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Preparation of Radiological Effluent Technical Specifications for Nuclear Power Plants

A Guidance Manual for Users of Standard Technical Specifications

U.S. Nuclear Regulatory Commission

Office of Nuclear Reactor Regulation

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PREPARATION OF RADIOLOGICAL EFFLUENT TECHNICAL SPECIFICATIONS FOR NUCLEAR POWER PLANTS

A Guidance Manual for Users of Standard Technical Specifications

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CHAPTER 1

INTRODUCTION

1.1 PURPOSE

The purpose of this manual is to describe methods found acceptable to the staff of the U.S. Nuclear Regulatory Commission (NRC) for the calculation of certain key values required in the preparation of proposed radiological effluent Technical Specifications using the Standard Technical Specifications for light-water-cooled nuclear power plants. This manual also provides guidance to applicants for operating licenses for nuclear power plants in the preparation of proposed radiological effluent Technical Specifications or in preparing requests for changes to existing radiological effluent Technical Specifications for operating licenses. The manual additionally describes current staff positions on the methodology for estimating radiation exposure due to the release of radioactive materials in effluents and on the administrative control of radioactive waste treatment systems.

1.2 BACKGROUND

Section 50.36, "Technical Specifications," of 10 CFR Part 50, "Licensing of Production and Utilization Facilities" (Ref. 1), requires that each nuclear power reactor operating license issued by the NRC contain Technical Specifications that set forth limits, operating conditions, and other regulatory requirements imposed on the facility operation for the protection of the health and safety of the public. Conditions and limitations corresponding to certain key values which are system-dependent and site-related are to be incorporated in these Technical Specifications for compliance with 10 CFR 50.36a, "Technical Specifications on Effluents from Nuclear Power Reactors." Under the provisions of Section 50.36, each applicant for an operating license is required to submit proposed Technical Specifications for his facility, including the supporting bases. These are reviewed by the NRC staff to assure that the proposed Technical Specifications contain such conditions and limitations as deemed appropriate and necessary; approved Technical Specifications are then included as Appendix A of the operating license.

Standard Technical Specifications have been developed by the staff for each appropriate nuclear steam supply system (NSSS) vendor to provide guidance to applicants for the preparation of proposed Technical Specifications. These are as follows:

NUREG-0212 - "Standard Technical Specifications for Combustion Engineering Pressurized Water Reactors"

NUREG-0103 - "Standard Technical Specifications for Babcock and Wilcox Pressurized Water Reactors"

NUREG-0452 - "Standard Technical Specifications for Westinghouse Pressurized Water Reactors"

NUREG-0123 - "Standard Technical Specifications for General Electric Boiling Water Reactors"

Current Standard Technical Specifications are available from the National Technical Information Service (NTIS), Springfield, Virginia, 22161. These Standard Technical Specifications will contain the radiological effluent Technical Specifications to be used by the applicant for an operating license. In the interim, model radioactive effluent Technical Specifications have been provided in NUREG-0472 (Ref. 2) for pressurized water reactors, and NUREG-0473 (Ref. 3) for boiling water reactors. Table 1.1 provides a summary of those applicable sections in the Standard Technical Specifications which contain conditions and limitations relative to the radiological effluent Technical Specifications to be discussed in this manual.

The Standard Technical Specifications contain the limiting conditions for operation necessary for complying with the Commission's regulations and are in a format that is acceptable to the NRC staff. The reporting requirements reflect the guidelines provided in Regulatory Guide 1.16, "Reporting of Operating Information - Appendix A Technical Specifications," Revision 4, August 1975 (Ref. 4) and Regulatory Guide 10.1, "Compilation of Reporting Requirements for Persons Subject to NRC Regulations," Revision 3, May 1977 (Ref. 5).

The methodology discussed in this manual and used to implement the requirements of 10 CFR Part 50, Appendix I, "Numerical Guides for Design Objectives and Limiting Conditions for Operation to Meet the Criterion 'As Low As Practicable' for Radioactive Material in Light-Water-Cooled Nuclear Power Reactor Effluents" (Ref. 1), is consistent with the Regulatory Guides used in the staff's safety evaluations pursuant to 10 CFR 50.34a(c). These guides are as follows:

Regulatory Guide 1.109 - "Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR Part 50, Appendix I" (Revision 1), October 1977. (Ref. 6)

Regulatory Guide 1.110 - "Cost-Benefit Analysis for Radwaste Systems for Light-Water-Cooled Nuclear Power Reactors," March 1976. (Ref. 7)

Regulatory Guide 1.111 - "Methods for Estimating Atmospheric Transport and Dispersion of Gaseous Effluents in Routine Releases from Light-Water-Cooled Reactors" (Revision 1), July 1977. (Ref. 8)

Regulatory Guide 1.112 - "Calculation of Releases of Radioactive Materials in Gaseous and Liquid Effluents from Light-Water-Cooled Power Reactors," April 1976. (Ref. 9)

