Most of these will be transfers of UF_6 from Piketon, Ohio, and Oak Ridge, Tennessee, to O'Hare airport for export overseas.

The following paragraphs contain a description of current requirements (both regulations and specific license conditions) for physical protection during transit and an assessment of the adequacy of these requirements relative to a postulated threat consisting of an internal threat of one employee occupying any position and an external threat of a determined violent assault by several well-armed, well-trained persons who might possess inside knowledge or assistance.*

7.4.2 ROAD SHIPMENTS

Shipments are required to be made in a vehicle that has an armored cab with a crew of three armed guards and a cargo compartment that is constructed to resist penetration and delay entry. A separate vehicle with two additional armed guards must escort the transporter.

Communication requirements include radiotelephones in both vehicles for communication to the licensee, his agent, or the police, radios for intervehicle communication, and citizen band radios in both vehicles for use in emergencies.

Shipments are required to be made on primary roads during daylight hours. (If a trip is to extend into the night, a second escort vehicle with two additional guards is required.) Transfers from vehicle to storage, from one vehicle to another, and from storage to vehicle as well as material in storage must be monitored by guards who are equipped with communications to local police and who must keep the shipment under continuous visual surveillance.

*On the basis of intelligence and other relevant information available to the NRC, there are no known groups in this country having the combination of motivation, skill, and resources required to carry out an assault against a protected shipment or facility.

Many other specific requirements, such as requirements for vehicle markings, scheduled calls, guard training, route selection, notification of shipment, are contained in NRC regulations and license conditions.

The combination of five well-trained armed guards, armor protection, and penetration-resistant cargo compartments is considered adequate to withstand an assault by a small group for a prolonged period of time. The requirements for multiple means of communication and the restriction of travel to daylight hours on well-traveled roads are designed to ensure that local police forces would be notified and would be able to respond in time to seal off and neutralize the threat. (As noted above a second escort vehicle is required if travel extends into the night.)

The protection system does not necessarily fail even if the attack is conducted by a large force that outnumbers the guards. The margin of safety might be less and casualties perhaps higher. However, the capabilities of the local and state police relative to communication networks, area isolation, response force numbers, armament, and transportation provide protection against threats larger than that postulated.

The penetration-resistant transport vehicle provides resistance to penetration and containment against acts of sabotage directed at dispersal of the plutonium. It is estimated that, for a wide range of assaults, including road mines, gunfire, hand-carried explosives, and vehicle-to-vehicle and other crash environments, this type of vehicle would prevent wide-scale dispersal of the plutonium cargo. There is, of course, a practical limit to the protection against unlimited amounts of explosives. A trailer truckload of TNT (40,000 lb) detonated next to the transporter would cause massive damage to the vehicle and to the surrounding environment. The consequence of such a blast might exceed the consequences of the plutonium contamination.

Transfers or material stored while awaiting transfer (24 hours or less) are protected by armed guards. In addition, all U.S. airports and sea terminals used for transfer of SNM have security systems that provide control of access and a reserve of armed individuals that could respond to a security emergency.

Plutonium shipments in quantities less than 2 kilograms do not fall within the physical protection requirements of 10 CFR Part 73. The cutoff point was established at this level in order to provide a substantial margin of safety below the quantity of plutonium generally accepted as being required to construct an improvised nuclear explosive.

While this level is not directly related to risks associated with dispersal weapons, it can be shown that the possible consequences from dispersal of such quantities would be of the same order as malevolent use of chemical explosives and small compared to a nuclear explosion. (It has been estimated in Reference 7-3 that plutonium dispersed in a city having a high population density could result in one fatality for each 15 grams dispersed.)

The protection afforded to road shipment and storage in transit is considered to be as effective as that provided by ERDA (now DOE) during the transport of government-owned SNM.

7.4.3 RAIL SHIPMENTS

At present, no physical protection plans have been approved by the NRC for rail shipments, and no shipments of NRC-licensed SNM are being made using this mode of transport. In order for a security plan utilizing this mode to be approved, protection comparable to that currently afforded road shipments would have to be provided. Such features of the plan as guard strength and deployment, communications, armor, penetration resistance of the cargo compartment, and route selection would be assessed to ensure that the escort force could withstand an attack by a small group until police response was ensured. For plutonium shipments, the resistance to penetration or sabotage of the cargo compartment would be evaluated to ensure a level equivalent to that for road shipments.

