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INTERTRAN:
A SYSTEM FOR ASSESSING THE IMPACT FROM TRANSPORTING RADIOACTIVE MATERIAL

A GUIDE PREPARED BY
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FOR THE
INTERNATIONAL ATOMIC ENERGY AGENCY

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IAEA, VIENNA, 1983
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FOREWORD

Large numbers of packages of radioactive material are being shipped by all modes of transport throughout the world. There is growing interest in evaluating the real and potential radiation exposures from such movements. Although the record of safety is outstanding, public concern about safety in transportation has been expressed in some countries. In 1977 the Agency undertook a program leading to an assessment of the risk from transportation of radioactive materials world-wide. The first step was to provide to its Member States a simple method to assess the impact from such transportation. In 1979, Sweden offered to assist by developing a model for transport risk assessment. The system which follows was developed by Ann-Margret Ericsson, and Mark Elert of Kemakta Konsult AB for the Swedish Nuclear Power Inspectorate under contract B22/81. It was completed in September 1982 and provided by the Swedish Nuclear Power Inspectorate to the Agency under Research Agreement No. 2620/CF. The Guide is reproduced here exactly as it was received. The authors are solely responsible for the content of the document, its editing and general style of presentation. Any views expressed in the document are those of the authors and do not necessarily represent the views of the IAEA.

In the document, several terms are used more liberally than in the Basic Safety Standards for Radiation Protection, Safety Series No. 9, 1982. For example: "risk" may mean not only the probability of an effect occurring (as in the BSS) but also the mathematical expectation of harm or just a harmful impact; "dose" may mean any one of several terms defined in the Basic Safety Standards including absorbed dose, dose equivalent, and effective dose equivalent, and committed and collective effective dose equivalent; "limit" may mean a primary dose equivalent, a secondary limit, a derived limit, an authorized limit or even a reference level as the case may be. In the Basic Safety Standards, in addition to the limits, a reference level is the value of a quantity which is used to determine a particular course of action; it is not a limit. An example of a reference level would be the transport index on a package.

INTERTRAN is provided for use in assessing the impact from transportation in a Member State anywhere in the world.

Although SI units have been adopted for international use and are used in all new Agency documents, it is recognized that other than SI units continue to be used in the transport regulations and in the radiological safety practices in many countries. The relationship between the SI units and some of the existing units are shown in the table below:

Quantity	SI unit and and symbol	In other SI units	Old special unit and symbol	Conversion factor
Exposure	-	$C\ kg^{-1}$	röntgen (R)	$1\ C\ kg^{-1} \sim 3876\ R$
Absorbed dose	gray	$J\ kg^{-1}$	rad (rad)	1 Gy = 100 rad
Dose equivalent	sievert (Sv)	$J\ kg^{-1}$	rem (rem)	1 Sv = 100 rem
Activity	becquerel (Bq)	s^{-1}	curie (Ci)	$1\ Bq \sim 2.7 \times 10^{-11} Ci$

TABLE OF CONTENTS

0. Summary

0.1 Purpose and Background of the World-wide Risk-assessment

Transportation of radioactive materials is an integral part of every activity involving the use of nuclear energy, including education, medicine, industry, research and power generation. Increasing numbers and quantities of radioactive material in many different forms are being transported with an estimate of 9 million shipments having been made in the world during 1981.

The record of safety in the transportation of radioactive materials so far has been outstanding. It is believed that this is due to the fact that all shipments of radioacative materials must comply with safety standards based on or consistent with the standards recommended by the International Atomic Energy Agency in its Regulatins for the Safe Transport of Radioactive Materials (Safety Series no. 6).

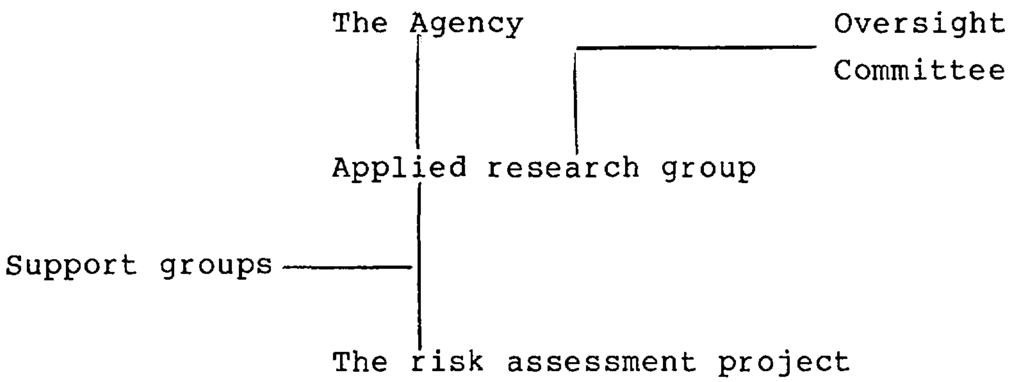
Although the record of safety in transport of radioactive materials is very good, public concern about safety in transport is being expressed in many countries.

The International Atomic Energy Agency's Standing Advisory Group on the Safe Transport of Radioactive Materials (SAGSTRAM) at its meetings in October 1978 and April 1980 recommended that the Agency initiate a risk assessment program intended to develop a simple method of risk analysis that could be applied to the transport of radioactive materials throughout the world.

In 1979 Sweden, through the Swedish Nuclear Power Inspectorate, offered to assist the IAEA in its work to develope a model for a risk assessment of radioactive materials worldwide.

A research agreement between Sweden and the Agency was made which stated that Sweden together with other interested Member States develop a model for calculating the risk from transporting radioactive materials world-wide.

The development of the model started in 1980 and the project organization was as follows.



- The Agency administers and has the overall responsibility for the project.

- The applied research group, (Sweden), manages the project and makes the applied research work or assures that the work is done.

- Research support groups (US, Italy etc) supply data, make analyses and perform other parts of the project were the applied research group need assistance.

- An Oversight Committee including members from eight Member States reviews the progress of the project and recommendations necessary to ensure successful completion.

The intension is that this model shall be easy to handle and that it has the flexibility and sophistication needed to be used by all Member States. It is also necessary that the model gives results that are defensible and adequate for an evaluation of the acceptability of the risk involved.

To ensure that the results are comparable it is necessary that the same model is used when the risk is calculatd. Therefor the model has been made flexibel in the way that it contains different levels of sophistication. The lowest level contains a lot of default data so that it can be used by all Member States and by changing the default datas Member States with a lot of own experiences and data can use their own data and still feel comfortable with the results.

As mentioned in the beginning one of the main purposes for making a risk assessment is to meet the public concern in this area. It should therefor be pointed out that it is not the feeling that the results will lead to a lot of changes in the regulations, the model is probably to general to be used for that purpose, but to get results that can be used for public relations to show that the risk from transportation is on an acceptabel level. It is also possible to identify major contributors to the risk. For those Member States that so wish the model can be used in making parametric studies on single shipments but this is outside of the world wide risk assessment project.

0.2 The Model

At the first meeting of the Oversight Committée, August 1980, it was decided that the American computer code RADTRAN II should be the basis for the development of an international code INTERTRAN. RADTRAN II is an extended version of the earlier RADTRAN which was used in performing the USNUREG-0170 Study. RADTRAN and RADTRAN II were both developed by Sandia National Laboratories, Albuquerque, NM.

The RADTRAN II computer code was changed and reworked to meet the needs of this special project. The methodology as well as formating and data of the input and output were changed to make the code more internationally oriented.

The computer code INTERTRAN calculates the radiological impact from incident-free transports and vehicular accidents involving radioactive materials. The code also adresses accidents which may occur during handling operations.

The model contains several different submodels which are shown in Figure 1.

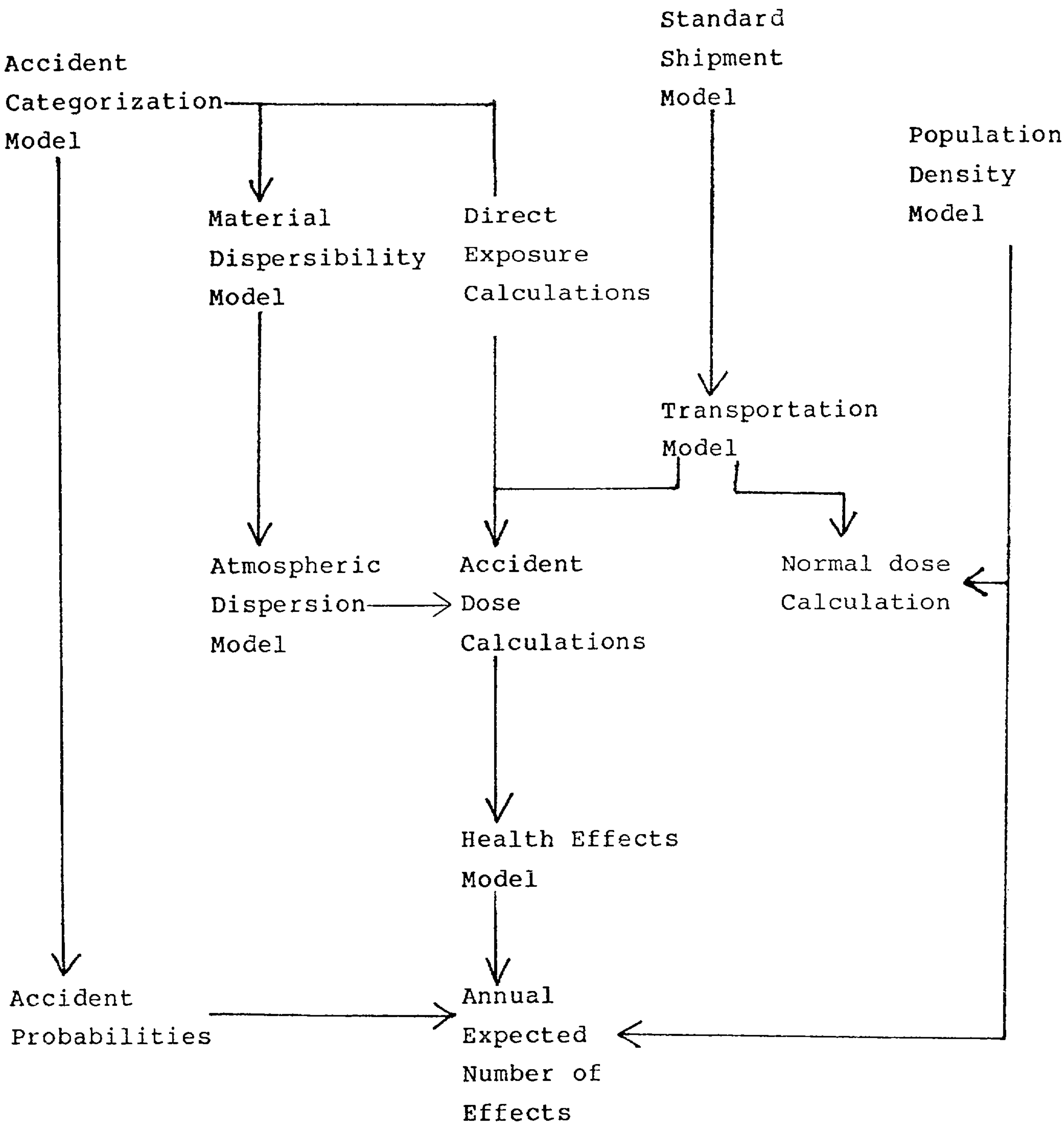


Figure 1 The INTERTRAN computer code

To fit into the Standard shipment model the shipments have to be divided into Standard Shipments. The way of doing this is described in the users manual. The reason for having the standard shipment model is the waste number of materials that are shipped and it is not possible to adress all of them in the same run of he code. The code can handle 200 different shipments in the same run.

The Transportation model can handle ten different transport situations. It consists of a traffic pattern section, a shipment section and an accident rate section.

The population distribution model can handle three population density zones.

The Incident free dose calculation part calculates doses to

- crew
- passengers
- flight attendents
- handlers
- population surrounding transport link
- population traveling on transport link
- population near the transport vehicle while stopped
- warehouse personnel

The impact due to incident free transports is given as the annual expected population dose in person-rem per year.

The accident categorization model contains frequences of occurence for different accident severities in different environments.

The model contains ten different default package types.

For every severity category and each of the ten package types a package failure fraction is determined. It describes the relative degree of damage caused by an accident to the packages of a shipment. A package failure fraction has been assigned for the accident severity categories with environments exceeding the IAEA regulations, depending on the degree of failure and the probability of failure.

In the accident probability model the probability of a certain accident is given by:

- the overall accident rate for the actual mode

- the fractional occurence of the actual accident severity category for that mode

- the accident rate factor for the population density zone, the accident severity category and the transport mode.

The material dispersibility model takes into consideration the dispersibility difference due to different chemical and physical properties of the materials shipped. Eleven dispersibility catgories are available for classifying the different materials. Each category is assigned an aerosolization factor for each accident severity category. The aerosolization factor describes the fraction of the available material which is aerosolized and readily dispersed in an accident. Combined with the package failure fraction the aerosolization factor gives the amount material dispersed in an accident.

The dispersed material will be spread over a wide area and thereby be diluted. The time-integrated concentration at a specific distance from release is calculated in the atmospheric dispersion model. In this section isodose curves can be formed. The amount material deposited during the passage of the cloud and the resulting depletion of the cloud is also calculated in this section of the code.

The dosimetric model deals with the calculation of dose. The pathways that are included in the code are:

Internal pathways:

- Inhalation of aerosolized materials
- Inhalation of resuspended materials

External pathways:

- Ground shine
- Direct exposure from unshielded material

The inhalation dose is calculated for lung, marrow, bone, thyroid, gonads and gastrointestinal tract. The dose from direct exposure is calculated using the average photon energy per disintegration for the transported nuclide.

In the accident dose calculation section the doses from vehicle and handling accidents are calculated. Both the individual and population dose are calculated for every accident analyzed. The calculations are made differently for dispersable and non-dispersable materials. For the dispersable material the doses from inhalation and groundshine are calculated and for non-dispersable materials the direct exposure from a damaged package is calculated.

The results from the dose calculations are used in the health-effect model to determine the health-effects of an accident. This section analyses early effects in the form of early fatalities and early morbidities and latent effects in the form of latent cancer fatalities and genetic effects.

The early effects are calculatd using the individual doses while the latent effects are calculated using the population doses.

The expected number of early fatalities are calculated using a dose-effect table containing the probability of an early effect for specified lung and marrow doses. The expected number of early morbidities are calculated using threshold values for the individual organs.

The expected number of latent cancers is calculated by multiplying the population-dose for an organ with the chronic effect risk factor for that organ. In the case of non-dispersable materials the whole-body risk factor is used.

To enable the user to get a more detailed analyses of the population dose the weighted whole-body dose is calculated from the individual organ doses using the ICRP whole-body weight factors. Two dose levels can be specified and the number of people receiving higher doses than those levels can be calculated.

The annual expected number of effects deals with the risk calculation. Here the consequences are multiplied with the probabilities of the event leading to the calculated consequence.

The results are summed over the severity categories, the population zones and the tansport modes. Results from individual accidents can also be received.

The accident rates and consequences of accidents with each shipment is given as separate output which can be used to calculate the cumulative probability distribution.

The handling accidents are treated in a similar way assuming a suburban population density and an expected number of handling accidents given as a function of the number of handlings per shipment.

To the code has also been added a sensitivity analysis. In the incident free case this analysis is based on the error propagation formula and calculates the relative importance of the input parameters. In the accident case the annual expected effects are divided according to population zone and accident sverity category. These diversified values will give the user a possibility to determine which of the parameters will cause the largest impact on the final result.

A run with the INTERTRAN code requires a large amount of input data. To simplify for the user default values are provided for a lot of the input data. These default values can be changed by the user in most of the cases if he feels that his country can provide more accurate data for his countries special situation. An interactive program which produces an input data file is provided together with the code.

For each run the user has the option to choose a complete output for each or some shipments or a summary output. The complete output consists of:

For the incident free case:

- Dose to the population subgroups from the primary and secondary transport modes.

For the accident case:

- Dispersion and ground contamination values for the involved material.

- Individual organ doses for the different distances, the different accident categories and the different population zones.

- The expected number of people in the isodose or annular areas.

- The annual expected number of early and latent effects and the expected number of accidents for each severity category.

- The annual expected number of people receiving a dose higher than the specified weighted whole-body dose limit.

The summary output consists of:

For the incident free case:

- The number of transported TI per year and the received dose for each material.

- The dose to different population subgroups divided over the materials shipped.

- The dose to different population subgroups divided over the transport modes used.

- The relative importance of the input parameters.

For the accident case:

- The annual expected radiological risk for each material.

- The annul expected number of persons receiving more than a specified whole-body dose.

- The expected latent cancer fatalities for each material from groundshine, inhalation and total sorted in decreasing order.

- The annual expected radiological risk divided according to population zone and accident severity category.

- A summary of the amount of material transported divided into material categories.

1. INTRODUCTION

The International Atomic Energy Agency's (IAEA's) Standing Advisory Group on the Safe Transport of Radioactive Materials (SAGSTRAM) at its meetings in October 1978 and April 1980 recommended that the Agency initiate a risk assessment program to develope a simple method of risk analysis that could be applied to the transport of radioactive materials throughout the world.

In late 1979 Sweden, through the Swedish Nuclear Power Inspectorate, offered to assist the IAEA in its work to develop a model for a risk assessment on the transportation of radioactive materials world-wide.

A research agreement between Sweden and the IAEA was made which implies that Sweden together with other interested Member States develop a model that can be used for assessing the risk from transportation of radioactive materials anywhere in the world.

The project started in 1980 and was organized the following way:

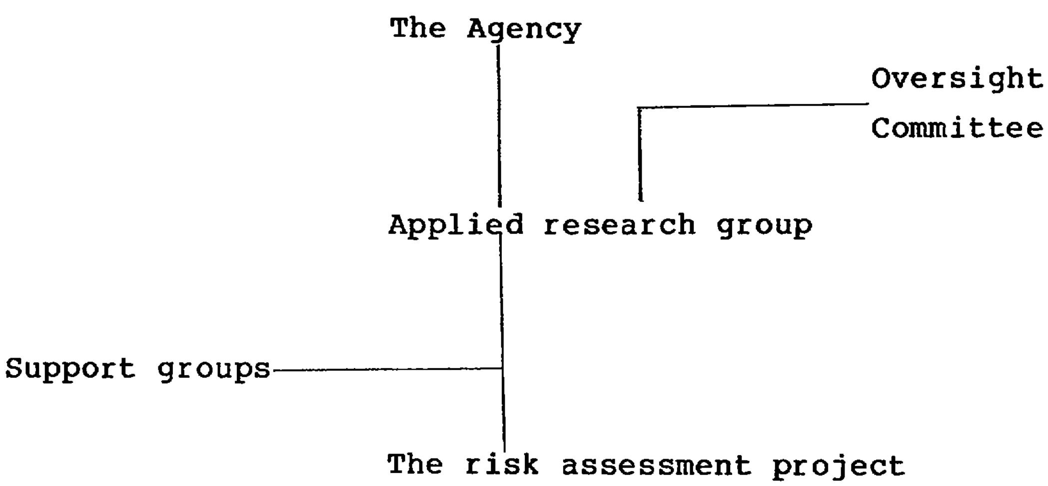


Figure 1.1 Project organization

- The Agency administers and has the over all responsibility for the project.

- The applied research group, (Sweden), manages the project and makes the applied research work or ensures that the work is done.

- Research support groups (US, Italy, etc) supply data, make analyses and perform other parts of the project where the applied research group need assistance.

- An Oversight Committee, including representatives from nine Member States *), reviews the progress of the project and makes recommendations necessary to ensure successful completion.

At the first meeting of the Oversight Committee, August 1980 in Vienna, it was decided that the computer code RADTRAN II /1-1/ should be the basis for the development of an international code, INTERTRAN. RADTRAN II is an extended version of the earlier RADTRAN-code which was used in the USNUREG-0170 Study. RADTRAN and RADTRAN II were both developed by Sandia National Laboratories, Albuquerque, NM.

In cooperation with Sandia Laboratories changes in the methodology of the code were made. In addition to this KEMAKTA Konsult, who has had the responsibility for the program, has made changes felt to be necessary for the international implementation. Changes have also been made to make the code more international oriented. In addition, changes in the input and output have been made in order to simplify the task of the user.

The intention is that this model shall be easy to handle and still retain the flexibility and sophistication necessary so it can be used by all Member Stats. It was decided that

*) (Canada, Federal Republic of Germany, France, Italy, Japan, Sweden, Switzerland, United Kingdom and United States of America)

it also must give results that are adequate and defensible for an evaluation of the acceptability of the risk involved.

It is necessary to have one basic model from which meaningful results can be obtained even if different levels of sophistication in input data are used in different Member States.

Therefore the model has to be made simple enough that all Member States can use it and accurate enough that countries with considerable experience and data feel comfortable using it.

The results from the risk assessments made by Member States of the IAEA will be collected and analyzed. This may lead to improvements in the model and in the input data as well as permit some evaluation of the adequacy of the safety standards.

With refinements of both the model and input data, improved results may be obtained and an overall assessment of the risk from transport of radioactive materials world-wide may be undertaken in 1985.

2. DESCRIPTION OF THE MODEL

2.1 Methodology

The computer code INTERTRAN calculates the radiological impact from incident-free transportion and vehicular accidents involving radioactives materials. The code also adresses accidents which may occur during handling operations. The output in the incident-free case is given in the form of annual integrated population dose received by a number of population subgroups. In the accident case both early and latent effects are analysed.

The model can be divided into submodels as shown in Figure 2.1. These submodels are either a part of the computer code or a separate part preparing input data for the INTERTRAN code. The transportation model, the material dispersibility model and the health effects model are included in the computer code. The standard shipment model, the population distribution model, the accident categorization model and the atmospheric dispersion model are separate from the code. All of these models will be described in this section.

2.1.1 Standard Shipment Model

A vast number of radioactive materials with varying properties are transported. Since the code can not adress all of these transports separately the Standard Shipment model is introduced. A more detailed description of this is found in Chapter 3.

The transported materials that are going to be analysed are divided into standard materials according to nuclide, package type, activity content, transport index and number of packages per shipment. Eighty such standard materials are possible. These standard materials can be shipped by any of the ten transport situations available.

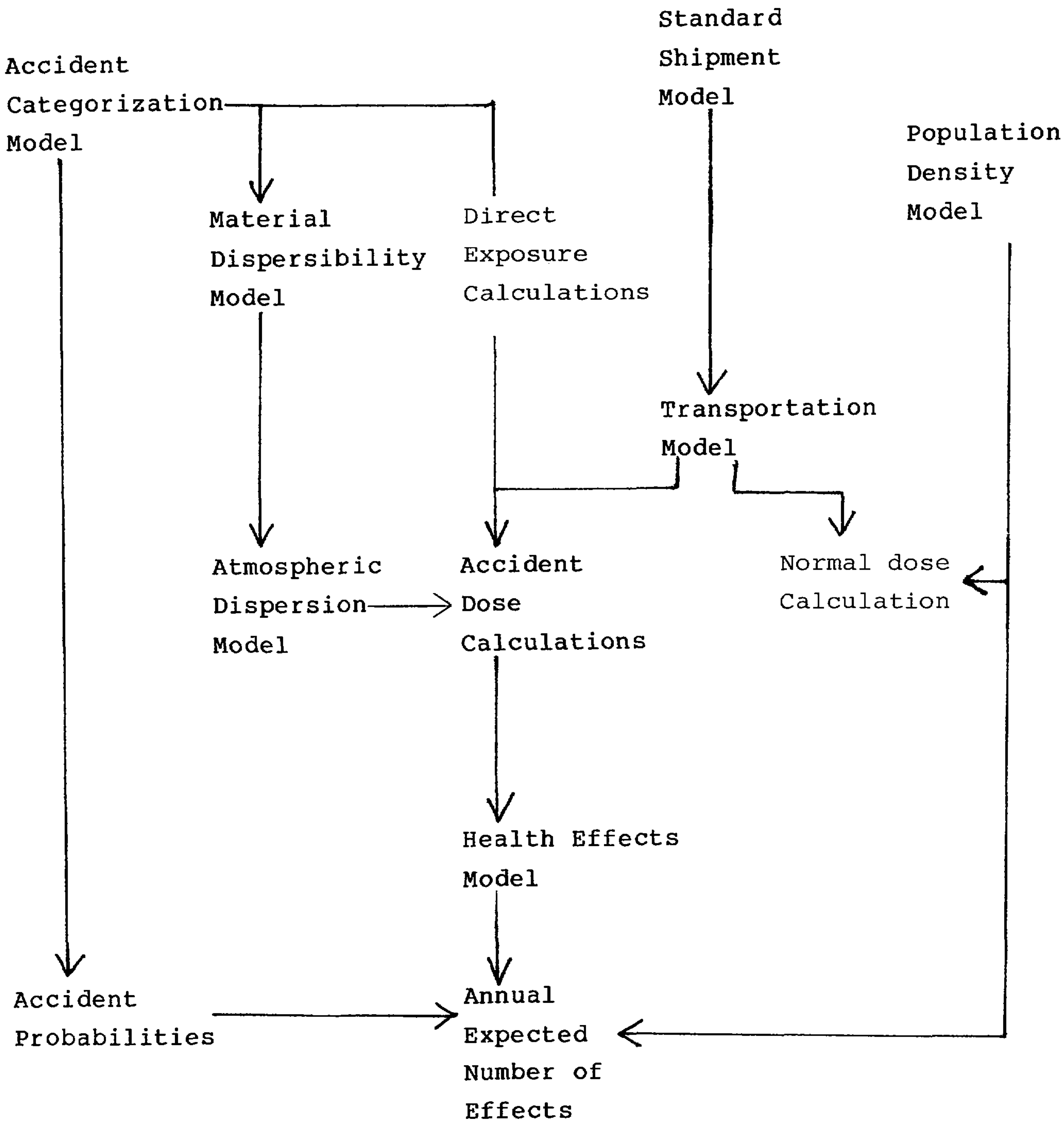


Figure 2.1 The INTERTRAN computer code

The user specifies the number of shipments per year and the distance per shipment for each standard material. A shipment of a radioactive material can include two different transport modes, such a combination is called a shipment scenario. The primary transport mode is used for the main part of the distance and the secondary transport mode is used for the last part of the trip. The user is able to combine two transport modes to a standard shipment of a material. This is made in the CONTROL block in the input data (see Appendix B). Up to 200 standard shipments can be calculated in one run of the code.

In Chapter 3 a more detailed description is given of how to divide the annual shipments in a country into standard shipments.

2.1.2 The Transportation Model

The INTERTRAN code can handle ten different transport situations. These can either be the default situations included in the code or situations defined by the user. The transport situations are divided into four major modes road, rail, air and water, which are treated somewhat differently.

The Transportation Model consists of a traffic pattern section, a shipment section and an accident rate section. The parameters in the different sections are used in the radiological impact calculations.

In the traffic pattern section the fraction of travel in each of the three population zones is specified. These fractions are used in the calculation of the dose in the incident-free case and when calculating the probability of an accident in the different zones. This section also contains the parameters used to determine the dose during shipment stops and the dose to persons in the vicinity of the transport link.

The shipment data section deals with the parameters used to evaluate the dose to crew, handlers, passengers and flight attendants, as well as the dose received while the cargo is stored. A more detailed description of these parameters will be given in Section 2.1.4.

The accident rate section of the transportation model calculates the accident rate depending on the severity of the accident and the population zone where it is assumed to occur. An overall accident rate and a fractional occurence of the accident severities are specified for each mode. These are combined with the accident risk factors which give the fractional accident rate in population zone to over-all accident rate for each mode, severity, category and population zone.

2.1.3 Population Distribution Model

Three separate population zones with an evenly distributed population can be handled by the INTERTRAN code. The three population zones are:

- Urban zone or high-population density zone.
- Suburban zone or medium-population density zone.
- Rural zone or low-population density zone .

For incident-free transports by road mode the code takes into consideration the higher population density of pedestrians by inserting a factor R_{PD} which is the ratio of pedestrian density to the population density in the over-all area.

In the accident dose calculations in the urban zone the population is divided into two parts, one is people inside buildings with the specified urban population density and another for people on the streets with a population density increased with the pedestrian density factor.

Areas near the shipment path are where the highest doses are received and a higher concentration of the population in these areas can be expected. In addition, especially in the rural areas the concentration of population in the vicinity of the roads can be significant. This makes it necessary for the user to adjust the over-all population density to make it correspond to the population density in the vicinity of the shipment paths. A description of how this can be done is made in Appendix D.

2.1.4 Impact Due to Incident-free Transport

Under normal transport conditions the radiological impact arise from direct X-ray, gamma or neutron radiation from the packages being transported. The dose resulting from each shipment is proportional to the total transport index (TI) for all packages in the shipment.

In the INTERTRAN code the exposed population is divided into eight subgroups:

- Crew
- Passengers
- Flight attendants
- Handlers
- Population surrounding transport link
- Population traveling on transport link
- Population near the transport vehicle while stopped
- Warehouse personnel

The impact due to incident-free transport conditions is given as the annually expected population dose in person-rem per year.

When calculating the dose rate, the package is considered a point source. The point source dose rate is given by:

$$DR(r) = \frac{K \cdot e^{-\mu r} \cdot B(r)}{r^2} \qquad (1)$$

$DR(r)$ = dose rate at distance r (rem/h)

r = distance from source (m)

μ = attenuation coefficient for air (1/m)

$B(r)$ = buildup factor for air

K = dose rate conversion factor

The point source approximation is acceptable for distances from the source of more than two source characteristic lengths. The source charcteristic length is assumed to be the largest physical dimension of the package. For smaller distances the dose rate will give a conservative estimate of the dose.

In air, the product of $e^{-\mu r}.B(r)$ is less than 1 for all distances. This means that the absorbtion and the buildup effect can be neglected without losing conservatism. The dose rate expression can be written in a simpler form:

$$D(r) = \frac{K}{r^2} \qquad (2)$$

2.1.4.1 Dose to Crewman

The annual population dose to crewman can be calculated from equation (2). The user specifies an average distance between source and crew and the exposure time is calculated from the annual travel distance divided by the average velocity.

The dose rate factor K can be expressed as:

$$K = K_o \cdot TI \qquad (3a)$$

TI = transport index (mrem/h . at 1 meter from package)
K_o = TI-to-dose-rate conversion factor (m^2)

K_o is defined as:

$$K_o = (1.0 + \frac{d}{2}p)^2 \qquad (3b)$$

where d_p is the typical package dimension. For smaller packages d_p is the diameter of a sphere with equal volume to the package and for larger packages such as casks it is the largest physical dimension, for example the length.

The dose to crew is calculated as:

$$D = Q_1 \cdot K_o \cdot TI \cdot PPS \cdot SPY \cdot N_c \cdot \frac{1}{r^2} \cdot FKMPS \cdot \left(\frac{f_r}{f_r} + \frac{f_s}{v_s} + \frac{f_u}{v_u} \right) \qquad (4)$$

D = Integrated crew exposure

Q_1 = units conversion factor = $2 \cdot 8 \cdot 10^{-4}$ rem·m·h/mrem/km/sec

K_o = TI-dose rate conversion factor (m^2)

TI = transport index (mrem/h, at 1 meter)

PPS = packages per shipment

SPY = shipments per year

N_c = number of crewmen aboard

r = average distance source to crew (m)

FKMPS = distance per shipment (km)

f_n = fraction of travel in population zone n

v_n = velocity in population zone n (m/s)

with the subscripts:

r = rural zone

s = suburban zone

u = urban zone

The maximum dose rate in the crew compartment of a vehicle is limited to 2 mrem/hour in transport regulations. The regulations in some countries state this limit only to exclusive use vehicles while in other cases this limit applies to all vehicles. The user can with the variable IDOSLM specify the option desired:

IDOSLM = 0 Dose limit of 2 mrem/h set for crew on exclusive-use vehicles

IDOSLM = 1 Dose limit of 2 mrem/h to all crews

If the dose rate of a shipment exceeds the limit it is assumed that action will be taken to reduce it to 2 mrem/-

hour. The program will print a warning stating the calculated dose rate.

2.1.4.2 Dose to Airline Passengers and Flight Attendants

The calculation of dose to airline passengers and flight attendants is based on an empirical formula, presented by Barker, Hopkins and Tse /2-1/. The value of $3 \cdot 10^{-5}$ rem per hour per TI carried was derived for both passengers and flight attendants. The integrated dose formula used is:

$$D = PPS \cdot SPY \cdot TI \cdot N_p \cdot K_p \cdot \frac{FKMPS}{VELM} \quad (5)$$

D = integrated population exposure (person rem/year)

N_p = number of passengers of flight attendants aboard
K_p = TI to dose rate conversion factor (rem/hr/TI)
VELM = average shipment velocity (m/s)

2.1.4.3 Dose to Handlers

The dose to handlers is specified separate for handlers of exclusive-use shipments and handlers of non-exclusive use shipments.

The calculation of the dose to handlers is made in three ways depending on the package size.

- Small packages readily handleable by a single person

- Intermediate sized packages requiring lifting equipment such as forklifts

- Large packages requiring rigging equipment and cranes

The method to use is automaticly chosen in the program by comparing the specified package dimension with preset size limits. Small packages have a typical dimension less than

0.5 meter, intermediate size packages between 0.5 and 1 meter and 1 meter and large packages greater than 1 meter.

The size limits are assigned in data statements in the BLOCKDATA section of the code.

The calculation of dose to handlers from small packages is done with an empirical formula derived by Shapiro /2-2/. The dose is estimated to be $2.5 \cdot 10^{-4}$ person-rem per handling per TI, where a handling is defined as the entire process of moving a package from one location to another, regardless of the number of physical movements. The integrated dose formula used is:

$$D = PPS \cdot SPY \cdot TI \cdot K_h \cdot N_h \qquad (6)$$

D = integrated population exposure (person rem/year)
K_h = handling to dose conversion factor (rem/handling/TI)
N_h = average number of handlings per shipment

The handling of intermediate sized packages such as drums may require more than one handler. In this case the dose is calculated by specifying a fixed distance were the handlers will be exposed for a period of time. The integrated dose formula used is:

$$D = Q_2 \cdot PPS \cdot SPY \cdot PPH \cdot T_h \cdot N_h \cdot \frac{K_o \cdot TI}{r^2} \qquad (7)$$

D = integrated population exposure (person·rem/year)
Q_2 = unit conversion factor, 10^{-3} (rem/mrem)
PPH= number of persons exposed per handling
T_h= length of exposure time (hours)
N_h= number of handlings per shipment
r = average distance from source to handler (meters)

The values assigned to r, PPH and T_h are provided in Table 2.1 at the end of this section. If the assigned values need to be modified, the user must change the data statements in the BLOCKDATA routine of the code.

In the case of large packages such as spent fuel casks the dose is calculated in a similar way as for intermediate size packages. However, the exposure distance is short compared to the typical package size which makes the assumption of a point source inappropriate. In this case line source geometry is assumed.

The dose is proportional to the reciprocal of the exposure distance rather than the square of the reciprocal and the TI to dose rate conversion value is the square root of the value defined in Equation (3).

The integrated dose formula used is:

$$D = Q_2 \cdot PPS \cdot SPY \cdot PPH \cdot T_h \cdot N_h \cdot \frac{K_o' \, TI}{r} \qquad (8)$$

D = integrated population dose (person rem/year)

K_o'=line source TI to dose rate conversion factor (m)

The values assigned for r, T_h and PPH in the code are given in Table 2.1 below.

Table 2.1 Assigned Handler Parameter Values.

Package size		r(m)	T_h (hr)	PPH
Intermediate	0.5<x<1	1	0.25	2
Large	x>1	2	1	5

2.1.4.4 Dose to Warehouse Personnel While Package is in Storage

While the package is in storage persons in the immediate area of the package will be exposed. Because of the difficulties to assess the variations in exposure geometry, shielding, and exposure time, a simple model using the average values for distance and number of persons exposed is used:

$$D = Q_2 \cdot PPS \cdot SPY\ P_{stor} \cdot T_{stor} \cdot \frac{K_o\ TI}{r^2_{stor}} \qquad (9)$$

D = integrated population exposure (person rem/year)
P_{stor}=average number of persons in warehouse area
T_{stor}=total storage time per shipment (hr)
r_{stor}=average exposure distance (m)

2.1.4.5 Dose to Population During Shipment Stops

During a shipment the transport vehicle can stop for crew changes, passenger transfers, breaks, refueling etc. While the vehicle is stopped persons in the surrounding will be exposed. The integrated dose from stops is calculated in a similar way as the dose from storage.

As an input value the stop time per 24-hour trip is given. This value is used to calculate the stop-time for a specific shipment. It is assumed that no shipment have a shorter stop time than 0.5 hours. Thus, the integrated dose is given by:

$$D = Q_2 \cdot PPS \cdot SPY \cdot P_{st} \cdot \frac{K_o \cdot TI}{r^2_{st}} \cdot \begin{bmatrix} 0.5 \quad \text{if} \quad \dfrac{FKMPS \cdot T_{st}}{VELM \cdot Q_3 \cdot T_{max}} < 0.5 \\ \dfrac{FKMPS \cdot T_{st}}{VELM \cdot Q_3 \cdot T_{max}} > 0.5 \end{bmatrix} \qquad (10)$$

D = integrated population dose (person rem/year)
P_{st} = number of exposed persons
r_{st} = average exposure distance (m)
T_{st} = stop-time for a 24-hour trip (hr)
VELM = mean velocity (m/s)

Q_3 = units conversion factor. 3.6 $(\frac{km \cdot s}{h \cdot m})$
T_{max}= 24 hours

The IAEA regulations for the dose rate on the exterior of road and rail shipping vehicles have been applied to the calculation. For non-exclusive-use vehicles the dose rate at 1 meter from the vehicle should not be greater than 10 mrem/hour. Since the transport index is defined as the dose rate in mrem/hour at 1 meter from a package the product PPS·TI can be used as an approximation of the dose rate at 1 meter. It is assumed that measures will be taken to reduce the dose rate to the regulated level and this reduced level will be used in the dose calculations.

For exclusive-use shipments the IAEA dose rate limit is 10 mrem/hour at 2 meters. The shipment is assumed to be a line source between 1 and 2 meters and PPS·TI·1/2 approximates the dose rate at 2 meters. The same procedure as for non-exclusive-use shipments is used to calculate the dose rate. If a reduced dose rate is used a warning statement will be printed and the original dose rate will be specified.

2.1.4.6 Dose to Persons Surrounding the Transport Link While the Shipment is Moving

The dose to surrounding population is calculated for the road, rail and water modes.

The integrated dose absorbed by an individual from a passing vehicle is given by:

$$D(X) = \frac{2K}{VELM} \int_{x}^{\infty} \frac{dr}{r(r^2 - x^2)^{1/2}} = \frac{K \cdot \pi}{VELM \cdot X} \qquad (11)$$

An expression derived from Equation 1 /2-3/.

K = dose rate factor
VELM= vehicle velocity
x = perpendicular distance from shipment path

The integrated population dose is obtained by multiplying Equation (11) by the average population density for the length of the trip and integrating over areas of width d on both sides of the shipment path

$$D = 2 \cdot PD \cdot FKMPS \int_{d_{min}}^{d_{max}} D(x)\,dx \qquad (12)$$

D = integrated population dose

PD = uniform population density

FKMPS=distance of shipment

d_{min} =minimum distance from population to shipment centerline

d_{max} =maximum distance over which exposures is evaluated

D(x) =dose as a function of distance. Equation (11)

By inserting the expression for D(x) and integrating, Equation (4) can be rewritten as

$$D = \frac{2 \cdot \Pi \cdot PD \cdot FKMPS \cdot K}{V} \cdot \ln\left(\frac{d_{max}}{d_{min}}\right) \qquad (13)$$

Since equation (13) will approach infinity as d_{min} approaches 0 and d approaches infinity, limits for these values have to be set. The values for d_{min} and d_{max} are based on shipment path dimensions and the reduction of the radiation at greater distance due to shielding and attenuation.

The total dose to surrounding population from a shipment will be the sum of the dose received in the different population zones,

$$D = D_r + D_s + D_u \qquad (14)$$

For each type of transport mode, road, rail and water, the population distribution and shielding configuration in the different population zones have been treated differently.

For the road modes the rural population is assumed to be uniformly distributed in a strip 30-800 meters from the center of the roadway. The shielding is assumed to be negligable in this area.

The code also considers the dose to pedestrians which are assumed to be found in a strip 27-30 meters from the center of the road. The population density for pedestrians is assumed to be a factor greater than the over-all population density. The ratio pedestrian density to over-all population factor is input data to the code.

The dose in the suburban zone is calculated in a similar way except that a shielding factor R_s is introduced. The dose to the population off the transport link is reduced with a factor R_s while the pedestrian are unshielded. The R_s factor is input data to the code.

Appendix E will include a description of the method used to derive the shielding factors.

In the urban zone three options can be used assuming different degrees of shielding.

Option 1 assumes that the population inside buildings are so effectivly shielded that their contribution to the population dose can be neglected. For the fraction of travel on city streets the dose is calculated for pedestrians on the sidewalk 5-8 meters from the center of the street. The pedestrian population density is assumed to be the over-all population density multiplied by the RPD factor.

In option 2 the dose to pedestrians on city-streets is calculated the same way as in option 1. The dose to the population inside buildings along the city-streets is calculated with an urban shielding factor R_u over an area 8-800 meters from the shipment path. In the case with travel outside the city-street area of the urban zone, for example on freeways, the dose is calculated over an area 30 to 800 meters from the roadway. No pedestrians are assumed to be found on these roads.

Option 3 is the most conservative approach. In the city-street area the population dose is calculated for a uniformly distributed population in the area 5-800 meters from the shipment path. No shielding is assumed. The same assumtions are used in the non-city-street area but calculated over an area 30-800 meters from the shipment path.