TABLE 1.1

SUMMARY OF APPLICABLE SECTIONS IN THE STANDARD TECHNICAL SPECIFICATIONS
CONSIDERED IN THIS MANUAL

PLANT TYPE	Standard Technical Specification or Model Technical Specification in NUREG-0472 (Ref. 2) or NUREG-0473 (Ref. 3) SECTION	TABLES	BASES	TITLE	SECTION REFERENCE IN THIS MANUAL
PWR BWR	1.0	Yes	No	Definitions	2.0
PWR BWR	3/4.3.3.8	Yes	Yes	Radioactive Liquid Effluent Instrumentation	4.1
PWR BWR	3/4.3.3.9	Yes	Yes	Radioactive Gaseous Effluent Instrumentation	5.1
PWR BWR	3/4.11.1.1	Yes	Yes	Liquid Effluents, Concentration	4.2
PWR BWR	3/4.11.1.2	No	Yes	Liquid Effluents, Dose	4.3
PWR BWR	3/4.11.1.3	No	Yes	Liquid Effluents, Liquid Waste Treatment	4.5
PWR BWR	3/4.11.1.4	No	Yes	Liquid Effluents, Liquid Holdup Tanks	4.4
PWR BWR	3/4.11.2.1	Yes	Yes	Gaseous Effluents, Dose Rate	5.2
PWR BWR	3/4.11.2.2	No	Yes	Dose, Noble Gases	5.3
PWR BWR	3/4.11.2.3	No	Yes	Dose Radioiodines, Radioactive Material in Particulate Form and Radionuclides Other than Noble Gases	5.3
PWR BWR	3/4.11.2.4	No	Yes	Gaseous Effluents, Gaseous Waste Treatment	5.4
PWR BWR	3/4.11.2.5	No	Yes	Gaseous Effluents, Dose	3.8
PWR BWR	3/4.11.2.6A	No	Yes	Explosive Gas Mixtures (Systems designed to withstand a hydrogen explosion)	5.5
PWR BWR	3/4.11.2.6B	No	Yes	Explosive Gas Mixtures (Systems not designed to withstand a hydrogen explosion)	5.5
PWR	3/4.11.2.7	No	Yes	Gaseous Effluents, Gas Storage Tanks	5.6
BWR	3/4.11.2.7	No	Yes	Gaseous Effluents, Main Condenser	5.6
BWR	3/4.11.3.8	No	Yes	Gaseous Effluents, Mark I or II Containment (Optional)	3.0
PWR BWR	3/4.11.3.1	No	Yes	Solid Radioactive Waste	3.0
PWR BWR	3/4.12.1	Yes	Yes	Monitoring Program	4.3, 5.3
PWR BWR	3/4.12.2	No	Yes	Land Use Census	4.3, 5.3
PWR BWR	Fig. 3.11-1	No	No	Unrestricted Area Boundary for Liquid Effluents	2.0
PWR BWR	Fig. 5.1-1	No	No	Unrestricted Area Boundary for Gaseous Effluents	2.0
PWR BWR	6.9	No	No	Reporting Requirements	General

Regulatory Guide 1.113 - "Estimating Aquatic Dispersion of Effluents from Accidental and Routine Reactor Releases for the Purpose of Implementing Appendix I" (Revision 1), April 1977. (Ref. 10)

Computer codes used to determine certain values and parameters used with the Regulatory Guides listed above are described in the following documents:

NUREG-0017 - "Calculation of Releases of Radioactive Materials in Gaseous and Liquid Effluents from Pressurized Water Reactors (PWR-GALE Code)," April 1976 (Ref. 11)

NUREG-0016 - "Calculation of Releases of Radioactive Materials in Gaseous and Liquid Effluents from Boiling Water Reactors (BWR-GALE Code)" April 1976 (Ref. 12)

NUREG-0324 - "XOQDOQ, Program for the Meteorological Evaluation of Routine Effluent Releases at Nuclear Power Stations," September 1977 (Ref. 13)

These guides and computer codes provide acceptable methods of complying with the Commission's regulations; however, conformance with the staff's guidelines on Standard Technical Specifications, Regulatory Guides, and dose calculation methodology is not required. If the proposed Technical Specifications include mathematical models and parameters that differ from the methodology used by the staff to calculate set points and release rates or estimate doses due to releases of radioactive materials in effluents, the parameters and calculations used shall be substantiated in the Offsite Dose Calculation Manual.

Based on the findings of the Environmental and Safety Hearings, the Commission may impose certain additional or alternative limiting conditions for operation based on values that are more restrictive than those determined using this manual or provided in the Standard Technical Specifications. In such cases, the limiting conditions will be based on the decisions of the Atomic Safety and Licensing Board rather than the limiting values determined by this manual or included in the Standard Technical Specifications.

