ADVISORY MATERIAL

for the INTERTRAN2 computer program.

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Prepared by the Coordinated Research Programme on Probabilistic Safety Assessment Techniques Related to the Safe Transport of Radioactive Materials

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1. INTRODUCTION.

This document is one in a series of documents prepared within the framework of the IAEA's Coordinated Research Programme on the Probabilistic Safety Techniques Related to the Safe Transport of radioactive Materials.

The documents in this series contain information about the different parts included in the INTERTRAN2 package for risk assessment on transportation of radioactive material. The package is a result of the work within the above mentioned IAEA Coordinated Research Programme.

The following countries have been participating in the work;

Canada
Egypt
Finland
France
Germany
India
Japan
Peoples Republic of China
Sweden
United Kingdom
United States

A pre-meeting to this CRP took place in Stockholm 1987, hosted by the Swedish Nuclear Power Inspectorate. At this meeting the experiences with the earlier developed computer programme INTERTRAN were discussed. The INTERTRAN computer code have been available since 1983 and it was felt that all experiences gained from using the code should be taken into account and that the time for updating the code was appropriate. The meeting in Stockholm in 1987 led to the upstart of this CRP.

This Coordinating Research programme started in 1989 with a first meeting hosted by the Sandia National Laboratories in Albuquerque , New Mexico, USA. After that meetings have been held in Vienna 1990 hosted by the IAEA, in Paris 1991 hosted by Institut de Protection et de Sureté Nucléaire (IPSN), in Cologne 1993 hosted by the Gesellschaft fur Reaktorsicherheit GmbH and 1994 in Canada hosted by the Ontario Hydro.

The main tasks for this CRP have been to improve the INTERTRAN package in accordance with the experienced gained from using the previous version. The new package is called the INTERTRAN2. The INTERTRAN2 model, however does not contain anything from the older INTERTRAN but are completely built around independent parts that have been modified and linked together for this purpose.

The INTERTRAN2 package contains a base for risk assessment , the RADTRAN 4 computer code modified for international purposes and PC use by AMC konsult AB. The RADTRAN 4 main frame computer code has been made available and modified in accordance with the recommendations of the CRP by the Sandia National Laboratories, Albuquerque, NM, USA. The INTERTRAN2 package also contains an atmospheric dispersion model made available and modified for this purpose by Institut de Protection et Sureté Nucléaire (IPSN), France. The input data handler developed by the AMC Konsult AB , in Sweden under contract with the Swedish Nuclear Power Inspectorate was included after request from member states to get a tool which could facilitate for less experienced users to create their input data files for the programme.
In addition two independent programmes have been submitted by the Sandia National Laboratories, one dealing with calculation of individual doses (TICLD) and one dealing with sensitivity analysis (LHS).

The risk assessment computer codes RADTRAN 4 and the TICLD are also installed on the TRANSNET network at Sandia National Laboratories in the United States. The installation on TRANSNET is using a different preprocessor than the PC version Other codes, including TRANSAT; several domestic databases; and a number of sample RADTRAN files are also available on this network. TRANSNET is accessible via the INTERNET with the following INTERNET address:

TTD9.TTD.SANDIA.GOV

and a password. Passwords are issued by Sandia National Laboratories. For further information write to Richard Orzel, System Administrator, Sandia National Laboratories, Mail Stop 0718, Albuquerque, NM, 87123, USA.

The documentation has been written by different authors from participating countries. The documentation for each of the included programmes have been written by the organisation submitting the programmes. The Advisory document is a jointly written document.

During the work within the CRP all participants have been testing the different parts of the programme and given valuable input for the modifications that have been made. The final package is therefore a product jointly produced by all participants of the CRP.

The INTERTRAN2 package contains the following computer programmes and documents;

Computer Programmes:

The INTERTRAN2 Windows program including:

The RADTRAN4.19.IOSI computer code (PC version)
The TRANSAT atmospheric dispersion model

Code for calculating individual doses (on request/downloadable)
Code for Sensitivity Analysis (on request/downloadable)

Documentation:

Advisory Material
Technical documentation, Programmer´s Manual and User´s Guide for each of the programmes.
QA documentation for the models

All computer programmes are available on 3 1/2" diskettes, CD-ROM or downloadable at: www.amckonsult.se

1.1 Scope

The INTERTRAN2 package is a computer code system for the assessment of radiological consequences and risks for the transport of radioactive material. It allows to study incident-free and accident conditions of transport separately. It is applicable to all modes of transport, in particular to multi modal shipments, and it can deal with nuclear material and industrial material as well as radiopharmapheuticals.

Under normal conditions of transport (incident-free case) the expected dose to workers and to different members of the public along the transport route can be calculated as collective dose, taking into account also handling operations. this incident-free case exposure of persons results from the external radiation originating from the radioactive material within the package during shipment. In addition to the collective dose of different subgroups the code also computes a hypothetical maximum dose to an individual member of the public who lives beside a highway or a railroad track. Under accident conditions the INTERTRAN2 package can be used to estimate the resulting external and internal individual and population doses as the consequence of an accident to be analysed and the corresponding risk.

The INTERTRAN2 package provides a tool, e.g. for

- specific shipment studies
- national assessments
- comparison of shipment options
- supporting decision making processes and optimization of transport concepts and technologies from the viewpoint of radioactive protection safety.

The computer code system allows the user to adjust the analysis to the specific problem being analyzed, but the resolution of an analysis may be limited by the quality of available data. Taking this into account the scope of the INTERTRAN2 package and the accuracy of the results are mainly limited by the availability and quality of the data which are necessary to represent the specific transport situation to be analyzed.

2. LIMITATIONS IN THE MODEL.

2.1 Limitations in RADTRAN 4

RADTRAN 4 is not intended for the performance of site specific consequence or risk analyses. In a site -specific analyses, the consequences and risk associated with events or operations at specific locations are estimated. Many of the analytical methodologies in RADTRAN 4 differ mathematically from those used with fixed locations because RADTRAN 4 is used to analyze the effects of radioactive transport involving a source moving through a constantly variating landscape and potentially stopped at virtually any location along a route in the same landscape. To address this difficulty, populations along route segments are modelled as being uniformly distributed. Different population densities may be assigned to different route segments, but the distribution is always treated as uniform.

At fixed locations, wind-direction data (wind roses) from weather stations in the same area are often used in risk analyses. Wind-rose data are not used in the dispersal accident analysis in RADTRAN 4. Wind-rose data are used to distinguish between differences in potential population exposures according to wind direction, but with a uniformly distributed population model, all wind directions would give the same results. Further, weather stations are absent on most links of any transportation route and detailed meteorological data are not available for those links. The RADTRAN 4 calculation strategy for dispersal intentionally precludes the need for such unobtainable data. The possibility exists of extrapolating from weather data at a few locations and applying these data to the surrounding region (so called "mesoscale" weather), but meteorologists have not yet developed reliable methods of doing this. Much broader national-average data have been used for analyses of cross-country transportation, however. If particular locations along potential routes are of special interest, then detailed site-specific consequence analyses may be performed to complement a RADTRAN 4 risk analysis. Further, in many codes used for stationary facilities that have been in operation for years, chronic releases are modeled. Releases of this type cannot be analyzed with RADTRAN 4.

Chemical hazards analyses necessary in assessing the consequences and risks of shipping hazardous substances such as uranium hexafluoride are also not performed by RADTRAN 4. In addition, RADTRAN 4 does not address radiological consequences to emergency response personnel.

