IAEA-TECDOC-955

# Generic assessment procedures for determining protective actions during a reactor accident

INTERNATIONAL ATOMIC ENERGY AGENCY

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The originating Section of this publication in the IAEA was:

Radiation Safety Section
International Atomic Energy Agency
Wagramerstrasse 5
P.O. Box 100
A-1400 Vienna, Austria

GENERIC ASSESSMENT PROCEDURES FOR DETERMINING PROTECTIVE ACTIONS
DURING A REACTOR ACCIDENT
IAEA, VIENNA, 1997
IAEA-TECDOC-955
ISSN 1011-4289



Printed by the IAEA in Austria
August 1997

# FOREWORD

One of the most important aspects of managing a nuclear emergency is the ability to promptly and adequately estimate the consequences of an accident. Because of the need for protective actions to be initiated promptly in order to be effective, nuclear accident assessment must make use of all information that is available to on-site and off-site organizations. Assessment must be an iterative and dynamic process aimed at continually refining the evaluation as more detailed and complete information becomes available.

This manual provides the tools, procedures and data needed to evaluate the consequences of a nuclear accident occurring at a nuclear power plant throughout all phases of the emergency before, during and after a release of radioactive material. It is intended for use by on-site and off-site groups responsible for evaluating the accident consequences and making recommendations for the protection of the plant personnel, the emergency workers and the public.

The scope of this manual is restricted to the *technical assessment* of radiological consequences. It does not address the emergency response infrastructure requirements, nor does it cover the emergency management aspects of accident assessment (e.g. reporting, staff qualification, shift replacement, and procedure implementation). These aspects are covered by other IAEA documents, including the *Method for the Development of Emergency Response Preparedness for Nuclear or Radiological Accidents*(Safety Series No. 109), and *Intervention Criteria in a Nuclear or Radiation Emergency* (IAEA-TECDOC-953)].

The models, data and procedures in this report are being used in training courses. If this interim use identifies any necessary revisions, they will be made in the later versions.

The procedures and methods in this manual were developed based on a number of assumptions concerning the design and operation of the nuclear power plant and national practices. Therefore, this manual must be reviewed and revised as part of the planning process to match the potential accidents, local conditions, national criteria and other unique characteristics of an area or nuclear reactor where it may be used.

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# INTRODUCTION

The aim of this publication is to provide practical guidance and tools for accident assessment that, if implemented now, will provide a basic assessment capability needed in the event of a serious reactor accident.

(a) This manual must be reviewed and revised as part of the planning process to match the potential accidents, local conditions, national criteria and other unique characteristics of an area or nuclear reactor where it may be used..

(b) This manual is consistent with international guidance [IAEA94, IAEA96]. **Introducing additional conservative assumptions may cause confusion and may increase the overall risk to the public and emergency workers.**

(c) This manual is designed to be used primarily during the first 30 days of a response. After this period, more time and resources should be available to conduct more advanced assessments based on accident specific information

(d) This manual should only be used by personnel who have been trained and drilled on its use.

(e) The steps in the procedures are listed in the general sequence they should be performed, but it is possible to perform steps out of sequence. Therefore, read each procedure completely before applying it.

(f) The procedures have been grouped into sections that correspond to the response organization shown in Figure O1 in Procedure O1.

(g) Figure 1 at the end of the Introduction provides an overview of the assessment process and can be used as a quick method for locating assessment tools or procedures.

## SCOPE

This manual provides technical procedures for determining protective actions for the public and controlling dose to emergency workers for accidents at a nuclear reactor. These include: procedures for classifying an accident, projecting consequences, coordinating environmental monitoring, interpreting environmental data, determining public protective actions and controlling emergency worker doses. This manual describes an emergency assessment organizational structure recommended for the optimum implementation of the accident assessment procedures.

This manual was primarily designed for use with reactors. Therefore, tables and figures may need to be modified for use with other reactor designs.

This manual does not contain procedures for other important functions such as activation of the response organization, implementation of protective actions or on-site control of the damage. Guidance for development of these procedures are found in IAEA97.

## OBJECTIVES OF EMERGENCY RESPONSE

The objectives of emergency response are to:

(a) Prevent deterministic health effects (deaths and injuries) by:

- Taking action before or shortly after a major (core damage) release or exposure from a reactor accident.
- Keeping the public and emergency worker doses below the thresholds for deterministic health effects.

(b) Reduce the risk of stochastic effects on health (primarily cancer and severe hereditary effects) by:

- Implementing protective actions in accordance with IAEA guidance [IAEA96].
- Keeping emergency worker doses below the guidance limits established in IAEA guidance [IAEA96].

Deterministic health effects can be prevented by taking protective actions before or shortly after a release. These immediate actions must be based on plant conditions and then refined subsequently based on environmental measurements. The risk of stochastic health effects is reduced by taking actions based on ambient dose rates and analysis of environmental samples. Sampling and analysis are performed to evaluate the safety of food, milk, and water in areas where ambient dose rates or deposition concentrations indicate that restrictions may be warranted. Sample analysis is also used to refine the operational intervention levels (OILs) used to interpret environmental measurements.

## PHILOSOPHY

Implementing protective measures early in an accident should not be delayed by meetings, detailed calculations or other time consuming activities. In addition severe accidents are not well understood and early in an accident there will be only limited reliable information on which to make decisions.

Therefore the basic philosophy of this manual is to keep the process simple, yet effective. The manual provides criteria that are:

(a) predetermined, allowing for immediate actions to be taken,
(b) measurable by the instruments used,
(c) very simple, yet effective and
(d) based on our best understanding of severe accidents and international guidance.

This manual follows a process (see Figure 1) that relates reactor plant information and environmental monitoring data to the appropriate protective actions, covering the entire course of an accident. Plant conditions are assessed using control room instrument readings and other observable information to determine the risk and characteristics of a potential release. Environmental data are assessed primarily through the use of operational intervention levels (OIL), which are quantities directly measured by the field instruments. Default OILs have been calculated in advance on the basis of the characteristics of severe reactor accidents. These default OILs are used to assess environmental data and take protective actions until sufficient environmental samples are taken and analysed to provide a basis for their revision. This approach allows data to be quickly evaluated, and decisions on protective actions to be promptly made.

STRUCTURE

The manual is organized in sections based on proposed assessment organization and in the order that assessments most likely will be performed. Each section contains methods, that are stand-alone procedures. Sections start with an overview, containing a prioritized summary of tasks followed by procedures which provide detailed instructions.

There are four ways how to find the appropriate item in the manual based on:

(a) accident assessment process by using Figure 1,
(b) accident assessment organization by using Figure O1,
(c) contents by using Table of Contents, and
(d) key words using Index at the end of the document.

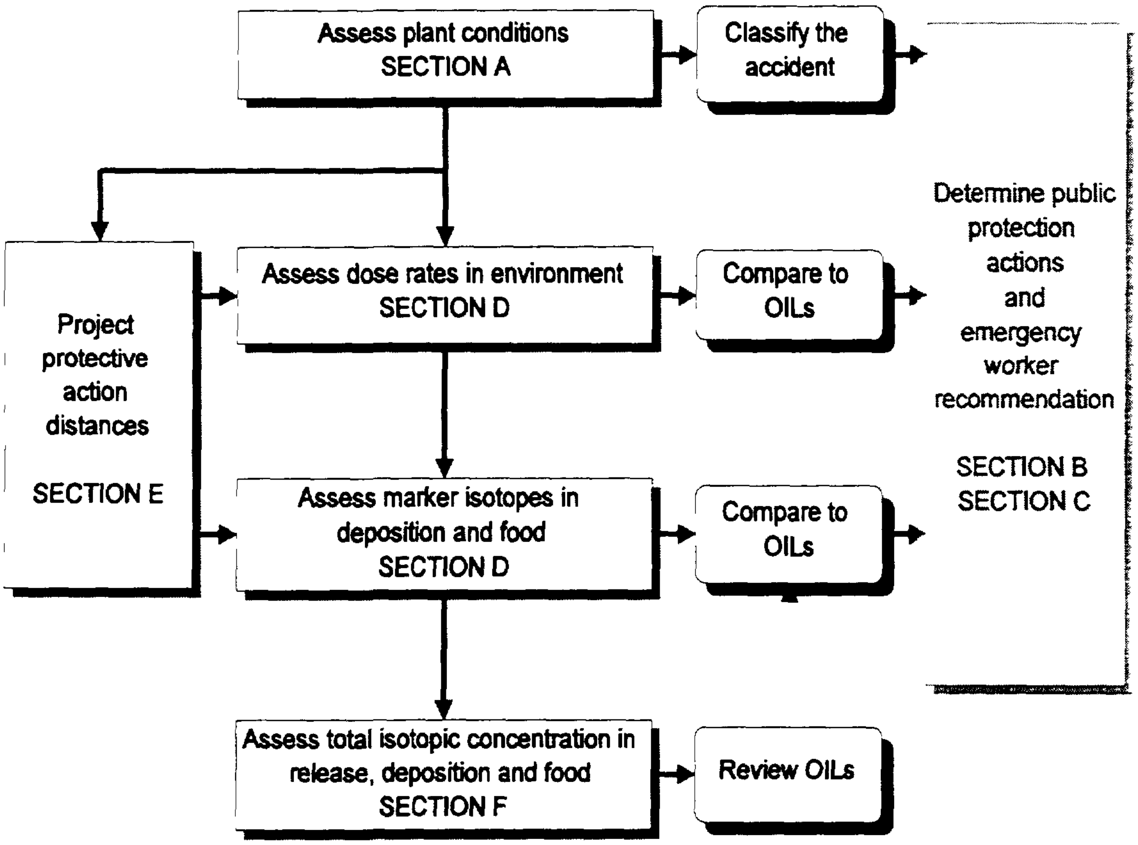


FIGURE 1
OVERVIEW OF THE ACCIDENT ASSESSMENT PROCESS

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SECTION O

# ACCIDENT ASSESSMENT MANAGER PROCEDURES

Caution: The procedures in this section must be revised to reflect local and plant conditions for which they will be applied.

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| *Performed by:*<br><br>*Accident Assessment Manager* | **PROCEDURE O1**<br><br>**ACCIDENT CONSEQUENCE ASSESSMENT MANAGEMENT** | *Pg. 1 of 3* |
|---|---|---|

**Purpose**
To establish and manage the organization responsible for assessing an accident to develop protective action recommendations for the public and radiation protection guidance for emergency workers.

**Discussion**
Deterministic health effects can be prevented by taking protective actions before or shortly after a major release. This is accomplished by taking immediate actions based on plant conditions and by refining these initial protective actions based on environmental measurements. The risk of stochastic health effects is reduced by taking actions based on ambient dose rates and sample analysis. Sampling and analysis are performed to evaluate the safety of the food, milk, and water in areas where ambient dose rates or deposition levels indicate that restriction may be warranted. Sample analysis can also be used to refine the operational intervention levels (OILs) used in protective action decision making.

**Input**
- ► Initial event briefings

**Output**
- ► Recommended actions

**Step 1**
Obtain briefing on the plant and radiological situation.

**Step 2**
Initiate Priority 1 actions in Table O1

**Step 3**
Use Worksheet O1 for assignment of personnel.

**Step 4**
Review responsibilities with staff as outlined in Figure O1. Ensure assessments are performed in accordance with priorities in Table O1.

Hold initial and periodic briefings to discuss assessment priorities and individual radiation protection.

**Step 5**
Establish communication with officials responsible for off-site implementation of protective action and provide continual briefings on protective actions for the public and emergency workers exposure guidance.

**Step 6**
Ensure that personnel are relieved at least every 12 hours.

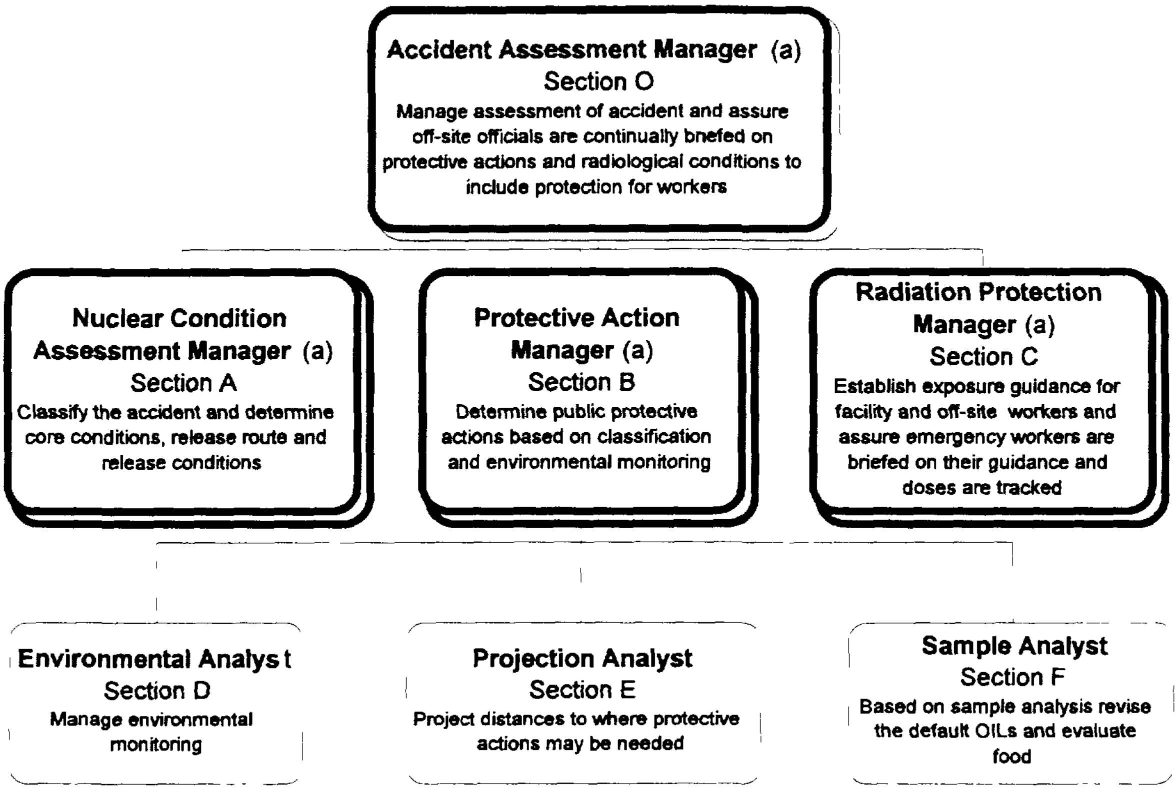


FIGURE O1
ACCIDENT ASSESSMENT ORGANIZATION

(a) This position must be performed on an on-going basis by the staff in the nuclear power plant until relieved. *[A standalone immediate response procedure should be developed for the nuclear power plant shift supervisor. This procedure will direct the immediate actions to be performed by the shift supervisor for each emergency class].*

TABLE O1 RESPONSE PRIORITIES

| Priority | Action | Accident Classification | | | When | Who |
|---|---|---|---|---|---|---|
| | | **Alert** | **Site Area Emergency** | **General Emergency** | | |
| 1 | Classify accident based on plant and radiological conditions | | | | On an on-going basis | Nuclear Condition Assessment Manager (a) |
| 1 | Notify on-site officials and off-site authorities | ✔ | ✔ | ✔ | Complete within 15 min. after classification | Accident Assessment Manager (a) |
| 1 | Activate emergency response organization | | ✔ | ✔ | Complete within 2 hours after classification | Accident Assessment Manager (a) |
| 1 | Determine and recommend public protective actions | | ✔ | ✔ | Immediately after classification and after major changes in plant or radiological conditions | Protective Action Manager (a) |
| 2 | Implement emergency worker radiation protection guidance | | ✔ | ✔ | Complete within 30 min. after classification | Radiation Protection Manager (a) |
| 2 | Deploy monitoring teams | ✔ | ✔ | ✔ | Initiate within 30 min. after classification | Accident Assessment Manager (a) |
| 3 | Assess ambient dose rates | ✔ | ✔ | ✔ | On-site, complete within 30 min. after classification | Environmental Analyst |
| 3 | Assess ambient dose rates | | ✔ | ✔ | Around the reactor site, complete within 60 min. after classification | Environmental Analyst |
| 3 | Assess ambient dose rates | | | ✔ | Beyond vicinity of reactor site, initiate within 4 hours after classification | Environmental Analyst |
| 4 | Project off-site consequences | | ✔ | ✔ | Complete within 2 hours after classification | Projection Analyst |
| 5 | Assess air and deposition concentrations | | | ✔ | Begin within 4 hours after classification | Sample Analyst |
| 6 | Assess food, milk and water contamination | | | ✔ | Begin within 24 hours after classification | Environmental Analyst and Sample Analyst |

(a) These tasks must be performed by personnel available immediately at the site on a 24 hour basis until transfer to others.

## SECTION A

# NUCLEAR CONDITION ASSESSMENT MANAGER PROCEDURES

Caution: The procedures in this section must be revised to reflect local and plant conditions for which they will be applied.

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| *Performed by:* <br><br> *Nuclear Condition Assessment Manager* | **PROCEDURE A0** <br><br> **NUCLEAR CONDITION ASSESSMENT OVERVIEW** | *Pg. 1 of 1* |
|---|---|---|

**Purpose**
To provide overview of tasks performed by Nuclear Condition Assessment Manager.

**Discussion**
Classification of the accident is most important. All changes in plant conditions or radiological conditions must be evaluated immediately to determine if the classification should be changed. Report an increase in class immediately to the Accident Assessment Manager and Protective Action Manager.

**Step 1**
Obtain briefing on the situation from the Accident Assessment Manager. Follow the applicable radiation protection instructions provided by the Radiation Protection Manager.

**Step 2**
Classify all major changes in plant or radiological conditions in accordance with procedure A1. Immediately report core damage or changes in classification to the Accident Assessment Manager.

**Step 3**
Evaluate core damage state, release routes and conditions using procedures A2 and A3.

**Step 4**
Ensure Worksheet A1 is updated and distributed at each major change in plant or radiological conditions.

**Step 5**
Keep recording all major actions and/or decisions in a logbook.

**Step 6**
At the end of your shift ensure that your replacement is thoroughly briefed.

**Purpose**
To classify abnormal plant and radiological conditions.

**Discussion**
Many instruments will be unreliable during an accident. Consequently, never use a single instrument as the basis of a classification.

**Input**
- From Control room
  - i. Reactor systems status
  - ii. In plant radiological conditions
  - iii. Fuel pool status
  - iv. Security status
- Ambient dose rate around the plant (Worksheet D1)

**Output**
- Accident class

**Step 1**
Classify abnormal plant and radiological conditions based on the following:

| If the reactor is in: | Then use: |
|---|---|
| Operating, stand-by or hot shutdown mode | Table A1 |
| Cold shutdown or refueling mode | Table A2 |

**Step 2**
Record the class on Worksheet A1 along with a description of the accident conditions.

**Step 3**
Reassess the classification whenever there is a major change in plant or radiological conditions or once in an hour.

**Step 4**
Report any change in class immediately to the Accident Assessment Manager and the Protective Action Manager.

TABLE A1 ACCIDENT CLASSIFICATION THE OPERATING, STAND-BY OR HOT SHUTDOWN MODE

**Read me first**
The table must be reviewed and revised to match site specifics and where possible the emergency action levels (EAL) should be replaced with a specific plant instrument readings, equipment status or other observable. The three possible levels of emergency are defined as:

*General Emergency*: Events resulting in an actual or substantial risk of a release requiring implementation of urgent protective actions off-site. This includes: 1) actual or projected damage to the core or large amounts of spent fuel or 2) releases off-site resulting in a dose exceeding the urgent protective actions interventions levels. Urgent protective actions are recommended immediately for the public near the plant when this level of emergency is declared.

*Site Area Emergency*: Events resulting in a major decrease in the level of protection for the public or on-site personnel. This includes: 1) a major decrease in the level of protection provided to the core or large amounts of spent fuel, 2) conditions where any additional failures could result in damage to core or spent fuel or 3) high doses on-site or doses off-site approaching the urgent protective actions interventions levels. At this class actions should be taken to control the dose to on-site personnel and preparations should be made to take protective actions off-site.

*Alert:* Events involving an unknown or significant decrease in the level of protection for the public or on-site personnel. At this class the state of readiness of the on and off-site response organizations is increased and additional assessments are made.

**How to use the table**:

Review all the accident entry conditions in column 1. For each entry condition that applies, select the class by matching the EAL criteria to the left. Classify the accident at the highest level indicated: Highest - General Emergency, Lowest - Alert.

TABLE A1 ACCIDENT CLASSIFICATION THE OPERATING, STAND-BY OR HOT SHUTDOWN MODE

| **For the following accident entry conditions:** | **Declare a General Emergency if:** | **Declare a Site Area Emergency if:** | **Declare an Alert if:** |
|---|---|---|---|
| **CRITICAL SAFETY FUNCTION IMPAIRMENT** | | | |
| Failure to scram (stop nuclear reaction) | Failure to scram when above 5% power **and** any of the following:<br>▸ PWR negative cooling margin by Figure A1<br>**or**<br>▸ vessel water level below top of active fuel,<br>**or**<br>▸ major (100 - 1000x) increase in multiple radiation monitors<br>**or**<br>▸ other indication of actual or imminent core damage | Failure to scram when above 5% power and abnormal conditions indicate automatic or manual scram is necessary | Failure to fully shutdown as part of normal shutdown and there is sufficient heat removal available (ultimate heat sink available and sufficient) |
| Inadequate primary system decay heat removal | | Actual or protected long term failure of the ability to remove decay heat to the environment potentially affecting the ability to protect the core | |

TABLE A1 ACCIDENT CLASSIFICATION THE OPERATING, STAND-BY OR HOT SHUTDOWN MODE

| **For the following accident entry conditions:** | **Declare a General Emergency if:** | **Declare a Site Area Emergency if:** | **Declare an Alert if:** |
|---|---|---|---|
| PWR abnormal primary system temperature (Inadequate core cooling)<br>*Note: Temperature should be measures in the vessel. Most PWRs have core exit thermocouples (CET) to measure temperatures in the vessel. Use the average of the highest four CET readings. If there is water flow the hot leg temperature ($T_{hot}$) could also be used if CETs are not available. CETs are not accurate after core damage.*<br>*For BWR there are no instruments that provide a valid reading of core temperature.* | PWR - Negative cooling margin by Figure A1 or primary system temperature exceeds scale for greater than 15 minutes *[or insert site specific time for core damage following a loss of coolant accident]* **and** any of the following:<br>▸ vessel injection rate less than Figure A2 *[plant specific pump capacity vs pressure]*<br>**or**<br>▸ vessel water level below top of active fuel<br>**or**<br>▸ major (100 - 1000x) increases in multiple radiation monitors<br>**or**<br>▸ other indications of actual or imminent core damage | PWR - Negative cooling margin by Figure A1 for greater than 15 minutes *[or insert site specific time that core damage is possible following a loss of coolant accident]* | PWR primary system pressure and temperature indicate negative cooling margin by Figure A1 for greater than 5 minutes. |
| | Primary system temperature greater than 750 °C | | |

TABLE A1 ACCIDENT CLASSIFICATION THE OPERATING, STAND-BY OR HOT SHUTDOWN MODE

<table>
<tr><th>For the following accident entry conditions:</th><th>Declare a General Emergency if:</th><th>Declare a Site Area Emergency if:</th><th>Declare an Alert if:</th></tr>
<tr><td rowspan="2">Abnormal vessel water level (Inadequate core cooling)<br><br>Notes:<br>- PWR pressurizer levels may not be valid indicators of vessel water level under accident conditions<br>- PWR water levels measured in the vessel can have considerable uncertainties (30%) and should only be used for trends assessment.<br>- BWR high drywell temperature and low pressure accidents (e.g. LOCAs) can cause the water level to read erroneously high.<br>- Both PWR and BWR water level readings are unreliable after core damage.</td><td>Vessel water level is, or projected to be, below top of active fuel for greater than 15 minutes.</td><td>Vessel water is or is projected to be below top of active fuel.</td><td>Vessel water level decreasing over a longer time period than expected if systems are responding as designed.</td></tr>
<tr><td>Vessel water level is or projected to be below top of active fuel and any of the following:<br><br>▸ vessel injection rate less than Figure A2 [plant specific pump capacity vs pressure]<br>or<br>▸ major (100 - 1000x) increases in multiple radiation monitors<br>or<br>▸ other indications of imminent or actual core damage</td><td></td><td></td></tr>
</table>

TABLE A1 ACCIDENT CLASSIFICATION THE OPERATING, STAND-BY OR HOT SHUTDOWN MODE

| For the following accident entry conditions: | Declare a General Emergency if: | Declare a Site Area Emergency if: | Declare an Alert if: |
|---|---|---|---|
| Loss of AC or DC power sources | Actual or projected loss of all AC or DC power needed for safety systems operation likely for greater than 45 minutes *[or insert site specific time required to uncover core for more than 15 minutes]* | Actual or projected loss of AC or DC power needed for safety systems operation for greater than 30 minutes *[or insert site specific time required to uncover the core]* | AC or DC power needed for safety systems operation is lost or reduced to a single source |
| | Loss of all AC or DC power needed for safety systems operation **and** any of the following:<br>▸ vessel water level below top of active fuel,<br>**or**<br>▸ major (100 - 1000x) increase in multiple radiation monitors<br>**or**<br>▸ other indication of actual or imminent core damage | | |
| Puzzling conditions affecting safety systems | | | Conditions which are not understood and which could potentially affect safety systems. |

TABLE A1 ACCIDENT CLASSIFICATION THE OPERATING, STAND-BY OR HOT SHUTDOWN MODE

| **For the following accident entry conditions:** | **Declare a General Emergency if:** | **Declare a Site Area Emergency if:** | **Declare an Alert if:** |
|---|---|---|---|
| Loss or degraded control of safety systems. | Unavailability or unreliable functioning of safety system instruments or controls in the control room and remote control locations **and** any of the following:<br>▸ vessel water level below the top of active fuel<br>**or**<br>▸ major (100 - 1000x) increases in multiple radiation monitors<br>**or**<br>▸ other indications of imminent or actual core damage | Unavailability or unreliable functioning of safety system instruments or controls in the control room for more than 15 minutes and major transient in progress potentially affecting the ability to protect the core. | Unavailability or unreliable functioning of safety system instruments or controls in the control room for more than 15 minutes. |
| **LOSS OF FISSION PRODUCT BARRIERS** | | | |
| Major increased risk of damage to the core or spent fuel<br>*Note: Core damage can occur if the core is uncovered for more than 15 minutes.* | Loss of all the systems required to protect the core or spent fuel for more than 45 minutes *[or insert site specific time required to uncover core for more than 15 minutes]* | Failure of an additional safety system component will result in uncovery of the core or spent fuel (Loss of redundancy in safety systems) | Actual or predicted failures which increase the risk of core damage, spent fuel damage or of a major release |
| Confirmed core damage | *[insert site specific readings such as PWR failed fuel monitor or BWR off-gas monitor indicating release of 20% of gap inventory]..* | *[insert site specific readings such as PWR failed fuel monitor or BWR off-gas monitor indicating 1% release of gap inventory* ] | |

TABLE A1 ACCIDENT CLASSIFICATION THE OPERATING, STAND-BY OR HOT SHUTDOWN MODE

| **For the following accident entry conditions:** | **Declare a General Emergency if:** | **Declare a Site Area Emergency if:** | **Declare an Alert if:** |
|---|---|---|---|
| High primary coolant I-131 concentration<br><br>*Note:*<br>*Coolant samples should not be taken if they will result in high individual doses.*<br>*-Use only concentrations from sample taken after the start of the event.*<br>*-Coolant concentrations may not be representative*<br>*- Assumes the core may be uncoolable after 10% melt.* | I-131 concentration is greater than.. *[insert site specific values for release of 10% of core inventory]* | I-131 concentration is greater than .... *[insert site specific value indicating release of 20% of the gap inventory]* | I-131 concentration greater than ... *[insert site specific value 100 times technical specifications or other operational limits]* |
| Primary system leak. | Primary system leak and all normal and emergency core coolant systems (ECCS) operational **and** any of the following:<br><br>▸ injection into the vessel less than the amount shown in Figure A2<br>**or**<br>▸ vessel water level below top of active fuel and decreasing<br>**or**<br>▸ major (100 - 1000x) increases in multiple radiation monitors<br>**or**<br>▸ other indications of imminent or actual core damage | Primary system leak for more than 15 minutes requiring all normal and high pressure emergency core coolant systems to maintain primary system water level *[insert site specific indicators]* | Primary system leak rate for more than 15 minutes requiring at least continuous operation of all normal charging pumps to maintain primary system water level *[insert site specific indicators]* |

TABLE A1 ACCIDENT CLASSIFICATION THE OPERATING, STAND-BY OR HOT SHUTDOWN MODE

| **For the following accident entry conditions:** | **Declare a General Emergency if:** | **Declare a Site Area Emergency if:** | **Declare an Alert if:** |
|---|---|---|---|
| Primary system leak directly to atmosphere such as:<br>▸ PWR: Steam generator tube rupture (SGTR)<br>▸ BWR: Main steam isolation valve (MSIV) failure outside of containment<br>▸ A leak with a failure of the containment to isolate<br>▸ A plant with no containment | Primary system leak directly to the atmosphere **and** any of the following:<br>▸ projected or confirmed vessel water level below top of active fuel,<br>**or**<br>▸ major (100 - 1000x) increase in multiple radiation monitors<br>**or**<br>▸ other indication of actual or imminent core damage | Primary system leak for more than 15 minutes directly to atmosphere requiring more than all normal charging pump capacity to maintain primary system water level . | Primary system leak for more than 15 minutes directly to atmosphere requiring continuous operation of more than one normal charging pump to maintain primary system water level. |
| **RADIATION LEVELS** | | | |
| Effluent release rates > 100 times release limits. | Effluent monitor readings for more than 15 minutes greater than ... *[insert site specific list of effluent monitors and readings indicating that in 1 hour the off-site doses will be greater than the intervention levels for urgent protective actions assuming average metro logical conditions].* | Effluent monitor readings for more than 15 minutes greater than ...*[ insert site specific list of effluent monitors and readings indicating that in 4 hours the off-site doses will be greater than 0.10 of the intervention levels for urgent protective actions assuming average metro logical conditions]* | Effluent monitor readings for more than 15 minutes greater than ... *[ insert site specific list of effluent monitors and readings indicating 100 times release limits]* |

TABLE A1 ACCIDENT CLASSIFICATION THE OPERATING, STAND-BY OR HOT SHUTDOWN MODE

| For the following accident entry conditions: | Declare a General Emergency if: | Declare a Site Area Emergency if: | Declare an Alert if: |
|---|---|---|---|
| High radiation levels in control room or other areas requiring continuous access for safety system operation and maintenance.<br><br>*Note: Inconsistent monitor readings could result from incomplete mixing, a failed monitor or by seeing radiation from a contaminated system nearby. Monitors may show high, low or centre range if they fail. Readings can be confirmed using hand-held monitors outside the area* | Radiation levels greater than 10 mSv/h | Radiation levels greater than 1 mSv/h potentially lasting several hours. | Radiation levels greater than 0.10 mSv/h potentially lasting several hours. |
| High radiation levels in areas requiring occasional occupancy to maintain or control safety systems. | Radiation levels greater than 100 mSv/h potentially lasting several hours. | Radiation levels greater than 10 mSv/h potentially lasting several hours.. | Radiation levels greater than 1 mSv/h potentially lasting several hours.. |
| Elevated containment radiation levels.<br><br>*Note: Inconsistent monitor readings could result from incomplete mixing or a failed monitor. Monitors may show high, low or centre range if they fail Readings can be confirmed using hand-held monitors outside the containment.* | Greater than 5 Gy/h *[ or insert site specific reading indicating release of greater than 20% gap inventory ]* | Greater than 1 Gy/h *[ or insert site specific reading indicating release of greater than 1% gap inventory]* | Containment radiation levels increase greater than 0.10 mGy/h *[ or insert site specific reading indicating release of greater than 10% coolant inventory]* |

TABLE A1 ACCIDENT CLASSIFICATION THE OPERATING, STAND-BY OR HOT SHUTDOWN MODE

| **For the following accident entry conditions:** | **Declare a General Emergency if:** | **Declare a Site Area Emergency if:** | **Declare an Alert if:** |
|---|---|---|---|
| Unplanned increase in plant radiation levels | Multiple plant radiation monitors show an unplanned or unpredicted increase by a factor of 100 or more and any other indication of actual core damage. | Multiple plant radiation monitors show an unplanned or unpredicted increase by a factor of 100 or more and a major transient in progress potentially affecting the ability to protect the core.. | Multiple plant radiation monitors show an unplanned or unpredicted increase by a factor of 100 or more |
| High ambient dose rates beyond the site boundary. | Ambient dose rates beyond the site boundary greater than 1 mSv/h *[or insert the site specific operational intervention level for evacuation, see Procedure B1]*. | Ambient dose rates beyond the site boundary greater than 0.1 mSv/h.*[or insert 1/10 of the site specific operational intervention level for evacuation, see Procedure B1]* | Ambient dose rates beyond the site boundary greater than 10 µSv/h *[or insert site specific reading indicating 100 times background]* |
| **SECURITY, FIRE, NATURAL AND OTHER EVENTS** | | | |
| Security event (intruder or terrorist attack) | Security event resulting in loss of the ability to monitor and control safety functions needed to protect core. | Security event resulting in damage to safety systems or access to safety systems | Security event with potential to affect safety system operation or uncertain security conditions |
| Fire or explosion (to include turbine failures) | | . | Fire or explosions potentially affecting areas containing safety systems |
| Toxic or flammable gases | | Flammable gas concentrations that prevent control or maintenance of safety systems | Toxic or flammable gases in plant |

TABLE A1 ACCIDENT CLASSIFICATION THE OPERATING, STAND-BY OR HOT SHUTDOWN MODE

| **For the following accident entry conditions:** | **Declare a General Emergency if:** | **Declare a Site Area Emergency if:** | **Declare an Alert if:** |
|---|---|---|---|
| Major natural or other disaster such as:<br>▸ earthquake<br>▸ tornado<br>▸ floods<br>▸ high winds<br>▸ vehicle crash<br>▸ hurricane<br>▸ tsunami<br>▸ storm surge<br>▸ low water | | Natural or other major events resulting in damage to safety systems or access to safety systems or affecting long term operation | Natural or other major events that threaten the plant such as :<br>▸ Events beyond the design basis of the plant<br>▸ Events resulting in actual or potential loss of access to the site for an extensive period of time<br>▸ Events resulting in actual or potential loss of communications to the site for an extensive period of time |

TABLE A1 ACCIDENT CLASSIFICATION THE OPERATING, STAND-BY OR HOT SHUTDOWN MODE

| **For the following accident entry conditions:** | **Declare a General Emergency if:** | **Declare a Site Area Emergency if:** | **Declare an Alert if:** |
|---|---|---|---|
| Plant shift supervisor opinion | Conditions that warrant taking urgent protective actions off-site | Conditions that warrant preparing the public to implement urgent protective actions<br>**or**<br>Conditions that warrant taking protective actions on-site | Abnormal conditions warranting obtaining immediate additional assistance for the on-site operations staff<br>**or**<br>Abnormal conditions warranting increased preparedness of off-site officials |
| **SPENT FUEL POOL EVENTS** | | | |
| Abnormal refuelling or spent fuel conditions | Fully drained pool containing more than 1/3 of a core removed from the reactor core within the last 3 years.<br>**or**<br>radiation level in pool area > 3 Gy/h | Water level below top of irradiated fuel<br>**or**<br>radiation level in pool area > 30 mGy/h | Loss of ability to maintain water level above spent fuel<br>**or**<br>Damage to spent fuel |

TABLE A2 ACCIDENT CLASSIFICATION FOR COLD SHUTDOWN OR REFUELLING

**Read me first**
The table must be reviewed and revised to match site specifics and where possible the emergency action levels (EAL) should be replaced with a specific plant instrument readings, equipment status or other observable. The three possible levels of emergency are defined as:

*General Emergency:* Events resulting in an actual or substantial risk of a release requiring implementation of urgent protective actions off-site. This includes: 1) actual or projected damage to the core or large amounts of spent pool or 2) releases off-site resulting in a dose exceeding the urgent protective actions interventions levels. Urgent protective actions are recommended immediately for the public near the plant when this level of emergency is declared.

*Site Area Emergency*: Events resulting in a major decrease in the level of protection for the public or on-site personnel. This includes: 1) a major decrease in the level of protection provided to the core or large amounts of spent fuel, 2) conditions where any additional failures could result in damage to core or spent fuel or 3) high doses on-site or doses off-site approaching the urgent protective actions interventions levels. At this class actions should be taken to control the dose to on-site personnel and preparations should be made to take protective actions off-site.

*Alert:* Events involving an unknown or significant decrease in the level of protection for the public or on-site personnel. At this class the state of readiness of the on and off-site response organizations is increased and additional assessments are made.

**How to use the table**:

Review all the accident entry conditions in column 1. For each entry condition that applies, select the class by matching the EAL criteria to the left. Classify the accident at the highest level indicated: Highest - General Emergency, Lowest - Alert.

TABLE A2 ACCIDENT CLASSIFICATION FOR COLD SHUTDOWN OR REFUELLING

| **For the following accident entry conditions:** | **Declare a General Emergency if:** | **Declare a Site Area Emergency if:** | **Declare an Alert if:** |
|---|---|---|---|
| **CRITICAL SAFETY FUNCTION IMPAIRMENT** | | | |
| Inability to maintain the plant shut down (sub-critical) | Failure to maintain the plant subcritical **and** any of the following :<br>▸ vessel injection rate less than Figure A2<br>**or**<br>▸ vessel water level below top of active fuel<br>**or**<br>▸ major (100 - 1000x) increases in multiple radiation monitors<br>**or**<br>▸ other indications of actual or imminent core or spent fuel damage | Failure to maintain the plant subcritical | |
| PWR abnormal primary system temperature (inadequate core cooling)<br><br>*Note: Temperature should be measures in the vessel. Most PWRs have core exit thermocouples (CET) to measure temperatures in the vessel. Use the average of the highest four CET readings. If there is water flow the hot leg temperature ($T_{hot}$) could also be used if CETs are not available. CET are not accurate after core damage.* | PWR primary system temperature > 350°C or exceeds the scale **and** any of the following:<br><br>▸ vessel injection rate less than Figure A2 *[plant specific pump capacity vs pressure]*<br>**or**<br>▸ vessel water level below top of active fuel<br>**or**<br>▸ major (100 - 1000 x) increases in multiple radiation monitors<br>**or**<br>▸ other indications of imminent core or spent fuel damage | PWR primary system temperature > 350°C or exceeds the scale for more than 30 minutes | PWR primary system temperature > 350°C or exceeds the scale. |

TABLE A2 ACCIDENT CLASSIFICATION FOR COLD SHUTDOWN OR REFUELLING

| **For the following accident entry conditions:** | **Declare a General Emergency if:** | **Declare a Site Area Emergency if:** | **Declare an Alert if:** |
|---|---|---|---|
| PWR abnormal primary system temperature (inadequate core cooling)<br><br>*Note: See note above.* | PWR primary system temperature greater than 750 °C | | |
| Low vessel or refuelling area water level (inadequate core or spent fuel cooling) | Water level projected to be below top of active fuel for more than 30 minutes | Water level projected to be below top of active fuel. | |
| | Water level projected to be below top of active fuel **and** any of the following:<br><br>▸ vessel injection rate less than Figure A2 *[plant specific pump capacity vs pressure]*<br>**or**<br>▸ major (100 - 1000x) increases in areas or process radiation monitors<br>**or**<br>▸ other indications of imminent core damage | | |

TABLE A2 ACCIDENT CLASSIFICATION FOR COLD SHUTDOWN OR REFUELLING

| **For the following accident entry conditions:** | **Declare a General Emergency if:** | **Declare a Site Area Emergency if:** | **Declare an Alert if:** |
|---|---|---|---|
| Loss of AC or DC power sources. | Actual or projected loss of all AC or DC power needed for safety systems operation likely for greater than 90 minutes *[or insert site specific time required to uncover core or spent fuel for more than 30 minutes]* | Actual or projected loss of all AC or DC power needed for safety systems operation for greater than 60 minutes *[or insert site specific time required to uncover the core or spent fuel ]* | AC or DC power needed for safety systems operation reduced to a single source |
| | Loss of all AC or DC power needed for safety systems operation **and** any of the following:<br>▸ vessel water level below top of active fuel,<br>**or**<br>▸ major (100 - 1000x) increase in multiple radiation monitors<br>**or**<br>▸ other indication of actual or imminent core damage | | |
| Puzzling conditions affecting safety systems | | | Conditions which are not understood and which could potentially affect safety systems. |

TABLE A2 ACCIDENT CLASSIFICATION FOR COLD SHUTDOWN OR REFUELLING

| **For the following accident entry conditions:** | **Declare a General Emergency if:** | **Declare a Site Area Emergency if:** | **Declare an Alert if:** |
|---|---|---|---|
| Loss or degraded control of safety systems. | Unavailability or unreliable functioning of safety system instruments or controls in the control room and remote control locations **and** any of the following:<br>▸ projected or confirmed vessel water level below the top of irradiate fuel<br>**or**<br>▸ major (100 - 1000 x) increases in multiple radiation monitors<br>**or**<br>▸ other indications of actual or imminent core damage | Unavailability or unreliable functioning of safety system instruments or controls in the control room for more than 30 minutes and major transient in progress potentially affecting the ability to protect irradiate fuel. | Unavailability or unreliable functioning of safety system instruments or controls in the control room for more than 30 minutes. |
| **LOSS OF FISSION PRODUCT BARRIERS** | | | |
| Major increased risk of core or spent fuel damage. | Loss of all the systems required to protect the core or spent fuel for more than 90 minutes *[or insert site specific time required to uncover core for more than 30 minutes]* . | Failure of one or more safety system components will result in uncovery of the core or spent fuel (Loss of redundancy in safety systems) | Actual or predicted safety system failures which increase the risk of core or spent fuel damage |

TABLE A2 ACCIDENT CLASSIFICATION FOR COLD SHUTDOWN OR REFUELLING

| For the following accident entry conditions: | Declare a General Emergency if: | Declare a Site Area Emergency if: | Declare an Alert if: |
|---|---|---|---|
| Confirmed or projected core or spent fuel damage | Confirmed release greater than 20% gap release from the fuel. | Confirmed release greater than 1% gap release from the fuel. | |
| **RADIATION LEVELS** | | | |
| Effluent release rates > 100 times release limits. | Effluent monitor readings for more than 15 minutes greater than ... *[insert site specific list of effluent monitors and readings indicating that in 1 hour the off-site doses will be greater than the intervention levels for urgent protective actions assuming average metro logical conditions].* | Effluent monitor readings for more than 15 minutes greater than ...*[ insert site specific list of effluent monitors and readings indicating that in 4 hours the off-site doses will be greater than 0.10 of the intervention levels for urgent protective actions assuming average metro logical conditions*] | Effluent monitor readings for more than 15 minutes greater than ... *[ insert site specific list of effluent monitors and readings indicating 100 times release limits]* |
| High radiation levels in areas requiring continuous access for safety system operation and maintenance.<br><br>*Note: Inconsistent monitor readings could result from incomplete mixing, a failed monitor or by seeing radiation from a contaminated system nearby. Monitors may show high, low or centre range if they fail. Readings can be confirmed using hand-held monitors outside the area.* | Radiation levels greater than 10 mSv/h | Radiation levels greater than 1 mSv/h potentially lasting several hours. | Radiation levels greater than 0.10 mSv/h potentially lasting several hours. |
| High radiation levels in areas requiring occasional occupancy to maintain or control safety systems. | Radiation levels greater than 100 mSv/h potentially lasting several hours | Radiation levels greater than 10 mSv/h potentially lasting several hours. | Radiation levels greater than 1 mSv/h potentially lasting several hours. |

TABLE A2 ACCIDENT CLASSIFICATION FOR COLD SHUTDOWN OR REFUELLING

| **For the following accident entry conditions:** | **Declare a General Emergency if:** | **Declare a Site Area Emergency if:** | **Declare an Alert if:** |
|---|---|---|---|
| Evaluated containment radiation levels.<br><br>*Note: Inconsistent monitor readings could result from incomplete mixing, a failed monitor or by seeing radiation from a contaminated system nearby. Monitors may show high, low or centre range if they fail. Readings can be confirmed using hand-held monitors outside the containment.* | Greater than 5 Gy/h *[ or insert site specific or reading indicating release of greater than 20% gap inventory]* | Greater than 1 Gy/h *[ or insert site specific or reading indicating release of greater than 1% gap inventory]* | Containment radiation levels increase greater than 0.10 mGy/h *[ or insert site specific or reading indicating release of greater than 10% coolant]* |
| Unplanned increase in plant radiation levels as indicated by monitors. | Multiple plant radiation monitors show an unplanned or unpredicted increase by a factor of 100 or more and any other indication of actual core damage. | Multiple plant radiation monitors show an unplanned or unpredicted increase by a factor of 100 or more and a major transient in progress potentially affecting the ability to protect the core.. | Multiple plant radiation monitors show an unplanned or unpredicted increase by a factor of 100 or more |
| High ambient dose rates beyond the site boundary. | Ambient dose rates beyond the site boundary greater than 1 mSv/h *[or insert the site specific operational intervention level for evacuation, see Procedure B1].* | Ambient dose rates beyond the site boundary greater than 0.1 mSv/h.*[or insert 1/10 of the site specific operational intervention level for evacuation, see Procedure B1]* | Ambient dose rates beyond the site boundary greater than 10 µSv/h *[or insert site specific reading indicating 100 times background]* |
| **SECURITY, FIRE, NATURAL AND OTHER EVENTS** | | | |
| Security event (intruder or terrorist attack) | Security event resulting in loss of the ability to monitor and control safety functions needed to protect core. | Security event resulting in damage to safety systems or access to safety systems | Security event with potential to affect safety system operation or uncertain security conditions |

TABLE A2 ACCIDENT CLASSIFICATION FOR COLD SHUTDOWN OR REFUELLING

| For the following accident entry conditions: | Declare a General Emergency if: | Declare a Site Area Emergency if: | Declare an Alert if: |
|---|---|---|---|
| Fire or explosion<br>(to include turbine failures) | | | Fire or explosions potentially affecting areas containing safety systems |
| Toxic or flammable gases | | | Toxic or flammable gases in plant |
| A major natural or other disasters such as:<br>▸ earthquake<br>▸ tornado<br>▸ floods<br>▸ high winds<br>▸ vehicle crash<br>▸ hurricane<br>▸ tsunami<br>▸ storm surge<br>▸ low water | | Natural or other events resulting in damage to safety systems or access to safety systems . | Natural or other major events that threaten the plant such as :<br>▸ Events beyond the design basis of the plant<br>▸ Events resulting in actual or potential loss of access to site for extensive period of time<br>▸ Events resulting in actual or potential loss of communication with the site for extensive period of time |
| Plant shift supervisor opinion | Conditions that warrant taking urgent protective actions off-site | Conditions that warrant preparing the public to implement urgent protective actions or taking protective actions on-site | Abnormal conditions warranting immediate additional assistance for the on-site operations staff or increased preparedness of off-site officials |
| **SPENT FUEL POOL EVENTS** | | | |
| Abnormal refuelling or spent fuel conditions | Fully drained pool containing fuel removed from the reactor core within the last 6 months<br>**or**<br>radiation level in pool area > 3 Gy /h | Water level below top of irradiated fuel<br>**or**<br>radiation level in pool area > 30 mGy/h | Loss of ability to maintain water level in pool containing irradiated fuel<br>**or**<br>Damage to irradiated fuel |

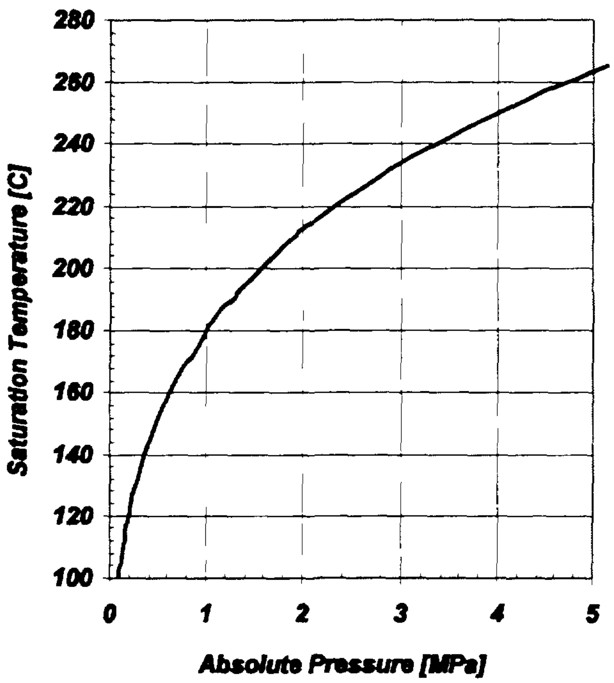
FIGURE A1
COOLING MARGIN - SATURATION CURVE

**Discussion**
A primary system temperature greater than the saturation temperature indicates that the water in the core is boiling. The cooling margin can be approximated by subtracting the coolant temperature from the saturation temperature for the given primary system pressure. For a PWR a negative cooling margin indicates water is boiling in the vessel and the core may be uncovered (source: NRC93).