The expression for the population dose will be:

$$D=2\pi \cdot Q_4 \cdot FKMPS \cdot SPY \cdot PPS \cdot K_o \cdot TI \cdot$$

$$\cdot \left[\left(\frac{IV1 \cdot f_r \cdot PD_r}{V_r} + \frac{IV2 \cdot f_r \cdot PD_r \cdot RPD}{V_r} \right) + \right.$$

$$+ \left(\frac{IV1 \cdot R_s \cdot f_s \cdot PD_s}{V_s} + \frac{IV2 \cdot f_s \cdot PD_s \cdot RPD}{V_s} \right) +$$

$$\left. + \frac{f_u \; PD_u}{V_u} \left[\begin{array}{ll} \text{Option 1:} & (IV3 \cdot f_{cs} \cdot RPD) \\ \text{Option 2:} & \left[f_{cs} (IV3 \cdot RPD + IV4 \cdot R_u) + \right. \\ & \left. + (1-f_{cs}) \; IV1 \cdot R_u \right] \\ \text{Option 3:} & \left[IV5 \; f_{cs} + IV1 \; (1-f_{cs}) \right] \end{array} \right] \right] \quad (15)$$

D = integrated population dose for road modes (person rem/year)

Q_4 = units conversion factor = $2.8 \cdot 10^{-10}$ (rem/mrem·km/m·h/s)

PD_n= population density in zone n (persons/km^2)

RPD = ratio pedestrian population density to over-all population density

R_s = shielding factor suburban zone

R_u = shielding factor urban zone

f_{cs}=fraction travel on city-streets

$IV1 = \ln\left(\frac{800}{30}\right)$ $\quad$ $IV4 = \ln\left(\frac{800}{8}\right)$

$IV2 = \ln\left(\frac{30}{27}\right)$ $\quad$ $IV5 = \ln\left(\frac{800}{5}\right)$

$IV3 = \ln\left(\frac{8}{5}\right)$

The rail mode is treated in a similar way with the exception that no dose to pedestrians is considered. In the urban zone the population dose is calculated for an area 30 to 800 meters from the shipment path. Shielding to the urban population is assumed by inserting the urban zone shielding factor, R_u. The population dose will be:

$$D=2\Pi \cdot Q_4 \cdot FKMPS \cdot SPY \cdot PPS \cdot K_o \cdot TI \cdot \left[\frac{IV6 \cdot f_r \cdot PD_r}{V_r} + \frac{IV6 \cdot f_s \cdot PD_s \cdot R_s}{V_s} + \frac{IV6 \cdot f_u \cdot PD_u \cdot R_u}{V_u}\right] \qquad (16)$$

D= integrated population dose for rail mode (personrem/year)

$IV6 = \ln\left(\frac{800}{30}\right)$

For the water modes the fraction of travel in urban zones is set to 0, which means that the part of the distance for a water mode shipment that does not pass through rural ares is said to pass through the suburban area. The area over which the dose is calculated is the area 200-800 meters from the shipment path. In the suburban areas the shielding factor R_s is used. The population dose from water modes is calculated as:

$$D=2\pi \cdot Q_4 \cdot FKMPS \cdot SPY \cdot PPS \cdot K_o \cdot TI \cdot \left[\frac{IV7 \cdot f_r \cdot PD_r}{V_r} + \frac{IV7 \cdot (1-f_r) PD_s}{V_s}\right] \qquad (17)$$

D= integrated population dose from water modes (person rem/year)

$IV7= \ln\left(\frac{800}{200}\right)$

The dose rate limitations on the outside of vehicles described in Section 2.1.4.5 are used in the calculations of dose from the road and rail modes.

2.1.4.7 Dose to Persons in Vehicles Sharing the Transport Link with the Shipment

The calculations of the dose to persons sharing the transport link are made for the road and rail modes. The calculations are divided into two parts:

- dose to persons travelling in the opposite direction to the shipment
- dose to persons travelling in the same direction as the shipment

The dose to a person travelling in a vehicle meeting the shipment can be calculated in Equation (11) by assuming that the meeting vehicle is at rest and shipment is travelling with the speed of 2 VELM. The average integrated dose will be:

$$\frac{K \cdot \pi}{2\ VELM \cdot x} \qquad (18')$$

D = integrated dose (personrem/year)

x = perpendicular distance between passing vehicles (m)

The number of persons exposed can be seen as the linear population density along the shipment path and can be expressed as:

$$PD_1 = \frac{N_n \cdot PPV}{VELM} \qquad (19)$$

PD_1 = linear population density (persons/m)

N_n = average number of vehicles passing a specific point in one direction (traffic count) in population zone n.

PPV = number of persons per vehicle

Since the vehicles are travelling in the opposite direction the number of exposed persons will be $2PD_1$. The annual population dose to persons travelling in the opposite direction to the shipment will be:

$$D = SPY\ FKMPS\ PPV\ K_o\ TI\ \frac{\pi \cdot 2N_n}{2x \cdot VELM^2} \qquad (20)$$

For the road modes average values of the velocity and the traffic count for the three population zones are given as input data. The traffic count and velocity depend on the time of the day. During rush-hour the traffic count will increase and the velocity decrease. The fraction of travel during rush-hour traffic is input data. The distance between passing vehicles depends on the type of road used. The values used in the code for different roads are listed in Table 2.2. The fraction of travel on freeways and city-streets are given as input.

Table 2.2 Distance between passing vehicles for different type of roads

Type of Road	Distance (meter)
Freeway	15
Two-Lane Highway	3
City Street	3

When calculating the dose from road vehicles the following assumptions are made.

Rural and suburban truck travel may be on either 2-lane roads or freeways.

Traffic count doubles during the commuter rush periods.

The average speeds in suburban and urban zones decrease by a factor of 2 during commuter rush periods.

Urban travel may be on freeways or city streets.

Urban travel on freeways is at half the average suburban velocity during rush hours.

Urban travel on freeways during nonrush hours is at the average suburban velocity.

The dose is given by:

$$D_{opp}=Q_5 \cdot K_o \cdot TI \cdot PPS \cdot SPY \cdot FMPS \cdot PPV \cdot 2 \cdot$$

$$\begin{aligned} \cdot \Bigg\{ & f_r \cdot \left(\frac{f_{fwy} \cdot N_r \cdot IV8}{V_r^2} + \frac{(1-f_{fwy}) \cdot N_r \cdot IV9}{V_r^2} \right) \\ & + f_s \cdot \Bigg(IV8 \cdot f_{fwy} \left[\frac{f_{rh} \cdot 2N_s}{\left(\frac{V_s}{2}\right)^2} + \frac{(1-f_{rh}) \cdot N_s}{V_r^2} \right] \\ & IV9 \cdot (1-f_{fwy}) \left[\frac{f_{rh} \cdot 2N_s}{\left(\frac{V_s}{2}\right)^2} + \frac{(1-f_{rh}) \cdot N_s}{V_s^2} \right] \Bigg) \\ & + f_u \Bigg(IV8 \cdot (1-f_{cs}) \left[\frac{f_{rh} \cdot 2N_u}{\left(\frac{V_s}{2}\right)^2} + \frac{(1-f_{rh}) \cdot N_u}{V_s^2} \right] \\ & IV10 \cdot f_{cs} \left[\frac{f_{rh} \cdot 2N_u}{\left(\frac{V_u}{2}\right)^2} + \frac{(1-f_{rh}) \cdot N_u}{V_u^2} \right] \Bigg) \Bigg\} \end{aligned} \qquad (21)$$

u = subscript denoting urban travel

s = subscript denoting suburban travel

r = subscript denoting rural travel

f = fraction of distance traveled in specific population zone zones, respectively

f_{rh} = fraction of distance travel during rush hour traffic

f_{fwy} = fraction of travel on freeways, interstate-highways or 4-lane roads

f_{cs} = fraction of travel on city streets

VELM = average velocity in specific population zone (m/s

Q_5 = units conversion factor=$7.7 \cdot 10^{-8}$ $\frac{\text{rem-hr}^2\text{-m}}{\text{mrem-sec}^2\text{-km}}$

IV8 = integral value for freeways $\frac{\pi}{2 \cdot 15} = 0.1$

IV9 = integral value for twolane highways $\frac{\pi}{2 \cdot 3} = 0.52$

IV10 = integral value for city-streets $\frac{\pi}{2 \cdot 3} = 0.52$

When calculating the dose to persons travelling in the same direction as the shipment it is assumed that the shipment travels with the same speed as the rest of the traffic. The shipment vehicle will then follow and be followed by vehicles at a constant distances. The dose to a person in a followed or following vehicle at the distance r from the shipment will be:

$$D = \frac{K \cdot T}{r^2}$$

D = integrated dose to individual (22)

T = exposure time

The number of persons exposed is given by the linear population density expressd in Equation (19). The integrated population dose is given by integrating from a minimum to a maximum exposure distance:

$$D = PD_i \cdot K \cdot T \cdot \int_{d_{min}}^{d_{max}} \frac{d_r}{r^2} = K \cdot T \left(\frac{1}{d_{min}} - \frac{1}{d_{max}} \right) \quad (23)$$

d_{max} = maximum exposure distance

d_{min} = minimum exposure distance

The minimum exposure distance will depend on the vehicle velocity and it is here assumed that the closest vehicle will be located within 2 seconds of travel from the shipment vehicle and is given by 2VELM. The maximum exposure distance is assumed to be infinity. The annual exposure time is calculated by dividing the annual distance traveled by the average velocity. The same assumptions for velocities, traffic counts, road types and traffic condition as in the case of persons travelling in the opposite direction will be used. The resulting annual population dose will be:

$$D_{SD} = Q_5 \cdot K_o \cdot TI \cdot PPS \cdot FMPS \cdot SPY \cdot PPV \cdot 2 .$$

$$\cdot \left[\frac{f_r \cdot N_r}{V_r^2} \cdot \frac{1}{V_r} + f_s \left(f_{fwy} \left[\frac{f_{rh} \cdot 2N_s}{\left(\frac{V_s}{2}\right)^2} \cdot \frac{1}{V_s} + \frac{(1-f_{rh}) \cdot N_s}{V_r^2} \cdot \frac{1}{2V_r} \right] \right. \right.$$

$$\left. + (1-f_{fwy}) \left[\frac{f_{rh} \cdot 2N_s}{\left(\frac{V_s}{2}\right)^2} \cdot \frac{1}{V_s} + \frac{(1-f_{rh}) \cdot N_s}{V_s^2} \cdot \frac{1}{2V_s} \right] \right)$$

$$+ f_u \left(\left[(1-f_{cs}) \frac{f_{rh} \cdot 2N_u}{\left(\frac{V_s}{2}\right)^2} \cdot \frac{1}{V_s} + \frac{(1-f_{rh}) \cdot N_u}{V_s^2} \cdot \frac{1}{2V_s} \right] \right. \qquad (24)$$

$$\left. \left. + f_{cs} \left[\frac{f_{rh} \cdot 2N_u}{\left(\frac{V_u}{2}\right)^2} \cdot \frac{1}{V_u} + \frac{(1-f_{rh}) \cdot N_u}{V_u^2} \cdot \frac{1}{2V_u} \right] \right) \right]$$

For rail mode the dose to persons in passenger trains meeting a train shipping radioactive material is calculated. The distance between the passengers and the shipment is assumed to be 3 meters. No assumptions for traffic during rush-hour periods are made. The annual dose to train passengers is given by:

$$D = Q_5 \cdot IV11 \cdot SPY \cdot FKMPS \cdot PPV \cdot TI \cdot K \cdot \left(\frac{f_r \cdot N_r}{V_r^2} + \frac{f_s \cdot N_s}{V_s^2} + \frac{f_u \cdot N_u}{V_u^2} \right) \quad (25)$$

D = integrated population dose (person rem/year)

IV11 = integral value for railroads $\frac{\pi}{2 \cdot 3} = 0.52$

The limitations of the exterior dose rate of the vehicle described in Section 2.1.4.5 are applied to the calculations of dose to persons sharing the transport link.

2.1.4.8 Output from the Incident-free Calculations

For each material shipped the code will tabulate the annual population dose received by the population subgroups. A similar table showing the population dose for each of the transport modes is also printed. If the user specifies a more complete output for a standard shipment the dose received by the population subgroups will be printed for the transport modes used in that standard shipment. An example of the INTERTRAN output is shown in Chapter 6.

2.2 ACCIDENT IMPACT CALCULATIONS

2.2.1 Accident Severity Categorization Model

The purpose of the accident severity categorization model is to define an accident environment or a combination of accident environments which gives a specified impact on a package. An accident severity category can be defined differently for the different transport modes, but will always give the same impact on a package. Every transport mode will have a probability specified for each accident severity category.

The accident severity categorization model used in INTERTRAN is based on the analysis of accidents involving trucks, trains and air carriers made by Clarke, et al /2-4/. In this report an accident is described by the crush, impact, puncture and fire environments. In this report the environments are defined as:

- Crush- compression caused by relatively long time (10 ms) loading on a package as a result of inertial loading from other cargo in the vehicle or from heavy sections of the vehicle resting on top of the package

- Impact-collision between a package and some other body where the force of the collision is applied over a wide area of the package.

- Puncture - Striking or being struck by an object which penetrates the protective structures of the package.

- Fire - A hightemperature environment produced by combustion.

The probability of exceeding a given severity of an environment is calculated in the report. The two or three most significant accident environments for each mode are chosen and the joint probability of these is estimated. The probability of an accident of a certain severity will of course vary for different circumstances see Section 3.2.

One of the problems with categorization of accidents is that two accidents giving the same impact on a package not necessarily will result in the same amount of material released. An accident involving only mechanical damage will not necessarily cause the same release as an accident where the same damage to the package is caused by fire. Due to the chemical and physical properties of the material in the package different amount of material may be released and aerosolized. For example the dose from an accident involving UF_6 is considerably larger in a fire accident than in an impact accident.

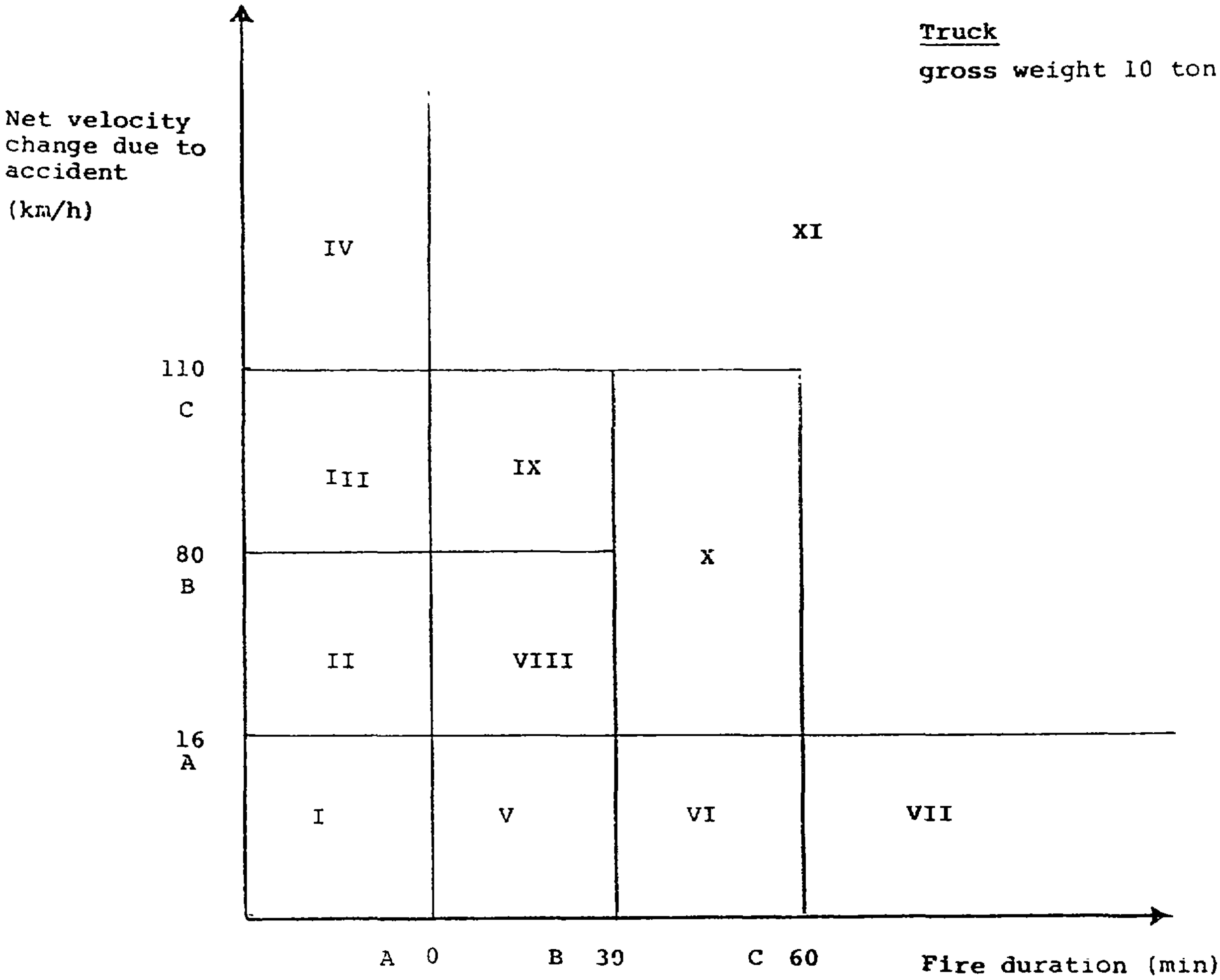


Figure 2.2 Accident Severity Categorization Scheme for the Truck Mode

The accident categorization is illustrated in a scheme with the severity of the mechanical environments along the y-axis and the severity of the fire environment along the x-axis. In figure 2.2 the categorization scheme for the truck mode is shown. The scheme is divided into eleven accident severity categories depending on mechanical damage and fire duration. The accidents of category I-IV are accidents involving only mechanical damage, the accidents of category V-VII involves only fire and the accidents of category VIII-XI involves combinations of fire and mechanical damage.

The limits for the accident severity categories are based on the IAEA qualification test for type A and type B packages. In the figure, A represents the limit for the mechanical impact to which a type A package will remain intact, since no fire test is required for type A packages the fire duration limit is set to zero.

The limit B is the same limit for a type B package, but with a fire duration limit included. The limit C is chosen in order to avoid having to calculate with a maximum failure as soon as the type B limit is exceeded.

The INTERTRAN code accident severity categorization for the default transport modes, which is described in Section 3.2. The fractional occurence of the accident severities for each transport mode are available in the default data sets initiated in the BLOCK NORACC part of the code.

A user can of course define up to eleven accident severity categories as desired and give the fractional occurence for each of these as input data to the code.

For each of the ten package types a package failure fraction, RF, in each severity category is determined.

The package failure fraction (RF) describes the relative degree of damage causd by an accident to the packages of a shipment. A package with no loss of packaging integrity but not necessarily undamaged is assigned an RF of 0 and a package which has lost all its packaging integrity is assigned and RF of 1.

The IAEA regulations are used as a basis when determining the package failure fraction, but it is not realistic to assume that the packages lose all of their integrity when the regulated limits are exceeded. A package failure fraction has to be assigned for the accident severity categories with accident environments exceeding the IAEA regulations, depending on the degree of failure and the probability of failure. The limited amount of data available calls for a great degree of conservatism when deciding the package failure fraction. The default RF values initiated in the code are described in Chapter 3.

2.2.2 The Material Dispersibility Model

The most important pathway for radioactive material released in transportation accidents is inhalation of airborne material. In order to get airborne release and downwind dispersion of a material it must be in a form that can be suspended, transported downwind and inhaled, i.e. as a gas as small particles or as small liquid droplets. Not all the content of a package will be in dispersable form. To be able to determine the impact of a transportation accident the fraction of material available as a dispersable aerosol must be estimated.

There are many mechanisms which can generate aerosols, powders can be entrained by an airstream as a result of aerodynamic or mechanical forces. Solids and large particles can be reduced in size by shock and impact and attain dispersable size. Many materials vaporize or react chemically to become more volatile. Liquid droplets can form through breakup of films or flash evaporation of superheated liquids.

The characteristics of the aerosol formed and its reactions during the dispersion will also effect the concentration.

As a result of the above a number of things must be considered when determining the fractional amount of material released:

- The physical and chemical properties of the radioactive material

- The accident environment, mechanical forces, fire etc.

- The response of the material to the accident environment.

To be able to take this into consideration the materials are divided into eleven material dispersibility categories according to their physical and chemical form.

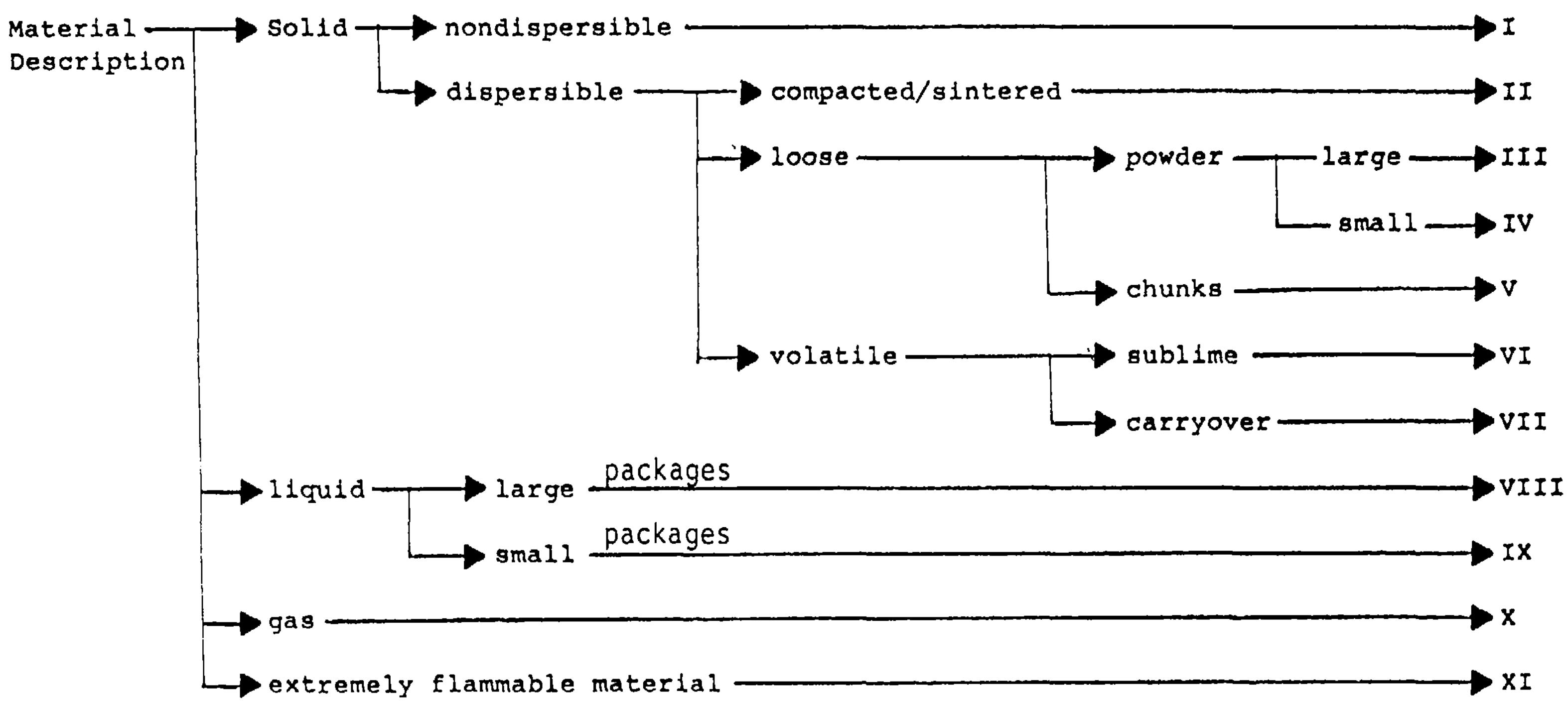


Figure 2.3 Decision Tree for Determining Material Dispersibility

The aerosolization factor describes the proportion of material which is aerosolized and readily dispersed in an accident. An aerosolization factor is assigned for each accident category and material dispersibility category.

The scheme used to determine the material dispersibility category is shown in Figure 2.3. The materials are first divided according to their state of aggregation and then according to their dispersibility. The dispersible solids are divided into compacted/sintered, loose or volatile materials. The loose materials are chunks or powders in large or small containers and the volatile materials are divided into materials which sublime or which carry-over. The liquids are separated in two categories depending on package size. There is also a category for gases and one for extremely flammable materials.

Default values of the aerosolization factors are initiated in the code. These values can be changed with input data if found necessary. The default values are given in Section 3.

Knowing the package failure fraction and the aerosolization fraction for a material the amount dispersed can be calculated. Only the dispersed particles which have an aerodynamic diameter less than about 10 μm will be respirable. The fraction of the material which is respirable, RESP, is given as default data.

2.2.3 The Atmospheric Dispersion Model

The radioactive materials which are aerosolized in an accident will form a cloud which will spread downwind. The size and form of the cloud will depend on the nature of the release. A puff release will result in a cloud of radioactive material which will be diluted as it travels downwind. In the case of a long time release the radioactive material will form a plume spreading out vertically and sideways.

The concentration of radioactive material in the air downwind from a radioactive release will depend on the distance from the release, the atmospheric stability and the wind speed. The concentration can be described by dilution factors.

By assuming that the affected persons remain in the same place during the whole passage of the plume the amount of material inhaled and there by the dose can be described with a dilution factor χ . The dilution factors for a specific meteorological condition will be a function of the distance x from the point of release and the perpendicular distance y from the wind direction, see Figure 2.4.

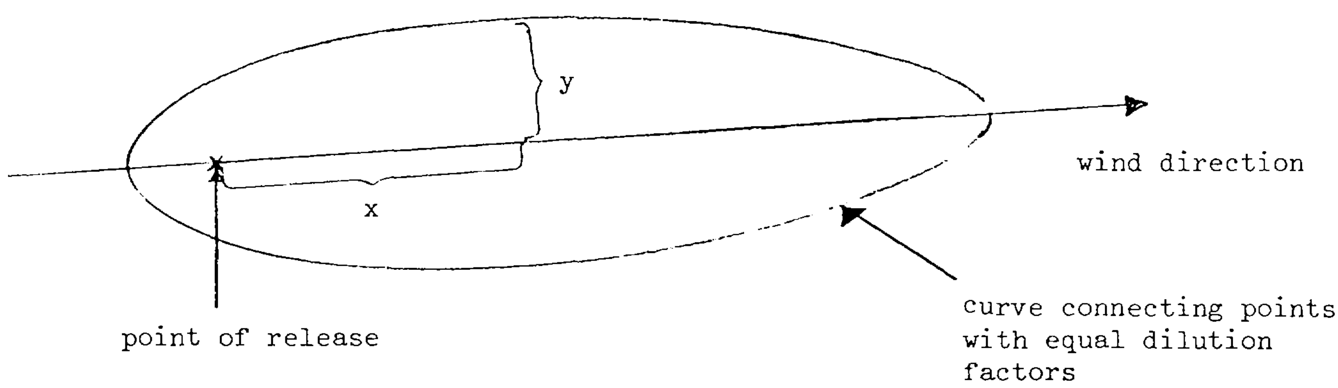


Figure 2.4 Isodose curves

By connecting points with equal χ -values isodose curves can be formed that will look like nested ovals.

The atmospheric stability is characterized by the Pasquill stability categories A-F, were A is an extremely unstable situation with strong turbulent dispersion, D is a situation with neutral stability and F is an extremely stable situation with weak turbulent dispersion. The relative occurence of the various Pasquill stability categories can often be estimated for a specific location.

The user has two options when calculating the atmospheric dispersion:

- Supply a set of dilution factors and the areas encircled by their isodose curves calculated by a suitable atmospheric dispersion model. These dilution factors should be calculated assuming a total reflection of material at the ground level.

- Supply the relative occurence of the various Pasquill stability categories. In this case a set of weighted average dilution factors will be calculated using data from the Pasquill stability library included in the code. The Pasquill stability library is shown in Table 2.3.

It should be noted that the use of the average dilution factors may give misleading results when calculating the impact of early non-stochastic effects.

These effects often have a threshold dose which can be exceeded in very stable conditions, but not exceeded when using the weighted average dilution factors. To compensate for this effect a separate calculation can be made with the dilution factors for each Pasquill stability category and the risk can be weighted against the relative occurence of the various categories.

During the dispersion, however, material will continiously deposit on the ground. The amount deposited and the resulting depletion of the cloud is calculated in the code. The average dilution factor in the annular areas formed between the isodose curves is given by the geometric mean,

$$\bar{\chi}_n = \sqrt{\chi_n \cdot \chi_{n-1}} \qquad (26)$$

The amount of material deposited on each area is obtained by multiplying the average dilution factor with the area of the annulus and the deposition velocity for the dispersed material,

Table 2.3 Integrated Air Concentration Values in Pasquill Stability Library

Area (m^2)	Pasquill Category A	B	C	D	E	F
	(u = 1 m/s)	(u = 2 m/s)	(u = 3 m/s)	(u = 4 m/s)	(u = 2.5 m/s)	(u = 1 m/s)
460	6 - 3	4 - 3	4 - 3**	4.3 - 3**	9.6 - 3**	6.2 - 2**
1500	1.7 - 3	1.3 - 3	1.1 - 3	1.3 - 3	3.2 - 3	1.8 - 2**
3900	8.4 - 4	5.5 - 4	5.7 - 4	6.5 - 4	1.6 - 3	8.4 - 3
1.3 + 4	1.7 - 4	1.3 - 4	1.3 - 4	1.8 - 4	4 - 4	2 - 3
3.0 + 4	7.8 - 5	6 - 5	6.7 - 5	9.5 - 5	2.1 - 4	9.2 - 4
6.9 + 4	2.8 - 5	2.7 - 5	3 - 5	4.3 - 5	1.4 - 4	4.4 - 4
1.8 + 5	8 - 6	1 - 5	1.0 - 5	1.8 - 5	4.4 - 5	2 - 4
4.5 + 5	2.2 - 6	3.5 - 6	5.0 - 6	8.5 - 6	2.1 - 5	1.0 - 4
8.6 + 5	9 - 7**	1.6 - 6	2.8 - 6	5 - 6	1.2 - 5	6.2 - 5
2.6 + 6	1.4 - 7**	4.1 - 7**	1.0 - 6	1.9 - 6	4.8 - 6	2.6 - 5
4.5 + 6	7 - 8**	2.2 - 7**	6 - 7	1.3 - 6	3.6 - 6	1.9 - 5
1.7 + 7	1.1 - 8**	5 - 8**	1.7 - 7**	4 - 7**	1.4 - 6	8.4 - 6
2.2 + 7	4 - 9**	3.2 - 8**	1.3 - 7**	3 - 7**	1.2 - 6	7 - 6
5.5 + 7	5.8 - 10**	1.1 - 8**	5.7 - 8**	1.5 - 7**	6.0 - 7	4 - 6
1.8 + 8	7 - 12**	2.5 - 9**	1.7 - 8**	5.5 - 8**	2.8 - 7**	2 - 6

*Taken from Figure A.8 of "Meteorology and Atomic Energy" by Slade; Windspeeds (u) as shown and no deposition assumed.

**Extrapolated from referenced figure.

$$D_n = V_d \cdot \chi_n (A_n - A_{n-1}) \qquad (27)$$

D_n = Relative amount of material deposited in area n

V_d = Deposition velocity for material (m/s)

χ_n = Average dilution factor in area n (s/m^3)

A_n = Area encircled by isodose curve for (m^2)

The deposition velocities are included in the nuclide data library of the code.

Since the values are directly proportional to the source strength, a new source strength can be calculated by subtracting the material deposited. When this is done iteratively starting from the area closest to the point of release continuing outwards the airborne concentration and ground contamination levels can be calculated for each annular area.

The code checks that the amount of deposited material does not exceed the source. Note that the largest area which can be used is 10^9 square meters.

2.2.4 Dosimetric Model

Several pathways are possible for the radiological impact on man from an accident. The pathways calculated in INTERTRAN are:

Internal pathways:

- Inhalation of aerosolized material
- Inhalation of resuspended material

External pathways:

- Exposure from ground contamination
- Direct exposure from unshielded material

Ingestion is not included in this version of the code. The release of radioactive materials to the biosphere can give a radiological exposure through the food chain, but is difficult to evaluate reliably in a generic model. Administrative measures can reduce the potential exposure.

The inhalation dose is calculated for a number of organs using dose rate factors from the INREM II code /2-5/. In the case of early effects the dose rate factors for one-year exposure of lung and marrow are used. When calculating the latent effects the dose factors for 50-year exposure to lung, marrow, bone, thyroid, gonads and gastrointestinal tract are used.

The code also calculates the weighted whole body dose using the effective dose equivalent as defined by the ICRP /2-6/.

The dose from direct exposure is calculated using the average photon energy per disintegration for the transported nuclide. The dose rate factor, DR, is calculated as:

$$DR = \Gamma \cdot E \qquad (28)$$

E = average photon energy per disintegration (MeV)

Γ = gamma constant = 0.5

The gamma constant 0.5 is valid for the photon energies of the nuclides transported.

Included in the code is a Nuclide Data Library where the dose rate factors and photon energies for 80 nuclides are given. These data will be retrieved during the calculations. A listing of the Nuclide Data Library is given in Appendix C. The user also has an option to insert other nuclides if desired.

2.2.5 Radiological Impact Due to Accidents

The INTERTRAN code calculates the impact from vehicle and handling accidents. For the analyzed shipment the code calculates the consequences of an accident of every accident severity category in each population zone. The annual expected impact of these accidents are also calculated. The risk of an accident is given by the consequences multiplied by the annual expected number of accidents.

The radioactive materials transported are divided into two types, non-dispersable materials (Material Category 1) and dispersable materials (Material Category 2 - 11). The dose calculations for the two types of materials are different.

2.2.5.1 Dose from Inhalation of Dispersable Materials

For the estimation of the early effects of an accident, the individual dose in each isodose area is calculated. The individual organ in an isodose area are given by:

$$D_{ijklno} = CI_j \cdot PPS_j \cdot RF_{ik} \cdot AER_{il} \cdot \qquad (29)$$

$$RESP_{il} \cdot RPC_{jo} \cdot DF_n \cdot BR$$

D = Individual dose (rem)
CI = Activity per package (Ci)
PPS = Number of packages per shipment
RF = Package failure fraction
AER = Fraction of material which becomes aerosolized
RESP = Fraction of aerosolized material of respirable size
RPC = Inhalation dose factor (rem/Ci)
DF = Dilution factor (sec/m^3)
BR = Breathing rate (m^3/sec)
i = Index over accident severity categories
j = Index over materials
k = Index over package types
l = Index over material dispersivity categories
n = Index over isodose areas
o = Index over organs

The breathing rate is set to $3.3 \cdot 10^{-4}$ m^3/s.

Equation (29) is used to calculate the dose to individuals in the rural and suburban zone and to pedestrians in the urban zone. The dose to people inside buildings in the urban zone will be reduced by filtration through the building ventilation system and by deposition on floors, walls and ceilings. The protective effect of buildings is considered by introducing the Building Dose Factor which describes the ratio dose inside a building to the dose outside. The Building Dose Factor is given as input data, see Chapter 3.

The dose to individual in city buildings is given by

$$D_b = D \cdot BDF \tag{30}$$

D_b = Individual dose in buildings
D = Individual dose from Equation (29)
BDF = Building Dose Factor

The population dose from an accident is used for the calculation of the latent effects. In this case an integrated dilution factor is used, given by:

$$IF = \sum_{n=2}^{N} \sqrt{\chi_n \cdot \chi_{n-1}} \, (A_n - A_{n-1}) \tag{31}$$

IF = integrated dilution factor (sec/m/ci)
χ_n = dilution factor for area n ($sec/m^3/ci$)
A_n = area encircled by isodose curve for χ_n (m^2)

The population dose to a specific organ is given by :

$$D_{ijklop} = CI_j \cdot PPS_j \cdot RF_{jk} \cdot AER_{ik} \cdot RESP_{jo} \cdot IF \cdot PD_p \cdot BR \tag{32}$$

D_o = population dose to organ o
PD_p = population density in zone p

In the urban population density zone the dose to persons inside buildings is reduced with the Building Dose Factor.

When calculating the population dose, the dose received from inhalation of resuspended particles must be considered. This is done with the resuspension dose factor, which multiplied by the inhalation dose will give the total dose from inhalation and resuspension,

$$D_{tot} = D_{inh} \cdot RDF \tag{33}$$

D_{tot} = total population dose
D_{inh} = population dose from inhalation
RDF = resuspension dose factor

The resuspension dose factor is given by:

$$RDF = 1 + V_d \cdot K_R \tag{34}$$

V_d = deposition velocity (m/s)
K_R = integrated resuspension factor (s/m)

K_R relates the amount of material deposited on the ground to a time-integrated airborne concentration of resuspended material. In the WASH-1400 study /2-8/ a formula for K_R is suggested:

$$K_R = \int_0^t \left(10^{-5} e^{\frac{\ln 2 \cdot t}{RT_{1/2}}} + 10^{-9}\right) \cdot \left(e^{\frac{\ln 2}{t_{1/2}}} \right) (8.64 \cdot 10^4) \, dt \tag{35}$$

$RT_{1/2}$ = resuspension halflife (days)
86 400 = seconds per day
$t_{1/2}$ = nuclide halflife (days)

When Equation is integrated over the 50 year (18 250 days) used for the calculation population dose the form for RDF will be

$$RDF = 1 + V_d \left(\frac{10^{-5}}{\lambda_1} (1 - e^{-18250 \lambda_1}) + \frac{10^{-9}}{\lambda_2} (1 - e^{-18250 \lambda_2}) \right) \tag{36}$$

$$\lambda_1 = \frac{\ln 2}{RT_{1/2}} + \frac{\ln 2}{t_{1/2}}$$

$$\lambda_2 = \frac{\ln 2}{t_{1/2}}$$

2.2.5.2 Dose from Groundshine

The radioactive material deposited on the ground will give a direct exposure to persons in the area. In order to simplify the calculation of the dose rate above the contaminated surface the assumption is made that each nuclear decay, single or cascade, behaves as it were a single photon decay. In this case the dose rate one meter above an ideal infinite plane source will be:

$$DR = Q \cdot CLVL \cdot E_d \qquad (37)$$

DR = dose rate (rem/day)
CLVL= contamination level (Ci/m^2)
E_d = total photon energy per disintegration (MeV)
Q = $3.04 \cdot 10^{-4}$ ($rem \cdot m^2/day/Ci/MeV$)

The INTERTRAN model uses a dose rate formula from the WASH-1400 report /2-8/ which takes soil uprate, radioactive decay and wind dispersion into account. The dose rate is given by:

$$DR(t) = Q \cdot CLVL \cdot E \quad 0.63e^{-0.0031t} + 0.37e^{-.000021t} \cdot e^{\frac{\ln 2t}{t_{1/2}}} \qquad (38)$$

The first exponential term in the expression describes the physical removal due to weathering resuspension and the second the loss due to radioactive decay.

If an accident causing ground contamination should occur it is assumed that action will be taken for decontamination of the area to a level decided by the authorities. This level is called criterion clean-up level and is input data to the code.

The dose from groundshine is calculated by assuming that the population the first 24 hours are exposed to a radiation corresponding to the contamination from the accident. These 24 hours are followed of a period of ten days during which the population is evacuated and no dose is received. If the contamination level is greater than the criterion clean-up level the ground is assumed to be decontaminated to the criterion clean-up level. This level of contamination is then used for calculating the population dose during the following 50 years. Otherwise the contamination level is used to calculate the population dose.

Thus, the integrated population exposure from groundshine in each isodose area is given by:

$$D_n = Q_7 \cdot CULVL \cdot E_d \cdot PD \cdot A_n \cdot$$

$$\left[DECON_n \left[\frac{.63}{0.0031+\lambda} \left(1 - e^{-(0.000021+\lambda)}\right) + \right. \right.$$

$$\left. + \frac{0.37}{0.000021+\lambda} \left(1 - e^{-(0.000021+\lambda)}\right) \right] +$$

$$+ \left[\frac{0.63}{0.0031+\lambda} \left(e^{-(0.0031+\lambda)10}\right) + \right. \quad (39)$$

$$\left. \left. + \frac{0.37}{0.000021+\lambda} \left(e^{-(0.000021+\lambda)10} - e^{-(0.000021+\lambda)18250}\right) \right] \right]$$

$$\lambda = \frac{\ln 2}{t1/2}$$

DECON = the ratio between the contamination level and the criterion clean-up level.

CULVL = criterion clean-up level

If the contamination level is less than the criterion clean-up level the term integrated from 10 days to 50 years is multiplied with DECON.

2.2.5.3 Dose from Accidents with Non-dispersable Materials

Accidents involving non-dispersable materials can cause radiological impact because of reduction of the package shielding capability. A damaged package can give a significant external exposure. The dose rate is given by:

$$DR(r) = CI \cdot PPS \cdot RF \frac{\Gamma \cdot E_d e^{-\mu r} \cdot B(r)}{r^2} \tag{40}$$

DR(r) = dose rate at distance r (rem/h)
CI = activity of package (Ci)
E_d = photon energy (MeV)
μ = attenuation coefficient (m^{-1})
Γ = gamma constant
B(r) = build-up factor

The assumption is made that $e^{-r} \cdot B(r) = 1.0$.
The dose received by an individual will be:

$$DR(r) = CI \cdot PPS \cdot RF \frac{\Gamma \cdot E_d}{r^2} \cdot T \tag{41}$$

D(r) = dose at distance (rem)
T = exposure time (h)

The exposure time is assumed to be 1 hour in the rural and suburban zone. In the urban zone it is assumed that the persons inside buildings are shielded against external penetrating radiation with the urban shielding factor R_u.

The dose to pedestrians is calculated with an assumed exposure time of 15 minutes.

The dose in each area is calculated at a number of specified radial distances from the accident site. Those distances can be chosen by the user and need not be the same for the three population zones.

The population dose from accident with non-dispersable materials is calculated by integrating the dose rate in Equation (41) over the exposed area. In the suburban zone this area is an annulus of a circle and the population dose is given by:

$$D_{r,s,p} = Q_6 \cdot CI_j \cdot PPS_j \cdot RF_{i,k} \cdot PD_{u,r} \cdot T_{u,r} \cdot \Gamma \cdot E_d \cdot \int_{d_{min}}^{d_{max}} \frac{2\pi r}{r^2}\, dr \qquad (42)$$

D_{rs} = population dose in rural and suburban areas (person rem)

PD = population density in rural or suburban zone persons/km^2

T_p = exposure time in rural or suburban zone (h)

d_{max}= maximum exposure distance (m)

d_{min}= minimum exposure distance (m)

Q_6 = unit conversion factor = (10^{-6} km^2/m^2)

In the urban zone the dose is given by:

$$D_u = Q_6 \cdot CI \cdot PPS \cdot RF \cdot PD \cdot R_s \cdot T \int_{d_{min}}^{d_{max}} \frac{\Gamma\, E_d}{r^2}\, dr \qquad (43)$$

In the urban zone the dose to pedestrians is calculated over the sidewalk segments exposed from an intersection accident site. The dose is given by:

$$D_{up} = Q_6 \cdot CI_j \cdot PPS_j \cdot RF_{i,k} \cdot RPD \cdot PD_u \cdot T_u \;\Gamma\; E_d \int_{d_{min}}^{d_{max}} \frac{8\, W_s}{r^2}\, dr \qquad (44)$$

D_{up} = pedestrian dose in urban zone (person rem)

PD_u = population density in urban zone (persons/km^2)

T_u = exposure time in urban zone (h)

W_s = sidewalk width (m)

r = distance from accident site (m)

RPD = ratio pedestrian density over-all population density

In an intersection accident eight sidewalk sections will be exposed, one on each side of the four joining streets.

The sidewalk width is assumed to be 3 meters and the factor of 8 is the number of sidewalk segments exposed.

When these integrals are evaluated the result will be:

$$D_{r,s} = 2 \cdot Q_6 \cdot CI \cdot PPS \cdot RF \cdot PD \cdot T \cdot \Gamma \; E_d \cdot \ln\left(\frac{d_{max}}{d_{min}}\right) \quad (45)$$

$$D_u = 12 \cdot Q_6 \cdot CI \cdot PPS \cdot RF \cdot PD \cdot RPD \cdot T \cdot \Gamma \cdot E_d \left(\frac{1}{d_{min}} - \frac{1}{d_{max}}\right) \quad (46)$$

The exposure times are the same as in the individual dose calculations 1 hour for the rural and suburban zones and 15 minutes for the urban zone.