2.1.1 Stop time with link option.

When using the LINK option, the user must be aware that entered values for Stop Time are applied on a <u>per link</u> basis. Since stop time dat a are usually only available on per trip basis, the user must divide trip stop time by the number of links and assign the resulting value to the Stop Time parameter (2nd level keyword STOPTIM under NORMAL).

2.1.2 Health Effect Model.

Another limitation of RADTRAN 4 is that the internal health effects model is out of date and should not be used. Results should be obtained as dose-risks; and current conversion factors from CRP-60 or other source should be applied the dose-risk values to yield health-effects risks.

Another limitation of RADTRAN is that the internal health effects model is out of date and should not be used. Results should be obtained as dose-risks and conversion factors from an appropriate source used to calculate health effects. The default dose per unit intake values in RADTRAN for inhalation and ingestion are for Committed Effective Dose Equivalent (CEDE) which is the appropriate dose for use with the dose risk conversion factor from ICRP 26 ($1.25x10^{-4}$ fatal cancers rem^{-1}). RADTRAN 4 allows the user to modify these values in the input data file, Committed Effective Dose (CED) per unit intake factors can therefore be entered in place of the CEDEs These are appropriate for use with the dose risk conversion factor from ICRP 60 for the whole population ($5x10^{-4}$ fatal cancers rem^{-1}) CEDs can be obtained from, for example, ICRP 68 (multiplied by $3.7x10^{12}$ to convert from $Sv.Bq^{-1}$ to rem Ci^{-1}).

The above approach is acceptable provided the individual doses are sufficiently low that there are no early effects. If there is the potential for early effects the Dose and Dose Rate Effectiveness Factor needs to be modified.

ICRP 26 Recommendations of the International Commission on Radiological Protection, Annals of ICRP Vol 1 No 2, Jan 1977.

ICRP 60 1990 Recommendations of the International Commission on Radiological Protection, Annals of ICRP Vol 21 No 1-3, March 1991.

ICRP 68 Dose Coefficients for Intakes of Radionuclides by Workers, Annals of ICRP Vol 24 No 4,1994.

2.1.3 Meteorological parameters not route specific.

User cannot apply separate sets of meteorological data to individual route segments in the LINK option. Segment-level data are seldom available in the US, and conservative values are routinely used anyway because the latter approach is preferred for the most common type of RADTRAN 4 applications in the United States, the preparation of environmental impact statements (EIS's) and environmental assessments (EA's) under U.S. federal law (National Environmental Policy Act). However, this may be a limitation to persons with detailed meteorological data who whish to use them in a RADTRAN analysis. The only method to employ such data is to perform a separate run of the code for every segment(s) with distinct meteorological characteristics.

2.1.4 Ground scatter

Ground scatter is not directly accounted for in the code, but the curve-fitting coefficients for gamma and neutron radiation maybe altered to account for scatter if the user has data to support the change. Since the nature of the ground surface (albedo, roughness, etc.) may vary widely as a conveyance traverses a route, it is virtually impossible to accurately account for this effect within a numerical model. It is probably best accounted for by means of uncertainty analysis. In addition, the inherent conservatism of the basic point- and line-source models generally encompasses the scatter contributions (i.e. gives a result that bounds actual measurements that include all contributions to dose rate). Therefore, the user should benchmark against actual measurements, if possible, before changing the default coefficients.

The use of a resuspension fraction and adhesion half time at the upper end of the ranges of postulated values gives an integrated resuspension factor which is higher than equivalent values used in, for example, the UK. The contribution to total dose from resuspension in RADTRAN can therefore be large when compared to the initial inhalation dose and is considered very conservative for wetter climates. The user should consider applying country specific correction factors based on the nuclides involved.

2.1.6 *Additional Considerations*

Incident free calculations

Doses to drivers for road vehicles carrying a large number of packages can be significantly overestimated (refer to user manual for advice on overcoming this problem).

Regulatory checks limit the dose to the crew to 2 mrem h^{-1} based on US regulatory requirements. The IAEA Regulations limit the radiation level to 2 mrem h^{-1} unless persons occupying the position are provided with personal monitoring devices; ie radiation levels may exceed the cut-off without contravening the regulations. RADTRAN may therefore underestimate the dose to the crew in some cases.

Dose to passengers is not considered for air transport.

The distance of pedestrians to the centre of the road in the rural and suburban zone is based on US conditions and is long compared to, for example UK conditions. This could lead to an underestimate of doses by a factor of up to 5.

Accident conditions

In determining the consequences of accidents resulting in a release of activity to the atmosphere RADTRAN 4 utilises predetermined time integrated airborne concentrations and associated isopleth areas. The isopleth areas are dependant on the values of parameters in the dispersion model used to generate them. Users should check if the parameters used are suitable for their application and generate alternative isopleth areas if this is not the case. The TRANSAT code may be useful, but it is noted that there is no option to modify the roughness length in TRANSAT.

Default Data

Default data is provided in the RADTRAN code and discussed in Section 3 of the RADTRAN User Guide. It is important that the user does not simply accept this data as much of it is country or route specific. For example the Building Dose Factor default is more suited to areas with a high proportion of air conditioned buildings. Section 3 of this document underlines the importance of using application specific data and discusses in detail data collection concerning accident rates, release fractions and route data.

2.2 Limitations in TRANSAT.

The TRANSAT atmospheric dispersion code is founded on the widely used Gaussian model with standard deviations expressed according to the PASQUILL's categorization scheme of weather conditions. Moreover, the time-integration of the downwind concentrations relies on the analytical bi-gaussian approximation.

The basic hypotheses associated to this Gaussian model implementation are:

- point source release
- open downwind surface (no obstacles)
- no gravitational effects
- constant meteorological conditions.

It should be noted that gravitational effects are essentially important in the case of cryogenic gas transportation and thus of limited interest in the specific case of radioactive material transportation.

The point source hypothesis is also of minor importance in the case of transportation releases where involved quantities are generally much lower than in releases from fixed plants.

Regarding the open downwind hypothesis, this assumption is obviously not well suited in the case of accidental release in an urban area. Nevertheless, one should admit that alternative 3 dimensional models and related data collection are out of the scope for a generic probabilistic transportation safety assessment.

Finally, the constant meteorological conditions hypothesis (PASQUILL's weather category and wind direction) could be a problem in situations where the duration of the exposure or the duration of the wind transportation to the downwind observation point are well beyond a commonly accepted limit of two hours (ca 10 km for A and F PASQUILL weather categories).

In this later case, the downwind integrated concentrations are generally overestimated. Source limitations more specific to the TRANSAT implementation are associated to both the standard deviation formulation and to the release height, boundary layer, and deposition modelling.

The standard deviation formats used in the 1.6 version of TRANSAT are those of Hann, Briggs and Hoster (1982) and are especially recommended for the 100 to10 000 m downwind distances range.

The TRANSAT code does not include any modelling of plume rise. The user must thus add the plume rise effect, when appropriate, to the physical release height to obtain the effective release height to be used in TRANSAT.

The reflections due to the ground and to the mixing layer are taken into account by a multiple image source model.

A complete reflection of the plume is assumed, leading to an upper limitation of the effective release height to the one of the mixing layer (2 000 m for A and B PASQUILL categories, 1 000 m for D, 200 m for E and F). Furthermore, the constant meteorological conditions hypothesis leads to the vertical variation of wind speeds and directions. The effective release height should be neglected, thus limited to a more narrow range (< 50 m).

The depletion of the cloud by dry deposition on the ground surface is actually accounted for by the internal INTERTRAN calculations and thus, is not considered in the 1.6 TRANSAT version.