**How to use the figure**
Determine the absolute pressure and temperature in the primary system. Then use the graphs below to determine the saturation temperature and following the cooling margin using the equation below:

$$\text{Cooling Margin} = T_{sat} - T_{PS}$$

where:
$T_{PS}$ = Primary system temperature
$T_{sat}$ = Saturation temperature from figure below



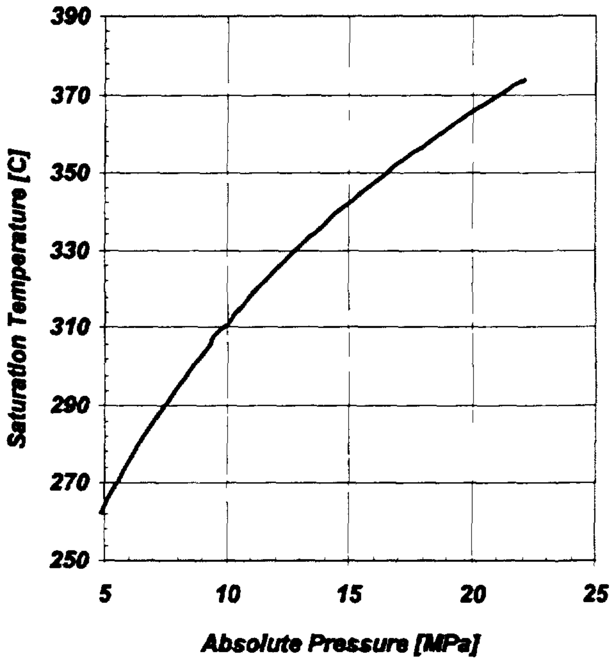



FIGURE A2
INJECTION REQUIRED TO REPLACE WATER LOST
BY BOILING DUE TO DECAY HEAT FOR A
3000 MW(th) PLANT

**Discussion**
These curves show the amount of water that must be injected into the vessel to replace water lost due to decay heat. This curve is based on a 3000 MW(th) plant operated at a constant power for an infinite period and then shut down instantaneously. *This is the minimum amount of water that must be injected into a core to cool it once it is shutdown (Source: NRC93).*

## Step 1
Determine the amount of water injection required by:

$$W_i = W_i^{3000} \times \frac{P_{plant}\ [MW(th)]}{3000\ [MW(th)]}$$

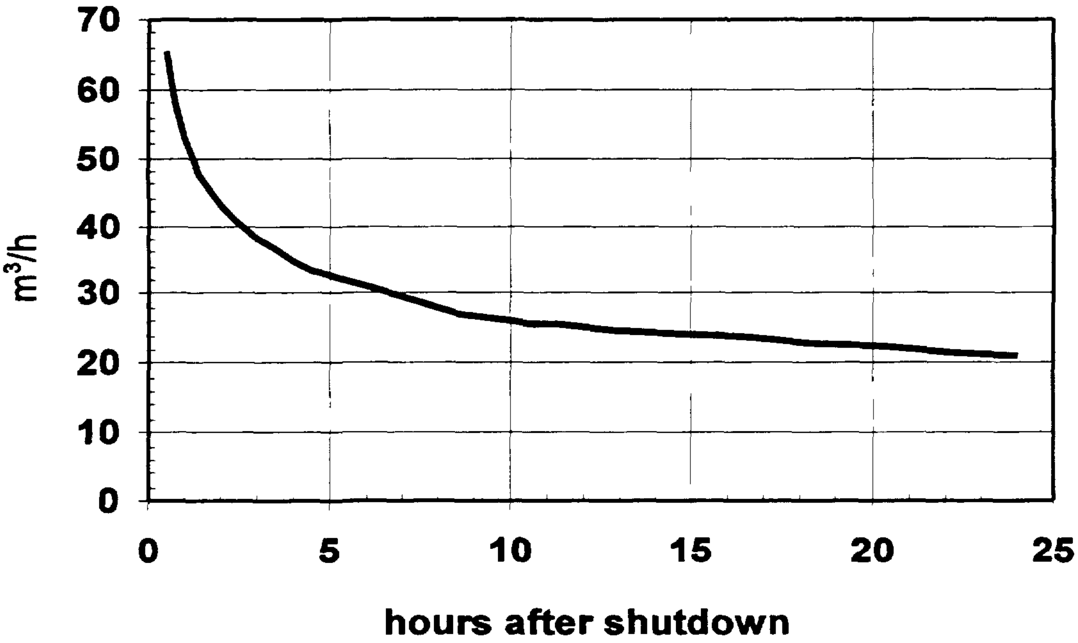
where:

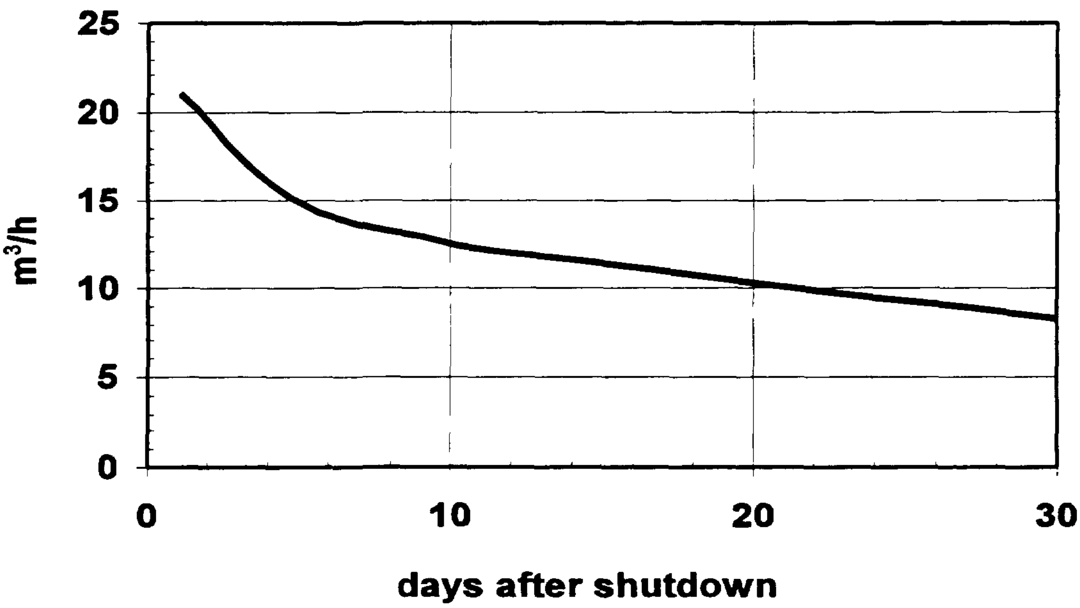
| | | |
|---|---|---|
| $W_i$ | = | Water injection required [$m^3/h$] |
| $W_i^{3000}$ | = | Water injection required for 3000 MW(th) plant [$m^3/h$] from figure below |
| $P_{plant}$ | = | Size of the plant in MW(th) [MW(th) ≅ 3 × MW(e)] |

## Step 2
If the core has been uncovered for greater than 15 minutes **increase the injection rate by a factor of three** to accommodate the heat from the Zr-$H_2O$ reaction and built up energy.

SEE FIGURES ON THE NEXT PAGE

FIGURE A2 (continued)
INJECTION REQUIRED TO REPLACE WATER LOST
BY BOILING DUE TO DECAY HEAT FOR A
3000 MW(th) PLANT



| Performed by: Nuclear Condition Assessment Manager | PROCEDURE A2 — ASSESSMENT OF CORE OR SPENT FUEL DAMAGE | Pg. 1 of 1 |
|---|---|---|

## Purpose
To estimate core or spent fuel damage.

## Discussion
The estimate the level of core damage is primarily based on the projected time the core has been uncovered. Coolant samples and containment monitor readings can also be used to assess core damage. However they are not required because they are either late or unreliable under accident conditions.

## Input
- ► Data needed to project time the core was (or will be) uncovered:
  - i. Primary system water level and trends,
  - ii. PWR core exit thermocouple readings or
  - iii. Radiation level and trends
- ► Containment monitor readings
- ► Coolant concentrations taken after the accident (if available)

## Output
- ► Level of core or spent fuel damage.

## Step 1
Determine if there are indications of potential core damage and if so go to the appropriate procedure to assess the damage.

| If the following conditions exist: | Then use: |
|---|---|
| Indications that the core is or may become uncovered such as:<br>► PWR primary system temperature > 400 ° C<br>► Water level indicator below the top of active fuel<br>► Major increases in radiation levels | Procedure A2a |
| Above normal containment monitor readings | Procedure A2b |
| Above normal primary coolant contamination levels | Procedure A2c |
| Indications that the spent fuel is uncovered such as increased radiation in pool area | Procedure A2d |

## Step 2
Reassess whenever there has been a major change in conditions.

## Purpose
To estimate core damage based on the length of time the core is uncovered.

## Discussion
This procedure uses the projected length of time the core is uncovered to estimate the core damage state. The possible levels of core damage given in Table A3 are reasonable if the core is uncovered within a few hours of shutdown (including failure to scram) without coolant injection. If there is injection of coolant, core heat-up may be stopped or slowed due to steam cooling. Steam cooling may not prevent core damage under accident conditions. A severely damaged core may not be in a coolable state even if it is recovered with water. Core exit thermocouple or primary system water temperatures cannot confirm that the core is adequately cooled once it has been damaged.

This procedure is only directly applicable for PWR and BWR plants.

## Input
Data indicating the length of time the core was (will be) uncovered:
- ► PWR negative cooling margin and (downward trend in water level)
- ► Water level indication at or below the top of active fuel
- ► Major increases in radiation levels

## Output
- ► Level of core damage

## Step 1
Estimate the time at which the top of the core is uncovered. Assume the time at which:

(a) Water level is at the top of active fuel or
(b) PWR primary system temperature is > 400 °C.

## Step 2

Estimate the time the core is cooled. Assume the time at which:

(a) Water level is at top of active fuel,
(b) Most of the CETs are < 300 °C or
(c) Injection rate into the vessel is 3 times greater than amount shown in Figure A2.

## Step 3
Estimate the time the core is not covered with water by:

$$T_{UC} = Time\,Cooled\ (Step\,2) - Time\ Uncovered\ (Step\,1)$$

## Step 4
Use Table A3 to determine the potential core damage states and record on Worksheet A1.

## Step 5
Reassess whenever there has been a major change in conditions.

TABLE A3 CORE DAMAGE vs. TIME THAT CORE IS UNCOVERED

| **Time core is uncovered $T_{UC}$ [h]** | **Estimated core damage** | **Insights** |
|---|---|---|
| 0 | normal coolant | Core remains covered and there is a slow reduction in power and pressure. |
| 0 | coolant with 10 to 100 times normal isotope concentrations (spike) | Core remains covered and there is a rapid shutdown or de-pressurization of primary system. |
| >1/4 | 100% gap release | Exothermic Zr-$H_2O$ reaction (self sustaining) with rapid $H_2$ generation<br><br>Fuel heat-up rate increases by a factor of 2 or 3<br><br>Rapid fuel cladding failure and local fuel melting |
| >½ | 10-50 % core melt | Rapid release of volatile fission products<br><br>Possible relocation (slump) of molten core<br><br>Possible un-coolable core even if recovered with water |
| >1 | 100% core melt | Possible melt through of vessel and containment failure even if core is recovered with water. |

Source:NRC93

**Purpose**
To estimate core damage based on containment monitor readings.

**Discussion**
Containment monitor readings indicate the minimum level of core damage. Low containment radiation readings do not guarantee that the core is undamaged. Actual containment radiation monitors may provide inconsistent readings or may underestimate the level of core damage because the release from the core may by-pass the containment, may be retained in the primary system, may be released over a long period of time, may not be uniformly mixed in the containment atmosphere, or the mixture may be different than assumed in developing this procedure.

**Input**
- Representative (unshielded) containment monitor readings [mGy/h]
- Time of readings after release into containment [h]
- Containment sprays status [*on* or *off*]

**Output**
- Level of core damage.

**Step 1**
Obtain the increase above normal background radiation levels in containment.

**Step 2**
Estimate the level of the core damage using the following:

| For the following containment types: | Use or go to: |
|---|---|
| Large PWR | Figure A3 |
| BWR Mark I & II Dry Well | Figure A4 |
| BWR Mark I & II Wet Well | Figure A5 |
| BWR Mark III Dry Well | Figure A6 |
| BWR Mark III Containment | Figure A7 |
| WWER 230 | Figure A8 |
| WWER 213 | Figure A9 |
| Unknown type or other assumptions | from formula below |

Project containment monitor readings for a uniform mixture of 100% release of fission products for various levels of core damage using the formula below:

$$X_{monitor} = X_{damage} \times \frac{10^5\ [m^3]}{V_c\ [m^3]} \times \frac{P_{plant}\ [MW(th)]}{3000\ [MW(th)]} \times SF \times F_s$$

where:

| | | |
|---|---|---|
| $X_{damge}$ | = | Normalized monitor reading [mGy/h] from table A4. |
| $X_{monitor}$ | = | Estimated monitor reading [mSv/h] to be used in assessment of actual reading |
| $V_c$ | = | Volume of containment [$m^3$] |
| $P_{plant}$ | = | Thermal power level of the plant in MW(th) |
| SF | = | Shield factor if monitor is shielded |
| $F_s$ | = | Fraction of containment volume $V_c$ seen by monitor |

TABLE A4 NORMALIZED MONITOR READINGS (a)

| **Level of core damage** | **No spray or pool Time after shutdown** | | **With spray or pool removal (b) Time after shutdown** | |
|---|---|---|---|---|
| | **1 [h]** | **24 [h]** | **1 [h]** | **24 [h]** |
| | **Dose Rate mGy/h (c)** | | **Dose Rate mGy/h (c)** | |
| Core melt | 5E+06 | 2E+06 | 2E+06 | 2E+05 |
| Gap release | 1E+06 | 5E+05 | 5E+05 | 5E+04 |
| Normal coolant | 1E+01 | 5E+00 | 5E+00 | 2E+00 |

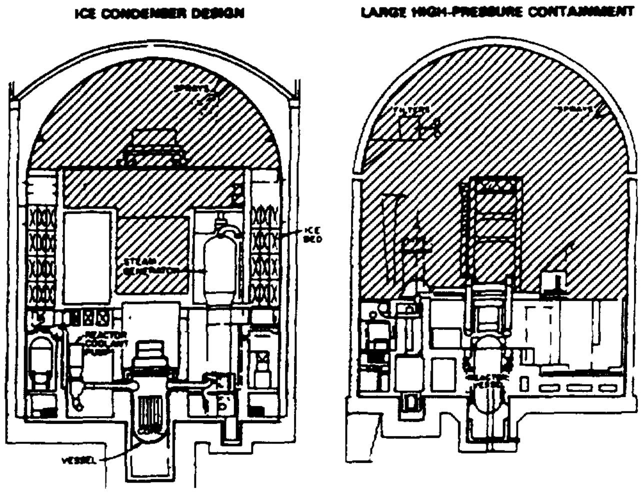
(a) Unshielded containment monitor and a containment volume of $10^5$ $m^3$.
(b) Spray or pool has removed the non-noble gases to where they can not be seen by monitors.
(c) Above normal background

**Step 2**
Record the results on Worksheet A1.

**Step 3**
Reassess whenever there has been a major change in conditions.

FIGURE A3
LARGE PWR CONTAINMENT MONITOR

It is assumed that the release from the core is uniformly mixed in the containment; the monitor is not shielded and that the containment radiation monitor "sees" the shaded area shown on the figure. Sprays are assumed to remove non-nobles to a location where the monitor can not see them. Monitor readings at 1 hour and 24 hours after shutdown are shown.



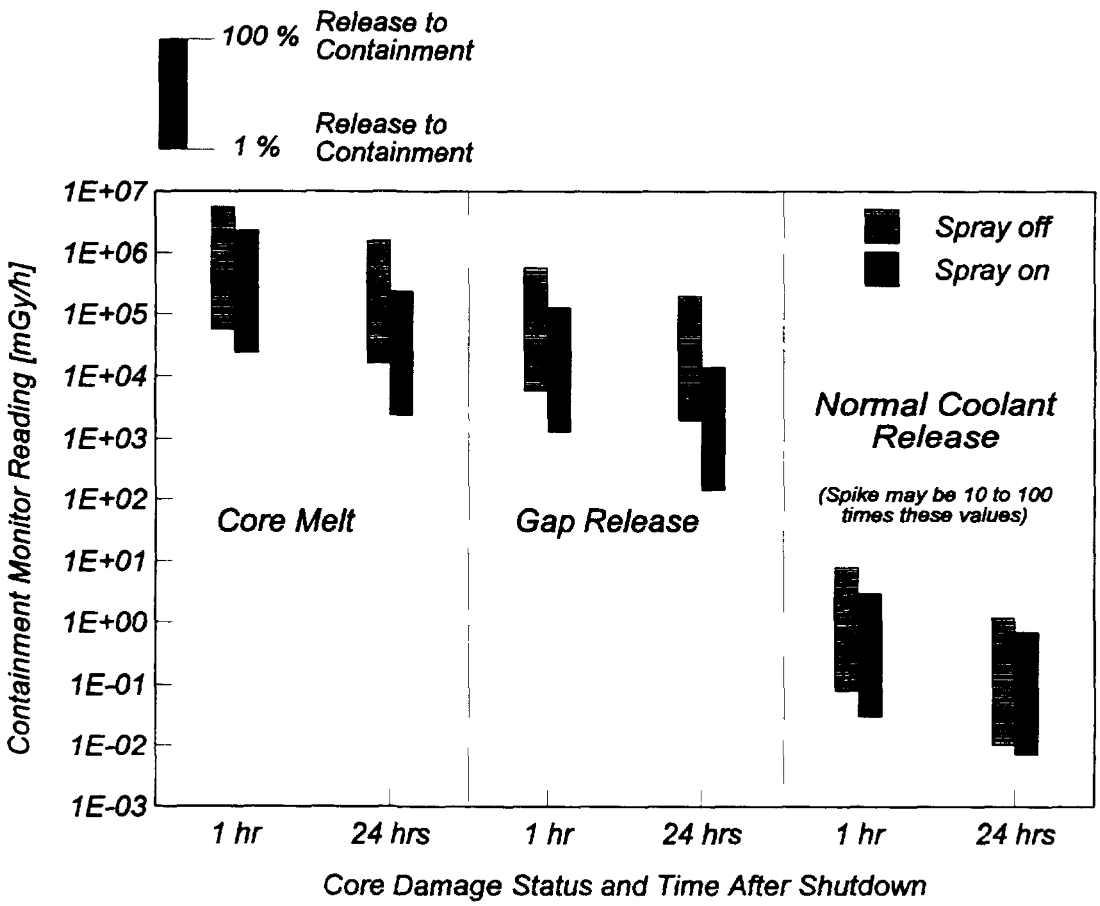



FIGURE A4
BWR MARK I & II DRY WELL CONTAINMENT MONITOR

It is assumed that the release from the core is uniformly mixed in the containment; the monitor is not shielded and that the containment radiation monitor "sees" the shaded area shown on the figure. Sprays are assumed to remove non-nobles to a location where the monitor can not see them. Monitor readings at 1 hour and 24 hours after shutdown are shown.

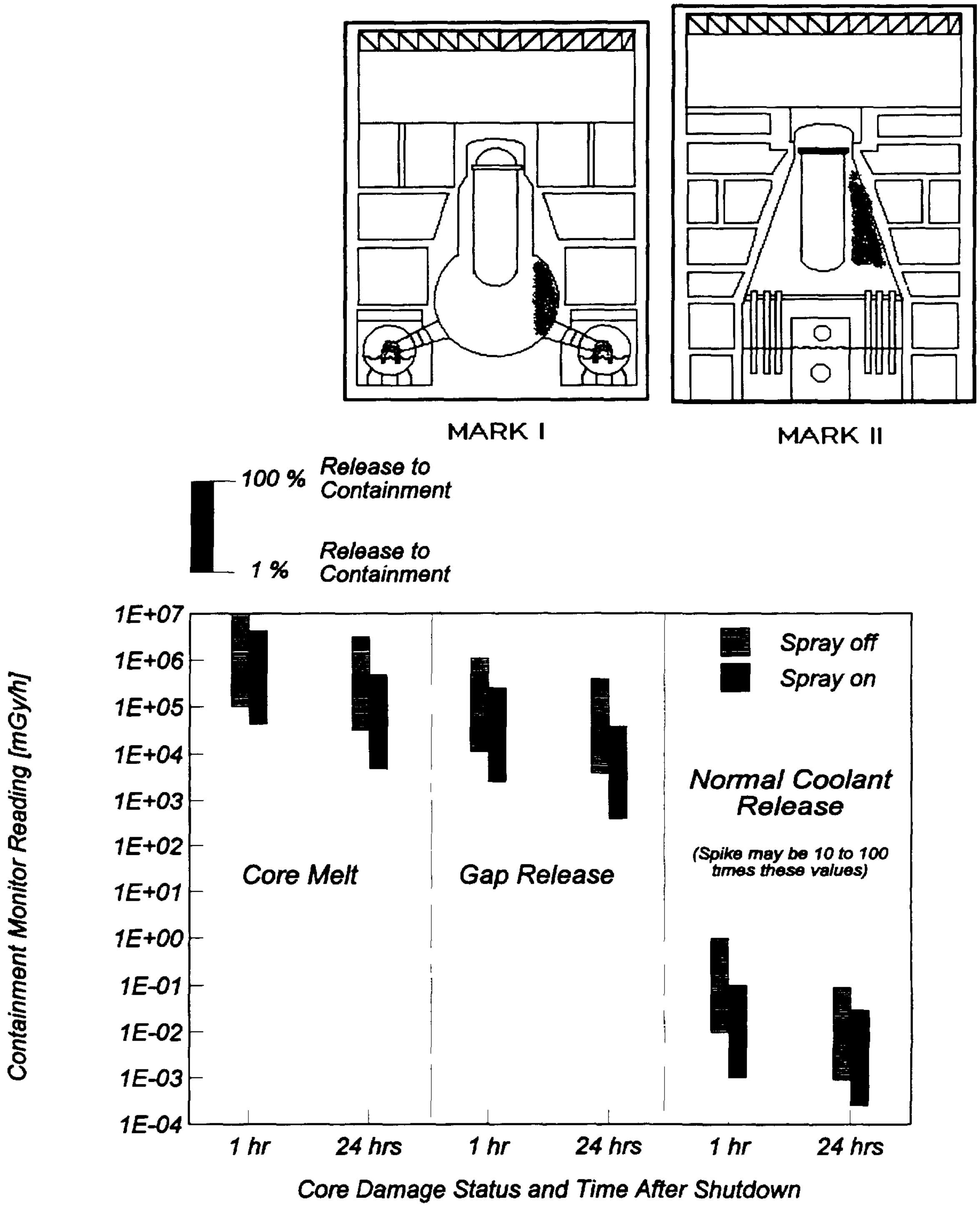


FIGURE A5
BWR MARK I & II WET WELL CONTAINMENT MONITOR

It is assumed that the release from the core is uniformly mixed in the containment; the monitor is not shielded and that the containment radiation monitor "sees" the shaded area shown on the figure. The pool is assumed to remove non-nobles to a location where the monitor can not see them. Monitor readings at 1 hour and 24 hours after shutdown are shown.

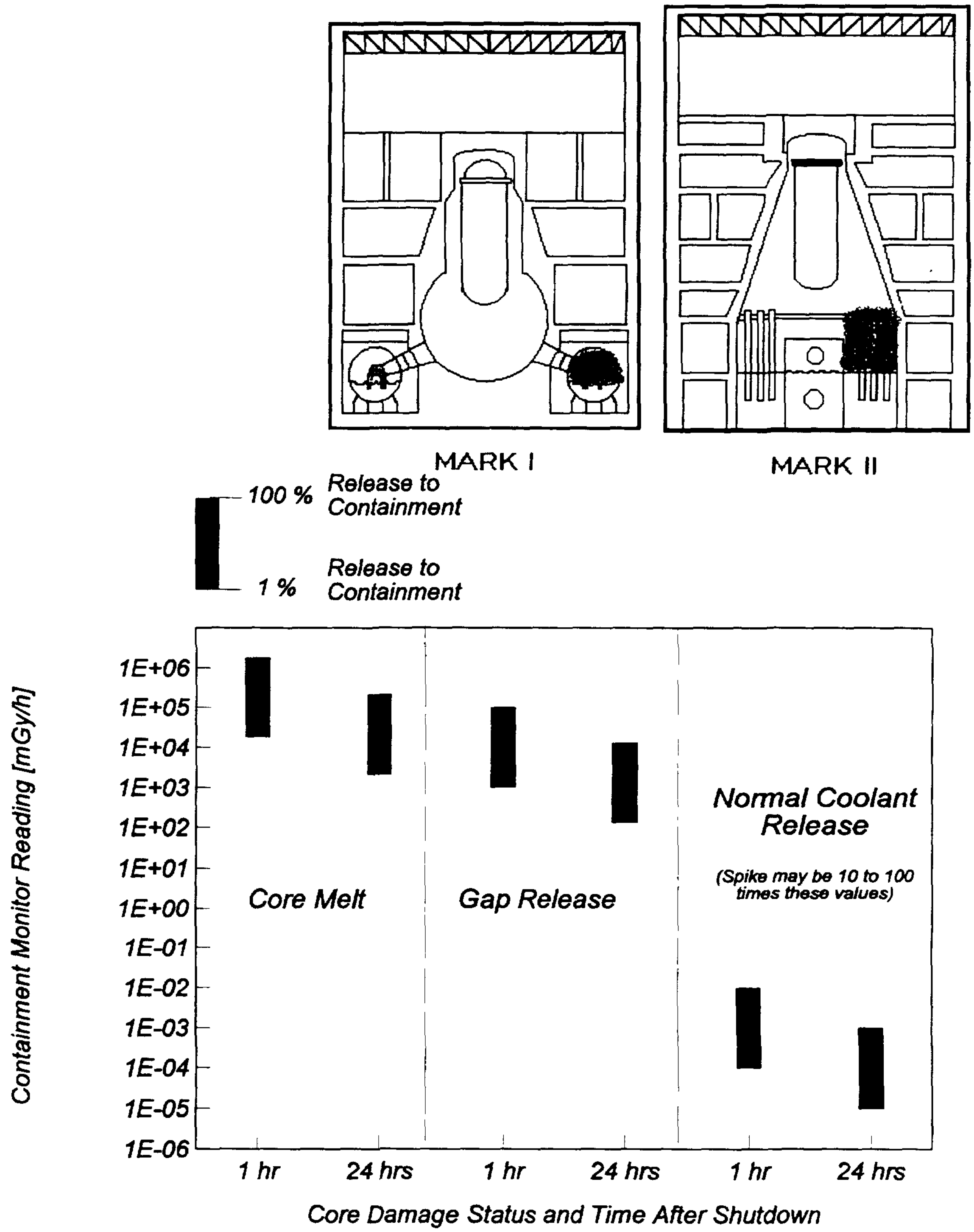
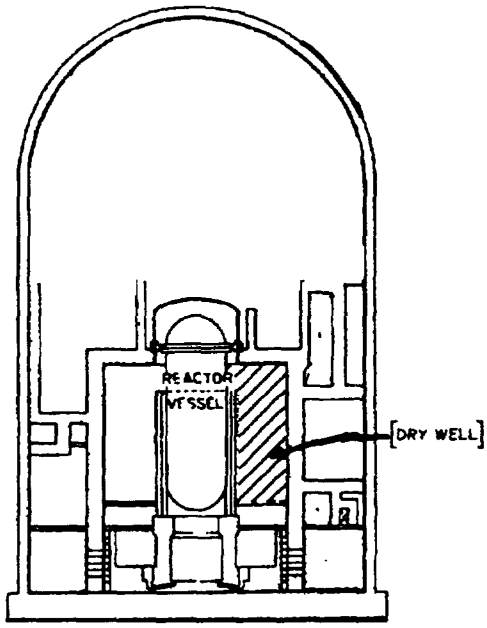


FIGURE A6
BWR MARK III DRY WELL CONTAINMENT MONITOR

It is assumed that the release from the core is uniformly mixed in the containment; the monitor is not shielded and that the containment radiation monitor "sees" the shaded area shown on the figure. Sprays are assumed to remove non-nobles to a location where the monitor can not see them. Monitor readings at 1 hour and 24 hours after shutdown are shown.

**BWR MARK III CONTAINMENT DESIGN**



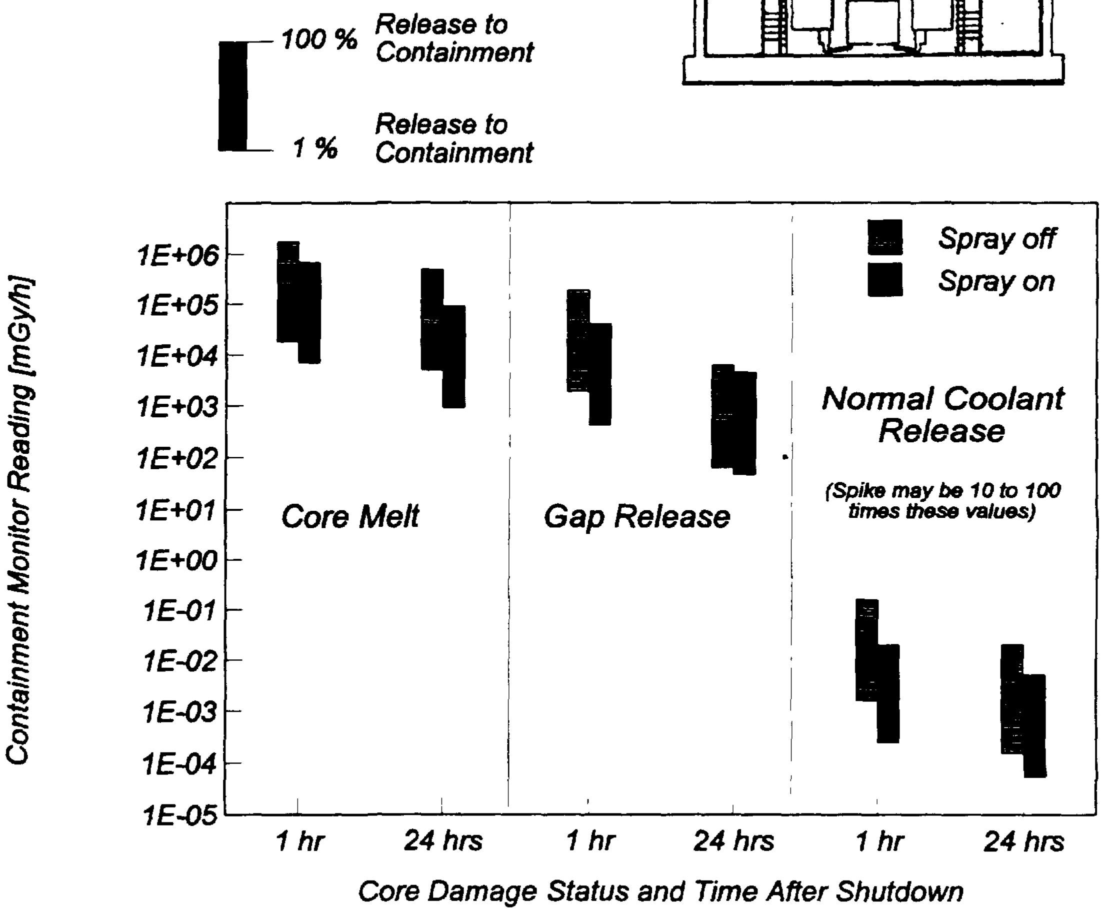



FIGURE A7
BWR MARK III CONTAINMENT MONITOR

It is assumed that the release from the core is uniformly mixed in the containment; the monitor is not shielded and that the containment radiation monitor "sees" the shaded area shown on the figure. The suppression pool is assumed to remove non-nobles to a location where the monitor can not see them. Monitor readings at 1 hour and 24 hours after shutdown are shown. This area correspond to the wet well in other BWR designs.

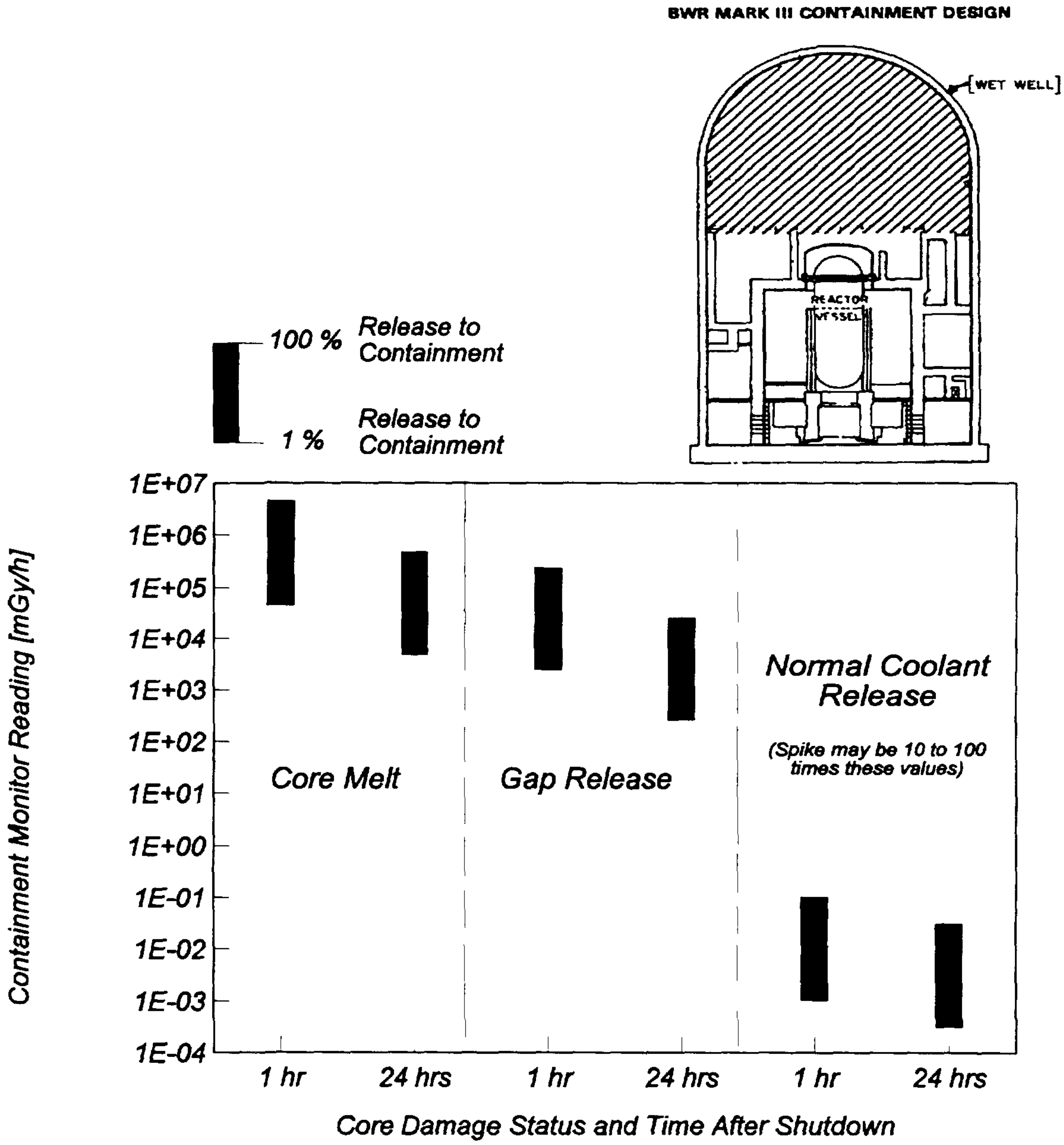


FIGURE A8
WWER-230 CONTAINMENT MONITOR

It is assumed that the release from the core is uniformly mixed in the containment; the monitor is not shielded and that the containment radiation monitor "sees" the shaded area shown on the figure. Sprays are assumed to remove non-nobles to a location where the monitor can not see them. Monitor readings at 1 hour and 24 hours after shutdown are shown.

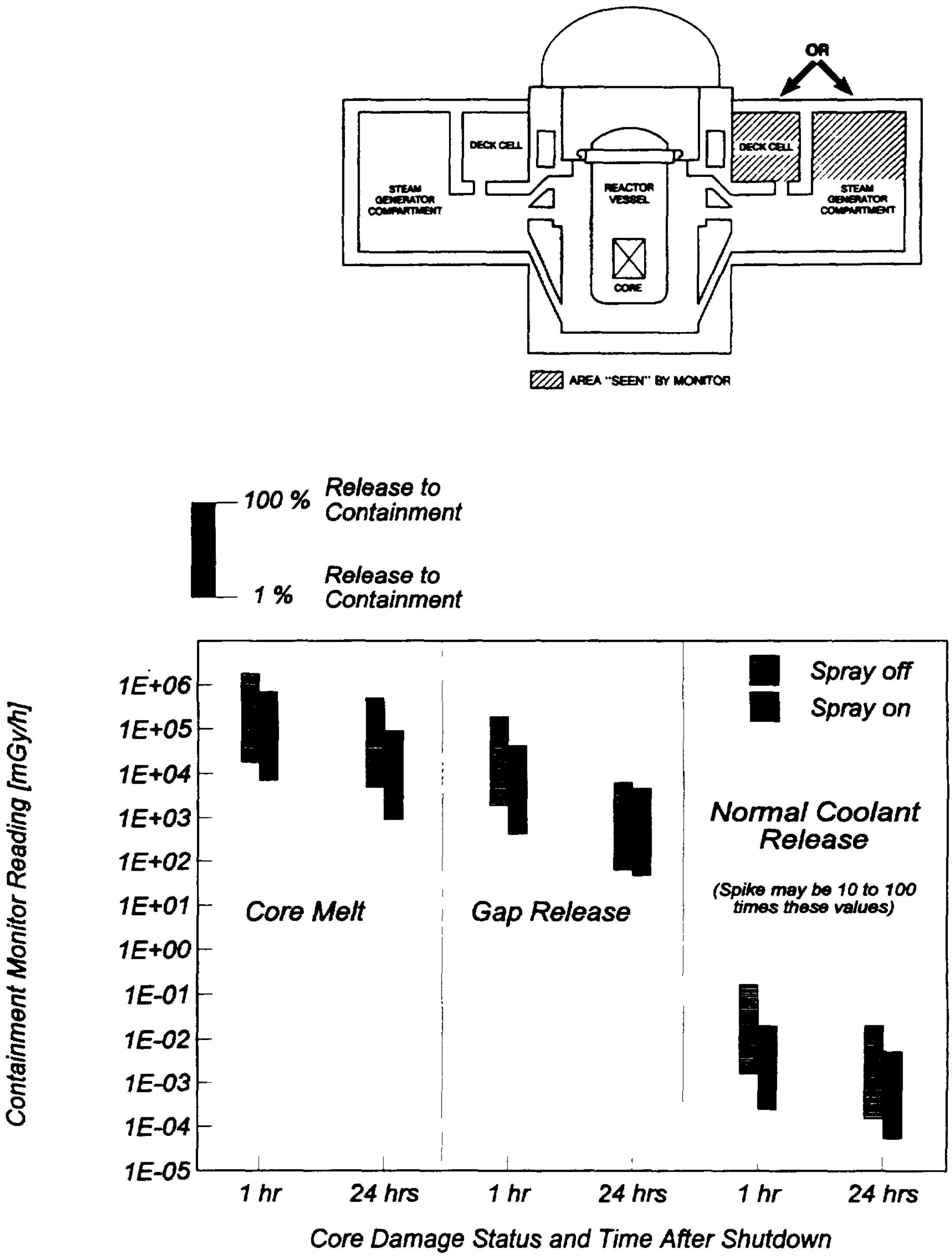
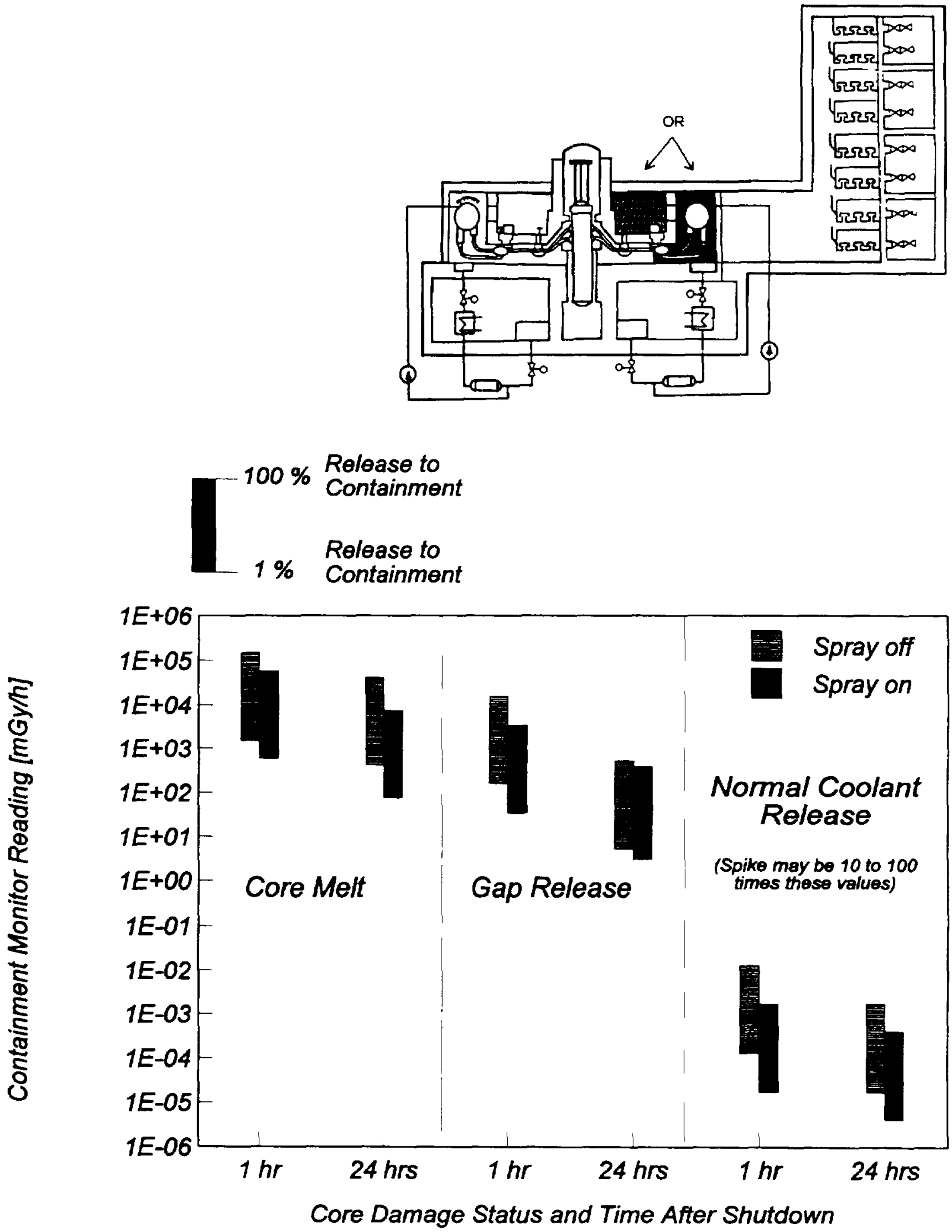


FIGURE A9
WWER-213 CONTAINMENT MONITOR

It is assumed that the release from the core is uniformly mixed in the containment; the monitor is not shielded and that the containment radiation monitor "sees" the shaded area shown on the figure. Sprays are assumed to remove non-nobles to a location where the monitor can not see them. Monitor readings at 1 hour and 24 hours after shutdown are shown.



**Purpose**
To estimate core damage based on primary coolant isotope concentrations.

**Discussion**
Coolant samples should only be used to assess core damage where the results of procedures A2a and A2b are inconclusive.

Coolant isotope concentrations should not be required to confirm core damage because there may not be any coolant to sample (e.g., no flow through sample line), samples may take hours to draw and analyse and may not be representative of primary system concentrations. Coolant samples should not be taken if they result in high individual doses.

**Input**
► Primary system coolant isotope concentrations after the event

**Output**
► Level of core damage

**Step 1**
Obtain primary coolant isotope concentration after the event if it will not result in a high dose to any worker.

**Step 2**
Compare primary system coolant isotope concentrations to the following:

| If reactor is; | Then use or go to: |
|---|---|
| PWR with primary coolant inventories:<br>2E+05 kg to 4E+05 kg | Table A5 |
| US BWR | Table A6 |
| Reactors with other coolant inventories | use formula below |

For other reactors with primary system coolant inventories considerably different from $2.5x10^5$ kg adjust the Table A5 baseline concentration as follows:

$$C_{spec} = C_{tab} \times \frac{2.5\times10^5 \ [kg]}{I_{prim} \ [kg]} \times \frac{P_{plant} \ [MW(th)]}{3000 \ [MW(th)]}$$

where

$C_{spec}$ = Coolant isotope concentrations for specific plant

$C_{tab}$ = Gap and core melt coolant isotope concentration from Table A5

$I_{prim}$ = Primary system coolant inventory [kg]

$P_{plant}$ = Average thermal power level of plant [MW(th)]

**Step 3**
Determine which of the core damage states best matches the current conditions and record on Worksheet A1.

**Step 4**
Reassess when there has been a major change in conditions.

TABLE A5 PWR BASELINE COOLANT ISOTOPE CONCENTRATIONS

**Discussion:** This is for a reactor with a primary coolant inventory of about 2.5 E +05 kg. The gap and core melt cases are for a 3000 MW(th) plant and the core has been uncovered, damaged and recovered. It also assumes that releases from the core are uniformly mixed in the coolant and that there is no dilution due to injection. The baseline coolant concentrations are for 0.5 hour after shutdown of a core that has been through at least one refuelling cycle. These tables will overestimate the concentrations of Cs for a reactor that has been operating for less than 18 months.

| Nuclide | Normal to 100 Times Normal Concentration (a) [kBq/g] | Concentration After > 20% Gap Release (b) [kBq/g] | Concentration After > 10% Core Melt Release (b) (c) [kBq/g] |
|---|---|---|---|
| I-131 | 2E+00 to 2E+02 | 2E+05 | 7E+05 |
| Cs-134 | 3E-01 to 3E+01 | 1E+04 | 6E+04 |
| Cs-137 | 3E-01 to 3E+01 | 6E+03 | 3E+04 |
| Ba-140 | 5E-01 to 5E+01 | NC | 1E+05 |

(a) Based on ANSI84, should be replaced with site specific normal isotopic concentration
(b) Assumes a release from the fuel for this level of core damage before the core is recovered with water.
(c) A vessel melt through should be considered possible for any core with these levels of damage that has not been covered with water for more than 6 hours.
NC Not calculated (data not available).

## TABLE A6 BWR BASELINE COOLANT ISOTOPE CONCENTRATIONS

**Discussion:** The gap and core melt cases assume the core of a 3000 MW(th) reactor that has been uncovered, damaged and recovered. It is assumed that the release from the core is uniformly mixed in the reactor coolant system and suppression pool. It also assumes that there is no dilution due to injection. The baseline coolant concentrations are for 0.5 hour after shutdown of a core that has been through at least one refuelling cycle. These tables will overestimate the concentrations of Cs for a reactor that has been operating for less than 18 months

| Nuclide | Normal to 100 times normal concentration (a) [kBq/g] | Concentration After > 20% Gap Release (b) [kBq/g] | Concentration After > 10% Core Melt Release (b)(c) [kBq/g] |
|---|---|---|---|
| I-131 | 7E-02 to 7E+00 | 8E+03 | 4E+04 |
| Cs-134 | 1E-03 to 1E-01 | 8E+02 | 4E+03 |
| Cs-137 | 3E-03 to 3E-01 | 6E+02 | 3E+03 |
| Ba-140 | 2E-02 to 2E+00 | NC | 7E+03 |

(a) Based on ANSI84, should be replaced with site specific normal isotopic concentration

(b) Assumes a release from the fuel for this level of core damage before the core is recovered with water. Also assumes the fission products are equally distributed in the RCS and suppression pool.

(c) A vessel melt through should be considered possible for any core with these levels of damage that has not been covered with water for more than 6 hours.

NC Not calculated (data not available)

| Performed by: Nuclear Condition Assessment Manager | PROCEDURE A2d<br>SPENT FUEL DAMAGE ASSESSMENT | Pg. 1 of 1 |
|---|---|---|

**Purpose**
To assess accidents involving loss of coolant from the spent fuel pool.

**Discussion**
This procedure is only for a spent fuel pool that contains spent fuel discharged from the core within the last 3 years.

Spent fuel damage can result from the pool being drained for more than 2 hours with insufficient (< 25 $m^3/h$) water spray. Spent fuel pool drainage indications include high radiation alarm in the spent fuel pool area.

**Input**
- ► Water level in the pool

**Output**
- ► Spent fuel conditions

**Step 1**
Assume there will be a gap release from the spent fuel in the pool if:

(a) there is less than 25 $m^3/h$ of water is being sprayed onto the fuel in the pool and
(b) the pool may be uncovered for more than 2 hours.

If the fuel is damaged under water only small amounts of Kr can be released.

**Step 2**
Record the result on Worksheet A1.

**Step 3**
Reassess whenever there has been a major change in conditions.

| *Performed by:* <br><br> *Nuclear Condition Assessment Manager* | **PROCEDURE A3** <br><br> **ASSESSMENT OF RELEASE ROUTES AND CONDITIONS** | *Pg. 1 of 4* |
|---|---|---|

**Purpose**:
To estimate potential and actual atmospheric release routes and conditions.

**Discussion**
The release route conditions are crucial to interpreting environmental measurements. All potential release routes should be examined to ensure that releases are not missed and operations do not result in undetected or unmonitored releases.

**Input**
- Plant system conditions

**Output**
- Estimated potential and actual release routes and conditions.

**Step 1**
Determine all the routes that can result in a release to the atmosphere. Use Table A7 as a guide.

**Step 2**
For the release routes identified in step 1 estimate if the releases will be reduced or not and the release rates. Use Tables A8 and A9 as a guide.