2.2.6 Health Effects Model

The results from the dose calculations described in section 2.2.5 are used for assessment of potential health effects. The health effects analyzed are:

Early effects
- Early fatalities
- Early morbidities

Latent effects
- Latent cancer fatalities
- Genetic effects

The early effects are calculated with the individual doses and the latent effects with the population doses.

The health effects model used is based on that developed in the Reactor Safety Study /2-8/.

2.2.6.1 Early Fatalities

In the case of dispersable materials the one-year lung dose is used to calculate the probability of an early fatality for an individual. Four different dose-effect relationships can be used, depending on the halflife and the linear energy transfer (LET) of the nuclide.

The different dose-effect relationships are shown in Figure 2.5 and Table 2.4 lists how they are chosen.

Table 2.4 Dose-effect Relationships for Lung Exposure

Dose-effect relationship	Half-life	Nuclide data Linear energy transfer
Lung type 1	short	low
Lung type 2	short	high
Lung type 3	long	low
Lung type 4	long	high

The lung types for the nuclides are included in the nuclide data bank.

For each isodose area the lung dose is compared with values in a dose-effect table and the probability of an early fatality is received. This probability is multiplied by the expected number of persons in that isodose area to get the expected number of early fatalities.

In the case of non-dispersable materials the individual one-year marrow dose is used. The dose at a specific distance r_n is compared with values in a dose-effect table for the probability for early fatalities from bone marrow exposure. The dose-response curve is illustrated in Figure

2.6. In the rural and suburban zone the people receiving the dose are assumed to be within an annulus of a circle with an inner radius of r_n and an outer radius of r_{n+1}. In the urban zone are the assumptions with eight sidewalk segments exposed previously described in section 2.2.5.3 used.

For both material types are the total number of expected early fatalities given by:

$$EF = \sum_n PD \cdot A_n \cdot PI_n \tag{47}$$

PD = population density (persons/km^2)

A_n = area (km^2)

PI_n = individual probability of early fatality

2.2.6.2 Early Morbidities

The expected number of early morbidities is calculated in a similar way. In this case the individual organ dose is compared with a threshold value. If the dose exceeds this threshold value the probability of an early morbidity is set to 1, otherwise the probability is 0. The expected number of early morbidites is calculated by multiplying the probability by the number of exposed persons. The method for this is identical to that used for early fatalities.

The organs for which early morbidities are calculated, the threshold values and their physiological effect are given in Table 2.5.

Table 2.5 Early Morbidity Threshold Values

Organ	Morbidity Dose Threshold (rem)	Physiological Effect
Lung	3000	Radiation Pneumoniti
Total Body/Bone Marrow	75	Acute Radiation Syndrome
GI Tract	1000	Stem-Cell Loss
Gonads	50	Temporary Sterility (Males)
Thyroid	10000	Early Thyroid Disturbance

2.2.6.3 Latent Cancer Effects and Genetic Effects

The probability of cancer developing later in life for an exposed person is assumed to be proportional to the dose.

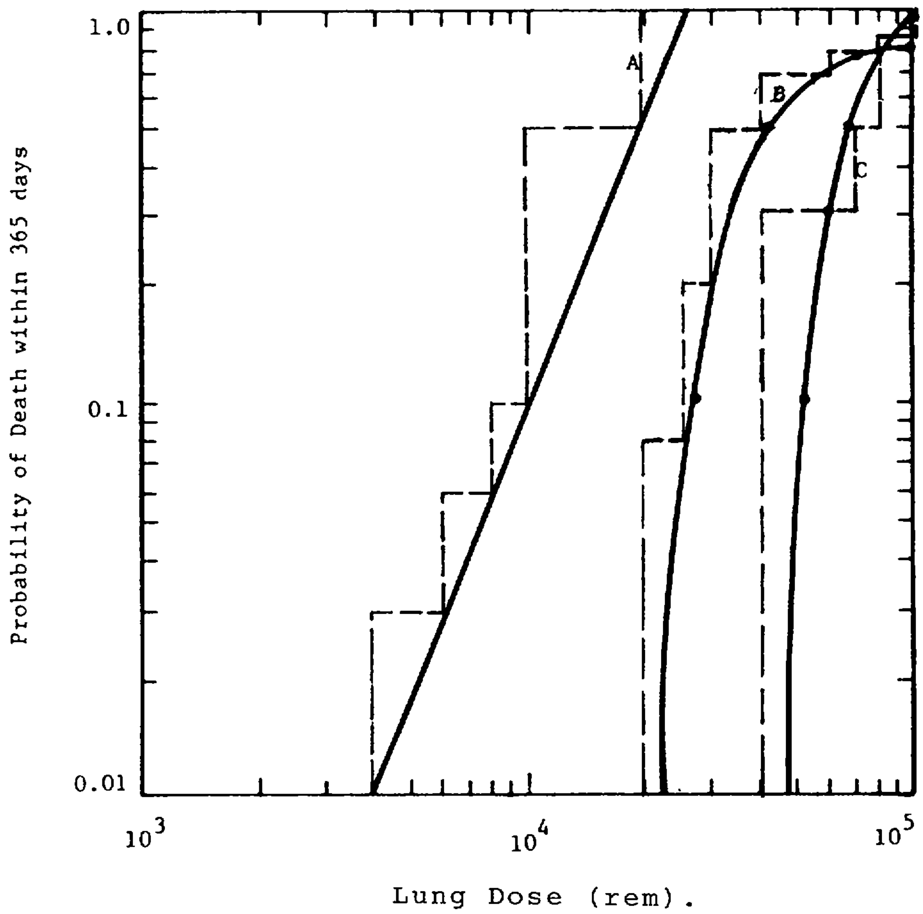


FIGURE 2.5. Dose-Response Curves for Mortality Due to Acute Pulmonary Effects of Radiation.

A. Yttrium-90 and -91 were the isotopes used to obtain this curve. It is equally valid for other short half-life beta of gamma emitting isotopes which result in approximately the same dose rate. This curve is used for all short half-life materials potentially encountered in transportation accidents.

B. This curve is based on data using Sr-90/Y-90 inhalation by beagles, and is used for long half-life, low-LET[x] radiation.

C. This curve is based on data from Pu-239 inhalation by beagles, and is used for long half-life, High-LET[x] radiation.

x) LET (Linear Energy Transport) is a measure of the energy deposited per unit distance traveled in a particular medium. High LET radiation includes α-particles and fast neutrons; low LET radiation includes X-rays, γ-rays, and β-particles.

From Reference (2-7, 2-8)

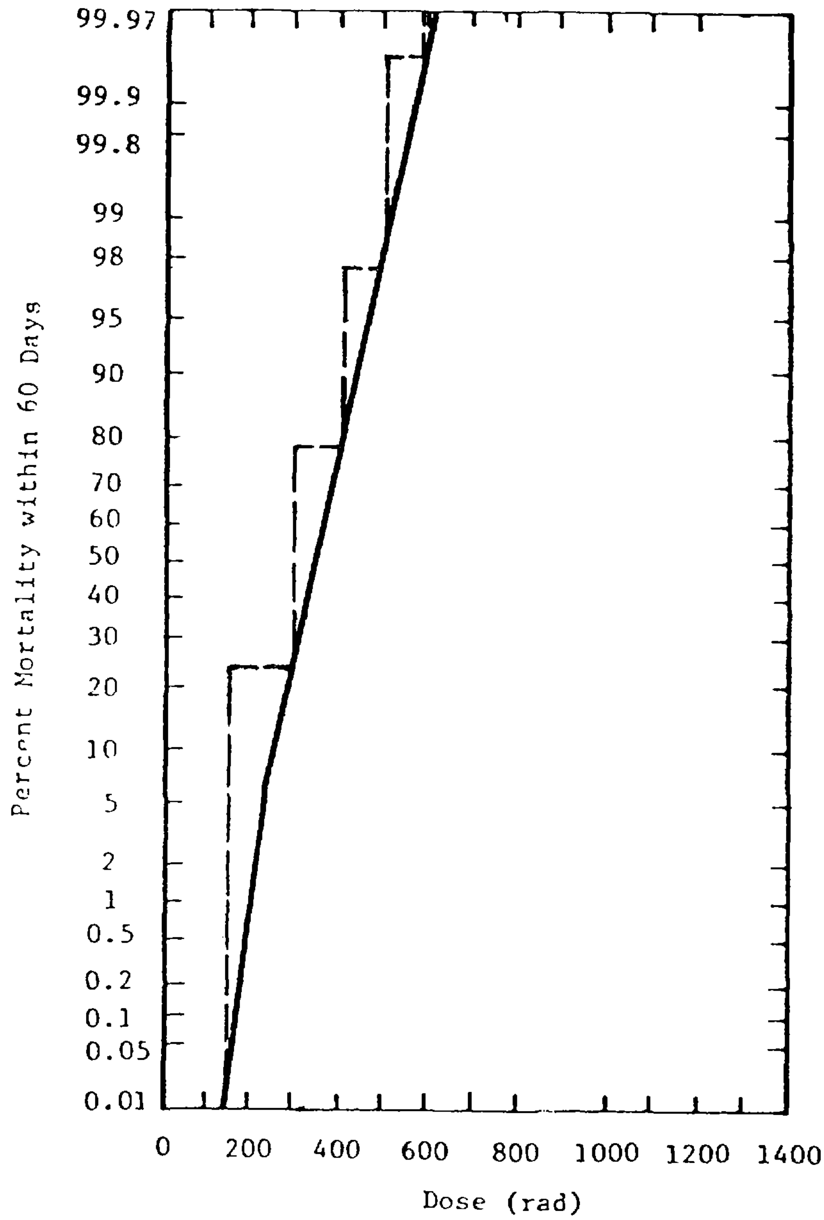


FIGURE 2.6 Dose-Response Curve for Mortality Due to Acute Bone Marrow Irradiation.

The percentage of mortality within 60 days of irradiation is plotted for doses requiring minimal treatment.

The broken line are the values used in subrontine SPFIT. From Reference /2-7, 2-8/

Thus, the expected number of latent cancer effects in the exposed population can be calculated as the product of the population dose and the chronic effect risk factor. The risk factors used in INTERTRAN are shown in Table 2.6 and are taken from ICRP/2-6/.

In the case with non-dispersable materials the whole body risk factor is used giving the expected number of latent fatalities by:

$$LCF_{wb} = K_{wb} \cdot D_{wb} \tag{48}$$

LCF_{wb} = expected number of latent fatalities
K_{wb} = whole body risk factor
D_{wb} = whole body dose

Dispersable materials which are inhaled will give a non-uniform irradiation of the body organs. The total risk will be calculated as the sum of the risk to the individual organs most sensitive to radiation. The organs are lung, marrow, bone, thyroid and the gastrointestinal tract. In this case the expected number of latent cancer effects will be given by:

$$LCF = \sum_{o=1}^{5} K_o \cdot D_o \tag{49}$$

K_o = chronic effect risk factor for organ o
D_o = population dose to organ o

Exposures of the gonads can induce gene mutations and chromosonal changes which can lead to hereditary defects. When assessing the total population detriment the risk factor of $80 \cdot 10^{-6}$ per rem for genetic effects in all subsequent generations is used.

$$GE = K_g \cdot D_g \tag{50}$$

GE = expected number of genetic effects
K_g = genetic effect risk factor (person rem^{-1})
D_g = population dose to gonads (person rem)

Table 2.6 Expected Chronic Effects per Million Person-Rem of Exposure /2-6/

Exposed Organ	Expected Effects per 10^6 Person-Rem
Bone Marrow (leukemia)	20 latent cancer fatalities
Lung	20 " " "
Alimentary Canal	5 " " "
Bone	5 " " "
Whole Body	125 " " "
Thyroid	5 " " "
Gonads	80 genetic effects

2.2.6.4 Weighted Whole-Body Dose

To enable the user to get a more detailed analysis of the population dose the weighted whole-body dose is calculated using the effective dose equivalent as defined by ICRP /2-6/. The user can specify two dose levels and the number of persons receiving a dose exceeding these levels will be printed for each accident severity category. These calculations are made basically the same way as the calculations of early morbidities.

2.2.7 Risk Calculations

The annual expected number of accidents of each accident severity category in each population zone is calculated for each material by:

$$APY_{ijmp} = SPY_{jm} \cdot FKMPS_{jm} \cdot APM_m \cdot SEVFRC_{im} \cdot ACCRSK_{imp} \qquad (51)$$

APY = the expected number of accidents per year
SPY = number of shipments per year
FKMPS = distance per shipment (kilometer)
APM = over-all accident rate (accident/vehicle-kilometer)
SEVFRC= fractional occurence of accident severities
ACCRSK= accident risk factor

i = index over accident severities

j = index over materials

m = index over transport situations

p = index over population zones

The accident risk factor is the ratio between the rate for an accident of a specific severity in a population zone and the average accident rate for that specific severity.

The expected number of accidents per year of each severity category is multiplied by the expected number of effects and summed up for each of the standard shipments. The annual expected number of effects is the given by:

$$EPYR = \sum_{m} \sum_{p} \sum_{i} APY_{i,j,m,p} \cdot EXPE_{i,j,p} \qquad (52)$$

EPYR = annual expected number of effects, early or latent

APY = annual expected number of accidents

EXPE = expected number of effects per accident, early or latent

The annual expected number of effects is printed out for each standard shipment, see Chapter 4.

In addition to this, the accident rates and the effects for each material is written on a file. The data on this file can be used to calculate the cumulative probability distribution for the different types of effects.

2.2.8 Handling Accident Calculations

The INTERTRAN code calculates the impacts caused by handling accidents. The handling accidents are assumed to occur in an area with a population density that corresponds to the suburban area. The dose received from a handling accident of a specific severity category is assumed to be the same as the dose received from a vehicular accident of the same severity category in the suburban population zone.

The expected number of handling accidents is given by:

$$HNDAPY_i = NH_m \cdot HNDACC_m \cdot HNDSEV_{jk} \qquad (53)$$

HNDAPY = expected number of accidents of severity i

NH_m = number of handlings for mode m

$HNDACC_k$ = handling accident rate for package type K

$HNDSEV_{i,k}$ = fractional occurence of accident severity i for package type k

2.2.9 Criticality

In the international regulations /2-9/ it is stated that "All fissile materials shall be packed and shipped in such a manner that criticality cannot be reached under any foreseeable circumstances of transport. In particular, the following contiugencies shall be considered:

a) Water leakage into or out of packages;

b) the loss of efficiency of built-in neutron absorbers or moderators;

c) possible rearrangement of contents into more reactive arrays, either within the package or as a result of loss from the package;

d) reduction of spaces between packages or contents;

e) packages becoming immersed in water or buried in snow;

f) possible increase of reactivity due to temperature changes".

In addition the regulations state assumptions that shall be made for irradiated fuel or unspecified fissile materials.

Due to this very strong safety requirements to avoid criticality under any forseeable circumstance, the probability for this scenario can be neglected and criticality has therefor not been taken into account in the analysis.

3. DESCRIPTION OF THE INPUT PARAMETERS

In this section the different input parameters will be defined and methods to acquire the data will be described. In the case where default data are available they will be presented and the references will be given. At the end of this section a number of tables filled out with the default data are included. An empty version that can be filled out using the user's own data is also given. Some of the data discussed in this section will be used for both accident dose and incident free dose calculations while other data will be used only in connection with the incident free dose calculations.

3.1 Transport Situation Data

A transport situation is a transport vehicle which travels on a defined route or in a specific environment, e.g. a train travelling between two specific locations or a van travelling in a city area.

The INTERTRAN code can handle up to 10 different transport situations which can be one of any four different transport mode types, road, air, rail or water. The default transport situations are given at the top of table 3.1.

TRUCK refers to a vehicle used for shipment of for example yellow-cake or uranium hexafluoride.

PVAN refers to a small passenger car used for distribution of radiopharmaceuticals or small packages of radionuclides.

PASS AIR is an aircraft also used for passenger transportation

CARGO AIR is an aircraft exclusively used for cargo transportation.

RAIL is a railcar in a train set.

SHIP-1 refers to a larger vessel travelling on longer routes.

SHIP-2 refers to a smaller vessel travelling in coastal traffic

TRUCK-2 is a heavy vehicle used for transport of spent fuel.

CVAN-1 and CVAN-2 are two types of delivery vans which can be used as secondary transport situations. The default data are the same for the two types of vehicle.

For each of the default transport situations a set of default transport situation data is prepared. The user can, if desired, either change only the default transport situation data or introduce new transport situations. In case of chosing a transport situation that is not default the transport situation data may have to be changed to correspond to the new transport situation. Single figures may also be changed to correspond to the user's situation.

The transport situation default data is presented in table 3.1-3.3.

For each transport situation and population density zone a fraction of travel and average velocity in km/hour shall be listed. The three population density zones are defined in Appendix D.

The fraction of travel means the fraction of the total distance per shipment that an average transport passes through a certain population density zone. This data can be obtained by studying population density maps for specific transport routes. It is an advantage if the maps are rather detailed since especially landtransports tend to pass in the vicinity of densely populated areas.

The default data presented in table 3.1 are estimations made for an urbanized country based on population density maps.

The fractions of travel in the different population zones are used for both the calculations of the accident dose and the incident free dose.

The velocity is the average velocity of that transport situation inside the population zone. The default values are assumptions based on traffic speed limits inside and outside built-up areas. The air and ship data are taken from international statistics. Note that the velocity shall be given in km/hour but will be recomputed to meters/second in the code.

<u>Dose to crew</u>

Calculations of the dose from incident free shipments to the shipment crew are governed by the following parameters.

- Number of crew
- Average distance from radioactive package to crew

The default values for the number of crew is based on experience.

The average distance from the source to the crew on trucks and vans can easily be estimated. For ships, barges and trains where the crew is not stationary in one part of the vehicle, and the shielding from the vehicle is not negligable, these factors have to be taken into account when determining the average distance.

<u>Dose to handlers</u>

A handling is defined as the entire process of moving a package from one location to another, regardless of the number of physical movements. The dose will depend of the number of handlings per shipment.

The default values for the number of handlings on the primary modes i.e. truck, air, rail and ship are set to two and for the secondary modes i.e. passenger van and cargo van the number of handlings are set to one.

Dose to Population During Shipment Stops

If the transport vehicle stops for crew change, passenger transfer, meals, refueling etc., people in an area around the vehicle are exposed. The population dose is governed by the following parameters:

- Total stop time per 24 hours trip (in hours)
- Number of people exposed
- Average distance to population (in meters)

The transport vehicle stop time is assumed to be proportional to the shipment time. However, the minimal stop time for an individual shipment is set in the code to 30 minutes.

As input the user will give for each transport situation the stop-time for a 24-hour trip.

As default values for the stop-time the assumption of eight hours stop time per 24-hour trip is used for all transport situations.

Number of persons exposed at stops and their average exposure distance are values which can be determined for an average stop.

The default values are determined considering a stop at a gas station for the road modes, a stop on a siding for the rail mode, a stop in a harbour for the water modes and a stop at an air terminal for the air modes.

Dose to Warehouse Personel while Package is in Storage

The dose to warehouse personel is computed the same way as the dose to population during shipment stops. The dose is determined by:

- The total storage time per shipment (in hours)
- The number of persons exposed
- The average distance to exposed persons (in meters)

Number of People per Vehicle

For the road and rail modes the number of persons per vehicle is used to calculate the dose to persons sharing the transport link, i.e. the average number of persons in vehicles on the transport link. For the passenger-air transport mode the average number of passengers should be given. The number of flight attendants are given as a separate variable.

The number of persons per vehicle should be zero for cargo air mode and the water modes.

The default value for the average number of persons in road vehicles is taken from international transportation statistics. The number of air passengers is taken from IATA statistics.

The following fractions are used when calculating the normal dose for the road modes:

- Fraction of travel in rush-hour traffic
- Fraction of travel on city streets
- Fraction of travel on free ways

Fraction of Travel in Rush-Hour Traffic

For the road modes this is the fraction of the urban zone shipment path which will occur during rush-hour traffic. Rush-hour traffic is when the amount of traffic is at least twice the normal. The rush-hour factor is used when calculating the dose to persons sharing the transport link. The default values are based on assumption made from traffic counts on urban streets in Stockholm. These fractions will of course vary with the time of the day the shipment takes place.

Fraction of Travel on City Streets

This is the fraction of travel in the urban zone which occurs on streets with adjacent buildings. The fraction of city street travel is used when calculating the dose to persons in the vicinity of the transport link and the dose to persons sharing the transport link.

Fraction of Travel on Freeways

The fraction of travel on freeways is used for all population zones in the calculation of dose to persons sharing the transport link.

The traffic count is defined as the average number of vehicles per hour in one direction. The traffic count should also be given for the rail modes.

The default values are characteristic values for the different transport situations.

The user shall also specify the average number of flight attendants on a passenger aircraft.

The user is given the possibility to choose if the maximum dose rate limit of 2 mrem/hr shall be used for all crews or only for crews on exclusive-use vehicles. The 2 mrem limit is used on all vehicles as default value

3.2 Accident Data

Vehicular Accidents

As described in section 2.2.7 the expected accident rate of a specific accident category in a specified population zone is given by three parameters.

- Overall accident rate for each mode per traveled kilo meter.

- Fractional occurrence of the accident severities for each mode.

- Accident risk factors, i.e. the ratio between the rate for an accident of a specific severity in a population zone and the average accident rate for that specific severity.

A standard set of accident data is included in the code. The data used is presented in tables 3.4-3.8.

The standard data sets have been designed to correspond to data from a fairly developed country.

The over-all accident rates have been derived from international transportation statistics /3.1-3.5/.

The fractional occurence of accident severities for the road-, rail- and air-modes is taken from SAND-74-0001/3-6/, SAND-77-0001/3-7/ and SAND-76-0708/3-8/. The report SAND-77-0001 was written to quantify the accidents environments of a large package but the impact environment is calculated for the vehicle i.e. truck or railroad car. To be able to calculate the package response the package type, packing configuration, the tie-down procedure must be known.

One of the reasons of chosing the SAND-77-0001 report was that the division of mechanical severity ccording to the velocity change of the vehicle which occurs in an accident is more understandable and makes it easier for member states to use their own accident statistics. Of course the impact and the dynamic crush on the package has to be estimated.

The actual impact on the package will depend on the vehicle walls and the mass of the package. According to SAND-74-0001 the impact on a light package will be considerably less than the velocity change of the vehicle. The full scale crash tests of truck-trailer-cask systems reported in SAND-77-0270/3.9/ indicates a velocity ratio impact velocity yielding surface to impact velocity unyielding surface >2.8.

In an analytical study made by Romander and Colton /3-10/ a comparison between the deflection produced on various packages by a 9 meter drop on an unyielding surface and the deflection produced by impact on softer surfaces.

For packages hardening when chrushed the 9 meter drop test protection level is equivalent to a 60 mph impact into a concrete wall. For softening packages the 9 meter test provides protection equivalent to a 40 mph impact into a soften target.

Romander and Colton also tries to determine the current level of protection against crush. A barrier package model with four identical packages was used. The crush deflection was within 20% of the deflection caused by a 9 meter drop for hardening packages. The impact velocity can be as great as 40 mph for slightly softening packags. The presence of gaps between packages was found to reduce the deflection on soft packages.

The new proposals on crush test of certain typ B packages will also set a level of protection to soft light-weight type B packages.

The velocity limit chosen for a type B limit is 50 mph (80 km/h) considering that most type B packages are of the hardening type. For extreme softening packags the package failure fractions can be adjusted to consider their sensitivity to crush.

Type A packages are considered to be less rigid so the velocity limit is set to 10 mph (16 km/h) equivalent to the 1.2 meter drop.

These limits can be considered conservative for crush and impact.

As a limit between category III and IV the velocity change of 70 mph (112 km/h) is chosen.

For the fire environment the limits are 0, 30 and 60 minutes of 1300 K fire.

The categorization of the ship accidents is more difficult than for the other modes. The mechanical damage will mainly consist of the crush forces arising from the penetration of the bow of a colliding ship. The impact on a radioactive material shipment will depend heavily on the tie-down procedure and the structure of the surrounding cargo.

To be able to calculate the severity fractions a more general method has been used.

In ship accident statistics the accidents are often divided into the categories: strandings and founderings, fire, collisions and other casualities. In this analysis it has been assumed that only the collision accidents will produce a mechanical environment more severe than category I. About a quarter of all ship accidents are collision accidents.

According to reference /3-11/ 10% of the accident collisions are relatively serious and about 1% will lead to a total loss of the ship.

It has been assumed that one hold of the ship is filled with RAM and that the probability of crush given a collision is 0.034 a figure derived from reference /3-12/.

The probability of a fire is 0.058 also taken from reference /3-12/. The distribution of the severity of the fire has been made using data from (IMCO).

The vehicular accident parameters can also be given as input data and are filled out the same way as in the tables.

Handling Accidents

The expected handling accident rate is given by:

- Overall accident rate per handling for each package type

- Fractionel occurrence of the accident severities for each package type.

The handling accident severity categories are defined to give the same package response as the vehicular accident severity categories, but in the handling case only the mechanical environment is considered.

The default values given in table 3.9 for the overall handling accident rate are based on United States incident statistics /3-13/. The total number of packages handled is derived from reference /3-14/.

3.3 Package Data

The INTERTRAN code can handle ten different package types. Each package type is given a package label and a typical package dimension.

The typical package dimension is defined as the diameter of a sphere with a volume that equals the volume of the package. For large packages such as casks it is the largest physical dimension, usually the length.

The typical package dimension is used in the incident-free dose calculations.

The default package types presented in Table 3.10 are chosen to cover the most common package types. Only if the package dimension differ substantially from the default data a change of the default package types is necessary.

Each package type is assigned a package failure fraction for each accident severity category. The package failure fraction describes the relative degree of damage caused by an accident to the packages of a shipment. A package with no loss of packaging integrity but not necessarily undamaged is assigned a package failure fraction of 0 and a package which has lost all its packaging integrity is assigned a package failure fraction of 1.

The default values have been specified with the IAEA requirements as a basis. The package failure fraction for a type A package is assumed to be 0 for the accident environments less that the type A package requirements. For more severe environments the package failure fraction will increase gradually. Since it is not realistic to assume that the packages will lose all its integrity when the regulated limits are exceeded. The package failure fractions for type B packages and casks are made on the same principle. For packages classified as Exempt the assumtion is made that a package will fail completely in 10% of the category I accidents and in 100% of the more severe accident categories. The default package failure fractions are presented in table 3.8.

The limited amount of data available calls for a great degree of conservatism when deciding the package failure fraction. But users who have data on package failure can of course change the default values.

3.4 Population Density Data

The code can adress three different population density zones called urban, suburban, and rural. The definition of these zones and some advise for calculating population densities are given in Appendix D.

The default values given in Table 3.11 are included for use in simple testruns and parametric studies. The actual population densities can be found relatively easy and shall be used for risk assessments.

Pedestrian Density Ratio

The pedestrian population density ratio is defined as the ratio between the pedestrian population density and the overall population density in a specific zone.

Shielding Factors

The shielding factors describe the shielding effect of buildings in the urban and suburban zone. A further description of the shielding factors is given in Appendix E.

3.5 Material Data

The block data section of the code includes a nuclide data library with 80 different nuclides where the following parameters are given:

- half life (days)
- average photon energy per disintegration (MeV)
- dose factors (Rem/Ci)
- lung dose characteristics (see section 2.2.6.1)
- deposition velocity (m/s)

These data are shown in Appendix C. The nuclides are identified by the 5 character name they are given.

The user can replace the nuclide data library with other nuclides if found necessary.

The transported materials can be divided into eleven material dispersivity categories according to their chemical and physical properties. To each material dispersivity category an aerosolization factor is assigned for every accident severity category. The aerosolization factor describes the proportion of released material which is aerosolized and readily dispersed in an accident.

The scheme used to determine the material dispersibility category is shown in figure 2.3. The materials are first divided according to their state of aggregation and then according to their dispersibility. The dispersible solids are divided into compacted/sintered, loose or volatile materials. The loose materials are chunks or powders in large or small containers and the volatile materials are divided into materials which sublime or which carry-over. The liquids are separated into categories depending on package size. There is also a category for gases and one for extremely flammable materials.

Default values of the aerosolization factors are initiated in the code. These values can be changed with input data if found necesary. The default values are given in Table 3.12.

For non-dispersable materials the aerosolization of loose powder in small containers are taken from reference /3-15/. For the accident categories I to IV the values represent the airborne release of a freshly dispersed fine powder from a stainless steel surface with a wind speed of 8.9 m/s. The values for the fire accidents, categories V to VII are for a petroleum fire over a fine powder dispersed on a stainless steel surface with a wind speed of 1.1 m/s the aerosolization fractions have adjusted according to the fire duration. A combination of the values for fire and non-fire conditions are used for accident categories VIII and IX. For category X the value for fire involving contaminated material is used and for category XI a value of one tenth is used. The aerosolization factors for chunks and loose powder in large containers are assumed to be one tenth of the values for loose powder in small containers. For compacted and sintered materials the aerosolization factors are one hundredth of the values for loose powder in small containers for categories I to III, for the accidents involving fire a decomposing of the material is assumed and aerosolization factors for chunks is used. For the volatile materials the aerosolization factors are for uranium hexafluoride taken from reference /3-16/.

The aerosolization factors for liquid in small containers are estimated with data from reference /3-15/ using the same assumptions as for loose powder. The values for large containers are considered to be ten times lower.

Gaseous materials have an aerosolization factor of one for all accident categories.

For the flammable materials such as ion exchange resins in bitumen the values for compacted and sintered solids are used for accident categories I to IV and the aerosolization from accidents involving fire, Categories V to XI, are estimated using data from reference /3-17/.

Only the dispersed particles which have an aerodynamic diameter less than about 10 μm will be respirable. The fraction of the material which is respirable, RESP, is set to one for all material dispersibility categories.

3.6 Atmospheric Dispersion Data

Input data to the atmospheric dispersion model is a set of dilution factors and the corresponding set of areas encircled by their isodose curves.

If the set of areas are kept constant the dilution factors will vary as a function of the meterological stability conditions. To simplify for the user a default set of areas and six sets of dilution factors corresponding to the six Pasquill stability categories (A through F) are provided. The user specifies the frequency of each Pasquill stability category, the code checks that the frequencies add up to 1 and then calculates a frequency weighted set of dilution factors. The weighted set is later used in the actual calculations. The dilution factors are shown in Table 2.3 in section 2.2.3.

The dilution factors used are derived from Figure A-8 in reference /3-18/ by assuming a wind speed of 1 m/s for Pasquill stability categories A and F, 2 m/s for B, 3 m/s for C, 4 m/s for D and 2.5 m/s for E (see Luna, Church /3-

19/).As default values the code uses the Pasquill F category dilution factors.

The user can also input his own set of dilution factors and corresponding areas. The code can use up to 30 areas with corresponding dilution factors.

3.7 Regulatory Data

This section deals with data concerning regulatory limits having influence on the results.

As an input the user can give the criterion clean-up level (in $\mu Ci/m^2$) which is used when determining what is the maximum ground contamination level which will be accepted after a clean-up operation. The default value is $0.1 \mu Ci/m^2$.

The user can also specify the two dose limits for which the number of people receiving an weighted whole body dose higher than this limits is calculated.

The default values used are 0.1 rem and 5 rem which are the annual limits of exposure to general public and radiational workers respectively.

3.8 Standard Shipment Data

Due to the often large number of shipments it is necessary to combine and summarize the shipments to get a number that is comfortable to handle.

A standard shipment has been defined as an average shipment of a material on one special transport situation. No default data can be provided for the standard shipment data, but Table 3.14 gives an example of how standard shipments can be arranged and how the blank versions of the table can be filled out.

In Table 3.14 the first column, all materials that are shipped are listed. To make it possible to retrieve data from the Nuclide Data Library the first five characters of the material name should correspond with the five characters of the nuclide name in Nuclide Data Library. The remaining five characters (three characters in the IBM-version) can be used for identification. For example enriched UF_6 can be named U-F6E-HEX.

The shipments are combined so that a standard shipment consists of an average shipment of a material transported by a certain transport mode or a certain combination of two transport modes. For example, enriched UF_6 and depleted UF_6 have to be separated as two materials due to their different composition.

Sealed and unsealed radioactive sources are separated. In addition, when different shipment modes are used have to be looked at as different standard shipments. In the table the Co-60 shipments are used as an example. Here some Co-60 shipments go by truck only and some by ship and truck and are therefore counted as two different standard shipments.

This methodology of combining shipments into standard shipments is mainly due to the vast amount of shipments a country usually have. As the computer code is able to use 200 different standard shipments in one run a country who's shipments are within that number naturally may list all its shipments without using the standard shipment model. Of course it is also possible to list all shipments and if they are more than 200 make more than one run of the code. Listing all shipments individually gives also a more accurate result as the real values instead of averages can be used.

In the second column the package type which is used for different standard shipments, shall be listed. Note that if shipment of a material, due to different activity content and transportation index sometimes is transported in a type-A package and sometimes in a type B these have to be dealt with as different shipments.

In the column packages per shipment, the average number of packages per shipment is listed. Note that the number of packages per shipment might be different between the primary and secondary mode, for example this usually is the case in the combination ship-truck or rail-truck.

The transport index in the fourth column of Table 3.14 is by the same token the average transport index of the shipments that are grouped into the actual standard shipment.

Activity per package is listed in the fifth column. The activity per package is calculated as the average Ci-content of a standard shipment.

In the sixth column the material dispersivity categories shall be listed. The model allow eleven different categories described previously. A list of the most common materials and their corresponding dispersivity category is given in Figure 3.1.

Material	Dispersivity	No
Am-241	non-dispersible	1
Co-60	"	1
C-14	small liquid	9
Cs-137	non-dispersible	1
H-3	small liquid	9
I-131	" "	9
Ra-226	" "	9
Kr-85	gas	10
Pu-238	non-dispersible	1
Pu-239	small powder	4
Pu-239(lq)	small liquid	9
Spent fuel (fission pr)	volatile solid	7
Spent fuel (external)	non-dispersable	1
U_3O_8	large powder	3
UF_6 (depl)	volatile sublime	6
UF_6 (enriched)	volatile sublime	6
Xe-133	gas	10

Figure 3.1 Common Materials and Corresponding Dispersivity Category.

In the last part of Table 3.15 data for the shipment modes are listed. The very last part, secondary transport mode, is only used when a standard shipment uses two different transport modes and is otherwise left empty.

Transport mode lists as the name says the actual transport mode. Shipments per year is the total number of shipments of a material by one transport mode that occurs every year. Here the number of shipments per year are different for primary and secondary transport mode if the number of package per shipment is different.

Finally the average distance, in kilometer, for each standard shipment is given. When all this is done the activity per package times the package per shipment times shipments per year shall equals the total activity of a certain material that are shipped by a single mode within your country each year.

3.9 Computation Input Data

This section deals with the part of the input data which governs the actual computations. In block PARM the user can decide if he wants to analyze impact from incident-free transports, vehicular accidents, handling accidents or any combination of these. The user can also choose if he wants to do a sensitivity analysis. The results from the vehicular accidents can also be written on a separate file for plotting cumulative probability graphs with the program PPLOTT.

If necessary the user can also change the dimensions of a number of arrays in the code. The maximum size of these arrays are stated in the first of the INTERTRAN Input Data Tables and the given dimensions will be compared with these. If the maximum size is exceeded the execution will be terminated and error message will be printed. The maximum size can be exceeded if the appropriate changes are made in the code.

The computation input data can be filled out in Table 3.15 the first of the set of empty input tables.

3.10 Input Data Handling

When the default data which is desired to be changed is filled out in the empty input Tables 3.15-3.29 and the standard shipment data is filled out in Table 3.30 the input data file can be created. This can be done in two ways either can the necessary blocks be written directly using the format description in Appendix B, The Input Data Guide, or if an interactive facility is available can the interactive program INREAD be used. The program INREAD is described in Appendix G.

Table 3.1

TRANSPORT SITUATION DATA Block: TRANSMODE NORMAL

Transport situations		TRUCK	PVAN	PASS AIR	CARGO AIR	RAIL	SHIP-1	SHIP-2	TRUCK-2	CVAN-1	CVAN-2
Mode type	1=road 2=air 3=rail 4=water	1	1	2	2	3	4	4	1	1	1
Fraction of travel in pop. zones	rural	0.80	0.05	0.95	0.95	0.80	0.99	0.90	0.90	0.05	0.05
	suburb	0.15	0.40	0.03	0.03	0.15	0.01	0.1	0.08	0.40	0.40
	urban	0.05	0.55	0.02	0.02	0.05	0.0	0.0	0.02	0.55	0.55
Velocity in pop. zone km/h	rural	70	90	600	600	90	18	18	50	90	90
	suburb	50	50	600	600	70	14	14	30	50	50
	urban	30	30	600	600	50	5	5	15	30	30

Table 3.2 TRANSPORT SITUATION DATA (cont'd) Block: NORMAL

Transport situations	TRUCK	PVAN	PASS.AIR	CARGO AIR	RAIL	SHIP-1	SHIP-2	TRUCK-2	CVAN-1	CVAN-2
Number of crew	2	1	3	3	2	20	10	2	1	1
Distance source to crew m	3	2	15	6	150	50	25	6	2	2
Number of handlings	2	1	2	2	2	2	2	2	1	1
Stop time per 24-h trip h	8	8	8	8	8	8	8	8	8	8
N:o persons exposed at stops	50	100	1000	50	50	50	50	10	100	100
Exposure dist. at stops m	20	10	50	50	20	50	50	20	10	10
Storage time h	2	4	0	0	24	48	24	0	4	4
N:o persons exposed at storage	100	100	0	0	100	100	100	0	100	100
Exposure dist. at storage m	100	100	0	0	100	100	100	0	100	100
N:o of persons per vehicle	2	2	110	-	300	-	-	2	2	2

Table 3.3

Number of passenger air flight attendants: 4

TRANSPORT SITUATION DATA (cont'd) Block: NORMAL

Transport situation		TRUCK	PVAN	PASS.AIR	CARGO AIR	RAIL	SHIP-1	SHIP-2	CVAN-1	CVAN-2	CVAN-3
Fraction of rush-hour traffic		0.08	0.17	-	-	-	-	-	0.08	0.17	0.17
Fraction of travel on city streets		0.05	0.65	-	-	-	-	-	0.05	0.65	0.65
Fraction of travel on freeways		0.5	0.25	-	-	-	-	-	0.5	0.25	0.25
Traffic count in one direction h^{-1}	rural	250	250	-	-	2	-	-	250	250	250
	suburb	700	700	-	-	5	-	-	700	700	700
	urban	1200	1200	-	-	5	-	-	1200	1200	1200

Table 3.4 VEHICULAR ACCIDENT DATA Block: ACCIDENT

FRACTIONAL OCCURENCE OF ACCIDENT SEVERITY CATEGORIES

Transport situation	Over-all accident rate km^{-1}	I	II	III	IV	V	VI	VII	VIII	IX	X	XI
TRUCK-1	$1\cdot10^{-6}$	0.715	0.2648	0.0127	$5.6\cdot10^{-4}$	0.00533	$4.5\cdot10^{-4}$	$6.4\cdot10^{-4}$	$3.7\cdot10^{-4}$	$1.8\cdot10^{-5}$	$3.3\cdot10^{-5}$	$4.8\cdot10^{-5}$
PVAN	$1\cdot10^{-6}$	0.3941	0.5491	0.045	0.005	0.0049	$4.1\cdot10^{-4}$	$5.9\cdot10^{-4}$	$7.8\cdot10^{-4}$	$6.3\cdot10^{-5}$	$7.1\cdot10^{-5}$	$1.1\cdot10^{-4}$
PASS AIR	$9\cdot10^{-8}$	0.5004	0.0612	0.0224	0.076	0.1493	0.00466	0.00124	0.06815	0.025	0.0029	0.088
CARGO AIR	$9\cdot10^{-8}$	0.5004	0.0612	0.0224	0.076	0.1493	0.00466	0.00124	0.06815	0.025	0.0029	0.088
RAIL	$3\cdot10^{-7}$	0.8024	0.1722	0.0068	0.0041	0.0063	$3.8\cdot10^{-3}$	$2.5\cdot10^{-3}$	$8.7\cdot10^{-4}$	$3.4\cdot10^{-5}$	$5.4\cdot10^{-4}$	$4\cdot10^{-4}$
SHIP-1	$2\cdot10^{-6}$	0.9651	0.0264	0.0026	$2.6\cdot10^{-4}$	0.0021	$4.5\cdot10^{-4}$	0.0028	$5.6\cdot10^{-5}$	$1.1\cdot10^{-5}$	$1.4\cdot10^{-5}$	$1.6\cdot10^{-4}$
SHIP-2	$2\cdot10^{-6}$	0.9651	0.0264	0.0026	$2.6\cdot10^{-4}$	0.0021	$4.5\cdot10^{-4}$	0.0028	$5.6\cdot10^{-5}$	$1.1\cdot10^{-5}$	$1.4\cdot10^{-5}$	$1.6\cdot10^{-4}$
TRUCK-2	$1\cdot10^{-6}$	0.8682	0.1148	0.0101	$8\cdot10^{-5}$	0.0055	$4.7\cdot10^{-4}$	$6.7\cdot10^{-4}$	$1.6\cdot10^{-4}$	$1.4\cdot10^{-5}$	$1.5\cdot10^{-5}$	$2.1\cdot10^{-5}$
CVAN-1	$1\cdot10^{-6}$	0.5917	0.3841	0.0158	0.0016	0.0052	$4.3\cdot10^{-4}$	$6.2\cdot10^{-4}$	$5.4\cdot10^{-4}$	$2.2\cdot10^{-5}$	$4.7\cdot10^{-5}$	$7.1\cdot10^{-5}$
CVAN -2	$1\cdot10^{-6}$	0.5917	0.3841	0.0158	0.0016	0.0052	$4.3\cdot10^{-4}$	$6.2\cdot10^{-4}$	$5.4\cdot10^{-4}$	$2.2\cdot10^{-5}$	$4.7\cdot10^{-5}$	$7.1\cdot10^{-5}$

Table 3.5 ACCIDENT RISK FACTOR VEHICULAR ACCIDENT DATA (cont'd) Block: ACCIDENT

Sev. category	Transport situat.	TRUCK	PVAN	PASS.AIR	CARGO AIR	RAIL	SHIP-1	SHIP-2	TRUCK-2	CVAN-1	CVAN-2
I	rural	0.4	0.4	0.6	0.6	0.5	0.5	0.5	0.4	0.4	0.4
	suburb	2.3	2.3	12	12	2.5	5.5	5.5	2.3	2.3	2.3
	urban	2.3	2.3	4	4	4.5	5.5	5.5	2.3	2.3	2.3
II	rural	0.5	0.5	0.6	0.6	0.5	0.5	0.5	0.5	0.5	0.5
	suburb	2.1	12	12	1.2	2.5	5.5	5.5	2.1	2.1	2.1
	urban	2.1	2.1	4	4	4.5	5.5	5.5	2.1	2.1	2.1
III	rural	0.9	0.9	0.6	0.6	0.8	0.7	0.7	0.9	0.9	0.9
	suburb	1.3	1.3	12	12	1.7	4	4	1.3	1.3	1.3
	urban	1.3	1.3	4	4	2.5	4	4	1.3	1.3	1.3