CHAPTER 2

DEFINITIONS AND STAFF POSITIONS

2.1 DEFINITIONS

Section 1.0, DEFINITIONS, of the Standard Technical Specifications provides standard definitions of terms and phrases which appear capitalized throughout the specifications. Standard definitions are provided to assure licensing consistency. When a term or phrase is used in a limited subject area of the Standard Technical Specifications, it is defined in the limited subject area and referenced by Specification number, table, figure or footnote.

2.2 STAFF POSITIONS AUGMENTING STANDARD DEFINITIONS

In certain circumstances, terms used in the Standard Technical Specifications are defined or specified in applicable regulations, such as 10 CFR Part 50 (Ref. 1). Staff positions clarifying certain of these definitions are as discussed below.

LIMITING CONDITIONS FOR OPERATION (LCO) is defined in 10 CFR 50.36(c)(2) as "the lowest functional capability or performance levels of equipment required for safe operation of the facility." This definition is applicable to the components of the radioactive waste management systems during normal reactor operations, including anticipated operational occurrences. When an LCO for a nuclear power reactor is not met, the licensee shall either shut down the reactor or follow any remedial action permitted by the Technical Specifications until the LCO can be met. Remedial action by the licensee may include processing by normal or alternate modes of operation for the control of radioactive effluents using such existing equipment as may be installed in the radioactive waste management systems.

MAINTENANCE AND USE of the equipment installed in the radioactive waste management systems is required in 10 CFR 50.34a(c) and in 10 CFR 50.36a(a)(1). The term, MAINTENANCE AND USE, is applicable to the installed components of the liquid, gaseous, and solid radioactive waste management systems and to instrumentation installed for the monitoring and control of potentially radioactive effluents. MAINTENANCE AND USE does not require the installation of fully redundant systems; however, prudent management procedures, such as scheduled standby and maintenance periods should be employed. The Standard Technical Specifications specify levels or values above which equipment installed in the radioactive waste management systems shall be used to enable the licensee to show that he is exerting his best efforts to maintain levels of radioactive effluents "as low as is reasonably achievable," in accordance with 10 CFR 50.36a.

UNRESTRICTED AREA is defined in 10 CFR 20.3(a)(17) (Ref. 14), as "any area access to which is not controlled by the licensee for purposes of protection of individuals from exposure to radiation and radioactive materials, and any area used for residential quarters."

For purposes of implementation, the definition of UNRESTRICTED AREA has been expanded as follows: "any area at or beyond the site boundary access to which is not controlled by the licensee for purposes of protection of individuals from exposure to radiation and radioactive materials, and any area within the site boundary used for residential quarters or industrial, commercial, institutional and recreational facilities". The UNRESTRICTED AREA boundary may coincide with the exclusion (fenced) area boundary, as defined in 10 CFR 100.3(a) (Ref. 15), may include land areas owned by the licensee, provided that occupancy is controlled by the licensee for the purposes of meeting the requirements of 10 CFR Part 20, but does not include areas over water bodies.

To assure that the UNRESTRICTED AREA boundary is defined in each license, the Standard Technical Specifications require two maps, one for liquid effluents (Figure 3.11-1)* and one for gaseous effluents (Figure 5.1-1)* locating all points surrounding the facility at which the licensee shall comply with the expanded definition, given above. These boundaries shall be consistent with those established in the Safety Analysis Report, or the Final Hazard Summary for the facility. The UNRESTRICTED AREAS, established at or beyond these boundaries, are also considered in the LIMITING CONDITIONS FOR OPERATION to keep levels of radioactive materials in effluents as low as is reasonably achievable, pursuant to 10 CFR 50.36a.

RELEASE RATE used in this manual is defined as, "the discharge of radioactive materials in liquid or gaseous effluents per unit time." The "second" is used as the practical reporting time unit for establishing release rates to show compliance with the requirements of 10 CFR Part 20 and for establishing instantaneous limitations based on potentially radioactive releases. The "hour" is used as the practical reporting time unit in establishing average release rates to show conformance with the requirements of 10 CFR Part 50 for noble gas releases, for gaseous radioactive effluents other than noble gases (radioiodines and particulates) and for radioactive materials released in liquid effluents. Liquid releases are further subdivided into batch and continuous releases. Gaseous releases are subdivided into short- and long-term releases. These gaseous release subdivisions classify cumulative releases as being either less than or greater than 500 hrs/year, respectively, for gaseous effluents. Further discussion is provided in Sections 3.3, 4.2 and 5.2 of this manual.

RADIOACTIVE WASTE MANAGEMENT SYSTEMS are defined as all process and control equipment provided to reduce the amount or concentration of radioactive materials (in any form) released from the facility. The overall systems may be divided into subsystems to handle the radioactive materials contained in liquid and gaseous streams and in solid waste. The Standard Technical Specifications have adopted nomenclature for systems and components which are in common use in the industry. In preparing proposed Technical Specifications, the system and component names may be changed to correspond to the terminology used in the Final Safety Analysis Report (FSAR) or the Final Hazard Summary, if applicable. Engineered Safety Feature (ESF) atmospheric cleanup systems are not considered to be radioactive waste management system components and, therefore, are not within the scope of this manual.