The depletion of the cloud by rain is modeled through a user input wet removal rate directly proportional to the rain intensity. This simple modeling assumes a uniform vertical wash-out of the cloud and a constant rain-fall along the dispersion path.

The previously exposed set of limitations leads to the following expected range of parameter values:

Parameter	Possible Range	Advised
Distance (x)	1 m-100 km	100 m-10 km
Effective release height (h)	0 m-200 m	0 m-50 m
Removal rate (w)	0 s^{-1}-1 s^{-1}	10^{-4} R *

(*) R = rain intensity (x, h, w) $mm \cdot h^{-1}$

3. DATA COLLECTION

The limited number of accidents that have occurred during transport of radioactive materials do not provide a large enough data base for examining the effects of all potential transport conditions. Assessment of risk from transportation programmes therefore depends on calculations, using a data base for a larger group of transports (e.g. all_vehicle, or all-truck). The frequencies of a range of transportation accident scenarios are estimated. These frequencies are combined with estimates of accident consequences in terms of the amount of radioactive material released, and the corresponding potential radiation doses, to give the risk.

The risk calculations are carried out by the code INTERTRAN2. The user has to supply input data, including basic accident rates and severity probabilities, appropriate to their particular case. Some default data are provided with the preprocessor. However, the user is advised to generate their own input data in order to provide meaningful results. The default data should be resorted to only when there is no avenue available for generating the required input data.

In many cases data will be generated from statistical databases or by considering similar operations. However, where results are critical, or in certain particular situations (for example when modelling an inter-modal transfer such as ship to truck), it will be necessary to observe how the operations are carried out, to follow shipments, and to conduct timing and other studies.

Generation of input data can be a formidable task. In the incident-free case, much of the effort can be saved by carrying out a sensitivity analysis using `first cut', or approximate, data. The INTERTRAN2 output lists the input parameters required for incident-free conditions in the order of their importance. On the basis of this listing, effort on data refinement can concentrate on the more important parameters.

The first section below describes some of the sources of data that might be used to derive (1) basic accident rates and (2) the frequency of scenarios of a particular severity. In the second section, data on routes are described. Finally, sample input data files for a range of transport cases are given. As mentioned above, these are provided only to assist new users in developing their own input data sets, and must be used with an awareness of their limited applicability.

3.1. Accident rates

It is not possible to list here all sources of data, and all studies which may contain useful data. However, it is aimed to give some guidance as to the type of sources and data bases that are available in the general literature, and comment on some of the factors that need to be taken into account in collecting and applying accident data for risk analysis purposes.

Generally, a major problem exists in collecting accident data which are readily relevant and applicable for risk analysis purposes. Most accident data compilations are compiled for purposes other than risk analysis and are defined, for example, in terms of human casualties, the overall (human and material) accident-related costs, or the level of compensation.

For a transport risk analysis, the primary quantity required is the frequency of transport or handling accidents releasing a particular quantity of radionuclides. Such data are rarely - if ever - available. In the absence of such very specific information, other resources and data bases must be explored. A widely-accepted method is based on an analysis of vehicular accident data including information such as the velocity prior to the accident, the event description, the material damage or costs, etc., to derive useful accident rates and severity estimates for the given transport mode. Accidents causing only minor damage, or resulting in costs not exceeding a certain limit, are excluded from such an analysis. An element of uncertainty is inevitably introduced into the result of such an assessment by the substantial level of judgement required.

Reviews of accident data have been carried out by various researchers looking at transport risks. Some work of particular interest to INTERTRAN2 users is a presentation of some basic data and sources by AEA Consultancy Services (SRD) in the UK (Appleton 1988), and the results of a major programme of work by Sandia National Laboratories in the US (Clarke et al. 1976, Dennis et al. 1978, McClure 1977, Sandia 1980). Although dated, this work has not been superseded. The results are basically supported by more recent studies in Germany (Fett et al. 1992, Lange et al. 1992). The results in the Sandia reports are based on an examination of US data bases, together with theoretical analyses (e.g. Monte Carlo analysis for fire duration using parameter distributions for fuel availability etc.). The results were quantified in terms compatible with the accident conditions specified in the IAEA Regulations for the Safe Transport of Radioactive Materials (IAEA 1990). The German work represents an extensive statistical analysis of a 10-year accident record of German Federal Railways goods train traffic, and of heavy trucks on interstate highways.

Extensive examination of accident data has also been carried out in France (see for example Raffestin et al. 1994).

3.1.1 *Overall accident rate*

For reporting and statistical purposes, an accident may be defined in various ways, for example, as an event during transport resulting in personal injury, or material damage exceeding a certain amount, or both. Different definitions may be used by different jurisdictions. Caution has therefore to be used when combining or comparing data from different sources.

When an accident rate is given, it is based on the number of accidents that has occurred (a more appropriate measure for analysis is actually the number of damaged vehicles or trains of a particular type), together with an estimate of the corresponding vehicle distance travelled. It is sometimes of interest to be aware of how this estimate of distance has been made, or, if only the number of incidents is available, it may be necessary for the analyst to make such an estimate. For example, mileage in a large statistical area may be based on fuel consumption statistics. On short sections of routes, mileage may be based on the length of the section, multiplied by the vehicle count from traffic surveys.

Where the data are available as the number of accidents in a year (or the number of road accidents per, say, 1000 vehicles in a year), the accident rate is derived using the average distance travelled by each vehicle as follows:

Number of accidents in a year = a
Total number of vehicles plying in that year = N
Average distance travelled by a vehicle in a year = d
Accident rate = $p = a/(N \times d)$

If the number of accidents in a year = b per 1000 vehicles, then $a = (b/1000) \times N$

Available accident rates may be based on statistics for:

- all vehicles;
- a particular type of vehicle, e.g. heavy trucks, freight trains (as compared with passenger trains), barge (as compared with ship);
- dangerous goods (if separate statistics are kept by the regulatory agency);
- a single industry;
- a single company.

These rates may vary depending on such factors as the degree of driver training and regulation, vehicle or vessel design and maintenance, and shipping policies, such as avoidance of severe winter weather conditions and traffic control.

Another source of variation arises from changes over time in safety practices, road improvements, and new regulations. A sufficient period to ensure reliable statistics should be used, while balancing this against uncertainty introduced by these temporal changes.

Where local statistics are available, these may be for relatively short segments of particular routes. In this case, the rate for a segment may be based on a small number of incidents only, so there may be considerable variation among the segments.

In the case of special arrangement shipments, for which a speed limit, use of an escort, etc., are imposed, the probability of an accident may be decreased. Judgment should be used in taking credit for these factors in the risk analysis.

Statistics from other countries should be used with circumspection, in particular the rail accident rate. Different rail environments exist, for example as between North America and Europe. In comparing statistics, the length of the train, the type of train (mixed or special), and the causes of accidents, for example equipment-related or other, should be considered. In the US accident rates are often quoted in terms of railcar accidents per railcar-km, while for analysis of accidents to shipments of radioactive materials, the train accident rate may be of more relevance. Conversion involves consideration of the length of the trains represented in the statistics, the causes of the accidents represented in the statistics, the length of the train carrying the radioactive shipment, and the number of railcars affected per train accident. In addition, one major reason for diverging figures in this field may be the threshold used to determine whether a railcar is "affected"; a low threshold would result in a high railcar accident rate.