Table 3.6 VEHICULAR ACCIDENT DATA (cont'd) Block: ACCIDENT

Sev. category	Transport situat.	TRUCK	PVAN	PASS AIR	CARGO AIR	RAIL	SHIP-1	SHIP-2	TRUCK-2	CVAN-1	CVAN-2
IV	rural	1.0	1	0.6	0.6	1	0.9	0.9	1	1	1
	suburb	1.0	1	12	12	1	2.8	2.8	1	1	1
	urban	1.0	1	4	4	1	2.8	2.8	1	1	1
V	rural	1	1	0.6	0.6	1	1	1	1	1	1
	suburb	1	1	12	12	1	1	1	1	1	1
	urban	1	1	4	4	1	1	1	1	1	1
VI	rural	1.0	1	0.6	0.6	1	1	1	1	1	1
	suburb	1.0	1	12	12	1	1	1	1	1	1
	urban	1.0	1	4	4	1	1	1	1	1	1

Table 3.7 VEHICULAR ACCIDENT DATA (cont'd) Block: ACCIDENT

Transport situat. Sev. category		TRUCK	PVAN	PASS AIR	CARGO AIR	RAIL	SHIP-1	SHIP-2	TRUCK-2	CVAN-1	CVAN-2
VII	rural	1.0	1	0.6	0.6	1	1	1	1	1	1
	suburb	1.0	1	12	12	1	1	1	1	1	1
	urban	1.0	1	4	4	1	1	1	1	1	1
VIII	rural	0.5	0.5	0.6	0.6	0.5	0.5	0.5	0.5	0.5	0.5
	suburb	2.1	2.1	12	12	2.5	5.5	5.5	2.1	2.1	2.1
	urban	2.1	2.1	4	4	4.5	5.5	5.5	2.1	2.1	2.1
IX	rural	0.9	0.9	0.6	0.6	0.8	0.7	0.7	0.9	0.9	0.9
	suburb	1.3	1.3	12	12	1.7	4	4	1.3	1.3	1.3
	urban	1.3	1.3	4	4	2.5	4	4	1.3	1.3	1.3

Table 3.8

VEHICULAR ACCIDENT DATA (cont'd) Block: ACCIDENT

Sev. category	Transport situat.	TRUCK	PVAN	PASS AIR	CARGO AIR	RAIL	SHIP-1	SHIP-2	TRUCK-2	CVAN-1	CVAN-2
X	rural	0.9	0.9	0.6	0.6	0.8	0.7	0.7	0.9	0.9	0.9
	suburb	1.3	1.3	12	12	1.7	4	4	1.3	1.3	1.3
	urban	1.3	1.3	4	4	2.5	4	4	1.3	1.3	1.3
XI	rural	1.0	1	0.6	0.6	1	0.9	0.9	1	1	1
	suburb	1.0	1	12	12	1	2.8	2.8	1	1	1
	urban	1.0	1	4	4	1	2.8	2.8	1	1	1
	rural										
	suburb										
	urban										

Table 3.9 HANDLING ACCIDENT DATA Block:HANDLING

Fractional occurence for accident severity categories

PACKAGE TYPE	Over-all rate handling^{-1}	I	II	III	IV	V	VI	VII	VIII	IX	X	XI
A-1	$1.5\cdot10^{-5}$	0.68	0.30	0.019	0.001	0	0	0	0	0	0	0
B-1	$6\cdot10^{-6}$	0.68	0.30	0.019	0.001	0	0	0	0	0	0	0
CASK-EXT1	$6\cdot10^{-6}$	0.68	0.30	0.019	0.001	0	0	0	0	0	0	0
CASK-REL	$6\cdot10^{-6}$	0.68	0.30	0.019	0.001	0	0	0	0	0	0	0
BPU	$6\cdot10^{-6}$	0.68	0.30	0.019	0.001	0	0	0	0	0	0	0
DRUM	$5.6\cdot10^{-6}$	0.60	0.38	0.019	0.001	0	0	0	0	0	0	0
A-2	$1.5\cdot10^{-5}$	0.68	0.30	0.019	0.001	0	0	0	0	0	0	0
B-2	$6\cdot10^{-6}$	0.68	0.30	0.019	0.001	0	0	0	0	0	0	0
CASK-EXT2	$6\cdot10^{-6}$	0.68	0.30	0.019	0.001	0	0	0	0	0	0	0
EXEMPT	$8\cdot10^{-6}$	0.60	0.38	0.019	0.001	0	0	0	0	0	0	0

Table 3.10

PACKAGE DATA Block: PACKAGE and RELEASE

Package failure fractions for the accident severity categories

PACKAGE TYPE	Dimension m	I	II	III	IV	V	VI	VII	VIII	IX	X	XI
A-1	0.44	0	0.1	1.0	1.0	0.1	1.0	1.0	0.1	1.0	1.0	1.0
B-1	0.64	0	0	0.1	1.0	0	0.1	1.0	0	0.1	0.1	1.0
CASK-EX1	5.5	0	0	0	$1 \cdot 10^{-4}$	0	0	$1 \cdot 10^{-4}$	0	0	0	$1 \cdot 10^{-4}$
CASK-REL	5.5	0	0	0.1	1.0	0	0.1	1.0	0	0.1	0.1	1.0
BPU	0.64	0	0	0	0.1	0	0	0.1	0	0	0	0.1
DRUM	0.55	0	0.1	1.0	1.0	0.1	1.0	1.0	0.1	1.0	1.0	1.0
A-2	1.50	0	0.1	1.0	1.0	0.1	1.0	1.0	0.1	1.0	1.0	1.0
B-2	1.50	0	0	0.1	1.0	0	0.1	1.0	0	0.1	0.1	1.0
CASK-EX2	1.0	0	0	0	$3 \cdot 10^{-4}$	0	0	$3 \cdot 10^{-4}$	0	0	0	$3 \cdot 10^{-4}$
EXEMPT	0.12	0.1	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Table 3.11

POPULATION DENSITY DATA Block:POPDEN

	Rural pop. zone	Suburban pop. zone	Urban pop. zone
Population density km^{-2}	50	500	5 000

Pedestrian density factor:	6

SHIELDING DATA Block: SHIELD

Shielding factor suburban zone:	0.5
Shielding factor urban zone:	0.05

Table 3.12

AEROSOLIZATION DATA Block: AEROSOL

Accident severity categories

Material Dispersibility Category	I	II	III	IV	V	VI	VII	VIII	IX	X	XI
Solid: non-dispersable	0	0	0	0	0	0	0	0	0	0	0
compact/sintered	$3\cdot10^{-5}$	$3\cdot10^{-5}$	$3\cdot10^{-5}$	$3\cdot10^{-5}$	$3\cdot10^{-4}$	$3\cdot10^{-4}$	$8\cdot10^{-4}$	$3\cdot10^{-4}$	$1\cdot10^{-3}$	$3\cdot10^{-3}$	$1\cdot10^{-2}$
loose powder large package	$3\cdot10^{-4}$	$3\cdot10^{-4}$	$3\cdot10^{-4}$	$3\cdot10^{-4}$	$3\cdot10^{-4}$	$3\cdot10^{-4}$	$8\cdot10^{-4}$	$3\cdot10^{-4}$	$1\cdot10^{-3}$	$3\cdot10^{-3}$	$1\cdot10^{-2}$
loose powder small package	$3\cdot10^{-3}$	$3\cdot10^{-3}$	$3\cdot10^{-3}$	$3\cdot10^{-3}$	$3\cdot10^{-3}$	$3\cdot10^{-3}$	$8\cdot10^{-3}$	$3\cdot10^{-3}$	$1\cdot10^{-2}$	$3\cdot10^{-2}$	$1\cdot10^{-1}$
chunks	$3\cdot10^{-5}$	$3\cdot10^{-5}$	$3\cdot10^{-5}$	$3\cdot10^{-5}$	$3\cdot10^{-5}$	$3\cdot10^{-5}$	$8\cdot10^{-5}$	$3\cdot10^{-5}$	$1\cdot10^{-4}$	$3\cdot10^{-4}$	$1\cdot10^{-3}$
volatile: sublime	$1\cdot10^{-3}$	$1\cdot10^{-3}$	$1\cdot10^{-3}$	$1\cdot10^{-3}$	$1\cdot10^{-2}$	$1\cdot10^{-1}$	1.0	$1\cdot10^{-1}$	$1\cdot10^{-1}$	$1\cdot10^{-1}$	1.0
volatile: carry-over	$1\cdot10^{-3}$	$1\cdot10^{-3}$	$1\cdot10^{-3}$	$1\cdot10^{-3}$	$1\cdot10^{-2}$	$1\cdot10^{-1}$	1.0	$1\cdot10^{-1}$	$1\cdot10^{-1}$	$1\cdot10^{-1}$	1.0
Liquid: large package	$8\cdot10^{-4}$	$8\cdot10^{-4}$	$8\cdot10^{-4}$	$8\cdot10^{-4}$	$8\cdot10^{-4}$	$4\cdot10^{-3}$	$4\cdot10^{-3}$	$4\cdot10^{-3}$	$4\cdot10^{-3}$	$8\cdot10^{-3}$	$1\cdot10^{-2}$
small package	$8\cdot10^{-3}$	$8\cdot10^{-3}$	$8\cdot10^{-3}$	$8\cdot10^{-3}$	$8\cdot10^{-3}$	$4\cdot10^{-2}$	$4\cdot10^{-2}$	$4\cdot10$	$4\cdot10^{-2}$	$8\cdot10^{-2}$	$1\cdot10^{-1}$
Gas	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Extremely flammable material	$3\cdot10^{-5}$	$3\cdot10^{-5}$	$3\cdot10^{-5}$	$3\cdot10^{-5}$	$1\cdot10^{-1}$	1.0	1.0	$1\cdot10^{-1}$	$1\cdot10^{-1}$	1.0	1.0

Table 3.13

METEOROLOGICAL INPUT DATA Block: METRO

	A	B	C	D	E	F
Relative frequency of Pasquill Stability Cat.	0	0	0	0	0	1

REGULATORY DATA Block: CONTAM and LIMITS

Criterion clean-up level Ci/m^2	0.1	
Dose limits for individuals rem	0.1	5.0

Table 3.14 STANDARD SHIPMENT DATA Block: SHIPMENT

MATERIAL	Package type	Package/ shipment	Transport index	Activity /package Ci	Material dispersi-bility category	PRIMARY MODE			SECONDARY MODE		
						Transport situation	Shipments/ year	Distance/ shipment	Transport situation	Shipments/ year	Distance/ shipment
U-FGE	B-2	10	0.1	2.3	6	SHIP-1	25	1300			
U-F6D	A-2	6	0.1	3.8	6	RAIL	20	800			
SFVEL-FP	CASK-REL	10	0	600	7	SHIP-2	16	1000			
SFVEL-EXT	CASK-EX1	10	10	$2.8 \cdot 10^6$	1	SHIP-2	16	1000			
CO60-SEAL	CASK-EX2	1	1	$1 \cdot 10^4$	1	SHIP-1	16	1000			
CO60-UNS 1	B-1	1	5.8	10	1	SHIP-1	7	1000			
CO60-UNS 2	B-1	3	5.8	10	1	RAIL	4	400	TRUCK	12	20

Table 3.15 **INTERTRAN INPUT DATA TABLES**

TITLE OF RUN:
Max 80 char.

1 5 10 15 20 25 30 35 40 45 50 55 60 65 71 73 80

PARAMETERS (BLOCK: PARM)

	YES	NO
ANALYSIS OF INCIDENT-FREE TRANSPORTS		
ANALYSIS OF VEHICULAR ACCIDENTS		
SENSITIVITY ANALYSIS		
CUMULATIVE PROBABILITY OUTPUT		
ANALYSIS OF HANDLING ACCIDENTS		

DIMENSIONS (BLOCK DIMENSION)

	PACKAGE TYPES < 10	ACCIDENT SEVERITIES < 11	RADII FOR DIRECT EXPOSURE < 15	MATERIAL DISPERSIBILITY CATEGORIES < 11	ISO-DOSE AREAS < 30
NUMBER OF:					

Table 3.16 TRANSPORT SITUATION DATA Block: TRANSMODE NORMAL

Transport situations											
Mode type	1=road 2=air 3=rail 4=water										
Fraction of travel in pop. zones	rural										
	suburb										
	urban										
Velocity in pop. zone km/h	rural										
	suburb										
	urban										

Table 3.17 TRANSPORT SITUATION DATA (cont'd) Block: NORMAL

Transport situations										
Number of crew										
Distance source to crew m										
Number of handlings										
Stop time per 24-h trip h										
N:o persons exposed at stops										
Exposure dist. at stops m										
Storage time h										
N:o persons exposed at storage										
Exposure dist. at storage m										
N:o of persons per vehicle										

TRANSPORT SITUATION DATA (cont'd) Block: NORMAL

Transport situation											
Fraction of rush-hour traffic											
Fraction of travel on city streets											
Fraction of travel on freeways											
Traffic count in one direction h^{-1}	rural										
	suburb										
	urban										

Number of passenger air flight attendants

Table 3.19 VEHICULAR ACCIDENT DATA Block: ACCIDENT

FRACTIONAL OCCURENCE OF ACCIDENT SEVERITY CATEGORIES

Transport situation	Over-all accident rate km^{-1}	I	II	III	IV	V	VI	VII	VIII	IX	X	XI

Table 3.20 VEHICULAR ACCIDENT DATA (cont'd) Block: ACCIDENT

Transport situat. Sev. category											
	rural										
	suburb										
	urban										
	rural										
	suburb										
	urban										
	rural										
	suburb										
	urban										

Table 3.21 VEHICULAR ACCIDENT DATA (cont'd) Block: ACCIDENT

Sev. category	Transport situat.										
	rural										
	suburb										
	urban										
	rural										
	suburb										
	urban										
	rural										
	suburb										
	urban										

Table 3.22 VEHICULAR ACCIDENT DATA (cont'd) Block: ACCIDENT

Transport situat. Sev. category											
	rural										
	suburb										
	urban										
	rural										
	suburb										
	urban										
	rural										
	suburb										
	urban										

Table 3.23 VEHICULAR ACCIDENT DATA (cont'd) Block: ACCIDENT

Transport situat. / Sev. category											
	rural										
	suburb										
	urban										
	rural										
	suburb										
	urban										
	rural										
	suburb										
	urban										

Table 3.24 HANDLING ACCIDENT DATA Block:HANDLING

Fractional occurence for accident severity categories

PACKAGE TYPE	Over-all rate handling^{-1}	I	II	III	IV	V	VI	VII	VIII	IX	X	XI

Table 3.25

PACKAGE DATA Block: PACKAGE and RELEASE

Package failure fractions for the accident severity categories

PACKAGE TYPE	Dimension m	I	II	III	IV	V	VI	VII	VIII	IX	X	XI

Table 3.26 POPULATION DENSITY DATA Block:POPDEN

	Rural pop. zone	Suburban pop. zone	Urban pop. zone
Population density km^{-2}			

Pedestrian density ratio:	

SHIELDING DATA Block: SHIELD

Shielding factor suburban zone:	
Shielding factor urban zone:	

Table 3.27 AEROSOLIZATION DATA Block: AEROSOL

Accident severity categories

Material Dispersivity Category	I	II	III	IV	V	VI	VII	VIII	IX	X	XI
Solid: non-dispersable											
compact/sintered											
loose powder large package											
loose powder small package											
chunks											
volatile: sublime											
volatile: carry-over											
Liquid: large package											
small package											
Gas											
Extremely flammable material											

Table 3.28 AEROSOLIZATION DATA Block: AEROSOL

	Accident severity categories										
Material Dispersivity Category	I	II	III	IV	V	VI	VII	VIII	IX	X	XI

Table 3.29 METEOROLOGICAL INPUT DATA Block: METRO

	A	B	C	D	E	F
Relative frequency of Pasquill Stability Cat.						

REGULATORY DATA Block: CONTAM and LIMITS

Criterion clean-up level Ci/m^2		
Dose limits for individuals rem		

Table 3.30 STANDARD SHIPMENT DATA Block: SHIPMENT

MATERIAL	Package type	Package/ shipment	Transport index	Activity /package Ci	Material dispersi-bility category	PRIMARY MODE			SECONDARY MODE		
						Transport situation	Shipments/ year	Distance/ shipment	Transport situation	Shipments/ year	Distance/ shipment

4. SENSITIVITY ANALYSIS

The objective of the sensitivity analysis included in INTERTRAN code is to estimate the effect a variation of an input variable will have on the output. The result of the sensitivity analysis will give the user an idea of the relative importance of the different input variables and thus indicate were further efforts should be made to collect better input data. The sensitivity analysis can also be used in a more extensive statistical analysis. If the distribution functions of the input variables are know a sampling of the input variables can be made and the distribution function of the output result can be estimated. In some cases a number of INTERTRAN runs can be necessary.

The basic structure of the INTERTRAN code is mathematically straight forward but the final result is formed by adding a great number of contributions from individual scenarios which will make it difficult to estimate the importance of different variables. Many of the variables will give a linear or near linear effect on the output which means that the sensitivity can be estimated over large intervals. In the incident-free case the error propagation formula is used and in the accident case the annual expected effects are divided according to the population zone, accident severity category, transport situation and material dispersibility category used in each individual scenario. The description in section 4.2 will guide the user in how to use this information.

4.1 Incident-free Case Sensitivity Analysis

The sensitivity analysis that is based on an error propagation formula which calculates the relative importance, RI_J, of the input parameter Xj. A change in the parameter of p percent will result in a change of the total result with p·RI percent. Note that an increase the parameters used in the denomination of the equations will decrease the total dose.

The total dose is given by:

$$D_{tot} = \sum_{i=1}^{n} D_i(x_1, x_2, \ldots, x_k) \qquad (54)$$

D_{tot} = Total dose for transport mode

D_i = Dose for population subgroup i

X = Parameters

n = Number of population subgroups

k = Number of parameters

The relative importance, RI_j, for parameter x_j, is calculated by summing the partial derivates for x_j and multiplying by the parameter value and dividing by the total dose.

$$RI_J = \frac{\sum_{i=1}^{n} x_j \frac{\partial D_j}{\partial x_j}}{D_{tot}} \qquad (55)$$

The relative importance values are summed over all shipments.

The normal sensitivity analysis output is printed in the end of the normal case output summary. Note that the relative importance of a parameter will vary between runs with different input data.

Figure 4.1 shows an example of the incident-free sensitivity output and Table 4.1 explains the parameters and the different population subgroups they influence.

The use of the sensitivity analysis is best explained with a simple example.

In Figure 4.1 the relative importance of the number of crewmen can be used to estimate the effect of a change of

NORMAL SENSITIVITY ANALYSIS SUMMARY
****

	PARAMETER	RELATIVE IMPORTANCE
1	DSTRVL	4.421E-01
2	CAYZER	1.404E+00
3	TI	1.000E+00
4	PPS	1.000E+00
5	SPY	1.000E+00
6	FTZNR	3.606E-01
7	POPDR	1.238E-03
8	VELR	-3.686E-01
9	RS	8.817E-04
10	FTZNS	4.703E-02
11	POPDS	8.817E-04
12	VELS	-4.798E-02
13	FTZNU	1.466E-02
14	POPDU	6.332E-06
15	VELU	-1.469E-02
16	FCTST	2.343E-07
17	RPD	4.426E-08
18	RU	6.288E-06
19	DTST	1.368E-01
20	PDST	1.368E-01
21	RST	-2.736E-01
22	-	0.
23	RSTOR	-1.704E-01
24	DTSTOR	8.519E-02
25	PDSTOR	8.519E-02
26	CREWNO	2.920E-01
27	ADSTCW	-5.841E-01
28	VELM	-4.288E-01
29	HANDNO	4.727E-01
30	PPV	1.305E-04
31	FTLFWY	-3.538E-06
32	TCNTPR	7.588E-05
33	FRSHR	1.908E-06
34	TCNTPS	6.053E-05
35	TCNTPU	3.888E-05
36	PASSENGERS	0.
37	----	0.

Figure 4.1 Incident-free Case Output

the input data. In the example the number of crewmen was 2 giving a total population dose of 10.0 person-rem.

An increase of the number of crew with 100% to 4 will give an increase of the total dose of RI·100% or 29.2% resulting in a total dose of 12.9 person-rem. This method could be used for the linear parameters, for the non-linear parameters, marked with an asterisk in Table 4.1, the effect can

Table 4.1 Incident-free Case Sensitivity Parameters

Variable	Denomination in output	Subgroups
Distance per shipment	DSTRVL	All except Handl Store
Package shape factor	CAYZER*	All except Pass Att
Transportation Index	TI	All
Packages per shipment	PPS	All
Shipment per year	SPY	All
Fraction of rural travel	FTZNR	All except Handl Store
Rural population density	POPDR	Off-link
Velocity in rural zone	VELR	All except Handl Store
Suburban shielding factor	RS	Off link
Fraction of suburban travel	FTZNS	All except Handl Store
Suburban population density	POPDS	Off-link
Velocity in suburban zone	VELS	All except Handl Store
Fraction of urban travel	FTZNV	All except Handl Store
Urban population density	POPDU	Off-link
Velocity in urban zone	VELU	All except Handl Store
Frac. City-street travel	FCTST	Off-link On-link
Pedestrian density ratio	RPD	Off-link
Urban shielding factor	RU	Off-link
Stop-time	DTST	Stop
Persons at stops	PDST	Stop
Distance at stops	RST*	Stop
Distance at storage	RSTOR*	Store
Storage time	DTSTOR	Store
Persons at storage	PDSTOR	Store
Number of crew	CREWNO	Crew
Distance to crew	ADSTCW*	Crew
Mean velocity	VELM	Pass Crew Att Stop
Number of handlings	HANDNO	Handl
Persons per vehicle	PPV	On-link Pass
Freeway-travel	FTLFWY	On-link
Traffic count rural	TCNTPR	"
Rushhour traffic	FRSHR	"
Traffic count suburban	TCNTPS	"
Traffic count urban	TCNTPU	"
Passengers	PASSENGERS	Pass

* Non-linear parameters

Population subgroups:

Pass	air passengers
Crew	crew
Att	flight attendants
Handl	handlers
Off-link	persons surrounding shipment path
On-link	persons sharing shipment path
Stop	persons surrounding shipment while stopped
Store	person surrounding stored packages

---

vary for large changes of input data. Note that the limits for external dose, crew dose and stoptime can result in deviations from the relative importance.

4.2 The Accident Sensitivity Analysis

In the vehicular accident case the method with the partial derivates is not used, instead the output result is divided according to various categories. The annual expected number of early and latent health effects are divided according to population density zone and accident severity category. The annual expected latent effects for the different accident severities is further more divided according to the transport situation, the package type and the material dispersivity category used. The radiological risk summary can also be used to estimate the sensitivity of the standard shipment variables such as distance per shipment, packages per shipment and shipments per year.

The number of latent effects will for many variables vary linear while the number of early health effects will depend on threshold dose values and will vary more irregularly. The effect of a variation of the different input variables presented in Table 4.1 will have on the accident sensitivity tables is presented in Table 4.2.

Table 4.2 Input Variables Used in Accident Calculations

Indices used in table:

i = index of accident severity categories

j = index of materials

k = index of package types

l = index of material dispersibility categories

m = index of transport situations

o = index of organs

p = index of population density zones

Input variables:

Variable	Denomination in equations	Index	Competer denominations
Activity per package	CI	j	CIPKG
Packages per shipment	PPS	j	PPS
Distance per shipment	FKMPS	j,m	FKMPS
Dose factors	RPC	j	RPCVAL
Population density	PD	p	POPDEN
Fraction of travel in rural zone	f_r	-	FTZNR
Fraction of travel in suburban zone	f_s	-	FTZNS
Fraction of travel in urban zone	f_u	-	FTZNU
Pedestrian population density ratio	RPD	-	RPD
Shielding factor urban zone	RU	-	RU
Accident severity factors	ACCRSK	i,m,p	ACCRSK
Over-all accident rate	ARATMD	m	ARATMD
Fractional occurence of accident severities	SEVFRC	i,m	SEVFRC
Package failure fraction	RF	i,k	RFRAC
Aerosolization factor	AER	i,l	AERSOL
Respirable factor	RESP	i,l	RESP
Deposition velocity	V_j	j	VELDEP

Table 4.3 The Effect of Various Input Data on the Output

Effects divided according to	Variable	Early effects	Latent effects
Standard Shipment	TABSPY	linear	linear
	PKGSHP	non-linear	linear
	C1PKG	-"-	linear
	FKMPS	linear	linear
	(RPCVAL)	non-linear	linear
Population Density Zone	POPDEN	linear	linear
	FTZNR		
	FTZNS	also depending on transport	
	FTZNU	situation	
	ACCRSK	also depending on transport situation and accident sev.cat.	
	RU	non-linear	non-linear
	RPD		
Transport Situation	ARATMD	linear	linear
	SEVFRC	linear for accident sev.cat.	
	ACCRSK	also depending on pop.den.zone and accident severity cat.	
Package Types	RFRAC	non-linear	linear for accident sev.
Material Dispersibility Category	AERSOL	non-linear	linear for accident sev.
	RESP	non-linear	linear for accident sev.
	VELDEP	non-linear effect for category 2-11	

For the variables which are linear the effect of a input parameter variation can be directly calculated by using the data in the accident sensitivity tables, according to:

$$D' = D - d_i + d_i \cdot k = D + (k-1)d_i \qquad (56)$$

D' = result of variation of parameter i with factor k

D = former result

k = factor change

d_i = dose contribution from parameter i

In Figure 4.2 the accident sensitivity output is shown. By studying the tables the user can determine which of the individual parameters will have greatest influence on the total result.

As an example it can be mentioned that the early effects will occur mostly from category X accidents. For the latent cancer effects the accident categories VI, VII, X and XI will dominate. Changes in any input parameters for these categories will give effect on the total result. Further it can be noted that the transport situations rail and Ship-2 will have the dominating effect on the annual expected latent cancer fatalities. Thus for this analysis changes of the parameters giving effect on these transport situations will be important, see Table 4.3. By the same token it can be seen that the package types A-1 and B-1 are important and the material dispersibility category 6.

RADIOLOGICAL RISK SUMMARY
****

EXPECTED VALUE OF RADIOLOGICAL RISK

NO.	MATERIAL	MODES P	MODES S	EARLY EFFECTS FATAL	EARLY EFFECTS MORT.	LATENT CANCER FATALITIES GRND SHN	LATENT CANCER FATALITIES INHAL	LATENT CANCER FATALITIES RESUSP	LATENT CANCER FATALITIES TOTAL	GENETIC EFFECTS GRND SHN	GENETIC EFFECTS INHAL	GENETIC EFFECTS RESUSP	GENETIC EFFECTS TOTAL
1	U-ENR-FO	7	0	0.	4.9E-05	3.8E-08	2.0E-05	1.3E-05	3.3E-05	5.1E-08	3.6E-07	2.3E-07	6.4E-07
2	U-DEP-F3B	5	0	0.	6.4E-05	1.5E-08	1.4E-05	9.1E-06	2.3E-05	2.0E-08	2.5E-07	1.6E-07	4.3E-07
3	SF-FP	-6	0	1.4E-05	5.0E-04	6.2E-07	8.1E-07	5.1E-07	1.9E-06	[illegible]	[illegible]	2.7E-06	6.5E-06
4	SFUEL-EXT	-6	0	0.	0.	0.	5.2E-08	0.	5.2E-08	0.	7.1E-08	0.	7.1E-08
5	CO60-SEAL	7	0	0.	0.	0.	2.2E-11	0.	2.2E-11	0.	3.0E-11	0.	3.0E-11
6	CO60-UMS1	7	0	0.	0.	0.	1.5E-09	0.	1.5E-09	0.	2.1E-09	0.	2.1E-09
7	CO60-UMS2	5	1	0.	0.	2.1E-09	8.1E-11	4.9E-11	2.3E-09	2.9E-09	[illegible]	5.4E-12	2.9E-09
	TOTALS			1.4E-05	6.2E-04	6.8E-07	3.5E-05	2.3E-05	5.9E-05	9.2E-07	4.2E-06	2.6E-06	7.7E-06
				LF	EM	LCF-GS	LCF-INH	LCF-RES	LCF-TOT	GE-GS	GE-INH	GE-RES	GE-TOT

NOTE -- NEGATIVE MODE INDICATES EXCLUSIVE USE SHIPMENT

Figure 4.2 Accident Impact per Shipment

ACCIDENT SENSITIVITY ANALYSIS SUMMARY
****

ANNUAL EXPECTED IMPACT ON MAN

POP.ZONE	EARLY FAT.	EARLY MOR.	LCF	GEN.EFF.
RURAL	8.847E-06	3.227E-04	9.911E-06	4.076E-06
SUBURBAN	3.217E-06	1.415E-04	1.908E-05	1.770E-06
URBAN	2.280E-06	1.528E-04	2.973E-05	1.814E-06

RURAL ACC.SEV.	EARLY FAT.	EARLY MOR.	LCF	GEN.EFF.
1	0.	0.	0.	0.
2	0.	0.	1.675E-08	3.388E-10
3	0.	0.	4.134E-07	3.825E-07
4	0.	6.604E-06	1.091E-07	7.941E-08
5	0.	0.	1.216E-07	2.214E-09
6	0.	8.357E-06	2.926E-06	6.050E-08
7	0.	9.901E-06	2.131E-06	5.056E-08
8	0.	0.	1.365E-08	2.490E-10
9	0.	2.786E-07	7.947E-07	3.721E-08
10	4.992E-06	2.287E-04	2.357E-06	2.170E-06
11	3.856E-06	6.380E-05	1.027E-06	1.294E-06

SUBURBAN ACC.SEV.	EARLY FAT.	EARLY MOR.	LCF	GEN.EFF.
1	0.	0.	0.	0.
2	0.	0.	2.792E-08	5.647E-10
3	0.	0.	5.933E-07	1.494E-07
4	0.	2.402E-06	1.306E-07	3.049E-08
5	0.	0.	2.027E-07	3.659E-09
6	0.	4.643E-06	3.834E-06	7.316E-08
7	0.	1.769E-05	3.011E-06	5.566E-08
8	0.	0.	2.281E-08	4.151E-10
9	0.	1.546E-07	2.869E-06	6.148E-08
10	1.815E-06	8.313E-05	6.675E-06	8.972E-07
11	1.402E-06	3.346E-05	1.711E-06	4.947E-07

URBAN ACC.SEV.	EARLY FAT.	EARLY MOR.	LCF	GEN.EFF.
1	0.	0.	0.	0.
2	0.	0.	3.265E-07	7.744E-09
3	0.	0.	7.960E-07	2.186E-07
4	0.	1.601E-06	1.759E-07	2.597E-08
5	0.	0.	2.367E-06	4.519E-08
6	0.	2.786E-05	1.087E-05	2.061E-07
7	0.	2.046E-05	5.102E-06	9.665E-08
8	0.	0.	2.662E-07	5.054E-09
9	0.	9.285E-07	2.501E-06	6.137E-08
10	1.210E-06	7.326E-05	5.596E-06	7.541E-07
11	[illegible]	[illegible]	[illegible]	[illegible]

Figure 4.2 (continued) Accident Severity Output. Early fatalities, early morbidities latent cancer fatalities and genetic effects per population density zone

ANNUAL EXPECTED LATENT CANCER FATALITIES

BY TRANSPORT MODE

ACC.SEV.	TRUCK	PVAN	AIR-1	AIR-2	RAIL	SHIP-1	SHIP-2	TRUCK-2	CVAN	CVAN-2
1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
2	0.	0.	0.	0.	3.71E-07	0.	0.	0.	0.	0.
3	2.69E-11	0.	0.	0.	4.15E-07	4.31E-07	9.57E-07	0.	0.	0.
4	4.43E-12	0.	0.	0.	1.35E-07	7.23E-08	2.09E-07	0.	0.	0.
5	0.	0.	0.	0.	2.69E-06	0.	0.	0.	0.	0.
6	2.27E-14	0.	0.	0.	1.24E-05	9.86E-09	5.20E-06	0.	0.	0.
7	3.15E-13	0.	0.	0.	5.03E-06	1.33E-08	5.20E-06	0.	0.	0.
8	0.	0.	0.	0.	3.03E-07	0.	0.	0.	0.	0.
9	4.39E-14	0.	0.	0.	4.14E-07	2.59E-08	5.72E-06	0.	0.	0.
10	1.27E-12	0.	0.	0.	6.71E-07	9.46E-07	1.30E-05	0.	0.	0.
11	1.17E-11	0.	0.	0.	8.50E-07	4.94E-07	3.12E-06	0.	0.	0.
TOTAL	4.46E-11	0.	0.	0.	2.33E-05	1.99E-06	3.34E-05	0.	0.	0.

BY PACKAGE TYPE

ACC.SEV.	A-1	B-1	CASK-1	CASK-2	BPU	DRUM	A-2	B-2	CASK-3	EXEMPT
1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
2	0.	0.	0.	0.	0.	0.	3.71E-07	0.	0.	0.
3	0.	1.13E-09	0.	4.31E-07	0.	0.	4.15E-07	9.56E-07	0.	0.
4	0.	5.92E-10	3.71E-08	3.51E-08	0.	0.	1.34E-07	2.09E-07	1.56E-11	0.
5	0.	0.	0.	0.	0.	0.	2.69E-06	0.	0.	0.
6	0.	6.32E-11	0.	9.86E-09	0.	0.	1.24E-05	5.20E-06	0.	0.
7	0.	9.10E-11	9.29E-09	4.05E-09	0.	0.	5.03E-06	5.20E-06	3.90E-12	0.
8	0.	0.	0.	0.	0.	0.	3.03E-07	0.	0.	0.
9	0.	5.99E-11	0.	2.59E-08	0.	0.	4.14E-07	5.72E-06	0.	0.
10	0.	2.54E-10	0.	9.46E-07	0.	0.	6.71E-07	1.30E-05	0.	0.
11	0.	1.57E-09	5.57E-09	4.88E-07	0.	0.	6.49E-07	3.12E-06	2.34E-12	0.
TOTAL	0.	3.77E-09	5.20E-08	1.94E-06	0.	0.	2.33E-05	3.34E-05	2.18E-11	0.

BY MATERIAL DISPERSIVITY CATEGORY

ACC.SEV.	DISPERSIVITY CATEGORY 1	2	3	4	5	6	7	8	9	10	11
1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
2	0.	0.	0.	0.	0.	3.71E-07	0.	0.	0.	0.	0.
3	9.75E-10	1.50E-10	0.	4.31E-07	0.	1.37E-06	0.	0.	0.	0.	0.
4	3.74E-10	3.78E-10	0.	3.51E-08	0.	3.43E-07	0.	0.	0.	0.	0.
5	0.	0.	0.	0.	0.	2.69E-06	0.	0.	0.	0.	0.
6	5.33E-11	2.90E-12	0.	9.86E-09	0.	1.76E-05	0.	0.	0.	0.	0.
7	9.34E-12	3.77E-11	0.	4.05E-09	0.	1.02E-05	0.	0.	0.	0.	0.
8	0.	0.	0.	0.	0.	3.03E-07	0.	0.	0.	0.	0.
9	5.86E-11	1.25E-12	0.	2.59E-08	0.	6.14E-06	0.	0.	0.	0.	0.
10	1.33E-10	1.21E-10	0.	9.46E-07	0.	1.37E-05	0.	0.	0.	0.	0.
11	5.61E-09	1.55E-09	0.	4.88E-07	0.	3.97E-06	0.	0.	0.	0.	0.
TOTAL	5.35E-08	2.25E-09	0.	1.94E-06	0.	5.67E-05	0.	0.	0.	0.	0.

Figure 4.2 (continued) Accident Sensitivity Output.
Latent Cancer Fatalities per Transport Mode, Package type, Material

5. The INTERTRAN Code

In this section the computer code INTERTRAN will be described. The INTERTRAN code will be available in two versions written in the FORTRAN IV language, one CDC version and one IBM version.

5.1 The Structure of the INTERTRAN Code

The INTERTRAN code is divided into one main program, 16 subroutines, 1 function and two block data parts. Figure 5.1 shows the basic structure of the code and the information flow through the program.

Here follows a short description of what is done in each program part.

INTRAN (MAIN in the IBM-version) is the main program which calls the input and output routines and administrates the incident-free case and the accident case calculations.

READIN reads the input data blocks from file 2.

DATOUT writes the output data on file 4. DATOUT is called from INTRAN through a number of ENTRY statements.

WTRNK writes the probability and consequence data from the accident calculations on file 6. These data can be used for probability calculations and plotting.

SETVAL is used to set the parameters for shipment, from the data arrays.

NORMAL (NORM in the IBM-version) calculates the dose from incident-free transports.

ACC (ACCID in the IBM-version) calculates the dose and the health effects caused by vehicular and handling accidents.

MDT calculates the recomputed dilution factors and ground contamination levels.

ƨPFIT is used to calculate the probability of early fatalities.

SENSTV calculates the derivates of the normal case parameters for the incident- free case sensitivity analysis.

SENSUM makes the summations of the derivates for the incident- free case sensitivity analysis.

DATSUM makes the summation of the amounts of radioactive material transported. The result is printed on file 4.

AVINT calculates the integrated dilution factor used for the calculation of population dose from accidents with dispersable materials.

PARSORT is called by DATOUT for the ranking of the expected latent effects.

INTMAT is a function which gives the internal nuclide number for a input material. The internal nuclide number is used as a reference to the nuclide data library.

BLOCK DATA blank initiates the default data and contains the nuclide data library.

BLOCK DATA NORACC initiates the default normal and accident case default data.

CHEM calculates the chemical effects of uranium release accidents

CHEMRS is used to calculate the early fatalities from chemical accidents

5.2 The Data Flow in the INTERTRAN Model

This section is going to describe the various input and out put files used and the various help programs available.

One of the goals when developing the system has been to make it simple to use. Since a vast amount of input data is needed for an INTERTRAN run default values are provided for most of the input data. The analyst can use the default data or replace them with other data when desired. The data describing the shipments must be provided, e.g. number of shipments and activity per package.

Figure 5.2 shows the dataflow in the INTERTRAN model. The user has data for the shipments which are to be analyzed and replacement data for the default data which better describes the conditions for the analysis. The replacement data are prepared according to Chapter 3 and can be filled out in the tables at the end of that section. The user can either prepare an input data deck according to the input data guide in APPENDIX B or use the interactive input program INREAD, described in Appendix G.

INREAD asks questions about what to be calculated and gives the user a possibility to enter the replacement data. The output from INREAD is an input file for INTERTRAN. The program reads the input file and takes the rest of the data from the default data sets in the BLOCK DATA section of the code. There are two BLOCK DATA parts one contains the accident probabilities and the incident-free case data and the other the rest of the default data. A user can of course change the default data directly in the code.

The output from the INTERTRAN code will be given in the format described in chapter 6 and as probability-consequence data for the individual scenarios written on a separate file. This file can be read by the program PPLOTT which plots cumulative probability graphs.

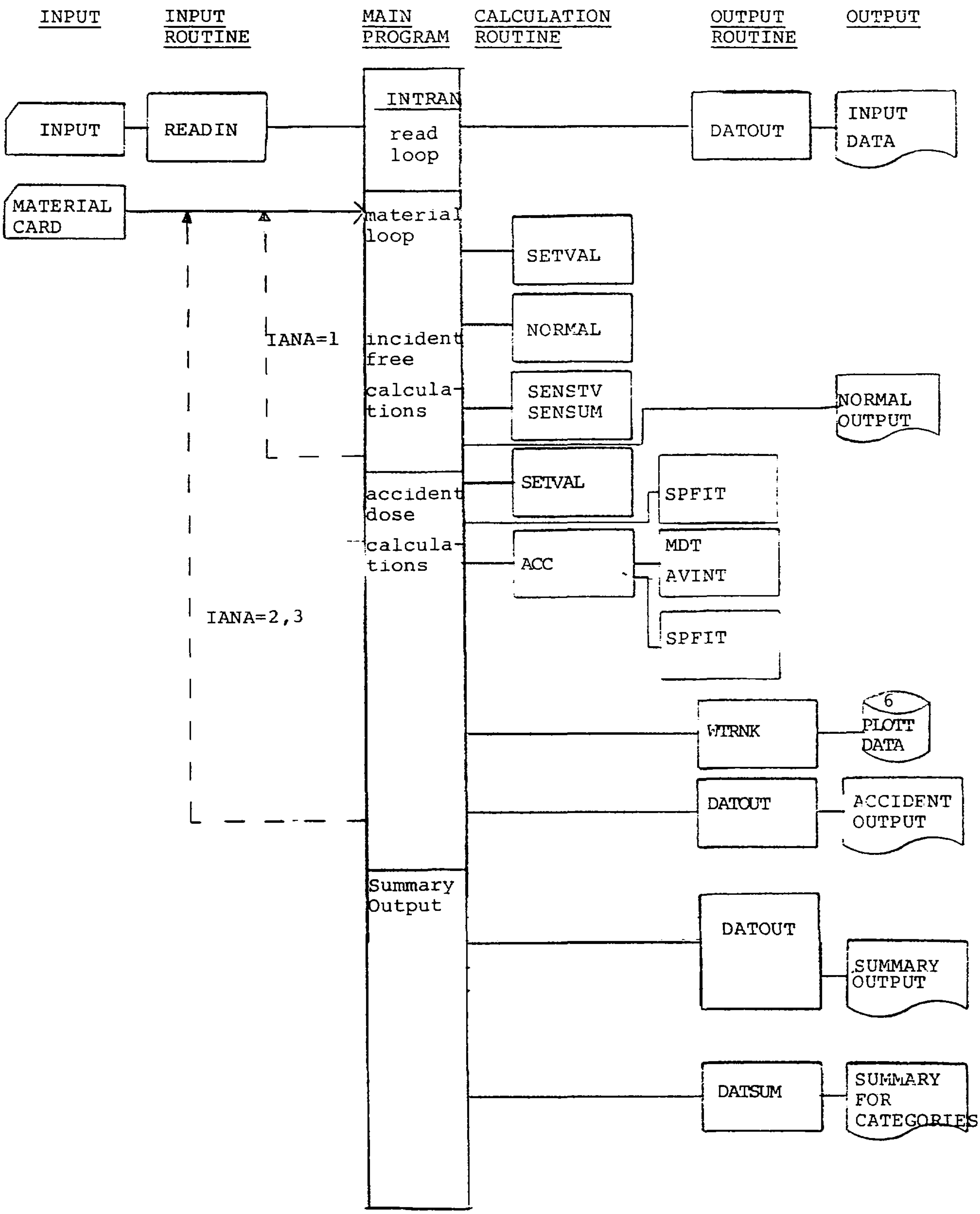


Figure 5.1 Structure of the code

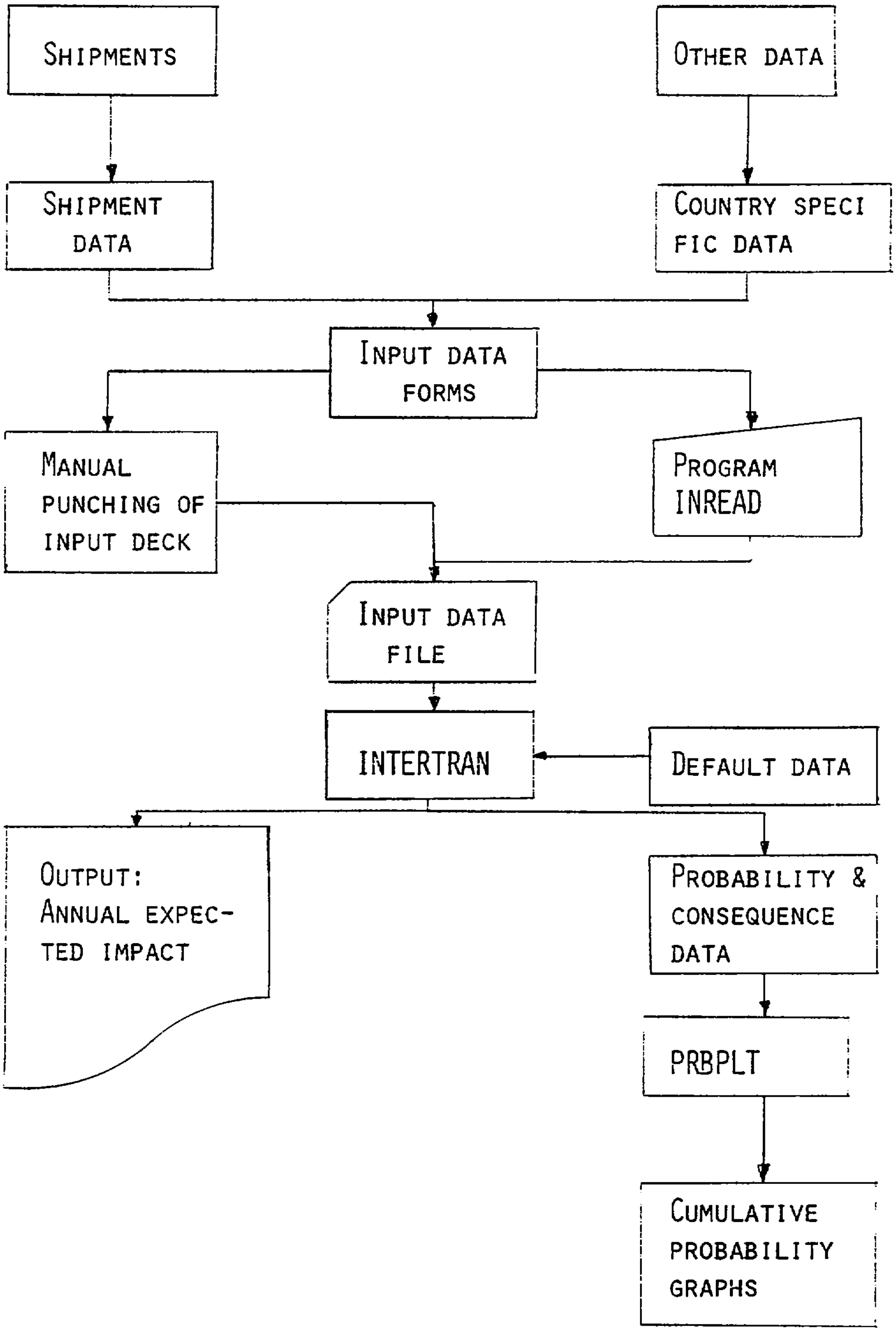


FIGURE 5.2 DATA FLOW FOR THE INTERTRAN MODEL.