7.4.4 SHIPMENT BY INLAND WATERWAYS

No physical protection plans have been approved by the NRC for shipment by inland waterway, and no shipments of NRC licensed SNM are currently being made using this mode of transport. A security plan for shipment by inland waterway would be approved only if the protection against assault and sabotage were equal to that presently applied to road shipments.

7.4.5 AIR SHIPMENTS

Shipments of strategically significant quantities of SNM are required to be made in cargo-only aircraft. SNM being transferred to or from such aircraft (including periods while in storage) must be protected by guards equipped with a capability for radio communications to either a local law enforcement agency or an air terminal guard force. Preplanned in-transit storage may not exceed 24 hours. Guard surveillance of the cargo compartment whenever the compartment containing SNM is open and observation of the aircraft until it departs are required.

The combination of assigned guards, communications to local police, and a reserve of armed airport security personnel stationed at the flight lines at major commercial airports provide significant protection against an assault or covert attempts by unauthorized personnel to board the plane. (The only air shipments currently being made or projected through 1978 are imports and exports at O'Hare airport. These flights are escorted by an unarmed employee or agent of the licensee. U.S. safeguards responsibilities in the transportation of nuclear materials for export end when the shipment is unloaded at a foreign terminal. The NRC regional offices inspect every import and export shipment for compliance with requirements.) The surveillance of the transfer onto the aircraft plus the normal preflight check of the cargo compartment by the flight crew make it unlikely a stowaway could board and occupy the aircraft undetected. An attempt at diversion of the aircraft by a member of the flight crew once airborne is considered to be unlikely.

Transport of plutonium by air presents a unique problem. If both the aircraft were damaged and the shipping container were breached during flight, the altitude and velocity of the aircraft might aid in the plutonium dispersal. Similarly, a high velocity crash of an aircraft might cause or contribute to the rupture of a shipping container and the scattering of the contents.

However, no shipments of plutonium by air will be licensed by the NRC (except for individual medical applications) until the Nuclear Regulatory Commission has certified to the Joint Committee on Atomic Energy of the Congress, as required by law, that a safe container that will not rupture under crash and blast-testing equivalent to the crash and explosion of a high-flying aircraft has been developed and tested.

7.4.6 SEA SHIPMENTS

Shipments of SNM by sea are conducted in accordance with physical protection provisions similar to those applied to air shipments. Guards equipped with radio equipment capable of communicating with local police or a nearby commercial guard force maintain surveillance over the SNM during transfer operations. Vessels are observed by these guards until they depart the harbor. Sea shipments are escorted by an unarmed employee or agent of the licensee. Ship-to-shore contact is made at least every 24 hours to relay position information and status of the shipment. It is considered unlikely that a shipment, while at sea, could be successfully diverted or sabotaged to the extent that a significant radiological hazard would result.

7.5 ALTERNATIVES

The present in-transit physical security requirements provide protection, at a minimum, against theft or sabotage by a postulated threat consisting of an internal threat of one employee occupying any position and an external threat of a determined violent assault by several well-armed, well-trained persons who might possess inside knowledge or assistance. This protection is the responsibility of and is supplied by the licensee or his agent and consists of privately owned facilities and equipment under the control of private guard forces.

Consideration has been given to using such other means of protecting SNM in transit as a Federal guard force, the ERDA transport system, Department of Defense escorts, and systems designed to withstand a larger, more violent assault. These alternatives are discussed below.

7.5.1 FEDERAL GUARD FORCE

The need for and feasibility of an NRC security agency to assume operating responsibility for security forces to protect the nuclear industry was the subject of a special review by the NRC in 1975-76 (Security Agency Study, Ref. 7-4). The principal conclusion was:

> "The study has found that creation of a Federal guard force for maintaining security in the nuclear industry would not result in a higher degree of guard force effectiveness than can be achieved by the use of private guards, properly qualified, trained and certified (by NRC). Analysis of the existing regulatory structure indicates that NRC can fulfill its responsibilities to assure adequate physical protection of licensed facilities and materials through stringently enforced regulations."

7.5.2 THE ERDA (DOE) TRANSPORT SYSTEM

The Security Agency Study also addressed the question of whether a Federal transport system was necessary for privately owned strategic special nuclear material. The study concluded:

> "With regard to shipping containers and transportation vehicles, the private sector can provide a level of security equivalent to that provided by the ERDA system which is responsible for transport of government-owned special nuclear material. Equivalent security can be provided by the private sector using drivers, guards and operating techniques under stringent standards now being established by NRC. Reliable and effective communications can be provided by a system such as the ERDA communication system if commercial carriers are required to use it."