**Step 3**
Record results on Worksheet A1

**Step 4**
Reassess whenever there has been a major change in conditions.

TABLE A7 RELEASE ROUTE EVALUATION GUIDE

| Possible Routes | Indicators |
|---|---|
| **Release from the containment:**<br>*Release out of primary system through the containment to the atmosphere.* | Core melts until core has been recovered with water for several hours<br>**or**<br>High pressure, temperatures or radiation in containment |
| **Containment by-pass under dry conditions:**<br>*The core is uncovered and the release route is dry and extends from the primary system to the atmosphere by-passing the containment. This includes steam generator tube ruptures and interfacing loss of coolant accidents.* | Water level below top of core<br>**and**<br>High pressure, temperatures or radiation outside containment<br>**and**<br>Low pressure, temperatures or radiation inside containment |
| **Containment by-pass under wet conditions:**<br>*The core is covered and the release is carried by contaminated coolant from the primary system to the atmosphere by-passing the containment. This includes steam generator tube ruptures and interfacing loss of coolant accidents.* | Primary system full of coolant<br>**and**<br>High pressure, temperatures or radiation outside containment<br>**and**<br>Low pressure, temperatures or radiation inside containment |
| **Release from spent fuel pool:**<br>*Fuel in pool is damaged.* | High temperatures or radiation in spent fuel pool area |

## TABLE A8 ATMOSPHERIC RELEASE ROUTE EVALUATION GUIDE

**Discussion**: For the purposes of this manual, an atmospheric release route is either reduced or not reduced. It is reduced it the release from the fuel passes through some process (e.g., sprays) on the way to the atmosphere that will remove a large fraction of the iodine and particulate.

| Reduction method | Assume release reduced by the method if: |
|---|---|
| **Release from the containment** | |
| Spray | Release passes through a containment volume that is sprayed. |
| Pool > 2 metres | Release passes through containment suppression pool that is at least 2 metres deep and the pool is subcooled (not boiling).<br><br>*Assume release is not reduced if it may by-pass pool.* |
| Filters | Release is slow and dry and passes through the filter.<br><br>*Assume the release is not reduced for large or wet releases because filters may clog and fail. Normally assume the release is not reduced if the filters are in containment because a large release may clog them.* |
| Ice condenser | Release has been recirculated through the ice for several hours.<br><br>*Assume the release is not reduced if : a) the recirculation has not operated for several hours, b) the ice condenser is by-passed or c) the ice may be exhausted (melted) before the release from core.* |
| **Containment by-pass under dry conditions** | |
| Filters | Same as above. |
| **Containment by-pass under wet conditions** | |
| Steam generator partitioning | Release is by a steam generator tube rupture and is reduced if all the following are true: a) it is a WWER or U tube steam generator, b) the rupture is below the secondary side water level c) the secondary side is not full of water and d) there is only a single tube failure.<br><br>*Assume the release is not reduced if: a) it is a once through steam generator, b) the secondary side may be full of coolant, c) there may be multiple tube failures, or d) if the break may be above the secondary side water level.* |
| Condenser partitioning | Release is by the off-gas system of an operational condenser (e.g., has maintained its vacuum). |
| **Release from spent fuel pool** | |
| Sprays | Release is from area being sprayed. |
| Filters | Same as above. |

TABLE A9 RELEASE RATE GUIDE

**Discussion:** The release rate will be very difficult if not impossible to determine early in an accident and yet it is the single most important factor in determining off-site consequences. Therefore you should attempt to bound the release rates by selecting the rate closest to your best estimate and a reasonable worst case. For the purposes of this manual only a few potential release rates are provided. Select those that best fit the conditions.

| Rate | Assume if: |
|---|---|
| | **Release from the containment** |
| 100% per hour<br><br>*Most of the release from the core will be released within several hours.* | Rapid depressurization of containment.<br><br>Core melts until a damaged core has been recovered with water for several hours.<br><br>Containment pressure > ___ *(insert site specific value e.g., 2 times design pressure).*<br><br>$H_2$ concentration > _____ *(insert site specific value).*<br><br>Intentional venting of containment |
| 100% per day | Containment has a design leak rates > 1 % per day and is isolated<br><br>Containment is not fully isolated. |
| <0.1% per day | Containment has a design leak rates < 1 % per day and is isolated |
| | **Containment by-pass under dry conditions** |
| 100% per hour | Primary system is at high pressure. |
| 100% per day | Primary system is depressurized. |
| | **Containment by-pass under wet conditions** |
| 100 $m^3/h$<br><br>*100% of the coolant in 1 h.* | Multiple steam generator tube ruptures (SGTR)<br><br>Rupture of a single steam generator tube and the primary system is kept at high pressure.<br><br>Interfacing loss of coolant accident (LOCA) with high primary system pressure. |
| 10 $m^3/h$<br><br>*10% of the coolant in 1 h.* | Steam generator tube rupture involving a single tube with primary system depressurized.<br><br>Interfacing loss of coolant accidents with primary system depressurized. |
| | **Release from spent fuel pool** |
| 100% per hour | There are indications of large failure of structure containing pool e.g., high radiation in other areas. |
| 100% per day | Pools located in isolated structures with design leakages > 1 % per day. |
| < 0.1% per day | Pools located in isolated structures with design leakages < 1% per day. |

## SECTION B

# PROTECTIVE ACTION MANAGER PROCEDURES

Caution: The procedures in this section must be revised to reflect local and plant conditions for which they will be applied.

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**Purpose**
To determine public protective actions.

**Discussion**
Protective actions are first taken based on the classification of the accident. The initial actions are taken to prevent early health effects or high doses. The actions are then revised based on environmental measurements.

In general, protective actions should be implemented equally among all population groups. For example children should be evacuated with their families whenever possible. However, if it is difficult to implement the protective actions equally (due to limited resources, etc.), then priority should be given to children or others at higher risk.

**Input**
- ► Accident classification from Worksheet A1
- ► Environmental ambient dose rates and isotopic concentrations from Worksheets D2, D3, D5 and D6
- ► Projected protective action distances from Worksheet E1
- ► Revised OILs based on isotopic analysis of samples from Worksheets F1 & F2

**Output**
- ► Public protective action recommendations to off-site officials.

**Step 1**
Obtain briefing on the situation from the Accident Assessment Manager. Follow the applicable radiation protection instructions provided by the Radiation Protection Manager.

**Step 2**
Determine public protective actions based on the following:

| During the following phase: | Use: |
|---|---|
| *At all time:* based on classification of accident | Table B1 |
| *During a release:* based on projections and in plume ambient dose rate measurements | Table B2 |
| *After a plume passage:* based on deposition concentration and ambient dose rate measurements | Table B3 |

**Step 3**
Update Worksheets B1 and B2 and ensure they are distributed. Immediately inform the Accident Assessment Manager of any change in protective action assessment.

**Step 4**
After the results of the environmental samples have been assessed, revise OILs using the procedure indicated in Table B4. The OILs should revised and adopted only if: a) the accident conditions are stable, b) the accident course is understood and c) the revised OILs will have a major impact on the protective actions being taken.

**Step 5**
After the threat of a major release is over and the composition of the deposition has been fully characterized, request the sample analyst to calculate the OILs for temporary relocation for any subsequent month and for permanent resettlement using Procedure F2.

**Step 6**
Relax protective actions when indicated by the following conditions.

Re-entry may be allowed if the following conditions are met:

(a) no further major releases are possible,

(b) ambient dose rates should be less than the temporary relocation OILs for any subsequent month or permanent resettlement (calculated in Step 5),

(c) there are no existing plant conditions which could result in a Site Area Emergency or the General Emergency and

(d) evacuees returning to contaminated areas are warned that there is a possibility that they may be relocated in the future after the situation has been fully assessed.

Sheltering and thyroid blocking should be relaxed under the following conditions:

(a) no further major releases are possible,

(b) there are no existing plant conditions which could result in a Site Area Emergency or the General Emergency.

(c) ambient dose rates are below the shelter and evacuation intervention levels.

Food Restrictions should be relaxed when:

(a) no further major releases are possible and

(b) the results of food sample analysis taken in the area below the intervention level specific for the location.

**Step 7**
Establish a committee of national and international experts to determine criteria for long term resettlement and long term restriction of food that conforms with international guidance.

**Step 8**
Keep recording all major actions and/or decisions in a logbook.

**Step 9**
At the end of your shift ensure that your replacement is thoroughly briefed.

TABLE B1 PROTECTIVE ACTIONS BASED ON CLASSIFICATION

| **Protective actions (a)** | **Classification** | |
|---|---|---|
| | **Site Area Emergency** | **General Emergency** |
| Evacuate or shelter non-essential personnel at the plant. | ✔ | ✔ |
| Provide in-plant personnel and emergency workers with thyroid blocking agent, self-reading dosimeter and respiratory protection as required and brief them on exposure guidance. | ✔ | ✔ |
| Prepare for evacuation or sheltering of the public within the precautionary protective action zone and urgent protective action planning zone [b]. | ✔ | |
| Evacuate or provide substantial shelter for the public within the precautionary protective action zone [b,c,d]. | | ✔ |
| Provide thyroid blocking agent and temporary shelter within the urgent protective action planning zone [b,c,e]. | | ✔ |
| Recommend public within 300 km to avoid eating potentially contaminated food or milk [f]. | | ✔ |
| Initiate the system for giving emergency information on urgent agricultural countermeasures to farmers and food industry [g]. | | ✔ |
| Initiate the system for tracking potentially highly exposed individuals for later medical follow-up | | ✔ |

(a) Do not relax protective actions taken based on plant conditions until the threat to the core is over and the risk of a major release is substantially reduced.

(b) The default distances for the protective action zones are given in Table B5.

(c) Shelter should be considered only for 24-48 hours and its effectiveness should be confirmed by monitoring especially in high dose rate areas. Temporary shelter: remain indoors with the doors and windows closed and monitor radios/TV for further information. Substantial shelter is provided by specially designed shelters or the inside halls or basements of large masonry buildings.

(d) Evacuation should be conducted even if the release has begun unless something prevents all movements (e.g. heavy snow). While population is waiting to evacuate they should be instructed to stay inside their homes and to take a thyroid blocking agent if available.

(e) Distribution of thyroid blocking agents must not delay the evacuation or sheltering.

(f) Food, milk, and water restrictions should be revised based on samples following a release. Food restrictions can be relaxed if food is scarce.

(g) Prevent the ingestion of potentially contaminated herbage by grazing animals and avoid direct contamination of agricultural products e.g. by housing animals which are grazing outdoors, covering uncovered feed/food stores and open sources of water with plastic sheeting etc (see IAEA94a).

TABLE B2 PUBLIC PROTECTIVE ACTIONS BASED ON PROJECTIONS AND IN PLUME MEASUREMENTS

| BASIS | OIL No. | DEFAULT CRITERIA | PROTECTIVE ACTION |
|---|---|---|---|
| Projections | | Projections indicate that urgent protective actions should be taken | Shelter and prepare to evacuate to distance indicated by the projections |
| Ambient dose rate in the plume | 1 | 1 mSv/h [a,b,d] | Evacuate or provide substantial shelter [c] for this sector, the two adjacent sectors and the sectors closer to the plant. Until evacuated people should be instructed to *stay inside with their windows closed.* |
| | 2 | 0.1 mSv/h [d] | Take thyroid blocking agent if available, go inside, close windows and doors and monitor radio and TV for further instructions. |

(a) A description of the operational intervention levels (OILs) is given in Table B4.
(b) If there is no indication of core damage, OIL1 = 10 mSv/h
(c) Substantial shelter is provided by specially designed shelters or the inside halls or basements of large masonry buildings. Shelter should be considered only for 24-48 hours and effectiveness must be confirmed by monitoring especially in high dose rate areas.
(d) Monitor evacuees and instruct the public on decontamination measures

TABLE B3 PUBLIC PROTECTIVE ACTIONS BASED ON DEPOSITION AND FOOD MEASUREMENTS

| BASIS | OIL No. | DEFAULT CRITERIA | | PROTECTIVE ACTION |
|---|---|---|---|---|
| Ambient dose rate from deposition | 3 | 1 mSv/h | | Evacuate or provide substantial shelter within sector |
| | 4 | 0.2 mSv/h [a,b,c] | | Consider relocating people from sector |
| | 5 | 1 μSv/h [d] | | Restrict immediate consumption of potentially contaminated food, and milk in area until samples are evaluated |
| Ground deposition levels | | General Food (F) | Milk (M) | Restrict immediate consumption of potentially contaminated food and milk in area until samples are evaluated |
| I-131 [g] | 6 | 10 kBq/m² [a,e] | 2 kBq/m² [a,e,f] | |
| Cs-137 [g] | 7 | 2 kBq/m² [a,e] | 10 kBq/m² [a,e,f] | |
| Food, milk, water concentrations | | General Food (F) | Milk and Water (M) | Restrict consumption |
| I-131 [g] | 8 | 1 kBq/kg [a,e] | 0.1 kBq/kg [a,e] | |
| Cs-137 [g] | 9 | 0.2 kBq/kg [a,e] | 0.3 kBq/kg [a,e] | Restrict consumption |

(a) Recalculate based on sample analysis as soon as possible using the procedures specified in Table B4.
(b) For 2-7 days after the accident.
(c) Relocate at a higher level if the relocation will be very disruptive.
(d) 1 μSv/h was chosen to indicate areas with dose rates clearly above background.
(e) Use higher OILs if food is scarce or if it will be processed to remove contamination before consumption (e.g, washed, peeled or allowed to decay), see Section F.
(f) For goat milk multiply by 0.10.
(g) Measurements should be compared separately with both the I-131 and Cs-137 OILs.

TABLE B4 DEFAULT OPERATIONAL INTERVENTION LEVELS, ASSUMPTIONS AND REVISIONS

| OIL # | Default value | A-Protective action<br>B-Definition<br>C-Summary of default assumptions [a] | Procedure to revise default value |
|---|---|---|---|
| OIL1 | 1 mSv/h | A-Recommend evacuation or substantial shelter .<br>**B-Ambient dose rate in plume.**<br>C-Calculated assuming an unreduced release from a core melt accident resulting in an inhalation dose 10 times the dose from external exposure, 4 hour exposure to the plume, and 50 mSv can be averted (IAEA GAL for evacuation) by the action. | Procedure **F1** |
| OIL2 | 0.1 mSv/h | A-Recommend thyroid blocking agent and temporary shelter<br>**B-Ambient dose rates in plume.**<br>C-Calculated assuming an unreduced release from a core melt accident resulting in a thyroid dose from inhalation of iodine 200 times the dose from external exposure, 4 hour exposure to the plume, and 100 mSv (IAEA GAL for administration of thyroid blocking agent) can be averted by the action. | Procedure **F1** |
| OIL3 | 1 mSv/h | A-Recommend evacuation or substantial shelter.<br>**B-Ambient dose rates from deposition.**<br>C-Calculated to avert 50 mSv (IAEA GAL for evacuation) by the action, 1 week exposure period and approximately a 75% reduction in dose due to decay, sheltering and partial occupancy. | None |
| OIL4 | 0.2 mSv/h | A-Recommend temporary relocation.<br>**B-Ambient dose rates from deposition.**<br>C-Calculated to avert 30 mSv by the action in 30 days (IAEA GAL for first month temporary relocation ), ground contamination of a typical core melt mixture of isotopes 4 days after accident and 50% reduction in dose due to partial occupancy, decay and weathering. Should be valid for 2-7 days after shutdown. | Procedure **F2** |
| OIL5 | 1 µSv/h | A-Recommend precautionary restriction of food and milk.<br>**B-Ambient dose rates from deposition.**<br>C-Assumes that the food or milk produced in an area with above background dose rates from deposition may be contaminated beyond the GALs. This is true for most core melt accident and directly contaminated food before processing and milk from cow grazing on contaminated grass. | None |

| OIL # | Default value | | A-Protective action<br>B-Definition<br>C-Summary of default assumptions [a] | Procedure to revise default value |
|---|---|---|---|---|
| OIL6 | General food<br>F<br>10 kBq/m² | Milk<br>M<br>2 kBq/m² | A-Recommend restrictions for food or milk.<br>**B-Activity of I-131 (marker isotope) in deposition.**<br>C-Calculated assuming: a) I-131 will be controlling which should be valid for fresh fission product mixes (within 1-2 months of shutdown), b) food is directly contaminated or the cows are grazing on contaminated grass, c) food is consumed immediately without processing to reduced contamination and d) IAEA generic action levels in Table F6 groups 1 and 5. . | Procedure F3 |
| OIL7 | 2 kBq/m² | 10 kBq/m² | A-Recommend restrictions for food or milk.<br>**B-Activity of Cs-137 (marker isotope) in deposition.**<br>C-Calculated assuming: a) Cs-137 will be controlling which should be valid for old fission product mixes (spent fuel or core releases > 2 months after shutdown), b) food is directly contaminated or the cows are grazing on contaminated grass, c) food is consumed without processing to remove contamination and d) IAEA generic action levels in Table F6 for groups 1 and 4. | Procedure F3 |
| OIL8 | General food<br>F<br>1 kBq/kg | Milk, Water[b]<br>M<br>0.1 kBq/kg | A-Recommend restrictions for food, milk, or water.<br>**B-Activity of I-131 (marker isotope) in food, water or milk samples.**<br>C-Calculated assuming: a) I-131 will be controlling which should be valid for fresh fission product mixes (within 1-2 months of shutdown), b) food is consumed immediately without processing to remove contamination and c) IAEA generic action levels in Table F6 for groups 1 and 5. | Procedure F5 |
| OIL9 | 0.2 kBq/kg | 0.3 kBq/kg | A-Recommend restrictions for food, milk, or water.<br>**B-Activity of Cs-137 (marker isotope) in food, water or milk samples**<br>C-Calculated assuming: a) Cs-137 will be controlling which should be valid for old fission product mixes (spent fuel or core releases > 2 months after shutdown), b) food is directly contaminated and consumed immediately without processing to reduce contamination and c) IAEA generic action levels Table F6 for groups 1 and 4. | Procedure F5 |

(a) See Appendix I for a full discussion of the assumptions.
(b) Water can only be assessed by sampling (OIL 8 and 9)

TABLE B5 SUGGESTED PROTECTIVE ACTION ZONES[a]

| **Reactor power level** | **Precautionary protective action zone (PAZ)** | **Urgent protective action planning zone (UPZ)** | **Longer term protective action planning zone (LPZ)** |
|---|---|---|---|
| 2 - 50 MW(th) | on-site | 0.5 - 2 km | 5 - 20 km |
| >50 - 100 MW(th) | on-site | 1.5 - 2 km | 15 - 20 km |
| > 100 MW(th) | 3 - 5 km | 10 - 25 km | 50 - 100 km |

a: These are approximate sizes. The actual size and boundaries of the zones must be established after consideration of local conditions.

Source: IAEA97

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SECTION C

# RADIATION PROTECTION MANAGER PROCEDURES

Caution: The procedures in this section must be revised to reflect local and plant conditions for which they will be applied.

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| *Performed by:* <br><br> *Radiation Protection Manager* | **PROCEDURE C1** <br><br> **EMERGENCY WORKER RADIATION PROTECTION GUIDANCE** | *Page 1 of 2* |
|---|---|---|

**Purpose**
To provide emergency worker turn back guidance.

**Discussion**

Emergency worker turn back guidance should be given as an integrated external dose on a self reading dosimeter. Emergency worker should take all reasonable efforts not to exceed this value. These values have been calculated to account for the inhalation dose from a core melt accident assuming that thyroid blocking has been taken. Note that skin contamination can also be a major source dose and can lead to deterministic health effects for workers in highly contaminated areas if they not provided with adequate protective clothing.

Emergency worker turn back doses are to serve as guidance and not limits. Judgement must be used in their application.

Once the early phase of the accident is over, the total dose incurred (during the early phase) must be confirmed before an emergency worker is allowed to perform activities that may result in additional dose.

**Input**
- ► Type of personal protective action taken
- ► Type of tasks performed by workers

**Output**
- ► Emergency worker turn-back guidance

**Step 1**
Obtain briefing on the situation from the Accident Assessment Manager. Follow the applicable radiation protection procedures.

**Step 2**
Use Table C1 to determine initial emergency worker turn back dose guidance.

**Step 3**

Provide the emergency workers with the following instructions:

(a) make all reasonable efforts not to exceed the turn back dose guidance.

(b) take thyroid blocking (General Emergency, Site Area Emergency)

(c) *[insert additional site or organization specific instructions]*

**Step 4**
If analysis of air samples (Procedure F1) or other conditions (see Table C1 notes) results in emergency worker turn back dose guidance that are significantly different from the Table C1, then revise the guidance used and instruct the responders on their new guidance.

**Step 5**
Keep recording all major actions and/or decisions in a logbook.

**Step 6**
At the end of your shift ensure that your replacement is thoroughly briefed.

TABLE C1 EMERGENCY WORKER TURN BACK DOSE GUIDANCE EXPRESSED AS INTEGRATED EXTERNAL GAMMA DOSE

| TASKS | EWG [mSv] |
|---|---|
| Type 1:<br>► Life saving actions<br>► Prevention of core damage or given core damage to prevention of a large release. | >250 (a,b) |
| Type 2:<br>► Prevent serious injury<br>► Avert a large collective dose<br>► Prevent the development of catastrophic conditions<br>► Recovery of reactor safety systems<br>► Off-site ambient dose rate monitoring (gamma dose rate) | < 50 (a) |
| Type 3:<br>► Short term recovery operations<br>► Implement urgent protective actions<br>► Environmental sampling | < 25 (a) |
| Type 4:<br>► Longer term recovery operations<br>► Work not directly connected with an accident | Occupational exposure guidance (IAEA96) |

(a) It is supposed that thyroid blocking was taken before exposure. If no thyroid blocking is provided divide EWG by 5, if respiratory protection is provided or there is no airborne release multiply EWG by 2. Workers must be volunteers and be instructed on the potential consequences of exposure.

(b) These dose can be exceeded if justified BUT every effort shall be made to keep dose below this level (thresholds for deterministic effects). The workers should be trained on radiation protection and understand the risk they face.

## SECTION D
# ENVIRONMENTAL ANALYST PROCEDURES

Caution: The procedures in this section must be revised to reflect local and plant conditions for which they will be applied.

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**Purpose**
To manage environmental monitoring.

**Discussion**
The measurements are arranged by priorities the results are needed in case of an accident, so do not change the order.

**Input**
- ▶ Accident class from Worksheet A1
- ▶ Release duration projection from Worksheet A1
- ▶ Wind direction
- ▶ Projections from Worksheet E1 (if available)

**Output**
- ▶ Ambient dose rates around the plant on Worksheet D1
- ▶ Ambient dose rate results on Worksheet D2 and D3
- ▶ Isotope concentrations in air on Worksheet D4
- ▶ Deposition maps for I-131 and Cs-137 on Worksheet D5 and D6
- ▶ Isotope mix in deposition on Worksheet D7
- ▶ Isotope concentrations in food samples on Worksheet D8

**Step 1**
Obtain briefing on the situation from the Accident Assessment Manager. Follow the applicable radiation protection instructions provided by the Radiation Protection Manager.

**Step 2**
Use Table D1 to manage the environmental monitoring.

**Step 3**
Keep recording all major actions and/or decisions in a logbook.

**Step 4**
At the end of your shift ensure that your replacement is thoroughly briefed.

TABLE D1 ENVIRONMENTAL MONITORING PRIORITIES

| Priority | When | Where | Team | Objective | Results |
|---|---|---|---|---|---|
| 1 | After declaration of Alert and thereafter once an hour | Areas close to the plant in all directions (a) | Gamma/Beta Survey Team | To detect major releases from the plant and locate plume direction. | Record on Worksheet D1 and provide results to: Nuclear Condition Assessment Manager, Protective Action Manager and Projection Analyst |
| 2 | During and after a release | Areas not evacuated - begin in populated areas (e.g., towns) where projections from Projection Analyst (if available) indicate evacuation is warranted but ensure that all directions are monitored. | Gamma/Beta Survey Team | To identify where ambient dose rates indicate urgent protective actions are warranted (OIL1, OIL2 and OIL3 are exceeded) | Record on Worksheets D2 and D3, and provide to Protective Action Manager |
| 3 | During a release (b) | In plume | Air sampling team | To take and analyse air samples and ambient dose rates to recalculate OIL1 and OIL2 | Record on Worksheet D4 and provide to Sample Analyst |
| 4 | After a release has ended or after plume passage (c) | Areas not evacuated, start with area where highest dose rates were seen during release | Gamma/Beta Survey Team | To identify where ambient dose rates from deposition indicate that relocation is warranted (OIL4 exceeded) or indicate that food should be restricted until sampled (OIL5 exceeded) | Record on Worksheets D2 and D3 and provide to Protective Action Manager |
| 5 | After a release has ended or after plume passage (c) | Areas not evacuated and beyond those where the relocation OIL4 has been exceeded. | *In-situ* Gamma Spectrometry Team | Identify where I-131 or Cs-137 deposition concentration indicate food should be restricted until sampled (exceeds OIL6 and OIL7) | Record on Worksheets D5 and D6 and provide to Protection Action Manager |

TABLE D1 ENVIRONMENTAL MONITORING PRIORITIES

| Priority | When | Where | Team | Objective | Results |
|---|---|---|---|---|---|
| 6 | After a release has ended or after plume passage (c) | Representative points in all directions of contaminated area. (d) | Environmental Sampling Team | To take and analyse deposition samples or use gamma *in-situ* spectroscopy to recalculate the OIL4, OIL6 and OIL7 | Record on Worksheet D7 and provide to Sample Analyst |
| 7 | After a release has ended or after plume passage (c) | Start where OIL6 and OIL7 were exceeded, but ensure that all areas where deposition could result in food restrictions should be evaluated | Environmental Sampling Team | To take and analyse food, water and milk samples to identify if OIL8 and OIL9 in food are exceeded and restriction on ingestion are warranted (e) | Record on Worksheet D8 and provide to Sample Analyst |

(a) Conduct monitoring in all directions around the plant and record sector, distance from the plant, time and highest dose on Worksheet D1. Monitoring results should be obtained within 1 - 2 km zone around the plant.

(b) Perform only if: 1) the release is expected to last 4 hours or more and 2) the plume can be measured at ground level.

(c) E.g., after a wind shift while the release is still going on.

(d) The deposition pattern may be very complex and the mixture of fission products may vary by location and time (e.g., decay and ingrowth). Therefore sufficient samples must be taken to ensure the deposition pattern and mixture are understood.

(e) Take food and milk samples in areas where ambient dose rates and depositions concentrations indicate restrictions may be needed. Take samples of each major food type in accordance with the agricultural sampling plan (developed as part of the planning process).

## SECTION E
# PROJECTION ANALYST PROCEDURES

Caution: The procedures in this section must be revised to reflect local and plant conditions for which they will be applied.

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**Purpose**
To project distances to which protective actions may be needed.

**Discussion**
This procedure is used to estimate the distance to which the operational intervention levels (OILs) may be exceeded and to provide guidance on where monitoring and preparation for protective actions may be warranted.

There are great uncertainties in projecting plume movement. Until the plume is located implementation of protective actions and conducting monitoring should be considered in all directions to the distance indicated by the projection (not just downwind). Projections based on plant conditions should be performed as long as a major release is possible.

**Input**
- Plant conditions from Worksheet A1.
- Ambient dose rates around the plant from Worksheet D1.
- Deposition dose rates from Worksheet D2 and D3.
- Meteorological data.

**Output**
- Projected protective action distances

**Step 1**
Obtain briefing on the situation from the Accident Assessment Manager. Follow the applicable radiation protection instructions provided by the Radiation Protection Manager.

**Step 2**
Project protective action distances where operational intervention levels may be exceeded.

| In the following phase: | Use: |
|---|---|
| *As long as large future release is possible:* based on plant conditions | Procedure E1 or InterRAS code |
| *During a release:* based on ambient dose rates in the plume | Procedure E2 |
| *After a release:* based on ambient dose rates from deposition | Procedure E3 |

**Step 3**
Ensure Worksheet E1 is completed and distributed.

**Step 4**
Inform Environmental Analyst of projected protective action distances so that confirmatory surveys can be conducted.

**Step 5**
Repeat projection as new plant condition data and environmental measurements become available.

**Step 6**
Keep recording all major actions and/or decisions in a logbook.

**Step 7**
At the end of your shift ensure that your replacement is thoroughly briefed.

| *Performed by:*<br><br>*Projection Analyst* | **PROCEDURE E1**<br><br>**PROJECTED URGENT PROTECTIVE ACTION DISTANCES BASED ON PLANT CONDITIONS** | *Pg. 1 of 1* |
|---|---|---|

**Purpose**
To estimate urgent protective action distances based on plant conditions.

**Discussion**
This procedure uses figures to project the potential distance to which urgent protective actions may be required. These estimates should be reasonable for reactors of power levels > 750 MW(th). They are expected to be very uncertain. Therefore, it is not recommended to implement protective actions to the distance indicated in the figures without further environmental assessment (Section D).

**Input**
- ► Level of core damage from Worksheet A1
- ► Potential release routes and conditions from Worksheet A1

**Output**
- ► Projected urgent protective action distances

**Step 1**
Go to the appropriate procedure:

| If the release route is: | Then use: |
|---|---|
| Release from the containment | Procedure E1a |
| Containment by-pass under dry conditions | Procedure E1b |
| Containment by-pass under wet conditions | Procedure E1c |
| Release from the spent fuel pool | Procedure E1d |

**Purpose**
To estimate protective action distances for a release which passes through the primary system and through the containment (or accident localization volume) to atmosphere, carried by steam or gasses.

**Discussion**
Estimates are provided for extensive core melt or gap release, average weather conditions and one of two release durations, 1 hour for the 100% per hour leak rate and 4 hours for all other leak rates.

The effects of sprays or natural processes are considered.

**Input**

- ► Actual and/or projected conditions of the core from Worksheet A1
- ► Potential release conditions from Worksheet A1
- ► Weather conditions

**Output**

- ► Projected protective action distances

**Step 1**
Project urgent protective action distances using the following:

| If the level of core damage is: | And if: | Then use: |
|---|---|---|
| Gap release | No rain | Figure E1 |
| | Rain | Figure E2 |
| Core melt | No rain | Figure E3 |
| | Rain | Figure E4 |

**Step 2**
Record results on Worksheet E1.and show the worst and most likely case results. Attach a markup of the Figure (tree) used.

FIGURE E1
Projected Urgent Protective Action Distances for
RELEASE FROM THE CONTAINMENT
*GAP RELEASE - NO RAIN*

| **Core** | **Release** | | | **Projected Urgent Protective Action Distances (b) [km]** | |
|---|---|---|---|---|---|
| **Condition** | **Condition** | **Leak Rate** | **Holdup Time (a)** | **Evacuation** | **Thyroid Blocking and Shelter** |
| Uncovered 15-30 min / Gap Release | Not Reduced | <0.1%/day | any | 0 | 0 |
| | | 100%/day | < 12 h | 10 | 25 |
| | | | > 12 h | < 0.5 | < 0.5 |
| | | 100%/hour | < 2 h | 50 | 50 |
| | | | 2 - 12 h | 25 | 50 |
| | | | > 12 h | 5 | 25 |
| | Reduced | <0.1%/day | any | 0 | 0 |
| | | 100%/day | any | < 0.5 | < 0.5 |
| | | 100%/hour | < 2 h | 10 | 25 |
| | | | 2 - 12 h | 5 | 10 |
| | | | > 12 h | 2 | 10 |

(a) Average time radioactive material released from core remains in containment before release.
(b) 50 kilometres means at least 50 kilometres or even more.

FIGURE E2
Projected Urgent Protective Action Distances for
RELEASE FROM THE CONTAINMENT
*GAP RELEASE - RAIN*(a)

| **Core** | **Release** | | | **Projected Urgent Protective Action Distances [km]** | |
|---|---|---|---|---|---|
| **Condition** | **Condition** | **Leak Rate** | **Holdup Time (b)** | **Evacuation** | **Thyroid Blocking and Shelter** |
| Uncovered 15-30 min Gap Release | Not Reduced | <0.1%/day | any | 0 | 0 |
| | | 100%/day | < 12 h | 5 | 10 |
| | | | > 12 h | 2 | 2 |
| | | 100%/hour | < 12 h | 10 | 10 |
| | | | > 12 h | 5 | 5 |
| | Reduced | <0.1%/day | any | 0 | 0 |
| | | 100%/day | any | <0.5 | 2 |
| | | 100%/hour | < 2 h | 10 | 10 |
| | | | 2 - 12 h | 5 | 5 |
| | | | > 12 h | 2 | 2 |

(a) Rain over entire area
(b) Average time radioactive material release from core remains in containment before release.

FIGURE E3
Projected Urgent Protective Action Distances for
RELEASE FROM THE CONTAINMENT
*CORE MELT - NO RAIN*

| **Core** | **Release** | | | **Projected Urgent Protective Action Distances (b) [km]** | |
|---|---|---|---|---|---|
| **Condition** | **Condition** | **Leak Rate** | **Holdup Time (a)** | **Evacuation** | **Thyroid Blocking and Shelter** |
| Uncovered > 30 min Core Melt | Not Reduced | <0.1%/day | any | 0 | 0 |
| | | 100%/day | < 12 h | 50 | 50 |
| | | | > 12 h | 10 | 25 |
| | | 100%/hour | < 2 h | 50 | 50 |
| | | | 2 - 12 h | 50 | 50 |
| | | | > 12 h | 25 | 50 |
| | Reduced | <0.1%/day | any | 0 | 0 |
| | | 100%/day | < 12 h | 10 | 10 |
| | | | > 12 h | 2 | 10 |
| | | 100%/hour | < 2 h | 50 | 50 |
| | | | 2 - 12 h | 25 | 50 |
| | | | > 12 h | 10 | 25 |

(a) Average time radioactive material release from core remains in containment before release.
(b) 50 kilometres means at least 50 kilometres or even more.

FIGURE E4
Projected Urgent Protective Action Distances for
RELEASE FROM THE CONTAINMENT
*CORE MELT - RAIN*(a)

| Core Condition | Release Condition | Leak Rate | Holdup Time (b) | Projected Urgent Protective Action Distances [km]: Evacuation | Projected Urgent Protective Action Distances [km]: Thyroid Blocking and Shelter |
|---|---|---|---|---|---|
| Uncovered > 30 min Core Melt | Not Reduced | <0.1%/day | any | 0 | 0 |
| Uncovered > 30 min Core Melt | Not Reduced | 100%/day | < 12 h | 10 | 10 |
| Uncovered > 30 min Core Melt | Not Reduced | 100%/day | > 12 h | 5 | 10 |
| Uncovered > 30 min Core Melt | Not Reduced | 100%/hour | < 2 h | 25 | 25 |
| Uncovered > 30 min Core Melt | Not Reduced | 100%/hour | 2 - 12 h | 25 | 25 |
| Uncovered > 30 min Core Melt | Not Reduced | 100%/hour | > 12 h | 10 | 10 |
| Uncovered > 30 min Core Melt | Reduced | <0.1%/day | any | 0 | 0 |
| Uncovered > 30 min Core Melt | Reduced | 100%/day | < 12 h | 5 | 10 |
| Uncovered > 30 min Core Melt | Reduced | 100%/day | > 12 h | 5 | 5 |
| Uncovered > 30 min Core Melt | Reduced | 100%/hour | < 2 h | 25 | 25 |
| Uncovered > 30 min Core Melt | Reduced | 100%/hour | 2 - 12 h | 10 | 10 |
| Uncovered > 30 min Core Melt | Reduced | 100%/hour | > 12 h | 10 | 10 |

(a) Rain over entire area
(b) Average time radioactive material release from core remains in containment before release.

| *Performed by:* <br> *Projection Analyst* | **PROCEDURE E1b** <br> **CONTAINMENT BY-PASS UNDER DRY CONDITIONS** | *Pg. 1 of 3* |
|---|---|---|

**Purpose**
To estimate projected urgent protective action distances for cases where there is a steam and gaseous release from the primary system to the atmosphere that by-passes the containment.

**Discussion**
Estimates are provided for extensive core melt or gap release, average weather conditions, and one of two release durations, 1 hour for the 100% per hour leak rate and 4 hours for all other leak rates. In this case the core is assumed to be uncovered and fission products are carried by steam or other gases. Reduction due to plate out on the pipes is included.

If the release is carried by water, the procedure for the containment by-pass under wet conditions (procedure E1c) should be used.

**Input**
- ▶ Actual and/or projected conditions of the core from Worksheet A1
- ▶ Potential release conditions from Worksheet A1
- ▶ Meteorological data

**Output**
- ▶ Projected urgent protective action distances

**Step 1**
Project urgent protective action distances using the following:

| If the level of core damage is: | Then use: |
|---|---|
| Gap release | Figure E5 |
| Core melt | Figure E6 |

**Step 2**
Record results on Worksheet E1 and show the worst and most likely case results. Attach a markup of the Figure (tree) used.

FIGURE E5
Projected Urgent Protective Action Distances for
CONTAINMENT BY-PASS UNDER DRY CONDITIONS
*GAP RELEASE*

| **Core** | **Environment** | **Release** | | **Projected Urgent Protective Action Distances (a) [km]** | |
|---|---|---|---|---|---|
| **Condition** | **Rain(b)** | **Condition** | **Leak Rate** | **Evacuation** | **Thyroid Blocking and Shelter** |
| Uncovered 15-30 min Gap Release | No | Not Reduced | <0.1%/day | 0 | 0 |
| | | | 100%/day | 10 | 25 |
| | | | 100%/hour | 25 | 50 |
| | | Reduced | <0.1%/day | 0 | 0 |
| | | | 100%/day | < 0.5 | < 0.5 |
| | | | 100%/hour | NA | NA |
| | Yes | Not Reduced | <0.1%/day | 0 | 0 |
| | | | 100%/day | 5 | 10 |
| | | | 100%/hour | 10 | 10 |
| | | Reduced | <0.1%/day | 0 | 0 |
| | | | 100%/day | <0.5 | <0.5 |
| | | | 100%/hour | NA | NA |

NA Not applicable; filters are the only reduction mechanism assumed for this release route. At this leak rate filters are assumed to blow out, use the "not reduced" branch of the same leak rate.
(a) 50 kilometres means at least 50 kilometres or even more.
(b) Assumes it is raining over entire area

FIGURE E6
Projected Urgent Protective Action Distances for
CONTAINMENT BY-PASS UNDER DRY CONDITIONS
*CORE MELT*

| **Core** | **Environment** | **Release** | | **Projected Urgent Protective Action Distances (a) [km]** | |
|---|---|---|---|---|---|
| **Condition** | **Rain (b)** | **Condition** | **Leak Rate** | **Evacuation** | **Thyroid Blocking and Shelter** |
| Uncovered >30 min Core Melt | No | Not Reduced | <0.1%/day | 0 | 0 |
| | | | 100%/day | 25 | 50 |
| | | | 100%/hour | 50 | 50 |
| | | Reduced | <0.1%/day | 0 | 0 |
| | | | 100%/day | 10 | 25 |
| | | | 100%/hour | NA | NA |
| | Yes | Not Reduced | <0.1%/day | 0 | 0 |
| | | | 100%/day | 10 | 10 |
| | | | 100%/hour | 25 | 50 |
| | | Reduced | <0.1%/day | 0 | 0 |
| | | | 100%/day | 5 | 10 |
| | | | 100%/hour | NA | NA |

NA Not applicable; filters are the only reduction mechanism assumed for this release route. At this leak rate filters are assumed to blow out, use the "not reduced" branch of the same leak rate.
(a) 50 kilometres means at least 50 kilometres or even more.
(b) Assumes it is raining over entire area

**Purpose**
To estimate projected urgent protective action distances when the fission products are carried by the coolant to the atmosphere.

**Discussion**
Estimates are made for two release rates a) 100 $m^3/h$ (100% release of primary system inventory in an hour) and b) 10 $m^3/h$. Estimates for core melt or gap release assume the core was damaged and recovered with water (e.g., like TMI). It is assumed the fission products are carried by contaminated water.

The effectiveness of partitioning in the steam generator and operational condenser can be considered.

**Input**
- ► Actual and/or projected conditions of the core from Worksheet A1
- ► Potential release routes and conditions from Worksheet A1
- ► Meteorological data

**Output**
- ► Projected urgent protective action distances

**Step 1**
Project urgent protective action distances using the following:

| If the level of core damage is: | Then use: |
|---|---|
| Normal coolant and spike | Figure E7 |
| Gap release and core melt | Figure E8 |

**Step 2**
Record results on Worksheet E1 and show the worst and most likely case results. Attach a markup of the Figure (tree) used.

FIGURE E7
Projected Urgent Protective Action Distances for
CONTAINMENT BY-PASS UNDER WET CONDITIONS
*NORMAL COOLANT AND SPIKE RELEASE*

| **Core** | **Environment** | **Release** | | **Projected Urgent Protective Action Distances [km]** | |
|---|---|---|---|---|---|
| **Condition** | **Rain (b)** | **Condition** | **Leak Rate** | **Evacuation** | **Thyroid Blocking and Shelter** |
| Normal coolant | No | any | any | 0 | 0 |
| | Yes | any | any | 0 | 0 |
| Spike | No | Not reduced (a) | 100 m³/h | < 0.5 | < 0.5 |
| | | any | any | 0 | 0 |
| | Yes | any | any | 0 | 0 |

(a) Not partitioned
(b) Assumes it is raining over entire area

FIGURE E8
Projected Urgent Protective Action Distances for
CONTAINMENT BY-PASS UNDER WET CONDITIONS
*GAP RELEASE and CORE MELT*

| **Core** | **Environment** | **Release** | | **Projected Urgent Protective Action Distances (a) [km]** | |
|---|---|---|---|---|---|
| **Condition** | **Rain(c)** | **Condition** | **Leak Rate** | **Evacuation** | **Thyroid Blocking and Shelter** |
| Uncovered 15-30 min Gap Release and recovered | No | Not reduced (b) | 100 m³/h | 50 | 50 |
| | | | 10 m³/h | 25 | 50 |
| | | Reduced | 100 m³/h | 25 | 25 |
| | | | 10 m³/h | <0.5 | 5 |
| | Yes | Not reduced (b) | 100 m³/h | 10 | 25 |
| | | | 10 m³/h | 10 | 10 |
| | | Reduced | 100 m³/h | 10 | 10 |
| | | | 10 m³/h | 2 | 5 |
| Uncovered > 30 min Core Melt and recovered | No | Not Reduced (b) | 100 m³/h | 50 | 50 |
| | | | 10 m³/h | 50 | 50 |
| | | Reduced | 100 m³/h | 50 | 50 |
| | | | 10 m³/h | 25 | 25 |
| | Yes | Not Reduced (b) | 100 m³/h | 50 | 50 |
| | | | 10 m³/h | 10 | 25 |
| | | Reduced | 100 m³/h | 50 | 50 |
| | | | 10 m³/h | 10 | 25 |

(a) 50 kilometres means at least 50 kilometres or even more.
(b) Not partitioned
(c) Assumes it is raining over entire area

| *Performed by:* <br> *Projection Analyst* | **PROCEDURE E1d** <br> **RELEASE FROM THE SPENT FUEL POOL** | *Pg. 1 of 2* |
|---|---|---|

**Purpose**
To estimate projected urgent protective action distances for release from the spent fuel pool.

**Discussion**
This is valid for pools containing fuel that has been discharged from the core more than 30 days ago. Estimates assumed on average weather conditions and a 4 hour release at 100% per day release rate.

**Input**
- ► Actual and/or projected conditions of the spent fuel from Worksheet A1
- ► Potential release routes and conditions from Worksheet A1
- ► Meteorological data

**Output**
- ► Projected urgent protective action distances

**Step 1**
Project urgent protective action distances using Figure E9. This procedure should only be used for fuel that has been removed from the core at least two months (short lived isotopes will have decayed).

**Step 2**
Record results on Worksheet E1 and show the worst and most likely case results. Attach a markup of the Figure (tree) used.

FIGURE E9
Projected Urgent Protective Action Distances for
THE RELEASE FROM SPENT FUEL POOL
*GAP RELEASE*

| **Core** | **Environment** | **Release** | | **Projected Urgent Protective Action Distances [km]** | |
|---|---|---|---|---|---|
| **Condition** | **Rain (a)** | **Condition** | **Leak Rate** | **Evacuation** | **Thyroid Blocking and Shelter** |
| Cladding Failure Pool Drained | No | Not Reduced | 100%/day | <2 | <5 |
| | | Reduced | 100%/day | <0.5 | <0.5 |
| | Yes | Not Reduced | 100%/day | <5 | <5 |
| | | Reduced | 100%/day | <0.5 | <0.5 |

(a) Assumes it is raining over entire area

| Performed by: | PROCEDURE E2 | |
|---|---|---|
| *Projection Analyst* | **PROJECTED URGENT PROTECTIVE ACTION DISTANCES BASED ON AMBIENT DOSE RATES IN THE PLUME** | *Pg. 1 of 2* |

**Purpose**
To estimate projected urgent protective action distances based on ambient dose rates near the plant during a release or plume passage.

**Discussion**
The results of this procedure are only valid if monitoring is performed in the center of the plume within a 1-2 km zone around the plant. These estimates are very crude and uncertain and should only be used to indicate where additional surveys are appropriate.

**Input**
- ► Ambient dose rates from Worksheet D1
- ► Data from Worksheet A1
- ► Weather conditions (rain, no rain)

**Output**
- ► Projected urgent protective actions distances

**Step 1**
Estimate the urgent protective action distances using Figure E10.

**Step 2**
Record results on Worksheet E1.

**Step 3**
Inform Environmental Analyst of projected distances so that confirmatory surveys can be conducted.

FIGURE E10
Projected Urgent Protective Action Distances based on
MEASURED AMBIENT DOSE RATES AT 1 - 2 km FROM THE PLANT

| **Core Condition** | **Environment Rain (d)** | **Release Reduced (a)** | **Monitoring Range of Dose Rate [mSv/h]** | **Projected Urgent Protective Action Distances (c) Evacuation [km]** | **Thyroid Blocking and Shelter [km]** |
|---|---|---|---|---|---|
| Gap Release or Core Melt | No | No | < 0.1 | 0 | 0 |
| | | | 0.1 - <1 | 0 | 5 |
| | | | 1 - 10 | 10 | 25 |
| | | | > 10 | 50 | 50 |
| | | Yes | < 1 | 0 | 0 |
| | | | 1 - 10(b) | 0 | <0.5 |
| | | | 10 - 100(b) | 10 | 25 |
| | | | > 100(b) | 50 | 50 |
| | Yes | No | < 0.1 | 0 | 0 |
| | | | 0.1 - <1 | 0 | 2 |
| | | | 1 -10(b) | 5 | 10 |
| | | | 10 - 100(b) | 10 | 10 |
| | | | 100 - 1000(b) | 25 | 50 |
| | | | > 1000(b) | 50 | 50 |
| | | Yes | < 1 | 0 | 0 |
| | | | 1 - 10(b) | 2 | 5 |
| | | | 10 -100(b) | 10 | 10 |
| | | | 100 - 1000(b) | 25 | 50 |
| | | | > 1000(b) | 50 | 50 |

(a) Reduced means that most of the material that can result in an inhalation dose has been removed.
(b) At an ambient dose rate of 1 mSv/h the sector measured should be evacuated
(c) 50 kilometres means at least 50 kilometres or even more "0" means that protective actions are not needed at this location. But this does not indicate that there are no actions needed nearer to the plant
(d) Assumes it is raining over entire area

| *Performed by:* *Projection Analyst* | **PROCEDURE E3** **PROJECTED PROTECTIVE ACTION DISTANCES BASED ON AMBIENT DOSE RATES FROM DEPOSITION** | *Pg. 1 of 2* |
|---|---|---|

**Purpose**
To estimate projected protective action distances based on ambient dose rates after the plume passage.

**Discussion**
These results are for the average dose over large areas. Local doses could vary by a factor of 10 or more.

Protective actions should not be recommended based on this procedure without further survey, sampling and analysis.

This procedure should be used only after plume passage.

**Input**
- ► Ambient dose rates and distances where they were obtained (Worksheets D1, D2 and D3)

**Output**
- ► Projected protective action distances

**Step 1**
Assess the ambient dose rate from deposition using:

| If the ambient dose rate from deposition is greater than | use |
|---|---|
| OIL3 for evacuation (Procedure B1) | Step 1a |
| OIL4 for relocation (Procedure B1) | Step 1b |

**Step 1a Evacuation**
Project the distance evacuation is warranted using the formulas below.

**No rain**:

$$X_e = X \times N_x$$

**Rain over entire area**:

$$X_e = X \times \sqrt{N_x}$$

where:

$X$ = Distance from source of the release at which ambient dose rate measurements were taken [km]
$X_e$ = Projected evacuation distance [km]
$N_x$ = Multiplier for evacuation [dimensionless]

$$N_x = \frac{\dot{H}^*_g}{OIL3}$$

| | | |
|---|---|---|
| *OIL3* | = | Operational intervention level for evacuation from Table B3 (Procedure B1) |
| $\dot{H}^*_g$ | = | Ambient dose rate from deposition [mSv/h] at 1 metre above the ground. |

**Step 1b** **Relocation**

Project the distance relocation may be needed using the formula below.

**No rain**:

$$X_r = X \times N_x$$

**Rain over entire area**:

$$X_r = X \times \sqrt{N_x}$$

where:

| | | |
|---|---|---|
| $X$ | = | Distance from source of the release at which ambient dose rate measurements were taken [km] |
| $X_r$ | = | Projected relocation distance [km] |
| $N_x$ | = | Multiplier for relocation [dimensionless] |

$$N_x = \frac{\dot{H}^*_g}{OIL4}$$

| | | |
|---|---|---|
| *OIL4* | = | Operational intervention level for relocation from Table B3 (Procedure B1) |
| $\dot{H}^*_g$ | = | Ambient dose rate from deposition [mSv/h] at 1 metre above the ground. |

**Step 2**

Record results on Worksheet E1.

**Step 3**

Inform Environmental Analyst of projected distances so that confirmatory surveys can be conducted.

SECTION F

# SAMPLE ANALYST PROCEDURES

Caution: The procedures in this section must be revised to reflect local and plant conditions for which they will be applied.

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| *Performed by:* <br> *Sample Analyst* | **PROCEDURE F0** <br> **SAMPLE ANALYST OVERVIEW** | *Pg. 1 of 1* |
|---|---|---|

**Purpose**
To provide overview of tasks performed by Sample Analyst.

**Step 1**
Obtain briefing on the situation from the Accident Assessment Manager. Follow the applicable radiation protection instructions provided by the Radiation Protection Manager.

**Step 2**
When air sample isotope analysis results are available, and if the release is expected to continue for several hours, use procedure F1 to revise plume exposure OILs (OIL1 and OIL2), and emergency workers turn back guidance.

**Step 3**
When deposition sample isotopic analysis results are available, recalculate OIL4 using procedure F2.

**Step 4**
When food sample isotopic concentration analysis results are available recalculate OIL6 and OIL7 using procedure F3 and recalculate food, drinking water and milk OILs (OIL8 and OIL9) using procedure F5.

**Step 5**
Establish contact with your sources of information and provide relevant information as required. Advise the Protective Measures Manager of any major changes in OILs.

**Step 6**
Keep recording all major actions and/or decisions in logbook.

**Step 7**
At the end of your shift assure that your replacement is thoroughly briefed.

| Performed by: Sample Analyst | PROCEDURE F1 | Pg. 1 of 5 |
|---|---|---|
| | **REVISION OF PLUME EXPOSURE OILs AND EMERGENCY WORKER TURN BACK GUIDANCE** | |

**Purpose**
To revise: a) the operational intervention levels used to interpret measurement results in the plume for determining if evacuation, sheltering and thyroid blocking agent (OIL1 and OIL2) is warranted and b) the emergency worker turn back guidance.

**Discussion**
This procedure should be performed only if there are reliable air samples, accident condition are stable and a major release is on-going.

**Input**

- ▶ Isotope concentrations in air and external ambient dose rates taken while air sampling from Worksheet D4
- ▶ Default OIL1 and OIL2 values from Table B2
- ▶ Emergency worker turn back guidance from Table C1.

**Output**

- ▶ Recalculated OIL1 and OIL2 values
- ▶ Recalculated emergency worker turn back guidance (revised Table C1)

**Step 1**
Obtain: a) the air concentrations of the major isotopic contributors to thyroid and effective dose from inhalation (include iodine and caesium) and b) the average ambient dose rate during the air sampling time ($\overline{\dot{H}^*}$) from Worksheet D4.