Sources of basic accident rates are as follows:

- government statistical departments;

- national inspectorates;
- Coast Guard;
- national, state or provincial ministry of transport;
- local authority or municipality;
- trucking companies and associations;
- railway companies and associations;
- shipping companies and associations;
- insurance companies;
- seaway and canal authorities;
- the International Maritime Organisation (IMO);
- the International Civil Aviation Organisation (ICAO);

Typical accident rates that have been used in analysis are shown in Table I.

TABLE I. TYPICAL ACCIDENT RATES

Mode	Typical accident rate (accidents per 10^6 km travelled)
Road	0.3 - 5
Rail	0.03 - 1* 0.5** 10^{-6} per railcar handled***
Sea	1
Air	10^{-6} per flight****

* Railcar accidents per 10^6 railcar-km
** Train accidents per 10^6 train-km
*** shunting operations
**** Including takeoff and landing

3.1.2 Severity category schemes

As noted above, the basic accident rate has to be supplemented by data on accident severity before an estimate of risk can be made. As an illustration, for Type B packages, the percentage of accidents which may affect the safety function of the package is very small, e.g. 0.1% (for road transport).

It is generally necessary to break down the range of accidents according to some analyzable parameters such as impact force, crush force, and thermal input. This gives rise to the concept of severity categories, as used, for example, in the USNRC's Final Environmental Statement on the Transportation of Radioactive Material by Air and Other Modes (USNRC 1977). Severity categories are used to simplify the problem of calculating the frequency of different sizes and types of release by grouping together events which, for a particular material type, may be represented by a single representative source term defined in terms of a release fraction, aerosolisation fraction, etc.

A simple example of a severity category scheme is shown in Figure 1. In this example, the range of accidents has been divided into four categories. In category 1, the impact and thermal conditions are within the IAEA accident conditions, and no effect on the safety of a Type B package would be expected. Categories 2, 3 and 4 represent conditions beyond the IAEA accident conditions. The behaviour of the package and its contents in each category can then be examined. It may be necessary to further divide these categories, for example, to differentiate between small leaks and larger releases.

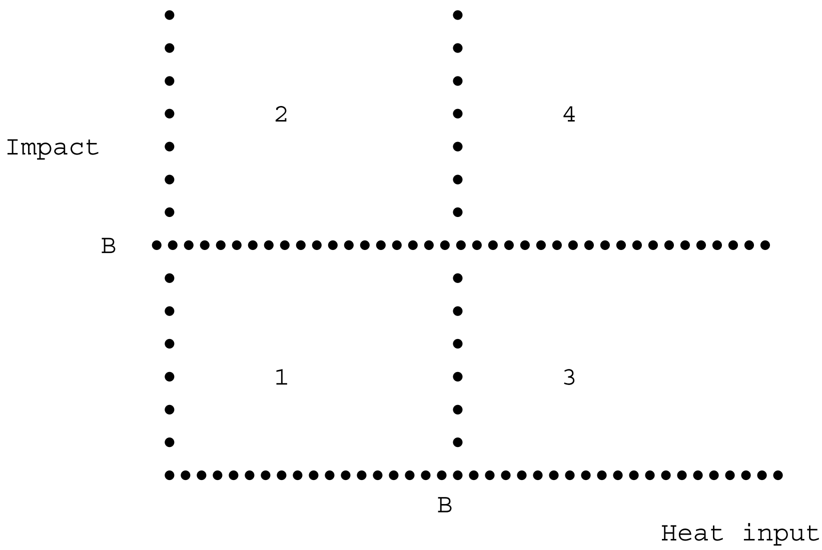

FIG. 1. Example of severity category scheme (B = mechanical or thermal challenge equivalent to that in the IAEA accident conditions)

The parameters used in this categorization are best chosen while considering the particular type or types of package being analyzed, and what the potential modes of failure would be. For lightweight Type A packages, crush may be appropriate, while for metal Type B casks, impact force would be more useful. It may be necessary to consider the effects of both crush and impact, especially for smaller packages. For example, seal failure, leading to a release, may be caused by crushing the package, dropping the package, the effects of heat, or combinations of impact and thermal challenge. It may be possible to define a category scheme in which the two types of mechanical challenge are represented on the same axis; the category limits may then be described as "an impact force greater than or equal to x but less than y, *or* a crush force greater than or equal to w but less than z". However, if the source terms for the impact and crush cases differ significantly, it will be necessary to consider them as separate categories.

In general, packages will not fail in conditions only marginally more severe than those for which they were designed, although this may be assumed as a first scoping assumption where no data are available. Prediction of the behaviour of the package in given conditions requires an examination of the potential modes of failure, supported by analysis or test data. The package design and approval process will provide some test and/or analytical data which may go beyond the IAEA requirements or which may be amenable to extrapolation. However, extrapolation is difficult because at some point new failure mechanisms can be expected.

In addition to considering the availability of data on package response, data on source terms, and in particular release fractions, must be taken into account when determining a sensible and useful severity categorisation scheme. These data are often very limited, and constructing a complex categorisation scheme could therefore be unproductive. In many cases simple schemes must be used with very broad categories. However, it should be noted that the use of broad severity category schemes can introduce bias into the results. For example, if the release fraction data available represents an average for the category, then the possibility of acute effects occurring may be hidden. On the other hand, if the release fraction representing a worst case accident scenario is chosen, then the results can be highly conservative.

INTERTRAN2 does not allow different atmospheric dispersion conditions for different severity categories. It may be desirable to carry out separate runs for the fire accident categories and the impact accident categories, since the releases from fire accidents may disperse very differently.

3.1.3 Package environment and package behaviour considerations

When deciding the severity categories, it should be recognized that the environment experienced by the package is not the same as that seen by the vehicle. The package is protected to a greater or lesser extent by the chassis and superstructure of the vehicle or vessel.

Package behaviour is usually predicted on the basis of the tested and accident conditions specified in the IAEA Regulations for the Safe Transport of Radioactive Materials (IAEA 1990). In the specification of tested and accident conditions in the Regulations, the effect of the following factors is taken into account:

- hardness of `target';
- package orientation in impact;
- package position in fire;
- emissivity of fire.

The impact condition is specified in terms of an `unyielding target'. In real life situations, much of the impact energy would be absorbed by damage to the target, for example, deformation of the other vehicle involved in vehicle_vehicle collisions, or cracking and disassembly of concrete or masonry in collisions with stationary objects. In addition, the vehicle carrying the transport package would be expected to absorb some of the impact energy before contact was made with the package itself.

In UK studies (CEGB 1985), a full_scale impact into a tunnel abutment of a cask on a railcar at 26.8 $m.s^{-1}$ (96 $km.h^{-1}$) was shown by analysis to be less severe than the regulatory 9 m drop test. In addition, it was found to be very improbable that the cask would impact the abutment in the most damaging orientation at a speed as high as 26.8 $m.s^{-1}$.

Use may be made of the concept of velocity ratio in correlating real accident conditions to the behaviour of the transport package. This is the ratio of the velocity of impact with a real surface to the velocity of impact with an unyielding surface required to cause the same degree of damage. A discussion of velocity ratio can be found in McClure et al. (1980). Useful data on the response of various surfaces may also be found in Gonzales (1987), Huerta (1978) and Jefferson and Yoshimura (1977).

As with the unyielding target, experience with fire testing show that, although the 30 minutes duration and 800EC temperature specified for the regulatory fire fall short of the most severe fires that have occurred in transport accidents, the conditions of the fire are such that it represents a very severe thermal environment.

Higher flame temperatures found in the literature represent peak flame temperatures which last only a short time, and have little effect on heat input. The flame emissivity may also be lower than that specified in the regulatory fire test. This would lead to lower radiative heat input in the real fires. Pope et al. (1980) discuss the factors _ location within fire, lack of controlled fuel feed and shielding by intervening structures _ which reduce the severity of actual fires relative to the regulatory fire.