*This Figure is to be included in proposed Technical Specifications.

CHAPTER 3

SPECIAL CONSIDERATIONS

3.1 MULTI-UNIT SITES WITH SHARED RADIOACTIVE WASTE MANAGEMENT SYSTEMS

The Standard Technical Specifications are written on a "per unit" basis, since this is the format in which operating licenses are issued. When shared radioactive waste management systems are used by more than one reactor unit on a site, the wastes from all units are mixed for shared treatment; by such mixing, the effluent releases cannot accurately be ascribed to a specific reactor unit. The licensee should estimate the contributions from each unit based on input conditions, e.g., flow rates and radioactivity concentrations, or, if not practicable, the treated effluent releases may be allocated equally to each of the radioactive waste producing reactors sharing the treatment system. For determining conformance to LCOs, these allocations from shared treatment systems are to be added to the releases specifically attributed to each unit to obtain the total releases per unit.

It is preferred that discharge lines leading to common release points be separately controlled and monitored, and the licensee should consider instrumentation which will provide volumetric recording and radiological effluent monitoring, sampling and analyses on a unit basis. This has been accomplished for some units by continuous representative sampling and analysis of the streams prior to mixing and continuously monitored and controlled at the common release point. Multi-unit sites with common release points, but without shared radioactive waste management systems, are also required to determine the alarm/trip setpoints in Sections 4.1 and 5.1 of this manual to assure compliance with the requirements of 10 CFR Part 20 (Ref. 14) at each release point.

In preparing Technical Specifications for units at adjacent sites (multi-unit stations with a common boundary), the sites should be considered as a multi-unit site.

3.2 POPULATION EXPOSURE

The Standard Technical Specifications 3.11.1.3 and 3.11.2.4 require the use of equipment installed in the radioactive waste management system to meet the requirements of 10 CFR 50.36a (Ref. 1).

To assure that the Technical Specifications consider the population radiation doses, the use of the installed radioactive waste management system is required when the projected cumulative doses exceed an appropriate fraction of the individual dose limitations. This method of establishing use of the radwaste equipment assures that the staff's Appendix I cost-benefit analysis in the safety evaluation is not invalidated. Sections 4.5 and 5.4 of this manual provide these values for the Standard Technical Specifications. Guidance on reporting population exposures is provided in Regulatory Guide 1.21 (Ref. 17).

3.3 METEOROLOGICAL DATA

The Standard Technical Specifications consider the historical annual average atmospheric dispersion condition rather than real time dispersion conditions in determining the LCO for radioactive materials in gaseous effluents.

Releases are characterized as "long" or "short" term, depending on the frequency and duration of the releases. This characterization permits the matching of the releases to more appropriate atmospheric diffusion, dispersion and decay conditions.

"Long-term" refers to releases that are generally continuous and stable in release rate with some anticipated variation (i.e., <50%, based on a running monthly average) in release rate, such as is experienced in normal ventilation system effluents at nuclear power plants. Determination of doses due to long-term releases should use the historical annual average relative concentration (χ/Q) based on meteorological data summarized, as recommended in Regulatory Guide 1.111 (Ref. 8).

"Short-term" refers to releases that are intermittent in radionuclide concentrations or flow, such as releases from PWR gas storage tanks, PWR containment ventings and purges, BWR drywell purges (See Standard Technical Specification 3.11.3.8), BWR mechanical vacuum pump exhausts, and systems or components with infrequent use. Short-term releases may be due to operational variations which result in radioactive releases greater than 50% of the releases normally considered as long-term. Short-term releases from these sources during normal operation, including anticipated operational occurrences, are defined as those which occur for a total of 500 hours or less in a calendar year but not more than 150 hours in any quarter. Determination of doses due to short-term releases can use the annual average relative concentration (long-term) if it can be demonstrated that past short-term releases were sufficiently random in both time of day and duration (e.g., the short-term release periods were not dependent solely on atmospheric conditions or time of day) to be represented by the annual average dispersion conditions. Otherwise, the short-term relative concentration value should be calculated in accordance with the guidelines provided in NUREG-0324 (Ref. 13) for short-term release.

Even though "annual average" atmospheric dispersion conditions are used as basis for the Standard Technical Specifications, "real time" meteorological data should be summarized hour-by-hour and coupled with the corresponding releases, and the summary should be included in the SEMIANNUAL RADIOACTIVE EFFLUENT RELEASE REPORT.