6. INPUT AND OUTPUT DESCRIPTION

This section gives an example of an input data file and an output listing. The example used is a run with the shipments listed in Table 3.14. The default data sets are used. The input data file is shown in Figure 6.1.

The output from the run is shown in the following figures. Figure 6.2 shows the first page of the output with the listing of the incident-free case input data and the shipment data. Figure 6.3 gives a listing of the incident-free dose parameters and the fraction of travel in the population zones. The accident input data is shown in Figures 6.4-6.7. Figure 6.4 gives a summary listing of the used materials and a listing of the dispersion data. Figure 6.5 shows the accident probability data and Figure 6.6 the dose and health effect data. The meteorological data used for the dispersion accident dose calculations are given in Figure 6.7. If the user has specified a complete output for a material the incident-free case dose results will be given as in Figure 6.8. For the case with dispersable material the recomputed dilution factors and the ground contamination levels will be shown as in Figure 6.9. For each population zone the individual organ dose in each isodose area will be given. A consequence summary and the number of people in each isodose area will be printed as shown in Figure 6.10-6.11. The consequence will be given as the expected number of effects for a given accident severity and the annual expected number of accidents of that severity. INTERTRAN also calculates the number of people receiving more than a specified dose the output from those calculations are shown in Figure 6.11.

Figure 6.12 shows the incident-free case output from a shipment using two transport modes. In this case a non-dispersable material is shipped. The individual dose from an accident with the primary transport mode is given for the population zones and for pedestrians in the urban zone as is shown in Figure 6.13 and a consequence summary is given as shown in Figure 6.14.

Since the number of packages per shipment can be less on the secondary mode, the relation between the individual dose in the case of an accident is given. The number of persons in the annular areas and the population dose is listed as in Figure 6.15.

After the listing of the specified complete shipment output the summary output is listed. Figure 6.16 shows the normal case summary and Figure 6.17 the normal case sensitivity output. The accident case summary is shown in Figure 6.18 with the expected annual risk for each material and the annual expected number of persons receiving more than a specified dose. In Figure 6.19 a listing of the latent effects in ranked order is given. Figure 6.20-6.21 shows the output from the accident case sensitivity analysis.

The annual expected risk is divided according to accident severity, the population zone, transport mode, package type and material dispersivity category. Finally the sum of the transported amounts are given for the categories defined in block CATEGORY in the input data file, as shown in Figure 6.22.

Included in the code are a number of error messages from abnormal ends of the run resulting from errors in the input data. The STOP numbers used in the IBM-version and the STOP description used in the CDC-versions are explained in Table 6.1. The STOP number or STOP description are usually available in the dayfile or as condition codes given by the computer system.

TABLE 6.1 Error Messages from the INTERTRAN Code

Stop number in IBM-version	Stop description in CDC-version	Explanation
1	NO SHIPMENT DATA	The compulsory input block SHIPMENT was not included in the Input File.
2	ILLEGAL OPTION	Subroutine READIN has not recognized the name of an input data option. The available options will be printed on the output file.
3	DIMENSION OUT OF RANGE	The number of NIM, NRAD, NSEV, NPTYPE or NIM excess the maximum dimension of the affected arrays. A description will be given on the output file.
4	NO CONTROL BLOCK IN INPUT	The compulsory input block CONTROL was not included in the Input File.
5	ZERO VELOCITY	Zero velocity has been assigned to a transport situation were the fraction of travel was not zero.
6	MATERIAL UNAVAILABLE	The function INTMAT was called with a nuclide name not included in the Nuclide Data Library. The available nuclides will be printed on the output file.

7	INCORRECT PACKAGE TYPE	A material is shipped in a package type which is not default data or a package type inserted by the user. The available package types are printed on the output file.
8	NO SHIPMENT SPECFIED	The transport situation given in the material card of the input block CONTROL specifies a transport situation for which no shipments were specified in the input block shipment. A description is given on the output file.
9	STABILITY FREQUENCES NOT EQUAL ONE	The sum of the fractional occurance of the Pasquill stability classes is not 1.A description is given on the output file.
11	(Not used in CDC-version)	End-of-file on the Input Data file when reading block CATEGORY.
12	(Not used in CDC-version)	End-of-file on the Input Data file. The last record will be printed on the output file.

FIGURE 6.1

```
TITLE
** EXAMPLE OF THE INREAD CODE ***
PARM
    0    3    1    0
DIMENSION
   11   10   10   11   15
SHIPMENT
    7
U-F6E-HEX U-F6D-HEX SFUEL-FP  SFUEL-EXT CO60 -SEALCO60 -UNS1CO60 -UNS2
B-2       A-2       CASK-REL  CASK-EX1  CASK-EX2  B-1       B-1
  .100E+02  .600E+01  .100E+02  .100E+02  .100E+01  .100E+01  .300E+01
  .100E+00  .100E+00 0.         .100E+02  .100E+01  .580E+01  .580E+01
  .230E+01  .230e+01  .600E+03  .280E+07  .100E+05  .100E+02  .100E+02
    6    6    7    1    1    1    1
 0.         0.         0.         0.         0.         .250E+02 0.         0.
 0.         0.
 0.         0.         0.         0.          .200E+02 0.         0.         0.
 0.         0.
 0.         0.         0.         0.         0.         .160E+02  .160E+02  .300E+01
 0.         0.
 0.         0.         0.         0.         0.         .160E+02  .160E+02 0.
 0.         0.
 0.         0.         0.         0.         0.         .160E+02 0.         0.
 0.         0.
 0.         0.         0.         0.         0.         .700E+01 0.         0.
 0.         0.
  .120E+02 0.         0.         0.          .400E+01 0.         0.         0.
 0.         0.
 0.         0.         0.         0.         0.         .130E+04 0.         0.
 0.         0.
 0.         0.         0.         0.          .800E+03 0.         0.         0.
 0.         0.
 0.         0.         0.         0.         0.         .100E+04  .100E+04 0.
 0.         0.
 0.         0.         0.         0.         0.         .100E+04  .100E+04 0.
 0.         0.
 0.         0.         0.         0.         0.         .100E+04 0.         0.
 0.         0.
 0.         0.         0.         0.         0.         .100E+04 0.         0.
 0.         0.
  .200E+02 0.         0.         0.          .400E+03 0.         0.         0.
 0.         0.
CONTROL
    1   -6    0    1
    2   -5    0    1
    3   -7    0    1
    4   -7    0    1
    5    6    0    0
    6    6    0    0
    7    5    1    1

CATEGORY
    2
NUCLEAR   RAD.NUC.
    1    1    1    1    2    2    2
--
```

FIGURE 6.2

** EXAMPLE OF THE INREAD CODE *** DATE= 82/09/01.

NORMAL INPUT DATA
****

NO.	MATERIAL	PKG TYPE	PPS	TI/PKG
1	U-F6E-HEX	B-2	10.	.1000
2	U-F6D-HEX	A-2	6.	.1000
3	SFUEL-FP	CASK-REL	10.	0.0000
4	SFUEL-EXT	CASK-EX1	10.	10.0000
5	CO60 -SEAL	CASK-EX2	1.	1.0000
6	CO60 -UNS1	B-1	1.	5.8000
7	CO60 -UNS2	B-1	3.	5.8000

ZONE	POPULATION (PER SQ KM)
RURAL	50.
SUBURBAN	500.
URBAN	5000.

SHIPMENTS PER YEAR

MATERIAL	TRUCK	P. VAN	PASS. AIR	CARGO AIR	RAIL	SHIP-1	SHIP-2	TRUCK-2	CVAN-1	CVAN-2
U-F6E-HEX	0.	0.	0.	0.	0.	25.	0.	0.	0.	0.
U-F6D-HEX	0.	0.	0.	0.	20.	0.	0.	0.	0.	0.
SFUEL-FP	0.	0.	0.	0.	0.	16.	16.	3.	0.	0.
SFUEL-EXT	0.	0.	0.	0.	0.	16.	16.	0.	0.	0.
CO60 -SEAL	0.	0.	0.	0.	0.	16.	0.	0.	0.	0.
CO60 -UNS1	0.	0.	0.	0.	0.	7.	0.	0.	0.	0.
CO60 -UNS2	12.	0.	0.	0.	4.	0.	0.	0.	0.	0.

DISTANCE PER SHIPMENT(KM)

MATERIAL	TRUCK	P. VAN	PASS. AIR	CARGO AIR	RAIL	SHIP-1	SHIP-2	TRUCK-2	CVAN-1	CVAN-2
U-F6E-HEX	0.	0	0.	0.	0.	1300.	0.	0.	0.	0.
U-F6D-HEX	0.	[illegible]	0.	0.	800.	0.	0.	0.	0.	0.
SFUEL-FP	0.	0.	0.	0.	0.	1000.	1000.	0.	0.	0.
SFUEL-EXT	0.	0.	0.	0.	0.	1000.	1000.	0.	0.	0.
CO60 -SEAL	0.	0.	0.	0.	0.	1000.	0.	0.	0.	0.
CO60 -UNS1	0.	0.	0.	0.	0.	1000.	0.	0.	0.	0.
CO60 -UNS2	20.	0.	0.	0.	400.	0.	0.	0.	0.	0.

PACKAGE CHARACTERISTICS

TYPE	DIMENSION (METER)	SHAPE FACTOR(KO) (SQ M)
A-1	.44	1.49
B-1	.64	1.74
CASK-EX1	5.50	14.06
CASK-REL	5.50	14.06
BPU	.64	1.74
DRUM	.55	1.63
A-2	1.50	3.06
B-2	1.50	3.06
CASK-EX2	1.00	2.25
EXEMPT	.12	1.12

DOSE INFORMATION	TRUCK	P. VAN	PASS. AIR	CARGO AIR	RAIL	SHIP-1	SHIP-2	TRUCK-2	CVAN-1	CVAN-2
FRACTION OF TRAVEL IN RURAL POPULATION ZONE	.800	5.000E-02	.950	.950	.800	.990	.900	.900	5.000E-02	5.000E-02
FRACTION OF TRAVEL IN SUBURBAN POPULATION ZONE	.150	.400	3.000E-02	3.000E-02	.150	1.000E-02	.100	8.000E-02	.400	.400
FRACTION OF TRAVEL IN URBAN POPULATION ZONE	5.000E-02	.550	2.000E-02	2.000E-02	5.000E-02	0.	0.	2.000E-02	.550	.550
VELOCITY IN RURAL POPULATION ZONE(KM/H)	70.0	90.0	600.	600.	90.0	18.0	18.0	50.0	90.0	90.0
VELOCITY IN SUBURBAN POP. ZONE (KM/H)	50.0	50.0	600.	600.	70.0	14.0	14.0	30.0	50.0	50.0
VELOCITY IN URBAN POPULATION ZONE(KM/H)	30.0	30.0	600.	600.	50.0	5.00	5.00	15.0	30.0	30.0
NUMBER OF CREWMEN	2.00	1.00	3.00	3.00	2.00	20.0	10.0	2.00	1.00	1.00
DISTANCE FROM SOURCE TO CREW (METERS)	3.00	2.00	15.0	6.00	150.	50.0	25.0	6.00	2.00	2.00
NUMBER OF HANDLINGS	2.00	1.00	2.00	2.00	2.00	2.00	2.00	2.00	1.00	1.00
STOP TIME PER 24-HOUR TRIP(HR)	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
PERSONS EXPOSED WHILE STOPPED	50.0	100.	1.000E+03	50.0	50.0	50.0	50.0	10.0	100.	100.
AVERAGE EXPOSURE DISTANCE (WHILE STOPPED)	20.0	10.0	50.0	50.0	20.0	50.0	50.0	20.0	10.0	10.0
STORAGE TIME	2.00	4.00	0.	0.	24.0	48.0	24.0	0.	4.00	4.00
NUMBER OF EXPOSED PERSONS--STORAGE	100.	100.	0.	0.	100.	100.	100.	0.	100.	100.
AVERAGE EXPOSURE DISTANCE (WHILE IN STORAGE)	100.	100.	0.	0.	100.	100.	100.	0.	100.	100.
NUMBER OF PEOPLE PER VEHICLE	2.00	2.00	110.	0.	300.	0.	0.	2.00	2.00	2.00
FRACTION TRAVEL IN URBAN POP. ZONE DURING RUSH HOUR TRAFFIC	8.000E-02	.170	0.	0.	0.	0.	0.	8.000E-02	.170	.170
FRACTION TRAVEL ON CITY STS.	5.000E-02	.650	0.	0.	0.	0.	0.	5.000E-02	.650	.650
FRACTION TRAVEL ON FREEWAYS	.500	.250	0.	0.	0.	0.	0.	.500	.250	.250
TRAFFIC COUNT PASSING A SPECIFIC POINT-RURAL POP.	250.	250.	0.	0.	2.00	0.	0.	250.	250.	250.
TRAFFIC COUNT PASSING A SPECIFIC POINT-SUBURBAN POP.	700.	700.	0.	0.	5.00	0.	0.	700.	700.	700.
TRAFFIC COUNT PASSING A SPECIFIC POINT-URBAN POP.	1.200E+03	1.200E+03	0.	0.	5.00	0.	0.	1.200E+03	1.200E+03	1.200E+03

NUMBER OF ATTENDANTS PER FLIGHT IS 4.

OPTION KODE FOR URBAN ZONE= 2

PEDEST. DEN. RATIO= 6.000E+00
SUBURB. SHIELD. RATIO= 5.000E-01
URBAN SHIELD. RATIO= 5.000E-02

DOSE RATE LIMIT OF 2 MREM/HR IS USED FOR CREW ON EXCLUSIVE-USE VEHICLES

FIGURE 6.3

ACCIDENT INPUT DATA

NO.	MATERIAL	PKG TYPE	PPS	CI/PKG	PHTON ENG (MEV)	RESUSP	HALF LIFE (DAYS)	DEP. VEL. (M/S)	LUNG TYPE	DISP CAT
1	U-F6E-HEX	B-2	10.	2.300E+00	3.000E-02	1.128E+00	1.650E+12	2.000E-03	4	6
2	U-F6D-HEX	A-2	6.	2.300E+00	1.320E-01	1.128E+00	1.650E+12	2.000E-03	4	6
3	SFUEL-FP	CASK-REL	10.	6.000E+02	6.000E-01	1.126E+00	1.100E+04	2.000E-03	3	7
4	SFUEL-EXT	CASK-EX1	10.	2.800E+06	6.000E-01	1.126E+00	1.100E+04	2.000E-03	3	1
5	CO60 -SEAL	CASK-EX2	1.	1.000E+04	2.500E+00	1.122E+00	1.920E+03	2.000E-03	3	1
6	CO60 -UNS1	B-1	1.	1.000E+01	2.500E+00	1.122E+00	1.920E+03	2.000E-03	3	1
7	CO60 -UNS2	B-1	3.	1.000E+01	2.500E+00	1.122E+00	1.920E+03	2.000E-03	3	1

FRACTION OF MATERIAL WHICH ESCAPES IN AEROSOL FORM

MATERIAL — SEVERITY CATEGORIES

DISP.CAT.	1	2	3	4	5	6	7	8	9	10	11
1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
2	3.00E-05	3.00E-05	3.00E-05	3.00E-05	3.00E-04	3.00E-04	8.00E-04	3.00E-04	1.00E-03	3.00E-03	1.00E-02
3	3.00E-04	3.00E-04	3.00E-04	3.00E-04	3.00E-04	3.00E-04	8.00E-04	3.00E-04	1.00E-03	3.00E-03	1.00E-02
4	3.00E-03	3.00E-03	3.00E-03	3.00E-03	3.00E-03	3.00E-03	8.00E-03	3.00E-03	1.00E-02	3.00E-02	1.00E-01
5	3.00E-05	3.00E-05	3.00E-05	3.00E-05	3.00E-05	3.00E-05	8.00E-05	3.00E-05	1.00E-04	3.00E-04	1.00E-03
6	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-02	1.00E-01	1.00E+00	1.00E-01	1.00E-01	1.00E-01	1.00E+00
7	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-02	1.00E-01	1.00E+00	1.00E-01	1.00E-01	1.00E-01	1.00E+00
8	8.00E-04	8.00E-04	8.00E-04	8.00E-04	8.00E-04	4.00E-03	4.00E-03	4.00E-03	4.00E-03	8.00E-03	1.00E-02
9	8.00E-03	8.00E-03	8.00E-03	8.00E-03	8.00E-03	4.00E-02	4.00E-02	4.00E-02	4.00E-02	8.00E-02	1.00E-01
10	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00
11	3.00E-05	3.00E-05	3.00E-05	3.00E-05	1.00E-01	1.00E+00	1.00E+00	1.00E-01	1.00E-01	1.00E+00	1.00E+00

FRACTION OF AEROSOL LESS THAN 10 MICRONS AERODYNAMIC DIAMETER

MATERIAL — SEVERITY CATEGORIES

DISP.CAT.	1	2	3	4	5	6	7	8	9	10	11
1	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00
2	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00
3	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00
4	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00
5	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00
6	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00
7	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00
8	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00
9	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00
10	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00
11	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00

PACKAGE FAILURE FRACTIONS

SEVERITY CATEGORIES

PACKAGE TYPE	1	2	3	4	5	6	7	8	9	10	11
A-1	0.	1.00E-01	1.00E+00	1.00E+00	1.00E-01	1.00E+00	1.00E+00	1.00E-01	1.00E+00	1.00E+00	1.00E+00
B-1	0.	0.	1.00E-01	1.00E+00	0.	1.00E-01	1.00E+00	0.	1.00E-01	1.00E-01	1.00E+00
CASK-EX1	0.	0.	0.	1.00E-04	0.	0.	1.00E-04	0.	0.	0.	1.00E-04
CASK-REL	0.	0.	1.00E-01	1.00E+00	0.	1.00E-01	1.00E+00	0.	1.00E-01	1.00E-01	1.00E+00
BPU	0.	0.	0.	1.00E-01	0.	0.	1.00E-01	0.	0.	0.	1.00E-01
DRUM	0.	1.00E-01	1.00E+00	1.00E+00	1.00E-01	1.00E+00	1.00E+00	1.00E-01	1.00E+00	1.00E+00	1.00E+00
A-2	0.	1.00E-01	1.00E+00	1.00E+00	1.00E-01	1.00E+00	1.00E+00	1.00E-01	1.00E+00	1.00E+00	1.00E+00
B-2	0.	0.	1.00E-01	1.00E+00	0.	1.00E-01	1.00E+00	0.	1.00E-01	1.00E-01	1.00E+00
CASK-EX2	0.	0.	0.	3.00E-04	0.	0.	3.00E-04	0.	0.	0.	3.00E-04
EXEMPT	1.00E-01	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00

FIGURE 6.4

ACCIDENT RATE PER KM AND SEVERITY FRACTIONS

MODE	ACCIDENT RATE	SEVERITY CATEGORIES 1	2	3	4	5	6	7	8	9	10	11
TRUCK	1.00E-06	7.15E-01	2.65E-01	1.27E-02	5.60E-04	5.30E-03	4.50E-04	6.40E-04	3.70E-04	1.80E-05	3.30E-05	4.80E-05
P. VAN	1.00E-06	3.94E-01	5.94E-01	4.50E-02	5.00E-03	4.90E-03	4.10E-04	5.90E-04	7.80E-04	6.30E-05	7.10E-05	1.10E-04
PASS. AIR	9.00E-03	5.00E-01	6.12E-02	2.24E-02	7.60E-02	1.49E-01	4.70E-03	1.20E-03	6.81E-02	2.50E-02	2.90E-03	8.80E-02
CARGO AIR	9.00E-08	5.00E-01	6.12E-02	2.24E-02	7.60E-02	1.49E-01	4.70E-03	1.20E-03	6.81E-02	2.50E-02	2.90E-03	8.80E-02
RAIL	3.00E-07	8.02E-01	1.72E-01	6.80E-03	4.10E-03	6.30E-03	3.80E-03	2.50E-03	8.70E-04	3.40E-05	5.40E-04	4.00E-04
SHIP-1	5.00E-06	9.65E-01	2.64E-02	2.60E-03	2.60E-04	2.10E-03	4.50E-04	2.80E-03	5.60E-05	1.10E-05	1.40E-05	1.60E-04
SHIP-2	5.00E-06	9.65E-01	2.64E-02	2.60E-03	2.60E-04	2.10E-03	4.50E-04	2.80E-03	5.60E-05	1.10E-05	1.40E-05	1.60E-04
TRUCK-2	1.00E-06	8.68E-01	1.15E-01	1.01E-02	8.00E-05	5.50E-03	4.70E-04	6.70E-04	1.60E-04	1.40E-05	1.50E-05	2.10E-05
CVAN-1	1.00E-06	5.92E-01	3.04E-01	1.58E-02	1.60E-03	5.20E-03	4.30E-04	6.20E-04	5.40E-04	2.20E-05	4.70E-05	7.10E-05
CVAN-2	1.00E-06	5.92E-01	3.04E-01	1.58E-02	1.60E-03	5.20E-03	4.30E-04	6.20E-04	5.40E-04	2.20E-05	4.70E-05	7.10E-05

ACCIDENT RISK FACTORS

TRUCK MODE	SEVERITY CATEGORIES 1	2	3	4	5	6	7	8	9	10	11
POPULATION RURAL	4.00E-01	5.00E-01	9.00E-01	1.00E+00	1.00E+00	1.00E+00	1.00E+00	5.00E-01	9.00E-01	9.00E-01	1.00E+00
SUBURBAN	2.30E+00	2.10E+00	1.30E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	2.10E+00	1.30E+00	1.30E+00	1.00E+00
URBAN	2.30E+00	2.10E+00	1.30E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	2.10E+00	1.30E+00	1.30E+00	1.00E+00

P. VAN MODE	SEVERITY CATEGORIES 1	2	3	4	5	6	7	8	9	10	11
POPULATION RURAL	4.00E-01	5.00E-01	9.00E-01	1.00E+00	1.00E+00	1.00E+00	1.00E+00	5.00E-01	9.00E-01	9.00E-01	1.00E+00
SUBURBAN	2.30E+00	2.10E+00	1.30E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	2.10E+00	1.30E+00	1.30E+00	1.00E+00
URBAN	2.30E+00	2.10E+00	1.30E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	2.10E+00	1.30E+00	1.30E+00	1.00E+00

PASS. AIR MODE	SEVERITY CATEGORIES 1	2	3	4	5	6	7	8	9	10	11
POPULATION RURAL	6.00E-01	6.00E-01	6.00E-01	6.00E-01	6.00E-01	6.00E-01	6.00E-01	6.00E-01	6.00E-01	6.00E-01	6.00E-01
SUBURBAN	1.20E+01	1.20E+01	1.20E+01	1.20E+01	1.20E+01	1.20E+01	1.20E+01	1.20E+01	1.20E+01	1.20E+01	1.20E+01
URBAN	4.00E+00	4.00E+00	4.00E+00	4.00E+00	4.00E+00	4.00E+00	4.00E+00	4.00E+00	4.00E+00	4.00E+00	4.00E+00

CARGO AIR MODE	SEVERITY CATEGORIES 1	2	3	4	5	6	7	8	9	10	11
POPULATION RURAL	6.00E-01	6.00E-01	6.00E-01	6.00E-01	6.00E-01	6.00E-01	6.00E-01	6.00E-01	6.00E-01	6.00E-01	6.00E-01
SUBURBAN	1.20E+01	1.20E+01	1.20E+01	1.20E+01	1.20E+01	1.20E+01	1.20E+01	1.20E+01	1.20E+01	1.20E+01	1.20E+01
URBAN	4.00E+00	4.00E+00	4.00E+00	4.00E+00	4.00E+00	4.00E+00	4.00E+00	4.00E+00	4.00E+00	4.00E+00	4.00E+00

RAIL MODE	SEVERITY CATEGORIES 1	2	3	4	5	6	7	8	9	10	11
POPULATION RURAL	5.00E-01	5.00E-01	8.00E-01	1.00E+00	1.00E+00	1.00E+00	1.00E+00	5.00E-01	8.00E-01	8.00E-01	1.00E+00
SUBURBAN	2.50E+00	2.50E+00	1.70E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	2.50E+00	1.70E+00	1.70E+00	1.00E+00
URBAN	4.50E+00	4.50E+00	2.50E+00	1.00E+00	1.00E+00	1.00E+00	1.00E+00	4.50E+00	2.50E+00	2.50E+00	1.00E+00

SHIP-1 MODE	SEVERITY CATEGORIES 1	2	3	4	5	6	7	8	9	10	11
POPULATION RURAL	5.00E-01	5.00E-01	7.00E-01	9.00E-01	1.00E+00	1.00E+00	1.00E+00	5.00E-01	7.00E-01	7.00E-01	9.00E-01
SUBURBAN	5.50E+00	5.50E+00	4.00E+00	2.80E+00	1.00E+00	1.00E+00	1.00E+00	5.50E+00	4.00E+00	4.00E+00	2.80E+00
URBAN	5.50E+00	5.50E+00	4.00E+00	2.80E+00	1.00E+00	1.00E+00	1.00E+00	5.50E+00	4.00E+00	4.00E+00	2.80E+00

SHIP-2 MODE	SEVERITY CATEGORIES 1	2	3	4	5	6	7	8	9	10	11
POPULATION RURAL	5.00E-01	5.00E-01	7.00E-01	9.00E-01	1.00E+00	1.00E+00	1.00E+00	5.00E-01	7.00E-01	7.00E-01	9.00E-01
SUBURBAN	5.50E+00	5.50E+00	4.00E+00	2.80E+00	1.00E+00	1.00E+00	1.00E+00	5.50E+00	4.00E+00	4.00E+00	2.80E+00
URBAN	5.50E+00	5.50E+00	4.00E+00	2.80E+00	1.00E+00	1.00E+00	1.00E+00	5.50E+00	4.00E+00	4.00E+00	2.80E+00

FIGURE 6.5

FIGURE 6.6

EXPECTED LATENT EFFECTS

ORGAN	EFFECTS(PER PERSON REM)
WHOLE BODY	1.25E-04
GONADS	8.00E-05
LLI	5.00E-06
THYROID	5.00E-06
BONE	7.00E-06
50/LUNG	2.00E-05
50/MARROW	2.00E-05
W WHOLE BD	0.

EARLY MORBIDITY THRESHOLD VALUES

ORGAN	THRESHOLD(REM)
1YR/LUNG	3.00E+03
1YR/MARROW	7.50E+01
GONADS	5.00E+01
LLI	1.00E+03
THYROID	1.00E+04

REM/CI TABLE

MATERIAL	1YR/LUNG	1YR/MARROW	GONADS	LLI	THYROID	BONE	50/LUNG	50/MARROW	W WHOLE BD
U-F6C-HEX	9.21E+05	2.00E+05	1.48E+05	4.07E+04	1.48E+05	7.53E+07	9.21E+05	2.23E+06	2.43E+06
U-F6D-HEX	8.60E+05	1.80E+05	1.40E+05	3.90E+04	1.40E+05	7.00E+07	8.60E+05	2.00E+06	2.22E+06
SFUEL-FP	1.60E+04	4.42E+04	5.00E+04	1.62E+04	4.47E+04	4.54E+04	1.60E+04	4.91E+04	4.83E+04
SFUEL-EXT	1.60E+04	4.42E+04	5.00E+04	1.62E+04	4.47E+04	4.54E+04	1.60E+04	4.91E+04	4.83E+04
CO60 -SEAL	6.10E+05	2.80E+04	1.85E+04	2.85E+04	6.01E+04	5.06E+04	1.30E+06	6.45E+04	2.41E+05
CO60 -UNS1	6.10E+05	2.80E+04	1.85E+04	2.85E+04	6.01E+04	5.06E+04	1.30E+06	6.45E+04	2.41E+05
CO60 -UNS2	6.10E+05	2.80E+04	1.85E+04	2.85E+04	6.01E+04	5.06E+04	1.30E+06	6.45E+04	2.41E+05

EARLY FATALITY PROBABILITIES

DOSE(REM)	LUNG-1	LUNG-2	LUNG-3	LUNG-4	MARROW
100000.000	1.000E+00	1.000E+00	1.000E+00	1.000E+00	1.000E+00
80000.000	1.000E+00	1.000E+00	8.500E-01	8.000E-01	1.000E+00
70000.000	1.000E+00	1.000E+00	8.000E-01	5.000E-01	1.000E+00
40000.000	1.000E+00	1.000E+00	7.000E-01	3.000E-01	1.000E+00
30000.000	1.000E+00	1.000E+00	5.000E-01	0.	1.000E+00
25000.000	1.000E+00	1.000E+00	2.000E-01	0.	1.000E+00
20000.000	1.000E+00	1.000E+00	8.000E-02	0.	1.000E+00
10000.000	6.000E-01	6.000E-01	0.	0.	1.000E+00
8000.000	1.000E-01	1.000E-01	0.	0.	1.000E+00
6000.000	6.000E-02	6.000E-02	0.	0.	1.000E+00
4000.000	3.000E-02	3.000E-02	0.	0.	1.000E+00
3000.000	0.	0.	0.	0.	1.000E+00
2000.000	0.	0.	0.	0.	1.000E+00
1000.000	0.	0.	0.	0.	1.000E+00
800.000	0.	0.	0.	0.	1.000E+00
700.000	0.	0.	0.	0.	1.000E+00
600.000	0.	0.	0.	0.	9.940E-01
500.000	0.	0.	0.	0.	9.850E-01
400.000	0.	0.	0.	0.	7.750E-01
300.000	0.	0.	0.	0.	2.250E-01
100.000	0.	0.	0.	0.	0.
75.000	0.	0.	0.	0.	0.
50.000	0.	0.	0.	0.	0.
30.000	0.	0.	0.	0.	0.
15.000	0.	0.	0.	0.	0.
5.000	0.	0.	0.	0.	0.
1.000	0.	0.	0.	0.	0.
.100	0.	0.	0.	0.	0.
.010	0.	0.	0.	0.	0.
.001	0.	0.	0.	0.	0.

PASQUILL CATEGORY FREQUENCY DATA

	A	B	C	D	E	F
FREQUENCY	0.	0.	0.	0.	0.	1.00

METEOROLOGICAL INPUT DATA

ISODOSE AREA(SQ M)	INTEGRATED DILUTION FACTORS (CI-S/CUB M) FOR PASQUILL CATEGORIES A	B	C	D	E	F	WEIGHTED DILUTION FACTORS
4.60E+02	6.00E-03	4.00E-03	4.00E-03	4.30E-03	9.60E-03	6.20E-02	6.20E-02
1.50E+03	1.70E-03	1.30E-03	1.10E-03	1.30E-03	3.20E-03	1.80E-02	1.80E-02
3.90E+03	8.40E-03	5.50E-04	5.70E-04	6.50E-04	1.60E-03	8.40E-03	8.40E-03
1.30E+04	1.70E-04	1.30E-04	1.30E-04	1.80E-04	4.00E-04	2.00E-03	2.00E-03
3.00E+04	7.80E-05	6.00E-05	6.70E-05	9.50E-05	2.10E-04	9.20E-04	9.20E-04
6.90E+04	2.80E-05	2.70E-05	3.00E-05	4.30E-05	1.40E-04	4.40E-04	4.40E-04
1.80E+05	3.00E-06	1.00E-05	1.00E-05	1.80E-05	4.40E-05	2.00E-04	2.00E-04
4.50E+05	2.20E-06	3.50E-06	5.00E-06	6.50E-06	2.10E-05	1.00E-04	1.00E-04
8.60E+05	9.00E-07	1.60E-06	2.80E-06	5.00E-06	1.20E-05	6.20E-05	6.20E-05
2.60E+06	1.40E-07	4.10E-07	1.00E-06	1.90E-06	4.80E-06	2.60E-05	2.60E-05
4.50E+06	7.00E-08	2.20E-07	6.00E-07	1.30E-06	3.60E-06	1.90E-05	1.90E-05
1.70E+07	1.10E-08	5.00E-08	1.70E-07	4.00E-07	1.40E-06	8.40E-06	8.40E-06
2.20E+07	4.00E-09	3.20E-08	1.30E-07	3.00E-07	1.60E-06	7.00E-06	7.00E-06
5.50E+07	5.80E-10	1.10E-08	5.70E-08	1.50E-07	6.00E-07	4.00E-06	4.00E-06
1.30E+0[illegible]	7.00E-12	2.50E-09	1.70E-08	5.50E-08	2.80E-07	2.00E-06	2.00E-06

INPUT PARAMETERS--

BUILD.DOSE.FACT 1.000E-01
CONTAM. CLEAN-UP LEV. 1.000E-01 (MICRO CI PER M SQ)
BREATH RATE 3.300E-04 (CUB M/SEC)

FIGURE 6.7

FIGURE 6.8

NORMAL CASE OUTPUT FROM TRANSPORTATION OF U-F6E-HEX BY SHIP-1

POPULATION DOSE (PERSON-REM) SHIP-1

DOSE TO PASSENGERS	0.
DOSE TO CREW	0.
DOSE TO CREW (EXCLUSIVE USE)	4.472E-02
DOSE TO ATTENDANTS	0.
DOSE TO HANDLERS	0.
DOSE TO HANDLERS (EXCLUSIVE USE)	2.188E-01
DOSE TO SURROUNDING POP. WHILE UNDERWAY	2.567E-03
DOSE TO PEOPLE TRAVELING ON TRANSPORT LINK	0.
DOSE TO SURROUNDING POP. WHILE STOPPED	3.697E-02
DOSE WHILE IN WAREHOUSE STORAGE	3.676E-02

FIGURE 6.9

ACCIDENT CASE OUTPUT FROM TRANSPORTATION OF U-F6D-HEX BY RAIL

METEOROLOGICAL DATA TABULATION

I	INITIAL AREA	INITIAL CHI	RECOMPUTED CHI	CONTAM. (CI)	CUMULATIVE LVL(MUCI)	DEP(CI)
1	4.600E+02	6.200E-02	6.200E-02			
2	1.500E+03	1.300E-02	1.798E-02	6.945E-02	3.596E+01	6.945E-02
3	3.900E+03	8.400E-03	7.801E-03	5.685E-02	1.560E+01	1.263E-01
4	1.300E+04	2.000E-03	1.745E-03	6.715E-02	3.490E+00	1.934E-01
5	3.000E+04	9.200E-04	7.407E-04	3.865E-02	1.481E+00	2.321E-01
6	6.900E+04	4.400E-04	3.375E-04	3.900E-02	6.750E-01	2.711E-01
7	1.800E+05	2.000E-04	1.456E-04	4.921E-02	2.912E-01	3.203E-01
8	4.500E+05	1.000E-04	6.787E-05	5.368E-02	1.357E-01	3.740E-01
9	8.600E+05	6.200E-05	3.875E-05	4.205E-02	7.750E-02	4.160E-01
10	2.600E+06	2.600E-05	1.515E-05	8.433E-02	3.031E-02	5.004E-01
11	4.500E+06	1.900E-05	9.483E-06	4.555E-02	1.897E-02	5.459E-01
12	1.700E+07	8.400E-06	3.809E-06	1.503E-01	7.618E-03	6.962E-01
13	2.200E+07	7.000E-06	2.124E-06	2.844E-02	4.248E-03	7.246E-01
14	5.500E+07	4.000E-06	1.100E-06	1.009E-01	2.200E-03	8.255E-01
15	1.800E+08	2.000E-06	3.484E-07	1.547E-01	6.967E-04	9.802E-01

INDIVIDUAL DOSE TABLES FOR U-F6D-HEX
TRANSPORTED BY RAIL (REM)

RURAL AND SUBURBAN--SEVERITY 1 W/O RESUSP. U-F6D-HEX

AREA	1YR/LUNG	1YR/MARROW	GONADS	LLI	THYROID	ORGAN BONE	50/LUNG	50/MARROW	W WHOLE BD
4.600E+02	0.	0.	0.	0.	0.	0.	0.	0.	0.
1.500E+03	0.	0.	0.	0.	0.	0.	0.	0.	0.
3.900E+03	0.	0.	0.	0.	0.	0.	0.	0.	0.
1.300E+04	0.	0.	0.	0.	0.	0.	0.	0.	0.
3.000E+04	0.	0.	0.	0.	0.	0.	0.	0.	0.
6.900E+04	0.	0.	0.	0.	0.	0.	0.	0.	0.
1.800E+05	0.	0.	0.	0.	0.	0.	0.	0.	0.
4.500E+05	0.	0.	0.	0.	0.	0.	0.	0.	0.
8.600E+05	0.	0.	0.	0.	0.	0.	0.	0.	0.
2.600E+06	0.	0.	0.	0.	0.	0.	0.	0.	0.
4.500E+06	0.	0.	0.	0.	0.	0.	0.	0.	0.
1.700E+07	0.	0.	0.	0.	0.	0.	0.	0.	0.
2.200E+07	0.	0.	0.	0.	0.	0.	0.	0.	0.
5.500E+07	0.	0.	0.	0.	0.	0.	0.	0.	0.
1.800E+08	0.	0.	0.	0.	0.	0.	0.	0.	0.