**Step 2**
Using Worksheet F1 calculate the thyroid dose and effective dose rate from inhalation of contaminated air based as specified below. [This can be performed using InterRAS-FM-DOSE]

$$\dot{H}_{thy} = \sum_{I}^{n} C_{a,I} \times CF_{1,I} \qquad \dot{E}_{inh} = \sum_{I}^{n} C_{a,I} \times CF_{2,I}$$

where:

| | |
|---|---|
| $C_{a,I}$ | Activity concentration of radionuclide $I$ in plume [kBq/m³] from Worksheet D4 |
| $CF_{1,I}$ | Thyroid inhalation dose conversion factor for isotope $I$ [(mSv/h)/(kBq/m³)] from Table F1 |
| $CF_{2,I}$ | Effective inhalation dose conversion factor for isotope $I$ [(mSv/h)/(kBq/m³)] from Table F1 |
| $\dot{H}_{thy}$ | Dose rate to the thyroid from inhalation [mSv/h] |
| $\dot{E}_{inh}$ | Effective dose rate from inhalation [mSv/h] |

**Step 3**
Calculate the ratios of the thyroid dose and the total effective dose rate to the external ambient dose rate as specified below.

$$R_1 = \frac{\dot{E}_{inh}}{\overline{\dot{H}^*}} + 1 \qquad R_2 = \frac{\dot{H}_{thy}}{\overline{\dot{H}^*}}$$

where:

| | |
|---|---|
| $R_1$ | Ratio of total effective dose rate to ambient dose rate (default assumed 10) [dimensionless]. |
| $R_2$ | Ratio of thyroid dose rate to ambient dose rate from inhalation of iodine (default assumed 200) [dimensionless] |
| $\overline{\dot{H}^*}$ | Average ambient dose rate from external exposure in the plume where the air sample was taken from Worksheet D4 [mSv/h] |
| $\dot{H}_{thy}$ | Dose rate to the thyroid from inhalation from Step 2 [mSv/h] |
| $\dot{E}_{inh}$ | Effective dose rate from inhalation from Step 2 [mSv/h] |

**Step 4**
Recalculate OIL1 as specified by the formula below. OIL1 should never be higher than 10 mSv/h.

$$OIL1 = GIL_e \times \frac{1}{R_1} \times \frac{1}{T_e}$$

where:

| | |
|---|---|
| $OIL1$ | Evacuation operational intervention level as defined in Table B2 [mSv/h] |
| $GIL_e$ | National intervention level for evacuation (IAEA defaults see Table F2) [mSv], assuming all the dose can be averted by evacuation. |
| $T_e$ | Exposure duration, assume 4 hours if unknown (typically the wind will shift every four hours) [h] |
| $R_1$ | Ratio of total effective dose rate to ambient dose rate from step 3 (default assumed 10) [dimensionless] |

**Step 5**
Recalculate OIL2 as specified below:

$$OIL2 = GIL_{thy} \times \frac{1}{R_2} \times \frac{1}{T_e}$$

where:

| | |
|---|---|
| $OIL2$ | Thyroid blocking operational intervention level as defined in Table B2 [mSv/h] |
| $GIL_{thy}$ | National intervention level for taking thyroid blocking agent (See Table F2 for IAEA recommended levels) [mSv] |
| $T_e$ | Exposure duration, assume 4 hours if unknown (typically the wind will shift every four hours) [h] |
| $R_2$ | Ratio of thyroid dose rate to ambient dose rate from step 3 (default assumed 200) [dimensionless] |

**Step 6**
Recalculate the emergency worker turn back guidance in Table C1 as specified below.

**Step 6.a**
**Thyroid blocking taken:**

$$EWG = E_T^{WG} \times \frac{5}{R_1}$$

where:

| | |
|---|---|
| *EWG* | Emergency worker turn back dose guidance [mSv] |
| $E_T^{WG}$ | IAEA total effective dose guidance for emergency workers [mSv] - total effective dose which should not be exceeded when performing emergency tasks (see Table F9) |
| $R_1$ | Ratio of total effective dose rate to ambient dose rate from Step 3 (default assumed 10) [dimensionless] |

**Step 6.b**

**Thyroid blocking NOT taken**:
Divide emergency worker turn back guidance calculated in step 6.a by 5.

**Step 7**
Provide results to the Radiation Protection Manager and to the Protective Action Manager.

TABLE F1 INHALATION DOSE RATE CONVERSION FACTORS

**Discussion**: For simplicity the dose conversion factors are provided in terms of mSv acquired in one hour, breathing an air concentration of 1 kBq/m$^3$. A breathing rate of 1.2 m$^3$ /h was assumed (as recommended by the ICRP75 for an adult performing light activity). See the assumption Appendix 1 for the basis of dose conversion factors.

| **Radionuclide** | **$CF_1$ Thyroid Inhalation Dose Conversion Factor [(mSv/h)/(kBq/m$^3$)]** | **$CF_2$ Effective Inhalation Dose Conversion Factor [(mSv/h)/(kBq/m$^3$)]** |
|---|---|---|
| H-3 (a) (b) | NA | 6.24E-04 |
| Mn-54 (a) | NA | 1.92E-03 |
| Co-58 (a) | NA | 2.52E-03 |
| Co-60 (a) | NA | 3.72E-02 |
| Rb-87 | NA | 6.00E-04 |
| Rb-88 | NA | 1.92E-05 |
| Sr-89 | NA | 9.48E-03 |
| Sr-90 | NA | 1.92E-01 |
| Sr-91 | NA | 4.92E-04 |
| Y-90 | NA | 1.80E-03 |
| Y-91 | NA | 1.07E-02 |
| Y-91m | NA | 1.32E-05 |
| Zr-95 | NA | 7.08E-03 |
| Nb-95 | NA | 2.16E-03 |
| Mo-99 | NA | 1.19E-03 |
| Tc-99 | NA | 1.56E-02 |
| Tc-99m | NA | 2.28E-05 |
| Ru-103 | NA | 3.60E-03 |
| Rh-106 | NA | 1.32E-04 |
| Sb-127 | NA | 2.28E-03 |
| Sb-129 | NA | 3.00E-04 |
| Te-127 | NA | 1.68E-04 |
| Te-127m | NA | 1.18E-02 |
| Te-129 | NA | 4.68E-05 |
| Te-129m | NA | 9.48E-03 |
| Te-131 | 3.16E-03 | 3.36E-05 |
| Te-131m | 4.33E-02 | 1.13E-03 |

| **Radionuclide** | **$CF_1$ Thyroid Inhalation Dose Conversion Factor [(mSv/h)/(kBq/m$^3$)]** | **$CF_2$ Effective Inhalation Dose Conversion Factor [(mSv/h)/(kBq/m$^3$)]** |
|---|---|---|
| Te-132 | 7.54E-02 | 2.40E-03 |
| I-131 | 3.50E-01 | 8.88E-03 |
| I-132 | 2.09E-03 | 1.32E-04 |
| I-133 | 5.83E-02 | 1.80E-03 |
| I-134 | 3.46E-04 | 6.60E-05 |
| I-135 | 1.02E-02 | 3.84E-04 |
| Cs-134 | NA | 2.40E-02 |
| Cs-136 | NA | 3.36E-03 |
| Cs-137 | NA | 4.68E-02 |
| Ba-140 | NA | 6.96E-03 |
| La-140 | NA | 1.32E-03 |
| Ce-141 | NA | 4.56E-03 |
| Ce-144 | NA | 6.36E-02 |
| Pr-144 | NA | 2.16E-05 |
| Th-231 | NA | 3.96E-04 |
| Np-239 | NA | 1.20E-03 |
| Pu-238 | NA | 1.32E+02 |
| Pu-239 | NA | 1.44E+02 |
| Pu-240 | NA | 1.44E+02 |
| Pu-241 | NA | 2.76E+00 |
| Pu-242 | NA | 1.32E+02 |
| Am-241 | NA | 1.15E+02 |

*Source:* IAEA96

NA Not applicable
(a) important only for spent fuel pool
(b) dose doubled to account for skin absorption

| *Performed by:* <br> *Sample Analyst* | **PROCEDURE F2** <br> **REVISION OF DEPOSITION EXPOSURE RELOCATION OPERATIONAL INTERVENTION LEVEL** | *Pg. 1 of 6* |
|---|---|---|

**Purpose**
To recalculate OIL4 (relocation based on ambient dose rates from deposition) for a known deposition isotope mixture.

**Discussion**
The isotopic mix of the deposition will change temporally (decay and ingrowth) and spatially. But for practical and human factors reasons only a single value for OIL4 should be used for the entire affected area. Therefore samples should be taken and analysed from a wide area to assure the value used is representative of the entire affected area. OIL4 should be re-evaluated every week for the first month to account for major changes in the composition of the deposition due to decay, and every month thereafter, until decay no longer has a major impact.

OILs can be calculated for different periods as shown in Table F3. Initially the first month should be calculated to replace OIL4. Later after the deposition has been fully assessed the OILs for the other periods should be calculated.

**Input**
- ► Isotopic mix of the deposition from Worksheet D7

**Output**
- ► Recalculated operational intervention level OIL4

**Step 1**
Using Worksheet F2 calculate the weighting ratio for the dose rate from ground deposition to the longer term dose from deposition using the formula below or by using InterRAS.

$$WR = \frac{\sum_{i}^{n} (C_{g,i} \times CF_{3,i})}{\sum_{i}^{n} (C_{g,i} \times CF_{4,i})}$$

where:
$C_{g,i}$ Isotope concentration of radionuclide *I* on the ground [kBq/m$^2$] from Worksheet D7
$CF_{3,i}$ Ambient dose rate conversion factor for deposition from Table F5
$CF_{4,i}$ Long term dose conversion factor for deposition from Table F5

**Step 2**
Recalculate the relocation operational intervention level (OIL4) as specified below.

$$OIL4 = GIL_r \times WR \times \frac{1}{[SF \times OF] + [1 - OF]}$$

where:

*OIL4* Relocation operational intervention level (Table B3) [mSv/h]
*SF* Shielding factor from measurements during occupancy (default 0.16) or from Table F4
*OF* Occupancy fraction, or the fraction of time the shielding factor SF is applicable (e.g., the fraction of time spent indoors) default = 0.6
$GIL_r$ Generic intervention level for relocation from Table F3 [mSv]
*WR* Weighting ratio for the dose rate from ground deposition to the longer term dose from deposition from Step 1

**Step 3**
Provide results to Protective Actions Manager.

TABLE F2 IAEA GENERIC INTERVENTION LEVELS FOR URGENT PROTECTIVE ACTIONS

| Protective action | Generic intervention level (dose avertable by the protective action)[a,b] |
|---|---|
| Sheltering | 10 mSv[c] |
| Evacuation | 50 mSv[d] |
| Iodine prophylaxis (thyroid blocking) | 100 mGy[e] |

Source: IAEA 94

(a) These levels are of avertable dose, i.e. the action should be taken if the dose that can be averted by the action, taking into account the loss of effectiveness due to any delays or for other practical reasons, is greater than the figure given.

(b) The levels in all cases refer to the average over suitably chosen samples of the population, not to the most exposed individuals. However, projected doses to groups of individuals with higher exposures should be kept below the thresholds for deterministic effects.

(c) Sheltering is not recommended for longer than 2 days. Authorities may wish to recommend sheltering at lower intervention levels for shorter periods or so as to facilitate further protective actions, e.g. evacuation.

(d) Evacuation is not recommended for a period of longer than 1 week. Authorities may wish to initiate evacuation at lower intervention levels, for shorter periods and also where evacuation can be carried out quickly and easily, e.g. for small groups of people. Higher intervention levels may be appropriate in situations in which evacuation would be difficult, e.g. for large population groups or with inadequate transport.

(e) Avertable committed absorbed dose to the thyroid due to radioiodine. For practical reasons, one intervention level is recommended for all age groups.

TABLE F3 IAEA GENERIC INTERVENTION LEVELS FOR TEMPORARY RELOCATION AND PERMANENT RESETTLEMENT

| Period | $GIL_r$ | Definition |
|---|---|---|
| 1st month | 30 mSv | Temp.Reloc. GIL |
| Subsequent month | 10 mSv | Temp. Reloc. GIL. |
| Lifetime (50 year) | 1000 mSv | Perm. Reset.GIL. |

Source: (IAEA94)

TABLE F4 SHIELDING FACTORS FOR SURFACE DEPOSITION

| Structure or Location | Representative Shielding Factor (a,b) |
|---|---|
| One and two story wood-frame house (without basement) | 0.4 |
| One and two story block and brick house (without basement) | 0.2 |
| House basement, one or two walls fully exposed<br>- one-story, less than 1 m of basement, wall exposed<br>- two story, less than 1 m of basement, wall exposed | <br>0.1<br>0.05 |
| Three or four story structures (500 to 1000 $m^2$ per floor)<br>- first and second floor<br>- basement | <br>0.05<br>0.01 |
| Multi-story structures (> 1000 $m^2$ per floor)<br>- upper floors<br>- basement | <br>0.01<br>0.005 |

Source: (EGG75)

(a) The ratio of the interior to the exterior doses.
(b) Away from doors and windows.

TABLE F5 DOSE AND DOSE RATE CONVERSION FACTORS FOR EXPOSURE TO GROUND CONTAMINATION

**Discussion**: This contains dose conversion factors (CF) for the first, second month and 50 year periods of exposure to ground contamination. Decay, ingrowth and weathering have been considered. The CFs are based on InterRAS runs. The $CF_4$ includes dose from external exposure and inhalation dose from resuspension. An initial resuspension factor of $R_S$ = 1E-6 $m^{-1}$ was used because it is considered to be the upper bound (conservative) assuming weathered (old) deposition. However, much lower resuspension factors have been seen in real accidents. The ambient dose rate conversion factor ($CF_3$) is the exposure rate at 1 m above ground level from 1 kBq/$m^2$ deposition of isotope *I*, corrected for ground roughness (0.7). The table contains those radionuclides that are a major source of dose from deposition for a reactor accident

| **Radionuclide** | **$CF_3$ (a) Ambient dose rate conversion factor for deposition [(mSv/h)/(kBq/$m^2$)]** | **$CF_4$ (b) Long term dose conversion factor for deposition [(mSv/kBq/$m^2$)]** | | |
|---|---|---|---|---|
| | | **1st Month** | **Subsequent Month** | **Lifetime (50 Year)** |
| Mn-54 | 2.86E-06 | 1.39E-03 | 1.23E-03 | 1.40E-02 |
| Co-58 | 3.35E-06 | 1.58E-03 | 9.39E-04 | 3.91E-03 |
| Co-60 | 8.29E-06 | 4.15E-03 | 3.88E-03 | 1.65E-01 |
| Rb-87 | 3.10E-10 | NC | NC | NC |
| Rb-88 | 2.10E-06 | NC | NC | NC |
| Sr-89 | 8.01E-09 | 1.05E-05 | 6.59E-06 | 2.83E-05 |
| Sr-90 | 1.00E-09 | 1.69E-04 | 1.61E-04 | 2.11E-02 |
| Sr-91 | 2.39E-06 | 3.38E-05 | 7.45E-08 | 3.40E-05 |
| Y-90 | 1.88E-08 | 1.69E-06 | 6.71E-10 | 1.69E-06 |
| Y-91 | 2.03E-08 | 1.66E-05 | 1.10E-05 | 4.94E-05 |
| Y-91m | 1.85E-06 | 1.59E-06 | 6.48E-09 | 1.61E-06 |
| Zr-95 (c) | 2.55E-06 | 1.38E-03 | 1.30E-03 | 6.83E-03 |
| Nb-95 (c) | 2.64E-06 | 9.98E-04 | 5.21E-04 | 2.09E-03 |
| Mo-99+Tc-99m | 9.53E-07 | 6.06E-05 | 3.08E-08 | 6.06E-05 |
| Tc-99 | 2.75E-10 | 4.11E-06 | 3.88E-06 | 8.23E-04 |
| Tc-99m | 4.27E-07 | 2.65E-06 | 1.21E-14 | 2.65E-06 |
| Ru-103 (c) | 1.63E-06 | 6.40E-04 | 3.56E-04 | 1.45E-03 |

| Radionuclide | $CF_3$ (a) Ambient dose rate conversion factor for deposition [(mSv/h)/(kBq/m²)] | $CF_4$ (b) Long term dose conversion factor for deposition [(mSv/kBq/m²)] | | |
|---|---|---|---|---|
| | | 1st Month | Subsequent Month | Lifetime (50 Year) |
| Ru-106 + Rh-106 | 7.48E-07 | 4.24E-04 | 3.79E-04 | 4.80E-03 |
| Rh-106 | 7.48E-07 | NC | NC | NC |
| Sb-127 | 2.38E-06 | 2.26E-04 | 1.14E-06 | 2.28E-04 |
| Sb-129 (c) | 4.87E-06 | 2.30E-05 | 4.88E-08 | 2.31E-05 |
| Te-127 | 1.83E-08 | 1.81E-07 | 1.81E-07 | 1.81E-07 |
| Te-127m | 3.99E-08 | 3.40E-05 | 2.67E-05 | 1.60E-04 |
| Te-129 | 2.12E-07 | 2.53E-07 | 9.68E-16 | 2.53E-07 |
| Te-129m | 1.33E-07 | 1.05E-04 | 5.37E-05 | 2.15E-04 |
| Te-131 | 1.45E-06 | 1.16E-06 | 3.83E-08 | 1.20E-06 |
| Te-131m (c) | 4.83E-06 | 1.97E-04 | 3.25E-06 | 2.00E-04 |
| Te-132 (c) | 8.04E-07 | 6.87E-04 | 1.13E-06 | 6.88E-04 |
| I-131 (c) | 1.33E-06 | 2.48E-04 | 1.76E-05 | 2.67E-04 |
| I-132 (c) | 7.80E-06 | 1.85E-05 | 0.00E+00 | 1.85E-05 |
| I-133 (c) | 2.11E-06 | 4.53E-05 | 0.00E+00 | 4.53E-05 |
| I-134 | 8.93E-06 | 8.06E-06 | 0.00E+00 | 8.06E-06 |
| I-135+Xe-135m (c) | 5.40E-06 | 3.70E-05 | 0.00E+00 | 3.70E-05 |
| Cs-134 (c) | 5.36E-06 | 2.66E-03 | 2.45E-03 | 5.12E-03 |
| Cs-136 (c) | 7.37E-06 | 1.87E-03 | 3.63E-04 | 2.32E-03 |
| Cs-137+Ba-137m (c) | 2.07E-06 | 9.94E-04 | 9.37E-04 | 1.25E-01 |
| Cs-138 | 7.73E-06 | NC | NC | NC |
| Ba-137m | 2.07E-06 | NC | NC | NC |
| Ba-140 (c) | 6.35E-07 | 1.98E-03 | 4.36E-03 | 2.52E-03 |
| La-140 (c) | 7.62E-06 | 3.15E-04 | 1.19E-09 | 3.15E-04 |
| Ce-141 (c) | 2.60E-07 | 9.92E-05 | 4.94E-05 | 1.98E-04 |

| **Radionuclide** | **$CF_3$ (a) Ambient dose rate conversion factor for deposition [(mSv/h)/(kBq/m$^2$)]** | **$CF_4$ (b) Long term dose conversion factor for deposition [(mSv/kBq/m$^2$)]** | | |
|---|---|---|---|---|
| | | **1st Month** | **Subsequent Month** | **Lifetime (50 Year)** |
| Ce-144+Pr-144 (c) | 2.01E-07 | 1.46E-04 | 1.29E-04 | 1.38E-03 |
| Pr-144 | 1.33E-07 | 3.97E-08 | 0.00E+00 | 3.97E-08 |
| Pr-144m | 4.59E-08 | 2.22E-08 | 0.00E+00 | 2.22E-08 |
| Th-231 | 6.53E-08 | NC | NC | NC |
| Np-239 (c) | 5.75E-07 | 3.35E-05 | 6.44E-09 | 3.39E-05 |
| Pu-238 (c) | 2.96E-09 | 3.88E-02 | 3.66E-02 | 6.55E+00 |
| Pu-239 | 1.29E-09 | 4.22E-02 | 3.99E-02 | 8.45E+00 |
| Pu-240 | 2.83E-09 | 4.22E-02 | 3.99E-02 | 8.44E+00 |
| Pu-241 (c) | 6.81E-12 | 7.61E-04 | 7.20E-04 | 1.93E-01 |
| Pu-242 | 2.35E-09 | 3.97E-02 | 3.75E-02 | 7.96E+00 |
| Am-241 | 9.70E-08 | 3.45E-02 | 3.26E-02 | 6.68E+00 |

NC Not calculated.

(a) Based on "Dose Conversion for Exposure to Contaminated Ground Surface" factors from EPA93, Table III.3. The effective dose was multiplied by 1.4 to estimate ambient dose rate as recommended by EPA (EPA92). A ground roughness factor of 0.7 was used. The external dose from daughters expected to be in equilibrium is included where noted (e.g., Cs-137 + Ba-137m).

(b) Based on InterRAS [NRC94 and Appendix2] (See Appendix I for description).

(c) Most principle isotopes contributing to the dose from external exposure from deposition for a reactor accident [NRC75].

| *Performed by:* <br> *Sample Analyst* | **PROCEDURE F3** <br> **REVISION OF I-131 AND Cs-137 DEPOSITION CONCENTRATION OIL FOR INGESTION** | *Pg.1 of 3* |
|---|---|---|

**Purpose:**
To recalculate the ingestion operational intervention levels OIL6 and OIL7 (deposition concentrations of marker isotopes I-131 and Cs-137) as defined in Table B3.

**Discussion:**
The OILs are for either food that has been directly contaminated by the deposition or for milk from animals grazing on contaminated ground. These OILs will be used to interpret in-situ measurements of ground deposition of I-131 and Cs-137 (marker isotope) to recalculate the OILs.

Default values were calculated (see Table B3 and B4) based on numerous assumptions about accidents and retention on food. This procedure will use the actual relationship between the food or milk concentrations and the deposition concentration of I-131 or Cs-137.

The mixture of the deposition could vary resulting in different relationships between the deposition concentrations of the marker isotope and food concentrations. In addition the OILs may vary depending on the food type and its preparation before consumption. Therefore the OILs for groups 1,2, 4, and 5 (see table F6) should be evaluated for different locations and food types (e.g., milk, fresh leafy vegetables, corn). Groups 3 and 6 will not be a concern for an LWR accident.

While the OILs may vary with location, time, food type and preparation for practical and human factors reasons only a limited number of OILs should be used for the affected area. Single values should be developed for each major food type (e.g., cows milk, goats milk, leafy vegetables, fruit, other vegetables) that take into account its typical preparation before consumption. These values may require revision with time to reflect decay and weathering.

**Input**
- Food or milk and deposition isotope concentrations from Worksheets D7 and D8; assure samples are taken at same location

**Output**
- Recalculated deposition operational intervention levels for the ingestion of food and milk

**Step 1**
Using Worksheet F3 recalculate OIL6 and OIL7 for both I-131 and Cs-137 for groups 1 and 2 for the OIL for general consumption and for groups 4 and 5 for the OIL for milk.

**Step 1a** - *I-131 as marker isotope in deposition*
Recalculate the deposition concentration of I-131 for restriction of food (OIL 6) using the formula below.

$$OIL6 = GAL_G \times \frac{C_{g,I-131}}{\sum_{I}^{n} C_{G,I}}$$

where:

| | |
|---|---|
| *OIL6* | Operational intervention level for deposition concentration [kBq/m$^2$] of I-131 used to identify where locally produced food (OIL6F) or milk (OIL6M) consumption should be restricted. For goat milk use 1/10 of OIL6M |
| $GAL_G$ | Generic Action Level for group G in Table F6. |
| $C_{g,I-131}$ | Deposition concentration of I-131 [kBq/m$^2$] from Worksheet D7 |
| $C_{G,I}$ | Concentration of each radionuclide *I* in group G in the food sample (see Table F6) [kBq/kg] from Worksheet D8. Assure that: a) the concentration in the milk represents the maximum concentration possible for a cow grazing at that location and b) the food concentrations represent those in the food at time of consumption. Procedure F4 can be used to adjust milk and food concentrations. |
| n | number of measured radionuclides in the isotope group G |

**Step 1b** - *Cs-137 as marker isotope in deposition*
Recalculate the deposition concentration of Cs-137 for restriction of food (OIL7) using the formula below.

$$OIL7 = GAL_G \times \frac{C_{g,Cs-137}}{\sum_{I}^{n} C_{G,I}}$$

where:

| | |
|---|---|
| *OIL7* | Operational intervention level for deposition concentration [kBq/m$^2$] of Cs-137 to identify where locally produced food (OIL7F) or milk (OIL7M) consumption should be restricted. For goat milk use 1/10 of OIL7M. |
| $GAL_G$ | Generic Action Level for group G in Table F6. |
| $C_{g,Cs-137}$ | Deposition concentration of Cs-137 [kBq/m$^2$] from Worksheet D7 |
| $C_{G,I}$ | Concentration of each radionuclide *I* in group G (see Table F6) [kBq/kg] in the food sample from Worksheet D8. Assure that: a) the concentration in the milk represents the maximum concentration possible for a cow grazing at that location and b) the food concentrations represent those in the food at time of consumption. Procedure F4 can be used to adjust milk and food concentrations. |
| *n* | number of measured radionuclides in the isotope group G |

**Step 2**
Prepare a set of recommended OIL for the major food types and provide to the Protective Action Manager.

If extensive food bans could result in shortages, then values of the operational intervention levels for the first week, which are 50 times higher, or the values for the first month, which are 10 times higher, are still reasonable [IAEA94].

TABLE F6 IAEA GENERIC ACTION LEVELS FOR FOOD

| **Foods destined for general consumption** | | |
|---|---|---|
| Isotope group G | Radionuclides | Generic action levels GAL[a] [kBq/kg] |
| 1 | Cs-134, Cs-137, Ru-103, Ru-106, Sr-89, I-131 | 1 |
| 2 | Sr-90 | 0.1 |
| 3[b] | Am-241, Pu-238, Pu-239, Pu-240, Pu-242 | 0.01 |
| **Milk, infant food, and water** | | |
| 4 | Cs-134, Cs-137, Ru-103, Ru-106, Sr-89 | 1 |
| 5 | Sr-90, I-131 | 0.1 |
| 6[b] | Am-241, Pu-238, Pu-239, Pu-240, Pu-242 | 0.001 |

Source: IAEA94

(a) The GAL apply to the sum of the activity of the isotopes in each group independently.

(b) The Pu and Am isotopes should not be important sources of ingestion dose for reactor accidents and their groups (Table F6 Group 3 and 4) need not be considered for LWR reactor accidents.

| Performed by: Sample Analyst | PROCEDURE F4 | Pg. 1 of 8 |
|---|---|---|
| | CALCULATION OF ISOTOPE CONCENTRATIONS IN FOOD | |

**Purpose**
To calculate the contamination levels in food after processing or milk produced by cows grazing on contaminated ground.

**Discussion**
Concentrations of radionuclides in food and milk can be altered by several natural and man-made mechanisms. The concentration of Cs, I and Sr will increase in milk for approximately the first 72 hours following consumption of contaminated feed by cows and goats. Reduction mechanisms include: dilution with uncontaminated food stuff, washing, filtering and radioactive decay.

**Input**
- ► Concentration of radionuclides in food, water or milk samples from Worksheet D8
- ► Time the cows eat contaminated feed (if unknown assume time of release as a default)
- ► Time at which samples of milk were collected

**Output**
- ► Adjusted concentrations in food or milk samples

**Step 1**
Determine maximum concentration of isotope in cows milk using the equation below:

$$C_i^{max} = C_i^{samp} \times cf_i\ (T_{rs})$$

where:

| | |
|---|---|
| $C_i^{max}$ | Projected maximum cow milk isotope concentration after consumption of contaminated feed. |
| $C_i^{samp}$ | Measured cow milk isotope concentration after consumption of contaminated feed. |
| $cf_i\ (T_{rs})$ | Milk concentration conversion factor for isotope I taken from Table F7. |
| $T_{rs}$ | Time the sample was taken after the start of intake of contaminated diet. This can be estimated by the time from the beginning of the release to the time the sample was collected. |

TABLE F7 MILK CONCENTRATION CONVERSION FACTORS

**Discussion**: Factors used to estimate the maximum future concentration in milk for a cow grazing in contaminated ground.

| **Milk Concentration Conversion Factors $cf_i$** | | | |
|---|---|---|---|
| $T_n$ | I-131 | Cs-137 | Sr-90 |
| 12 | 3.0 | 4.0 | 5.3 |
| 24 | 1.7 | 2.0 | 2.5 |
| 36 | 1.1 | 1.6 | 2.1 |
| 48 | 1.0 | 1.3 | 1.6 |
| 60 | 1.0 | 1.2 | 1.4 |
| 72 | 1.0 | 1.1 | 1.3 |
| 84 | 1.0 | 1.1 | 1.2 |
| 96 | 1.0 | 1.0 | 1.1 |
| 108 | 1.0 | 1.0 | 1.0 |

Source: FEMA 87

**Step 2**
If decay or other removal processes are used to decrease the concentration in the milk, food or drinking water calculate the adjusted concentrations. Use the following:

$$C_{I(before)} \times \prod_{j}^{n} RF_{I,J} \times \frac{W(before)}{W\ (after)} = C_{I(after)}$$

where:

*C* Concentration of isotope *I* in food, before and after decay or processing

*RF* Reduction factor is the fraction of the isotope remaining after decay or some removal process before food is released for consumption. The reduction factor for processing, washing, filtering or other treatment should be based on tests conducted before and after the process. The Table F8 provides estimates of the effectiveness of various processes in removing contamination. Using the parameter of reduction factor, it is necessary to take into account change in volume between initial product and prepared foodstuff. This is most important for processing of milk. For example, RF=0.61 for Sr for goat cheese means that 39% of radio strontium is removing from the product during the process of cheese preparation. But with consideration that effective quantity of cheese is 12% from initial volume of milk, radio strontium concentration in cheese will be 5 time higher than its initial concentration in milk (0.61/0.12=5). Accordingly, for estimation of total reduction effect during process of preparation it is necessary to divide parameters of RF to appropriate numbers of effective quantities. Effective quantity is determined as weight of a prepared product divided to weight of an initial product.

| | |
|---|---|
| $\prod_{j}^{n} RF_{i,j}$ | Multiply by all reduction factors that apply ($RF_1$ x $RF_2$ x ... x $RF_n$) |
| W (before) | Weight of the initial product |
| W (after) | Weight of the prepared foodstuff |

The reduction factor for decay is:

$$RF = 0.5^{(T_d / T_{1/2})}$$

where:

| | |
|---|---|
| $T_{1/2}$ | Half life from Appendix 4 |
| $T_d$ | Time food is held up before consumption. |

Note: ensure that $T_d$ and $T_{1/2}$ have the same units!

TABLE F8 REDUCTION FACTORS FOR PROCESSING OR FILTERING for FOOD

**Discussion**: Processing or filtering such as water filtration, washing produce or other preparation or culinary practice remove contamination. The reduction factor is based on measurements of contamination conducted before and after the process. The table below provides estimates of the effectiveness of various processes in removing contamination (IAEA94a).

| Element | Food | Preparation | RF |
|---|---|---|---|
| Iodine | Spinach | washing | 0.8 |
| | | washing and boiling | 0.7 |
| | | rinsing | 0.4 |
| | Leaf lettuce | washing | 0.5 |
| | | rinsing (15 minutes)* | 0.2 |
| | | rinsing (20 hours)* | 0.7 |
| | Cabbage | washing | 0.5 |
| | | outer leaves removing | 0.4 |
| | Cauliflower | peeling | 0.03 |
| | | rinsing (15 minutes)* | 0.3 |
| | | rinsing (20 hours)* | 0.4 |
| | | boiling (15 minutes)* | 0.1 |
| | Green beans | rinsing (15 minutes)* | 0.3 |
| | | rinsing (20 hours)* | 0.7 |
| | | boiling (15 minutes)* | 0.2 |
| | Tomatoes | washing | 0.5 |
| | | boiling | 0.2 |
| | Onions | ends and outer parts removing | 0.2 |
| | | washing | 0.2 |
| | Celery | rinsing (15 minutes)* | 0.5 |
| | | rinsing (20 hours)* | 0.7 |
| | | boiling (15 minutes)* | 0.2 |
| | Peppers | rinsing (15 minutes)* | 0.4 |
| | | boiling (15 minutes)* | 0.3 |
| | Milk | cream | 0.19 |
| | | butter | 0.035 |
| | | boiled butter | 0.2 |
| | | milk powder | 1.0 |

| Element | Food | Preparation | RF |
|---|---|---|---|
| Iodine | Milk | goat cheese | 0.14 |
| | Meat | boiling of meat | 0.6 |
| | | boiling of bones | 0.98 |
| | Fish | boiling | 0.9 |
| | | frying | 0.8 |
| Caesium | Spinach | washing | 0.9 |
| | | washing and boiling | 0.9 |
| | Leaf lettuce | washing | 1.0 |
| | Cabbage | outer leaves removing | 0.9 |
| | | washing | 0.09 |
| | | washing and boiling | 0.7 |
| | Cauliflower | peeling | 0.03 |
| | Green beans | boiling | 0.3 |
| | | salting | 0.4 |
| | Onions | ends and outer parts removing | 0.2 |
| | | washing | 0.3 |
| | Potatoes | peeling | 0.8 |
| | | peeling and boiling | 0.6 |
| | Carrots | peeling | 0.5 |
| | Beets | peeling | 0.7 |
| | | usual preparation after peeling | 0.7 |
| | Cereals | milling in white flour | 0.6 |
| | | milling in bran | 0.7 |
| | Dough flour | baking | 0.9 |
| | Rye | milling and baking | 0.7 |
| | Milk | cream | 0.05 |
| | | butter | 0.01 |
| | | boiled butter | 0.00 |
| | | milk powder | 1.00 |
| | | goat cheese | 0.15 |
| | | jogurt | 0.3 |
| | | whey | 0.9 |
| | Meat | boiling meat | 0.7 |

| Element | Food | Preparation | RF |
|---|---|---|---|
| Caesium | Meat | boiling bones | 0.3 |
| | | frying | 0.8 |
| | | wet salting | 0.7 |
| | | dry salting | 0.8 |
| | | pickling | 0.6 |
| | Fish | boiling | 0.9 |
| | | frying | 0.9 |
| | Mushrooms | cleaning and washing | 0.8 |
| | | boiling with pouring out of the first water | 0.6 |
| | | drying | 0.5 |
| | | frying | 0.3 |
| | | pickling | 0.3 |
| | Berries | washing | 0.9 |
| | | cooking of jam | 0.5 |
| Strontium | Spinach | washing | 0.2 |
| | | washing and boiling | 0.7 |
| | Cabbage | washing | 0.07 |
| | | washing and boiling | 0.3 |
| | Green beans | washing | 0.3 |
| | | salting | 0.4 |
| | Tomatoes | washing and slicing | 0.7 |
| | Onions | peeling, washing and boiling | 0.6 |
| | Potatoes | peeling | 0.9 |
| | | peeling and boiling | 0.8 |
| | | frying | 0.6 |
| | Carrots | scraping, washing and boiling | 0.8 |
| | | peeling | 0.7 |
| | Beets | peeling | 0.8 |
| | Cereals | milling in white flour | 0.6 |
| | | milling in bran | 0.9 |
| | Rye | milling and baking | 0.7 |
| | Rice | polished | 0.1 |
| | Milk | cream | 0.07 |

| Element | Food | Preparation | RF |
|---|---|---|---|
| Strontium | Milk | butter | 0.006 |
| | | boiled butter | 0.002 |
| | | milk powder | 1.0 |
| | | goat cheese | 0.61 |
| | | whey | 0.8 |
| | Meat | boiling meat | 0.5 |
| | | boiling bones | 0.999 |
| | | frying | 0.8 |
| | Fish | boiling | 0.9 |

* Time between contamination of the surface and start of removal process.

TABLE F9 IAEA TOTAL EFFECTIVE DOSE GUIDANCE FOR EMERGENCY WORKERS

| **TASKS** | $E_T^{WG}$ **[mSv]** |
|---|---|
| Type 1:<br>► Life saving actions<br>► Prevention of core damage or given core damage to prevention of a large release. | >500 (a) |
| Type 2:<br>► Prevent serious injury<br>► Avert a large collective dose<br>► Prevent the development of catastrophic conditions<br>► Recovery of reactor safety systems<br>► Off-site ambient dose rate monitoring (gamma dose rate) | < 100 |
| Type 3:<br>► Short term recovery operations<br>► Implement urgent protective actions<br>► Environmental sampling | < 50 |
| Type 4:<br>► Longer term recovery operations<br>► Work not directly connected with an accident | Occupational exposure guidance (IAEA96) |

Source: IAEA96

(a) These dose can be exceeded if justified BUT every effort shall be made to keep dose below this level and certainly below the thresholds for deterministic effects. The workers should be trained on radiation protection and understand the risk they face.

| *Performed by:* <br> *Sample Analyst* | **PROCEDURE F5** <br> **EVALUATION OF FOOD RESTRICTIONS AND REVISION OF FOOD OILS** | *Pg. 1 of 2* |
|---|---|---|

**Purpose**
To determine if concentration levels found in food, drinking water, or milk exceed the IAEA ingestion generic action levels (GALs) and to recalculate OIL8 and OIL9.

**Discussion**
Once the detailed isotopic concentration of food stuff is known, they can be compared with the GALs directly. However, a complete isotopic analysis of all food types is not always practical, or can require considerable time or resources. Once a representative isotopic composition has been obtained by food type, it is possible to calculate operational intervention levels based on a single marker isotope (Cs or I) that take into account the presence of the other isotopes in a GAL group (see Table F6). They are only valid for surface contamination, i.e. they do not account for root uptake by various plants.

While the OILs may vary with location, time, food type and preparation for practical and human factors reasons only a limited number of OILs should be used for the affected area. Single values should be developed for each major food type (e.g., cows milk, goats milk, leafy vegetables, fruit, other vegetables) that take into account its typical preparation before consumption. These values may require revision with time to reflect decay.

**Input**
- ► Concentration of radionuclides in food samples from Worksheet D8
- ► Generic action levels for foodstuffs

**Output**
- ► Ingestion protective actions and/or recalculated OIL8 and OIL9

**Step 1** - *Direct comparison to GALs*
Determine if the contamination in food, water or milk may exceed the GALs.

$$\sum_{i}^{n} C_{G,i} > GAL_G$$

where:

| | |
|---|---|
| $C_{G,i}$ | Isotope concentration in sample of each isotope *I* from group G from Worksheet D8 . Ensure that the food concentrations represent those in the food at time of consumption. Procedure F4 can be used to adjust food concentrations. |
| $GAL_G$ | Generic Action Level for group G from Table F6 [kBq/kg] |
| $n$ | number of measured radionuclides in food, milk or water in the isotope group G |

If the sum for concerned food is greater than corresponding GAL it indicates that the levels for restriction of food have been exceeded.

**Step 2**
Using Worksheet F4 recalculate the operational intervention levels for marker isotope concentrations in food, water or milk samples. Use groups 1 and 2 for the OIL for general consumption and groups 4 and 5 for the OIL for milk.

**Step 2a** - *I-131 as marker isotope in food*
Recalculate OIL8 for I-131 using the formula below.

$$OIL8 = GAL_G \times \frac{C_{f,I\text{-}131}}{\sum_{I}^{n} C_{G,I}}$$

where:

| | |
|---|---|
| *OIL8* | Operational intervention level for activity concentration in food (OIL8F) milk or water (OIL8M) for I-131 [kBq/kg] |
| $C_{G,I}$ | Isotope concentration in the representative food sample of each isotope *I* in group G from Worksheet D8 [kBq/kg]. |
| $C_{f,I\text{-}131}$ | Isotope concentration of I-131 in representative food sample from Worksheet D8 [kBq/kg] |
| $GAL_G$ | Generic Action Levels for group G from Table F6 [kBq/kg] |

**Step 2b** - *Cs-137 as marker isotope in food*
Recalculate OIL9 for Cs-137 using the formula below.

$$OIL9 = GAL_G \times \frac{C_{f,Cs\text{-}137}}{\sum_{I}^{n} C_{G,I}}$$

where:

| | |
|---|---|
| *OIL9* | Operational intervention level for activity concentration in food (OIL9F) and milk or water (OIL9M) for Cs-137 [kBq/kg]. |
| $C_{G,I}$ | Isotope concentration in representative food sample of isotope *I* for each isotope in group G from Worksheet D8 [kBq/kg] |
| $C_{f,Cs\text{-}137}$ | Isotope concentration of Cs-137 in representative food sample from Worksheet D8 [kBq/kg] |
| $GAL_G$ | Generic Action Levels for group G from Table F6 [kBq/kg] |

**Step 3**
Prepare a set of recommended OIL for the major food types and provide to the Protective Action Manager.

If extensive food bans could result in shortages, then values of the operational intervention levels for the first week, which are 50 times higher, or the values for the first month, which are 10 times higher, are still reasonable [IAEA94].

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# WORKSHEETS

Caution: The worksheets in this section must be revised to reflect local and plant conditions for which they will be applied.

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| *Performed by:*<br><br>*Accident Assessment Manager* | **WORKSHEET O1**<br><br>**RESPONSE ORGANIZATION ASSIGNMENT** | *No:*________ |
|---|---|---|

Prepared by: ____________________ (full name)    Date: ________

Provide copies to:    Time: ________

☐ Assigned personnel

☐ Off-site officials

---

| Position | Person assigned | Signature |
|---|---|---|
| Nuclear Condition Assessment Manager | | |
| Protective Action Manager | | |
| Radiation Protection Manager | | |
| Environmental Analyst | | |
| Projection Analyst | | |
| Sample Analyst | | |

**Remarks:**

**Signature**: ________________

| *Performed by:*<br><br>*Nuclear Condition Assessment Manager* | **WORKSHEET A1**<br><br>**PLANT CONDITION ASSESSMENT** | *No:*__________ |
|---|---|---|

Prepared by: ______________________________ (full name) Date: __________

Provide copies to: Time: __________

☐ Accident Assessment Manager ☐ Projection Analyst

☐ Protective Action Manager ☐ Environmental Analyst

---

Description of Accident Conditions:

| |
|---|
| |

**From Procedure A1**

**Class:** General Emergency ☐ Site Area Emergency ☐ Alert ☐

**From Procedure A2**

**Core State:** Normal ☐ Spike ☐ Gap release ☐ Core melt ☐

**Spent Fuel Damage State:** Gap release ☐

**From Procedure A3**

Potential or Actual Release Routes and Conditions

**Routes:**

Release from the containment ☐ Containment by-pass under dry conditions ☐

Containment by-pass under wet conditions ☐ Release from the spent fuel pool ☐

**Conditions:**

Holdup Time:

< 2 h ☐ 2-12 h ☐ > 12 h ☐

Reduced release:

Yes ☐ No ☐

Leak Rate: __________ Release Duration: __________

**Signature:** ________________

| *Performed by:*<br><br>*Protective Action Manager* | **WORKSHEET B1**<br><br>**EVACUATION, THYROID BLOCKING/ SHELTER and RELOCATION MAP** | *No:*_________ |
|---|---|---|

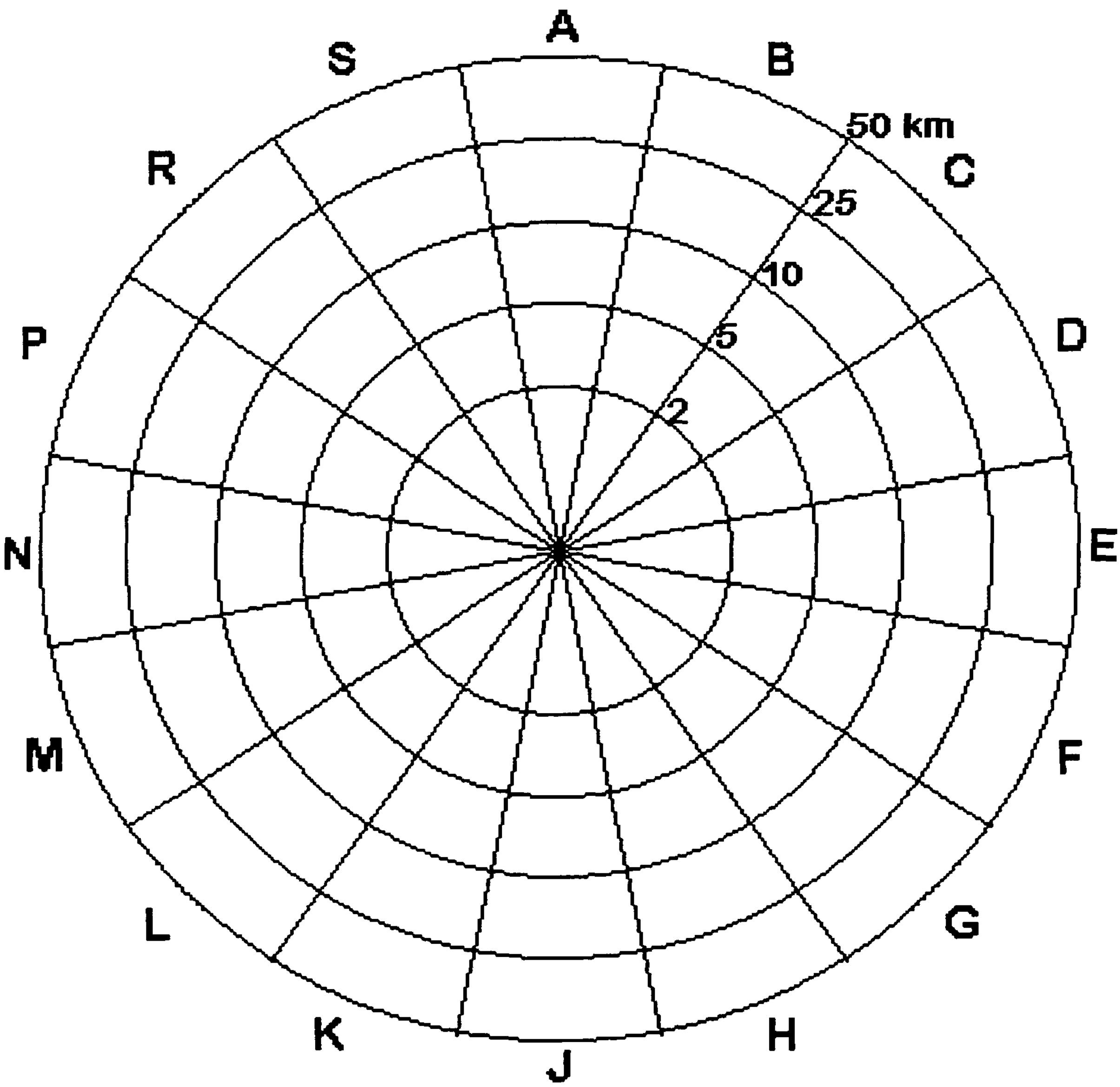
Prepared by: ____________________________ Date: _________

(full name)

Provide copies to: Time: _________

☐ Accident Assessment Manager ☐ Radiation Protection Manager

☐ Off-site officials




| | | | |
|---|---|---|---|
| E | Evacuation | ☐ recommended | ☐ implemented |
| T | Thyroid blocking/shelter | ☐ recommended | ☐ implemented |
| R | Relocation | ☐ recommended | ☐ implemented |

**Remarks:**

**Signature:** _______________

| *Performed by:*<br><br>*Protective Action Manager* | **WORKSHEET B2**<br><br>**FOOD EVALUATION AND RESTRICTION MAP** | *No:* ________ |
|---|---|---|

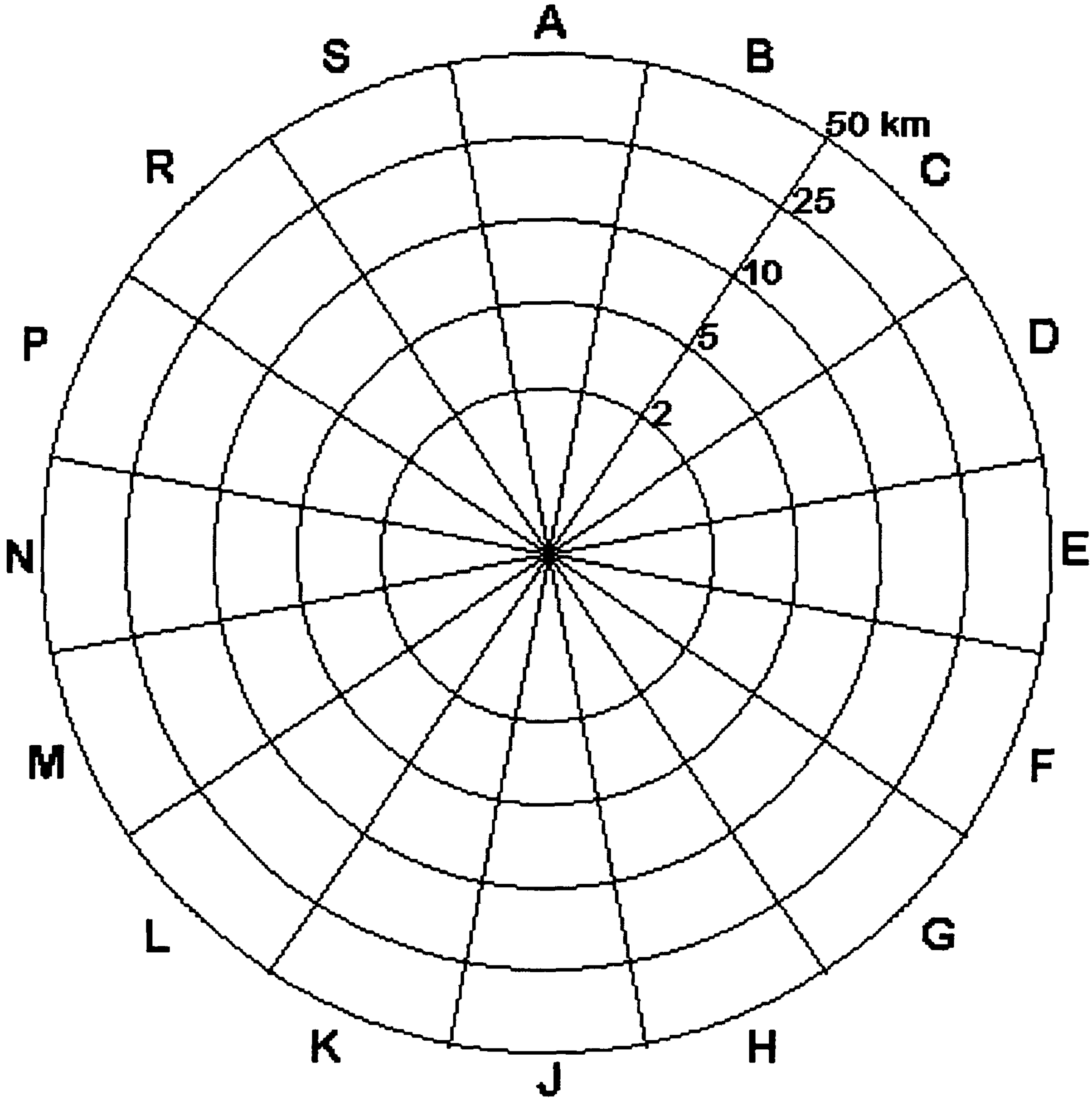
Prepared by: ______________________________ Date: __________

(full name)

Provide copies to: Time: __________

☐ Accident Assessment Manager ☐ Radiation Protection Manager

☐ Off-site officials ☐ Environmental Analyst




F Food restrictions ☐ recommended ☐ implemented

**Remarks:**

**Signature:** ______________

| *Performed by:* <br><br> *Environmental Analyst* | **WORKSHEET D1** <br><br> **AMBIENT DOSE RATE AROUND THE PLANT** | *No:*__________ |
|---|---|---|

Survey Team: ________________________________ Date: __________

(names)

Provide copies to:

☐ Radiation Protection Manager

☐ Protective Action Manager ☐ Projection Analyst

Survey monitor: ____________________ Weather: ______________

| Sector | Distance [km] | Time | Ambient Dose Rate [mSv/h] | | Remark |
|---|---|---|---|---|---|
| | | | Open Window | Close Window | |
| A | | | | | |
| B | | | | | |
| C | | | | | |
| D | | | | | |
| E | | | | | |
| F | | | | | |
| G | | | | | |
| H | | | | | |
| J | | | | | |
| K | | | | | |
| L | | | | | |
| M | | | | | |
| N | | | | | |
| P | | | | | |
| R | | | | | |
| S | | | | | |

Record the highest ambient dose rate for the opened and closed probe window within each sector, the distance from the plant and the time measurement was taken. These measurements should be made within 1 - 2 km zone around the plant. The maximum acceptable distance is 5 km. If you are using GPS record also latitude and longitude.