The INTERTRAN2 model assumes that all the packages of a shipment experience the same accident environment, i.e., the fractional release is applied to the total radioactive inventory of the shipment. While this may be appropriate (although conservative) for some cases, e.g., a tanker fire following a ship collision, it should be noted that it is not correct for other cases, e.g., release following impact of a colliding ship's bow with a cask, where the ship's bow would impact only one cask. The situation being analyzed should be examined, and if necessary the input parameters should be adjusted, e.g. by reducing the package failure fraction.

3.1.4 Calculation of severity category probabilities, and sources of event data

Many accident data bases use some form of severity classification. Unfortunately for the present purposes, this is almost universally based on the actual or potential production of human casualties in the accident, or on environmental damage, rather than on parameters related to the forces and temperatures experienced by the package during the accident.

To obtain the probability of an accident occurring in a particular severity category, fault tree analysis is commonly used. Explanations of this technique are given in a number of textbooks, for example McCormick 1981. At its simplest, fault tree analysis allows the probability of combinations of events to be calculated, given the individual probability of each event. The fault trees are constructed by setting down the events necessary for the parameters describing the accident to have the values appropriate to that category. The first step is to identify the hazardous events that may lead to accidents in each category. For example, referring to Figure 1, a Category 2 accident (mechanical challenge exceeding Type B accident condition tests) might, for a large package carried by rail, arise due to derailment and impact with a tunnel abutment, derailment and fall over 9 m from a bridge onto hard rock, or derailment and subsequent collision by another train.

The fault tree analysis technique has been developed to a high degree for use in reactor safety analysis. Computer codes using reliability databases are commonly used to handle the large amount of data generated. As applied to transportation risk assessment, a much simpler form is usually appropriate. This is, however, dependent on the amount of event data that can be compiled and supported; detailed fault trees were used in a series of studies by Battelle Pacific Northwest Laboratories (e.g. Elder et al. 1978).

A worked example is given at the end of this sub-section.

Individual probabilities, e.g. probability of an accident involving fire, given that an accident has occurred, are taken from statistical data bases or from reviews found in the literature. Studies for other hazardous materials may be a source of data on e.g. fire duration.
In many cases, where data are not available, and it is not possible to carry out analysis, conservative assumptions will have to be made to fill in gaps. For example, it may be assumed that impacts take place in the most unfavourable orientation in a significant fraction of accidents.

In some cases, the sources of accident rates listed in Section 1.1 also collect event data. This may be the case even when the classification scheme used for reporting is not useful. Accident report forms should therefore be scrutinised to ascertain what data are collected. Route surveys may be necessary to ascertain the potential for falls onto rock, head-on collision, etc.

The reports mentioned in the first section are also useful sources of event data (Appleton 1988, Clarke et al. 1976, Dennis et al. 1978, McClure 1977, Sandia 1980, Fett at al. 1992, Lange et al. 1992). The Sandia work in particular gives probability distributions for velocity change in an accident, and for fire duration. Fett et al. and Lange et al. present useful quantitative information on the severity, number of railcars affected, and probability for goods train accidents for various transport operations.

All data should be used with attention to package environment taking account of energy absorption by the vehicles involved, and of package position and orientation, as discussed in the previous section.

Worked example: calculation of accident severity probability

This example uses the severity category scheme shown in Figure 2. The scheme was drawn up for an analysis of irradiated fuel transport (Kempe and Grondin, 1992). Irradiated fuel requires packaging demonstrated to meet the IAEA accident conditions.

The range of accidents which are more severe than the IAEA accident conditions was sub-divided to allow calculation of consequences in fairly narrow categories. It may be noted that the definition of severity categories took account of the package environment, rather than more general accident parameters, i.e., the impact is defined as being with an unyielding object and the fire is defined as enveloping.

Given that an accident has already occurred, the probability for truck transport of an accident occurring in Severity Category 6 (i.e. impact greater than 75 $km.h^{-1}$ together with fire duration between 0.5 and 1 h) was to be calculated. Conservative assumptions were made, for example, the probability of the cask being enveloped in a fire, taken as 0.1, includes the probability of the following events:

- the other vehicle, carrying the fuel for the fire, ends up in the same location as the cask (after both vehicles have fallen 22 m);
- the fire is continuous, dense, and large enough to envelope the cask;
- the cask is physically located within the fire, and
- the cask is not shielded from the fire by the truck or the other vehicle.

The following scenarios were identified as being in Severity Category 6:

C impact of the shipment with a rock face or bridge abutment, with the cask exposed to the full impact, at a speed of greater than 75 $km.h^{-1}$, or

fall of the shipment 22 m or more onto hard rock, with the cask exposed to the full impact,

together with

C an enveloping fire of duration between 0.5 and 1 h.

Scenarios involving collision between the truck carrying the cask and another vehicle were found not to be credible contributors to this severity category, as the speeds required, after account was taken of energy absorption by the truck superstructures, were in excess of credible vehicle speeds. No account was taken of the `softness' (velocity ratio; see section 1.3) of the rock surfaces or bridge abutment. The events contributing to fire duration were

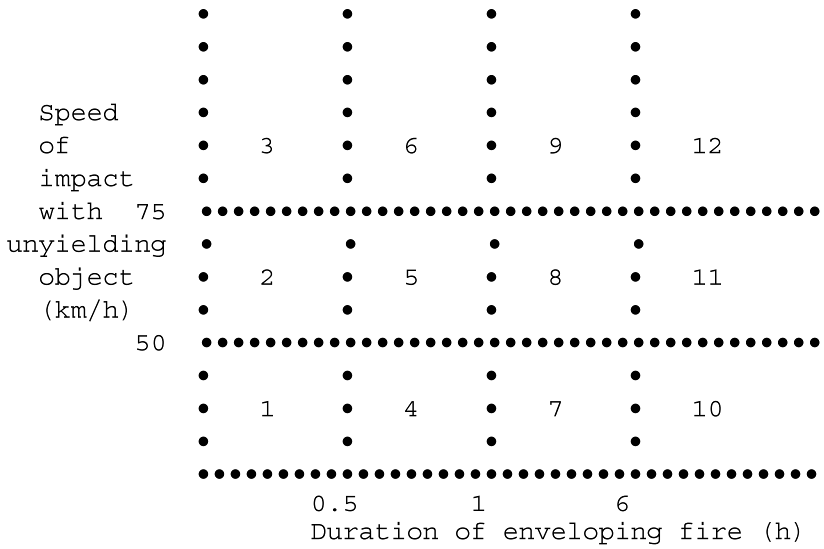

FIG. 2. Worked example: severity category scheme for analysis of spent fuel transportation

not developed further, as use was to be made of data giving probability versus fire duration directly.