RURAL AND SUBURBAN--SEVERITY 2 W/O RESUSP. U-F6D-HEX

AREA	1YR/LUNG	1YR/MARROW	GONADS	LLI	THYROID	ORGAN BONE	50/LUNG	50/MARROW	W WHOLE BD
4.600E+02	2.428E-02	5.032E-03	3.953E-03	1.101E-03	3.953E-03	1.976E+00	2.428E-02	5.647E-02	6.268E-02
1.500E+03	7.042E-03	1.474E-03	1.146E-03	3.193E-04	1.146E-03	5.732E-01	7.042E-03	1.638E-02	1.818E-02
3.900E+03	3.055E-03	6.395E-04	4.974E-04	1.386E-04	4.974E-04	2.487E-01	3.055E-03	7.105E-03	7.887E-03
1.300E+04	6.833E-04	1.430E-04	1.112E-04	3.099E-05	1.112E-04	5.562E-02	6.833E-04	1.589E-03	1.764E-03
3.000E+04	2.901E-04	6.072E-05	4.722E-05	1.316E-05	4.722E-05	2.361E-02	2.901E-04	6.746E-04	7.488E-04
6.900E+04	1.322E-04	2.767E-05	2.152E-05	5.995E-06	2.152E-05	1.076E-02	1.322E-04	3.074E-04	3.412E-04
1.800E+05	5.702E-05	1.194E-05	9.283E-06	2.586E-06	9.283E-06	4.641E-03	5.702E-05	1.326E-04	1.472E-04
4.500E+05	2.658E-05	5.563E-06	4.327E-06	1.205E-06	4.327E-06	2.164E-03	2.658E-05	6.182E-05	6.862E-05
8.600E+05	1.518E-05	3.176E-06	2.471E-06	6.882E-07	2.471E-06	1.235E-03	1.518E-05	3.529E-05	3.918E-05
2.600E+06	5.935E-06	1.242E-06	9.661E-07	2.691E-07	9.661E-07	4.831E-04	5.935E-06	1.380E-05	1.532E-05
4.500E+06	3.714E-06	7.773E-07	6.046E-07	1.684E-07	6.046E-07	3.023E-04	3.714E-06	8.637E-06	9.587E-06
1.700E+07	1.492E-06	3.122E-07	2.429E-07	6.765E-08	2.429E-07	1.214E-04	1.492E-06	3.469E-06	3.851E-06
2.200E+07	8.318E-07	1.741E-07	1.354E-07	3.772E-08	1.354E-07	6.770E-05	8.318E-07	1.934E-06	2.147E-06
5.500E+07	4.307E-07	9.015E-08	7.012E-08	1.953E-08	7.012E-08	3.506E-05	4.307E-07	1.002E-06	1.112E-06
1.800E+08	1.364E-07	2.856E-08	2.221E-08	6.187E-09	2.221E-08	1.111E-05	1.364E-07	3.173E-07	3.522E-07

FIGURE 6.10

CONSEQUENCE SUMMARY FOR U-F6D-HEX TRANSPORTED BY RAIL

EXPECTED NUMBER OF PEOPLE IN ISODOSE AREAS

AREA(SQ M)	RURAL	SUBURBAN	URBAN	PEDESTRIAN
4.600E+02- 1.500E+03	5.200E-02	5.200E-01	5.200E+00	3.120E+00
1.500E+03- 3.900E+03	1.200E-01	1.200E+00	1.200E+01	7.200E+00
3.900E+03- 1.300E+04	4.550E-01	4.550E+00	4.550E+01	2.730E+01
1.300E+04- 3.000E+04	8.500E-01	8.500E+00	8.500E+01	5.100E+01
3.000E+04- 6.900E+04	1.950E+00	1.950E+01	1.950E+02	1.170E+02
6.900E+04- 1.800E+05	5.550E+00	5.550E+01	5.550E+02	3.330E+02
1.800E+05- 4.500E+05	1.350E+01	1.350E+02	1.350E+03	8.100E+02
4.500E+05- 8.600E+05	2.050E+01	2.050E+02	2.050E+03	1.230E+03
8.600E+05- 2.600E+06	8.700E+01	8.700E+02	8.700E+03	5.220E+03
2.600E+06- 4.500E+06	9.500E+01	9.500E+02	9.500E+03	5.700E+03
4.500E+06- 1.700E+07	6.250E+02	6.250E+03	6.250E+04	3.750E+04
1.700E+07- 2.200E+07	2.500E+02	2.500E+03	2.500E+04	1.500E+04
2.200E+07- 5.500E+07	1.650E+03	1.650E+04	1.650E+05	9.900E+04
5.500E+07- 1.800E+08	6.250E+03	6.250E+04	6.250E+05	3.750E+05

EARLY FATALITY CONSEQUENCE SUMMARY U-F6D-HEX

SEVERITY CATEGORY	RURAL EARLY FAT.	RURAL EXP. NO. OF ACC/YEAR	SUBURBAN EARLY FAT.	SUBURBAN EXP. NO. OF ACC/YEAR	URBAN EARLY FAT.	URBAN EXP. NO. OF ACC/YEAR
1	0.	1.54E-03	0.	1.44E-03	0.	8.67E-04
2	0.	3.31E-04	0.	3.10E-04	0.	1.86E-04
3	0.	2.09E-05	0.	8.32E-06	0.	4.08E-06
4	0.	1.57E-05	0.	2.95E-06	0.	9.84E-07
5	0.	2.42E-05	0.	4.54E-06	0.	1.51E-06
6	0.	1.46E-05	0.	2.74E-06	0.	9.12E-07
7	0.	9.60E-06	0.	1.80E-06	0.	6.00E-07
8	0.	1.67E-06	0.	1.57E-06	0.	9.40E-07
9	0.	1.04E-07	0.	4.16E-08	0.	2.04E-08
10	0.	1.66E-06	0.	6.61E-07	0.	3.24E-07
11	0.	1.54E-06	0.	2.88E-07	0.	9.60E-08

EARLY MORBIDITY CONSEQUENCE SUMMARY U-F6D-HEX

SEVERITY CATEGORY	RURAL EARLY MOR.	RURAL EXP. NO. OF ACC/YEAR	SUBURBAN EARLY MOR.	SUBURBAN EXP. NO. OF ACC/YEAR	URBAN EARLY MOR.	URBAN EXP. NO. OF ACC/YEAR
1	0.	1.54E-03	0.	1.44E-03	0.	8.67E-04
2	0.	3.31E-04	0.	3.10E-04	0.	1.86E-04
3	0.	2.09E-05	0.	8.32E-06	0.	4.08E-06
4	0.	1.57E-05	0.	2.95E-06	0.	9.84E-07
5	0.	2.42E-05	0.	4.54E-06	0.	1.51E-06
6	0.	1.46E-05	0.	2.74E-06	0.	9.12E-07
7	0.	9.60E-06	0.	1.80E-06	0.	6.00E-07
8	0.	1.67E-06	0.	1.57E-06	0.	9.40E-07
9	0.	1.04E-07	0.	4.16E-08	0.	2.04E-08
10	0.	1.66E-06	0.	6.61E-07	0.	3.24E-07
11	0.	1.54E-06	0.	2.88E-07	0.	9.60E-08

LATENT CANCER FATALITY CONSEQUENCE SUMMARY U-F6D-HEX

SEVERITY CATEGORY	RURAL LCF	RURAL EXP. NO. OF ACC/YEAR	SUBURBAN LCF	SUBURBAN EXP. NO. OF ACC/YEAR	URBAN LCF	URBAN EXP. NO. OF ACC/YEAR
1	0.	1.54E-03	0.	1.44E-03	0.	8.67E-04
2	8.15E-06	3.31E-04	8.15E-05	3.10E-04	6.84E-04	1.86E-04
3	8.05E-05	2.09E-05	8.05E-04	8.32E-06	6.68E-03	4.08E-06
4	8.05E-05	1.57E-05	8.05E-04	2.95E-06	6.68E-03	9.84E-07
5	8.05E-05	2.42E-05	8.05E-04	4.54E-06	6.68E-03	1.51E-06
6	7.76E-03	1.46E-05	7.76E-02	2.74E-06	6.20E-01	9.12E-07
7	7.51E-02	9.60E-06	7.51E-01	1.80E-06	5.80E+00	6.00E-07
8	7.93E-04	1.67E-06	7.93E-03	1.57E-06	6.48E-02	9.40E-07
9	7.76E-03	1.04E-07	7.76E-02	4.16E-08	6.20E-01	2.04E-08
10	7.76E-03	1.66E-06	7.76E-02	6.61E-07	6.20E-01	3.24E-07
11	7.51E-02	1.54E-06	7.51E-01	2.88E-07	5.80E+00	9.60E-08

FIGURE 6.11

GENETIC EFFECT CONSEQUENCE SUMMARY U-F6D-HEX

SEVERITY CATEGORY	RURAL GEN. EFF.	RURAL EXP. NO. OF ACC/YEAR	SUBURBAN GEN. EFF.	SUBURBAN EXP. NO. OF ACC/YEAR	URBAN GEN. EFF.	URBAN EXP. NO. OF ACC/YEAR
1	0.	1.54E-03	0.	1.44E-03	0.	8.67E-04
2	9.45E-07	3.31E-04	9.45E-06	3.10E-04	1.38E-04	1.86E-04
3	8.80E-06	2.09E-05	8.80E-05	8.32E-06	1.28E-03	4.08E-06
4	8.80E-06	1.57E-05	8.80E-05	2.95E-06	1.28E-03	9.84E-07
5	8.80E-06	2.42E-05	8.80E-05	4.54E-06	1.28E-03	1.51E-06
6	6.90E-04	1.46E-05	6.90E-03	2.74E-06	9.77E-02	9.12E-07
7	5.31E-03	9.60E-06	5.31E-02	1.80E-06	7.23E-01	6.00E-07
8	8.01E-05	1.67E-06	8.01E-04	1.57E-06	1.16E-02	9.40E-07
9	6.90E-04	1.04E-07	6.90E-03	4.16E-08	9.77E-02	2.04E-08
10	6.90E-04	1.66E-06	6.90E-03	6.61E-07	9.77E-02	3.24E-07
11	5.31E-03	1.54E-06	5.31E-02	2.88E-07	7.23E-01	9.60E-08

NUMBER OF PERSONS RECEIVING A SPECIFIC WEIGHTED WHOLE-BODY DOSE (REM)

RURAL ZONE

SEVERITY CATEGORY	DOSE LESS THAN 1.0E-01	DOSE BETWEEN 1.0E-01 AND 5.0E+00	DOSE MORE THAN 5.0E+00	EXP. NO. OF ACC/YR
1	0.	0.	0.	1.54E-03
2	9.00E+03	0.	0.	3.31E-04
3	9.00E+03	1.72E-01	0.	2.09E-05
4	9.00E+03	1.72E-01	0.	1.57E-05
5	9.00E+03	1.72E-01	0.	2.42E-05
6	8.98E+03	2.19E+01	6.27E-01	1.46E-05
7	8.77E+03	2.22E+02	3.43E+00	9.60E-06
8	9.00E+03	1.43E+00	5.20E-02	1.67E-06
9	8.98E+03	2.19E+01	6.27E-01	1.04E-07
10	8.98E+03	2.19E+01	6.27E-01	1.66E-06
11	8.77E+03	2.22E+02	3.43E+00	1.54E-06

NUMBER OF PERSONS RECEIVING A SPECIFIC WEIGHTED WHOLE-BODY DOSE (REM)

SUBURBAN ZONE

SEVERITY CATEGORY	DOSE LESS THAN 1.0E-01	DOSE BETWEEN 1.0E-01 AND 5.0E+00	DOSE MORE THAN 5.0E+00	EXP. NO. OF ACC/YR
1	0.	0.	0.	1.44E-03
2	9.00E+04	0.	0.	3.10E-04
3	9.00E+04	1.72E+00	0.	8.32E-06
4	9.00E+04	1.72E+00	0.	2.95E-06
5	9.00E+04	1.72E+00	0.	4.54E-06
6	8.98E+04	2.19E+02	6.27E+00	2.74E-06
7	8.77E+04	2.22E+03	3.43E+01	1.80E-06
8	9.00E+04	1.43E+01	5.20E-01	1.57E-06
9	8.98E+04	2.19E+02	6.27E+00	4.16E-08
10	8.98E+04	2.19E+02	6.27E+00	6.61E-07
11	8.77E+04	2.22E+03	3.43E+01	2.88E-07

NUMBER OF PERSONS RECEIVING A SPECIFIC WEIGHTED WHOLE-BODY DOSE (REM)

URBAN ZONE

SEVERITY CATEGORY	DOSE LESS THAN 1.0E-01	DOSE BETWEEN 1.0E-01 AND 5.0E+00	DOSE MORE THAN 5.0E+00	EXP. NO. OF ACC/YR
1	0.	0.	0.	8.67E-04
2	1.44E+06	0.	0.	1.86E-04
3	1.44E+06	1.03E+01	0.	4.08E-06
4	1.44E+06	1.03E+01	0.	9.84E-07
5	1.44E+06	1.03E+01	0.	1.51E-06
6	1.44E+06	1.45E+03	4.28E+01	9.12E-07
7	1.42E+06	1.55E+04	2.68E+02	6.00E-07
8	1.44E+06	1.03E+02	3.12E+00	9.40E-07
9	1.44E+06	1.45E+03	4.28E+01	2.04E-08
10	1.44E+06	1.45E+03	4.28E+01	3.24E-07
11	1.42E+06	1.55E+04	2.68E+02	9.60E-08

NORMAL CASE OUTPUT FROM TRANSPORTATION OF CO60 -UNS2 BY RAIL AND TRUCK

WARNING -- DOSE RATE AT 1 METER= 17.400 MORE THAN 10 MREM/HR, FOR CO60 -UNS2 RAIL

POPULATION DOSE (PERSON-REM) RAIL	
DOSE TO PASSENGERS	0.
DOSE TO CREW	5.228E-05
DOSE TO CREW (EXCLUSIVE USE)	0.
DOSE TO ATTENDANTS	0.
DOSE TO HANDLERS	1.212E-01
DOSE TO HANDLERS (EXCLUSIVE USE)	0.
DOSE TO SURROUNDING POP. WHILE UNDERWAY	7.123E-04
DOSE TO PEOPLE TRAVELING ON TRANSPORT LINK	3.910E-03
DOSE TO SURROUNDING POP. WHILE STOPPED	1.397E-02
DOSE WHILE IN WAREHOUSE STORAGE	2.910E-02

POPULATION DOSE (PERSON-REM) TRUCK	
DOSE TO PASSENGERS	0.
DOSE TO CREW	8.742E-03
DOSE TO CREW (EXCLUSIVE USE)	0.
DOSE TO ATTENDANTS	0.
DOSE TO HANDLERS	1.212E-01
DOSE TO HANDLERS (EXCLUSIVE USE)	0.
DOSE TO SURROUNDING POP. WHILE UNDERWAY	1.251E-04
DOSE TO PEOPLE TRAVELING ON TRANSPORT LINK	4.303E-04
DOSE TO SURROUNDING POP. WHILF STOPPED	7.578E-03
DOSE WHILE IN WAREHOUSE STORAGE	2.425E-03

FIGURE 6.12

ACCIDENT CASE OUTPUT FROM TRANSPORTATION OF CO60 -UNS2 BY RAIL AND TRUCK

INDIVIDUAL DOSE TABLES FOR CO60 -UNS2
TRANSPORTED BY RAIL (REM)

DOSE VS DISTANCE BY SEVERITY CO60 -UNS2
RURAL
DOSE(REM)

DISTANCE (METRES)	1	2	3	4	5	6	7	8	9	10	11
10.	0.	0.	3.75E-02	3.75E-01	0.	3.75E-02	3.75E-01	0.	3.75E-02	3.75E-02	3.75E-01
20.	0.	0.	9.38E-03	9.38E-02	0.	9.38E-03	9.38E-02	0.	9.38E-03	9.38E-03	9.38E-02
30.	0.	0.	4.17E-03	4.17E-02	0.	4.17E-03	4.17E-02	0.	4.17E-03	4.17E-03	4.17E-02
40.	0.	0.	2.34E-03	2.34E-02	0.	2.34E-03	2.34E-02	0.	2.34E-03	2.34E-03	2.34E-02
50.	0.	0.	1.50E-03	1.50E-02	0.	1.50E-03	1.50E-02	0.	1.50E-03	1.50E-03	1.50E-02
100.	0.	0.	3.75E-04	3.75E-03	0.	3.75E-04	3.75E-03	0.	3.75E-04	3.75E-04	3.75E-03
200.	0.	0.	9.38E-05	9.38E-04	0.	9.38E-05	9.38E-04	0.	9.38E-05	9.38E-05	9.38E-04
300.	0.	0.	4.17E-05	4.17E-04	0.	4.17E-05	4.17E-04	0.	4.17E-05	4.17E-05	4.17E-04
500.	0.	0.	1.50E-05	1.50E-04	0.	1.50E-05	1.50E-04	0.	1.50E-05	1.50E-05	1.50E-04
1000.	0.	0.	3.75E-06	3.75E-05	0.	3.75E-06	3.75E-05	0.	3.75E-06	3.75E-06	3.75E-05

DOSE VS DISTANCE BY SEVERITY CO60 -UNS2
SUBURBAN
DOSE(REM)

DISTANCE (METRES)	1	2	3	4	5	6	7	8	9	10	11
10.	0.	0.	3.75E-02	3.75E-01	0.	3.75E-02	3.75E-01	0.	3.75E-02	3.75E-02	3.75E-01
20.	0.	0.	9.38E-03	9.38E-02	0.	9.38E-03	9.38E-02	0.	9.38E-03	9.38E-03	9.38E-02
30.	0.	0.	4.17E-03	4.17E-02	0.	4.17E-03	4.17E-02	0.	4.17E-03	4.17E-03	4.17E-02
40.	0.	0.	2.34E-03	2.34E-02	0.	2.34E-03	2.34E-02	0.	2.34E-03	2.34E-03	2.34E-02
50.	0.	0.	1.50E-03	1.50E-02	0.	1.50E-03	1.50E-02	0.	1.50E-03	1.50E-03	1.50E-02
100.	0.	0.	3.75E-04	3.75E-03	0.	3.75E-04	3.75E-03	0.	3.75E-04	3.75E-04	3.75E-03
200.	0.	0.	9.38E-05	9.38E-04	0.	9.38E-05	9.38E-04	0.	9.38E-05	9.38E-05	9.38E-04
300.	0.	0.	4.17E-05	4.17E-04	0.	4.17E-05	4.17E-04	0.	4.17E-05	4.17E-05	4.17E-04
500.	0.	0.	1.50E-05	1.50E-04	0.	1.50E-05	1.50E-04	0.	1.50E-05	1.50E-05	1.50E-04
1000.	0.	0.	3.75E-06	3.75E-05	0.	3.75E-06	3.75E-05	0.	3.75E-06	3.75E-06	3.75E-05

DOSE VS DISTANCE BY SEVERITY CO60 -UNS2
URBAN
DOSE(REM)

DISTANCE (METRES)	1	2	3	4	5	6	7	8	9	10	11
10.	0.	0.	1.88E-03	1.88E-02	0.	1.88E-03	1.88E-02	0.	1.88E-03	1.88E-03	1.88E-02
20.	0.	0.	4.69E-04	4.69E-03	0.	4.69E-04	4.69E-03	0.	4.69E-04	4.69E-04	4.69E-03
30.	0.	0.	2.08E-04	2.08E-03	0.	2.08E-04	2.08E-03	0.	2.08E-04	2.08E-04	2.08E-03
40.	0.	0.	1.17E-04	1.17E-03	0.	1.17E-04	1.17E-03	0.	1.17E-04	1.17E-04	1.17E-03
50.	0.	0.	7.50E-05	7.50E-04	0.	7.50E-05	7.50E-04	0.	7.50E-05	7.50E-05	7.50E-04
100.	0.	0.	1.88E-05	1.88E-04	0.	1.88E-05	1.88E-04	0.	1.88E-05	1.88E-05	1.88E-04
200.	0.	0.	4.69E-06	4.69E-05	0.	4.69E-06	4.69E-05	0.	4.69E-06	4.69E-06	4.69E-05
300.	0.	0.	2.08E-06	2.08E-05	0.	2.08E-06	2.08E-05	0.	2.08E-06	2.08E-06	2.08E-05
500.	0.	0.	7.50E-07	7.50E-06	0.	7.50E-07	7.50E-06	0.	7.50E-07	7.50E-07	7.50E-06
1000.	0.	0.	1.88E-07	1.88E-06	0.	1.88E-07	1.88E-06	0.	1.88E-07	1.88E-07	1.88E-06

DOSE VS DISTANCE BY SEVERITY CO60 -UNS2
PEDESTRIAN
DOSE(REM)

DISTANCE (METRES)	1	2	3	4	5	6	7	8	9	10	11
10.	0.	0.	9.38E-03	9.38E-02	0.	9.38E-03	9.38E-02	0.	9.38E-03	9.38E-03	9.38E-02
20.	0.	0.	2.34E-03	2.34E-02	0.	2.34E-03	2.34E-02	0.	2.34E-03	2.34E-03	2.34E-02
30.	0.	0.	1.04E-03	1.04E-02	0.	1.04E-03	1.04E-02	0.	1.04E-03	1.04E-03	1.04E-02
40.	0.	0.	5.86E-04	5.86E-03	0.	5.86E-04	5.86E-03	0.	5.86E-04	5.86E-04	5.86E-03
50.	0.	0.	3.75E-04	3.75E-03	0.	3.75E-04	3.75E-03	0.	3.75E-04	3.75E-04	3.75E-03
100.	0.	0.	9.38E-05	9.38E-04	0.	9.38E-05	9.38E-04	0.	9.38E-05	9.38E-05	9.38E-04
200.	0.	0.	2.34E-05	2.34E-04	0.	2.34E-05	2.34E-04	0.	2.34E-05	2.34E-05	2.34E-04
300.	0.	0.	1.04E-05	1.04E-04	0.	1.04E-05	1.04E-04	0.	1.04E-05	1.04E-05	1.04E-04
500.	0.	0.	3.75E-06	3.75E-05	0.	3.75E-06	3.75E-05	0.	3.75E-06	3.75E-06	3.75E-05
1000.	0.	0.	9.38E-07	9.38E-06	0.	9.38E-07	9.38E-06	0.	9.38E-07	9.38E-07	9.38E-06

FIGURE 6.13

FIGURE 6.14

CONSEQUENCE SUMMARY FOR CO60 -UNS2 TRANSPORTED BY RAIL

EXPECTED NUMBER OF PEOPLE IN ANNULAR AREAS

DISTANCE(M)	RURAL	DISTANCE(M)	SUBURBAN	DISTANCE(M)	URBAN	DISTANCE(M)	PEDESTRIAN
20.	0.	20.	0.	20.	5.	20.	7.
30.	0.	30.	1.	30.	8.	30.	7.
40.	0.	40.	1.	40.	11.	40.	7.
50.	0.	50.	1.	50.	14.	50.	7.
100.	1.	100.	12.	100.	118.	100.	36.
200.	5.	200.	47.	200.	471.	200.	72.
300.	8.	300.	79.	300.	785.	300.	72.
500.	25.	500.	251.	500.	2513.	500.	144.
1000.	118.	1000.	1178.	1000.	11781.	1000.	360.

RURAL PERSON-REM SUMMARY CO60 -UNS2

SEVERITY CATEGORIES

ORGAN	1	2	3	4	5	6	7	8	9	10	11
1YR/MARROW	0.	0.	5.42E-03	5.42E-02	0.	5.42E-03	5.42E-02	0.	5.42E-03	5.42E-03	5.42E-02
GONADS	0.	0.	5.42E-03	5.42E-02	0.	5.42E-03	5.42E-02	0.	5.42E-03	5.42E-03	5.42E-02

SUBURBAN PERSON-REM SUMMARY CO60 -UNS2

SEVERITY CATEGORIES

ORGAN	1	2	3	4	5	6	7	8	9	10	11
1YR/MARROW	0.	0.	5.42E-02	5.42E-01	0.	5.42E-02	5.42E-01	0.	5.42E-02	5.42E-02	5.42E-01
GONADS	0.	0.	5.42E-02	5.42E-01	0.	5.42E-02	5.42E-01	0.	5.42E-02	5.42E-02	5.42E-01

URBAN PERSON-REM SUMMARY CO60 -UNS2

SEVERITY CATEGORIES

ORGAN	1	2	3	4	5	6	7	8	9	10	11
1YR/MARROW	0.	0.	2.71E-02	2.71E-01	0.	2.71E-02	2.71E-01	0.	2.71E-02	2.71E-02	2.71E-01
GONADS	0.	0.	2.71E-02	2.71E-01	0.	2.71E-02	2.71E-01	0.	2.71E-02	2.71E-02	2.71E-01

PEDESTRIAN PERSON-REM SUMMARY CO60 -UNS2

SEVERITY CATEGORIES

ORGAN	1	2	3	4	5	6	7	8	9	10	11
1YR/MARROW	0.	0.	1.34E-01	1.34E+00	0.	1.34E-01	1.34E+00	0.	1.34E-01	1.34E-01	1.34E+00
GONADS	0.	0.	1.34E-01	1.34E+00	0.	1.34E-01	1.34E+00	0.	1.34E-01	1.34E-01	1.34E+00

INDIVIDUAL DOSE TABLE FOR CO60 -UNS2
TRANSPORTED BY TRUCK (REM)

INDIVIDUAL DOSES ARE AS ABOVE MULTIPLIED WITH .3333

CONSEQUENCE SUMMARY FOR CO60 -UNS2 TRANSPORTED BY TRUCK

EXPECTED NUMBER OF PEOPLE IN ANNULAR AREAS

DISTANCE(M)	RURAL	DISTANCE(M)	SUBURBAN	DISTANCE(M)	URBAN	DISTANCE(M)	PEDESTRIAN
20.	0.	20.	0.	20.	5.	20.	7.
30.	0.	30.	1.	30.	8.	30.	7.
40.	0.	40.	1.	40.	11.	40.	7.
50.	0.	50.	1.	50.	14.	50.	7.
100.	1.	100.	12.	100.	118.	100.	36.
200.	5.	200.	47.	200.	471.	200.	72.
300.	8.	300.	79.	300.	785.	300.	72.
500.	25.	500.	251.	500.	2513.	500.	144.
1000.	118.	1000.	1178.	1000.	11781.	1000.	360.

RURAL PERSON-REM SUMMARY CO60 -UNS2
SEVERITY CATEGORIES

ORGAN	1	2	3	4	5	6	7	8	9	10	11
1YR/MARROW	0.	0.	1.81E-03	1.81E-02	0.	1.81E-03	1.81E-02	0.	1.81E-03	1.81E-03	1.81E-02
GONADS	0.	0.	1.81E-03	1.81E-02	0.	1.81E-03	1.81E-02	0.	1.81E-03	1.81E-03	1.81E-02

SUBURBAN PERSON-REM SUMMARY CO60 -UNS2
SEVERITY CATEGORIES

ORGAN	1	2	3	4	5	6	7	8	9	10	11
1YR/MARROW	0.	0.	1.81E-02	1.81E-01	0.	1.81E-02	1.81E-01	0.	1.81E-02	1.81E-02	1.81E-01
GONADS	0.	0.	1.81E-02	1.81E-01	0.	1.81E-02	1.81E-01	0.	1.81E-02	1.81E-02	1.81E-01

URBAN PERSON-REM SUMMARY CO60 -UNS2
SEVERITY CATEGORIES

ORGAN	1	2	3	4	5	6	7	8	9	10	11
1YR/MARROW	0.	0.	9.04E-03	9.04E-02	0.	9.04E-03	9.04E-02	0.	9.04E-03	9.04E-03	9.04E-02
GONADS	0.	0.	9.04E-03	9.04E-02	0.	9.04E-03	9.04E-02	0.	9.04E-03	9.04E-03	9.04E-02

PEDESTRIAN PERSON-REM SUMMARY CO60 -UNS2
SEVERITY CATEGORIES

ORGAN	1	2	3	4	5	6	7	8	9	10	11
1YR/MARROW	0.	0.	4.45E-02	4.46E-01	0.	4.45E-02	4.46E-01	0.	4.45E-02	4.45E-02	4.46E-01
GONADS	0.	0.	4.45E-02	4.46E-01	0.	4.45E-02	4.46E-01	0.	4.45E-02	4.45E-02	4.46E-01

FIGURE 6.15

FIGURE 6.16

SUMMARY FOR NORMAL CASE
****

MATERIAL	PRI.MODE	SEC.MODE	TI/YR	DOSE SUM
U-F6E-HEX	SHIP-1		2.500E+01	3.398E-01
U-F6D-HEX	RAIL		1.200E+01	1.335E-01
SFUEL-FP	SHIP-2		0.	0.
SFUEL-EXT	SHIP-2		1.600E+03	6.325E+01
CO60 -SEAL	SHIP-1		1.600E+01	8.375E-02
CO60 -UNS1	SHIP-1		4.060E+01	1.645E-01
CO60 -UNS2	RAIL	TRUCK	2.088E+02	3.095E-01

SUMMATION OF GROUP POPULATION EXPOSURE TO RADIATION IN PERSON REM AS A RESULT OF TRANSPORT OF VARIOUS RADIOACTIVE MATERIALS UNDER NORMAL CONDITIONS

SHIPMENT	PASSENGERS	CREWMEN REG.	CREWMEN EX. USE	ATTENDANTS	HANDLERS REG.	HANDLERS EX. USE	WHILE MOVING OFF LINK	WHILE MOVING ON LINK	STOPS	STORAGE	TOTALS
U-F6E-HEX	0.	0.	4.5E-02	0.	0.	2.2E-01	2.6E-03	0.	3.7E-02	3.7E-02	3.4E-01
U-F6D-HEX	0.	0.	3.2E-05	0.	0.	1.1E-01	7.5E-04	4.1E-03	1.5E-02	8.8E-03	1.3E-01
SFUEL-EXT	0.	0.	1.8E+01	0.	0.	3.0E+01	8.5E-01	0.	8.6E+00	5.4E+00	6.3E+01
CO60 -SEAL	0.	1.6E-02	0.	0.	3.6E-02	0.	9.3E-04	0.	1.3E-02	1.7E-02	8.4E-02
CO60 -UNS1	0.	3.2E-02	0.	0.	7.1E-02	0.	1.8E-03	0.	2.6E-02	3.4E-02	1.6E-01
CO60 -UNS2	0.	8.8E-03	0.	0.	2.4E-01	0.	8.4E-04	4.3E-03	2.2E-02	3.2E-02	3.1E-01
TOTALS	0.	5.7E-02	1.8E+01	0.	3.5E-01	3.0E+01	8.6E-01	8.5E-03	8.7E+00	5.5E+00	6.4E+01

SUMMATION OF GROUP POPULATION EXPOSURE TO RADIATION IN PERSON REM AS A RESULT OF TRANSPORT OF VARIOUS RADIOACTIVE MATERIALS BY VARIOUS TRANSPORT MODES UNDER NORMAL CONDITIONS

SHIPMENT	PASSENGERS	CREWMEN REG.	CREWMEN EX. USE	ATTENDANTS	HANDLERS REG.	HANDLERS EX. USE	WHILE MOVING OFF LINK	WHILE MOVING ON LINK	STOPS	STORAGE	TOTALS
TRUCK	0.	8.7E-03	0.	0.	1.2E-01	0.	1.3E-04	4.3E-04	7.6E-03	2.4E-03	1.4E-01
P. VAN	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
PASS. AIR	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
CARGO AIR	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
RAIL	0.	5.2E-05	3.2E-05	0.	1.2E-01	1.1E-01	1.5E-03	8.0E-03	2.9E-02	3.8E-02	3.0E-01
SHIP-1	0.	4.8E-02	4.5E-02	0.	1.1E-01	2.2E-01	5.3E-03	0.	7.7E-02	8.8E-02	5.9E-01
SHIP-2	0.	0.	1.8E+01	0.	0.	3.0E+01	8.5E-01	0.	8.6E+00	5.4E+00	6.3E+01
TRUCK-2	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
CVAN-1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
CVAN-2	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
TOTALS	0.	5.7E-02	1.8E+01	0.	3.5E-01	3.0E+01	8.6E-01	8.5E-03	8.7E+00	5.5E+00	6.4E+01

FIGURE 6.17

NORMAL SENSITIVITY ANALYSIS SUMMARY
****

	PARAMETER	RELATIVE IMPORTANCE
1	DSTRVL	4.369E-01
2	CAYZER	1.408E+00
3	TI	1.000E+00
4	PPS	1.000E+00
5	SPY	1.000E+00
6	FTZNR	3.640E-01
7	POPDR	1.249E-03
8	VELR	-3.721E-01
9	RS	8.900E-04
10	FTZNS	5.273E-02
11	POPDS	8.901E-04
12	VELS	-5.368E-02
13	FTZNU	8.249E-05
14	POPDU	6.392E-06
15	VELU	-1.201E-04
16	FCTST	4.767E-07
17	RPD	4.468E-08
18	RU	6.347E-06
19	DTST	1.351E-01
20	PDST	1.351E-01
21	RST	-2.702E-01
22	-	0.
23	RSTOR	-1.720E-01
24	DTSTOR	8.599E-02
25	PDSTOR	8.599E-02
26	CREWNO	2.883E-01
27	ADSTCW	-5.767E-01
28	VELM	-4.234E-01
29	HANDNO	4.772E-01
30	PPV	1.317E-04
31	FTLFWY	-3.572E-06
32	TCNTPR	7.660E-05
33	FRSHR	1.926E-06
34	TCNTPS	6.111E-05
35	TCNTPU	3.925E-05
36	PASSENGERS	0.
37	----	0.

RADIOLOGICAL RISK SUMMARY

****

EXPECTED VALUE OF RADIOLOGICAL RISK

NO.	MATERIAL	MODES P	MODES S	EARLY EFFECTS FATAL	EARLY EFFECTS MORT.	LATENT CANCER FATALITIES GRND SHN	LATENT CANCER FATALITIES INHAL	LATENT CANCER FATALITIES RESUSP	LATENT CANCER FATALITIES TOTAL	GENETIC EFFECTS GRND SHN	GENETIC EFFECTS INHAL	GENETIC EFFECTS RESUSP	GENETIC EFFECTS TOTAL
1	U-F6E-HEX	-6	0	0.	5.5E-05	1.0E-06	5.8E-05	7.4E-06	6.6E-05	6.5E-07	1.2E-06	1.5E-07	2.0E-06
2	U-F6D-HEX	-5	0	0.	0.	1.2E-06	6.0E-06	7.6E-07	7.9E-06	7.4E-07	1.2E-07	1.6E-08	8.8E-07
3	SFUEL-FP	-7	0	2.9E-04	2.0E-03	5.2E-06	4.4E-05	5.6E-06	5.5E-05	3.3E-06	9.2E-05	1.2E-05	1.1E-04
4	SFUEL-EXT	-7	0	0.	0.	0.	8.3E-08	0.	8.3E-08	0.	5.3E-08	0.	5.3E-08
5	C060 -SEAL	6	0	0.	0.	0.	1.9E-10	0.	1.9E-10	0.	1.2E-10	0.	1.2E-10
6	C060 -UNS1	6	0	0.	0.	0.	3.1E-10	0.	3.1E-10	0.	2.0E-10	0.	2.0E-10
7	C060 -UNS2	5	1	0.	0.	0.	1.1E-10	0.	1.1E-10	0.	7.2E-11	0.	7.2E-11
	TOTALS			2.9E-04	2.1E-03	7.4E-06	1.1E-04	1.4E-05	1.3E-04	4.7E-06	9.3E-05	1.2E-05	1.1E-04
				EF	EM	LCF-GS	LCF-INH	LCF-RES	LCF-TOT	GE-GS	GE-INH	GE-RES	GE-TOT

NOTE -- NEGATIVE MODE INDICATES EXCLUSIVE USE SHIPMENT

SUMMARY OF ANNUAL EXPECTED NO. OF PERSONS RECEIVING A SPECIFIC WEIGHTED WHOLE-BODY DOSE

NO.	MATERIAL	MODES P	MODES S	DOSE LESS THAN 1.0E-01	DOSE BETWEEN 1.0E-01 AND 5.0E+00	DOSE MORE THAN 5.0E+00
1	U-F6E-HEX	-6	0	9.65E+00	4.43E-01	4.73E-03
2	U-F6D-HEX	-5	0	3.15E+02	2.10E-02	3.36E-04
3	SFUEL-FP	-7	0	1.00E+01	4.23E+00	2.03E-02
4	SFUEL-EXT	-7	0	8.50E-02	8.25E-04	2.58E-05
5	C060 -SEAL	6	0	4.45E-02	0.	0.
6	C060 -UNS1	6	0	3.79E-02	5.84E-06	0.
7	C060 -UNS2	5	1	2.02E-02	3.97E-07	0.

HANDLING ACCIDENT SUMMARY

MATERIAL	MODE1	MODE2	LCF	GEN.EFF.	EARLY MOR	EARLY FAT
U-F6E-HEX	SHIP-1		4.5E-11	1.9E-12	0.	0.
U-F6D-HEX	RAIL		1.2E-10	1.4E-11	0.	0.
SFUEL-FP	SHIP-2		3.7E-09	2.4E-09	0.	0.
SFUEL-EXT	SHIP-2		1.8E-11	1.2E-11	0.	0.
C060 -SEAL	SHIP-1		8.1E-14	5.2E-14	0.	0.
C060 -UNS1	SHIP-1		7.9E-13	5.0E-13	0.	0.
C060 -UNS2	RAIL	TRUCK	3.1E-12	2.0E-12	0.	0.

FIGURE 6.18

FIGURE 6.19

LATENT CANCER FATALITIES IN DECREASING ORDER

NO.	MATERIAL	PRI.MODE	SEC.MODE	LCF-GS
3	SFUEL-FP	SHIP-2		5.205E-06
2	U-F6D-HEX	RAIL		1.164E-06
1	U-F6E-HEX	SHIP-1		1.023E-06
4	SFUEL-EXT	SHIP-2		0.
5	C060 -SEAL	SHIP-1		0.
6	C060 -UNS1	SHIP-1		0.
7	C060 -UNS2	RAIL	TRUCK	0.

NO.	MATERIAL	PRI.MODE	SEC.MODE	LCF-INH
1	U-F6E-HEX	SHIP-1		5.797E-05
3	SFUEL-FP	SHIP-2		4.414E-05
2	U-F6D-HEX	RAIL		5.980E-06
4	SFUEL-EXT	SHIP-2		8.304E-08
6	C060 -UNS1	SHIP-1		3.068E-10
5	C060 -SEAL	SHIP-1		1.922E-10
7	C060 -UNS2	RAIL	TRUCK	1.132E-10

NO.	MATERIAL	PRI.MODE	SEC.MODE	LCF-TOT
1	U-F6E-HEX	SHIP-1		6.641E-05
3	SFUEL-FP	SHIP-2		5.491E-05
2	U-F6D-HEX	RAIL		7.908E-06
4	SFUEL-EXT	SHIP-2		8.304E-08
6	C060 -UNS1	SHIP-1		3.068E-10
5	C060 -SEAL	SHIP-1		1.922E-10
7	C060 -UNS2	RAIL	TRUCK	1.132E-10

FIGURE 6.20

ACCIDENT SENSITIVITY ANALYSIS SUMMARY

ANNUAL EXPECTED IMPACT ON MAN

POP.ZONE	EARLY FAT.	EARLY MOR.	LCF	GEN.EFF.
RURAL	1.323E-04	9.692E-04	8.486E-05	4.941E-05
SUBURBAN	1.622E-04	1.133E-03	3.939E-05	5.947E-05
URBAN	0.	0.	5.051E-06	6.710E-07

RURAL ACC.SEV.	EARLY FAT.	EARLY MOR.	LCF	GEN.EFF.
1	0.	0.	0.	0.
2	0.	0.	2.696E-09	3.123E-10
3	0.	0.	1.581E-07	1.001E-07
4	0.	0.	1.576E-07	9.986E-08
5	0.	0.	1.948E-09	2.130E-10
6	0.	1.685E-06	1.674E-06	1.002E-06
7	1.259E-04	9.201E-04	7.867E-05	4.580E-05
8	0.	0.	1.325E-09	1.339E-10
9	0.	2.883E-08	2.751E-08	1.705E-08
10	0.	3.669E-08	4.685E-08	2.275E-08
11	6.472E-06	4.732E-05	4.124E-06	2.361E-06

SUBURBAN ACC.SEV.	EARLY FAT.	EARLY MOR.	LCF	GEN.EFF.
1	0.	0.	0.	0.
2	0.	0.	2.527E-08	2.928E-09
3	0.	0.	9.783E-07	6.338E-07
4	0.	0.	5.276E-07	3.443E-07
5	0.	0.	3.653E-09	3.993E-10
6	0.	1.872E-06	1.853E-06	1.118E-06
7	1.398E-04	9.750E-04	3.066E-05	4.924E-05
8	0.	0.	1.242E-08	1.255E-09
9	0.	1.830E-07	1.636E-07	1.077E-07
10	0.	2.330E-07	2.554E-07	1.413E-07
11	2.237E-05	1.560E-04	4.906E-06	7.878E-06

URBAN ACC.SEV.	EARLY FAT.	EARLY MOR.	LCF	GEN.EFF.
1	0.	0.	0.	0.
2	0.	0.	1.272E-07	2.575E-08
3	0.	0.	2.725E-08	5.235E-09
4	0.	0.	6.591E-09	1.274E-09
5	0.	0.	1.010E-08	1.938E-09
6	0.	0.	5.656E-07	8.914E-08
7	0.	0.	3.483E-06	4.337E-07
8	0.	0.	6.089E-08	1.086E-08
9	0.	0.	1.265E-08	1.994E-09
10	0.	0.	2.009E-07	3.167E-03
11	0.	0.	5.572E-07	6.940E-08

FIGURE 6.21

ANNUAL EXPECTED LATENT CANCER FATALITIES

BY TRANSPORT MODE

ACC.SEV.	TRUCK	P. VAN	PASS. AIR	CARGO AIR	RAIL	SHIP-1	SHIP-2	TRUCK-2	CVAN-1	CVAN-2
1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
2	0.	0.	0.	0.	1.55E-07	0.	0.	0.	0.	0.
3	3.17E-12	0.	0.	0.	3.56E-08	5.97E-09	1.12E-06	0.	0.	0.
4	1.15E-12	0.	0.	0.	1.03E-08	6.39E-09	6.75E-07	0.	0.	0.
5	0.	0.	0.	0.	1.57E-08	0.	0.	0.	0.	0.
6	9.23E-14	0.	0.	0.	8.91E-07	1.02E-07	3.10E-06	0.	0.	0.
7	1.31E-12	0.	0.	0.	5.55E-06	6.25E-05	4.48E-05	0.	0.	0.
8	0.	0.	0.	0.	7.46E-08	0.	0.	0.	0.	0.
9	4.49E-15	0.	0.	0.	1.67E-08	2.50E-09	1.85E-07	0.	0.	0.
10	3.23E-15	0.	0.	0.	2.65E-07	3.18E-09	2.35E-07	0.	0.	0.
11	9.84E-14	0.	0.	0.	8.89E-07	3.83E-06	4.86E-06	0.	0.	0.
TOTAL	5.83E-12	0.	0.	0.	7.91E-06	6.64E-05	5.50E-05	0.	0.	0.

BY PACKAGE TYPE

ACC.SEV.	A-1	B-1	CASK-EX1	CASK-REL	BPU	DRUM	A-2	B-2	CASK-EX2	EXEMPT
1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
2	0.	0.	0.	0.	0.	0.	1.55E-07	0.	0.	0.
3	0.	4.09E-11	0.	1.12E-06	0.	0.	3.56E-08	5.95E-09	0.	0.
4	0.	7.57E-11	1.14E-08	6.64E-07	0.	0.	1.02E-08	6.35E-09	1.65E-11	0.
5	0.	0.	0.	0.	0.	0.	1.57E-08	0.	0.	0.
6	0.	8.65E-12	0.	3.10E-06	0.	0.	8.91E-07	1.02E-07	0.	0.
7	0.	2.73E-10	6.46E-08	4.47E-05	0.	0.	5.55E-06	6.25E-05	1.65E-10	0.
8	0.	0.	0.	0.	0.	0.	7.46E-08	0.	0.	0.
9	0.	1.76E-13	0.	1.85E-07	0.	0.	1.67E-08	2.50E-09	0.	0.
10	0.	1.34E-12	0.	2.35E-07	0.	0.	2.65E-07	3.18E-09	0.	0.
11	0.	1.98E-11	7.02E-09	4.86E-06	0.	0.	8.89E-07	3.83E-06	1.02E-11	0.
TOTAL	0.	4.20E-10	8.30E-08	5.49E-05	0.	0.	7.91E-06	6.64E-05	1.92E-10	0.

BY MATERIAL DISPERSIVITY CATEGORY

ACC.SEV.	DISPERSIVITY CATEGORY										
	1	2	3	4	5	6	7	8	9	10	11
1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
2	0.	0.	0.	0.	0.	1.55E-07	0.	0.	0.	0.	0.
3	4.09E-11	0.	0.	0.	0.	4.16E-08	1.12E-06	0.	0.	0.	0.
4	1.15E-08	0.	0.	0.	0.	1.66E-08	6.64E-07	0.	0.	0.	0.
5	0.	0.	0.	0.	0.	1.57E-08	0.	0.	0.	0.	0.
6	8.65E-12	0.	0.	0.	0.	9.93E-07	3.10E-06	0.	0.	0.	0.
7	6.51E-08	0.	0.	0.	0.	6.80E-05	4.47E-05	0.	0.	0.	0.
8	0.	0.	0.	0.	0.	7.46E-08	0.	0.	0.	0.	0.
9	1.76E-13	0.	0.	0.	0.	1.92E-08	1.85E-07	0.	0.	0.	0.
10	1.34E-12	0.	0.	0.	0.	2.68E-07	2.35E-07	0.	0.	0.	0.
11	7.05E-09	0.	0.	0.	0.	4.72E-06	4.86E-06	0.	0.	0.	0.
TOTAL	8.36E-08	0.	0.	0.	0.	7.43E-05	5.49E-05	0.	0.	0.	0.