**CAUTION:** In the case of instruments which do not use SI units use correct transformation.: 1R/h ≈ 10 mSv/h

**Remarks:**

**Team Leader Signature:** ______________

| *Performed by:*<br><br>*Environmental Analyst* | **WORKSHEET D2**<br><br>**NEAR-FIELD AMBIENT DOSE RATE MAP [mSv/h]** | *No:*_________ |
|---|---|---|

Prepared by: ______________________________ Date: __________

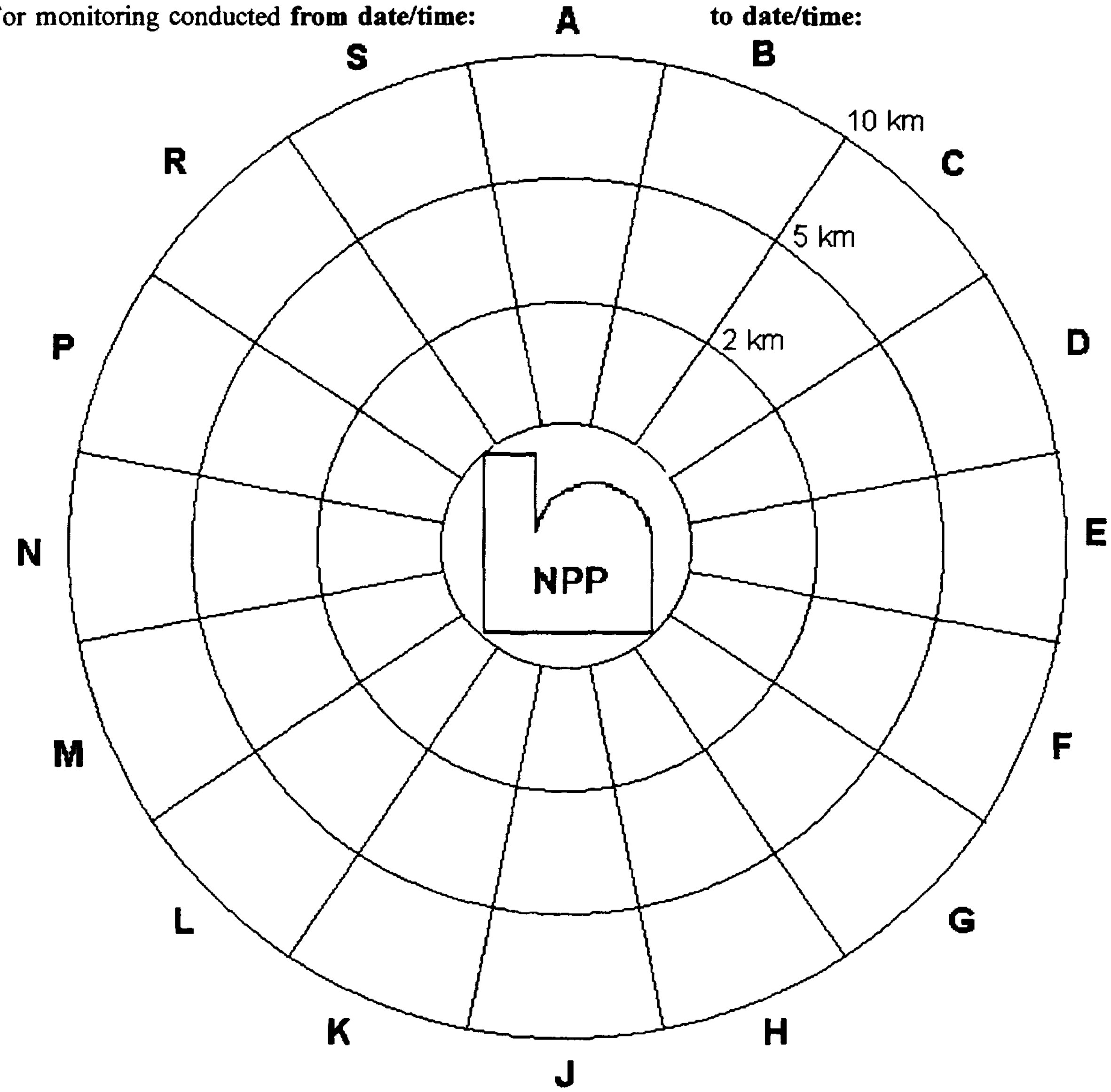
(full name)

Provide copies to: Time: __________

☐ Accident Assessment Manager ☐ Radiation Protection Manager

☐ Protective Action Manager ☐ Projection Analyst

For monitoring conducted **from date/time:** **to date/time:**




**Instructions:** Show highest confirmed reading for each sector monitored during this period.

Readings do not exceed natural background: **B**

**Signature:** ______________

| *Performed by:*<br><br>*Environmental Analyst* | **WORKSHEET D3**<br><br>**FAR-FIELD AMBIENT DOSE RATE MAP [mSv/h]** | *No:*________ |
|---|---|---|

Prepared by: ______________________________ (full name)

Date: __________

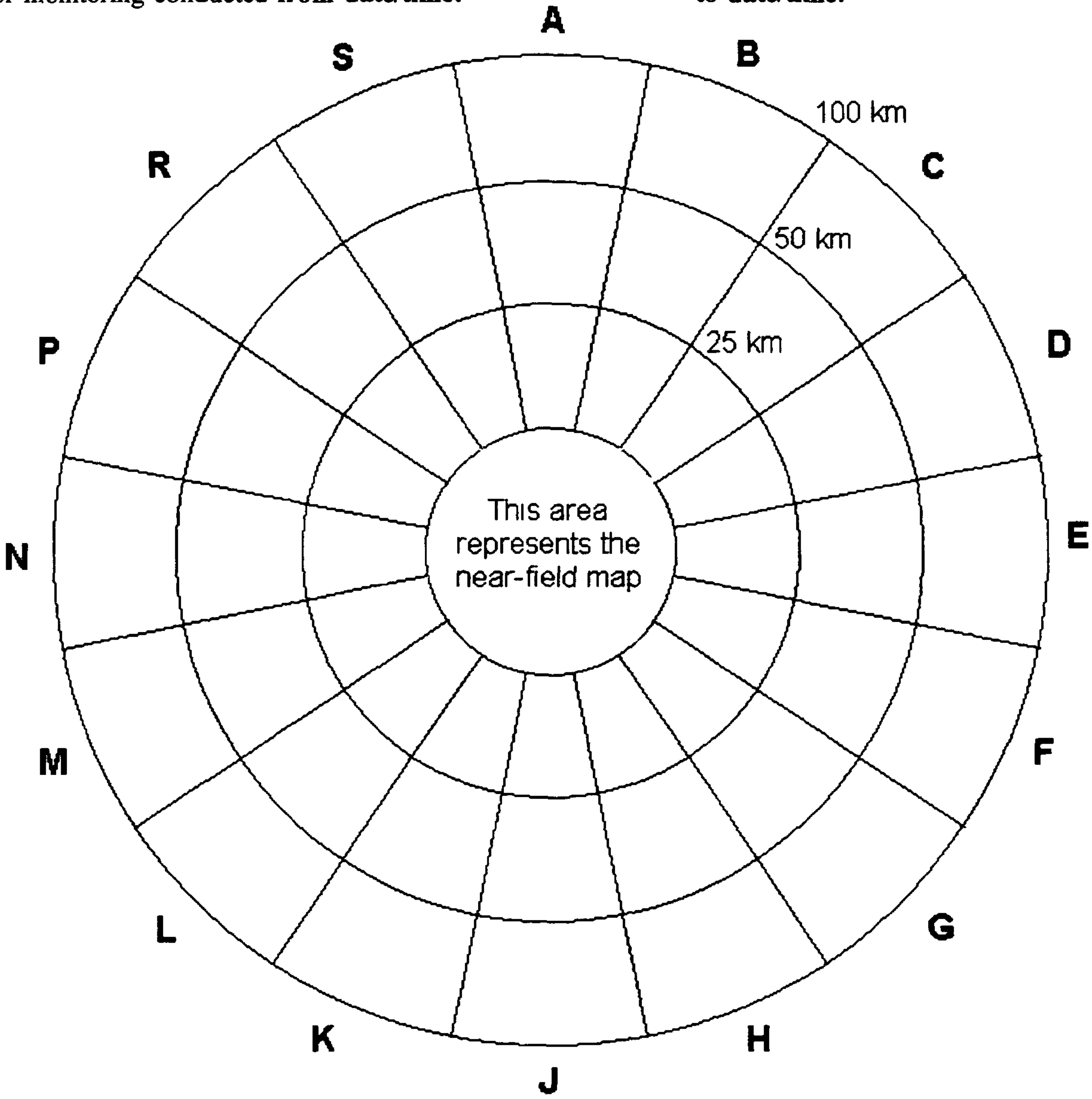
Provide copies to:

Time: __________

☐ Accident Assessment Manager ☐ Radiation Protection Manager

☐ Protective Action Manager ☐ Projection Analyst

For monitoring conducted **from date/time:** **to date/time:**




**Instructions:** Show highest confirmed reading for each sector monitored during this period.

Readings do not exceed natural background: B

**Signature:** ________________

| *Performed by:* <br> *Sample Analyst* | **WORKSHEET D4** <br> **RESULTS FROM THE AIR SAMPLE ANALYSIS** | *No:*________ |
|---|---|---|

Prepared by: ________________________ Date: ________
(full name)

Provide copies to: Time: ________

☐ Radiation Protection Manager ☐ Environmental Analyst

☐ Protective Action Manager ☐ Projection Analyst

---

Measurement performed by: ________________________

Sampling date/time: ________________ Sampling location (sector, distance)*: __________

Filter type: ________________ Measurement date/time: ____________

Date/time for which concentration was calculated: ____________

Average ambient dose rate while sampling: ____________ [mSv/h]

| **Isotope** | **Isotope Concentration** $C_{a,i}$ **[kBq/m³]** | **Isotope** | **Isotope Concentration** $C_{a,i}$ **[kBq/m³]** |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
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| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |

* If you are using GPS record also latitude and longitude.

**Signature:** ________________

| *Performed by:* *Environmental Analyst* | **WORKSHEET D5** **NEAR-FIELD MARKER ISOTOPE DEPOSITION CONCENTRATION MAP** | *No:*__________ |
|---|---|---|

Prepared by: ____________________________ Date: __________
(full name)

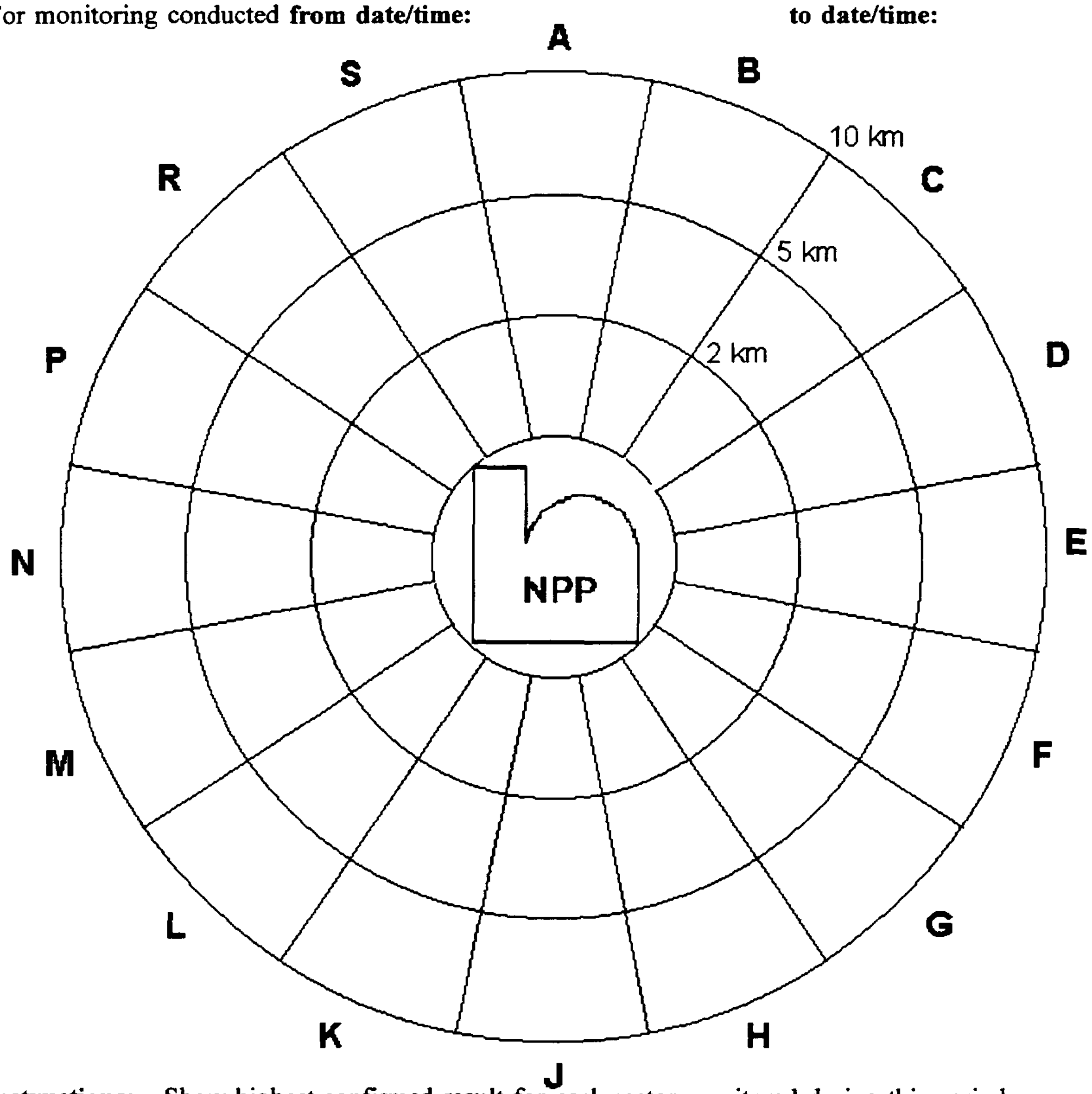
Provide copies to: Time: __________

☐ Accident Assessment Manager ☐ Radiation Protection Manager

☐ Protective Action Manager ☐ Projection Analyst

---

For monitoring conducted **from date/time:** **to date/time:**




**Instructions:** Show highest confirmed result for each sector monitored during this period.

I-131: ☐ I ......... [kBq/m$^2$]

Cs-137: ☐ Cs ...... [kBq/m$^2$]

Natural background: **B**

**Signature:** ________________

| *Performed by:* <br><br> *Environmental Analyst* | **WORKSHEET D6** <br><br> **FAR-FIELD MARKER ISOTOPE DEPOSITION CONCENTRATION MAP** | *No:*_________ |
|---|---|---|

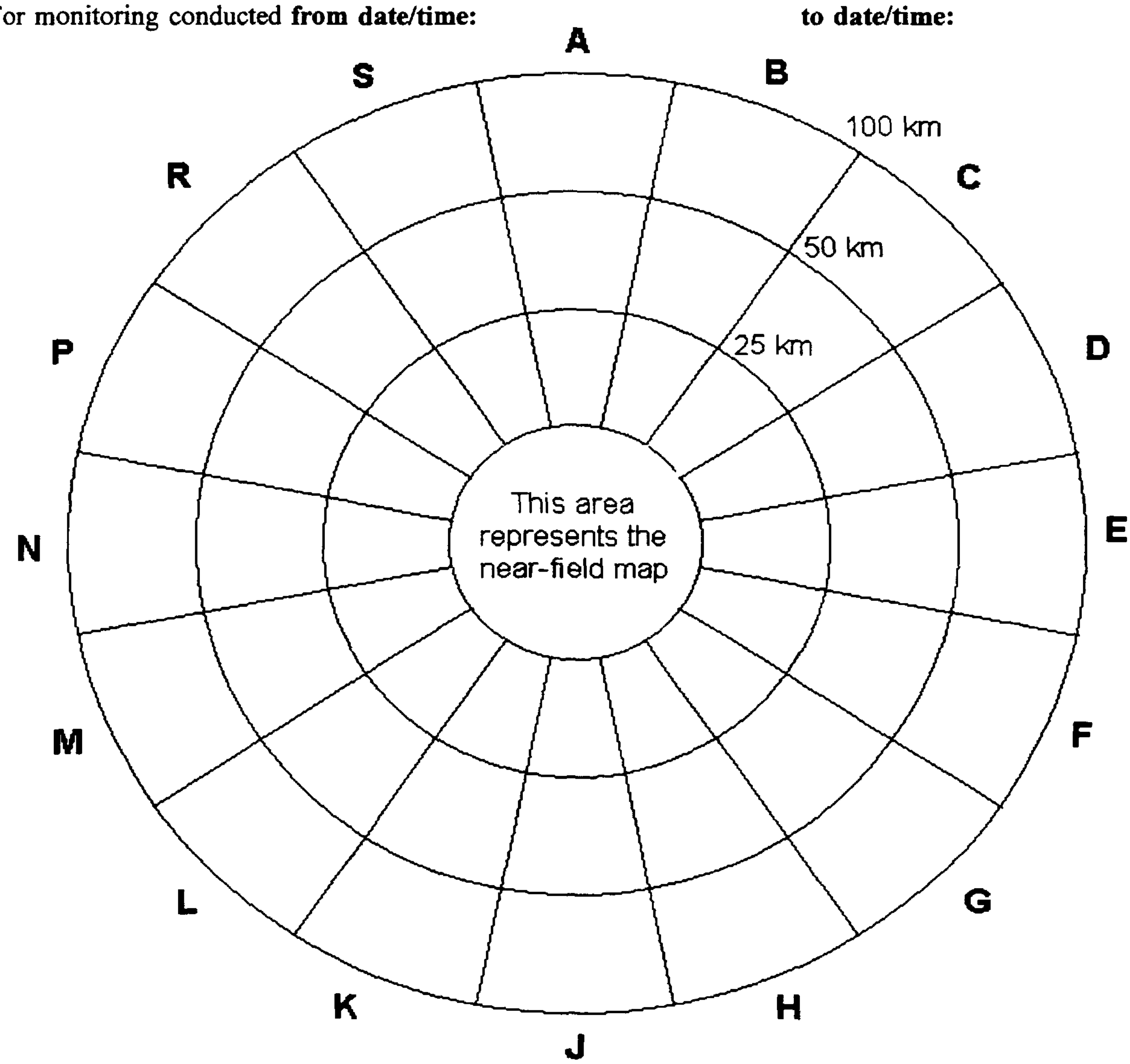
Prepared by: ______________________ Date: __________
(full name)
Time: __________

Provide copies to:

☐ Accident Assessment Manager ☐ Radiation Protection Manager

☐ Protective Action Manager ☐ Projection Analyst

For monitoring conducted **from date/time:** **to date/time:**




**Instructions:** Show highest confirmed result for each sector monitored during this period.

I-131: ☐ I ......... [kBq/m$^2$]
Cs-137: ☐ Cs ...... [kBq/m$^2$]
Natural background: **B**

**Signature:** ______________

| *Performed by:* <br> *Sample Analyst* | **WORKSHEET D7** <br> **RESULTS FROM THE DEPOSITION MIX ANALYSIS** | *No:*________ |
|---|---|---|

Prepared by: ________________________ Date: ________

(full name)

Provide copies to: Time: ________

☐ Radiation Protection Manager ☐ Environmental Analyst

☐ Protective Action Manager ☐ Projection Analyst

---

*Measurement method* In-situ gamma ☐ Sampling and analysis ☐

Measurement performed by:__________ In-situ measurement/sampling date/time: ________
In-situ measurement/sampling location (sector, distance)*: __________________
Sample type: ____________________ Sample Code or No.: __________
Laboratory measurement date/time: ______________
Average ambient dose rate at sampling location: __________ [mSv/h]

| Isotope | Isotope Concentration $C_{g,i}$ [kBq/m²] | Isotope | Isotope Concentration $C_{g,i}$ [kBq/m²] |
|---|---|---|---|
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* If you are using GPS record also latitude and longitude.

**Signature:** ________________________

| *Performed by:* <br> *Sample Analyst* | **WORKSHEET D8** <br> **RESULTS FROM THE FOOD SAMPLE ANALYSIS** | *No:*_________ |
|---|---|---|

Prepared by: ______________________________ Date: __________

(full name)

Provide copies to: Time: __________

☐ Radiation Protection Manager ☐ Environmental Analyst

☐ Protective Action Manager ☐ Projection Analyst

---

Measurement performed by: ______________________________

Sampling date/time: ____________________ Sampling location (sector, distance)*: ____________

Food (sample) type: ____________________ Sample Code or No.: ______________

Measurement date/time: ____________________

Date/time for which concentration was calculated: _______________

Average ambient dose rate at sampling location: _______________ [mSv/h]

| **Isotope** | **Isotope Concentration** <br> $C_f$ <br> **[kBq/kg]** | **Isotope** | **Isotope Concentration** <br> $C_f$ <br> **[kBq/kg]** |
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* If you are using GPS record also latitude and longitude.

**Signature:** ________________________

| *Performed by:* <br> *Projection Analyst* | **WORKSHEET E1** <br> **PROJECTED PROTECTIVE ACTION DISTANCES** | *No:*__________ |
|---|---|---|

Prepared by: ______________________________ Date: __________

(full name)

Time: __________

Provide copies to:

- ☐ Accident Assessment Manager
- ☐ Radiation Protection Manager
- ☐ Protective Action Manager
- ☐ Environmental Analyst

## PROJECTED DISTANCES BASED ON PLANT CONDITIONS: WORST CASE

*Plant Condition Summary*

*Core/spent fuel damage state*__________
*Release route*__________
*Release conditions*__________
Leak rate__________
Holdup time: __________
Weather conditions __________

Description of Projections

## PROJECTED DISTANCES BASED ON PLANT CONDITIONS: MOST LIKELY CASE

*Plant Condition Summary*

*Core/spent fuel damage state*__________
*Release route*__________
*Release conditions*__________
Leak rate__________
Holdup time:__________
Weather conditions __________

Description of Projections

## PROJECTED DISTANCES BASED ON CLOSE-IN (1 to 2 km) AMBIENT DOSE RATES

Weather conditions __________

Based on measurement results given in Worksheet __________

Description of Projections

## PROJECTED DISTANCES BASED ON AMBIENT DOSE RATES FROM DEPOSITION

Weather conditions __________

Based on measurement results given in Worksheet __________

Description of Projections

**Signature:** __________

| *Performed by:* <br> *Sample Analyst* | **WORKSHEET F1** <br> **REVISION OF PLUME EXPOSURE OIL1 AND OIL2 AND EMERGENCY WORKER TURN BACK GUIDANCE** | *No:*__________ |
|---|---|---|

Prepared by: ______________________________ Date: __________

(full name)

Provide copies to: Time: __________

☐ Radiation Protection Manager ☐ Environmental Analyst

☐ Protective Action Manager ☐ Projection Analyst

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Average ambient dose rate at sampling location: _______________ [mSv/h]

Measured data from Worksheet D4 / No: _______________

| **Isotope** | $C_{a,i}$ **[kBq/m$^3$]** | $CF_1$ **[(mSv/h)/(kBq/m$^3$)]** | $CF_2$ **[(mSv)/(kBq/m$^3$)]** | $C_{a,i}$ **x** $CF_1$ **[mSv/h]** | $C_{a,i}$ **x** $CF_2$ **[mSv]** |
|---|---|---|---|---|---|
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| **$GIL_e$ = mSv $GIL_{dry}$ = mSv $T_e$ = h** | | | $\Sigma$ | $\dot{H}_{dry}$ | $\dot{E}_{inh}$ |

$R_1 = \frac{\dot{E}_{inh}}{\dot{H}^*} + 1 =$ $OIL1 = \frac{GIL_e}{R_1 \times T_e} =$ **mSv/h**

**Action type:** $E_T^{WG} =$ **mSv** $EWG = E_T^{WG} \times \frac{5}{R_1} =$ **mSv**

$R_2 = \frac{\dot{H}_{dry}}{\dot{H}^*} =$ $OIL2 = \frac{GIL_{dry}}{R_2 \times T_e} =$ **mSv/h**

**Recommendation:**

☐ Accept new values ☐ Use old values

**Signature:** ________________________

| *Performed by:* *Sample Analyst* | **WORKSHEET F2** **REVISION OF DEPOSITION EXPOSURE OIL4** | *No:*________ |
|---|---|---|

Prepared by: ______________________________ Date: __________
(full name)

Provide copies to: Time: __________

☐ Radiation Protection Manager ☐ Environmental Analyst

☐ Protective Action Manager ☐ Projection Analyst

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Measured data from Worksheet D7 / No: __________

| **Isotope** | $C_{g,i}$ **[kBq/m²]** | $CF_3$ **[(mSv/h)/(kBq/m²)]** | $CF_4$ **Period:**______ **[(mSv)/(kBq/m²)]** | $C_{g,i}$ **x** $CF_3$ **[mSv/h]** | $C_{g,i}$ **x** $CF_4$ **[mSv]** |
|---|---|---|---|---|---|
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| | | | | | |
| **$GIL_r$ = mSv SF = OF =** | | | $\sum$ | **A** | **B** |
| $WR = \frac{A}{B} =$ $h^{-1}$ | | $OIL4 = \frac{GIL_r \times WR}{(SF \times OF) + (1 - OF)} =$ | | | **mSv/h** |

**Recommendation:**

☐ Accept new value ☐ Use old value

**Signature:** ______________

| *Performed by:* *Sample Analyst* | **WORKSHEET F3** **EVALUATION OF FOOD RESTRICTIONS AND REVISION OF FOOD OIL6 and OIL7** | *No:*________ |
|---|---|---|

Prepared by: ________________________ (full name) Date: ________

Provide copies to: Time: ________

☐ Radiation Protection Manager ☐ Environmental Analyst

☐ Protective Action Manager ☐ Projection Analyst

---

Food type: ______________ Sampling location: ______________

Sampling date: ______________

Measured data from Worksheet D7 / No: ____________

Measured data from Worksheet D8 / No: ____________

| | **Foods for general consumption** | | | **Milk, infant foods, drinking water** | | |
|---|---|---|---|---|---|---|
| | **Group 1** | **Group 2** | **Group 3** | **Group 4** | **Group 5** | **Group 6** |
| **Isotope concentration in food samples** $C_{G,I}$ **[kBq/kg]** | Cs-134 | Sr-90 | Am-241 | Cs-134 | Sr-90 | Am-241 |
| | Cs-137 | | Pu-238 | Cs-137 | I-131 | Pu-238 |
| | Ru-103 | | Pu-239 | Ru-103 | | Pu-239 |
| | Ru-106 | | Pu-240 | Ru-106 | | Pu-240 |
| | Sr-89 | | Pu-241 | Sr-89 | | Pu-241 |
| | I-131 | | | | | |
| $A_G = \Sigma C_{G,I}$ | | | | | | |
| $GAL_G$ | 1 | 0.1 | 0.01 | 1 | 0.1 | 0.001 |
| **If $A_G$ greater than $GAL_G$, recommend food restrictions** | | | | | | |
| $OIL6F = GAL_G \times \frac{C_{g,I\text{-}131}}{A_G} =$ kBq/m$^2$ <br> $OIL7F = GAL_G \times \frac{C_{g,Cs\text{-}137}}{A_G} =$ kBq/m$^2$ | | | | $OIL6M = GAL_G \times \frac{C_{g,I\text{-}131}}{A_G} =$ <br> $OIL7M = GAL_G \times \frac{C_{g,Cs\text{-}137}}{A_G} =$ | | |

**Recommendation:**

☐ Accept new values ☐ Use old values

**Signature:** ____________________

| *Performed by:* <br> *Sample Analyst* | **WORKSHEET F4** <br> **EVALUATION OF FOOD RESTRICTIONS AND REVISION OF FOOD OIL8 and OIL9** | *No:*__________ |
|---|---|---|

Prepared by: ______________________________ Date: __________

(full name)

Provide copies to: Time: __________

☐ Radiation Protection Manager ☐ Environmental Analyst

☐ Protective Action Manager ☐ Projection Analyst

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Food type: ___________________ Sampling location: ____________________

Sampling date: _________________

Measured data from Worksheet D8 / No: _______________

| | **Foods for general consumption** | | | **Milk, infant foods, drinking water** | | |
|---|---|---|---|---|---|---|
| | **Group 1** | **Group 2** | **Group 3** | **Group 4** | **Group 5** | **Group 6** |
| **Isotope concentration in food samples** <br> $C_{G,I}$ <br> **[kBq/kg]** | Cs-134 | Sr-90 | Am-241 | Cs-134 | Sr-90 | Am-241 |
| | Cs-137 | | Pu-238 | Cs-137 | I-131 | Pu-238 |
| | Ru-103 | | Pu-239 | Ru-103 | | Pu-239 |
| | Ru-106 | | Pu-240 | Ru-106 | | Pu-240 |
| | Sr-89 | | Pu-241 | Sr-89 | | Pu-241 |
| | I-131 | | | | | |
| $A_G = \Sigma C_{G,I}$ | | | | | | |
| $GAL_G$ | 1 | 0.1 | 0.01 | 1 | 0.1 | 0.001 |
| **If $A_G$ greater than $GAL_G$, recommend food restrictions** | | | | | | |

$$OIL8F = GAL_G \times \frac{C_{f,I\text{-}131}}{A_G} = \quad \text{kBq/kg} \qquad OIL8M = GAL_G \times \frac{C_{f,I\text{-}131}}{A_G} =$$

$$OIL9F = GAL_G \times \frac{C_{f,Cs\text{-}137}}{A_G} = \quad \text{kBq/kg} \qquad OIL9M = GAL_G \times \frac{C_{f,Cs\text{-}137}}{A_G} =$$

**Recommendation:**

☐ Accept new values ☐ Use old values

**Signature:** __________________________

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# APPENDICES

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# Appendix I

# ASSUMPTIONS

## Section A

### *Procedure A1*

*Classification*
Based on assumption that releases sufficient to result in doses in excess of the GILs and GALs (IAEA96) will require damage to the core or large amounts of spent fuel. It follows the basic scheme developed in NRC80 and NUMARC92 where the classes are based on the RISK of core damage in addition to radiological data. The goal is to declare an emergency and take effective action before a release. Some basic assumptions are:
- More than 20 % cladding failure indicated a severe accident beyond the design of the plant
- More than 10% core melt indicated the core may not be coolable even if covered with water.
- At core temperatures above 750°C there is rapid cladding failure due to Zr-$H_2O$ reaction
- Core damage is possible following being uncovered for 15 minutes if their is no injection

*Injection Required to Replace Water Lost By Boiling Due to Decay Heat* (Fig. A2)
The curves are based on a 3000 MW(th) nuclear power plant that has been operated at constant power and then shut down instantaneously. Decay heat is based on ANSI79. If the injected water is about 27°C, the curves are within 5% for pressures 0.1–17.2 MPa (14–2500 psia). The curves are valid within 20% for injected water temperatures up to 100°C. (Source NRC93)

### *Procedure A2a*

*Core Damage vs. Time the Time Core is Uncovered*
The fuel in the core will heat up at 0.5–1.0°C/s immediately after the top of an active core of a PWR is uncovered or 5–10 min after the top of an active core of a BWR is uncovered. These fuel heatup estimates are reasonable within a factor of two if the core is uncovered within a few hours of shutdown (including failure to scram) for a boil-down case (without injection).(Source NRC93)

### *Procedure A2b*

*Containment Monitor Readings*
- Prompt release into the containment of the fission products in the normal coolant, gap, or from core melt defined in the assumptions for procedure E1.
- Uniform mixing in the containment
- The readings are above normal operating background levels in the containment
- Unshielded monitor
- Monitor sees at least 1/2 of the area shown in the figures
- Non noble gas fission products are removed by sprays and pools of water to a location where they can not be seen by the monitor.

Source: NRC93

### *Procedure A2c*

*PWR Coolant Concentrations*

- Prompt release of the fission products in normal coolant, gap, or from core melt as defined in the assumptions for procedure E1.

- For gap and core melt, core was uncovered, damaged and recovered with water
- Releases from the core are uniformly mixed in the coolant
- No dilution from injection.
- 0.5 h after shutdown of a core that has been through at least one refuelling cycle (18 months).
- Normal coolant concentrations from ANSI84
- Coolant concentrations for gap release or core melt were obtained by multiplying the fission product inventory by the core release fractions typical for these core damage states of a 1000 MWe reactor with a primary coolant inventory of 2.5E5 kg.

Source: NRC93

*BWR Coolant Concentrations*

- Prompt release of the fission products in normal coolant, gap, or from core melt as defined in the assumptions for procedure E1.
- For gap and core melt, core was uncovered, damaged and recovered with water
- Releases from the core are uniformly mixed in the reactor coolant system and suppression pool.
- No dilution from injection.
- 0.5 h after shutdown of a core that has been through at least one refuelling cycle (18 months).
- Normal coolant concentrations from ANSI84

Source: NRC93

## Section B

### *Procedure B1*

*Operational Intervention Levels (OILs)*

**OIL1**: Evacuate based on ambient dose rate in plume.

- Person is exposed for 4 hours, time by which a major wind shift would be expected.
- Unsheltered person in the plume
- Mixture of fission products for a core melt as defined in the assumptions for procedure E1.
- Reduction in dose due to partial occupancy in normal home has small impact compared to great uncertainties in dose and dose measurement during a release and therefore need not be considered.
- The shelter GIL (30 mSv averted in 2 days, IAEA96) was evaluated and for reactor accidents and the difference between it and the OIL for evacuation was not significant and if partial occupancy was considered the shelter OIL was higher than the evacuation OIL.
- Calculated using method shown in Procedure F1 with :
  $T_e$ (exposure duration) = 4h
  $R_1$ = 10 (ratio of total effective dose rate to ambient dose rate) based on InterRAS code runs of a core melt unreduced release.
  $GIL_1$ (Generic Intervention Level) for evacuation 50 mSv (IAEA96) averted in one week.

$$OIL1 = \frac{50\ mSv}{4\ h} \times \frac{1}{10} = 1.25\ mSv/h \approx 1\ mSv/h$$

**OIL2**: Take thyroid blocking agent based on ambient dose rates in the plume.

- Person is exposed for 4 hours, time by which a major wind shift would be expected
- Unsheltered person in the plume
- Release of the fission products in the gap or from core melt as defined in the assumptions for procedure E1.
- Calculated using method shown in Procedure F1 with :
  $T_e$ (exposure duration) = 4h
  $R_2$ = 200 (ratio of thyroid dose rate to ambient dose rate) for a core melt unreduced release based on InterRAS code runs.
  $GIL_2$ (Generic Intervention Level for iodine prophylaxis ) dose of 100 mSv (IAEA96) can be averted

$$OIL2 = \frac{100\ mSv}{4\ h} \times \frac{1}{200} = 0.125\ mSv/h \approx 0.1\ mSv/h$$

**OIL3**: Evacuate based on ambient dose rates from deposition.

- No significant inhalation dose from resuspension (valid for reactor accidents)
- Intervention level for evacuation of 50 mSv (IAEA96), 1 week (168 h) exposure period
- About a 50% reduction in dose due to sheltering and partial occupancy and about 50% reduction in dose due to decay (valid for first few days).

$$OIL3 = \frac{50\ mSv}{168\ h} \times \frac{1}{0.5} \times \frac{1}{0.5} = 1\ mSv/h$$

**OIL4**: Relocate based on ambient dose rates from deposition.

- Calculated using InterRAS for a mix of fission products from a core melt release as defined in the assumptions for procedure E1 (FPI X $CRF_{core\ melt}$) four days after shutdown (decay and ingrowth are considered) as shown in the figure IA below (NRC93).
- $GIL_3$ (Generic Intervention Level) for relocation of 30 mSv (IAEA96) can be averted in a 30 day exposure period
- About 50% reduction in dose from deposition due to sheltering and partial occupancy

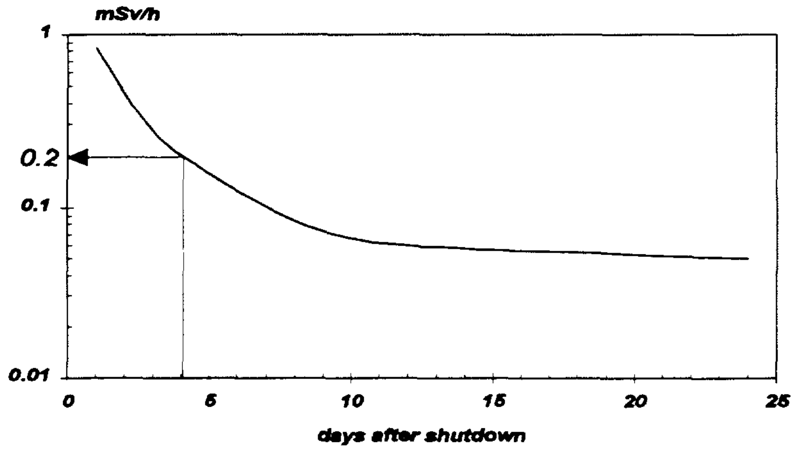


Figure IA: Relocation Deposition Dose Rate OIL for Core Melt Reactor Accident

**OIL5**: Restrict food based on ambient dose rates from deposition.

- Food is directly contaminated or cows grazed on contaminated grass
- Deposition containing fission products consistent with core melt inventories and release fractions (FPI X $CRF_{core\ melt}$) defined in the assumptions for procedure E1.
- Food will be contaminated beyond the IAEA action levels for restricting consumption anywhere the dose rates from deposition are a fraction of background (NRC93)
- The operational intervention level should be clearly higher than background (assumed 100 nSv/h), therefore the OIL5 was set to 1 μSv/h

**OIL6 and 7**: Restrict food or milk in area indicated based on ground deposition

- Food is directly contaminated or cows are grazing on contaminated grass
- Calculated using the formula below assuming all the iodine and particulate deposit in the same proportion as released.

**Food for general consumption (local produce)**

*I-131 as marker isotope*:

$$OIL6F = \frac{GAL_{G=1} \times Y}{r \times RF} \times \frac{C_{g,I\text{-}131,core\ melt}}{\sum_{i}^{n} C_{i,G=1,\ core\ melt}}$$

*Cs-137 as marker isotope*:

$$OIL7F = \frac{GAL_{G=1} \times Y}{r \times RF} \times \frac{C_{g,Cs\text{-}137,core\ melt}}{\sum_{i}^{n} C_{i,G=1,\ core\ melt}}$$

**Cows Milk**

*I-131 as marker isotope*:

$$OIL6M = \frac{GAL_{G=5} \times Y}{U_{cow} \times r \times f_f} \times \frac{C_{g,I\text{-}131,core\ melt}}{\sum_{i}^{n} (C_{i,G=5,core\ melt} \times f_{m,i})}$$

*Cs-137 as marker isotope:*

$$OIL7M = \frac{GAL_{G=4} \times Y}{U_{cow} \times r \times f_f} \times \frac{C_{g,Cs\text{-}137,core\ melt}}{\sum_{i}^{n} (C_{i,G=4,core\ melt} \times f_{m,i})}$$

where:

| | |
|---|---|
| Y | productivity; assume 2 kg/m² (NRC77) |
| r | fraction of deposition that is retained on the crop or grass eaten by grazing animals; assume 0.2 (NRC77) |
| RF | Reduction Factor is the fraction of the contamination remaining after decay or some process used to reduce the contamination before food is released for consumption; assume 1 |
| $U_{COW}$ | Cow consumption; assume 56 kg/day fresh (NRC77) |
| $f_f$ | Fraction of cows diet that is contaminated; assume 1. |
| $f_{m,i}$ | Cow transfer factor for each isotope i from Table IA [d/L] |
| OIL6 | OIL6F or OIL6M, deposition concentration for isotope I-131 indicating where the total concentration of all the isotopes in a group in local produced food or milk may exceed the GAL |
| OIL7 | OIL 7F or OIL7M, deposition concentration for isotope Cs-137 indicating where the total concentration of all the isotopes in a group in locally produced food or milk may exceed the GAL |
| $GAL_G$ | IAEA Generic action level [kBq/kg] for isotope group G (see table F6 ) |
| $C_{g,\ j,\ core\ melt}$ | Amount of marker isotope j ( Cs-137 or I-131) in a release from a core melt accident (assumed FPI X CRF from Procedure E1 assumptions). |
| $C_{i,\ G,\ core\ melt}$ | Amount of each isotope in group G from a core melt accident (assumed FPI X CRF from Procedure E1 assumptions). When calculating OIL7 for Cs-137, it was assumed that the release did not contain any iodine which should be valid for old fission product mixes (spent fuel or core releases > 2 months after shutdown). |

TABLE IA: Cow transfer factors

| **Element** | **Cow transfer factor $f_m$** [(kBq/L)/(kBq/d)] | **Element** | **Cow transfer factor $f_m$** [(kBq/L)/(kBq/d)] |
|---|---|---|---|
| Hydrogen (H) | 1.4E-02 | Antimony (Sb) | 2.0E-05 |
| Manganese (Mn) | 8.4E-05 | Tellurium (Te) | 2.0E-04 |
| Cobalt (Co) | 2.0E-03 | Iodine (I) | 9.9E-03 |
| Krypton (Kr) | 2.0E-02 | Xenon (Xe) | NC |
| Rubidium (Rb) | 1.2E-02 | Cesium (Cs) | 7.1E-03 |
| Strontium (Sr) | 1.4E-03 | Barium (Ba) | NC |
| Yttrium (Y) | 2.0E-05 | Lanthanum (La) | NC |
| Zirconium (Zr) | 8.0E-02 | Cerium (Ce) | NC |
| Niobium (Nb) | 2.0E-02 | Praseodymium (Pr) | NC |
| Molybdenum (Mo) | 1.4E-03 | Thorium (Th) | 5.0E-06 |
| Technetium (Tc) | 9.9E-03 | Neptumium (Np) | 5.0E-06 |
| Ruthenium (Ru) | 6.1E-07 | Plutonium (Pu) | 2.7E-09 |

| Element | Cow transfer factor $f_m$ [(kBq/L)/(kBq/d)] | Element | Cow transfer factor $f_m$ [(kBq/L)/(kBq/d)] |
|---|---|---|---|
| Rhodium (Rh) | NC | Americium (Am) | 2.0E-05 |

NC Not calculated
Source: NRC83 Table 5.36

**OIL8** (I-131 in food, water or milk)

- Restrict food or milk of the accident based on food concentration of I-131
- Food or milk is consumed immediately without washing or other process to reduce contamination
- The values are only appropriate if food supply are readily available.
- The values were calculated assuming core melt release mixture (assumed FPI X CRF from Procedure E1 assumptions). OIL8F assumed all the isotopes in group 1 and OIL8M assumed the isotopes in group 5. In both case the I-131 concentration dominated early in accident so the OIL8 is equal to GAL for the I-131 concentration.

**OIL9** (Cs-137 in food, water or milk)

- For the calculation of OIL9F and OIL9M a core melt release mix (assumed FPI X CRF from Procedure E1 assumptions) is assumed without any iodine which should be valid for old fission product mixes (spent fuel or core releases > 2 months after shutdown). The ratio Cs-137 to the total for group 1 (without iodine) is ≈ 0.2. For group 4 the mix in the milk was calculated using the transfer factors in Table AI (FPI X CRF X $f_m$) and the ratio of Cs-137 to the total of group 4 ≈ 0.3.

## Section C

### *Procedure C1*

- Person is exposed for 4 hours, time by which a major wind shift would be expected
- Release of the fission products in the gap or from core melt as defined in the assumptions for procedure E1.
- Unsheltered person in the plume
- Calculated using method shown in Procedure F1 with :
  $R_1$ = 10 (ratio of total effective dose to ambient dose rate) based on InterRAS code runs EWG (Emergency Worker Guidance) from IAEA96.
- If thyroid blocking agent has the total effective dose will be reduced by 50%.

## Section E

### *Procedure E1*

These calculations consider only the plant, release, and atmospheric conditions that have a major (greater than a factor of 10) impact on dose.

*Core and Spent Fuel Conditions*

The amount of fission products assumed to be released is approximately the mean value calculated for a range of core damage accidents. Five different basic core damage states are used:

- **Leakage of normal coolant** following a steam generator tube rupture (SGTR) accident that does not involve core damage.
- **Leakage of spiked coolant** following an SGTR accident that does not involve core damage. Spiked coolant assumes all the non-nobles in the normal coolant increase by a factor of 100 to estimate the maximum spiking sometimes seen with rapid shutdown or depressurization of the primary system.
- A **gap release** assumes that the core is damaged and all fuel pins have failed, releasing the gaseous fission products contained in the fuel pin gap.
- A **core melt release** assumes that the entire core has melted, releasing a mixture of isotopes believed to be representative for most core melt accidents.
- A **spent fuel pool release** assumes the fuel was discharged at least one month ago (> 1 month decay) and the maximum that can be released in the gap.

*Release Routes and Conditions*

For each release route, the mechanisms that will substantially reduce the release are considered (e.g., containment sprays). The effectiveness of the reduction mechanism used is representative for a range of assumptions. Three different release routes are assumed:

- A **release from the containment** assumes a release into the containment which leaks to the atmosphere. The effectiveness of sprays or natural processes (plate-out) can be considered.
- A **containment by-pass under wet conditions** assumes fission products are carried in the coolant by a route that does not go through the containment atmosphere. For core melt and gap it is assumed that the core is uncovered, damaged and recovered. Steam generator partitioning can be considered as a reduction mechanism. The effectiveness of the condenser may also be considered for releases out of the steam-jet air ejector. If the primary system is dry, then the containment bypass under dry condition release route should be used.
- A **containment by-pass under dry conditions** assumes a release through a dry route from the primary system by a route that does not go through the containment atmosphere. Only plate out on pipes and filtering (if established) in the release route can be considered.

*Source Term*

NRC88 contains a full description of the method and NRC93 contains the latest data. Source term assumptions in InterRAS are discussed in Appendix C of NRC94. The steps for calculating the source term is summarized below.

1. Estimate the amount of fission products in the core.
2. Estimate the fraction of the fission product inventory released from the core for a normal coolant, spiked coolant, gap release or core melt.
3. Estimate the fraction of the fission product inventory released from the core that is removed on the way to the environment.
4. Estimate the fraction of the available fission product inventory actually released to the environment.

Source term estimation:

$$SourceTerm_i = FPI_i \times CRF_i \times \prod_{J=1}^{N} RDF_{(i,j)} \times EF_i$$

| | |
|---|---|
| $FPI_i$ | Isotope inventory (Table IB, C, D) |
| $CRF_i$ | Amount of isotope i released out of core/core inventory of isotope i (Table IE) |
| $RDF_{i,j}$ | Fraction of the isotope i activity available for release following reduction mechanism (Tables IF, G) |
| $EF_i$ | Fraction of activity available for release that is released. (Table IH) |

The values used for these factors are contained in the tables below.