The fault tree for Severity Category 6 is shown in Figure 3. Numbering the events anticlockwise from the top left, the probabilities needed are as follows:

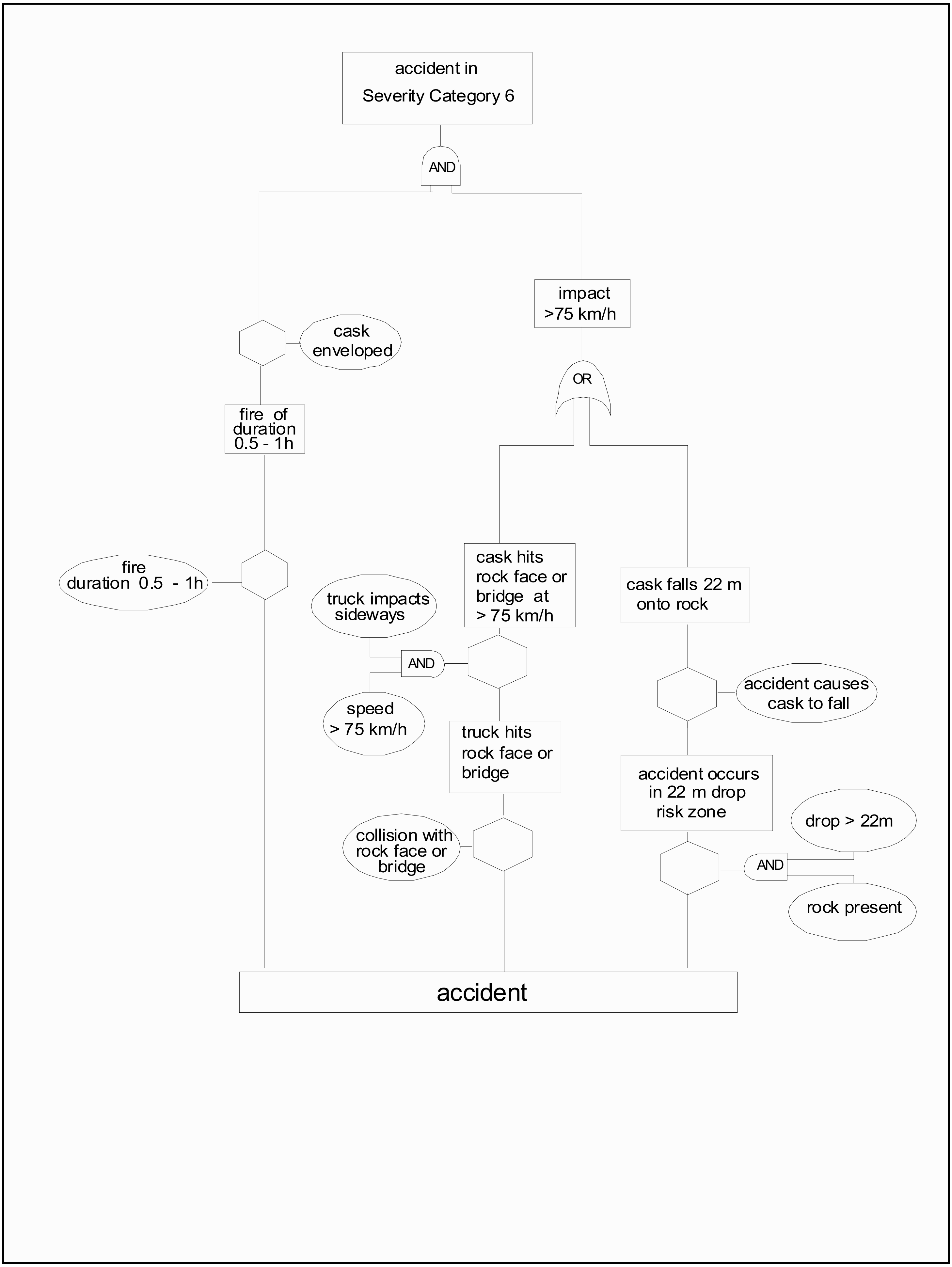
accident in
Severity Category 6
AND
impact
>75 km/h
cask
enveloped
OR
fire of
duration
0.5 - 1h
fire
duration 0.5 - 1h
cask hits
rock face or
bridge at
> 75 km/h
cask falls 22 m
onto rock
truck impacts
sideways
AND
speed
> 75 km/h
accident causes
cask to fall
truck hits
rock face or
bridge
accident occurs
in 22 m drop
risk zone
drop > 22m
collision with
rock face or
bridge
AND
rock present
accident

FIG. 3. Worked example: fault tree for one accident severity category

$P(A_1)$ = Probability that cask is enveloped, given a fire

- assumed to be 0.1

$P(A_2)$ = probability of a fire of duration 0.5 to 1 h, given an accident

= 7.2×10^{-4} (Dennis et al. 1978)

- the probability of fire is taken as independent of the impact probabilities, since it requires the involvement of another vehicle carrying a sufficient quantity of fuel to feed a significant fire (e.g. gasoline tanker)

$P(A_3)$ = probability of impact in the most damaging orientation

- assumed to be 1

$P(A_4)$ = probability that impact occurs at a speed of >75 km.h^{-1}

= 10^{-4} (Dennis et al. 1978)

$P(A_5)$ = probability that collision with a rockface or bridge abutment occurs, given an accident

= 0.006, from local statistics on accident causes

$P(A_6)$ = probability that rock is present

- assumed to be 1

$P(A_7)$ = probability that a drop of > 22m is adjacent to the road

= 4×10^{-4}, from a route survey

$P(A_8)$ = probability that the shipment leaves the road, given an accident.

- assumed to be 0.1

Combining probabilities according to the rules of Boolean algebra:

Probability of an accident in Severity Category 6, given an accident,

$$= P(A_1).P(A_2)\ \{P(A_3).P(A_4).P(A_5) + P(A_6).P(A_7).P(A_8)\}$$

$$= (0.1 \times 7.2 \times 10^{-4})\ \{(1 \times 10^{-4} \times 0.006) + (1 \times 4 \times 10^{-4}\ 0.1)\}$$

$$= \underline{3 \times 10^{-9}}$$

3.2. Release fractions

Given damage to a package, it is unrealistic to assume that all the radioactive material is released. In INTERTRAN2, the airborne release is calculated as the product of two factors: the release fraction and the aerosolisation fraction. A further factor, the respirable fraction is applied in calculating the dose from inhalation.

The release fraction considers the packaging strength as a function of severity. If the release fraction is 1, then the package is totally destroyed from the material containment point of view. If the release fraction is 0, then containment is unbreached.

For a given severity, the release fraction might represent, for a Type B package, a small breach, for example, loss of bolt tension and seal compression, allowing a small amount of bypass leakage carrying gaseous radioactive material. For a Type A or industrial package, the package might be considered to be completely destroyed.

The aerosolisation fraction is dependent on the type of material and on the accident environment. For example, impact can cause fragmentation or pulverisation of a solid material. Thermal conditions can cause fragmentation by oxidation of ceramic and other materials as well as release by destructive burning of contaminated material. In addition, the prevailing environmental conditions may be important. For example, high wind speeds can lead to the entrainment of large fractions of spilled particulate or liquid material.

Particle size is an important parameter in determining the overall release fraction. Only respirable particles are important in the calculation of inhalation doses, but it is also necessary to consider larger particles for other exposure pathways such as ground-shine. The relative importance of the different exposure pathways is related to the radionuclide composition of the release.

In general the release fraction is nuclide-specific. For example, for thermal accident conditions, a larger release fraction for a semi-volatile radionuclide such as caesium and a lower release fraction for a non-volatile radionuclide such as plutonium would be expected.

The overall release fraction is a very important parameter for all risk assessments. For gaseous material, total release is possible, and near-total release may be appropriate for some particulate material. However, for many radioactive materials and transport accident conditions experimental data show that only a very small fraction is dispersed. For example, Lange et al. employ a release fraction of only 3×10^{-8} for some waste under severe impact conditions.

Given the very large range of data for this important parameter, it is vitally important that the analyst both employs a suitable value or set of values and understands the degree of uncertainty associated with it.