FIGURE 6.22

SUMMARY TABLE

CATEGORIES	PKG/YR	TI/YR	CI/YR	KM/YR
NUCLEAR	3.600E+01	1.016E+02	2.801E+07	8.050E+04
RAD.NUC	5.000E+00	2.420E+01	1.004E+04	2.484E+04
TOTAL	4.100E+01	1.258E+02	2.802E+07	1.053E+05

NO.	NUCLEAR		
1	U-F6E-HEX	SHIP-1	
2	U-F6D-HEX	RAIL	
3	SFUEL-FP	SHIP-2	
4	SFUEL-EXT	SHIP-2	

NO.	RAD.NUC		
5	CO60 -SEAL	SHIP-1	
6	CO60 -UNS1	SHIP-1	
7	CO60 -UNS2	RAIL	TRUCK

REFERENCES

1-1 TAYLOR, DANIEL, LUNA, BIRINGER; RADTRAN II A Revised Computer Code for Analysis of Transportation of Radioactive Materials, Sandia National Laboratories, Albuquerque NM, SAND80-1943

2-1 BARKER, HOPKINS, TSE; Radiation Dose to Population (Crew and Passengers) Resulting from the Transportation of Radioactive Materials by Passenger Aircraft in the United States. IAEA-SM-184/15 (1974)

2-2 SHAPIRO J; Exposure of Airport Workers to Radiation from Shipments of Radioactive Material. Draft Report to USNRC (Jan 1976)

2-3 Environmental Survey of Transportation of Radioactive Material to and from Nuclear Power Plants. USAEC; WASH-1238 (Dec 1972)

2-4 CLARKE, FOLEY, HARTMAN, LARSON; Severities of Transportation Accidents. Sandia National Laboratories, Albuquerque, NM, SLA 74-0001. (July 1976)

2-5 KILLOUGH, DUNNING, BERNARD, PLEASANT; Estimates of Internal Dose Equivalent to 22 Target Organs for Radionuclides Occuring in Routine Releases from Nuclear Fuel-Cycle Facilities, Vol I & II, Oak Ridge National Laboratory Rep, NUREG/CR-0150

2-6 International Commission on Radiological Protection, ICRP Publication 26, Vol. 1 No. 3 1977

2-7 Transport of Radionuclides in Urban Environs Draft Assessment. Sandia Laboratories. Albuquerque. NM NUREG/CR-0743 (May 1980)

2-8 Calculation of Reactor Accident Consequences, Appendix VI of the Reactor Safety Study. USNRC; WASH-1400 (Oct 1975)

2-9 IAEA, Regulations for the Safe Transport of Radioactive Materials, 1973 Revised Edition, Safety Series No. 6, IAEA, Vienna (1973)

3-1 Statistics of Road Traffic Accidents in Europe (1979) United Nations Publication

3-2 World Road Statistics (1975-1978) International Road Federation, Geneve, Switzerland

3-3 Statistique internationale de chemins de fer (1978 Union internationale des chemins de fer, Paris, France

3-4 WIDSTRÖM, LEIBING, WIKLUND; Crew Complement and Flight Deck Design Certification, Board of Civil Aviation, Flight Safety Department, Norrköping, Sweden (1980)

3-5 Liverpool Underwriter's Associations Annual Reports (1969-1975)

3-6 CLARKE, FOLEY, HARTMAN, LARSON; Severities of Transportation Accidents. Sandia National Laboratories, Albuquerque NM, SAND-74-0001 (July 1976)

3-7 DENNIS, FOLEY, HARTMAN, LARSON; Severities of Transportation Accidents Involving Large Packages. Sandia National Laboratories, Albuquerque NM, SAND-77-0001 (July 1978)

3-8 McCLURE; An analysis of the Qualification Criteria for Small Radioactive Material Shipping Packages. Sandia National Laboratories, Albuquerque NM, SAND-76-0708 (October 1977)

3-9 HUERTA; Analysis, Scale Modeling and Full Scale Tests of a Truck-Spent-Nuclear-Fuel Shipping System in High Velocity Impacts Against a Rigid Barrier, Sandia National Laboratories, Albuquerque NM, SAND77-0270 (April 1978)

3-10 ROMANDER, COLTON; Comparison of Potential Crush and Impact Environments. PATRAM80. Proceedings Vol. 2. (November 10-14 1980)

3-11 RIEPE; Statistische Untersuchungen über Lechgrössen bei Schiffsunfällen. Hansa 103 (1966) Nr 18

3-12 Hazardous Environments Experienced by Radioactive Material Packages Transported by Water. Sandia National Laboratories, Albuquerque NM, TTC-0081, SAND-81-7213 (October 1980)

3-13 EMERSON, McCLURE; The Nature of Transportation Accidents Involving Radioactive Material Packagings, Sandia National Laboratories, Albuquerque NM, SAND81-1330C

3-14 Battelle Pacific Northwest Laboratories; Survey of Radioactive Material Shipments in the United States. BNWL-1972, April 1976

3-15 MISHIMA; Potential Aerosol Generation Mechanisms from Damaged Shipping Packages. IAEA-SR-10/15 (1976)

3-16 ELDER; Assessment of the Risk of Transporting Nuclear Fuel by Truck. Battelle Pacific Northwest Laboratories, PNL-2588 (Nov 1978)

3-17 RÄMÖ; Effect of Fire on Solified Reactor Waste Packaged into Steel Drums. Technical Research Centre of Finland (July 1979)

3-18 SLADE; Meteorology and Atomic Energy

3-19 LUNA, CHURCH; A Comparison of Turbulence Intensity and Stability Ratio Measurements to Pasquill Stability Categories, Journal of Applied Meteorology, Vol II, No 4, June 1972

APPENDIX A

Definitions and Abbreviations

A.1 Definitions

Material	- A nuclide or a special composition of nuclides.
Transport Situation	- A transport mode traveling on a defined route.
Standard Shipment	- Shipment of a material defined by the package type, the number of packages shipped per year, the average number of packages per shipment, the average Ci-content per package, the average transport-index per package, the average distance traveled per shipment and the transport situation used.
Urban Zone	- A high population density area meaning a central city with 50 000 or more inhabitants and surrounding closely settled teritory.
Suburban Zone	- A medium population density zone meaning an area with at least 200 houses not more than 200 m apart.
Rural Zone	- Low population density areas meaning all other areas.
Incident-free Transport	- A transport that occurs without unusual delay, loss of or damage to the package, or an accident involving the transporting vehicle.

Small Packages	- Packages readibly handleable by a single person ($dp \leq 0.5$ m).
Intermediate Size-packages	- Packages requiring lifting equipment such as forklifts ($0.5 \text{ m} < dp < 1 \text{ m}$).
Large Packages	- Packages requiring rigging equipment and cranes ($dp \geq 1$ m).
Type A-1 Package	- A package corresponding to the requirements for type A packages given by the IAEA safety series no. 6 and with a characteristic dimension of ca 0.44 m.
Type B-1 Package	- A package corresponding to the requirements for type B packages given by the IAEA safety series no. 6 and with a characteristic dimension of ca 0.64 m.
Cask-ex 1	- Transportation cask, meeting the type B requirements described in IAEA safety series no. 6. Used for transporting spent fuel, when calculating the dose from external radiation.
Cask-rel	- The same package as cask-1 but used to calculate the dose from released material after an accident. Characteristic dimension 5.5 m.
Cask-ex 2	- Same package as cask-1 and cask-2 but smaller. Characteristic dimension 1.0 m.
Type A-2 Package	- The same package as type A-1 but bigger. Characteristic dimension ca 1.50 m.

Type B-2 Package - The same package as type B-1 package but bigger. Characteristic dimension 1.50 m.

Drum - Cylindrical container usually containing waste, volyme 200 l, properties the same as type A package. Characteristic dimension 0.64 m.

Exempt - Package that not have to withstand any tests. Characteristic dimension 0.12 m.

Pedestrian Density Factor - The ratio between the pedestrian population density and the over-all population density in a population density zone.

Package Falure Fraction - The relative degree of damage caused by an accident to the packages in a shipment.

A.2 Abbreviations

DR(r)	=	dose rate at distance r $\left[\frac{rem}{h}\right]$
r	=	distance from source [m]
μ	=	attenuation coefficient for air $\left[\frac{1}{m}\right]$
B(r)	=	Build up factor
K	=	dose rate conversion factor $\left[\frac{mrem \cdot m^2}{h}\right]$
TI	=	transport index [mrem/h], 1 m from the package
K_o	=	TI to dose-rate conversion factor $[m^2]$
d_p	=	typical package dimension (for small packages d_p is the diameter of a sphere with equal volume to the package and for large packages dp is the largest physical dimension [m]
D	=	integrated exposure [personrem/year]

Q_1 = units conversion factor ($2.8 \cdot 10^{-4} \left[\frac{rem \cdot m \cdot h}{mrem \cdot km \cdot sec}\right]$)

PPS = package per shipment

SPY = shipments per year

Nc = number of crew

FKMPS = distance per shipment [km]

f_n = fraction of travel in population zone n

V_n = velocity in population zone n [m/s]

subscript

u = urban zone

s = suburban zone

r = rural zone

N_p = number of passengers or flight attendants

K_p = TI to dose rate conversion factor [rem/hr/Tl]

VELM = average shipment velocity [m/s]

K_h = handling to dose conversion factor [rem/handling/Tl]

N_h = number of handlings per shipment

Q_2 = unit conversion factor, 10^{-3}. [rem/mrem]

PPH = number of persons exposed per handling

T = length of exposure time [h]

K_o' = line of source Tl to dose rate conversion factor [m]

P_{stor} = average number of persons in warehouse area

T_{stor} = exposure time during storage per shipment [h]

P_{st} = number of exposed persons while stopped

T_{st} = exposure time during stop for a 24 hour trip [h]

Q_3 = unit conversion factor 3.6 $\left[\frac{km \cdot s}{h \cdot m}\right]$

T_{max} = 24 hours

D(x) = dose as a function of distance [mrem]

x = perpendicular distance from shipment path [m]

PD = uniform population density

d_{min} = minimum distance from population to shipment centerline [m]

d_{max} = maximum distance over which exposure is evaluated [m]

RPD = pedestrian density factor - ratio pedestrian density to over all population density.

R_i = shielding factor in population zone i

IV = value of $\int_{d_{min}}^{d_{max}} \frac{1}{x}\,dx$

Q_4 = units conversion factor ($2.8 \cdot 10^{-10} \left[\frac{rem \cdot km \cdot h}{mrem \cdot m \cdot sec}\right]$)

PD_n = population density in zone n [persons/km^2]

f_{cs} = fraction of travel on city streets

PPV = number of persons per vehicle

N_n = average number of vehicles passing a specific point in one direction (traffic count) in population zone n

PD_l = linear population density [persons/km]

f_{fwy} = fraction travelled on freeways

f_{rh} = fraction travelled during rush hours

Q_5 = units conversion factor ($7.7 \cdot 10^{-8} \left[\frac{rem \cdot h^2 \cdot m}{mrem \cdot s^2 \cdot km}\right]$)

RF = package failure fraction

M_n = amount of material deposited in area n [Ci]

v_d = deposition velocity for material [m/s]

χ = average dilution factor in area n $\left[\frac{Ci \cdot s}{m^3 \cdot Ci}\right]$

A_n = area encircled by isodose curve for χ_n [m^2]

E = average photon energy per disintegration [MeV]

Γ = γ-constant = 0.5

DI = individual dose [rem]

CI = activity per package [Ci]

AER = fraction of material aerosolized

RESP = fraction of aerosolized material that has respirable size

RPC = inhalation dose factor [rem/Ci]

BR = breathing rate $\left[\frac{m^3}{s}\right]$

BDF = building dose factor

IF = integrated dilution factor $\left[\frac{Ci \cdot s}{m \cdot Ci}\text{ released}\right]$

D_o = population dose to organ o [rem]

RDF = resuspension dose factor

IRF = integrated resuspension factor $\left[\frac{s}{m}\right]$

$RT_{1/2}$ = resuspension half-life [days]

$T_{1/2}$ = nuclide half-life [days]

DR_D = dose rate $\left[\frac{rem}{day}\right]$

CLVL = contamination level $\left[\frac{\mu Ci}{m^2}\right]$

Q_6 = units conversion factor ($3.04 \cdot 10^{-4}$ $\left[\frac{rem \cdot m^2}{day \cdot \mu Ci \cdot Mev}\right]$

CULVL = criterion clean-up level $\left[\frac{\mu Ci}{m^2}\right]$

DECON = the ratio between the contamination level and the criterion clean-up level

Q_7 = units conversion factor (10^{-6} $\left[\frac{km^2}{m^2}\right]$)

W = sidewalk width [m]

EF = total number of expected early fatalities

PI_n = individual probability of early fatality

LCF = total expected number of latent effects

C_o = chronic effect risk factor for organ o [1/personrem]

APY = expected number of accidents per year

APM = overall accident rate per transportkilometer

SEVFRC= fractional occurrence of accident severities

ACCRSK= accident risk factor

EPYR = annual expected number of effects, early of latent

EXPE = expected number of effects per accident, early or latent

HNDAPY expected number of accidents of severity i

NH_m = number of handlings for mode m

$HNDACC_k$= handling accident rate for package type k

$HNDSEV_{i,k}$= fractional occurrence of accident severity package type k

RSA = reciprocal specific activity (g/ci)

N_g = amount of uranium inhaled (g)

C	=	average concentration in isodose area (kg/m^3)
FHF	=	amount of HF formed from UF_6 (0.336 kg HF/kg UF_6)
RT_i	=	release time for an accident of severity i (ch)

APPENDIX B

INPUT DATA GUIDE

The input parameters of an INTERTRAN run are divided into blocks which are identified by keywords. All blocks are optional except SHIPMENT and CONTROL. If a block is not specified a default value intiated in the BLOCK DATA sections will be used. Default values are available for all blocks except SHIPMENT, CONTROL and CATEGORY. The default values of block NORMAL and ACCIDENT are intiated in BLOCK DATA NORACC and the default values for the other blocks are intiated in BLOCK DATA BLKDAT.

The default data in the blocks is changed by specifying a code word and then adding the data according to the Input Data Format description below. The data blocks can be put in any order except for the two last blocks, CONTROL and CATEGORY which must be placed last in the input data deck.

The input data blocks are divided into records with one or more variables. For each record the number of cards and their FORMAT is given. Since the number of cards in each record varies with the size of the arrays, e.g. the number of accident severity categories, the number can not be given explicitly. For example the form (1 card/8 ,NSEV) means that a new card is necessary for every eight accident severity categories. Ten accident categories, would need 2 cards. The form (NMODE·NPOP Cards/8,NSEV) means that the record shall contain NMODE·NPOP cards for every eight accident severity category.

Indices used in the INPUT DATA GUIDE

I=1,NPOP	Index over population zones NPOP=3 Order of population zones Rural, suburban, urban

I=1,NPTYPE	Index over package types NPTYPE input in block DIMENSION NPTYPE $\leq$ 10 Default value = 10
I=1,NMAT	Index over material types NMAT input in block SHIPMENT NMAT $\leq$ 80 No default value
I=1,NMODE	Index over transport modes NMODE =10
I=1,NSEV	Index over accident severity categories NSEV input in block PARM NSEV $\leq$ 11 Default value = 11
I=1,NAREAS	Index over iso-dose areas NAREAS input in block PARM NAREAS $\leq$ 30 Default value = 15
I=1,NREMLV	Index over rem levels NREMLV =30
I=1,NORG	Index over organs for which dose is calculated NORG= 8
I=1,NEF	Index over early fatality organs NEF=5 Order of organs: LUNG-1, LUNG-2, LUNG-3 LUNG-4, MARROW
I=1,NIM	Index over material dispersivity categories NIM input in block PARM NIM $\leq$ 11 Default value =11

I=1,NCAT	Index over material categories NCAT input in block CATEGORIES NCAT $\leq$ 10 No default value

An asterisk (x) indicates that an explicit do-loop is used for the READ statement and a new card should be used for each iteration.

Input Data Format

1. Block TITLE

In TITLE the user specifies title on head of listing.

Record 1 (1 card)		FORMAT (A10) IBM (A8)
cols 1-10	A	Specifies keyword TITLE
Record 2 (1 card)		FORMAT (8A10) IBM (10A8)
cols 1-80	TITLE(I) I=1,8	Titel of run

2. Block PARM

In PARM the user specifies what calculations are to be made and what output is desired.

Record 1 (1 card)		FORMAT (A10) IBM (A8)
cols 1-10	A	Specifies keyword PARM
Record 2 (1 card)		FORMAT (4I5)
cols 1-20	IRNKC	=1 Output on file 6 for plotting etc.
		=0 No output on file 6
	IANA	=1 Incident-free dose calculations only

		=2 Accident dose calculations only
		=3 Incident-free and Accident dose calcul.
	ISEN	=1 Sensitivity analysis made
		=0 No sensitivity analysis made
	IHANDL	=1 Handling accidents analyzed
		=0 Handling accidents not analyzed

3. Block DIMENSION

In DIMENSION the user specifies dimensions for a number of arrays.

Record 1 (1 card)		FORMAT (A10) IBM (A8)
cols 1-10	A	Specifies keyword DIMENSION
Record 2 (1 card)		FORMAT (5I5)
cols 1-25	NSEV	Number of accident severity categories (NSEV $\leq$10)
	NPTYPE	Number of package types (NPTYPE $\leq$ 9)
	NRAD	Number of radii for calculation of direct exposure (NRAD $\leq$15)
	NIM	Number of material dispersivity categories (NIM $\leq$ 11)
	NAREAS	Number of isodose areas for calculating dispersion dose (NAREAS $\leq$ 30)

4. Block POPDEN

In POPDEN the user specifies population density values.

Record 1 (1 card)		FORMAT (A10) IBM (A8)
cols 1-10	A	Specifies code word POPDEN
Record 2 (1 card)		FORMAT (3E10.3)
cols 1-30	POPZON(I) I=1,NPOP	Population density in rural suburban and urban zone. Population density out-doors in urbans zone is calculated in the code.
Record 3 (1 card)		FORMAT (E10.3)
cols 1-10	RPD	Pedestrian population density ratio

5. Block PACKAGE

In PACKAGE the user specifies package input data.

Record 1 (1 card)		FORMAT (A10) IBM (A8)
cols 1-10	A	Specifices code word PACKAGE
Record 2 (1 card/8 NPTYPE)		FORMAT (8A10) IBM (8(A8,2X))
cols 1-80	LABPKG(I) I=1,NPTYPE	Labels of packages used
Record 3	(1card/8 NPTYPE)	FORMAT (8E10.3)
cols 1-80	PKGCDM(I) I=1,NPTYPE	Typical package dimension

6. Block SHIPMENT

In SHIPMENT the user gives information on the shipments to be analyzed.

Record 1 (1 card)		FORMAT (A10) IBM (A8)
cols 1-10	A	Specifies code word SHIPMENT

Record 2 (1 card) cols 1-5	NMAT	FORMAT (I5) Numbers of materials to be analyzed. (NMAT $\leq$ 80)
Record 3 (1 card/8 NMAT) cols 1-80	LABMAT(I) I=1,NMAT	FORMAT (8A10) IBM (8(A8,2X)) Label of material
Record 4 (1 card/8 NMAT) cols 1-80	LTYPKG(I) I=1, NMAT	FORMAT (8A10) IBM (8(A8,2X)) Package type for each material Labels from set 5 or default data set should be used
Record 5 (1 card/8 NMAT) cols 1-80	PKGSHP(I) I=1,NMAT	FORMAT (8E10.3) Number of packages per shipment
Record 6 (1 card/8 NMAT) cols 1-80	TIPKG(I) I=1,NMAT	FORMAT (8E10.3) Transport index per package
Record 7 (1 card/8NMAT) cols 1-80	CIPKG(I) I=1,NMAT	FORMAT (8E10.3) Activity per package
Record 8 (1 card/8 NMAT) cols 1-80	IMMAT(I) I=1,NMAT	FORMAT (16I5) Material dispersivity category
Record 9 (NMAT cards/8 NMODE) cols 1-80	TABSPY(I,J) I=1,NMAT * J=1,NMODE	FORMAT (8E10.3) Number of shipments per year with each transport mode
Record 10 (NMAT cards/8 NMODE) cols 1-80	FKMPS(I,J) I=1,NMAT * J=1,NMODE	FORMAT (8E10.3) Distance per shipment with each transport mode

7. Block NORMAL

Block NORMAL contains the incident-free case parameters. Note that the fraction of travel in the different population zones is also used for the accident case.

Record 1 (1 card)		FORMAT (A10) IBM (A8)
cols 1-10	A	Specifies keyword NORMAL
Record 2 (1 card/8 NMODE)		FORMAT (8E10.3)
cols 1-80	FTZNR(I) I=1,NMODE	Fraction of travel in rural zone
Record 3 (1 card/8 NMODE)		FORMAT (8E10.3)
cols 1-80	FTZNS(I) I=1,NMODE	Fraction of travel in suburban zone
Record 4 (1 card/8 NMODE)		FORMAT (8E10.3)
cols 1-80	FTZNU(I) I=1,NMODE	Fraction of travel in urban zone
Record 5 (1 card/8 NMODE)		FORMAT (8E10.3)
cols 1-80	VELR(I) I=1,NMODE	Velocity in rural zone
Record 6 (1 card/8 NMODE)		FORMAT (8E10.3)
cols 1-80	VELS(I) I=1,NMODE	Velocity in suburban zone
Record 7 (1 card/8 NMODE)		FORMAT (8E10.3)
cols 1-80	VELU(I) I=1,NMODE	Velocity in urban zone
Record 8 (1 card/ NMODE)		FORMAT (8E10.3)
cols 1-80	CREWNO(I) I=1,NMODE	Number of crew
Record 9 (1 card/8 NMODE)		FORMAT (8E10.3)
cols 1-80	ADSTCW(I) I=1,NMODE	Distance from source to crew

Record 10 (1 card/8 NMODE)		FORMAT (8E10.3)
cols 1-80	HANDNO(I) I=1,NMODE	Number of handlings per shipment
Record 11 (1 card/8 NMODE)		FORMAT (8E10.3)
cols 1-80	DTST(I) I=1,NMODE	Stop-time per 24 hour trip
Record 12 (1 card/8 NMODE)		FORMAT (8E10.3)
cols 1-80	PDST(I) I=1,NMODE	Number of persons exposed at stops
Record 13 (1 card/8 NMODE)		FORMAT (8E10.3)
cols 1-80	RST(I) I=1,NMODE	Exposure distance at stops
Record 14 (1 card/8 NMODE)		FORMAT (8E10.3)
cols 1-80	DTSTOR(I) I=1,NMODE	Storage time per shipment
Record 15 (1 card/8 NMODE)		FORMAT (8E10.3)
cols 1-80	PDSTOR(I) I=1,NMODE	Number of persons exposed at storage
Record 16 (1 card/8 NMODE)		FORMAT (8E10.3)
cols 1-80	RSTOR(I) I=1,NMODE	Exposure distance at storage
Record 17 (1 card/8 NMODE)		FORMAT (8E10.3)
cols 1-80	PPV(I) I=1,NMODE	Number of persons per vehicle
Record 18 (1 card/8 NMODE)		FORMAT (8E10.3)
cols 1-80	FRSHR(I) I=1,NMODE	Fraction of rushhour traffic
Record 19 (1 card/8 NMODE)		FORMAT (8E10.3)
cols 1-80	FCTST(I) I=1,NMODE	Fraction of travel on city streets

Record 20 (1 card/8 NMODE)		FORMAT (8E10.3)
cols 1-80	FTLFWY(I) I=1,NMODE	Fraction of travel on freeways
Record 21 (1 card/8 NMODE)		FORMAT (8E10.3)
cols 1-80	TCNTPR(I) I=1,NMODE	Traffic count in rural zone
Record 22 (1 card/8 NMODE)		FORMAT (8E10.3)
cols 1-80	TCNTPS(I) I=1,NMODE	Traffic count in suburban zone
Record 23 (1 card/8 NMODE)		FORMAT (8E10.3)
cols 1-80	TCNTPU(I) I=1,NMODE	Traffic count in urban zone
Record 24 (1 card)		FORMAT (E10.3)
cols 1-10	FNOATT	Number of attendants on passenger air
Record 25 (1 card)		FORMAT (2I5)
cols 1-10	IUOPT	=1 Option 1 used when calculating dose to bystanders in urban zone =2 Option 2 =3 Option 3
	IDOSLM	=0 Dose limit of 2 mrem/hr set for crew on exclusive-use shipments =1 Dose limits for all crew.

8. Block ACCIDENT

This block contains the accident case parameters.

Record 1 (1 card)		FORMAT (A10) IBM (A8)
cols 1-10	A	Specifies keyword ACCIDENT
Record 2 (NMODE NPOP cards/8 NSEV)		FORMAT (8E10.3)
cols 1-80	ACCRSK(K,J,I) K=1,NMODE * I=1,NPOP * J=1,NSEV	Accident rate factor
Record 3 (1 card/8 NMODE)		FORMAT (8E10.3)
cols 1-80	ARATMD(I) I=1,NMODE	Over-all accident rate
Record 4 (1 card/8 NMODE)		FORMAT (8E10.3)
cols 1-80	SEVFRC(I) I=1,NMODE	Fractional occurence of the accident severities

9. Block RELEASE

This block contains the release fractions for the package types.

Record 1		FORMAT (A10) IBM (A8)
cols 1-10	A	Specifies keyword release
Record 2 (NPTYPE cards/8 NSEV)		FORMAT (8E10.3)
cols 1-80	RFRAC(I,J) I=1,NPTYPE * J=1,NSEV	Release fraction

10. Block SHIELD

Block SHIELD contains the shielding factors used for calculating the dose in the incident-free case and in the non-dispersion accident case.

Record 1 (1 card)		FORMAT (A10) IBM (A8)
cols 1-80	A	Specifies keyword SHIELD

Record 2 (1 card)		FORMAT (2E10.3)
cols 1-20	RS	Shielding factor suburban zone
	RU	Shielding factor urban zone

11. Block MATERIAL

Block MATERIAL can be used to change the material data set in the BLOCK DATA part.

Record 1 (1 card)		FORMAT (A10) IBM (A8)
cols 1-10	A	Specifies keyword MATERIAL
Record 2 (1 card/8 NMAT)		FORMAT (8E10.3)
Cols 1-80	PHTENG(I) I=1,NMAT	Average photon energy per disintegration
Record 3 (1 card/8 NMAT)		FORMAT (8E10.3)
Cols 1-80	TABHLF(I) I=1,NMAT	Half-life
Record 4 (1 card/8 NMAT)		FORMAT (8E10.3)
Cols 1-80	VELDEP(I) I=1,NMAT	Deposition velocity
Record 5 (1 card/8 NMAT)		FORMAT (16I5)
Cols 1-80	LNGTAB(I) I=1,NMAT	Lung type
Record 6 (NMAT cards/8 NORG)		FORMAT (8E10.3)
Cols 1-80	RPCVAL(I,J) I=1,NMAT * J=1,NORG	Rem-per-curie value

12. Block DISP

Block DISP contains areas and corresponding dilution factors for calculation of dispersion in the accident case.

Record 1 (1 card)		FORMAT (A10) IBM (A8)
cols 1-10	A	Specifies keyword DISP

Record 2 (1 card/8 NAREAS)		FORMAT (8E10.3)
cols 1-80	AREADA(I) I=1,NAREAS	Size of iso dose areas
Record 3 (6 card/8 NAREAS)		FORMAT (8E10.3)
cols 1-80	PASQ(I,J) J=1,6 * I=1,NAREAS	Dilution factor for areas

13. Block METRO

Block METRO is used to specify fractional occurence of the Pasquill stability classes.

Record 1 (1 card)		FORMAT (A10)IBM (A8)
cols 1-10	A	Specifies keyword METRO
Record 2	(1 card)	FORMAT (6E10.3)
cols 1-60	METPRB(I) I=1,6	Fractional occurence of Pasquill class A to F
Record 3	(1 card)	FORMAT (E10.3)
cols 1-10	BDF	Building dose factor

14. Block CONTAM

Block CONTAM contains the criterion clean-up level.

Record 1 (1 card)		FORMAT (A10) IBM (A8)
cols 1-10	A	Specifies keyword CONTAM
Record 2 (1 card)		FORMAT (E10.3)
cols 1-80	CULVL	Criterion clean-up level

15. Block AEROSOL

Block AEROSOL contains parameters which describe dispersion.

Record 1 (1 card)		FORMAT (A10)IBM (A8)
cols 1-10	A	Specifies keyword AEROSOL

Record 2 (NIM cards/8 NSEV)		FORMAT (8E10.3)
cols 1-80	AERSOL(I,J) I=1,NIM * J=1,NSEV	Fraction of released material which is aerosolized
Record 3 (NIM cards/8 NSEV)		FORMAT (8E10.3)
cols 1-80	RESP(I,J) I=1,NIM * J=1,NSEV	Fraction of aerosolized material which is respirable

16. Block TRANSMODE

If block TRANSMODE is specified the transport situation can be changed.

Record 1 (1 card)		FORMAT (A10) IBM (A8)
cols 1-10	A	Specifies keyword TRANSMODE
Record 2 (1 card/8 NMODE)		FORMAT (8A10) IBM (8(A8,2X))
cols 1-80	LABMOD(I) I=1,NMODE	Label of transport mode
Record 3 (1 card/16NMODE)		FORMAT (16I5)
cols 1-80	MODTYP(I) I=1,NMODE	Type of transport mode =1 Road =2 Air =3 Rail =4 Water

17. Block HANDLING

In block HANDLING the handling accident input data is given.

Record 1 (1 card)		FORMAT (A10) IBM (A8)
cols 1-10		Specifies keyword HANDLING
Record 2 (1 card/8 NMODE)		FORMAT (8E10.3)
cols 1-80	HNDACC(I) I=1,NPTYPE	Over all handling accident rate per handling operation
Record 3 (NPTYPE cards/8 NSEV)		FORMAT (8E10.3)
cols 1-80	HNDSEV(J,I) I=1,NPTYPE * J=1,NSEV	Fractional occurence of accident severities

18. Block LIMITS

In block LIMITS the dose limits for the calculations of the number of persons receiving more than that specified dose are specified.

Record 1 (1 card)		FORMAT (A10) IBM (A8)
cols 1-10	A	Specifies keyword LIMITS
Record (1 card)		FORMAT (2E10.3)
cols 1-20	DOSLIM	Weighted whole body dose limits

19. Block CHEM

Block CHEM has to be provided if the chemical effects shall be calculated. In block CHEM the regulatory limits for the chemical effect of uranium is specified.

Record 1 (1 card)		FORMAT (A10) IBM (A8)
cols 1-10	A	
Record 2 (1 card)		FORMAT (8E10.3)
cols 1-20	HF	Limit for hydrogen fluoride concentration
	UF	Limit for uranium inhalation

20. Block CONTROL

In this block are the standard shipments combined and the materials to be analyzed are chosen. Each shipment can use a primary and a secondary transport mode. For each shipment is a complete output an option. Up to 200 standard shipment cards can be used.

Record 1 (1 card)		FORMAT (A10) IBM (A8)
cols 1-10	A	Specifies keyword CONTROL

Record 2 (Up to 200 cards)		FORMAT (4I5)
cols 1-20	MAT	Index of material shipped
	IMODE1	Primary shipment mode index. Note - if exclusive-use vehicles are used IMODE1 is negative.
	IMODE2	Secondary shipment mode index
	IPRINT	Printout option 0 = no extra printout 1 = consequense summary 2 = individual doses.
Record 3 (1 card)		
cols 1-80		Blank card ending block CONTROL

21. Block CATEGORY

In this block the material categories for the final summation can be specified. If block CATEGORY is not specified a summation of all the analyzed shipment will be made.

Record 1 (1 card)		FORMAT (A10) IBM (A8)
cols 1-10	A	Specifies keyword CATEGORY
Record 2 (1 card)		FORMAT (I5)
cols 1-5	NCAT	Number of material categories
Record 3 (1 card/8 NCAT)		FORMAT (8A10) IBM (8(A8,2X))
cols 1-80	ITYPKG(I) I=1,NCAT	Category label
Record 4 (1 card/8 NMAT)		FORMAT (16I5)
cols 1-80	IMTCAT(I) I=1,NMAT	Category index for material

APPENDIX C

NUCLIDE DATA LIBRARY

The Nuclide Data Library contains information of half-life, average photon energy, dose factors,deposition velocity and and lung fatality type for a number of nuclides and radioactive materials frequentl̂y transported. These data are presented in Table C-1 and C-2. The list includes composite materials like natural and enriched (3.5%) uranium in oxide form and enriched and depleted uranium in hexavalent form (UF_6) and mixed plutonium as dioxide or as a soluable compound (nitrate or chloride). The library also includes entries for materials like spent fuel, mixed fission products and mixed corrosion products.

The half-lives and the average photon energy per disintegration was taken from reference C-1. The average photon energy for daughter nuclides which can be expected to be in equilibrium have been included, e.g. Sr 90-Y90, Mo99-Tc99m and Sn113-In113m. Uranium is considered to be in equilibrium with some of the daughter nuclides, see Notes to Table C-1.

The dose factors integrated over 50 years are given for gonads lower large intestine (LLI), thyroid, bone, lung and marrow. The values are calculated for inhalation of 10^{-6} m particles and are taken from References C-2 and C-3. The dose factor integrated over 10^{-6} one year for lung and marrow, used for the early effect calculations, are calculated using the retention times given in Reference C-2. The weighted whole-body dose factors are taken from Reference C-2.

The lung fatality type is described in section 2.2.6.1 and depend on the half-life of the nuclide and the type of radiation (High-Linear Energy Transfer on Low Linear Energy Transfer).

The deposition velocities used are taken from Reference C-4.A value of $1 \cdot 10^{-2}$ is used for chemicaly reactive materials, a value of $2 \cdot 10^{-3}$ is used for chemical inert materials and a value of zero is used for gases.

TABLE C.1. Half-life, Photon Energy, Deposition Velocity and Lung Type used in the Nuclide Data Library.

N:O	NUCLIDE	HALF LIFE	PHOTON ENERGY	DEP VELOCITY	LUNG TYPE
1	H3	4.500E+03	0.	0.	1
2	C14	2.090E+06	0.	2.000E-03	1
3	NA22	9.490E+02	2.070E+00	2.000E-03	1
4	NA24	6.250E-01	4.120E+00	2.000E-03	1
5	P32	1.430E+01	0.	2.000E-03	1
6	P33	2.530E+01	0.	2.000E-03	1
7	S35	8.740E+01	0.	1.000E-02	1
8	K43	6.000E-02	9.050E-01	2.000E-03	1
9	CA45	1.630E+02	2.100E-07	2.000E-03	1
10	CR51	2.780E+01	3.140E-02	2.000E-03	1
11	MN54	3.130E+02	8.350E-01	2.000E-03	1
12	FE55	9.860E+02	0.	2.000E-03	3
13	FE59	4.460E+01	1.190E+00	2.000E-03	1
14	CO57	2.700E+02	1.210E-01	2.000E-03	1
15	CO58	7.130E+01	9.740E-01	2.000E-03	1
16	CO60	1.920E+03	2.500E+00	2.000E-03	3
17	ZN65	2.430E+02	5.740E-01	2.000E-03	1
18	GA67	3.250E+00	1.430E-01	2.000E-03	1
19	SE75	1.200E+02	3.880E-01	1.000E-02	1
20	KR85	3.910E+03	2.210E-03	0.	1
21	RB86	1.860E+01	9.490E-02	2.000E-03	1
22	SR89	5.200E+01	8.200E-05	2.000E-03	1
23	SR90 a)	1.050E+04	0.	2.000E-03	3
24	Y90	2.670E+00	3.520E-04	2.000E-03	1
25	ZR95 b)	6.550E+01	7.250E-01	2.000E-03	1
26	NB95	3.520E+01	7.580E-01	2.000E-03	1
27	MO99 c)	2.760E+00	2.750E-01	2.000E-03	1
28	TC99M	2.510E-01	1.210E-01	2.000E-03	1
29	RU106 d)	3.670E+02	2.050E-01	2.000E-03	1
30	IN111	2.830E+00	4.060E-01	2.000E-03	1
31	IN114 e)	5.000E+01	1.050E-01	2.000E-03	1
32	SN113 f)	1.150E+02	5.380E-01	2.000E-03	1
33	I123	5.540E-01	1.680E-01	1.000E-02	1
34	I125	6.010E+01	2.170E-02	1.000E-02	1
35	I129	6.210E+09	9.330E-02	1.000E-02	1
36	I131	8.060E+00	3.810E-01	1.000E-02	1
37	XE127	3.640E+01	2.240E-01	0.	1
38	XE133	5.290E+00	4.470E-02	0.	1
39	CS134	7.480E+02	1.600E+00	2.000E-03	1
40	CS137 g)	1.100E+04	5.620E-01	2.000E-03	3

TABLE C.1 (continued)

NO	NUCLIDE	HALF LIFE	PHOTON ENERGY	DEP VELOCITY	LUNG TYPE
41	BA140 h)	1.280E+01	2.520E+00	2.000E-03	1
42	LA140	1.680E+00	2.330E+00	2.000E-03	1
43	CE141	3.240E+01	7.780E-02	2.000E-03	1
44	PM147	9.560E+02	5.000E-06	2.000E-03	1
45	EU152	4.640E+03	1.420E+00	2.000E-03	3
46	IR192	7.420E+01	9.040E-01	2.000E-03	1
47	AU198	2.700E+00	4.030E-01	2.000E-03	1
48	HG197	2.670E+00	7.190E-02	2.000E-03	1
49	HG203	4.660E+01	2.380E-01	2.000E-03	1
50	TL201	3.060E+00	8.880E-02	2.000E-03	1
51	PO210	1.380E+02	9.000E-06	2.000E-03	2
52	RA226 i)	5.840E+05	1.920E+00	2.000E-03	4
53	TH230	2.810E+07	2.020E-03	2.000E-03	4
54	TH232 j)	5.150E+12	4.350E+00	2.000E-03	4
55	U233	5.800E+07	8.600E-04	2.000E-03	4
56	U235 k)	2.590E+11	1.640E-01	2.000E-03	4
57	U238 l)	1.650E+12	1.760E-01	2.000E-03	4
58	NP237 m)	7.810E+08	2.340E-01	2.000E-03	4
59	PU238	3.140E+04	2.750E-03	2.000E-03	4
60	PU239	8.900E+06	1.960E-04	2.000E-03	4
61	PU240	2.380E+06	1.600E-05	2.000E-03	4
62	PU241	5.550E+03	5.000E-06	2.000E-03	3
63	PU242	1.370E+08	0.	2.000E-03	4
64	AM241	1.670E+05	2.190E-02	2.000E-03	4
65	AM243 n)	2.700E+06	4.940E-02	2.000E-03	4
66	CM242	1.630E+02	2.780E-03	2.000E-03	4
67	CM244	6.530E+03	1.300E-05	2.000E-03	4
68	CF252	8.980E+02	9.000E+00	2.000E-03	4
69	U-OXN o)	1.650E+12	9.000E-02	2.000E-03	4
70	U-OXE p)	1.650E+12	3.000E-02	2.000E-03	4
71	U-F6E q)	1.650E+12	3.000E-02	2.000E-03	4
72	U-F6D r)	1.650E+12	1.320E-01	2.000E-03	4
73	PU-OX s)	3.140E+04	2.000E-05	2.000E-03	4
74	PU-MX t)	3.140E+04	2.000E-05	2.000E-03	4
75	SFUEL u)	1.100E+04	6.000E-01	2.000E-03	3
76	MIXFI v)	1.100E+04	6.000E-01	2.000E-03	3
77	MIXCO x)	1.920E+03	2.500E+00	2.000E-03	3
78		0.	0.	0.	0
79		0.	0.	0.	0
80		0.	0.	0.	0

Notes to Table C.1.

a) Y-90 assumed to be in equilibrium.

b) Zr-95 assumed to be in equilibrium.

c) Tc 99M assumed to be in equilibrium.

d) Rh-106 assumed to be in equilibrium.

e) Refers to intermediate state In114m. In 114 assumed to be in equilibrium.

f) In113m assumed to be in equilibrium.

g) Ba-137m assumed to be in equilibrium.

h) La-140 assumed to be in equilibrium.

i) Rn-222, Po-218, Pb-214, Bi-214, Po-214 and Pb210 assumed to be in equilibrium.

j) Ra-228, Ac-228, Th-228, Ra-224, Rn-220, Po-216, Pb-212, Bi-212. Tl-208 assumed to be in equilibrium.

k) Th-231 assumed to be in equilibrium.

l) Th-234 and Pa-234 assumed to be in equilibrium.

m) Pa-233 assumed to be in equilibrium.

n) Np-239 assumed to be in equilibrium.

o) Natural uranium oxide (UO_2 on U_2O_3)

p) Enriched uranium oxide (UO_2 on U_2O_3).

q) Enriched hexavalent uranium (UF_6).

r) Depleted hexavalent uranium (UF_6).

s) Mixed plutonium in oxide form (PO_2)

t) Mixed plutonium in soluable form (nitrate,chloride).

u) Spent fuel - fission products + external.

v) Mixed fission products modeled as CS-137.

x) Mixed corrosion products modeled as Co-60.

TABLE C.2 Dose Factors used in the Nuclide Data Library.