3.4 NATIONAL INTERIM PRIMARY DRINKING WATER REGULATIONS

Operators of nuclear power plants located on fresh water bodies which are used as sources of water for drinking water supply systems, are required to make a special report concerning the impact on the water supply system due to liquid effluent releases into the water bodies which are above the value(s) permitted in Specification 3.11.1.2 of the Standard Technical Specifications. The NRC has no legal responsibility to implement 40 CFR Part 141, "National Interim Primary Drinking Water Regulations" (Ref. 16), or to assure routine conformance to the Act since this is the responsibility of the Environmental Protection Agency and the water plant operator. This special report is intended for public information and as a tool to assure awareness by the licensee of the impact of radioactive liquid releases on the community's water supply system. The impact within the water supply system is dependent on treatment given to the water taken into the system. The water plant operator is responsible for providing appropriate treatment to assure that 40 CFR Part 141 requirements are met. While the operator of the nuclear power plant is not responsible for meeting the requirements of 40 CFR Part 141 in the water supply system, his success in meeting the requirements of Specification 3.11.1.2 will assure an environmentally acceptable impact on the water supply system. The non-radiological impact is separately considered in the Appendix B Technical Specifications.

3.5 SOLID WASTE MANAGEMENT SYSTEM - PROCESS CONTROL PROGRAM

Standard Technical Specification 3.11.3.1 requires the operator of each nuclear power plant to establish a PROCESS CONTROL PROGRAM for the solid radioactive waste management system. The purpose of the PROCESS CONTROL PROGRAM is to provide reasonable assurance of the complete SOLIDIFICATION of processed wastes and of the absence of free water in the processed waste. At the time the applicant submits proposed Technical Specifications, he should submit the PROCESS CONTROL PROGRAM for NRC review and approval prior to implementation. The PROCESS CONTROL PROGRAM should consist of the processing steps and a set of established process parameters, which include but are not limited to pH, oil content, ratio of solidification agent to influent waste, water content, and ratio of solidification agent to chemical additive for each type of anticipated waste (filter sludges, spent resins, evaporator bottoms, boric acid solutions, sodium sulfate solutions and filter media). The surveillance requirements in the Standard Technical Specifications provide the steps to be taken to assure that operation is within the parameters established by the PROCESS CONTROL PROGRAM. Packaging procedures should demonstrate conformance with Specification 3.11.3.1. The PROCESS CONTROL PROGRAM required by the Standard Technical Specifications is to be documented in the operating procedures for each reactor and available for review by the NRC inspector. A summary of changes to the PROCESS CONTROL PROGRAM shall be provided in the SEMIANNUAL RADIOACTIVE EFFLUENT RELEASE REPORT.

3.6 OFFSITE DOSE CALCULATION MANUAL (ODCM)

Standard Technical Specifications 3.3.3.8 and 3.3.3.9 require the operator of each nuclear power plant to establish alarm and trip action setpoints for each radioactive liquid and gaseous effluent release point in maintained, auditable records, determined in accordance with the OFFSITE DOSE CALCULATION MANUAL (ODCM). The ODCM shall contain the methodology and parameters to be used in the calculation of offsite doses due to radioactive liquid and gaseous effluents pursuant to Specifications 3.11.1.2, 3.11.2.2 and 3.11.2.3, and the established limits of Specifications 3.11.1.1 and 3.11.2.1. The ODCM shall be submitted to the NRC with the proposed Technical Specifications for review and approval by the NRC. Changes to the ODCM shall be provided in the SEMIANNUAL RADIOACTIVE EFFLUENT RELEASE REPORT.

3.7 IDENTIFICATION OF RADIONUCLIDES IN EFFLUENTS

In order to determine the radiological impact associated with the release of radioactive materials in liquid and gaseous effluents, the principal radionuclides contributing to the dose must be identified. Tables 4.11-1 and 4.11-2** of the Standard Technical Specifications contain the sampling and analysis programs required for identifying principal radionuclides in effluents. These tables were compiled using the guidelines of Regulatory Guide 1.21 (Ref. 17) and reflect current radiochemical analytical methods. Other methods may be necessary to enhance identification and analysis, as provided by the footnotes to Tables 4.11-1 and 4.11-2. In lieu of sample-analysis, if the applicant does not consider that the collection, radiochemical separation, and analytical methods are technically feasible or practical at the specified LLD, then the dose limitations in Specifications 3.11.1.2, 3.11.2.2, and 3.11.2.3 should be proportionally reduced by assuming the continued presence and release concentrations of those radionuclides as determined by the source term (GALE Code, Ref. 11 or 12). For example, the dose LCO may be reduced based on predicted radioactive materials in gaseous effuents from PWR turbine buildings if sampling is not provided. For BWRs and PWRs it may be reduced if carbon-14 analysis is not provided.