TABLE IB: PWR Typical Normal Coolant Concentrations

| Nuclide | Normal Concentration [kBq/g] |
|---|---|
| H-3 | 3.70E+01 |
| Mn-54 | 5.92E-02 |
| Co-58 | 1.70E-01 |
| Co-60 | 1.96E-02 |
| Kr-85 | 1.59E+01 |
| Kr-85m | 5.92E+00 |
| Kr-87 | 5.55E+00 |
| Kr-88 | 1.04E+01 |
| Sr-89 | 5.18E-03 |
| Sr-90 | 4.44E-04 |
| Sr-91 | 3.55E-02 |
| Y-91 | 1.92E-04 |
| Mo-99 | 2.37E-01 |
| Tc-99 | 1.74E-01 |
| Ru-103 | 2.78E-01 |
| Ru-106 | 3.55E+00 |
| Te-129m | 7.03E-03 |
| Te-131m | 5.55E-02 |
| Te-132 | 6.29E-02 |
| Sb-127 | 0.00 |
| Sb-129 | 0.00 |
| I-131 | 1.67E+00 |
| I-132 | 7.77E+00 |
| I-133 | 5.18E+00 |
| I-134 | 1.26E+01 |
| I-135 | 9.62E+00 |
| Xe-131m | 2.70E+01 |
| Xe-133 | 9.62E+01 |
| Xe-133m | 2.59E+00 |
| Xe-135 | 3.15E+01 |
| Xe-138 | 4.44E+00 |
| Cs-134 | 2.63E-01 |
| Cs-136 | 3.22E-02 |
| Cs-137 | 3.48E-01 |
| Ba-140 | 4.81E-01 |
| La-140 | 9.25E-01 |
| Ce-144 | 1.48E-01 |
| Np-239 | 8.14E-02 |

Source: ANSI84

TABLE IC: BWR Typical Normal Coolant Concentrations

| Nuclide | Normal Concentration [kBq/g] |
|---|---|
| H-3 | 3.70E-01 |
| Mn-54 | 2.59E-03 |
| Co-58 | 7.40E-03 |
| Co-60 | 1.48E-02 |
| Kr-85 | 0.00 |
| Kr-85m | 0.00 |
| Kr-87 | 0.00 |
| Kr-88 | 0.00 |
| Sr-89 | 3.70E-03 |
| Sr-90 | 2.59E-04 |
| Sr-91 | 1.48E-01 |
| Y-91 | 1.48E-03 |
| Mo-99 | 7.40E-02 |
| Tc-99 | 7.40E-02 |
| Ru-103 | 7.40E-04 |
| Ru-106 | 1.11E-04 |
| Te-129m | 1.48E-03 |
| Te-131m | 3.70E-03 |
| Te-132 | 3.70E-04 |
| Sb-127 | 0.00E+00 |
| Sb-129 | 0.00E+00 |
| I-131 | 8.14E-02 |
| I-132 | 8.14E-01 |
| I-133 | 5.55E-01 |
| I-134 | 1.59E+00 |
| I-135 | 8.14E-01 |
| Xe-131m | 0.00E+00 |
| Xe-133 | 0.00E+00 |
| Xe-133m | 0.00E+00 |
| Xe-135 | 0.00E+00 |
| Xe-138 | 0.00E+00 |
| Cs-134 | 1.11E-03 |
| Cs-136 | 7.40E-04 |
| Cs-137 | 2.96E-03 |
| Ba-140 | 1.48E-03 |
| La-140 | 1.48E-02 |
| Ce-144 | 1.11E-04 |
| Np-239 | 2.96E-01 |

Source: ANSI84

Table ID: Fission Product Inventory (FPI)[a]

**Discussion:** This lists the fission product (and activation product) inventories assumed to be present in an LWR core about 30 minutes after shutdown. It is assumed that the core is at equilibrium i.e., been operating for at least one fuelling cycle (18 months). This could over-estimate the inventory of long-lived fission products for a new core.

| **Fission Product (I)** | **Inventory [kBq/$MW_e$]** | **Inventory [kBq/(1000$MW_e$)]** |
|---|---|---|
| Kr-85[b] | 2.07E+10 | 2.07E+13 |
| Kr-85m[b] | 8.88E+11 | 8.88E+14 |
| Kr-87[b] | 1.74E+12 | 1.74E+15 |
| Kr-88[b] | 2.52E+12 | 2.52E+15 |
| Rb-86 | 9.62E+08 | 9.62E+11 |
| Sr-89[b] | 3.48E+12 | 3.48E+15 |
| Sr-90[b] | 1.37E+11 | 1.37E+14 |
| Sr-91[b] | 4.07E+12 | 4.07E+15 |
| Y-90 | 1.44E+11 | 1.44E+14 |
| Y-91[b] | 4.44E+12 | 4.44E+15 |
| Zr-95 | 5.55E+12 | 5.55E+15 |
| Zr-97 | 5.55E+12 | 5.55E+15 |
| Nb-95 | 5.55E+12 | 5.55E+15 |
| Mo-99[b] | 5.92E+12 | 5.92E+15 |
| Tc-99m | 5.18E+12 | 5.18E+15 |
| Ru-103[b] | 4.07E+12 | 4.07E+15 |
| Ru-105 | 2.66E+12 | 2.66E+15 |
| Ru-106 | 9.25E+11 | 9.25E+14 |
| Rh-105 | 1.81E+12 | 1.81E+15 |
| Te-127 | 2.18E+11 | 2.18E+14 |
| Te-127m | 4.07E+10 | 4.07E+13 |
| Te-129 | 1.15E+12 | 1.15E+15 |
| Te-129m[b] | 1.96E+11 | 1.96E+14 |
| Te-131m[b] | 4.81E+11 | 4.81E+14 |
| Te-132[b] | 4.44E+12 | 4.44E+15 |
| Sb-127[b] | 2.26E+11 | 2.26E+14 |
| Sb-129[b] | 1.22E+12 | 1.22E+15 |
| I-131[b] | 3.15E+12 | 3.15E+15 |

| **Fission Product (I)** | **Inventory [kBq/MW$_e$]** | **Inventory [kBq/(1000MW$_e$)]** |
|---|---|---|
| I-132[b] | 4.44E+12 | 4.44E+15 |
| I-133[b] | 6.29E+12 | 6.29E+15 |
| I-134[b] | 7.03E+12 | 7.03E+15 |
| I-135[b] | 5.55E+12 | 5.55E+15 |
| Xe-131m[b] | 3.70E+10 | 3.70E+13 |
| Xe-133[b] | 6.29E+12 | 6.29E+15 |
| Xe-133m[b] | 2.22E+11 | 2.22E+14 |
| Xe-135[b] | 1.26E+12 | 1.26E+15 |
| Xe-138[b] | 6.29E+12 | 6.29E+15 |
| Cs-134[b] | 2.78E+11 | 2.78E+14 |
| Cs-136[b] | 1.11E+11 | 1.11E+14 |
| Cs-137[b] | 1.74E+11 | 1.74E+14 |
| Ba-140[b] | 5.92E+12 | 5.92E+15 |
| La-140[b] | 5.92E+12 | 5.92E+15 |
| Ce-141 | 5.55E+12 | 5.55E+15 |
| Ce-143 | 4.81E+12 | 4.81E+15 |
| Ce-144[b] | 3.15E+12 | 3.15E+15 |
| Pr-143 | 4.81E+12 | 4.81E+15 |
| Nd-137 | 2.22E+12 | 2.22E+15 |
| Np-239[b] | 5.92E+13 | 5.92E+16 |
| Pu-238 | 2.11E+09 | 2.11E+12 |
| Pu-239 | 7.77E+08 | 7.77E+11 |
| Pu-240 | 7.77E+08 | 7.77E+11 |
| Pu-241 | 1.26E+11 | 1.26E+14 |
| Am-241 | 6.29E+07 | 6.29E+10 |
| Cm-242 | 1.85E+10 | 1.85E+13 |
| Cm-244 | 8.51E+08 | 8.51E+11 |

Source: NRC75, Table VI-3-1

(a) For end of cycle core, only the fission products with half lives greater than ½ hours.

(b) Fission products to be considered in assessments because they are either a major contributor to early phase dose or are likely to be released (noble gases).

Table IE: Core Release Fractions (CRF)

**Discussion**: This lists the fraction of each element that is assumed to be released from the core for different core damage states. It is assumed that the entire core is in one state. The fractions are mean estimates for the range of core damage accidents.

| **Core Condition** | **Fuel Cladding Temperature** | **Element** | **Core Release Fraction (CRF[a])** |
|---|---|---|---|
| Fuel Pin Cladding Intact - Normal Leakage | 316°C | | See coolant tables IB and IC[b] |
| Spikes resulting from rapid shutdown or depressurization, core remains covered | 316°C | | 100x Normal Coolant[b] |
| Gap Release<br>(Cladding Failure)<br>(uncovered 15-30 min.) | 650 - 1250°C | Xe, Kr<br>I<br>Cs | 0.05<br>0.05<br>0.05 |
| Core Melt<br>(uncovered > 30 min.) | >1650°C | Xe, Kr<br>I, Br<br>Cs, Rb<br>Te, Sb, Se<br>Ba<br>Sr<br>Ce, Np, Pu<br>Ru, Mo, Tc, Rh, Pd<br>La, Y, Pm, Zr, Nd, Eu, Nb, Pr, Sm | 0.95<br>0.35<br>0.25<br>0.15<br>0.04<br>0.03<br>0.01<br>0.008<br>0.002 |

Source:NRC93

(a) $$CRF = \frac{Activity\ (Bq)\ released}{Core\ Inventory(Bq)}$$

(b) Coolant concentration assuming the core is not uncovered. Normal concentration is based on ANSI84. Spikes assume that all the non-noble concentrations are 100 times higher than normal. A 100 times increase is a reasonable upper bound if the core remains covered.

TABLE IF: System Particulate/Aerosol Release Reduction Factors (RDF)

| Reduction Mechanism | RDF Reduction Factor[c] | assumed for in Section E for the following routes and conditions |
|---|---|---|
| Standby Gas Treatment System Filters: | | |
| Dry-low pressure flow | 0.01 | |
| Wet-high pressure flow (blowout) | 1.00 | |
| Other Filters: | | |
| Dry-low pressure flow | 0.01 | Reduced containment dry by-pass |
| Wet-high pressure flow (blowout) | 1.00 | |
| Suppression Pool Scrubbing: | | |
| Slow study flow (decay heat) | | |
| Pool sub-cooled | | |
| 0.5-1.0 metre | 0.50[b] | |
| 1.0-2.0 metres | 0.10[b] | |
| >2.0 metres | 0.05[b] | |
| Pool saturated | 1.00 | |
| Pool bypass | 1.00 | |
| Sprays on | | |
| <1 hour holdup time | 0.03 | Reduced release from the containment |
| 1 to 12-hour holdup time | 0.02 | Reduced release from the containment |
| > 12 hour holdup time | 0.01 | Reduced release from the containment |
| Steam Generator Partitioning (Liquid Release from RCS): | | |
| Partitioned | 0.02 | Reduced containment wet by-pass |
| Not partitioned | 0.50 | Not-reduced containment wet by-pass |
| Air Ejector | 0.02 | |

TABLE IG: Natural Particulate/Aerosol Release Reduction Factors

| Reduction Mechanism | RDF Reduction Factor[c] | assumed for in Section E for the following routes and conditions |
|---|---|---|
| Natural processes (no sprays) | | |
| holdup time: | | |
| <1 hour | 0.75[a] | Not reduced release from the containment and spent fuel pool |
| 1 to 12-hour | 0.36 | Not reduced release from the containment |
| > 12 hour | 0.03 | Not reduced release from the containment |
| Primary System Retention (Plate-out): Bypass accidents only | 0.20[a] | Containment wet by-pass |

Source: NRC88 except where noted:

(a) NRC90

(b) NRC92

(c) $RDF = \dfrac{Activity\ (Bq)\ available\ for\ release\ following\ mechanism}{Activity\ (Bq)\ available\ before\ mechanism}$

TABLE 1H: Escape Fractions (EF)

| Release Route | Escape fraction * |
|---|---|
| Primary containment failure leakage | |
| Typical design leakage: | |
| US PWR - large dry (0.1%/day) | 4E-05 |
| US PWR - subatmospheric (0.1%/day) | 4E-05 |
| US PWR - ice condenser (0.25%/day) | 1E-04 |
| BWRs (0.5%/day) | 2E-04 |
| Failure to isolate (100%/day) | |
| Failure of isolation valve seal | 0.04 |
| Catastrophic failures: | |
| 1-hr puff release | 1.00 |
| Steam generator tube rupture | |
| 1 tube at full pressure (100 $m^3/h$) | 0.35 |
| 1 tube at low-pressure single charging pump flow (10 $m^3/h$)) | 0.03 |

* fraction of containment volume or primary system coolant inventory released in 1 hour.

*Dose Calculation*

Doses are calculated with InterRAS using the following assumptions:

- a ground-level release
- not isolated release location, and
- average meteorological conditions ( 2 m/s and D stability).

Transport and diffusion assumptions in the InterRAS code are discussed in Appendix D of NRC94.

The dose estimates should be within a factor of 10–100 if the plant, release height, and rain conditions are accurately represented. The distances given in the figures were obtained by interpolating between the dose values InterRAS gives, and calculating the distance where the IAEA GIL were exceeded by using the function derived from exponential interpolation. To avoid a fine structure is giving distances only 2, 5, 10, 25 and 50 kilometres were given.

### *Procedure E2*

The values in the figures were obtained by running InterRAS and interpreting the results. The procedure only leads to satisfying results if the ambient dose rate measurements used were taken within this 1.5 - 2.0 kilometre from the release point. see Procedure E1 for a discussion of the source rem assumptions.

### *Procedure E3*

Dose decreases with distance as shown in the formulas ( $\approx \frac{1}{R}$ for no rain and $\approx \frac{1}{R^2}$ with rain).

During Chernobyl this was a reasonable assumption if all the deposition is averaged, but is not valid for local contamination (hot spots).

## Section F

### *Procedure F1*

These OILs are for short duration exposures to the plume (e.g., 4-hours) because of wind shifts. Due to the short exposure periods and great uncertainties in the process of inferring total dose from external dose the comparatively minor dose reduction due to partial occupancy have been ignored. The revision to the operational intervention levels and emergency worker turn back guidance is based on ambient dose to effective dose ratios.

- This is used for extended releases where release conditions and isotopic mix are expected to be constant.
- Unity is added to the ratios as the ratio of the dose from external exposure for 1 hour to the ambient dose rate.
- Calculation method of Table F1:
  Conversion factor $CF_1$ is calculated using:

$$CF_1 = h_{thyroid,50} \times BR \times UCF$$

where

$h_{thyroid,50}$ committed dose equivalent per unit intake from inhalation for the thyroid from EPA88, Table 2.1

$BR$ breathing rate for an adult performing light activity (1.2 $m^3/h$) from ICRP75

$UCF$ units conversion factor ($10^6$ (mSv/kBq)/(Sv/Bq))

Conversion factor $CF_2$ is calculated using:

$$CF_2 = e(g) \times BR \times UCF$$

where

$e(g)$ committed effective dose per unit intake from inhalation for adults (age > 17 y) from IAEA96, Table II - VII

$BR$ breathing rate for an adult performing light activity (1.2 $m^3/h$)from ICRP75

$UCF$ units conversion factor ($10^6$ (mSv/kBq)/(Sv/Bq))

***Procedure F2***

- Calculation method of Table F5:
  Conversion factor $CF_3$ is calculated using:

$$CF_3 = h_E \times GRCF \times UCF \times ADCF$$

where

$h_E$ effective dose equivalent conversion factor for exposure to contaminated ground surface from EPA93, Table III.3

$GRCF$ ground correction factor of 0.7 (1 = smooth plane)

$UCF$ units conversion factor (3.6 x $10^9$ (mSv/h/kBq)/(Sv/s/Bq))

$ADCF$ 1.4 to estimate ambient dose rate from $h_E$.

- Conversion factor $CF_4$ is calculated using InterRAS (Appendix2) runs assuming a ground surface correction factor of 0.7 and a resuspension rate of $10^{-6}$ [IAEA86]. It is the sum of the ground shine dose and the inhalation dose from resuspended material considering decay, ingrowth and weathering.

Conversion factors $CF_3$ and $CF_4$ can be recalculated using InterRAS FM-DOSE. Enter a ground deposition of the radionuclide considered of 1 $kBq/m^2$. If there is a decay product given in the table enter also the ground deposition of the given decay product of 1 $kBq/m^2$.
The Ground Shine given in the "View Early Doses" screen x ADCF is the $CF_3$.
The Total Long Term Dose given in the "View Long Term Dose" screen is the $CF_4$.
There might be minor differences to the values given as some dose conversion factors were updated in the InterRAS program, while writing this document.

***Procedure F3***

- ► Food is directly contaminated
- ► Short term, does not consider long term uptake

### *Procedures F4*

- Table F4 represents the increase in milk concentration after a single contaminating event in areas, where cows or goats are grazing (FEMA87).

### *Procedures F5*

- Food is directly contaminated
- Short term, does not consider long term uptake

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# Appendix II
# InterRAS MODEL
(May, 1997 release)

## INDEX



## 1. INTRODUCTION

The International Radiological Assessment System (InterRAS) is a set of personal computer-based tools. InterRAS Version 1 contains tools to estimate the distance that urgent protective actions may be needed based on nuclear power plant conditions or release rates (ST-DOSE), to estimate early and longer term dose from field measurements of radionuclide concentrations (FM-DOSE), and to compute decay of radionuclides (DECAY). InterRAS was developed for use by personnel who conduct an independent assessment of protective actions. InterRAS Version 1.1 is based on the U.S. NRC's InterRAS Version 2.1 code (NRC94) but was modified to allow assessment a greater range of accidents and to conform to the guidance in the IAEA Basic Safety Standard (IAEA96).

This document provides a brief discussion of how to install, run and modify InterRAS. For a more detailed discussion see InterRAS 2.1 Users Guide (NRC94).

## 2. RUNNING InterRAS

This section presents general information about how to interact with the computer to run InterRAS. It includes

- start up information (Section 2.1)
- specifics on how to use the keyboard and mouse to enter information and make choices (Section 2.2)
- information on how to leave the program (Section 2.3).

Make full use of the on-line help to best understand what InterRAS is doing.

### 2.1. Getting Started

If the program has not yet been installed go to Section 7 or installation instructions.

If you are operating from DOS and not from a menu system, follow the procedures below for starting InterRAS. Users operating from a menu system or some other shell should consult that system's documentation on how to access the InterRAS programs.

If you want to save and restore ST-DOSE and FM-DOSE cases in a directory other than the one in which you have installed InterRAS, you will need to set up a InterRAS21.CFG file. Please see Section 7 for a description of this file.

To start InterRAS, set the default directory to the location where the main programs of InterRAS Version 1.1 were installed, then type **INTERRAS** and press **Enter**. For example, if InterRAS is installed on the C: drive in a sub-directory named INTERRAS, two commands are needed to start the code:

**C:>CD INTERRAS**
**C:\INTERRAS> INTERRAS**

This will start up the InterRAS Version 1.1 program and display text showing the version being run. Press any key or mouse button to continue.

### 2.2. Capabilities

Next the opening InterRAS Version 1.1 menu offers four choices:

- **Source Term to Dose (ST-DOSE)**

The model requires only information that might be available during an emergency. The data required are accident location, either an assessment of plant conditions or an estimated source term, and basic meteorological information. For the source term, you can enter the isotopic concentrations or release rates or, for reactor accidents, compute the release using (1) source term estimation based on plant conditions, (2) a source term based on the containment monitor reading, (3) a release rate and an elemental mix, or (4) a spent fuel or spent fuel pool accident scenario. ST-DOSE should be used to assess the consequences of potential or ongoing releases. This program should not be used to estimate doses based on concentrations measured in the environment. If you have concentrations measured in the environment, you should use the FM-DOSE (Field Measurement To Dose) program..

- **Field Measurement to Dose (FM-DOSE)**

FM-DOSE computes doses starting from isotopic concentrations measured in the air or on the ground. Ground shine, cloud immersion, and inhalation doses are computed. The overhead cloud shine dose is not computed. The computed doses may be viewed on the screen or printed. Both early-phase and intermediate-phase doses are computed. The dose computations and dose factors used in FM-DOSE are the same as those used in ST-DOSE except that the ingrowth of radioactive decay products is included for the intermediate-phase doses in FM-DOSE. This program should not be used to estimate doses based on reactor conditions. If you have information about reactor conditions, you should use the ST-DOSE (Source Term To Dose) program.

- **Decay Calculator**

DECAY computes the activities of radionuclides after an input time for radioactive decay and buildup. It also computes the integrated activities over that time. It uses the same algorithm as in FM-DOSE and ST-DOSE. It does not compute doses. The concentrations computed here may be imported to ST-DOSE using the Import push-button in the Isotopic Concentrations source term option.

- **EXIT / Return to System**

Choose this option if you do not want to proceed with any of the InterRAS tools. It will return you to the system prompt.

The main menu of InterRAS is shown below.

```
                 Models Available in InterRAS Version 1.1


        Select Model: Source Term to Dose (ST-DOSE)

                      Field Measurement to Dose (FM-DOSE)

                      Decay Calculator

                      EXIT / Return to System
```

## 2.3. Getting Around the Program

Interaction with the program is via the keyboard or mouse. You will be guided through the data entry by text on each screen. InterRAS uses several methods to request user input or display information. These methods are:

- menus
- data forms

- help windows
- text windows
- graphics screens.

The functions of the keys and mouse differ according to which method is being used. The functions associated with each of the methods are discussed below. A beep will sound if an inappropriate key has been pressed. For example, a beep will sound if a letter key is entered in a numeric data field. A beep will also sound if a numeric value has been entered that is outside the permitted range. In most cases, a message will be displayed that explains how to correct the error.

### 2.3.1. Menus

Menus present two or more options on a single screen for selecting the next activity. The items appear as a set of words describing actions to be taken or a set of conditions to be used. A choice must be made to continue. The default choice is highlighted when the menu first appears. Pressing the **Enter** key selects the item that is highlighted and exits the menu.

The functions of the keys for menus are as follows:

| | |
|---|---|
| *Arrow Keys* | Move highlighted bar between entries |
| *Ctrl-Home* | Move to first line or choice at top |
| *Ctrl-End* | Move to last line or choice at bottom |
| *Enter* | Choose item that is currently highlighted and exit menu |
| *F1* | Open help window at bottom of screen and display help text |
| *Alt-F1* | Expand an already open help window to use the whole screen. |

A single-letter choice selection is available in addition to moving the highlighted bar to the desired entry. In each menu item, a single character is shown in reverse video or by some other enhancement. Pressing the corresponding letter key will activate that item, just as would highlighting it and pressing **Enter**.

The functions of the mouse for forms are as follows:

Clicking the left mouse button on any choice selects that choice.
Clicking the right mouse button displays the help text for the choice that is currently highlighted.

Error messages and informational messages are displayed on the bottom line of the screen and in special message windows. Understanding these messages is important to running InterRAS correctly.

### 2.3.2. Forms

Forms consist of one or more data input fields, radio buttons, and pushbuttons. In each field you must specify information (such as the date, radionuclide activity, or wind speed). Default values are supplied for all items to be entered. Each data item is validated after you enter it. If the value is out of range, a message appears and you must correct the entry. None of the programs will allow you to enter an alphabetic character in a numeric field. Radio buttons allow you to select one of a list of items. Pushbuttons are similar to menu choices in that they allow you to perform other actions, such as displaying a sub-form or exiting the current form. Pushbuttons appear as black text on a grey background, e.g. ◂ **Calculate** ▸. Unlike menus in which you make a single choice and then proceed, data entered in forms can be modified until the form is completed and you leave the form.

The functions of the keys for forms are as follows:

| | |
|---|---|
| *Arrow Keys* | Move between data entry fields; move within radio button groups; the left and right arrows also move within fields |
| *Home* | Within a field, move to first character of a field |
| *End* | Within a field, move to last character of a field |
| *Ctrl-Home* | Move to first field on the form |
| *Ctrl-End* | Move to last field on the form |
| *Enter* | Accept data entered in the field or radio button group and move to the next field; exit the forms from the last field; Perform the function associated with a pushbutton (e.g., exit a form) |
| *SpaceBar* | Toggles [X] fields on and off |
| *Tab* | Move forward from one field to the next |
| *Shift-Tab* | Move backward from one field to the next |
| *F1* | Open a help window at bottom of screen and display the help text |
| *F2* | Re-display the choice list; within a choice list, the keys function as described for menus |
| *F7* | Same as Tab |
| *F8* | Same as Shift-Tab |
| *Alt-F1* | Expand an already open help window to use the whole screen |
| *F10* | Exit the form. |

Keys for which no functions are defined have no effect on item selection.

Note that the use of the arrow keys or **Tab** and **Shift-Tab**, and *not* **Enter**, is strongly recommended for moving through the data fields on the screens. Note also that the key that you use to move into a field that has a choice list affects the way that field works. If you move into the field using the **Enter** key, the choice list will pop-up automatically. If you move into the field with an arrow or Tab key, the choice list will not appear until you press the **F2** key.

The functions of the mouse for forms are as follows:

Clicking the left mouse button:

on a pushbutton, performs the function associated with it
on a field, makes that field active
on a choice list or radio button group item, selects that item

Double-clicking the left mouse button on a field with a choice list pops-up the list if it is not visible

Clicking the right mouse button causes the help text to appear for the field that is currently active, NOT the field where the mouse is positioned.

After filling in the fields as desired, to leave a form press **F10** or click the left mouse button on the ◂ **Main Menu (F10)** ▸ pushbutton.

### 2.3.3. Help Windows

Help windows provide you with additional information. Help is generally available for each menu item and data field. The functions of the keys for help windows are as follows:

| | |
|---|---|
| *Arrow Keys* | Move text up or down in the window one line at a time |
| *Home* | First, move to the first character of the current line of the text; second, move to the first line of the file; third, move to the first character of the file |
| *End* | First, move to the last character of the current line of the text; second, move to the last line of the file; third, move to the last character of the file |
| *Enter* | Close the text window and return to the previous form |
| *Alt-F1* | Expand an already open help window to use the whole screen |
| *PgUp* | Scroll text up in the window one page at a time |
| *PgDn* | Scroll text down in the window one page at a time. |

The functions of the mouse for help windows are as follows:

Clicking the left mouse button on a help window will close it.

Clicking the left mouse button on any corner of the help window and holding the button down, allows you to resize the window. Move the mouse and release the button when the size is as you want. The help window will remain this size, even if you close and re-open it.

Clicking the left mouse button on the top or bottom border of the help window and holding the button down, allows you to move the help window. Move the mouse and release the button when the window is where you want it.

When a scroll bar appears on the right side of the window, you can use the mouse to scroll the text up and down.

### 2.3.4. Text Windows

Text windows are similar to help windows in appearance, but they display results generated by InterRAS in text form. The functions of the keys for text windows are as follows:

| | |
|---|---|
| *Arrow Keys* | Move text up or down in the window one line at a time |
| *Home* | First, move to the first character of the current line of the text; second, move to the first line of the file; third, move to the first character of the file |
| *End* | First, move to the last character of the current line of the text; second, move to the last line of the file; third, move to the last character of the file |
| *F10* | Close the text window and return to the previous form |
| *PgUp* | Scroll text up in the window one page at a time |
| *PgDn* | Scroll text down in the window one page at a time. |
| *Alt-P* | Prints the graphic being displayed. |

The functions of the mouse for text windows are as follows:

Clicking the left mouse button on the ◂ **Main Menu (F10)** ▸ pushbutton will close it.

Clicking the left mouse button on the ◂ **Print (Alt-P)** ▸ pushbutton will print the entire text that you are viewing, not just the portion visible on the screen.

When a scroll bar appears on the right side of the window, you can use the mouse to scroll the text up and down.

### 2.3.5. Graphics Screens

Graphics screens generally require minimal user interaction.

The functions of the keys for graphics screens are as follows:

| | |
|---|---|
| *Esc* | Exit the graphics screen and return to menus |
| *Enter* | Switch to the alternate display, if one is available. |
| *Alt-P* | Print the graphic |

The functions of the mouse buttons for the graphics screens are as follows:

Clicking the left mouse button will exit the graphics screen and return to menus

Clicking the right mouse button will switch to the alternate display, if one is available.

## 2.4. Running InterRAS Without a Mouse

Section 2 describes how to run InterRAS with a mouse. The following are points to remember from that section, when you are running on a PC that does not have a mouse.

**HELP** Access help by pressing the **F1** key. **Alt-F1** enlarges the help window. **Enter** or **Esc** close the help window.

**MENUS** Make selections from menus by pressing the letter key that is highlighted.

**FORMS** Right and left arrow keys usually move *within* a field. Up and down arrow keys and **Tab** keys move *between* fields. Right and left arrow keys move to the next field only when you are at the far right of left of the field.

Arrow keys only work when there is a field to go to in that direction. For example if you are in a field on the bottom of the screen and then you press the down arrow, nothing will happen. Even if you are at the top of the screen if there is no field below the one you are in, the down arrow will have no effect. If you think that you are stuck in a field, use the **Tab** keys to get out. If that doesn't work, use **Enter**. If neither one works, you have broken something and you will have to re-boot your computer.

Up and down arrows move within a group of radio buttons. You must press **Enter** to exit the group.

**Ctrl-Home** takes you to the first field on a screen. **Ctrl-End** takes you to the last field on a screen.

**F10** exits the screen. Don't use **F10** on menus.

**F2** redisplays a choice list. (This is useful if you make an incorrect choice and want to change it.)

**GRAPHICS** **Enter** switches to the other graphic. **Esc** exits the graphic screen.

### 2.5. Exiting InterRAS

When you exit any InterRAS model, you return to the main InterRAS menu. To exit from this menu and return to the operating system, click the left mouse button on **EXIT / Return to System**, press the X key, or highlight **EXIT / Return to System** and press the **Enter** key.

## 3. MODIFICATIONS TO RASCAL 2.1. TO CREATE InterRAS

InterRAS has been created for analysis of radiological accidents at international power reactors as well as other non-reactor accidents. It is based on the US NRC RASCAL v2.1 codes. Modifications to the calculations include the addition of some radionuclides, the modification of the plant-conditions source term options, and the removal of USA specifics (e.g.,EPA Protective Action Guides (PAGs) calculations) and changing the dose factors, calculation methods and output to conform to the guidance in the IAEA Basic Safety Standard (IAEA96).

This document describes the changes made to RASCAL 2.1 to produce the InterRAS Version 1.1. It assumes that the reader is familiar with and has access to the RASCAL 2.1 documentation.

### 3.1. ST-DOSE Modifications

Modifications have been made to ST-DOSE to make it more appropriate for International assessments. The modified main screen is shown below.

```
   Case Title: this is a test title
    Site Name: this is a sample location

 Effective                      Release  (•) Not Isolated     Default  ( ) Ci
 Release Height:    0 m        Location: ( ) Isolated         Units: (•) kBq

 ◄ Source Term ►
 Reactor Accident Based On Plant Conditions
     Release Route: Through Pool (Wet Well) or Bubble Tower
       Core Condition: Gap Release (uncovered 15-30 min)
        Reactor Power: 3000 MW(t)
 Pool or Bubble Tower: Saturated (Boiling)       Release Route: Unfiltered
            Leak Rate: 0.1%/h
 ◄ Events ►                   |          ◄ Meteorological Data ►
 Shut Down  01/08/96 00:00    |     date    time     winds  stb  mix    precip
 Rel->Cont  01/08/96 00:00    | 1 01/08/96 00:00  3 m/s 270 D  500 m      NONE
 Rel->Envi  01/08/96 00:00    | 2   < undefined >
 Rel End    01/08/96 01:00    | 3   < undefined >
 Calc End   01/08/96 04:00    | 4   < undefined >
 ──────────────────────────────────── Actions ──────────────────────────────
   ◄ Calculate ►                  ◄ Results ►              ◄ Case Menu (F10) ►
```

Note the change in the default units and the change in the way that the site name is entered. Also, only the Lagrangian puff model is available. The 'Actual/Projected' labeling option has been removed.

#### 3.1.1. Plant-Specific Data

All plant-specific data have been removed from InterRAS. The plant name is entered on the main menu as a text string and is only used for labeling purposes.

### 3.1.2. Default Units

The default units for activity are kBq. The default units for dose are mSv. The default distance units are km. English units, Ci, and rem, are available. The date format used has been changed the European convention (DD/MM/YY).

### 3.1.3. Isotopic Release Rates and Isotopic Concentrations

The following radionuclides have been added to the isotopic source terms:
I-129 U-238 Pu-236
U-234 U ore Pu-240
U-235 Enriched U Pu-241
U-236 UF6 Pu-242

### 3.1.4. Plant Conditions

The plant conditions options have been slightly modified for this version of InterRAS. The modified plant conditions source term menu is shown below.

```
                      Release Pathway

       Dry Containment Leakage
       Coolant Bypass of Containment
       Ice Condenser Containment Leakage
       Through Pool (Wet Well) or Bubble Tower
       Dry Bypass of Containment

              Select the appropriate accident condition
```

Two of these options are new. They are the Dry Containment Leakage and Through Pool (Wet Well) or Bubble Tower options. The first replaces both the Large Dry or Sub-atmospheric and Dry Well options in RASCAL 2.1. The second replaces the Wet Well option. The new screens are shown below and illustrate the modifications made to the other plant conditions source term data entry screens.

```
This is a test                                  This is the site name entered

      Core Condition: [•] Gap Release (uncovered 15-30 min)
                      [ ] Core Melt (uncovered >30 min)

       Reactor Power: 3000 Mw(t)

             Sprays: [ ] On              Release Route: [ ] Filtered
                     [•] Off                            [•] Unfiltered

          Leak Rate: [ ] 100%/h
                     [ ]  50%/h
                     [ ]  10%/h
                     [ ]   4%/h
                     [ ]   1%/h
                     [ ]   0.5%/h
                     [•]   0.1%/h
                     [ ]   0.05%/h

                                                     ◄ Main Menu (F10)►
```

Note that the Vessel Melt core damage option has been removed and that the In-Vessel Melt option has been renamed Core Melt. Also the 0.1%/h and 0.05%/h have replaced the two design-based leak rates used in RASCAL 2.1.

```
This is a test                            This is the site name entered

    Core Condition:  [•] Gap Release (uncovered 15-30 min)
                     [ ] Core Melt (uncovered >30 min)

     Reactor Power:  3000 Mw(t)
                                   Bubbling Depth
     Pool or Tower:  [ ] Subcooled  0.5 - 1.0 m
                     [ ] Subcooled  1.0 - 2.0 m
                     [ ] Subcooled   > 2.0 m

                     [•] Saturated or Bypassed

         Leak Rate:  [ ] 100%/h     Release Route:  [ ] Filtered
                     [ ]  50%/h                     [•] Unfiltered
                     [ ]  10%/h
                     [ ]   4%/h
                     [ ]   1%/h
                     [ ]   0.5%/h
                     [•]   0.1%/h
                     [ ]   0.05%/h
                                                      ◄ Main Menu (F10)►
```

Note that for either a suppression pool or a bubble tower, you can select either a saturated or a subcooled condition. If subcooled is selected, then you also select an estimate of the water depth. The reduction factors used for these cases are:

| Water Depth m | Reduction Factor |
|---|---|
| Saturated: | 1.0 |
| Subcooled: | |
| 0.5 - 1.0 | 0.50 |
| 1.0 - 2.0 | 0.10 |
| > 2.0 | 0.05 |

### 3.1.5. Containment Monitor Reading

The containment monitor source term option has been modified to allow calculation at any reactor type. The input screen has been modified as shown below.

```
This is a test title                            This is a sample location


   Monitor Reading:      1.0000000 Sv/h

   Containment Volume:   1.00E+005 m**3       Fraction of
                                              volume seen: 1.0000000
   Shielding Factor:     1.0000000


   Reactor Power: 3000 MW(t)

   Containment Sprays:   [ ] On      Release Route:     [ ] Filtered
                         [•] Off                        [•] Unfiltered
      Leak Rate:   [ ] 100%/h
                   [ ]  50%/h
                   [ ]  10%/h
                   [ ]   4%/h
                   [ ]   1%/h
                   [ ]   0.5%/h
                   [•]   0.02%/h
                   [ ]   0.004%/h
                                                ◄ Main Menu (F10) ►
```

Note that instead of selecting the monitor location, you now enter values for the containment volume, the fraction of the containment volume seen by the monitor, and a shielding factor for the monitor.

### 3.1.6. Dose Calculations

The doses calculated have not been changed for this version of InterRAS. Note that the maximum early exposure period has been increased from four days to one week, and the 4-day ground-shine calculation has been eliminated. Radiologic decay and ingrowth are now included in the calculation of the ground-shine dose. The new output format is shown below.

```
This is a test title                                          01/08/96
13:49
Distance                    Maximum EARLY Doses (mSv)
from Site, km         1.0       2.0       5.0       25.0      50.0
                    --------  --------  --------  --------  --------
Total EDE           2.1E+05   1.2E+05   4.7E+04   5.6E+03   8.5E+00
Thyroid             1.4E+06   7.6E+05   3.0E+05   3.5E+04   5.4E+01

Cloud Shine         4.5E+03   2.7E+03   1.5E+03   2.7E+02   3.7E-01
Ground Shine        3.3E+03   1.9E+03   7.4E+02   8.7E+01   1.3E-01
Eff. Inhalation     2.0E+05   1.1E+05   4.5E+04   5.2E+03   8.0E+00

NOTES for International Version:
1. All values below 1.0E-02 have been set to zero
2. Thyroid dose includes Iodine only
3. Total EDE = Eff. Inhalation + Cloud Shine + Ground Shine
```

### 3.2. FM-DOSE Modifications

The dose calculations have not been changed for this version of InterRAS. Note that the maximum early exposure period has been increased from four days to one week, and the 4-day ground shine calculation has been eliminated. Also, the intermediate phase first and second year doses have been changed to first and second month doses. The radionuclides added are:

| | | | | |
|---|---|---|---|---|
| Y-91m | Cd-115 | La-141 | U-236 | UF6 |
| Nb-95m | Sb-131 | Pr-144m | U ore | |
| Rh-123m | Te-131 | Pr-144 | Enriched U | |

The new output format is shown below.

```
 Field Measurements to Dose Output (International) Run Time: 01/08/96
13:50
 Title: this is a sample title
 Sample date and time: 01/08/96 01:00
                             EARLY Doses
 TEDE Components:
 Ground Shine         5.92E-004 mSv
 Cloud Submersion     1.72E-004 mSv        TEDE          4.81E+002 mSv
 50-yr Inhalation     4.81E+002 mSv

------------------------------------------------------------------------
 Thyroid Inhalation   0.00E+000 mSv       (Iodine only)

 NOTES:
 1. NC = Not Calculated
 2. Resuspension doses and re-entry delay are not computed
```

```
 Field Measurements to Dose Output (International) Run Time: 01/08/96
13:50
 Title: this is a sample title
 Sample date and time: 01/08/96 01:00

                    LONG TERM Doses (mSv)
                                                ----- With Delay -----
 Exposure     First Month Second Month 50 Years   First Month  50 Years
 Ground Shine   1.98E-003  4.35E-004  2.51E-003    1.57E-003  1.93E-003
 Inhalation     2.75E-006  5.57E-007  3.43E-006    2.02E-006  2.48E-006
 Total          1.98E-003  4.36E-004  2.52E-003    1.57E-003  1.93E-003

 First Month Dose (mSv)
 ---------------------------  =  2.83E+003  (used to compute 1st month
dose
      Dose Rate (mSv/h)                  from meter reading)

 NOTES:
 1. Ground shine includes decay and weathering
 2. Ground shine excludes noble gas daughters
 3. All doses are independent of the entered ground exposure
```

### 3.3. DECAY Modifications

No modifications were made to the DECAY program made for this version of InterRAS.

## 4. SETTING RUNTIME OPTIONS

### 4.1. Configuration File

InterRAS uses a configuration file named RASCAL21.CFG to control where files are stored on the hard disk and to indicate the type of printer installed for printing graphics. The installation program may create this file or you can create it using a text editor. The file must be in the same directory as the program files. The file is needed only if you wish to change from the default storage location or graphics printer. By default all files are stored in the directory with the program files and the graphics printer is a HP LaserJet at 150x150 dpi.

| Keywords | Discussion |
|---|---|
| STD_WS_PATH = | Specifies the location for all ST-DOSE result files on the workstation including case files and PCX graphics. |
| FMD_WS_PATH = | Specifies the location for all FM-DOSE result files on the workstation. |
| PRINTER = | Specifies the printer driver to be used in printing ST-DOSE graphics. |

An example of the RASCAL21.CFG file is shown below.

```
STD_WS_PATH = c:\InterRAS\save\
FMD_WS_PATH = c:\InterRAS\save\
PRINTER = hplsvrh.prd
```

The printer definition applies only to printing graphics. Text will print to any printer. Refer to the separate installation instructions for a list of the available printer drivers.

### 4.2. Enabling Black-and-White Video Mode

The InterRAS input/output forms are normally set up to display colours. On computers with monochrome screens, the colour mode may not be very readable. These machines include some laptop computers with plasma and liquid crystal display (LCD) screens and machines with older amber or green monitors. The easiest fix may be to use the DOS MODE command. At the DOS prompt, before starting InterRAS, type **MODE BW80** and press **Enter**.

## 5. PROBLEMS

This section describes how to report problems with the InterRAS software and offers solutions to some of the commonly encountered problems.

### 5.1. Reporting Problems

This is a developmental version of the code. Problems should be reported to the IAEA, Division of Radiation and Waste Safety, Radiation Safety Section, Emergency Preparedness Unit.

The major portions of InterRAS are controlled by a DOS batch file. The batch file will detect some program errors and attempt to tell you where a problem occurred. Likewise, the individual programs report their own specific problems. If you do encounter difficulties with InterRAS, please note as much of the following specific information as you can:

Describe the problem:

- Which tool of InterRAS was being used when the problem occurred?
- What exactly is the problem? Be specific (for example, computer locked up and had to be rebooted or printer would not handle ASCII graphics).
- What activity was under way when the problem occurred? (For example, entering data to a form, performing calculations, or attempting to print.) Be as specific as possible.
- What error messages, if any, were displayed?
- Is the problem reproducible? If so, what exact steps from starting up InterRAS bring about the problem?
- What action, if any, did you take to recover from the problem?

Describe the operating environment:

- What computer was in use? (Include brand, model, CPU type, amount of RAM, and display type.)
- What version and revision of DOS was in use?
- What brand and model of printer was in use? (If relevant.)
- What memory-resident software was installed (e.g., PCTOOLS, SIDEKICK) at the time of the problem?

If possible, provide a printed listing or copies on disk of the following files:

- The AUTOEXEC.BAT and CONFIG.SYS files from your root directory
- All of the .TMP and .TXT files created by InterRAS. These are in the same directory as the InterRAS program files.

## 5.2 Common Problems

The following is a summary of commonly encountered problems and their solutions.

---

Problem: You get a series of messages on the screen preceded by cryptic characters. The characters may be scrolling up your screen (similar to those shown below) instead of being a stationary message with only the percent value changing:

**^{ [[2J^{ [[05;10HCalculating transport, diffusion and cloud shine.**
**^{ [[08;15H 0.0 percent complete.**
**^{ [[08;15H 2. percent complete.**
**^{ [[08;15H 4. percent complete.**
**^{ [[08;15H 6. percent complete.**

Solution: The ANSI.SYS device driver is not installed correctly. Check the CONFIG.SYS file in the root directory to see if it includes the DEVICE=C:\DOS\ANSI.SYS line.

---

Problem: You receive an error message during the Transport/Diffusion or Dose Calculation sections similar to that shown below:

**error opening thyroid.out in RASCAL/DOSCAL, ier = 6417**
**Return code 1**

Solution: The number in the FILES= statement in your CONFIG.SYS file is not set to 20 or greater. Edit the file using a text editor and make sure there is a FILES= line included and that the number is set to 20 or greater.

Problem: You attempt to print a graphics screen using the **Print Screen** key. The machine sounds a double beep, there is no action by the printer, or you get nonsense on the printer.

Solution: There are two possible causes of the problem. The first is that **GRAPHICS.COM** has not been run. This is a program in memory that allows DOS to copy a graphics screen to the printer. The program is usually loaded by the AUTOEXEC.BAT file. In this case, the line GRAPHICS may be missing from the AUTOEXEC.BAT file. Edit the AUTOEXEC.BAT file to add the line GRAPHICS. Then reboot and run InterRAS again.

The second possibility is that GRAPHICS.COM does not support the screen type or printer type you are using. DOS versions differ in the ability to print graphics from the screen. Update your DOS to a later version, preferably DOS Version 6.+, which supports screen prints to a variety of printers, including laser printers.

---

Problem: The computer has locked up. Nothing has changed on the screen for several minutes and the keyboard is not active.

Problem: The computer is acting strangely. For example, the mouse has stopped working or is drawing coloured boxes on the screen. Another example is that drawing of the graphics to the screen is incomplete or corrupted.

Solution: The problem may have been caused by having insufficient memory to run a portion of InterRAS. Check to make sure that you do not have memory resident routines using up space. InterRAS requires 520 KB of RAM at run time.

The computer must be rebooted, either by pressing the **Ctrl**, **Alt**, and **Del** keys simultaneously or by turning the power off and then back on. Then try running InterRAS again after rebooting. If the problem persists, try to free up more memory.

---

Problem: As InterRAS is started or when you are trying to view graphics, you receive an error message that reads:

**Out of Environment Space.**

Problem: InterRAS terminates abnormally with the message:

**Error while executing the program** _________

Solution: InterRAS makes use of the DOS environment to control certain options and to pass information between modules. In this case, while InterRAS was trying to store information, the environment space was exhausted. InterRAS behaviour may be erratic (i.e., some sections may not work) if this error message is received. Add the line **SHELL=C:\COMMAND.COM C:\ /P /E:500** to the CONFIG.SYS file and reboot. Refer to your DOS manual for further information on the SHELL command.

---

Problem: You have to press **Enter** twice to get the printer to work with the first selected output option that attempts to use the printer.

Solution: The command PRINT /D:PRN was not executed before running InterRAS. This command is usually run from the AUTOEXEC.BAT file. Add **PRINT /D:PRN** to your AUTOEXEC.BAT file.

---

Problem: You receive the message **Floating Point Not Loaded**

Solution: Your computer does not have a math coprocessor installed. InterRAS v1.1 modules require the math coprocessor. You must upgrade your system to be able to run InterRAS v1.1.

---

Problem: The printed version of the Inputs report contains lines of non-standard characters, as in the example below:

**Summary of ST-DOSE inputs NEW CASE**
**6666666666666666666666666666666666666666666666666666666666666**
**Title: TITLE 12/17/91 14:37**

This may be seen in other printer outputs as well.

Solution: The printer is not set up to use the extended character set containing the line-drawing characters. If possible, change the printer configuration to use an appropriate extended character set. For example, in the Roman-8 character set, the character with decimal number 196 is an á. In the PC-8 symbol set, the character with decimal number 196 is a horizontal line (—), which is the desired character.

---

Problem: You want to load a case in either ST-DOSE or FM-DOSE, but the **Load Case** menu option is not available.

Solution: Either you have not previously saved a case, or the file DN.DAT in your save area has been deleted. If DN.DAT has been deleted, you can try to restore it with the DOS UNDELETE command. Otherwise, any cases you may have saved have been lost.

---

## 6. PROGRAMMING LANGUAGES USED

The following software packages and compilers were used in the creation of InterRAS Version 1.1:

Microsoft C Version 7.0
Microsoft FORTRAN Version 5.10
Microsoft Segmented-Executable Linker Version 5.31
Vermont Views Version 3.05 with Designer
Genus Microprogramming libraries
  GX Printer v1.5
  GX Graphics v3.0
  GX Text v3.0
  GX PCX Toolkit v6.0
Microsoft DOS Version 6.0

Vermont Creative Software
Pinnacle Meadows
Richford, VT 05476
(802) 848-7731  FAX (802) 848-3502

Genus Microprogramming, Inc.
1155 Dairy Ashford, Suite 200
Houston, TX 77079
(713) 870-0737  FAX (713) 870-0288

### 6.1. Text and Ranges for Plotting Results

When InterRAS presents results graphically, actual dose values are represented by a symbol. The range of values represented by a given symbol and the text accompanying the key to symbols is defined in the file PLOTKEY.DAT. This file is used by RAS21OUT and CASE programs. The format of the file is illustrated below:

```
1 5 TOTAL DOSE CEDE                      <-- a
    REM      SV                          <-- b
1   1.0e-3   1.0e-5                      <-- c
              0.001 to 0.1 rem           <-- d
              0.01 to 1.0 mSv            <-- e
2   1.0e-1   1.0e-3
              0.1 to 1.0 rem
              1.0 to 10 mSv
3   1.0      1.0e-2  EPA PAG Range
              1 to 5 rem
              10 to 50 mSv
4   5.0      5.0e-2
              5 to 50 rem
              50 to 500 mSv
6   50.0     5.0e-1  Health Effects Possible
              > 50 rem
              > 500 mSv
```

Where:

a = result type number (reference to # written in *.OUT file), number of bins to follow, and the result type label to appear on outputs
b = comment line for the bins
c = symbol number to be used, lower range if source in Ci, lower range if source in Bq, text to be shown with all ranges (if any; may be blank)
d = range label if input in Ci; should match ranges
e = range label if input in Bq; should match ranges

Lines C, D and E are repeated for each bin. A result type number is assigned to each dose or concentration file created by the ST-DOSE model. The number is written as the 1st element of the output (.OUT) files and is used by the output programs in determining the appropriate labels, symbols and keys. The second element of the output file is the type of input (Ci or Bq). This is used to determine which column of range numbers to use.

## 6.2. Files

### 6.2.1. Result Files

The program DOSCAL of ST-DOSE generates the final result files. These files are unformatted, FORTRAN files with one for each result type. Each contains a result type number, a units string and the doses on the Cartesian and polar grids. The result type number, file name and contents are shown below:

| Result Type Number | File Name | Description of contents |
|---|---|---|
| 1 | EFF-EPA.OUT | Total Effective Dose |
| 2 | BONE-ACU.OUT | Acute Bone Dose (not used) |
| 3 | IMM.OUT | Whole Body Cloud Shine |
| 4 | GSE.OUT | Whole Body Ground Shine |
| 5 | INH-EPA.OUT | Inhalation Dose Effective |
| 6 | INH-ACU.OUT | Acute Bone Marrow Inhalation (not used) |
| 7 | THYROID.OUT | Thyroid Dose |
| 8 | LUNG-ACU.OUT | Acute Lung Dose (not used) |
| 9 | DEPCUM.OUT | Deposition |
| 10 | DPLCUM.OUT | Particulate Ground Level Air Conc. |
| 11 | EXPCUM.OUT | Noble-Gas Ground Level Air Conc. |
| 12 | GS4DAY.OUT | 4-day Ground Shine Dose (not used) |

The format of the file is:

> result type (integer*2)
> engineering units (character*3)
> Cartesian grid array (31,31) (real*4)
> polar grid array (36,3) (real*4)

### 6.2.2. InterRAS Batch File

InterRAS is composed of a number of standalone executable files. The running of theses files in the correct order is controlled by a DOS batch file named INTERRAS.BAT. Individual programs return values to the batch file through the ErrorLevel numbers. The batch file uses this information to determine whether an error has occurred or what program to execute next. A portion of the batch file is listed below as an example.

```
:RASCMENU
  cls
  echo off
  set pnam=rastart.exe
  if not exist %pnam% goto notfnd
  set from=start
  rastart
  if errorlevel 99 goto DONE
  if errorlevel 20 goto DECAY
  if errorlevel 15 goto FM2D
  if errorlevel 10 goto CASE
  if errorlevel 1 goto ERROR
  goto UNKNOWN

:DECAY
  cls
  set pnam=decay.exe
  if not exist %pnam% goto notfnd
  DECAY
  goto RASCMENU
```

An environmental variable, pnam, is used to hold the name of the executing program. It is used to check to make sure the file exists before attempting to execute it and to provide the name to the user if a problem occurs.

The following table summarizes the codes used in the INTERRAS.BAT file as returned by the programs.