REM PER CURIE VALUES

N:O	NUCLIDE	1YR/LUNG	1YR/MARROW	GONADS	LLI	THYROID	BONE	50/LUNG	50/MARROW	W WHOLE BD
1	H3	1.25E+02	1.24E+02	1.25E+02	1.33E+02	1.24E+02	6.60E+00	1.25E+02	1.24E+02	1.26E+02
2	C14	6.18E+00	2.42E+01	5.42E+00	7.22E+00	6.48E+00	8.46E-01	6.18E+00	2.42E+01	1.09E+01
3	NA22	9.43E+03	1.30E+04	1.45E+04	7.53E+03	8.14E+03	1.67E+04	9.43E+03	1.30E+04	1.14E+04
4	NA24	4.60E+03	1.00E+03	7.40E+02	6.80E+03	6.20E+02	1.20E+03	4.60E+03	1.00E+03	1.10E+03
5	P32	7.63E+03	1.11E+04	3.01E+03	3.91E+03	3.01E+03	2.42E+04	7.63E+03	1.11E+04	5.21E+03
6	P33	4.00E+04	7.10E+03	3.10E+03	4.80E+03	3.10E+03	1.10E+04	4.00E+04	7.10E+03	1.33E+04
7	S35	7.10E+04	4.90E+03	3.30E+03	2.70E+03	4.10E+03	4.30E+03	7.10E+04	4.90E+03	1.10E+04
8	K43	1.50E+03	4.10E+02	3.90E+02	3.10E+01	3.20E+02	3.70E+02	1.50E+03	4.10E+02	5.00E+02
9	CA45	3.60E+04	2.20E+03	2.80E+02	5.00E+03	2.80E+02	2.00E+04	3.60E+04	2.70E+03	5.90E+03
10	CR51	5.60E+04	2.30E+03	2.40E+03	1.50E+04	1.70E+03	1.80E+03	5.60E+04	2.30E+04	1.00E+04
11	MN54	4.18E+03	5.96E+03	3.79E+03	3.98E+03	2.30E+03	6.12E+03	4.18E+03	5.96E+03	5.69E+03
12	FE55	3.20E+03	3.44E+02	1.11E+03	3.64E+02	1.07E+03	8.92E+02	3.20E+03	1.08E+03	1.57E+03
13	FE59	5.15E+04	5.72E+03	6.23E+03	1.56E+04	4.74E+03	4.75E+03	5.15E+04	5.72E+03	1.34E+04
14	CO57	1.49E+04	1.72E+03	4.85E+02	2.45E+03	1.03E+03	1.67E+03	6.17E+04	2.20E+03	9.60E+03
15	CO58	5.90E+04	3.44E+03	2.36E+03	7.40E+03	3.44E+03	2.57E+03	5.92E+04	3.44E+03	1.15E+04
16	CO60	6.10E+05	2.80E+04	1.85E+04	2.85E+04	6.01E+04	5.06E+04	1.30E+06	6.45E+04	2.41E+05
17	ZN65	2.53E+04	1.10E+04	1.18E+04	1.03E+04	9.32E+03	1.26E+04	2.53E+04	1.36E+04	1.56E+04
18	GA67	8.90E+03	6.80E+02	1.40E+03	8.90E+03	3.00E+02	5.10E+02	8.90E+03	6.80E+02	1.50E+03
19	SE75	7.90E+04	4.10E+03	3.70E+03	1.70E+04	2.90E+03	3.10E+03	7.90E+04	4.10E+03	3.10E+03
20	KR85	1.50E+00	5.80E-05	7.10E-06	3.60E-06	5.60E-05	4.60E-05	1.50E+00	5.80E-05	1.80E-01
21	RB86	7.68E+03	1.10E+04	1.11E+04	1.26E+03	1.10E+04	1.10E+04	7.68E+03	1.10E+04	1.09E+04
22	SR89	6.55E+03	1.33E+04	2.18E+03	1.38E+04	2.18E+03	3.38E+04	6.55E+03	1.33E+04	5.73E+03
23	SR90	9.89E+03	1.70E+05	1.46E+04	1.41E+04	1.46E+04	3.00E+06	9.89E+03	1.10E+06	2.10E+05
24	Y90	3.93E+04	5.03E+02	4.61E+01	4.09E+04	4.61E+00	1.23E+03	3.93E+04	5.03E+02	8.71E+03
25	ZR95	6.85E+04	5.46E+03	3.24E+03	1.55E+04	2.94E+03	9.15E+03	6.85E+04	5.46E+03	1.34E+04
26	NB95	3.10E+04	1.61E+03	1.64E+03	7.17E+03	1.35E+03	1.22E+03	3.10E+04	1.61E+03	6.06E+03
27	MO99	4.04E+03	7.15E+02	3.54E+02	5.01E+02	3.69E+02	1.27E+03	4.04E+03	7.15E+02	2.30E+03
28	TC99M	8.54E+01	1.45E+01	1.16E+01	1.67E+01	1.33E+02	1.04E+01	8.54E+01	1.45E+01	2.85E+01
29	RU106	2.70E+06	6.20E+03	7.67E+03	1.40E+05	9.19E+03	8.76E+03	3.80E+06	9.37E+03	5.22E+05
30	IN111	2.70E+03	4.30E+02	6.00E+02	2.70E+03	8.30E+01	2.10E+02	2.70E+03	4.30E+02	1.00E+04
31	IN114	2.70E+05	4.70E+04	4.30E+03	7.60E+04	4.00E+03	2.40E+04	2.70E+05	4.70E+04	4.00E+04
32	SN113	6.70E+04	3.50E+03	1.90E+03	1.40E+04	1.50E+03	5.70E+03	6.70E+04	3.50E+03	9.80E+03
33	I123	2.40E+02	2.10E+01	8.70E+00	4.30E+00	1.20E+04	1.80E+01	2.40E+02	2.10E+01	3.90E+02
34	I125	3.70E+02	1.50E+02	5.60E+01	1.40E+01	7.50E+05	1.30E+02	3.70E+02	1.50E+02	2.40E+04
35	I129	7.88E+02	5.32E+02	3.78E+02	4.28E+00	5.00E+06	5.79E+02	7.88E+02	6.05E+02	1.50E+05
36	I131	2.40E+03	2.02E+02	3.98E+00	3.41E+01	1.10E+06	2.38E+02	2.40E+03	2.02E+02	3.43E+04
37	XE127	3.00E-01	1.00E-02	6.80E-04	5.60E-04	5.00E-03	7.90E-03	3.00E-01	1.00E-02	4.00E-02
38	XE133	8.50E-01	3.10E-03	5.30E-05	2.80E-05	6.80E-04	2.60E-03	8.50E-01	3.10E-03	1.00E-01
39	CS134	3.38E+04	5.70E+04	6.45E+04	3.71E+04	5.19E+04	5.36E+04	3.38E+04	6.16E+04	6.55E+04
40	CS137	1.60E+04	4.42E+04	5.00E+04	1.62E+04	4.47E+04	4.54E+04	1.60E+04	4.91E+04	4.83E+04

TABLE C.2 (continued)

41	BA140	9.74E+03	3.61E+03	2.74E+03	1.78E+04	1.97E+03	5.72E+03	9.74E+03	3.61E+03	4.91E+03
42	LA140	2.01E+04	8.52E+02	1.67E+03	2.11E+04	2.87E+02	8.00E+02	2.01E+04	8.52E+02	5.54E+03
43	CE141	4.25E+04	9.36E+02	2.76E+02	1.44E+04	1.40E+02	2.98E+03	4.25E+04	9.36E+02	7.64E+03
44	PM147	1.60E+05	1.90E+02	1.23E+04	6.44E+03	1.24E+02	6.58E+03	2.90E+05	6.96E+02	4.32E+04
45	EU152	6.90E+04	1.20E+04	3.40E+04	4.10E+04	5.20E+04	1.60E+05	1.60E+05	1.20E+05	2.40E+05
46	IR192	1.90E+05	3.60E+03	2.30E+03	2.40E+04	2.50E+03	2.70E+03	1.90E+05	3.60E+03	2.60E+04
47	AU198	1.60E+04	2.30E+02	5.50E+02	1.60E+04	1.10E+02	1.60E+02	1.60E+04	2.30E+02	3.00E+03
48	HG197	3.00E+03	1.10E+02	1.40E+02	2.90E+03	3.50E+01	7.10E+01	3.00E+03	1.10E+02	6.70E+02
49	HG203	3.50E+04	1.20E+03	1.20E+03	1.00E+04	8.00E+02	1.00E+03	3.50E+04	1.20E+03	5.30E+03
50	TL201	2.10E+03	1.70E+02	9.30E+01	1.30E+02	8.80E+01	1.40E+02	2.10E+03	1.70E+02	3.20E+02
51	PO210	4.60E+07	8.30E+05	8.00E+05	8.79E+04	8.00E+05	8.10E+05	4.60E+07	8.30E+05	8.76E+06
52	RA226	5.60E+07	2.30E+05	6.70E+05	1.80E+05	6.60E+05	4.90E+07	5.60E+07	2.50E+06	8.51E+06
53	TH230	2.10E+08	1.02E+07	1.10E+06	1.00E+05	1.10E+06	3.06E+08	5.26E+08	2.54E+08	2.59E+08
54	TH232	1.80E+08	1.08E+07	1.10E+06	1.10E+05	1.10E+06	3.27E+08	4.54E+08	2.71E+08	2.06E+08
55	U233	2.20E+08	2.20E+04	1.55E+04	1.10E+05	1.64E+04	8.00E+06	5.42E+08	2.40E+05	1.12E+08
56	U235	1.90E+08	1.70E+04	1.62E+04	2.50E+05	2.07E+04	7.20E+06	4.84E+08	1.90E+05	9.97E+07
57	U238	1.90E+08	1.80E+04	1.47E+04	2.80E+05	1.59E+04	7.10E+06	4.80E+08	2.00E+05	9.86E+07
58	NP237	5.90E+07	1.75E+07	9.90E+07	1.60E+05	1.40E+07	8.86E+08	5.90E+07	7.43E+08	3.46E+08
59	PU238	1.70E+08	7.30E+06	3.50E+07	1.20E+05	5.10E+06	3.11E+08	6.08E+08	2.61E+08	3.07E+08
60	PU239	2.30E+08	7.20E+06	4.00E+07	1.10E+05	5.80E+06	3.59E+08	5.80E+08	3.03E+08	3.47E+08
61	PU240	2.30E+08	7.20E+06	4.00E+07	1.10E+05	5.80E+06	3.58E+08	5.79E+08	3.02E+08	3.46E+08
62	PU241	4.70E+05	2.30E+04	9.00E+05	6.88E+02	1.60E+05	8.10E+06	1.10E+06	6.80E+06	5.38E+06
63	PU242	2.20E+08	6.80E+06	3.80E+07	1.10E+05	5.60E+06	3.42E+08	5.50E+08	2.87E+08	3.36E+08
64	AM241	6.40E+07	3.10E+07	1.03E+08	1.10E+05	1.50E+07	9.25E+08	6.40E+07	7.77E+08	5.63E+08
65	AM243	6.10E+07	3.10E+07	1.03E+08	1.90E+05	6.10E+06	9.27E+08	6.10E+07	7.77E+8	5.74E+08
66	CM242	5.50E+07	1.20E+07	2.00E+06	1.10E+05	3.00E+05	1.80E+07	5.50E+07	1.50E+07	1.76E+07
67	CM244	6.70E+07	3.20E+07	5.30E+07	1.10E+05	7.70E+06	4.76E+08	6.70E+07	3.99E+08	2.85E+08
68	CF252	1.30E+08	7.70E+07	2.00E+07	4.00E+05	3.00E+06	1.76E+08	1.30E+08	7.70E+07	8.84E+07
69	U-OXN	2.00E+08	2.00E+07	1.54E+04	1.93E+05	1.61E+04	7.50E+06	5.08E+08	2.20E+08	1.05E+08
70	U-OXE	2.10E+08	2.10E+07	1.59E+04	1.40E+05	1.62E+04	7.76E+06	5.26E+08	2.33E+08	1.09E+08
71	U-F6E	9.21E+05	2.00E+05	1.48E+05	4.07E+04	1.48E+05	7.53E+07	9.21E+05	2.23E+06	2.43E+06
72	U-F6D	8.60E+05	1.80E+05	1.40E+05	3.90E+04	1.40E+05	7.00E+07	8.60E+05	2.00E+06	2.22E+06
73	PU-OX	6.60E+06	3.60E+05	2.00E+06	3.80E+03	3.10E+05	1.80E+07	1.70E+07	1.50E+07	1.63E+07
74	PU-MX	1.70E+06	8.50E+05	4.80E+06	3.40E+03	7.00E+05	4.30E+07	1.70E+06	3.60E+07	2.60E+07
75	SFUEL	1.60E+04	4.42E+04	5.00E+04	1.62E+04	4.47E+04	4.54E+04	1.60E+04	4.91E+04	4.83E+04
76	MIXFI	1.60E+04	4.42E+04	5.00E+04	1.62E+04	4.47E+04	4.54E+04	1.60E+04	4.91E+04	4.83E+04
77	MIXCO	6.10E+05	2.80E+04	1.85E+04	2.85E+04	6.01E+04	5.06E+04	1.30E+06	6.45E+04	2.41E+05
78		0.	0.	0.	0.	0.	0.	0.	0.	0.
79		0.	0.	0.	0.	0.	0.	0.	0.	0.
80		0.	0.	0.	0.	0.	0.	0.	0.	0.

References

C-1 SVENSSON, Dose Conversion Factors for External Photon Radiation, FOA report C-40060-A3 (Oct. 1979).The Resarch Institute of the Swedish National Defense

C-2 DUNNING, et al; Estimates of Internal Dose Equivalent to 22 Target Organs for Radionuclides Occuring in Routine Releases from Nuclear Fuel-Cycle Facilities Vol.III Oak Ridge National Laboratory.ORNL/NUREG/TM-190/V3(1981).

C-3 FINLEY, et al; Transportation of Radionuclides in Urban Environs. NUREG/CR-0743, SAND79-0369, Sandia National Laboratories.

C-4 ROED; Investigation of Surface Deposition Pertaining to the Calculation of Aerosols Releases in Core-Meltdown Accidents in Power Reactors.Risø-M-2274 (Oct. 1981). Risø National Laboratory, Denmark

APPENDIX D

Population Distribution Model

The INTERTRAN code uses three population density zones each with an evenly distributed population. The three population zones are:

- Urban zone or high-population density zone meaning a central city with 50 000 or more inhabitants and surrounding closely-settled teritory.

- Suburban zone or medium-population density zone - meaning an area with at least 200 houses not more than 200 meters apart, e.g., smaller cities, villages and suburban areas around bigger cities.

- Rural zone or low-population density zone - meaning all other areas.

In reality the population distribution will not be evenly distributed in the areas effected by the impact from transportation of radioactive materials. For the road modes a concentration of people to the vicinity of the roads can be expected, especially in the rural areas. In the suburban and urban areas the effect is probably minimal with the exception of pedestrians which are treated separately. For the rail modes a similar effect can be expected for the rural areas but no pedestrians will be found along the urban and suburban parts of the shipment path.

For the water modes the effect will be the contrary, for coastal travel the surrounding population will be reduced in the neighborhood of the shipment path and for the ocean travel the surrounding population will be zero.

Since the highest doses are received in the neighborhood of the shipment path it is necessary for the user to adjust the over-all population density.

The normal dose from road transports in the rural zone is calculated in a strip 30-800 metres from the centre of the shipment path.

In the case of accidents with non-dispersable materials the maximum distance from the accident site for which the exposure is calculated is given as input data. But at distances more than 1000 metres the attuenation, the shielding from obstacles and the topographical structure will reduce the dose rate to a negligable level.

Thus, for both the normal dose and the dose from accidents with non-dispersable materials the population density for the area within one kilometer of the shipment path is appropriate to use.

The case of accidents with dispersable materials is more complicated. The distance from the shipment path of the affected areas depends on the meterological conditions, the deposition velocity of the dispersed material and the geographical stretching of the road. The fraction of the integrated dilution factor which will affect the area within one kilometer of the shipment path is estimated with the following assumptions.

- All wind-directions have equal probability.

- When determining the length of the isodose areas, they are assumed to be elipses with a ratio length to width of 10. This value is derived from dispersions calculations made with data for the Pasquill classes D-F.

- For the population density model the isodose areas are assumed to be a set of similar triangles. This assumtion result in isodose areas placed at a unique distance from the accident site.

With dilution factors calculated for Pasquill F about 40 to 80 percent of the integrated dilution factor will effect the area within one kilometer of the road. The percentage increases with increasing deposition velocity.

The method to determine the population density is best described with an example.

The population density data is taken from a map were the population within each square of a grid is given. Each square in the grid is 1 km^2.

The average population density in the rural areas is estimated to be about 7 persons per square kilometer and the average population density within 1 kilometer of the road was estimated to be about 17 persons per square kilometer. By using this higher value a more correct result is received for the normal case dose and the dose from accidents with non-dispersable materials. In the case with dispersable materials the population dose will be overestimated with a factor of 1.5 for a material with a deposition velocity of $1 \cdot 10^{-2}$ m/s.

In the case with ocean travel it can be necessary to make a special run with a reduced rural population density.

APPENDIX E

The Shielding Factors

The dose to bystanders in the urban and the suburban zone will be reduced because of the shielding effect of buildings. This effect will also occur in the rural zone but will not be as pronounced there.

The dose reduction is described with shielding factors, which are calculated for the urban and the suburban zone. Two integrals are evaluated over the exposed strip, one considering the shielding effect of air and another considering an effective altuenation factor based on the composite of air and the shielding medium.

The effective attuenation factor is calculated as:

$$\mu_{eff} = f_w \cdot \mu_B + (1-f_w) \cdot \mu_{air}$$

where:

$$f_w = \frac{2 \cdot W_T \cdot B_S \cdot N_W}{(B_S+W_S)^2}$$

W_T = wall thickness (metres)

B_S = building size (metres)

N_W = number of walls per block

W_S = street width (m)

μ_B = attuenation factor for building material (m^{-1})

μ_{air} = attuenation factor for air (m^{-1})

The attuenation factors are given in Table E.1.

The evaluated integral is thus:

$$\int_{d_{min}}^{d_{max}} \frac{e^{-\mu_{eff}x}}{x} \cdot B_{eff}$$

B_{eff} is the weighted build-up factor for the materials. The build-up factor for concrete and wood is calculated according to Taylors expression:

$$B\ (\mu r) = A\ \ e^{-\alpha_1 \mu r} + (1 - A)e^{-\alpha_2 \mu r}.$$

The build-up factor for air is calculated as $B(r) = 1 + 0{,}00197 \cdot r$

Where d_{min} and d_{max} are the integration limits for the sub-urban zone and the urban zone. An example of such shielding factors are given in Table E-2 and E-3.

Table E.1. Attuenation factors and build-up coefficients for 0.5 MeV photons.

Shielding Medium	Attuention factor m^{-1}	Build-up A	α_1	coefficients α_2
Air	0.0086	-	-	-
Concrete	22	12.5	-0.111	0.006
Wood	5	11.0	-0.104	0.030

Table E.2 Suburban zone shielding factors evaluated over a distance 30-800 metres from the shipment path.

Building size B_s (m)	Street width W_s (m)	Number of walls per building N_w	Wall thickness (m)	Wall material	Shielding factor
14	30	1	0.15	Wood	0.509
14	30	1	0.05	Wood	0.775
14	30	1	0.15	Concrete	0.138
14	15	1	0.15	Wood	0.262
14	15	1	0.15	Concrete	0.023
30	50	1	0.15	Concrete	0.244
30	100	1	0.15	Concrete	0.777
30	100	1	0.30	Concrete	0.324

Table E.3 Urban zone shielding factors evaluated over a distance 8-800 metres from the shipment path.

Building size B_s (m)	Street width W_s (m)	Number of walls per building N_w	Wall thickness (m)	Wall material	Shielding factor
60	18	1	0.30	Concrete	0.141
60	18	1	0.15	Concrete	0.29
60	18	2	0.30	Concrete	0.045
60	10	1	0.30	Concrete	0.104
60	10	1	0.15	Concrete	0.239

APPENDIX F

F.1 Chemical Risks of Transportation Accidents

When a radioactive material is released to the environment the chemical toxicity of the material can also give a significant impact. The INTERTRAN code considereds the chemical toxicity of uranium and of hydrogen fluoride (HF). HF is produced when uranium hexafluoride comes in contact with air humidity.

Soluble uranium which is inhaled will be resorbed in the lungs and transported by the blood to various parts of the body. A large proportion is decomposed in the urine, but significant quantities will be retained by the kidneys and skeleton. Examples of soluble uranium compounds, usually six valued, are UF_6 and UO_2F_2. For depleted, natural and low-enriched soluble uranium compounds the chemical toxicity will dominate over the radiological toxicity.

The unsoluable uranium compound such as UO_2 is not as easily resorbed and will have a longer biological half-life in the lung. This will cause the radiological toxicity to be dominating.

In the case with uranium transports the code identifies the material which is to be analyzed. The amount of uranium inhaled in the different isodose areas are taken from the radioactive dose calculations. Thus, the amount inhaled in an isodose area is given by:

$$N_{ijklnp} = CI_j \cdot RSA_p \cdot PPS_j \cdot RF_{ik} \cdot AER_{il} \cdot RESP_{IL} \cdot DF_N \quad (1)$$

N = amount of uranium inhaled (g)
CI = activity per package (ci)
RSA = reciprocal specific activity (g/ci)

PPS = number of packages per shipment
RF = package failure fraction
AER = fraction of material which becomes aerosolized
RESP = fraction of material of respirable size
DF = dilution factor (sec/m^3)
BR = breathing rate (m^3/s)
i = index over accident severity categories
j = index over materials
k = index over package types
l = index over material dispersibility categories
n = index over isodose areas
p = index over nuclides

The reciprocal specific activity values used are presented in Table F.1.

Table F.1 Reciprocal specific activity values

Nuclide	g/Ci
U233	$1.05 \cdot 10^2$
U235	$4.76 \cdot 10^5$
U238	$3.03 \cdot 10^6$
U (enriched 5.0%)	$3.70 \cdot 10^5$
U (natural)	$1.42 \cdot 10^6$
U (depleted)	$2.00 \cdot 10^6$

The amount of uranium inhaled by an individual in a city building is calculated the same way as for the radiological impact using a building dose factor, see Section 2.2.5.1.

In the same manner as for the radiological effect calculations the amount of uranium inhaled is compared with a dose-effect table were the probability of an early fatality supplied. The dose-effect values used are presented in Table F.2.

Table F.2 Dose effect values for uranium

Amount inhaled (mg)	Probability of fatality
800	1.00
500	0.95
300	0.80
200	0.70
170	0.50
140	0.30
100	0.20
70	0.10
50	0
10	0

The inhaled amounts are also compared with a hygenic threshold value and the number of persons receiving a dose higher than that value is calculated.

If uranium hexafluoride is released in an accident it will react with the humidity in the air in the following way:

$$UF_6(g) + 2H_2O(g) \rightleftharpoons UO_2F_2(s) + 4HF(g)$$

The uranyl fluoride (UO_2F_2) will form a fine aerosol, the hydrogene fluoride (HF) will be released in gaseous form and they will be dispersed from the accident site.

In this reaction the availability of water will be the limiting factor. The water content of air is dependent on the temperature and the relative humidity. To perform a complete reaction of the contents of a 30B-cylinder (2 tons UF_6) would require about 20 000 m^3 of air with a temperature of 20°C and a relative humidity of 60%.

The impact of a uranium hexafluoride release is calculated based on the chemical toxicity of uranium which is determined the same way as above and the chemical toxicity of hydrogen fluoride. To calculate the impact of hydrogen fluoride the concentration in each isodose area has to be estimated. This is done by assigning an average release time for each accident severity category. The average concentration in each isodose area C is then given by:

$$C_{ijklnp} = CI_j \cdot RSA_p \cdot PPS_j \cdot FHF \cdot RF_{ik} \cdot AER_{il} \cdot RESP_{il} \cdot DF_n \cdot BR/RT_i \qquad (2)$$

FHF = amount HF formed from UF_6 (0.336 kg HF/kg UF_6)
RT_i = release time for accident of severity i

The default release times presented in Table F-3 are given in DATA statements in the code.

Table F.3 Release times for accidents with uranium hexafluoride

Accident Severity Category	Release time (h)
I	0.25
II	0.25
III	0.25
IV	0.25
V	1.0
VI	1.0
VII	1.0
VIII	1.0
IX	1.0
X	1.0
XI	1.0

A number of things makes it difficult to predict the actual concentrations in the cloud:

- the high density of UF_6 vapour
- the thermal lift from a fire accident
- the heat of reaction when HF is continuously formed in the cloud
- the increase in number of molecules when HF is formed.

The calculations made in INTERTRAN are very simple and assume that no thermal effects occurs. The UF_6 dispersion is calculated with the ordinary dispersion model and all of it will be converted to UO_2F_2 and HF. The reaction does not effect the dispersion calculations.
The concentration in each isodose area is used when calculating the individual lethality probability assuming one hours exposure time. The computations are made the same way as for uranium using the dose-effect values in Table F-4.

The concentration values are also compared with a hygenic limit and the number of persons exposed to a concentration higher than that limit is calculated

Table F.4 Dose-effect values for inhaling hydrogen fluoride 1-hour exposure

Concentration of hydrogen fluoride (mg/m^3)	Probability of fatality
800	1.00
500	1.00
300	1.00
200	0.95
170	0.75
140	0.50
100	0.30
70	0.10
50	0
10	0

It has been assumed in the calculations that the persons exposed to uranium will be the same people exposed to hydrogen fluoride. As a result of this the expected number of fatalities from a uranium hexafluoride accident is calculated from the maximum of the impact from uranium and the impact from hydrogen fluoride.

There is no compensation made for persons subjected to both the chemical and the radiological effect of transport accident with a uranium material. This must be considered when evaluating the final results.

F.2 Chemical Accident Data

The hygenic limits of uranium inhalation and hydrogen fluoride concentration must be given if the chemical risks of transportation accidents shall be analyzed. The ICRP states a maximum daily limit of 2.5 mg uranium inhaled /F-1/.

The Public Emergency Limit for airborne concentration from accidental unpredictible events of hydrogen fluoride release is 4 mg/m^3 for a 60 minute exposure /F-2/.

The chemical accident calculations are made if the datablock CHEM is included in the input datadeck, see Appendix B.

Note that in order to calculate the chemical risk of uranium hexafluorid the charcters "HEX" must be given in position 6-8 in the material name. For example enriched uranium hexafluoride must be written U-F6EHEX.

REFERENCES

F-1 International Commission of Radiological Protection, ICRP Publication 6

F-2 American Conference of Government Industrial Hygienists; Documentation of Threshold Limit Values

APPENDIX G

The Interactive Input Program INREAD.

INREAD is written to help the user to write the input data file for the INTERTRAN program. The INREAD program can be used if an interactive facility is available. It is constructed in such a way that the user gets a short instruction at the beginning of the program and is then asked to insert data in the different data blocks described in Appendix B. If no data needs to be changed in a data block the user can proceed to the next. Are changes to be made in a data block will the program ask for the parameter and the user can insert new data or use the default data by giving an empty carriage return. This means that if only a single parameter is to be changed in a data block the user can "advance" to this parameter by giving empty carriage returns, insert the wanted value of the parameter and proceed to the end of the block by empty carriage returns.

The order of the data blocks is given in Figure G.1. The first two blocks TITLE and PARM are compulsory to answer. The type of calculations which are to be made, incident-free case, accident case or both will determine the data blocks that will be used. Only the necessary input for each calculation have to be given. The user is also given a chance to correct already inserted data.

The data block SHIPMENT is a loop were the user specifies the number of materials which are to be inserted. The program will ask questions about material name,activity, transport index, etc. When asked about shipments per year and distance per shipment the user can give an empty carriage return to indicate zero shipments.

In the data block CONTROL the user will construct the standard shipments by giving the index of the material, the

PROGRAM INREAD

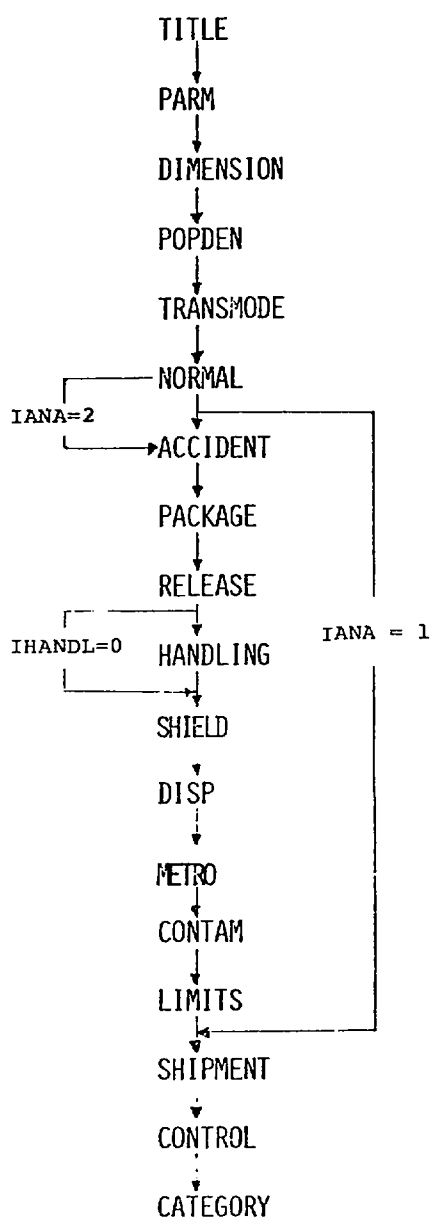


FIGURE G.1. The Structur of the Interactive Input Program INREAD.

primary transportation situation and the secondary transport situation. The program checks for the use of transport situations with no shipments specified and gives a warning, if a transport situation is used more than once for the same material. An example of the output from a run of program INREAD is given in Figures G.2 - G.7. The resulting input data file is shown i Figure G.8.

FIGURE C.2

```
THIS IS AN INTERACTIVE PROGRAM TO CREATE INPUT DATA FILES  FOR INTERTRAN RUNS

THE USER CAN INSERT REPLACMENT DATA FOR THE DEFAULT DATA WHEN THE QUESTION MARK
PROMPTER APPEARS. IF AN EMPTY <RETURN> IS ENTERED THE DEFAULT DATA WILL BE USED.
THE USER CAN "OK" OR CHANGE ANY DATA ENTERED.


HAVE YOU  READ THE USER S MANUAL AND PREPARED THE DATA TABLES?
IS THIS OK? (Y/N)
? Y
TITLE OF RUN?
? ** example of using the inread code **
** EXAMPLE OF USING THE INREAD CODE **
IS THIS OK? (Y/N)
? Y
ANALYSIS OF DOSE FROM NORMAL TRANSPORTS?
IS THIS OK? (Y/N)
? Y
ANALYSIS OF DOSE FROM ACCIDENTS?
IS THIS OK? (Y/N)
? Y
SENSITIVITY ANALYSIS MADE?
IS THIS OK? (Y/N)
? Y
ANALYSIS OF DOSE FROM HANDLING ACCIDENTS?
IS THIS OK? (Y/N)
? Y
PROBABILITY OUTPUT ON TAPE6?
IS THIS OK? (Y/N)
? n
IRNKC= 0 ,IANA= 3  ISEN= 1  IHANDL= 1
IS THIS OK? (Y/N)
? Y
DO YOU WISH TO CHANGE ANY DIMENSIONS?
IS THIS OK? (Y/N)
? n
NSEV= 11 NPTYPE= 10 NIM= 11 NAREAS= 15
IS THIS OK? (Y/N)
? Y
```

FIGURE G.3

```
CHANGES IN POPULATION DENSITY?
IS THIS OK? (Y/N)
? Y
     RURAL POPULATION DENSITY (PERSONS PER SQ. KM.)?
? 32
  SUBURBAN POPULATION DENSITY (PERSONS PER SQ. KM.)?
?
 500.
     URBAN POPULATION DENSITY (PERSONS PER SQ. KM.)?
? 2800
     RURAL POPDEN=     32.    SUBURBAN POPDEN=    500.       URBAN POPDEN=  2800.
IS THIS OK? (Y/N)
? Y
PEDESTRIAN DENSITY FACTOR ?
?
 6.
IS THIS OK? (Y/N)
? Y
CHANGES IN TRANSPORT MODES?
IS THIS OK? (Y/N)
? Y
NUMBER OF TRANSPORT MODES USED? LESS THAN 10 =DEFAULT
? 1
 1
IS THIS OK? (Y/N)
? Y
LABEL?
MODTYP? (ROAD=1 AIR=2 RAIL=3 WATER=4)
TRANSPORT MODE NUMBER  1
? sf-truck
? 1
TRANSPORT MODES ARE           OF TYPE
         SF-TRUCK                     1

IS THIS OK? (Y/N)
? Y
CHANGES IN THE TRANSPORT MODE PARAMETERS?


** WARNING ** YOU HAVE MADE CHANGES IN BLOCK TRANSMODE
CORRESPONDING CHANGES IN BLOCK NORMAL     MAY BE NECESSARY.
```

```
IS THIS OK? (Y/N)
? Y
WRITE FRACTION OF TRAVEL IN THE POPULTATION ZONES
SF-TRUCK
     RURAL
? .9
  SUBURBAN
? .08
     URBAN
? .02
                 RURAL    SUBURBAN       URBAN
SF-TRUCK     9.000E-01   8.000E-02   2.000E-02

IS THIS OK? (Y/N)
? Y
VELOCITY IN POPULATION ZONES (KM/H)?
SF-TRUCK
     RURAL
? 30
  SUBURBAN
? 30
     URBAN
? 15
                 RURAL    SUBURBAN       URBAN
SF-TRUCK     3.000E+01   3.000E+01   1.500E+01

IS THIS OK? (Y/N)
? Y
NUMBER OF CREW? DISTANCE SOURCE TO CREW (M)? NO. OF HANDLINGS?
SF-TRUCK
? 2 8 2
      MODE       CREW  DISTANCE  HANDLINGS
SF-TRUCK         2.00      8.00       2.00

IS THIS OK? (Y/N)
? Y
N:O OF ATTENDANTS ON PASSENGER AIR?
?
 4.
IS THIS OK? (Y/N)
? Y
```

FIGURE G.4

FIGURE G.5

```
STOP TIME/24HR(H)? PERSON EXPOSED? EXPOSURE DISTANCE(M)?
SF-TRUCK
? 0 0 0
MODE          EXP. TIME NO. EXPO.  DISTANCE
SF-TRUCK           0.00      0.00      0.00

IS THIS OK? (Y/N)
? Y
STORAGE TIME(H)? PERSONS EXPOSED? EXPOSURE DISTANCE (M)?
SF-TRUCK
? Q Φ0050
MODE          EXP. TIME NO. EXPO.  DISTANCE
SF-TRUCK           0.00      0.00      0.00

IS THIS OK? (Y/N)
? Y
NO. OF PERSONS PER VEHICLE? (NOT FOR SHIP OR CARGO AIR)
SF-TRUCK
? 2
SF-TRUCK    2.000E+00
IS THIS OK? (Y/N)
? Y
FRACTION OF RUSH-HOUR TRAFFIC?, CITY STREETTRAVEL? AND FREEWAY TRAVEL? (ONLY ROAD MODES)
SF-TRUCK
? 0 0 .25
MODE         RUSH-HOUR CITY STS  FREEWAYS
SF-TRUCK    0.         0.          .250

IS THIS OK? (Y/N)
? 50 205 550
FRACTION OF RUSH-HOUR TRAFFIC?, CITY STREET TRAVEL? AND FREEWAY TRAVEL? (ONLY ROAD MODES)
SF-TRUCK
? Y
         Y<-ERROR IN COL.  1, RETYPE RECORD FROM THIS FIELD
? 0
? 0 .25
MODE         RUSH-HOUR CITY STS  FREEWAYS
SF-TRUCK    0.         0.          .250

IS THIS OK? (Y/N)
? Y
```

```
TRAFFIC COUNT PASSING A SPECIFIC POINT IN THE ZONES (1/H)?
SF-TRUCK
     RURAL  SUBURBAN     URBAN
? 50 200 550
                 RURAL     SUBURBAN       URBAN
SF-TRUCK      5.000E+01   2.000E+02   5.500E+02

IS THIS OK? (Y/N)
? Y
OPTION FOR CALCULATION OF DOSE TO BYSTANDERS IN URBAN ZONE? (1, 2 OR 3)
? 2
 2
IS THIS OK? (Y/N)
? Y
DOSE LIMIT OF 2 MREM/H FOR CREW ON EXCLUSIVE-USE VEHICLES?      =0
DOSE LIMIT FOR CREW ON ALL VEHICLES?          =1
? 0
 0
IS THIS OK? (Y/N)
? Y
ACCIDENT DATA FOR MODES AND SEVERITY CATEGORIES?


** WARNING ** YOU HAVE MADE CHANGES IN BLOCK TRANSMODE
CORRESPONDING CHANGES IN BLOCK ACCIDENT   MAY BE NECESSARY.


IS THIS OK? (Y/N)
? n
CHANGES IN PACKAGE TYPES?
IS THIS OK? (Y/N)
? n
CHANGES IN PACKAGE FAILURE FRACTIONS?
IS THIS OK? (Y/N)
? n
CHANGES IN HANDLING ACCIDENT PROBABILITIES?
IS THIS OK? (Y/N)
? n
CHANGES IN SHIELDING FACTORS?
IS THIS OK? (Y/N)
? n
```

FIGURE 6.6

FIGURE 6.7

```
NEW SET OF DILUTION FACTORS?
IS THIS OK? (Y/N)
? n
CHANGE IN DISPERSION DATA?
IS THIS OK? (Y/N)
? n
CHANGES IN GROUND CONTAMINATION DATA?
IS THIS OK? (Y/N)
? n

 * END OF INPUT PARAMETER SECTION *

 * SHIPMENT DATA  SECTION *

INSERT INPUT DATA MADE UP ACCORDING TO SECTION 3 OF THE USER'S MANUAL


NUMBER OF MATERIALS TO BE ANALYZED?
? 2
LABEL OF MATERIAL    1?
? sfuel-ext
PACKAGE TYPE?
? cask-ex1
NUMBER OF PACKAGES PER SHIPMENT?
? 1
TRANSPORT INDEX PER PACKAGE?
? 11
ACTIVITY PER PACKAGE? (CURIES)
? 1234
MATERIAL DISPERSIVITY CATEGORY?
? 1
NUMBER OF SHIPMENTS AND DISTANCE PER SHIPMENT WITH SF-TRUCK
? 12 400
  1 SFUEL-EXT  LTYPKG: CASK-EX1   PPS:    1. TI=  11.0      ACT= 1.234E+03 IM=  1

N:O  MODE        N:O SHIPMENTS        DISTANCE
  1  SF-TRUCK         12.00           400.0
IS THIS OK? (Y/N)
? Y
```

FIGURE 6.8

```
LABEL OF MATERIAL    2?
? sfuel-rel
PACKAGE TYPE?
? cask-rel
NUMBER OF PACKAGES PER SHIPMENT?
? 1
TRANSPORT INDEX PER PACKAGE?
? 0
ACTIVITY PER PACKAGE? (CURIES)
? 567
MATERIAL DISPERSIVITY CATEGORY?
? 4
NUMBER OF SHIPMENTS AND DISTANCE PER SHIPMENT WITH SF-TRUCK
? 12 400
  2 SFUEL-REL  LTYPKG: CASK-REL    PPS:    1. TI= 0.         ACT=  567.      IM=  4

N:O  MODE         N:O SHIPMENTS        DISTANCE
  1  SF-TRUCK          12.00           400.0
IS THIS OK? (Y/N)
? Y

* STANDARD SHIPMENT DESIGN SECTION *
HERE THE ANALYSED  MATERIALS ARE CHOSEN AND THE STANDARD SHIPMENTS COMBINED.
200 STANDARD SHIPMENTS CAN BE USED. TO QUIT THIS SECTION ENTER   AN EMPTY
<RETURN>
STANDARD SHIPMENT N:O    1
INDEX OF MATERIAL SHIPPED? PRIMARY MODE? SECONDARY MODE?
? 1 1 0
EXCLUSIVE USE SHIPMENT
IS THIS OK? (Y/N)
? Y
PRINT OUT OPTION? (0,1 OR 2)
? 2
TRANSPORT OF SFUEL-EXT  WITH PRI. MODE SF-TRUCK   AND SEC. MODE
IS THIS OK? (Y/N)
? Y
```

FIGURE G.9

```
STANDARD SHIPMENT N:O    2
INDEX OF MATERIAL SHIPPED? PRIMARY MODE? SECONDARY MODE?
? 2 1 0
EXCLUSIVE USE SHIPMENT
IS THIS OK? (Y/N)
? Y
PRINt OUT OPTION? (0,1 OR 2)
? 2
TRANSPORT OF SFUEL-REL  WITH PRI. MODE SF-TRUCK    AND SEC. MODE
IS THIS OK? (Y/N)
? Y
STANDARD SHIPMENT N:O    3
INDEX OF MATERIAL SHIPPED? PRIMARY MODE? SECONDARY MODE?
?
CATEGORIES FOR FINAL SUMMATION?
IS THIS OK? (Y/N)
? n
     0.493 CP SECONDS EXECUTION TIME.
```

FIGURE 6.10

```
 ITLE
** EXAMPLE OF USING THE INREAD CODE **
 ARM
    0    3    1    1
 IMENSION
   11   10   10   11   15
POPDEN
 3.200E+01 5.000E+02 2.800E+03 0.
 6.000E+00
TRANSMODE
SF-TRUCK  P. VAN    PASS. AIR CARGO AIR RAIL       SHIP-1    SHIP-2    TRUCK-2
CVAN-1    CVAN-2
    1    1    2    2    3    4    4    1    1    1
NORMAL
 9.000E-01 5.000E-02 9.500E-01 9.500E-01 8.000E-01 9.900E-01 9.000E-01 9.000E-01
 5.000E-02 5.000E-02
 8.000E-02 4.000E-01 3.000E-02 3.000E-02 1.500E-01 1.000E-02 1.000E-01 8.000E-02
 4.000E-01 4.000E-01
 2.000E-02 5.500E-01 2.000E-02 2.000E-02 5.000E-02 0.        0.        2.000E-02
 5.500E-01 5.500E-01
 3.000E+01 9.000E+01 6.000E+02 6.000E+02 9.000E+01 1.800E+01 1.800E+01 5.000E+01
 9.000E+01 9.000E+01
 3.000E+01 5.000E+01 6.000E+02 6.000E+02 7.000E+01 1.400E+01 1.400E+01 3.000E+01
 5.000E+01 5.000E+01
 1.500E+01 3.000E+01 6.000E+02 6.000E+02 5.000E+01 5.000E+00 5.000E+00 1.500E+01
 3.000E+01 3.000E+01
 2.000E+00 1.000E+00 3.000E+00 3.000E+00 2.000E+00 2.000E+01 1.000E+01 2.000E+00
 1.000E+00 1.000E+00
 8.000E+00 2.000E+00 1.500E+01 6.000E+00 1.500E+02 5.000E+01 2.500E+01 6.000E+00
 2.000E+00 2.000E+00
 2.000E+00 1.000E+00 2.000E+00 2.000E+00 2.000E+00 2.000E+00 2.000E+00 2.000E+00
 1.000E+00 1.000E+00
 0.        8.000E+00 8.000E+00 8.000E+00 8.000E+00 8.000E+00 8.000E+00 8.000E+00
 8.000E+00 8.000E+00
 0.        1.000E+02 1.000E+03 5.000E+01 5.000E+01 5.000E+01 5.000E+01 1.000E+01
 1.000E+02 1.000E+02
 0.        1.000E+01 5.000E+01 5.000E+01 2.000E+01 5.000E+01 5.000E+01 2.000E+01
 1.000E+01 1.000E+01
 0.        4.000E+00 0.        0.        2.400E+01 4.800E+01 2.400E+01 0.
 4.000E+00 4.000E+00
 0.        1.000E+02 0.        0.        1.000E+02 1.000E+02 1.000E+02 0.
 1.000E+02 1.000E+02
 0.        1.000E+02 0.        0.        1.000E+02 1.000E+02 1.000E+02 0.
 1.000E+02 1.000E+02
 2.000E+00 2.000E+00 1.100E+02 0.        3.000E+02 0.        0.        2.000E+00
 2.000E+00 2.000E+00
 0.        1.700E-01 0.        0.        0.        0.        0.        8.000E-02
 1.700E-01 1.700E-01
 0.        6.500E-01 0.        0         0.        0.        0.        5.000E-02
 6.500E-01 6.500E-01
 2.500E-01 2.500E-01 0.        0.        0.        0.        0.        5.000E-01
 2.500E-01 2.500E-01
 5.000E+01 2.500E+02 0.        0.        2.000E+00 0.        0.        2.500E+02
 2.500E+02 2.500E+02
 2.000E+02 7.000E+02 0.        0.        5.000E+00 0.        0.        7.000E+02
 7.000E+02 7.000E+02
 5.500E+02 1.200E+03 0.        0.        5.000E+00 0.        0.        1.200E+03
 1.200E+03 1.200E+03
 4.000E+00
 0.        0.
SHIPMENT
    2
SFUEL-EXT SFUEL-REL
CASK-EX1  CASK-REL
 1.000E+00 1.000E+00
 1.100E+01 0.
 1.234E+03 5.670E+02
    1    4
 1.200E+01 0.        0.        0.        0.        0.        0.        0.
 0.        0.
 1.200E+01 0.        0.        0.        0.        0.        0.        0.
 0.        0.
 4.000E+02 0.        0.        0.        0.        0.        0.        0.
 0.        0.
 4.000E+02 0.        0.        0.        0.        0.        0.        0.
 0.        0.
 CONTROL
    1   -1    0    2
    2   -1    0    2
```

83-02666