3.8 ENVIRONMENTAL RADIATION PROTECTION STANDARDS FOR NUCLEAR POWER OPERATIONS

Standard Technical Specification 3.11.2.5 specifies in the Action that when the calculated doses associated with the effluent releases exceed twice* the limits of any one of the Specifications 3.11.1.2, 3.11.2.2 or 3.11.2.3, the licensee shall prepare and submit a Special Report to the Commission and limit subsequent releases such that the dose or dose commitment to a real individual from all uranium fuel cycle sources is limited to $\leq$ 25 mrem to the total body or any organ (except the thyroid, which is limited to $\leq$ 75 mrem) over 12 consecutive months. This Special Report shall include an analysis which demonstrates that radiation exposures to all real individuals from all uranium fuel cycle sources (including all liquid and gaseous effluent pathways and direct radiation) are less than the standards in 40 CFR Part 190, Environmental Radiation Protection Standards for Nuclear Power Operations (Ref. 18). If analysis indicates that releases resulting in doses that exceed the 40 CFR 190 Standard could occur, obtain a variance from the Commission to permit such releases. The Standard Technical Specifications 3.11.1.2, 3.11.2.2 and 3.11.2.3 consider doses to a real individual and apply to each reactor but do not include any other portion of the uranium fuel cycle or direct shine from the reactor.

The "Uranium fuel cycle" is defined in 40 CFR Part 190.02(b) as:

"Uranium fuel cycle means the operations of milling of uranium ore, chemical conversion of uranium, isotopic enrichment of uranium, fabrication of uranium fuel, generation of electricity by a light-water-cooled nuclear power plant using uranium fuel, and reprocessing of spent uranium fuel, to the extent that these directly support the production of electrical power for public use utilizing nuclear energy, but excludes mining operations, operations at waste disposal sites, transportation of any radioactive material in support of these operations, and the reuse of recovered non-uranium special nuclear and by-product materials from the cycle."

The following general guidelines are presented for preparation of the Special Report:

1) determine which uranium fuel cycle facilities or operations, in addition to the nuclear power reactor units at the site, contribute to the annual dose to the maximum exposed member of the public. The maximum exposed member of the public for

*This value may be reduced for multi-unit sites depending on staff analysis.

**These Tables are to be included in proposed Technical Specifications.

this evaluation may or may not correspond to the individual considered in the Technical Specification;

2) determine the total annual dose to this person from all existing pathways and sources of radioactivity and radiation using the methodologies described in this NUREG document and applicable references. Where additional information on pathways and nuclides is needed, the best available information should be used and documented;

3) include direct radiation from the site in the dose determination. An acceptable method for calculating radiation from the N-16 component of direct radiation is: SKYSHINE, A Computer Procedure for Evaluating Effects of Structure Design on N-16 Gamma-Ray Dose Rates, Radiation Research Associates, Inc. Report RRA-T7209, November 1972 (Ref. 19).

   In addition to N-16, all direct radiation from the plant and storage facilities should be considered in the dose determination. The direct dose component (including N-16) may be determined by calculation or actual measurement (e.g., high pressure ionization chamber). The calculation or actual measurement must be documented in this Special Report.

The 25 mrem and 75 mrem dose standards are effective December 1, 1979, except for doses arising from operations associated with the milling of uranium ore which is effective December 1, 1980.

Further information on the method of implementation of 40 CFR Part 190 is being developed by the NRC staff.

CHAPTER 4

LIQUID EFFLUENTS

4.1 INSTRUMENTATION

Standard Technical Specification 3.3.3.8 requires that:

"The radioactive liquid effluent monitoring instrumentation channels shown in Table 3.3-11* shall be OPERABLE with their alarm/trip setpoints set to ensure that the limits of Specification 3.11.1.1 are not exceeded. The setpoints shall be determined in accordance with procedures as described in the ODCM, and shall be recorded in the station log."

Table 3.3-11* provides a list of radioactive liquid effluent monitoring instrumentation needed to comply with the requirements of General Design Criteria (GDC) 60, 63, and 64 of Appendix A to 10 CFR Part 50 (Ref. 1). The list includes instrumentation such as radioactivity monitoring and sampling devices, automatic control devices, and essential flow and level devices which are components of the monitoring channels. The list uses common nomenclature for the effluent streams; however, the names may be revised, as necessary, to conform with a particular plant's nomenclature. Deletion of any item listed should be justified. Clarification of proposed Technical Specifications should be provided by a simple drawing or sketch showing stream intersections, instrumentation, and control features. Duplicate instrumentation (i.e., instruments that measure different sensor parameters or ranges) should be listed separately. The channel logic should assure that the alarmed trip action is not negated by switching.

The plant procedures should contain a quality assurance program for instruments as recommended in Regulatory Guide 4.15 (Ref. 20).

4.1.1 Setpoint Determination to be Provided in the ODCM

The alarm and trip setpoint(s) for each instrument channel listed in Table 3.3-11* should be provided and should correspond to a value(s) which represents a safe margin of assurance that the instantaneous liquid release limit of 10 CFR Part 20 is not exceeded. If the alarm and the automatic control trip are separate devices, the alarm/trip setpoint in the ODCM should list the separate trip setpoints. The alarm/trip setpoint in the ODCM should list the alarm setpoint where any trip actions are by manual initiation. The method for calculating fixed and adjustable setpoints shall be provided in the ODCM and auditable records shall be maintained indicating the actual setpoints used at all times. For setpoint calculations, see the Addendum to this manual.