3.3 Route data

A number of the parameters specifying the route are required to be given by the analyst for each of three population zones. This should be taken into account when establishing criteria for what represents a rural, suburban or urban zone. The zone-specific parameters include population density, other population parameters (e.g. building shielding factors and whether account is taken of pedestrians), and traffic conditions (e.g. velocities and densities of road vehicles, accident rates, and fractional occurrence of severity categories). In the LINK mode, the population densities, velocities, traffic densities and accident rates are all entered separately for each LINK segment, however, the same zone-specific severity category probabilities are used in each segment.

3.3.1 Distances

Route segment distances for road may be listed in statistical reports by national, state or provincial reports, e.g. traffic volume reports. These are then combined with population density data for local areas (to give the fraction of travel in different population zones, as required for INTERTRAN2).

The rail distance through given districts, municipalities etc. may be determined from maps showing rail lines.

For water, route distances may be taken from nautical charts showing normal or recommended shipping lanes.

3.3.2 Population density

INTERTRAN2 uses population density data in three zones, rural, suburban and urban. In some cases, national statistics may be divided into only two zones, rural and urban, and these may not correspond with the definitions used in INTERTRAN2. In such a case, the user should define zones appropriate to their analysis.

Density data may be taken from census results given for individual districts, municipalities, townships, cities, etc.

Some rural areas show higher than average population density along highways. The population densities for use in INTERTRAN2 may therefore be adjusted by use of the ratio (density of households within 800 m of road / density of households reported in local directories).

Population densities for use in the water mode should be drawn from data for shore districts.

3.3.3 Traffic data

Traffic counts and passenger data are obtainable from the general sources listed in Section 1.1.

3.4 Pasquill frequencies

The dispersion parameters used in calculations are dependent upon the Pasquill atmospheric stability class. There are six Pasquill Classes (A, B, C, D, E, and F), each with an associated typical wind speed. The Pasquill stability classes provide a means of classifying weather conditions in terms of the degree of atmospheric turbulence, and hence the degree to which airborne materials will be dispersed and diluted. Class A represents unstable (highly dispersive) conditions, while D is neutral, and F and E are stable (not very dispersive) conditions. Statistics on the occurrence of each Pasquill category can be compiled from observations made at weather stations. The typical frequency of each Pasquill class may be available from the national meteorological/environment service. This may give the distribution by wind speed and direction also, however, these are not used by INTERTRAN2.

(add if PSPROB is now included in LINK:

In assigning values for PSPROB, i.e. the probability for the various stability categories, it should be borne in mind that these values are applicable in a meaningful way only in a limited geographical region. In a large country, the same probability values cannot be expected to apply in all the various provinces, states or regions. Hence, in the case of transport through different regions, the user should:

- for each region, determine the PSPROB values,
- treat each region as a LINK, and
- run the code with the LINK option.)

3.4 Sample input data files

Sample input data files for a number of cases are given in Figures 2 - 17.

These files were used during the development programme for INTERTRAN2, and are provided to assist new users in developing their data sets. While the files represent real cases, they cannot be considered as default data; it is the responsibility of the user to scrutinise each number which they use in their own case.

It may be noted that, while the sample files each represent a single mode, it is possible to analyse more than one mode in the same run.

Additional sample input data sets are given in the code documentation.

(Do we want to have all the sample files present in the PPI files, or maybe in some other electronic form?)

3.5 References

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3.6 IAEA data bases

In 1989, the IAEA initiated development of a number of databases to aid Member States in assessing the efficacy of the regulatory standards for transport of radioactive materials, and to provide data for future regulatory revision and risk assessment activities. The databases are summarised in Table A1.

Eventually, radiological impact from transportation could be estimated directly from these data bases. EVTRAM in particular will provide useful data for inclusion in modelling. However, it is anticipated that it will be many years before sufficient incident reports are available to allow any conclusions to be drawn.

TABLE A1

IAEA Databases on Shipment of Radioactive Materials

Name of database	Information collected
SHIPTRAM	Number of shipments by mode within, into and out of each Member State, by mode and package type.
EXTRAM	Information on the main sources of radiation exposure to workers, and an estimate of collective dose to the public.
REDTRAM	Information on research and development in the area of safe transport of radioactive materials.
EVTRAM	Computerized reports of accidents and incidents in Member States, involving shipments of radioactive materials. Information includes: type of material, physical/chemical form, classification (e.g. LSA I), package type, transport index, conditions at the time and location of the accident or incident, damage to the package, the amount of radioactive material released, the radiological consequences, and the severity class, according to the following criteria: <u>Level</u> <u>Criteria</u> 6 Transport accident leading to the destruction of package Type F or B with total loss of shielding and/or an important release of the contents into the environment. 5 Transport accident having affected the safety function of package Type B, with a release or intervention(?) higher than the regulatory limit. Loss of Type B package during transport. 4 Transport accident having affected the safety function of Type B package but release less than the regulatory limits. 3 Transport accident leading to the total or partial destruction of a Type A or I package. Loss of Type A or I package during transport. 2 Transport accident which has potentially significant development concerning the safety and/or necessitating a large magnitude or long duration intervention. 1 Transport incident not having affected the safety function of the package but having necessitated intervention.

4. QUALITY ASSURANCE

4.1 Introduction

When using computer software in safety related applications it is necessary to have assurance that the programme has been produced in a quality assured environment. In many organisations approval for use will only be granted if the programmes have been developed to some recognised quality standard. Example of such standards include:

EN ISO 9001 (including TickIT requirements): Model for Quality Assurance in Design, Development, Production, Installation and Servicing
Interim Defence Standard 00-55(Part 2): The Procurement of Safety Critical Software in Defence Equipment, Issue 1
ANSI/IEEE Standard 730-89, IEEE Standard for Software and Quality Assurance Plans
ANSI/IEEE Standard 1012-86, IEEE for Software Verification and Validation Plans

Where the software was developed at a time when software quality assurance standards were not developed or generally in use, a company can carry out an evaluation of existing documentation to satisfy themselves that adequate validation and verification (V&V) has been carried out and that the limitations of the software are fully understood and documented. In some cases theoretical justification of the models used may exist and these should also be considered as part of the functional specification for the code.

When testing has been carried out, care needs to be taken to ensure that the hardware and software platforms on which the V&V were carried out are adequately described, eg compiler options, processor speed, existence (and type) of maths co-processor etc. The stability of the software should also be considered, eg how much use has been made of it and how often has it had to be changed. The users should ensure that the maintenance is being carried out under controlled conditions such that changes to the software are adequately tested and controlled.

This section discusses the quality assurance standards applied to the development and continued maintenance of the programmes in the INTERTRAN2 package. It is important that the user verifies that the Quality Assurance requirements of their organisation or those required for the particular application are satisfied.

4.2 RADTRAN 4

To be fully assured of RADTRAN 4's applicability and acceptability over the complete range of transport operations to which it may be applied as part of the INTERTRAN2 package it is necessary to be assured that a systematic procedure for developing the programme from conception through to final release and subsequent modification has been applied. It is impossible to test every possible pathway through the programme on completion. However, the code was originally developed in 1977 by Sandia National Laboratories when QA standards were not routinely applied and the development of the code was not controlled via a Quality Plan. In addition the development of the code focused on US conditions of transport. The user must therefore carry out an evaluation of existing documentation to determine whether the scope of their application lies within the scope of RADTRAN 4's applicability and validation (including use on the particular hardware platform available) and whether any limitations of the programme will affect the validity of the results for their particular application.