The present level of transport protection provided by the licensed industry is considered to be comparable to that required by ERDA (now DOE). While the licensee (or transport company) does not always have the capability of communicating directly to a command and control center while in transit (as does the ERDA system), the use of radiotelephone, intervehicle radio, and citizens band radio combined with restrictions that normally limit travel to daylight hours on primary highways is considered adequate to provide timely notification of local police of a security emergency.

7.5.3 DEPARTMENT OF DEFENSE ESCORTS

The Posse Comitatus Act prohibits the use of Armed Forces for civil law enforcement, which would include protection of private property, unless expressly authorized by the Constitution or by statutes. None of the present authorizations would permit the use of Armed Forces personnel except in emergencies caused by civil disorder, calamity, or disturbance or when State authority has broken down or there is armed insurrection. Even if this legal impediment did not exist, there is no need or justification for using military forces and equipment to protect against the postulated threat. The physical protection deemed necessary to defeat this threat can and is being provided by the private sector.

7.5.4 PROTECTION AGAINST A HIGHER THREAT LEVEL

The NRC is continuously evaluating the nature and extent of potential threats against nuclear materials and facilities. The threat assessment program has developed the following information:

- The intelligence community has no evidence that there are groups in this country having the motivation, skill, and resources to attack either a fuel facility or a fuel shipment.
- There have been no assaults in this country against facilities or shipments with the specific intent to cause a radiological release or to steal nuclear material.
- To date, there is no evidence to indicate any loss by theft or diversion to unauthorized use of significant quantities of special nuclear materials.
- An examination of over 1200 acts of violence characterized as terrorism occurring in the decade 1965-1975 revealed that 97% were carried out by 6 or less people and 86% by 3 or less.

Since there is no identifiable threat, the decision as to the level or protection to be applied (or the magnitude of the postulated threat against which defenses are to be established) demands the use of subjective judgment.

Based on the above threat assessment, it is believed that the requirements placed on the licensees by NRC provide a capability to protect against the postulated threat and are in the public interest. For purposes of a planned review in a public rulemaking proceeding, NRC has under preparation proposed new regulations that have as their objective the achievement of safeguards that would counter hypothetical threats more severe than those postulated in evaluating the adequacy of current safeguards for licensed operations, including transportation activities. In addition, consideration is being given to the protection of material during anomalous occurrences such as unscheduled emergency stops enroute.

7.5.5 RESTRICTING TRANSPORT TO A PARTICULAR MODE

Regardless of the mode of transportation, adequate protection against theft and acts of sabotage that would result in a significant radiological hazard can be provided. For example, while it might be argued that air shipments (fixed wing or helicopter) made from secure terminal to secure terminal are better protected than are road-air-road or all-road shipments (the evidence is not conclusive that this argument is correct), this is not sufficient justification to prohibit transport by these latter two methods when it can be shown that they have sufficient physical protection.

7.6 <u>CONCLUSIONS</u>

- Existing physical security requirements are adequate to protect, at a minimum, against theft or sabotage of strategic special nuclear materials (uranium enriched to 20% or more in the U-235 isotope, U-233, and plutonium) in transit by a postulated threat consisting of an internal threat of one employee occupying any position and an external threat of a determined violent assault by several well-armed, well-trained persons who might possess inside knowledge or assistance.

- The level of protection provided by these requirements reasonably ensures that transportation of strategic special nuclear material does not endanger the public health and safety or common defense and security. However, prudence dictates that safeguards policy be subject to close and continuing review. Thus, the NRC is conducting a public rulemaking proceeding to consider upgraded interim requirements and longer-term upgrading actions. The objective of the rulemaking proceeding is to consider additional safeguards measures to counter the hypothetical threats of internal conspiracies among licensee employees and determined violent assaults that would be more severe than those postulated in evaluating the adequacy of current safeguards.

- The use of the ERDA (now DOE) transport system is not, at this time, considered to be necessary for the protection of privately owned strategic special nuclear material because the present level of transport protection provided by the licensed industry is considered to be comparable to that presently required by ERDA (DOE). Similarly, the use of Department of Defense escorts is not presently needed to protect domestic shipments against the postulated threat because the physical protection deemed necessary to defeat this threat can and is being provided by the private sector.

- Shipments of radioactive materials not now covered by NRC physical protection requirements, such as spent fuel and large source nonfissile radioisotopes, do not constitute a threat to the public health and safety either because of their limited potential for misuse (due in part to the hazardous radiation levels which preclude direct handling) or because of the protection afforded by safety considerations, e.g., shipping containers.

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