**Program Return Code Summary**

| Program Name | Error Code | Action Taken |
|---|---|---|
| RASTART | 99 | EXIT / Terminate the batch file |
| | 15 | Begin field measurement to dose (FM-DOSE program) |
| | 20 | Begin DECAY calculator (DECAY program) |
| | 10 | Begin data input for ST-DOSE (CASE program) |
| | 1 | Branch to error message and terminate batch file |
| CASE | 99 | Return to opening menu (RASTART program) |
| | 30 | Branch to output (RAS21OUT program) |
| | 10 & 5 | Set the TYPE environment variable then start RAS21IN |
| | 2 | Branch back to opening menu (RASTART program) |
| | 1 | Branch to error message and terminate batch file |
| | 0 | EXIT / Terminate the batch file |
| RAS21IN | 99 | Return to opening menu (RASTART program) |
| | 30 | Branch to output (RAS21OUT program) |
| | 25 & 20 | Start the ST-DOSE calculations (STCALC program) |
| | 10 | Return to the ST-DOSE case menu (CASE program) |
| | 2 | Return to opening menu (RASTART program) |
| | 1 | Branch to error message and terminate batch file |
| | 0 | EXIT / Terminate the batch file |
| STCALC | 90 | Return to data input (RAS21IN program) |
| | 1 | Branch to error message and terminate batch file |
| | 0 | Continue with calculations (TADMOD program next) |
| TADMOD | 2 | Return to data input (RAS21IN program) |
| | 1 | Branch to error message and terminate batch file |
| | 0 | Continue with calculations (DOSCAL program next) |
| DOSCAL | 1 | Branch to error message and terminate batch file |
| | 0 | Calculations complete, go to output (RAS21OUT) |
| RAS21OUT | 99 | Error condition, return to RASTART program |
| | 90 | Return to data input (RAS21IN program) |
| | 2 | Branch back to opening menu (RASTART program) |
| | 1 | Branch to error message and terminate batch file |

### 6.2.3. DOSCAL.DAT File Format

The ASCII file DOSCAL.DAT defines the decay and source term characteristics of each radionuclide used in the source term calculations. A fragment of the file is shown below for illustration.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| H-3 | 0 | 7.96E+00 | 2.06E+03 | 7.96E+00 | 6.40E+01 | 1.06E-01 | 0.00E+00 |
| P-32 | 1 | 1.33E+04 | 2.15E+04 | 1.39E+03 | 1.79E+03 | 3.17E+01 | 9.31E-01 |
| S-35 | 1 | 1.01E+03 | 8.03E+03 | 6.48E+00 | 3.53E+02 | 7.78E-02 | 5.38E-03 |
| Mn-54 | 1 | 9.25E+02 | 8.55E+03 | 2.84E+02 | 2.74E+03 | 1.31E+04 | 2.60E+02 |

Each line contains:

nuclide name
noble gas (=0) or particle (=1) flag
<not used>
effective inhalation dose factor (rem/Ci)
<not used>
thyroid inhalation dose factor (rem/Ci)
effective air immersion dose factor ( (rem/d) / (Ci/m**3) )
effective ground shine dose factor ( (rem/d) / (Ci/m**2) )

### 6.2.4. DECNUC.DAT File Format

The ASCII file DECNUC.DAT lists the radionuclides available in the DECAY program. Do not edit this file.

### 6.2.5. NUCNAM.DAT File Format

The ASCII file NUCNAM.DAT lists the radionuclides available in the Isotopic source term options in the STCALC program. Do not edit this file.

### 6.2.6. STCALC.DAT File Format

The ASCII file STCALC.DAT defines the decay and source term characteristics of each radionuclide used in the source term calculations. A fragment of the file is shown below for illustration.

```
 2 1 0                                          <- a
 Kr-87     Rb-87                                <- b
-1.514E-04 0.000E+00                            <- c
 4.644E-19-4.644E-19
 1.60E+04 1.50E-07 0.00E+00 5.00E-02 9.50E-01 0.00E+00<- d
```

There is section of data similar to the above for each radionuclide.

a - number of daughters, WASH-1400 category, and a flag (0=gas, 1=non-gas)
b - names of the radionuclides in this chain
c - the decay matrix (may span multiple lines)
d - six numbers: Ci/MW(t) in inventory
PWR coolant concentrations (Ci/g)
BWR coolant concentrations (Ci/g) - NOT USED
gap release fraction
in-vessel release fraction
ex-vessel release fraction - NOT USED

### 6.2.7. R2NUC.DAT File Format

The ASCII file R2NUC.DAT defines the photon spectra of each radionuclide used in the source term calculations. A fragment of the file is shown below for illustration.

```
T  1Mn-54     T
          .00057    .00370    .00541    .07429
          .00541    .14711    .00595    .02944
          .83483    .99976
```

The file contains the following information:

Line 1:
- an unused flag; always T
- an index number; not used
- the nuclide name
- flag; T = particle, F = gas

Next lines: Up to 5 pairs of gamma energy (MeV) and gamma yield

### 6.2.8. FM-DOSE.DAT File Format

The ASCII file FM-DOSE.DAT defines the dose factors and decay matrices of each radionuclide used in the FM-DOSE calculations. A fragment of the file is shown below for illustration.

```
2                                                                    <- a
 Ti-44     Sc-44                                                     <- b
 0.00E+00  1.02E+06  0.00E+00  4.07E+05  3.54E+04  7.04E+02          <- c
 4.22E+01  6.62E+02                                                  <- d
 1.02E+06  4.92E+02
-4.64E-10  0.00E+00
 4.90E-05 -4.90E-05
```

The file consists of the following lines:

a - number of nuclides in this chain
b - the names of the nuclides in the chain
c - dose factors:
    30-day lung inhalation (rem/Ci) - NOT USED
    50-year CEDE inhalation (rem/Ci)
    30-day bone inhalation (rem/Ci) - NOT USED
    50-year thyroid inhalation (rem/Ci)
    immersion (rem/day / Ci/m**3)
    ground shine (rem/day / Ci/m**2)
    ground shine dose factor for each nuclide in the chain (rem/day / Ci/m**2)
    50-year CEDE for each nuclide in the chain (rem/Ci)
d - decay matrix

### 6.2.9. DECAY.DAT File Format

The ASCII file DECAY.DAT defines the decay matrices of each radionuclide used in the DECAY calculator. A fragment of the file is shown below for illustration.

```
 2                        <- a
  Ti-44     Sc-44         <- b
 -4.64E-10  0.00E+00      <- c
  4.90E-05 -4.90E-05
```

The file consists of the following lines:

- a - the number of nuclides in the chain
- b - names of the nuclides in the chain
- c - decay matrix

### 6.2.10. USERDATA.TMP File Format

The data input program RAS21IN creates an ASCII file to be used by later programs. A sample file and a description of contents and formats is shown below. The first 19 records will always exist. The number following those first 19 will vary depending on the source term options selected.

```
09/30/91 12:00¦ T T F P                             <-- a
TITLE   09/30/91  11:14¦                            <-- b
NO PLANT SELECTED    ¦ UNIT 1¦ 40 0.100 0           <-- c
3000   0 LWR 0 0  2000 Y 0000000000 0000000000      <-- d
0  m                                                <-- e
50                                                  <-- f
09/10/91 00:00                                      <-- g
09/10/91 00:00                                      <-- h
09/10/91 00:00                                      <-- i
09/10/91 01:00                                      <-- j
09/10/91 03:00                                      <-- k
09/10/91 00:00 D  3 m/s  90  500  m      NONE¦      <-- l
00/00/00 00:00 D  3 m/s  90  500  m      NONE¦
00/00/00 00:00 D  3 m/s  90  500  m      NONE¦
00/00/00 00:00 D  3 m/s  90  500  m      NONE¦
N                                                   <-- m
kBq                                                 <-- n
 60   5520                                          <-- o
0    0                                              <-- p
Plant Conditions¦                                   <-- q
Large, Dry, or Subatmospheric Containment Failure/Leakage¦
CORE MELT (>4500 F)¦
3000
OFF¦
100%/DAY¦
```

where:

a - the date and time on the computer system when the file was written. This string is terminated by the vertical bar character (¦). The three control flags represented as T or F. The fourth flag must be a P or A representing Projected or Actual data.
b - the run title; terminated by the vertical bar character (¦)
c - the plant name and unit name, each terminated by the vertical bar
the design pressure
the design leak rate
flag for BWR type; 1, 2, or 3 for Mark class; 0 for PWRs
flag for decommissioned reactors; 1 = decommissioned
d - reactor power in megawatts thermal, stack height, reactor type, ice condenser flag, oncethru flag, building cross-sectional area for wake calculations, and the building wake calculation flag, Albers X and Y coordinates
e - release height and height units
f - calculation radius (50)
g- reactor shutdown data and time
h - release to containment date and time
i - release to environment date and time
j - end of release date and time
k - end of exposure date and time
l - 4 records of met data
m - quick calculation flag; NOT USED
n - default units for activity
o - release duration (minutes) and exposure duration (minutes)
p - shutdown duration (minutes) and holdup time (minutes)
q - variable number of records defining the source term; all strings are terminated by a vertical bar.

### 6.2.11. Help Files

The Vermont Views package used in writing the programs RASTART, RAS21IN, and RAS21OUT allow the use of help file. These are ASCII text files which are accessed when the user presses the F1 (Help) key. Fields or menu items on the forms have keywords assigned to them allowing context sensitive help text to be displayed. The help text can be changed in these files using any ASCII text editor. There are some limitations.

1. The keywords are assigned in the form library file (*.VVD). These can be changed using the Vermont Views Designer, but must match the keywords in the help text file.

2. The maximum length of the help text file has been set in the main program. Generally this value has been set to allow some variation and expansion of the file during development. However, if a large number of text lines are added to the file, it is possible that an error message will be received when starting program execution. To accommodate a larger help file, go into the program source code for the function main() and increase the number of lines of help text to be read.

The help files for the screens are text files named *hlp.

### 6.2.12. Choice File Contents and Format

The programs DECAY, FM-DOSE and RAS21IN make use of choice list files. These are ASCII text files which are accessed automatically by the program or when the user presses the F2 (Choice) key. Some of the data fields on the forms have keywords assigned to them allowing a list of acceptable entries to be displayed. The choice text can be changed in these files using any

ASCII text editor. However, the programs may be written to recognize specific choices only. Changing the wording of a choice or adding or subtracting choices may interfere with the normal functioning of the program.

### 6.2.13. RAS21IN Control Flags

The data input program of ST-DOSE (RAS21IN) uses three logical variables to control the availability of some features. They are used to guide the user in entering the data and prevent actions from occurring out of sequence. For example, until a source term has been defined, calculations cannot be run. Also, if data has been altered, it is no longer possible to examine results from the previous run.

The three flags are:

- title - T if user has entered a new title
- sourceterm - T if user has passed at least once through the source term definition screens
- calcs_done - T if the user performed calculations after completing data input; F if data input was exited without selecting calculation

## 7. INSTALLATION OF INTERRAS VERSION 1.1

### 7.1. System Requirements:

InterRAS is distributed on one 1.44 MB (3.5") diskette. Before proceeding make sure your computer meets the minimum system requirements:

- IBM-compatible computer; if the CPU is less than a 486DX-class, it must have a math coprocessor installed (e.g. 80387 chip)
- DOS v3.30 or later
- Minimum of 3.1MB of storage space available on the hard disk
- VGA display adapter or better (required to view graphics)
- Mouse (recommended)

### 7.2. Installation Steps

1. Insert the InterRAS Version 1.1 disk into the appropriate floppy drive (A: or B:).
2. Make the drive with the InterRAS distribution disk the current drive. For example, if the diskette is in the A: drive, type A: and press <Enter>.
3. To begin the installation, type INSTALL and press <Enter>.

Messages on the screen will guide you through the installation process. You will be given the option of creating a configuration file. It is highly recommended that you allow the installation to generate the file. The configuration file is needed if:

- you want to print graphics to any type of device other than the default HP LaserJet
- you want to save cases and results to any location other than the InterRAS program directory

If you skip the file creation and later need it, a configuration file can be created using the configuration file editor (RCFG.EXE).

4. Look at the contents of the file README.TXT that has been installed with the InterRAS software. The file may be viewed on the screen or printed with the following commands:

    TYPE README.TXT ¦ MORE

    PRINT README.TXT

5. Make any changes needed to the AUTOEXEC.BAT and CONFIG.SYS files (see installation notes following). Reboot the computer before running InterRAS.

### 7.3. Installation Notes

*1. Distribution of InterRAS software*

This version of InterRAS contains no proprietary or licensed components. The distribution disks may be freely copied and redistributed.

*2. Modification of DOS startup files and environment size*

The installation process tries to determine whether changes are needed to the AUTOEXEC.BAT and CONFIG.SYS files. The installation looks for the following:

In the AUTOEXEC.BAT file

| Command | Discussion |
|---|---|
| PRINT /D:PRN | Required for printing of text results |
| GRAPHICS | Optional<br>Allows the use of the Print Screen key to print displayed graphics. This method works best with DOS version 5.0 or later and may require a command line argument to specify the printer type. The ST-DOSE model can print graphics directly using a printer defined in the RASCAL.CFG file (see Section A.2). This method generally produces a better quality picture but will take more time. |
| MOUSE | Required for the mouse to work with the InterRAS menus and forms. This command may be slightly different or in the CONFIG.SYS depending on the specific pointing device. |

In the CONFIG.SYS file

| **Command** | **Discussion** |
|---|---|
| DEVICE = C:\DOS\ANSI.SYS | Required for InterRAS programs to correctly control the screen. |
| SHELL=C:\COMMAND.COM C:\C /P /E:500 | Required to increase the environment size. InterRAS uses the environment to pass information between programs. The default environment size is not large enough. |
| FILES = 20 | Required, although the number may be higher if needed for other applications. |

Some of the commands above require that the location of your DOS files be in the system PATH. If not, the commands must be prefaced by the full path; e.g. C:\DOS\ANSI.SYS. On some computers these commands may be embedded in the commands of memory manager software such as 386MAX or QEMM. In these cases the installation software will not find the commands and will indicate that they need to be added.

The installation program will not make changes to these files. It will only recommend changes. You must make the changes manually using a text editor such as the DOS EDIT program. Refer to your DOS manual for further details about modifying these files.

*3. Configuration file*

The installation program creates a file named RASCAL21.CFG. This file contains path information to tell the programs where to save model case information and results. The installation sets all the path to the same directory as the program files. This should be adequate for most stand-alone computers. The file will also contain a PRINTER line defining the printer driver to be used when printing graphics. The installation does provide a few choices for printers. Other printers can be added using the configuration file editor program.

* Configuration File Editor (RCFG.EXE)

The program RCFG allows you to easily change the InterRAS configuration file. From the directory in which InterRAS was installed, start the configuration file editor by typing RCFG and pressing <Enter>. The configuration setup screen allows you to specify path names for the following:

ST-DOSE cases and result files on the local workstation (your PC)
FM-DOSE cases and result files on the local workstation

You may also select a graphics printer driver from a choice list. The printers listed are read from the file RCFG.DAT. The file pairs printer descriptions with printer definition file names. The data file as distributed does not contain all the printer drivers available from Genus Microprogramming. If your printer is not listed, you may be able to add it.

* Adding a printer to the RCFG.DAT file

Do not edit the RASCAL21.CFG file directly to add a printer. For InterRAS to recognize and use a printer driver it must be properly defined in the RCFG.DAT file. This means that the file must contain the same printer description text as follows the PRINTER keyword in the CFG file. Also, the description must be followed by a valid printer definition file name. The following steps should be used to add a printer:

i) Consult the complete list of printer definition files in the file PRNTDRVR.TXT. The file is installed in the InterRAS subdirectory and is on the distribution disk. Locate the appropriate definition file name ( ____.PRD).

ii) Edit the RCFG.DAT file to add a line for the new printer. The line should include a printer description (any text you choose to identify the printer), the ¦ character as a separator, and the printer definition file name (without the PRD extension).

For example, to add the Alps DMX800 printer at its highest resolution the following line would be added anywhere in the RCFG.DAT file:

Alps DMX800 (240x216)¦ epson9vh

iii) Now run the program RCFG.EXE again and select the new printer. This method will assure that InterRAS will find the appropriate device definition when needed.

If your printer is not specifically listed in the table, consult your printer documentation. Most printers will emulate some common types (e.g. Epson or IBM). Try using one of those printer definitions.

If your color printer is printing InterRAS graphics in black and white, make sure that the specified printer driver supports color. Many printers have both B&W and color drivers available.

Printing graphics can be slow especially when using high resolutions. For example, printing an ST-DOSE graphic using the HP LaserJet at 300x300 dpi resolution took 75 seconds when the printer was directly connected to the computer. When using a LAN shared printer, the job took 6 minutes.

### 4. *Environment Space*

InterRAS makes use of the DOS environment to communicate between program sections. If you have many SET commands in your AUTOEXEC.BAT file the environment space may be filled so much that InterRAS is unable to run. Use the /E: switch on the SHELL command in the CONFIG.SYS file to provide a larger environment.

A too small environment may show up in several ways. The most obvious is when the system can detect the problem and will report it clearly. Sometimes the problem is signaled by repeated error messages that some component program is missing. Before starting a program the batch file writes the name of the program component to an environment variable. This variable is used to determine whether the program is on the disk and available for execution. If the environment is too small the name will not be correctly saved and the component will not be found. This results in the error message. If you receive repeated errors of this type and the file is not missing from the disk, try increasing the environment space.

## 5. *Memory Requirements*

InterRAS v1.1 requires that about 520 KB of conventional RAM be free at runtime. The requirement stated in the RASCAL Version 2.1 User's Guide is too high.

The graphics portions of the InterRAS ST-DOSE model will make use of extended memory if it is available. This will reduce the amount of conventional memory required for those portions of the code.

## 6. *Installation under Windows*

InterRAS v1.1 can be configured to run as a DOS application under Windows. An icon is provided in a file called INTERRAS.ICO for use with Windows. Use the New command to create a program item for the InterRAS application. The command line of the Program Item Properties should be INTERRAS.BAT. Refer to the Microsoft Windows User's Guide for further details.

# Appendix III

# DOSE PROJECTIONS

## INTRODUCTION

This method is used to project urgent phase, longer term and ingestion doses based on samples.

It is difficult to estimate doses from air, ground and food samples in time for protective actions to be effective. That is why operational intervention levels are used during an emergency. However, there may be a need to calculate the doses which may have been received once the detailed isotopic composition of the source term (air samples), ground composition and food contamination is known.

The methods presented in this Appendix allows an estimate of the dose from detailed isotope concentrations. The first part describes two alternatives to estimate the inhalation dose. The first alternative is based on the ratio of the inhalation dose to the external dose rate. This will allow prompt estimation of dose. The second is based on a full analysis of the air concentration. The second part describes three alternatives to calculate dose from deposition, including inhalation and resuspension. The first one is based on isotopic surface concentration. The second one is based on ambient dose rates while the third one is based on OILs. The last part describes a method to calculate the dose from the consumption of contaminated food based on measured concentrations in food, milk, water or dirt.

Calculate the dose using:

| To calculate | use |
|---|---|
| Total Effective Dose, and thyroid dose (Urgent Phase Doses) | Section A |
| Long term dose from deposition (Late phase dose) | Section B |
| Ingestion dose | Section C |

## SECTION A
## CALCULATE URGENT PHASE DOSE (Total Effective Dose, $E_T$)

**Input to the calculations**
- Exposure rate in the plume from Worksheet D4
- Exposure-to-dose ratios from Sample Analyst (Procedure F1)
- Air concentrations from Worksheet D4

**Output**
- Thyroid dose from inhalation
- Total effective dose from inhalation

**Step 1**
Calculate the dose equivalent for penetrating radiation contributions from air submersion plus ground shine ($H_a + H_g$) based on ambient dose rate measured in the plume at 1 m above ground level.

$$H_a + H_g = \dot{H}^* \times T_e$$

where:

$H_a$ Personal dose equivalent from penetrating radiation from air (plume) submersion [mSv]
$H_g$ Personal dose equivalent from penetrating radiation from deposition (ground shine) [mSv]
$\dot{H}^*$ Average ambient dose rate in the plume of release or from ground deposition [mSv/h]
$T_e$ Exposure duration; expected duration or average wind persistence (default: 4h))

**Step 2**
Calculate the inhalation dose from the plume ($E_{inh}$) using:

| To calculate based on | use |
|---|---|
| Exposure-to-Dose Ratios | Step 2a |
| Air Concentrations | Step 2b |

**Step 2a: Inhalation Dose Based on Exposure-to-Dose Ratios For LWR Accidents.**

Calculate the thyroid dose and committed effective dose from inhalation of contaminated air using the ratio of thyroid dose to the average ambient dose rate in the plume ($R_2$), and the ratio of effective inhalation dose to the average ambient dose rate in the plume ($R_1$).

$$H_{thy} = \dot{H}^* \times R_2 \times T_e$$

$$E_{inh} = \dot{H}^* \times R_1 \times T_e$$

where:

$R_2$ Thyroid dose rate to the ambient dose rate (for calculation see Procedure F1)
$R_1$ Ratio of the effective dose rate to the ambient dose rate (for calculation see Procedure F1)
$H_{thy}$ Thyroid dose from inhalation [mSv]
$E_{inh}$ Effective dose from inhalation [mSv]
$\dot{H}^*$ Average ambient dose rate in the plume [mSv/h]
$T_e$ Exposure duration (expected duration or 4 hr) [h]

**Step 2b: Inhalation Dose Based on Air Concentrations.**
[This calculation can also be performed using InterRAS.]

Calculate the thyroid dose, and effective inhalation dose from inhalation of contaminated air. The dose conversion factors are provided in terms of air concentration and assume the breathing rate of an adult performing light activity (1.2 $m^3$/h as recommended by ICRP75).

$$H_{thy} = \sum_{i}^{n} (C_{a,i} \times CF_{1,i}) \times T_e$$

$$E_{inh} = \sum_{i}^{n} (C_{a,i} \times CF_{2,i}) \times T_e$$

where:

$CF_{1,i}$ Thyroid Inhalation dose conversion factor for isotope *I* from Table F1 [(mSv/h)/(kBq/$m^3$)]
$CF_{2,i}$ Effective inhalation dose conversion factor for isotope *I* from Table F1 [(mSv/hr)/(kBq/$m^3$)]
$H_{thy}$ Thyroid dose from inhalation [mSv]
$E_T$ Effective dose from inhalation [mSv]
$T_e$ Exposure duration (expected release duration or 4 hr) [h]
$C_{a,i}$ Concentration of isotope I in plume [kBq/$m^3$] from Worksheet D4

**Step 3**
Calculate the total effective dose as shown below

$$E_T = (H_a + H_g) + E_{inh}$$

where:

$(H_a + H_g)$ Effective dose from air submersion plus ground shine [mSv]
$E_{inh}$ Committed effective dose from inhalation [mSv]
$E_T$ Total effective dose equivalent [mSv]

## SECTION B
## LATE PHASE DOSE (Dose from Long Term Exposure to Deposition)

**Discussion**: This procedure assumes that inhalation dose from resuspension will not be an important contributor to long term dose, this should be confirmed.

**Input to the calculations**
- Deposition concentration of radionuclides from Worksheet D7
- Ambient dose rate from deposition

**Output**
- Late phase total effective dose

**Step 1**
Calculate the long term dose for remaining on contaminated ground using:

| To calculate based on | use |
|---|---|
| Deposition levels | Step 1a |
| Deposition Exposure Rate | Step 1b |
| OIL4 and exposure rates | Step 1c |

**Step 1a - Based on isotope deposition levels**
Calculate the dose using the formula below. This calculation can also be performed using the InterRAS code.

$$E_T^{LP} = \sum_i^n (C_{g,i} \times CF_{4,i})$$

where:

$E_T^{LP}$ Late phase total effective dose [mSv]
$C_{g,i}$ Deposition levels of isotope *I* from Worksheet D7 [kBq/m$^2$]
$CF_{4,i}$ Dose conversion factor for exposure to ground contamination for the period of interest for deposition from Table F5 [(mSv)/(kBq/m$^2$)]

**Step 1b - Based on exposure rates**
Calculate the late phase ambient-dose-rate-to-dose conversion factors.

$$CF_{lp} = \frac{\sum_i^n (C_{g,i} \times CF_{4,i})}{\sum_i^n (C_{g,i} \times CF_{3,i})}$$

$$E_T^{LP} = \dot{H}_g^* \times CF_{lp}$$

where:

| | |
|---|---|
| $E_T^{LP}$ | Late phase total effective dose [mSv] |
| $CF_{lp}$ | Late phase ambient dose rate to dose conversion factor [1/h], This can be calculated with InterRAS (FM-Dose) for the first month. |
| $C_{g,i}$ | Deposition concentration of isotope *I* [kBq/m$^2$] |
| $CF_{4,i}$ | Long term dose conversion factor for deposition for the period of interest from Table F5 [(mSv)/(kBq/m$^2$)] |
| $CF_{3,i}$ | Ambient dose rate conversion factor from Table F5 [(mSy/hr)/(kBq/m$^2$)] |
| $\dot{H}_g^*$ | Ambient dose rate from deposition [mSv/h] |

**Step 1c - Based on OIL and exposure rates**

The late phase total effective dose equivalent can be calculated using the formula below:

$$E_T^{LP} = \frac{\dot{H}_g^*}{OIL4} \times GIL_r$$

where:

| | |
|---|---|
| $E_T^{LP}$ | Late phase total effective dose for the period of 1st month, subsequent month and lifetime [mSv] |
| $OIL4$ | Operational intervention level that indicates that the late phase relocation GIL will be exceeded from Table B3 or recalculated in Procedure F2 [mSv/h] |
| $\dot{H}_g^*$ | Ambient equivalent dose rate from deposition from Worksheet D7 [mSv/h] |
| $GIL_r$ | IAEA or national relocation GILs for the period of interest. IAEA relocation GILs are found in Table F3 [mSv] |

**Step 2**

Adjust for shielding and partial occupancy using:

$$E_{T\,(PO)}^{LP} = E_T^{LP} \times [SF \times OF + (1 - OF)]$$

where:

| | |
|---|---|
| $E_T^{LP}$ | Late phase total effective dose without shielding for the period of 1st month, subsequent month and lifetime [mSv] from step 1. |
| $E_{T\,(PO)}^{LP}$ | Late phase total effective dose assuming shielding and partial occupancy for the period of 1st month, subsequent month and lifetime [mSv] |
| $SF$ | Shielding factor from measurements during occupancy or from Table F4 |
| $OF$ | Occupancy fraction, or the fraction of time the shielding factor SF is applicable (e.g., the fraction of time spent indoors; it is assumed that, for the rest of the time, there is no shielding); default = 0.6 |

## SECTION C
## INGESTION DOSE

**Input to the calculations**

- ► Concentration of radionuclides in food from Worksheet D8

**Output**

- ► Effective dose from ingestion

**Step 1**

Calculate the dose from consumption of food or dirt by using the formula shown below:

$$E_{Ing} = \sum_{i}^{n} (C_{f,i} \times U_{fi} \times DI_i \times CF_{5,i}) \times \prod_{j=1}^{n} RF_j$$

where:

$E_{Ing}$ Effective dose from ingestion [mSv]

$C_{f,i}$ Activity concentration in food of isotope *i* [kBq/kg]

$U_{fi}$ The amount of a food *f* consumed by the population of interest per day. For dirt ingestion maximum adult ingestion is about 100 mg/d with an average of about 25 mg/d; the maximum consumption for a child is 500 mg/d with an average of 100 mg/d; [kg/d or L/d]

$CF_{5,i}$ Ingestion dose conversion from table IIIA below [mSv/kBq]

$DI_i$ Days of intake is the period food is assumed to be consumed. If $T_{1/2} > 21$ days use 30 days. If $T_{1/2} < 21$ days use the mean life ($T_m$) of the isotope.

$$T_m = T_{1/2} \times 1.44$$

where:

$T_{½}$ Radiological half-life (see Appendix IV).

$RF_j$ Reduction Factor is the fraction of the contamination remaining after decay or some process j used to reduce the contamination before food is released for consumption. See Table F8 in Procedure F4 for RFs.

Table IIIA: Ingestion dose conversion factors (e(g))

| **Nuclide** | **Infant Age 1 -2 a [mSv/kBq]** | **Child Age 7 - 12a [mSv/kBq]** | **Adult Age > 17a [mSv/kBq]** |
|---|---|---|---|
| H-3 | 1.20E-04 | 5.70E-05 | 4.20E-05 |
| Mn-54 | 3.10E-03 | 1.30E-03 | 7.10E-04 |
| Co-58 | 4.40E-03 | 1.70E-03 | 7.40E-04 |
| Co-60 | 2.70E-02 | 1.10E-02 | 3.40E-03 |
| Rb-87 | 1.00E-02 | 3.10E-03 | 1.50E-03 |
| Rb-88 | 6.20E-04 | 1.70E-04 | 9.00E-05 |
| Sr-89 | 1.80E-02 | 5.80E-03 | 2.60E-03 |
| Sr-90 | 7.30E-02 | 6.00E-02 | 2.80E-02 |
| Sr-91 | 4.00E-03 | 1.20E-03 | 6.50E-04 |
| Y-90 | 2.00E-02 | 5.90E-03 | 2.70E-03 |
| Y-91 | 1.80E-02 | 5.20E-03 | 2.40E-03 |
| Y-91m | 6.00E-05 | 2.10E-05 | 1.20E-05 |
| Zr-95 | 5.60E-03 | 1.90E-03 | 9.50E-04 |
| Nb-95 | 3.20E-03 | 1.10E-03 | 5.90E-04 |
| Mo-99 | 3.50E-03 | 1.10E-03 | 6.00E-04 |
| Tc-99 | 4.80E-03 | 1.30E-03 | 6.40E-04 |
| Tc-99m | 1.30E-04 | 4.30E-05 | 2.20E-05 |
| Ru-103 | 4.60E-03 | 1.50E-03 | 7.30E-04 |
| Ru-106 | 4.90E-02 | 1.50E-02 | 7.00E-03 |
| Rh-106 | 9.70E-04 | 3.30E-04 | 1.60E-04 |
| Sb-127 | 1.20E-02 | 3.60E-03 | 1.70E-03 |
| Sb-129 | 2.90E-03 | 8.80E-04 | 4.20E-04 |
| Te-127 | 1.20E-03 | 3.60E-04 | 1.70E-04 |
| Te-127m | 1.80E-02 | 5.20E-03 | 2.30E-03 |
| Te-129 | 4.40E-04 | 1.20E-04 | 6.30E-05 |
| Te-129m | 2.40E-02 | 6.60E-03 | 3.00E-03 |
| Te-131 | 6.60E-04 | 1.90E-04 | 8.70E-05 |
| Te-131m | 1.40E-02 | 4.30E-03 | 1.90E-03 |
| Te-132 | 3.00E-02 | 8.30E-03 | 3.80E-03 |
| I-131 | 1.80E-01 | 5.20E-02 | 2.20E-02 |
| I-132 | 2.40E-03 | 6.20E-04 | 2.90E-04 |
| I-133 | 4.40E-02 | 1.10E-02 | 4.30E-03 |
| I-134 | 7.50E-04 | 2.10E-04 | 1.10E-04 |
| I-135 | 8.90E-03 | 2.20E-03 | 9.30E-04 |
| Cs-134 | 1.60E-02 | 1.40E-02 | 1.90E-02 |
| Cs-135 | 2.30E-03 | 1.70E-03 | 2.00E-03 |
| Cs-136 | 9.50E-03 | 4.40E-03 | 3.10E-03 |
| Cs-137 | 1.20E-02 | 1.00E-02 | 1.30E-02 |
| Cs-138 | 5.90E-04 | 1.70E-04 | 9.20E-05 |
| Ba-140 | 1.80E-02 | 5.80E-03 | 2.60E-03 |

| Nuclide | Infant Age 1 -2 a [mSv/kBq] | Child Age 7 - 12a [mSv/kBq] | Adult Age > 17a [mSv/kBq] |
|---|---|---|---|
| La-140 | 1.30E-02 | 4.20E-03 | 2.00E-03 |
| Ce-141 | 5.10E-03 | 1.50E-03 | 7.10E-04 |
| Ce-144 | 3.90E-02 | 1.10E-02 | 5.20E-03 |
| Pr-144 | 3.50E-04 | 9.50E-05 | 5.10E-05 |
| Th-231 | 2.50E-03 | 7.40E-04 | 3.40E-04 |
| Np-239 | 5.70E-03 | 1.70E-03 | 8.00E-04 |
| Pu-238 | 4.00E-01 | 2.40E-01 | 2.30E-01 |
| Pu-239 | 4.20E-01 | 2.70E-01 | 2.50E-01 |
| Pu-240 | 4.20E-01 | 2.70E-01 | 2.50E-01 |
| Pu-241 | 5.70E-03 | 5.00E-03 | 4.70E-03 |
| Pu-242 | 4.00E-01 | 2.60E-01 | 2.40E-01 |
| Am241 | 3.70E-01 | 2.20E-01 | 2.00E-01 |

Source: IAEA96, Table II-IV

# Appendix IV

## RADIOACTIVE HALF-LIVES, DECAY DATA AND DIAGRAMS

**Discussion**: Table contains element names, chemical symbols, atomic numbers, and radioactive half-lives for some selected radioisotopes. The atomic number is the number of protons in the nucleus of the atom; the number of protons defines the chemical properties of the element and thus defines the element. Radioactive half-life is the time required for one half of the nuclei of a radioactive species to decay.

**Element names, atomic numbers, and half-lives for selected radioisotopes (NRC96)**

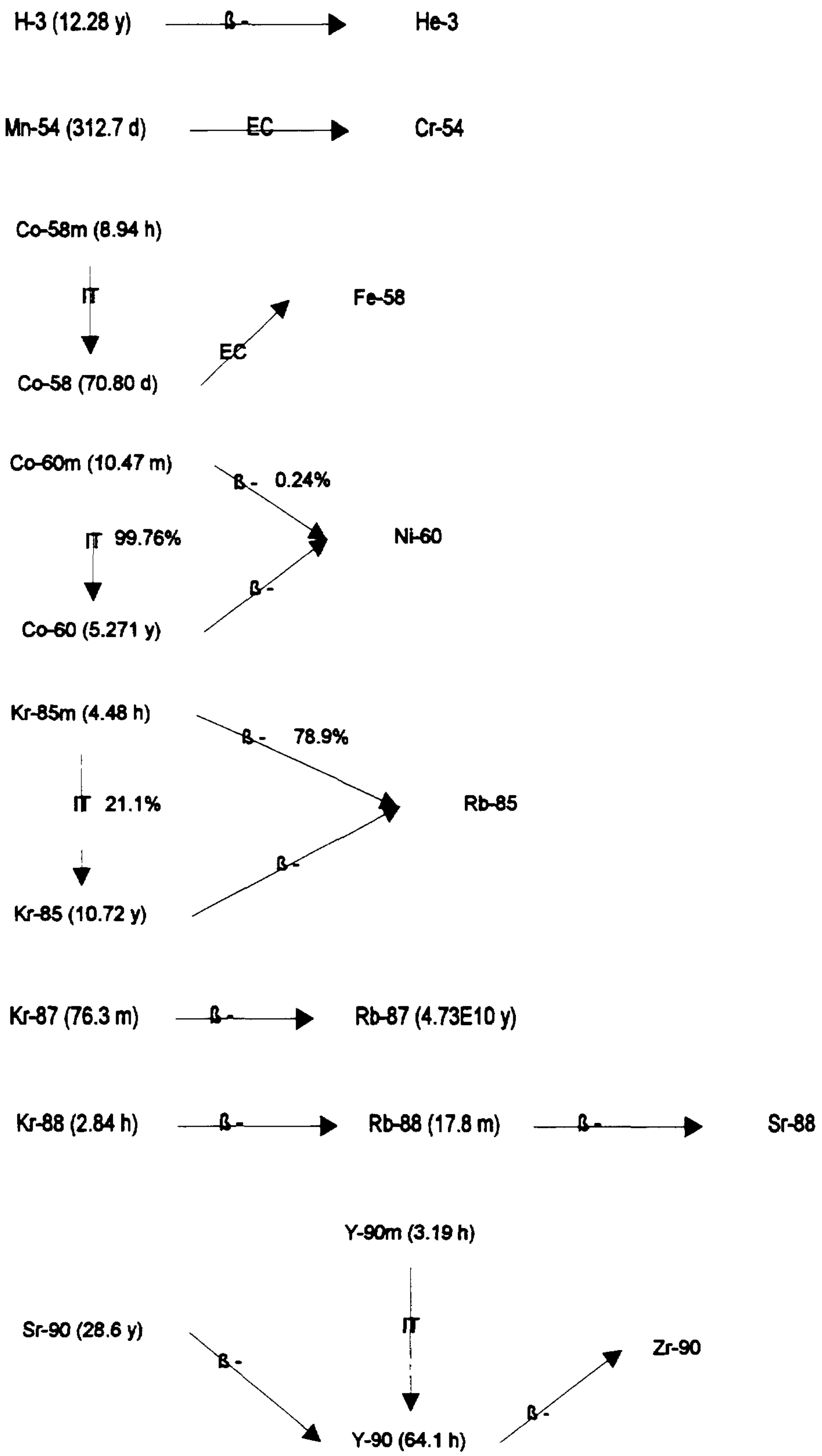
| Element name | Symbol | Atomic number (Z) | Radioisotope[a] | Half-life[b] |
|---|---|---|---|---|
| Hydrogen | H | 1 | H-3 | 12.28 y |
| Manganese | Mn | 25 | Mn-54 | 312.7 d |
| Cobalt | Co | 27 | Co-58 | 70.80 d |
| | | | Co-60 | 5.271 y |
| Krypton | Kr | 36 | Kr-85 | 10.72 y |
| | | | Kr-85m | 4.48 h |
| | | | Kr-87 | 76.3 m |
| | | | Kr-88 | 2.84 h |
| Rubidium | Rb | 37 | Rb-87 | 4.73E10 y |
| | | | Rb-88 | 17.8 m |
| Strontium | Sr | 38 | Sr-89 | 50.55 d |
| | | | Sr-90 | 28.6 y |
| | | | Sr-91 | 9.5 h |
| Yttrium | Y | 39 | Y-90 | 64.1 h |
| | | | Y-91 | 58.51 d |
| | | | Y-91m | 49.71 m |
| Zirconium | Zr | 40 | Zr-95 | 64.02 d |
| Niobium | Nb | 41 | Nb-95 | 35.06 d |
| Molybdenum | Mo | 42 | Mo-99 | 66.02 h |
| Technetium | Tc | 43 | Tc-99 | 2.13E5 y |
| | | | Tc-99m | 6.02 h |
| Ruthenium | Ru | 44 | Ru-103 | 39.35 d |
| | | | Ru-106 | 368.2 d |
| Rhodium | Rh | 45 | Rh-103m | 56.119 m |
| | | | Rh-106 | 29.92 s |
| Antimony | Sb | 51 | Sb-127 | 3.85 d |
| | | | Sb-129 | 4.40 h |
| Tellurium | Te | 52 | Te-127 | 9.35 h |
| | | | Te-127m | 109 d |
| | | | Te-129 | 69.6 m |
| | | | Te-129m | 33.6 d |
| | | | Te-131 | 25.0 m |
| | | | Te-131m | 30 h |
| | | | Te-132 | 78.2 h |

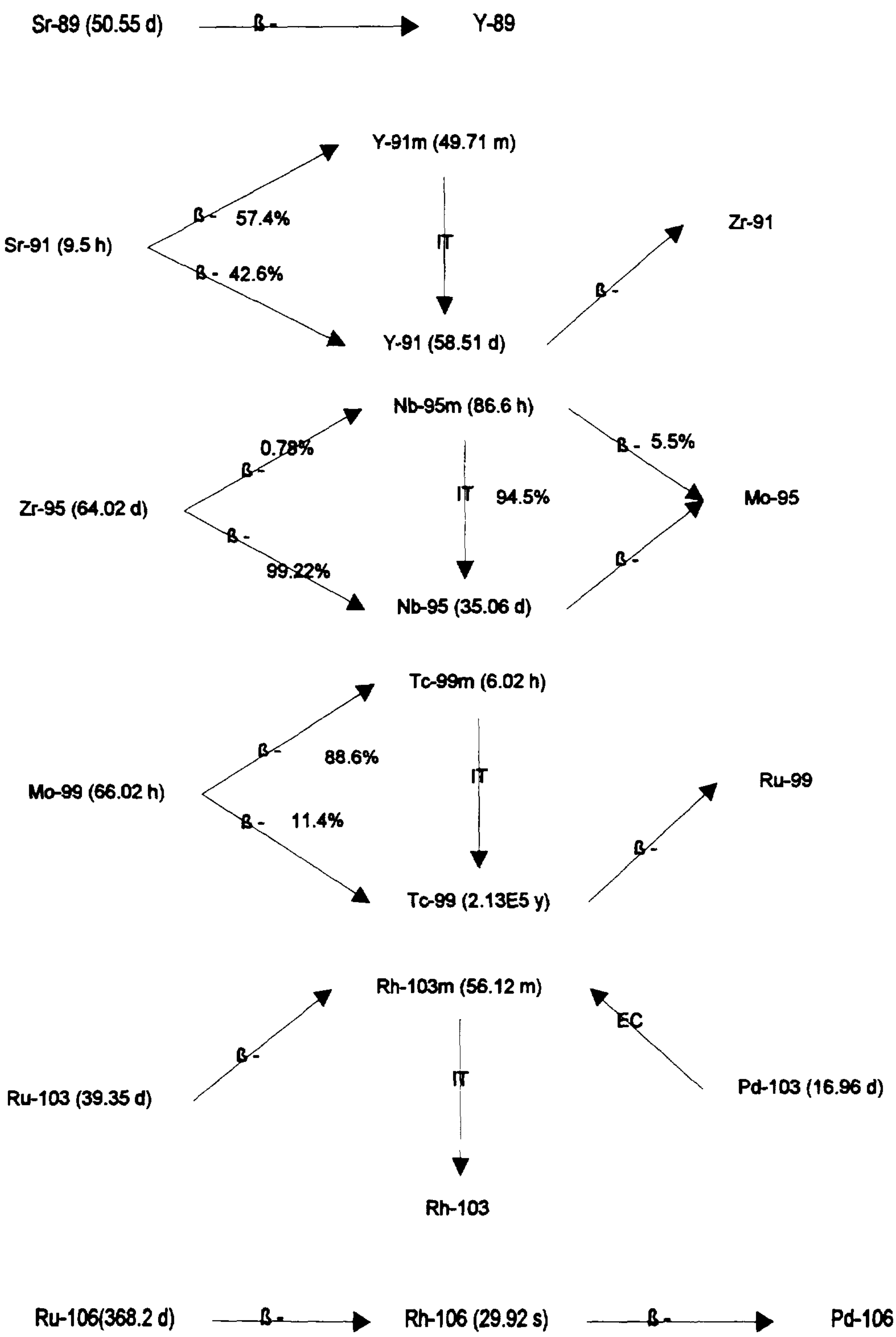
| Element name | Symbol | Atomic number (Z) | Radioisotope[a] | Half-life[b] |
|---|---|---|---|---|
| Iodine | I | 53 | I-131 | 8.040 d |
| | | | I-132 | 2.30 h |
| | | | I-133 | 20.8 h |
| | | | I-134 | 52.6 m |
| | | | I-135 | 6.61 h |
| Xenon | Xe | 54 | Xe-131m | 11.84 d |
| | | | Xe-133 | 5.245 d |
| | | | Xe-135 | 9.11 h |
| | | | Xe-135m | 15.36 m |
| | | | Xe-138 | 14.13 m |
| Cesium | Cs | 55 | Cs-134 | 2.062 y |
| | | | Cs-136 | 13.16 d |
| | | | Cs-137 | 30.17 y |
| Barium | Ba | 56 | Ba-137m | 2.552 m |
| | | | Ba-140 | 12.789 d |
| Lanthanum | La | 57 | La-140 | 40.22 h |
| Cerium | Ce | 58 | Ce-141 | 32.50 d |
| | | | Ce-144 | 284.3 d |
| Praseodymium | Pr | 59 | Pr-144 | 17.28 m |
| | | | Pr-144m | 7.2 m |
| Thorium | Th | 90 | Th-231 | 25.52 h |
| Neptunium | Np | 93 | Np-237 | 2.14E6 y |
| | | | Np-239 | 2.355 d |
| Plutonium | Pu | 94 | Pu-238 | 87.75 y |
| | | | Pu-239 | 24131 y |
| | | | Pu-240 | 6537 y |
| | | | Pu-241 | 14.4 y |
| | | | Pu-242 | 3.758E5 y |
| Americium | Am | 95 | Am-241 | 432.2 y |

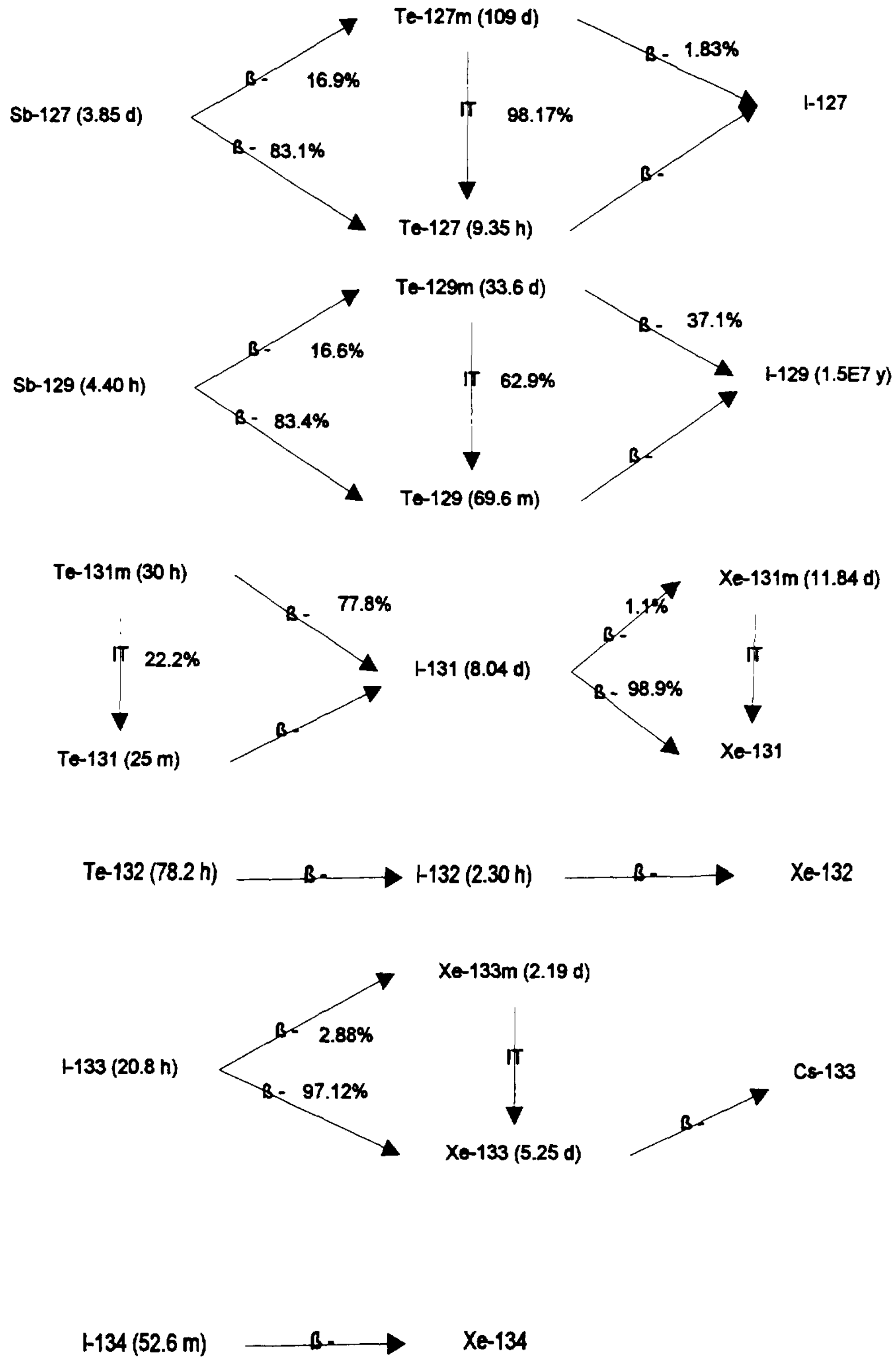
(a) The radioisotopes are listed in the form X-A, where X is the symbol for the element and A is the atomic mass number. When the atomic mass number is followed by an "m", it indicates that the radioisotope is "metastable." Metastable states are excited nuclear states that have a half-life long enough to be observed.

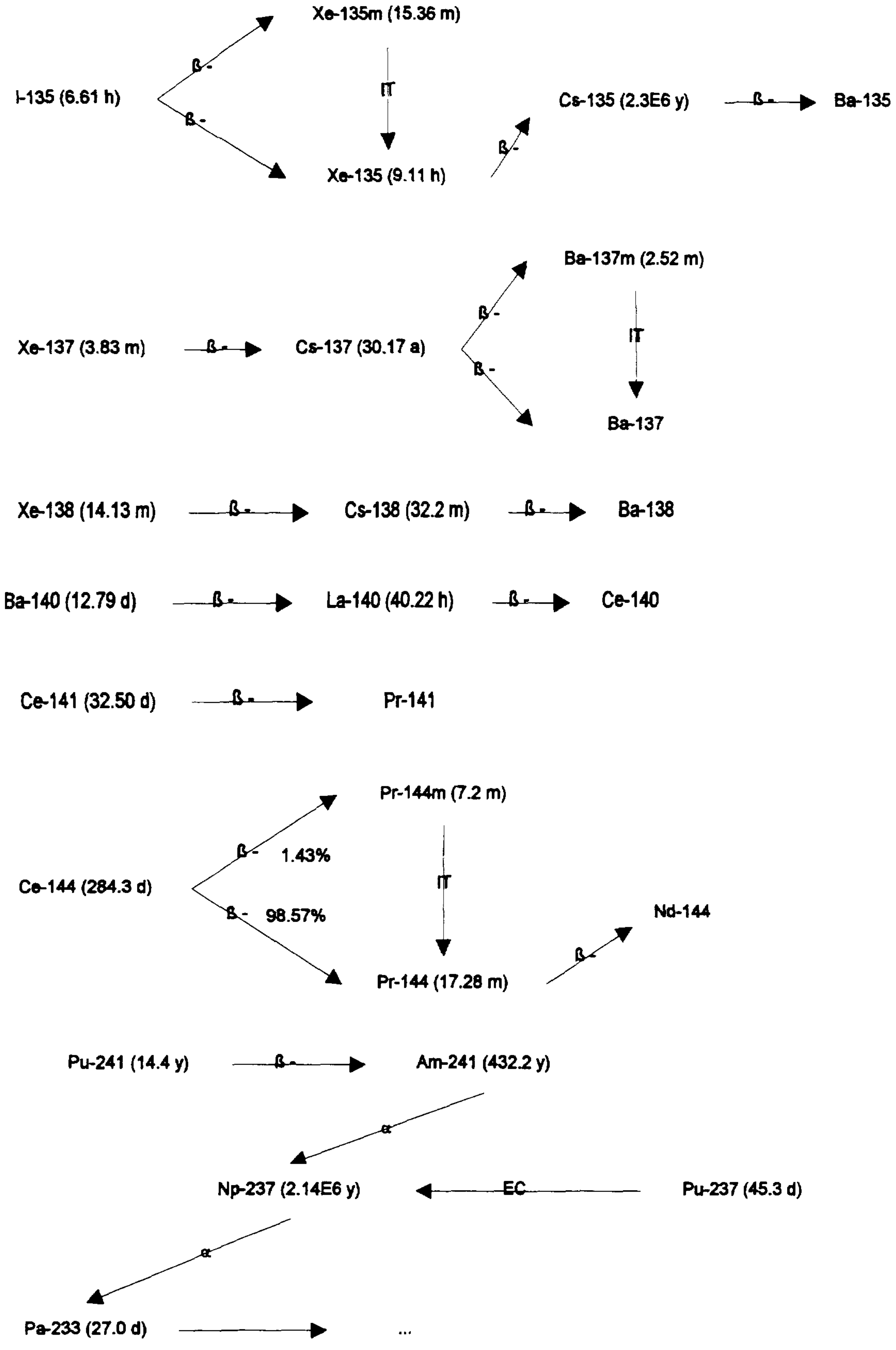
(b) In this column, s = second, m = minute, d = day, h = hour, and y = year. The letter "E" is used to indicate the power of ten, e.g., 5.73E3 = $5.73 \times 10^3$.