*This Table is to be included in proposed Technical Specifications.

The alarm/trip setpoint for a liquid effluent radiation monitor should be determined based on the instantaneous concentration limits of 10 CFR Part 20, Appendix B, Table II, Column 2, and are to be applied at the point of discharge for that stream, pipe or conduit into the unrestricted area, as defined by Figure 3.1-1.* The alarm/trip setpoint should not consider dilution, dispersion or decay in the unrestricted area beyond the release point. An isolation control valve or system shall be provided on the discharge line prior to the release point to permit termination of radioactive releases prior to exceeding the instantaneous concentration limits of 10 CFR Part 20. The isolation and radiation monitoring points are to be located upstream of the release point far enough to assure that the time lag between the established alarm and isolation of the release will not permit a release exceeding these limits. If the stream is diluted by non-radioactive effluents, and the stream dilution and effluent isolation control system is in the exclusion area, the monitor's alarm/trip setpoint may be determined by considering the known in-plant dilution. In-plant dilution is the ratio of the total release rate at the release point into the unrestricted area to the release rate of the undiluted stream, and should be based on continuous measurement of these liquid flows. In such cases, alarm/trip setpoints should also be provided on the flow or level instrumentation with indication in the main control room. The minimum or actual instantaneous in-plant dilution ratio on which the liquid effluent radiation monitor alarm/trip setpoint has been based, should be continuously measured to aid prompt corrective action to satisfy Specification 3.11.1.1.

Conservative assumptions may be included in establishing setpoints to account for such system variables as the control and measurement system efficiency and detection capabilities during normal and anticipated operating conditions, the effects of multiple release points with common or shared in-plant dilution, variability of dilution flow and principal radionuclide composition, and the time lag between alarm/trip action and final isolation of the radioactive effluent. A record of analyses showing current spectra of radionuclides used to calibrate radiation monitors should be maintained in the plant records.

The instruments listed in Table 3.3-11** should also be included in Table 4.3-11** to provide the instrument surveillance requirements, such as calibration, source checking, functional testing and channel checking.

4.2 REQUIREMENT FOR IMPLEMENTING 10 CFR PART 20

In preparing proposed Technical Specifications, Figure 3.11-1* should consist of a map of the site area, showing the unrestricted area boundary for liquid effluents, as defined in 10 CFR 20.3(a)(17). Guidelines for preparing the figure are contained in Section 2.1.1 of Regulatory Guide 1.70 (Ref. 21).

Standard Technical Specification 3.11.1.1 specifies that:

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*This Figure is to be included in proposed Technical Specifications.

**See footnote on page 12.

"The concentration of radioactive material released from the site to unrestricted areas (see Figure 3.11-1)* shall be limited to the concentrations specified in 10 CFR Part 20, Appendix B, Table II, Column 2 for radionuclides other than noble gases and 2×10^{-4} µCi/ml total activity concentration for all dissolved or entrained noble gases."

The concentration limits provided in 10 CFR Part 20, Appendix B, Table II, Column 2, do not include an MPC for noble gases dissolved or entrained in liquid effluents. An MPC of 2×10^{-4} µCi/ml has been established, based on the assumption that xenon-135 is the controlling radionuclide; the Xe-135 MPC in air (submersion) was converted to an equivalent concentration in water using the method described in International Commission on Radiological Protection (ICRP) Publication 2 (Ref. 22). The value of 2×10^{-4} µCi/ml shall be used for a mixture of dissolved or entrained noble gases, not otherwise identified in liquid releases.

To demonstrate that the Specifications are being met, the surveillance requirements specify that a sampling and analysis program be implemented according to Table 4.11-1.** There are two general types of releases: batch and continuous. A batch release is the discharge of liquid waste of a discrete volume. A continuous release is the discharge of liquid wastes of a nondiscrete volume; e.g., from a volume or system that has an input flow during the continuous release. For example, releases from sample monitor tanks are batch, and releases from steam generator blowdown are continuous. The sampling and analysis frequency and the type of analysis required by the Standard Technical Specifications is given in Table 4.11-1 for each type of release. The lower limit of detection is also specified in Table 4.11-1 for typical in-plant radiochemical analysis equipment. This program meets the requirements of 10 CFR Part 50, GDC 64, and conforms to the guidelines given in Regulatory Guides 1.21 (Ref. 17) and 4.15 (Ref. 20).