Earlier versions of RADTRAN and RADTRAN 4 itself have been extensively used in the United States and elsewhere to estimate the risks associated with the transportation of radioactive materials; peer-reviews by several groups have generally endorsed the codes, and problems identified during these reviews have been addressed (PNL, 1981; Mairs and Shaw, 1986). The programme is now in the operations and maintenance phase of the software lifecycle and a Software Quality Assurance Plan (SQAP) (Bespalko, Kanipe and Neuhauser, 1994) has been prepared for this phase to meet the requirements of ANSI/IEEE Standard 730-89 (IEEE, 1994). It specifies, in a manner conforming to ANSI/IEEE Standard 730-89, the minimum requirements for establishing the correctness of the RADTRAN risk assessment tool. Guidelines in the United States allow codes to be brought up to QA standards retoactively and the SQAP performs this function for RADTRAN 4. However, it should be noted that some organisations will not accept retroactive compliance and users must in any case check that the code is appropriate for their application.

RADTRAN is formally validated and verified in accordance with a Software Verification and Validation Plan (SVVP). Modifications are strictly controlled. The general procedures are outlined in the RADTRAN 4 Programmers Manual which is included as part of the INTERTRAN2 package and a summary of verification and validation activities is given in the RADTRAN 4 Executive Summary Document.

Verification is the process of determining that a code correctly performs the calculations embodied in it. A summary of the RADTRAN 4 verification and modification control processes has been published (Kanipe and Neuhauser, 1995). With all releases the NUREG-0170 data file is used for verification of the code output along with additional files created to test new capabilities. All files, databases, logs, and hand calculations are retained in a permanent QA file at Sandia National

Laboratories for inspection and audit.

Validation is the process of ensuring that the models embedded in the code accurately represent the processes they are intended to replicate. Many of the RADTRAN 4 dose calculations are either conservative simplifications or probabilistic calculations; validation by empirical means is difficult. Empirical studies are used where applicable and the code is updated when improved radiological data become available. The models have recently been formally validated by reference to measurements and hand calculations for a particular application, the preparation of the Environmental Restoration and Waste Management Programs Environmental Impact Statement, (Maheras and Pippen, 1995). This exercise concluded that the code yielded acceptable results and met the requirements for successful validation. Validation was carried out on a discreet set of parameters. Use outside of those parametric values was not assessed in this study. The code has also been informally tested over a wider range of applications through the IAEA Coordinated Research Programme and limitations/problems fed back to Sandia National Laboratories who have addressed them as part of their ongoing code maintenance activities. Selected older models in the code have also been subjected to validation up-dates (eg calculation of handler dose during intermodal transfer; Neuhauser and Weiner, 1992). Some outstanding and/or inherent limitations are reported in Section 2.

The SQAP and documentation including the Software Design Description and the SVVP are included in the INTERTRAN2 package. Further information can be obtained from Sandia National Laboratories on request. If the use of the programme is beyond the scope of the validation currently carried out extra validation will be required by, if possible, the organisation using the code.

4.3 TICLD

The TICLD software includes programming identical to a portion of RADTRAN 4 with a single additional arithmetic operation that produces an individual dose calculation for each downwind area rather than a population dose calculation. The correctness of the latter operation has been validated as part of RADTRAN 4 Software Validation and Verification activities. The programme thus falls under the quality assurance umbrella of the RADTRAN 4 SQAP.

4.4 TRANSAT

No formal Quality Assurance Plan or Programme has been applied to the development of TRANSAT. Informal testing and validation have been carried out and these indicate that the programme gives acceptable results for the cases tested (Category A with height zero including wet deposition and Category D with release height 30 m and no wet deposition). TRANSAT was developed as part of the activities of the IAEA Coordinated Research Programme to perform a specific function, namely, to produce Gaussian atmospheric dispersion data in the exact form in which it must appear to be used directly as input to INTERTAN2. The intent is to remove the need to perform hand operations on the outputs of other dispersion codes to render them usable for INTERTRAN2 and TICLD since such operations are themselves a common source of human error. The equations embodied in TRANSAT are simple, straightforward and well understood. The simple tests applied above should be adequate for most applications and users can apply their own tests to confirm the code is working properly. Where stricter Quality Assurance Requirements apply the user can employ another dispersion code, however, it is then important to apply quality procedures to the adjustments required to input the results to INTERTRAN2.

4.5 The INTERTRAN2 handler for Windows.

Again no formal Quality Assurance Plan or Programme has been applied to the development of **the INTERTRAN2 handler for Windows.** However, in this case **the INTERTRAN2 handler for Windows** just aids the construction of RADTRAN input files and the user should check the file before running the calculations and the input echo given in output. The lack of formal QA need not therefore limit the use of this software.

4.6 Summary

4.6.1 RADTRAN 4 and TICLD

The development of RADTRAN 4 was not controlled in accordance with a recognised quality standard. However, a Software Quality Assurance Plan (SQAP) (Bespalko, Kanipe and Neuhauser, 1994) that meets the requirements of ANSI/IEEE Standard 730-89 (IEEE, 1994) has been prepared for the operations and maintenance phase of the software lifecycle. The user should ensure that any of the limitations summarised in Section 2 will not adversely affect the validity of the results for their particular application. Further details of limitations of the programme and the models employed are given in the Technical Manual included as part of the INTERTRAN2 package. In strict quality environments the user may need to evaluate existing documents to determine whether the programme meets the Quality Assurance requirements of their organisation. This evaluation is likely to include an assessment of the following to determine their adequacy and applicability to their particular application:

- modification control
- verification and validation

Modification Control

The SQAP states that there are controls in place to ensure that RADTRAN 4 is maintained such that changes to the software have been adequately tested and controlled. These are summarised in Kanipe and Neuhauser, 1995.

Verification and Validation

The SQAP and documentation including the Software Design Description and the SVVP are included in the INTERTRAN2 package. A summary of the RADTRAN 4 verification processes has been published (Kanipe and Neuhauser, 1995). Further details of verification and validation exercises can be obtained from Sandia National Laboratories on request.

4.6.2 TRANSAT

TRANSAT has not been developed under a formal QA regime and has only limited informal testing. This may limit its application in a quality assured environment. However the correctness of the output is readily determined and such an exercise may be considered worthwhile since the alternative dispersion-data entry into RADTRAN is liable to human error.

4.6.3 **The INTERTRAN2 handler for Windows.**

The INTERTRAN2 handler for Windows has not been developed in accordance with a formal Quality Assurance Plan or Programme. However, the user should check the input file generated by **the INTERTRAN2 handler for Windows** before running RADTRAN and check the input echo given in the RADTRAN output. The lack of formal QA need not therefore limit the use of this programme.

4.7 References

EN ISO 9001 (including TickIT requirements): Model for Quality Assurance in Design, Development, Production, Installation and Servicing

Interim Defence Standard 00-55(Part 2): The Procurement of Safety Critical Software in Defence Equipment, Issue 1

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RADTRAN 4, Volume 3: User Guide, Sandia Report SAND89-2370

RADTRAN 4, Volume 4: Programmer’s Manual, Sandia Report SAND89-2370

5. USER SUPPORT

5.1 Downloads of new versions and other files

New versions, TICLD, LHS and other files and documentation will be available for downloading at:

www.amckonsult.se

5.2 Technical support

If any technical problems or errors arise while working with the INTERTRAN2 package the following persons will be happy to answer your questions:

Clifford Järnry
Ann-Margret Ericsson

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Web-site: www.amckonsult.se

5.3 Theoretical support

If any problems on how to put data together or how to make calculations arise while working with the INTERTRAN2 package the following persons will be happy to answer your questions

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