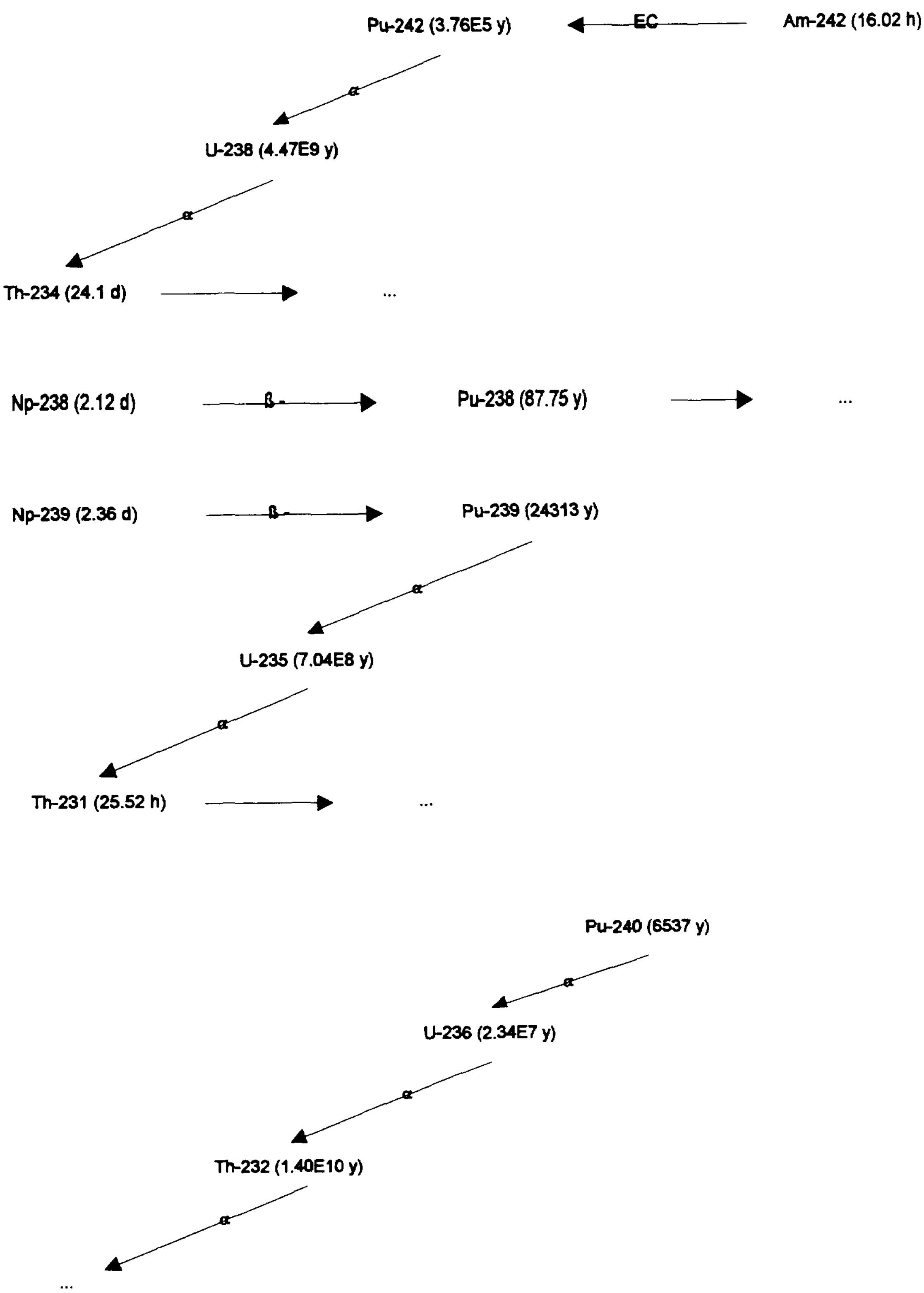
# DECAY DIAGRAMS




Sr-89 (50.55 d)
ß-
Y-89
Y-91m (49.71 m)
Sr-91 (9.5 h)
ß- 57.4%
ß- 42.6%
IT
Zr-91
ß-
Y-91 (58.51 d)
Nb-95m (86.6 h)
0.78%
ß-
Zr-95 (64.02 d)
ß-
99.22%
IT 94.5%
ß- 5.5%
Mo-95
ß-
Nb-95 (35.06 d)
Tc-99m (6.02 h)
ß-
88.6%
Mo-99 (66.02 h)
ß- 11.4%
IT
Ru-99
ß-
Tc-99 (2.13E5 y)
Rh-103m (56.12 m)
EC
ß-
Ru-103 (39.35 d)
IT
Pd-103 (16.96 d)
Rh-103
Ru-106(368.2 d)
ß-
Rh-106 (29.92 s)
ß-
Pd-106


Te-127m (109 d)
ß- 16.9%
Sb-127 (3.85 d)
ß- 83.1%
IT 98.17%
ß- 1.83%
I-127
ß-
Te-127 (9.35 h)
Te-129m (33.6 d)
ß- 16.6%
Sb-129 (4.40 h)
ß- 83.4%
IT 62.9%
ß- 37.1%
I-129 (1.5E7 y)
ß-
Te-129 (69.6 m)
Te-131m (30 h)
ß- 77.8%
IT 22.2%
Te-131 (25 m)
ß-
I-131 (8.04 d)
ß- 1.1%
ß- 98.9%
Xe-131m (11.84 d)
IT
Xe-131
Te-132 (78.2 h)
ß-
I-132 (2.30 h)
ß-
Xe-132
Xe-133m (2.19 d)
ß- 2.88%
I-133 (20.8 h)
ß- 97.12%
IT
Xe-133 (5.25 d)
ß-
Cs-133
I-134 (52.6 m)
ß-
Xe-134


Xe-135m (15.36 m)
I-135 (6.61 h)
ß-
ß-
IT
Cs-135 (2.3E6 y)
ß-
Ba-135
Xe-135 (9.11 h)
ß-
Ba-137m (2.52 m)
Xe-137 (3.83 m)
ß-
Cs-137 (30.17 a)
ß-
ß-
IT
Ba-137
Xe-138 (14.13 m)
ß-
Cs-138 (32.2 m)
ß-
Ba-138
Ba-140 (12.79 d)
ß-
La-140 (40.22 h)
ß-
Ce-140
Ce-141 (32.50 d)
ß-
Pr-141
Pr-144m (7.2 m)
ß- 1.43%
Ce-144 (284.3 d)
IT
ß- 98.57%
Nd-144
ß-
Pr-144 (17.28 m)
Pu-241 (14.4 y)
ß-
Am-241 (432.2 y)
α
Np-237 (2.14E6 y)
EC
Pu-237 (45.3 d)
α
Pa-233 (27.0 d)
...


Pu-242 (3.76E5 y)
EC
Am-242 (16.02 h)
α
U-238 (4.47E9 y)
α
Th-234 (24.1 d)
...
Np-238 (2.12 d)
ß -
Pu-238 (87.75 y)
...
Np-239 (2.36 d)
ß -
Pu-239 (24313 y)
α
U-235 (7.04E8 y)
α
Th-231 (25.52 h)
...
Pu-240 (6537 y)
α
U-236 (2.34E7 y)
α
Th-232 (1.40E10 y)
α
...

## SYMBOLS

Only the symbols that are used in more than one formula or procedure are shown

| Symbol | Unit | Description |
|---|---|---|
| *Br* | $m^3/h$ | Breathing rate |
| $C_{after}$ | kBq/kg or kBq/l | Concentration of isotope I after a process, decay etc |
| $C_{before}$ | kBq/kg or kBq/l | Concentration of isotope I before a process, decay etc |
| $C_{spec}$ | kBq/g | Coolant concentration for specific plant |
| $C_{table}$ | kBq/g | Coolant concentration from table |
| $C_{a,i}$ | $kBq/m^3$ | Air activity concentration of isotope *I* |
| $C_{b,i}$ | $kBq/m^2$ | Surface activity concentration (ground deposition) of isotope *I* |
| $C_{f,i}$ | kBq/kg or kBq/l | Food, water or milk activity concentration of isotope *I* |
| $C_G$ | kBq/kg | Isotope concentration in milk, infant food and drinking water for group G (see Table F6) |
| $C_{f,j}$ | $kBq/m^2$ | Surface activity concentration (ground deposition) of marker isotope *j* to be used in identifying where food (f) concentrations may exceed the GAL |
| $CF_{i}$ | $(mSv/h)/(kBq/m^3)$ | Committed inhalation dose to the thyroid per hour of inhaling air contaminated at unit contamination for isotope I |
| $CF_{2,i}$ | $(mSv/h)/(kBq/m^3)$ | Committed effective dose from inhalation per hour of inhaling air contaminated at unit contamination for isotope I |
| $CF_{3,i}$ | $(mSv/h)/(kBq/m^2)$ | Ambient dose equivalent rate at 1 m AGL per unit of deposition for isotope *I* |
| $CF_{4,i}$ | $(mSv)/(kBq/m^2)$ | Long term dose per unit of deposition for isotope *I*, includes external dose and committed effective dose from inhalation resulting from remaining on contaminated ground for the period of concern (1st month, the subsequent month or 50 years) |
| $CF_{5,i}$ | mSv/kBq | Committed effective dose from ingestion per unit intake of isotope I |
| *DI* | d | Days of Intake is the period food is assumed to be consumed |
| $E_{ing}$ | mSv | Committed effective dose from ingestion |
| $E_T$ | mSv | Total effective dose equivalent |
| $E_T^{WG}$ | mSv | Total effective dose equivalent that emergency workers should attempt not to exceeded (see Table F9 for IAEA guidance) |
| $E_{ing}$ | mSv/h | Effective dose rate from inhalation |
| $\dot{E}_{inh}$ | mSv/h | Committed effective dose per hour of inhalation assuming a breathing rate of 1 2 $m^3/h$ for an adult performing light activity per hour exposure |
| EWG | mSv | Emergency worker turn - the integrated dose on a self-reading *dosimeter that indicates that an emergency worker may have* exceeded the IAEA dose guidance Has been calculated to consider the potential inhalation dose |

| Symbol | Unit | Description |
|---|---|---|
| $f_m$ | (kBq/l)/(kBq/day) | Transfer factor for isotope $I$ from ingestion to cow's milk |
| $GAL_G$ | kBq/kg | Food, water or milk concentration Generic Action Level for group G above which food restriction should be considered ( See Table F6 for IAEA recommendations) |
| $GIL_e$ | mSv | Generic intervention level for evacuation, avertable dose that warrants evacuations (IAEA recommendation, 50mSv in 7 days) |
| $GIL_{thy}$ | mSv | Generic intervention level for thyroid blocking, avertable dose that warrants taking thyroid blocking (IAEA recommendation, 100 mGy) |
| $GIL_r$ | mSv | Generic intervention level for relocation, avertable dose that warrant relocation or resettlement (See Table F3 for IAEA recommendations) |
| $H_{i,a}$ | mSv | Integrated external dose equivalent from submersion in the plume from isotope $I$ |
| $H_{i,g}$ | mSv | Integrated external dose equivalent from the deposition of isotope $I$ |
| $H_{thy}$ | mSv | Dose equivalent to the thyroid from inhalation |
| $\dot{H}_{thy}$ | mSv/h | Dose equivalent to the thyroid per hour of inhalation of iodine only assuming a breathing rate of 1 2 $m^3$/h for an adult performing light activity per hour exposure |
| $\dot{H}^*_g$ | mSv/h | Ambient dose rate at 1 m above ground level from ground surface contamination |
| $\dot{H}^*_a$ | mSv/h | Ambient dose rate from external dose from air contamination |
| $\overline{\dot{H}^*}$ | mSv/h | Average ambient dose rate |
| OIL1 | mSv/h | Ambient dose rate (operational intervention level) indicating evacuation is warranted (See Table B4 for description) |
| OIL2 | mSv/h | Ambient dose rate (operational intervention level) in the plume indicating taking thyroid blocking is warranted (See Table B4 for description) |
| OIL3 | mSv/h | Ambient dose rate (operational intervention level) from deposition that indicates that evacuation is warranted This considers external dose and inhalation dose from resuspension from remaining on ground contamination for 1 week (See Table B4 for description) |
| OIL4 | mSv/h | Ambient dose rate (operational intervention level) from deposition indicating relocation is warranted, this considers external exposure and resuspension from remaining on ground contamination for the 1st month, the 2nd month or 50 years (See Table B4 for description) |
| OIL5 | µSv/h | Ambient dose rate (operational intervention level) from deposition that indicates that food growing in that area may need to be restricted (See Table B4 for description) |
| OIL6 | kBq/$m^2$ | Deposition levels of I-131 (operational intervention level) that indicates that food or milk produced in areas may need to be restricted (See Table B4 for description) |

| Symbol | Unit | Description |
|---|---|---|
| OIL7 | kBq/m² | Deposition levels of Cs-137 (operational intervention level) that indicates that food or milk produced in areas may need to be restricted (See Table B4 for description) |
| OIL8 | kBq/kg | Concentration of I-131 in food, milk or water (operational intervention level) that indicate that the total contamination in the food may exceed the GAL and should be restricted (See Table B4 for description) |
| OIL9 | kBq/kg | Concentration of Cs-137 in food, milk or water (operational intervention level) that indicate that the total contamination in the food may exceed the GAL and should be restricted (See Table B4 for description) |
| $P_{plant}$ | MW(th) | Average operating thermal power level of plant |
| $r$ | | Retention factor, fraction of deposition that is retained on the crop |
| RF | | Reduction factor, fraction of contamination remaining after decay or some process used to reduce the contamination |
| $R_1$ | | Ratio of total effective dose to external ambient dose rate |
| $R_2$ | | Ratio of thyroid inhalation dose to external ambient dose rate |
| SF | | Shielding factor, dose with shielding divided by dose without shielding |
| $T_e$ | h | Exposure duration in the plume, default value is 4 h for wind direction persistence |
| $T_d$ | | Time food is held up before consumption in the same units as half live is used in the formula |
| $T_w$ | days | Weathering half-life |
| $T_{1/2}$ | hours, days years | Radiological half-life |
| $U_{fi}$ | kg/d | The amount of a food f consumed by the population of interest per day |
| $U_{cow}$ | kg/d | Cow consumption per day (default 56 kg/d) |
| $X_e$ | km | Projected distance to which evacuation is warranted |
| $X_r$ | km | Projected distance to which relocation is warranted |
| $X_{thy}$ | km | Projected distance to which providing thyroid blocking agent is warranted |
| Y | kg/m² | Productivity - weight grown per unit area |

## REFERENCES


ANSI79 American National Standard for Decay Heat Power in Light Water Reactors, ANSI/ANS-5.1, American Nuclear Society, La Grange Park, IL, December 1979.

ANSI84 American National Standard Radioactive Source Term for Normal Operation of Light-Water Reactors, ANSI/ANS 18.1, American Nuclear Society, La Grange Park, IL, December 1984.

ASME93 ASME 1993 C. A Meyer, R. B. McClintock, G. J. Silvestri, and R. C. Spencer, Jr., ASME Steam Tables: Thermodynamic and Transport Properties of Steam, 6th Ed., American Society of Mechanical Engineers Press, New York, 1993.

DOE84 U.S. Department of Energy - Atmospheric Science and Power Production, DOE, DOE/TIC-27601, 1984.

DOE95 FRMAC Assessment Manual, vol. 1, Methods, and vol. 2, Tables, Charts, Worksheets, Glossary, Reference, Index, interim version, U.S. Department of Energy, Washington, D.C., July 1995.

EGG75 Structures Shielding from Cloud and Fallout Gamma-Ray Sources for Assessing the Consequence of Reactor Accidents, Burson E.G., EGG-1183-1670, 1975.

EPA70 Turner, Workbook of Atmospheric Dispersion Estimates, EPA, January 1970.

EPA88 Keith F. Eckerman, Anthony B. Wolbarst, and Allan C. B. Richardson, Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion, EPA-520/1-88-020, Federal Guidance Report No. 11, Environmental Protection Agency, Washington, D.C., September 1988.

EPA92 Manual of Protective Action Guides and Protective Actions for Nuclear Incidents, U.S. EPA, EPA 400-R-92-001, May 1992.

EPA93 External Exposure to Radionuclides in Air, Water, and Soil, Federal Guidance Report No. 12, U.S. EPA, EPA-402-R-93-081, September 1993.

EPA94 U.S. EPA, PAG Subcommittee Report on Implementation of EPA's Dose Limits for Emergency Workers, July 12, 1994.

FEMA87 Guidance on Offsite Emergency Radiation Measurement Systems Phase 2 - The Milk Pathway, FEMA, FEMA REP-12, September 1987.

IAEA74 International Atomic Energy Agency, Evaluation of Radiation Emergencies and Accidents: Selected Criteria and Data, Technical Reports Series No. 152, IAEA, Vienna (1974).

| | |
|---|---|
| IAEA86 | Derived Intervention Levels for Application in Controlling Radiation Doses to the Public in the event of a Nuclear Accident or Radiological Emergency, Safety Series No. 81, IAEA, Vienna, (1986). |
| IAEA94 | International Atomic Energy Agency , Intervention Criteria in a Nuclear or Radiation Emergency, Safety Series No. 109, IAEA, Vienna (1994). |
| IAEA94a | International Atomic Energy Agency, Guidelines for Agricultural Countermeasures Following an Accidental Release of Radionuclides, Technical Report Series No. 363, IAEA, Vienna, (1994). |
| IAEA96 | International Atomic Energy Agency, International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources, Safety Series 115, IAEA, Vienna, (1996). |
| IAEA97 | International Atomic Energy Agency, Method for the Development of Emergency Response Preparedness for Nuclear or Radiological Accidents, IAEA-TECDOC-953, IAEA, Vienna (1997). |
| ICRP75 | Report of the Task Group on Reference Man, ICRP-23, International Commission on Radiological Protection, October 1975. |
| ICRU92 | Measurement of Dose Equivalents form External Photon and Electron Radiations, ICRU Report 47, April 1992, International Commission on Radiation Units and Measurements, Bethesda Maryland |
| NRC75 | WASH-1400 Reactor Safety Study: An Assessment of Accident Risks in U.S. Commercial Nuclear Power Plants, App. VI, Calculation of Reactor Accident Consequences, WASH-1400 (NUREG 75/014), U.S. Nuclear Regulatory Commission, Washington, D.C., October 1975. |
| NRC77 | U.S. NRC, Regulatory Guide 1.109, Calculation of Annual Doses to Man from Routine Releases of Reactor Effluent for the Purpose of Evaluating Compliance with 10 CFR Part 50, Appendix I, October 1977. |
| NRC79a | NUREG-600 Investigation Into the March 28, 1979, Three Mile Island Accident by the Office of Inspection and Enforcement, U. S. Nuclear Regulatory Commission, Washington, D.C., August 1979. |
| NRC79b | Allan S. Benjamin, David J. McCloskey, Dana A. Powers, and Stephen A. Dupree, Spent Fuel Heatup Following Loss of Water During Storage, NUREG/CR-0649 (SAND77-1371, R-3), Sandia Laboratories, Albuquerque, NM, March 1979. |
| NRC80 | Criteria for Preparation and Evaluation of Radiological Emergency Response Plans and Preparedness in Support of Nuclear Power Plants, NUREG-0654 (FEMA-REP-1), Rev. 1, U.S. Nuclear Regulatory Commission and Federal Emergency Management Agency, Washington, D.C., November 1980. |
| NRC83 | John E. Till and H. Robert Meyer - Radiological Assessment: A Textbook on Environmental Dose Analysis, NRC, NUREG/CR-3332, September 1983. |

| | |
|---|---|
| NRC83a | A. L. Camp, et al., Light Water Reactor Hydrogen Manual, NUREG/CR-2726 (SAND82-1137, R3), U.S. Nuclear Regulatory Commission, Washington, D.C., June 1983. |
| NRC83b | J. T. Larkins and M. A. Cunningham, Nuclear-Power-Plant-Severe-Accident Research Plan, U. S. Nuclear Regulatory Commission, Washington, D.C., January 1983. |
| NRC88 | T. J. McKenna and J. G. Giitter, Source Term Estimation During Incident Response to Severe Nuclear Power Plant Accidents, NUREG-1228, U. S. Nuclear Regulatory Commission, Washington, D.C., October 1988. |
| NRC90 | Severe Accident Risks: An Assessment for Five U.S. Nuclear Power Plants, NUREG-1150, vol. 1, U.S. Nuclear Regulatory Commission, Washington, D.C., December 1990. |
| NRC91 | S. A. McGuire, Chemical Toxicity of Uranium Hexafluoride Compared to Acute Effects of Radiation, NUREG-1391, Nuclear Regulatory Commission, Washington, D.C., January 1991. |
| NRC92 | L. Soffer, Accident Source Terms for Light Water Nuclear Power Plants, U.S. NRC, NUREG-1465, Draft for Comment, June 1992. |
| NRC93 | Response Technical Manual, RTM93, U.S. NRC, NUREG/BR-0150, Volume 1, November 1993. |
| NRC94 | RASCAL Version 2.1, Users Guide, U.S. NRC, NUREG/CR-5247, Vol. 1, Rev. 2, 1994. |
| NRC96 | J. Trefethen, Response Technical Manual, RTM 96, U.S. NRC, NUREG/BR-0150, Volume 1, March 1996. |
| NUMARC92 | Methodology for Development of Emergency Action Levels, NuclearManagement Council Inc. , January 1992, Washington D.C. USA |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## GLOSSARY

***Definitions of terms and acronyms used in the document***

These definitions are only assist the user of this document.

**AC**
Alternating current

**Active fuel**
The part of the fuel pin that contain uranium fuel pellets.

**Activity**
The quantity A for an amount of radionuclide in a given energy state at a given time, defined as:

$$A = \frac{dN}{dt}$$

where dN is the expectation value of the number of spontaneous nuclear transformation from the given energy state in the time interval dt. The SI unit of activity is the reciprocal seconds ($s^{-1}$), termed by Becquerel (Bq).

**Acute dose**
Dose received over a short period of time (e.g., days) used to estimate the potential for deterministic health effects.

**AGL**
Above ground level

**Alert**
The third most serious of the three emergency classes. Events involving an unknown or significant decrease in the level of protection for the public or on-site personnel. At this class the state of readiness of the on and off-site response organizations is increased and additional assessments are made.

**Alternating current (AC)**
An electric current that reverses direction in a circuit at regular intervals, e.g., normal household electrical service. Alternating current is necessary to run such reactor components of the emergency core cooling system such as pumps and motor-operated valves.

**ALV**
Accident localization volume. An enclosure designed to confine and reduce a release in the event of an accident.

**Ambient dose equivalent**
The ambient Dose Equivalent, H*(d), at a point in a radiation field, is the dose equivalent that would be produced by the corresponding expanded and aligned field in the ICRU sphere at a depth, d, on the radius opposing the direction of the aligned field. Consequently, the values of both equivalent doses and dose equivalents are equal to those of absorbed doses. Many existing instruments can be used to measure ambient dose equivalent rate merely by a scale change from R/h to 10 mSv/h (approximately). The unit for this measurement is the sievert. In this document we are assuming a d of 10. (ICRU92)

**Ambient dose rate**
Ambient Dose Equivalent, H*(d) per hour. Many existing instruments can be used to measure ambient dose equivalent rate merely by a scale change from R/h to 10 mSv/h (approximately). The unit for this measurement is the sievert. In this document we are assuming a d of 10 (ICRU92).

**Area radiation monitor**
Radiation monitors intended to determine exposure rates an area in the facility, i.e. a containment monitor.

**Atomic number (Z)**
The number of protons in an atom. The number of protons defines the chemical properties of the element and thus defines the element.

**Atomic mass number (A)**
The sum of the number of protons plus the number of neutrons in the atom.

**Average meteorology or weather**
The meteorology conditions that provided dispersion estimates that area in the center (average) for the range of reasonably expected conditions. D stability, 4 mph (1.8 m/s) wind speed and no rain is used. This will provide dispersion (dose) estimated with in a factor of 10 for most transport conditions.

**Background (radiation).**
Ionizing radiation normally present in the region of interest and coming from sources other than that of primary concern.

**Batch**
Portion of nuclear material handled as a unit for accounting purposes. A batch of reactor fuel is usually one-third of the reactor fuel in the core, the amount typically used during refuelling.

**Barrier**
Structure that is designed to prevent a major release.

**Becquerel**
The specific name for the unit of activity of a radionuclide.
$1\ Bq = 1\ disintegration\ s^{-1}$

**Boiling water reactor (BWR)**
A type of reactor design in which the coolant water is boiled in the reactor to create steam which drives the turbines to produce electricity. This design is used in about one-third of the U.S. power reactors.

**Bone marrow**
Soft material that fills the cavity in most bones; it manufactures most of the formed elements of the blood.

**Building wake**
Distortions in the wind patterns which are caused by a building. This effect, which is most pronounced immediately downwind of a building, alters the distribution of material within an atmospheric plume released from a source at or near (within 0.5 km) the building.

**Bubble tower**
Structure containing trays of water through which steam released as result of a rupture of the RCS is passed to condensed the steam to reduce pressure.

**BWR**
See: Boiling water reactor

**By-pass**
Route that allows fission products released from a reactor core to enter the environment without passing through the containment or accident localization volume.

**Catastrophic failure**
Failure of the reactor containment in a manner that releases most of the fission products in the containment into the environment in a short time.

**Centerline (plume)**
An imaginary line drawn in the middle of the plume along its downwind travel direction with a straight-line Gaussian approximation model. The plume concentrations and deposition are assumed to be the highest along the centerline.

**CET**
See: Core exit thermocouple

**Charging Pump**
A pump used during normal operation to maintain primary system water level. Also referred to as a make-up pump or normal injection pump. This pump may also used as part of the ECCS system.

**Child**
A 10 year old.

**Chronic dose**
Radiation dose received over a long period of time (years).

**Cladding**
See: Fuel cladding.

**Cloud shine**
Gamma radiation from radioactive materials in an airborne plume.

**Cold leg**
In a pressurized water reactor, the part of the reactor coolant system from the exit of the steam generator to the reactor vessel; in a boiling water reactor, the reactor coolant system from the feedwater containment penetration to the reactor vessel.

**Committed effective dose**
The quantity $E(\tau)$, defined as:

$$E(\tau) = \int_{t_0}^{t_0+\tau} \dot{E}(t)\ dt$$

where $t_0$ is the time of intake, $E(t)dt$ is the effective dose rate at time t and $\tau$ is the elapsed time after an intake of radioactive substances. When $\tau$ is not specified it will be taken to be 50 years for adults and to age 70 years for intakes by children.

**Concentration**
The total activity of each radioisotope in a sample or surface area.

**Condenser**
A large heat exchanger designed to cool and condense exhaust steam from a turbine so that it can be returned to the heat source as water. In a pressurized water reactor, the water is returned to the steam

generator. In a boiling water reactor, it returns to the reactor vessel. The heat removed from the system by the condenser is transferred to a circulating water system and is exhausted to the environment, either through a cooling tower or directly into a body of water.

**Containment**
Physical structures designed to prevent or reduce release of radioactive substances during an accident.

**Containment spray**
The water system used to relieve pressure and temperature buildup by steam release in the containment structure and also to reduce potential radioactive releases.

**Coolant**
The material, often water, used to remove heat from the reactor core.

**Cooling margin**
The amount (in a PWR) by which the saturation temperature at the given primary system pressure exceeds the coolant temperature. When the coolant temperature is equal to or exceeds the saturation temperature, the coolant water is boiling.

**Core**
See: Reactor core.

**Core damage**
Damage to the core of the reactor beyond that expected if safety systems are operating correctly as indicated by failure of more than 20% of the fuel pins. This includes the gap release and core melt damage states in the manual.

**Core exit thermocouple** (CET)
A device to measure the temperature in the core of a PWR. They are typically located just above the active core.

**Core melt**
Extensive melting of portions of the reactor fuel or other core components. Can take place after the core has been uncovered for 30 minutes or more.

**Core melt release**
Release of fission products from a reactor core after the core has been uncovered for more than 30 minutes. See Assumption for Section E for release fractions.

**Core release fraction (CRF)**
The fraction of each isotope in the core inventory that is assumed to be released from the core under given core conditions.

**CRF**
See: Core release fraction

**Critical**
Most important: a) source of dose, b) organ, or c) population group. That is, effects will be dominated by this source of dose or effects (e.g., deaths) will occur first as a result of exposure to this organ or population (e.g., infants) when exposed to radiation via a certain pathway.

**Critical safety function (CSF)**
Functions that must be performed during normal reactor operations and following an accident to protect the integrity of the fission product or release barriers and prevent the release of radioactive materials into the environment.

**Curie (Ci)**
A unit of radioactivity equal to $3.7 \times 10^{10}$ disintegrations per second.

**DC**
See: Direct current

**Decay heat**
The heat produced by the energy emitted during radioactive decay of fission products.

**Delta T** ($\Delta T$)
Difference in temperature

**Deposition**
The contamination found on or within a few cm of the surface of the ground or on the surface of other material.

**Design leakage**
The expected leakage rate from the containment or accident localization volume at its design pressure.

**Deterministic health effects**
A radiation effect that result from high dose rates and typically appear a short time after exposure for which generally a threshold level of dose exists above which the severity of the effect is greater for a higher dose. (e.g., deaths)

**Direct current (DC)**
An electric current that flows in one direction only. Direct current is used to operate essential reactor safety systems such as circuit breakers, solenoid-operated valves, and instruments and permits control of many components from remote locations.

**Dry well**
The primary containment structure in a BWR system. The dry well houses the reactor and the recirculating loop.

**EAL**
See: Emergency Action Level

**ECCS**
See: Emergency core cooling system

**Effective dose**
The quantity E, defined as a summation of the tissue equivalent doses, each multiplied by the appropriate tissue weighting factor:

$$E = \sum_T W_T \cdot H_T$$

where $H_T$ is the equivalent dose in tissue T and $W_T$ is the tissue weighting factor for tissue T.

From the definition of equivalent dose, it follows that:

$$E = \sum_T W_T \cdot \sum_R W_R \cdot D_{T,R} = \sum_R W_R \cdot \sum_T W_T \cdot D_{T,R}$$

where $W_R$ is the radiation weighting factor for radiation R and $D_{T,R}$ the average absorbed dose in the organ or tissue T. The unit of effective dose is $J.kg^{-1}$, termed the sievert (Sv).

**Emergency action level (EAL)**
A pre-determined site specific observable threshold at which places a plant and off-site response organizations at a given level emergency class. **EALs** can be: an instrument reading, an equipment status, or other observable event (e.g., a fire).

**Emergency core cooling system (ECCS)**
Emergency Safety systems that are designed to provide emergency coolant to the reactor core in the event of a loss of coolant or other accident.

**Emergency worker guidance**
Total dose personnel should make every attempt not to exceed while performing emergency services.

**Emergency planning zone (EPZ)**
A defined area around a facility for which planning and preparation are made in advance to ensure that prompt and effective protective actions can be taken to protect the public in the event of an accident.

**EPZ**
See: Emergency planning zone

**Evacuation**
The rapid removal of people from an area to avoid or reduce high-level, short-term exposure to a hazard.

**Exponent**
A symbol or number, usually written to the right of and above another symbol or number, that indicates how many times the latter number should be multiplied by itself.

**Exposure (rate)**
A common term referring to x and gamma radiation ionization of air. The unit of measurement is the Roentgen. This has been replaced by ambient dose equivalent as the quantity used to measure x and gamma radiation. Many existing instruments to measure exposure (R), however existing instruments can be used to measure ambient dose equivalent rate merely by a scale change from R/h to 10 mSv/h (approximately).

**External dose (or exposure)**
The dose of radiation received by an individual from a source of ionizing radiation outside the body.

**Facility operator**
The organization that operates the facility.

**Fission products**
Isotopes (generally radioactive) formed as the result of nuclear fission. Often the term used to refer to all the radioactive material contained in a reactor core or spent fuel (often including fission and activation products).

**Fission product barrier**
Structure that is designed to prevent a release of fission products.

**Fuel cladding**
The outer coating (usually zirconium alloy, aluminum, or stainless steel) of the uranium-filled reactor fuel rods. Fuel cladding provides the first barrier to the release of radioactive materials from the reactor fuel.

**Fuel rod (fuel pin)**
A long, slender tube that holds fissionable material (fuel) for nuclear reactor use. Fuel rods are assembled into bundles called fuel elements or fuel assemblies, which are loaded individually into the reactor core.

**GAL**
See: Generic action level

**Gamma (γ)**
Electromagnetic radiation emitted from the nucleus of the atom in gamma decay.

**Gap release**
The release from the core of the fission products in the fuel pin gap. Occurs immediately after failure of the fuel cladding. See assumption for Section E for assumed release fractions. The release of the gap will be the first radiological indication of core damage > 20 %. Gap release indicates severe core damage. Expected after the core is uncovered 15-30 minutes.

**Gaussian plume dispersion model**
A plume model based on the assumption that the pattern of gaseous concentrations across a plume follows a Gaussian distribution in both the vertical and horizontal planes. Gaussian plume models have some important limitations. They do not deal well with complex terrain, light or calm winds, heavier-than-air gases, or materials that began as heavier-than-air and transform into neutrally buoyant gases, such as some cryogenically-stored materials.

**General emergency**
Most sever accident. Events resulting in an actual or substantial risk of a release requiring implementation of urgent protective actions off-site. This includes: 1) actual or projected damage to the core or large amounts of spent pool or 2) releases off-site resulting in doses exceeding the urgent protective actions interventions levels within hours. Urgent protective actions are recommended immediately for the public near the plant when this level of emergency is declared.

**Generic action level (GAL)**
The level of activity concentration in food, milk or water above which remedial actions or protective actions should be carried out in chronic exposure or emergency exposure situations.

**Generic intervention level (GIL)**
The level of avertable dose at which specific protective action or remedial action is taken in an emergency exposure situation or a chronic exposure situation.

**GIL**
See: Generic intervention level

**Gray**
The special name for the unit of absorbed dose, kerma, and specific energy imparted.
$1\ Gy = 1\ J \cdot kg^{-1}$ (1 Gy = 100 Rad)

**Ground level release.**
A release of materials to the atmosphere from a source or opening near ground level.

**Ground roughness correction factor.**
A factor used to reduce the estimated dose because the radioactive material has been deposited on a rough surface which provides some shielding instead of a smooth plane.

**Ground shine**
Gamma radiation from radioactive materials deposited on the ground.

**Half-life, biological**
The time for the activity of radionuclide to diminish by a factor of a half because of biological elimination of the material.

**Half-life, radiological**
The time for the activity of radionuclide to diminish by a factor of a half because of nuclear decay events.

**Holdup time**
Is the time from the release to the containment atmosphere to the start of the release to the environment.

**Hot leg**
In a PWR, the reactor coolant system from the reactor vessel, past the pressurizer to the entrance of the steam generator; in a BWR, the reactor coolant system from the reactor vessel to the penetration exiting containment.

**Hot Spots**
Localized areas of high dose rates or contamination as a result of deposition.

**Ice bed (ice condenser)**
Part of the containment system for some PWRs. During an accident, steam is directed through the ice bed to a containment compartment. The ice cools and condenses the steam, decreasing the volume, so less containment volume is required.

**Immersion**
To be surrounded or engulfed by the radioactive cloud.

**Inadequate core cooling**
A condition which may occur during a reactor cooling system failure that results in a heat buildup in the core. Indications of inadequate core cooling include the first indication of saturation, core uncovery, and increase in fuel cladding temperature, finally exceeding the maximum value for normal recovery from a small loss-of-cooling accident.

**Ingrowth, radioactive**.
The increase in activity of a daughter radioactive isotope over time (when its half-life is longer than that of the parent).

**Inhalation**
The process of breathing in. Radioactive contamination in the atmosphere may enter the body by being breathed into the lungs. Some of the material will remain in the lung; some will pass into the blood stream; some will leave the lungs and be swallowed; and the remainder will be exhaled.

**Inhalation dose**
The dose resulting from inhalation of radioactive materials and subsequent deposition of these radioisotopes in body tissues.

**Ingestion**
Taking material (e.g., food) into the body by swallowing.

**Interfacing LOCA**
A loss of coolant accident (LOCA) involving a break in a system outside the containment that interfaces with the primary system and a failure of the isolation valve between the two systems resulting in a release route that by-passes the containment.

**Intervention level**
The level of avertable dose at which a specific protective action or remedial action is taken in an emergency exposure situation or a chronic exposure situation.

**Isotopes**
Nuclides of a particular element that contain the same number of protons but different numbers of neutrons.

**Late phase**
The period beginning when recovery actions designed to reduce radiation levels in the environment to permanently acceptable levels are commenced, and ending when all recovery actions have been completed. This period may extend from months to years.

**Longer term protective action planning zone (LPZ)**
The zone where plans and procedures are in place for taking effective protective actions to reduce the exposure due to long term exposure from deposition and ingestion.

**Light water reactor (LWR)**
A nuclear reactor that uses natural water as a coolant and moderator. All US commercial power reactor are LWRs as are the Russian constructed VVERs.

**Loss of coolant accident**
Accident involving loss of water from the primary system used to cool the reactor core.

**LOCA**
See: Loss of coolant accident

**LPZ**
See Long term protective action planning zone

**LWR**
See: Light water reactor

**Major release**
Release that has the potential to result in doses or food contamination off-site in excess of IAEA or national GILs or GALs.

**MARK I, II, III**
Three different containment designs used with USA boiling water reactors (BWR).

**Marker isotope**
An isotope contained in deposition or samples that is easily identified in the field or laboratory. It is used to determine areas of concern before performing a comprehensive isotopic analysis.

**Mix**
The isotopic ratio (relative abundance) of the radionuclides in a sample or deposition.

**MSIV**
Main streamline isolation valve

**MW(e)**
Mega-watt electric [MW(e) ≅ 1/3 MW(th)]

**MW(th)**
Mega-watt thermal

**Normal coolant release**
The release into containment of the fission products typically found in the reactor coolant during normal operations.

**Nuclide**
Any isotope of an atom, a nuclear species.

**OIL**
See: Operational intervention level

**Off-site**
The area outside the boundary of the on-site area. For emergencies at a fixed nuclear facility, "off-site" generally refers to the area beyond the facility boundary and not controlled by the operator. For emergencies that do not occur at fixed nuclear facilities and for which no physical boundary exists, the circumstances of the emergency will dictate the boundary of the offsite area.

**On-site**
The area within the boundary of the area controlled by the owner or operator of a fixed nuclear facility.

**Operational intervention level (OIL)**
A calculated value (e.g., ambient dose rate or radionuclide concentration) measured by instruments or determined by laboratory analysis that correspond to a GIL or GAL.

**Partitioned**
Condition in a steam generator that results in a reduction in fission products. The steam generator condition is not **partitioned** if the tube break is above the secondary side water level or if the secondary side is full of primary coolant. Normally multiple tube failures and failures in once through steam generators are assumed not to be partitioned. See assumptions for Section E for partitioning factors.

**PAZ**
See: Precautionary action zone

**Plume, atmospheric**
The airborne "cloud" of material released to the environment, which may contain radioactive materials and may or may not be invisible. In a plume release (as opposed to a "puff release"), the release and sampling times are long compared with travel time from the source.

**PORV**
See: Power-operated relief valve

**Power-operated relief valve (PORV)**
A valve placed on a tank that is operated electrically, hydraulically, or pneumatically to relieve a pressure buildup inside the tank. The relief valves are set to open before the self-actuating safety valves in the tank
.

**Precautionary action zone (PAZ)**
A zone around the facility in which planning and preparations have been made to implement urgent protective actions to reduce the risk of serious deterministic health effects (deaths).

**Pressurized water reactor (PWR)**
Type of reactor that uses water under pressure as a coolant in which the water in the reactor vessel does not boil during normal operation. The water is heated in the reactor core and pumped to the steam generators to provide the heat for production of steam to drive the turbines to generate electricity. An electrically heated pressurized maintains the pressure so that the water does not boil within the vessel.

**Pressurizer**
A tank or vessel that acts as a head tank (or surge volume) to control the pressure in a pressurized water reactor.

**Primary system**
The pipes, pumps and other components that contain and circulate the water that is in direct contact with the reactor core.

**Process radiation monitor**
Radiation monitor on a facility process, i.e. a coolant line.

**PWR**
See: Pressurized water reactor

**R**
See: Roentgen

**Rad**
A unit of absorbed dose, equivalent to an energy deposition of 0.01 J/kg.

**Radioactive half-life**
The time required for one half of the nuclei of a radioactive species to decay.

**Radioactive decay**
Transformation of an unstable substance into a more stable form, usually accompanied by the emission of charged particles and gamma rays.

**Radioiodine**
One or more of the radioactive isotopes of iodine.

**RCS**
See: Reactor coolant system

**Reactor coolant pump**
Pump used to circulate coolant through the core of a reactor.

**Reactor coolant system (RCS)**
The system within a nuclear reactor for cooling the reactor core by the transfer of heat.

**Reactor core**
The fuel rod assemblies and structural materials that support fission inside the reactor vessel.

**Reactor vessel**
The structure containing the core of a reactor.

**Reduced**
A release is reduced if it has encountered some reduction mechanism (e.g., sprays) that remove most of the particulate and iodine before being released to the environment..

**Reduction factor (RF source term)**
The ratio of the radioactivity available for release after reduction mechanism is considered to the radioactivity available for release before the reduction mechanism.

**Reduction mechanisms**
Chemical or physical mechanisms that act to reduce the amount of radioactive material that escapes to the environment during an accident.

**Re-entry**
Temporary entry into a restricted zone under controlled conditions.

**Relocation**
A non-urgent removal or continued exclusion of people (households) from contaminated areas to avoid chronic radiation exposure.

**Rem**
A unit of dose equivalent, obtained by multiplying the absorbed dose in rad by a quality factor which reflects the ability of a particular type of radiation to cause damage.

**Resuspension**
Reintroduction to the atmosphere of material originally deposited onto surfaces.

**Roentgen (R)**
A quantity used to express the ionization of air produces by x ray and gamma radiation. This has been replaced by ambient dose equivalent as the quantity used to measure x and gamma radiation. Many existing instruments to measure exposure (R), however existing instruments can be used to measure ambient dose equivalent rate merely by a scale change from R/h to 10 mSv/h (approximately).

**Route**
The route radionuclides follow from the source through the environment, including vegetation and animals, to reach an individual or a population.

The route radioactive material follows from the core through plant systems to the environment.

**RTM**
Response Technical Manual

**Safety System**
In a reactor system needed or intended to protect the core of the reactor or spent fuel. This includes systems to: shutdown the fission reaction, maintaining water level over the core and remove decay heat to the atmosphere. For other facilities systems needed to protect barriers to a release.

**Saturation**
A condition in the atmosphere corresponding to 100% relative humidity.

**Saturation temperature**
The temperature at which the liquid and vapour phases are in equilibrium at some given pressure. (The temperature at which water will boil at a specific temperature).

**Scientific notation**
A form of mathematical notation in which the number is expressed as a number between 1 and 10 multiplied by a power of 10.

**Scram**
A rapid shutdown of the fission reaction in a reactor core.

**Secondary side**
For pressurized water reactors the secondary cooling cycle which contains coolant not normally in contact with the core.

**Sector**
Is a division of an land around the facility. They can and should be defined before and in such a way that local population and emergency workers can easily identify i.e. natural landmarks, roads, rivers.

**Severe core damage**
Damage to the reactor core greater than that expected if the systems, design and procedures intended to protect the core perform adequately ( e.g., failure of more than 20% of the fuel cladding). Level of damage that could release fission products sufficient to result in health effects off-site.

**SG**
Steam generator

**SGTR**
Steam generator tube rupture

**Sheltering**
The use of a structure for protection from an airborne plume and/or deposited materials. The structure can attenuate radiation from radioactive materials deposited on the ground and reduce exposure to airborne plumes.

**Short-lived daughters**
Radioactive progeny of radioactive isotopes that have half-lives on the order of a few hours or less.

**Shutdown time**
Amount of time since the reactor has been shut down.

**Sievert**
The special name of the unit of dose equivalent.
$1\ Sv = 1\ J \bullet kg^{-1}$ (1 Sv = 100 Rem)

**Site area emergency**
The second most serious of the three emergency classes. Events resulting in a major decrease in the level of protection for the public or on-site personnel. This includes 1) a major decrease in the level of protection provided to the core or large amounts of spent fuel, 2) conditions where any additional failures could result in damage to the core or spent fuel or 3) high doses on-site. At this class preparations should be made to take protective actions off-site and to control the dose to on-site personnel.

**Slump**
Relocation of molten reactor core to the bottom of the vessel during an accident.

**Source term**
The amount and isotopic composition of material released or the release rate, used in modelling releases of material to the environment.

**Specific activity**
The activity per unit weight of a sample of radioactive material.

**Spent fuel**
Reactor fuel removed from a reactor following irradiation, or which is no longer usable because of depletion of fissile material, poison buildup, or radiation damage.

**Spent fuel pool**
A large pool of water used to store and cool spent fuel and other radioactive elements before they are shipped for storage or disposal.

**Spike**
See: Spiked Coolant

**Spiked coolant release**
The release of 100 times the non-noble gas fission products found in the coolant.

**Spiked coolant**
Rapid increase in non-noble gas fission products in the reactor coolant. This can occur following rapid shutdown or de-pressurization accidents even if the core is not uncovered or damaged. It is assumed to be 100 times the concentrations of non-noble gas fission products found in normal coolant.

**Spontaneous fission**
Radioactive decay by fission that is not induced by the addition of energy, such as bombardment with neutrons.

**Spray**
See containment spray.

**Stability class**
A class which describes an atmospheric turbulence conditions. Classes are generally grouped into six classes, ranging from class A, very unstable, through class F, very stable.

**Stable iodine**
Iodine which is comprised of only non-radioactive isotopes. See thyroid blocking agent

**Steam jet air ejector**
A system in a reactor to remove non-condensable gases from the main condenser and vent them to the off-gas system.

**Stochastic health effects**
Radiation effects, generally occurring without a threshold level of dose, whose probability is proportional to the dose and whose severity is independent of the dose.(e.g., cancers)

**Subcooled**
The water temperature is below the saturation temperature for the pressure. The water is not boiling.

**Suppression pool**
A pool of water in the wet well of a BWR containment that is designed to condense steam. Steam vents through the pool and to the well after a rupture of the primary system in the dry well. Thus condensing the steam reduces the pressure inside the containment after an accident.

**TAF**
Top of active fuel in the core of a reactor.

**Thermocouple**
A temperature measuring device consisting of two different metals joined together at both ends. The temperature difference across the two metals produces a thermoelectric current proportional to the difference.

**Thyroid blocking agent**
A substance which prevents or reduces the uptake of radioactive iodine by the thyroid. Usually stable potassium iodide (KI) is taken orally for this purpose.

**Tissue weighting factor**
Multipliers (as follows) of the equivalent dose to an organ or tissue used for radiation protection purposes to account for the different sensitivities of different organs and tissues to the induction of stochastic effects of radiation.

| Tissue or organ | Tissue weighting factor $W_T$ |
|---|---|
| Gonads | 0.20 |
| Bone marrow (red) | 0.12 |
| Colon (a) | 0.12 |
| Lung | 0.12 |
| Stomach | 0.12 |
| Bladder | 0.05 |
| Breast | 0.05 |
| Liver | 0.05 |
| Oesophagus | 0.05 |
| Thyroid | 0.05 |
| Skin | 0.01 |
| Bone surface | 0.01 |
| Remainder (b) | 0.05 |

(a) Lower large intestine.

(b) For the purposes of calculation, the remainder is composed of adrenal glands, brain, upper large intestine, small intestine, kidney, muscle, pancreas, spleen, thymus and uterus. In those exceptional cases in which a single one of the remainder tissues or organs receives an equivalent dose in excess of the highest dose in any of the twelve tissues or organs for which a weighting factor is specified, a weighting factor of 0.025 shall be applied to that tissue or organ and a weighting factor of 0.025 to the average dose in the rest of the remainder as defined here.

**Top of active fuel ( TAF)**
See: Active fuel

**Total effective dose**

$$E_T = H_p(d) + \sum_j h(g)_{j,ing} I_{j,ing} + \sum_j h(g)_{j,inh} I_{j,inh}$$

where:
$H_p(d)$ = personnel dose equivalent from penetrating radiation
$h(g)_{j,ing}$ and $h(g)_{j,inh}$ = committed effective dose per ingested or inhaled intake of isotope j
$I_{j,ing}$ and $I_{j,inh}$ = Intake via ingestion or inhalation of isotope j.
(See IAEA96, II-12)

**Transient (reactor)**
A major change in the operating mode or status of the plant.

**Trans-uranic elements**
Artificially produced elements with atomic numbers greater than that of uranium (92).

**Trip**
To shutdown or stop an operation of a system.

**Turn back guidance**
An integrated dose reading on a self reading dosimeter indicating that an emergency worker dose guidance has been exceeded and that the emergency worker should leave the areas where further significant dose is possible

**UPZ**
See Urgent Protective Action Planning Zone

**Urgent Protective Action Planning Zone (UAZ)**
A zone around the facility in which planning and preparations have been made to promptly implement urgent protective actions

**Urgent protective actions**
These actions must be taken promptly in order to be effective and the effectiveness of which will be markedly reduced if delayed They include evacuation, sheltering and, administration of stable iodine

**Vessel**
See Reactor vessel

**Vessel melt through**
Melting through of the vessel by a reactor core Release of fission products from the core expected when a core melts through a vessel

**Volatile fission products**
Fission products that are release in large fraction when the core is over heated (e g , Xe, Kr, I, Cs)

**Weather, average**
The meteorological conditions that provided dispersion estimates that area in the center (average) for the range of reasonably expected conditions D stability, 4 mph (1 8 m/s) wind speed and no rain is used This will provide dispersion(dose) estimated with in a factor of 10 for most transport conditions

**Weathering**
Reduction of dose from deposited material on the ground, over time due to rain etc

**Wet well**
The volume of a BWR containment that holds the suppression pool Any release from the wet well is assumed to have passed through the suppression pool

**WWER**
Designation used for a pressurized water reactor of Russian design

**Zircaloy**
A zirconium alloy used as cladding for reactor fuel rods

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**21 - 31 October, 1996**

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