4.3 REQUIREMENT FOR IMPLEMENTING 10 CFR PART 50

The Standard Technical Specification 3.11.1.2 requires that the cumulative dose contributions be determined in accordance with the ODCM at least once per 31 days. The cumulative dose contributions should consider the dose contributions from the maximum exposed individual's consumption of fish, invertebrates and potable water, as appropriate. Normally, the adult is the maximum exposed individual. All of these pathways should be considered in the calculation unless demonstrated not to be present. For many plant sites, the dose calculations may be performed assuming conservative dilution factors and receptor locations to show compliance with the Technical Specification rather than a more rigorous determination. The relationships presented below are acceptable for inclusion in the ODCM. If other methods are selected to implement this Specification, it is expected that the alternate method will include the same general features considered below.

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*See footnote on page 13.

**See footnote on page 12.

The dose contributions for the total time period $\sum_{\ell=1}^{m} \Delta t_\ell$ should be determined by calculation at least once per 31 days and a cumulative summation of these total body and any organ doses should be maintained for each calendar quarter. These dose contributions should be calculated for all radionuclides identified in liquid effluents released to unrestricted areas using the following expression:

$$D_\tau = \sum_i [A_{i\tau} \sum_{\ell=1}^{m} \Delta t_\ell \; C_{i\ell} \, F_\ell]$$

where:

D_τ = the cumulative dose commitment to the total body or any organ, τ, from the liquid effluents for the total time period $\sum_{\ell=1}^{m} \Delta t_\ell$, in mrem.

Δt_ℓ = the length of the ℓth time period over which $C_{i\ell}$ and F_ℓ are averaged for all liquid releases, in hours.

$C_{i\ell}$ = the average concentration of radionuclide, i, in undiluted liquid effluent during time period Δt_ℓ from any liquid release, in μCi/ml.

$A_{i\tau}$ = the site related ingestion dose commitment factor to the total body or any organ τ for each identified principal gamma and beta emitter listed in Table 4.11-1,* in mrem-ml per hr-μCi.

F_ℓ = the near field average dilution factor for $C_{i\ell}$ during any liquid effluent release. Defined as the ratio of the maximum undiluted liquid waste flow during release to the product of the average flow from the site discharge structure to unrestricted receiving waters times ___. (___ is the site specific applicable factor for the mixing effect of the discharge structure.)

The term $C_{i\ell}$ is the composite undiluted concentration of radioactive material in liquid waste at the common release point determined from the Radioactive Liquid Waste Sampling and Analysis Program, Table 4.11-1* in the Standard Technical Specifications. All dilution factors beyond the sample point(s) are to be included in the F_ℓ and $A_{i\tau}$ terms.

The term F_ℓ is a near field average dilution factor, considering the combined liquid releases from each unit even if there is more than one release point to the unrestricted area per unit within one-quarter mile of each other. As described in Section 3.1 of this manual, multi-unit sites with shared radioactive waste management systems should calculate the total continuous and batch liquid release concentrations for each reactor. The value of the term F_ℓ should be determined as:

*See footnote on page 12.

$$F_\ell = \frac{\text{liquid radioactive waste flow per unit}}{\text{discharge structure exit flow per unit x applicable factor}}$$

The liquid radioactive waste flow is the maximum flow from all continuous and batch radioactive effluent releases specified in Table 4.11-1, from all liquid radioactive waste management systems, per unit. The discharge structure exit flow is the average flow during disposal from the discharge structure release point into the receiving water body (in an unrestricted area) per unit. The definition of F_ℓ also requires a value to be included in Specification 3.11.1.2 for the dilution as a result of mixing effects in the near field of the discharge structure. For plants with once through cooling, the applicable factor is set equal to one, i.e., no additional dilution is considered. For plants with cooling towers, onsite ponds, or lagoons, the factor shall be a number such that the product of the average blowdown flow to the receiving water body, in cfs and the applicable factor, is 1000 cfs or less. The 1000 cfs figure was selected to correspond to a typical flow for a unit with once-through cooling water and agrees with the staff method for determining compliance with Appendix I (Ref. 1) at the OL stage. The value of this applicable factor is to be included in the blank provided for the term F_ℓ. The actual dilution factor value is dependent upon the dilution available in the near field of the receiving water body; however, the applicable factor is limited, as stated above.

4.3.1 <u>Dose Factor Related to Liquid Effluents</u>

The above equation for calculating the dose contributions requires the use of a dose factor $A_{i\tau}$ for each nuclide, i, which embodies the dose factors, pathway transfer factors (e.g., bioaccumulation factors), pathway usage factors, and dilution factors for the points of pathway origin. The adult total body dose factor and the <u>maximum</u> adult organ dose factor for each radionuclide will be used from Table E-11 of Regulatory Guide 1.109 (Ref. 6); thus the list should contain critical organ dose factors for various organs. The dose factor may be written:

$$A_{i\tau} = k_o(U_W/D_W + U_F BF_i + U_I BI_i)DF_i$$

where

$A_{i\tau}$ = composite dose parameter for the total body or critical organ of an adult for nuclide, i, for all appropriate pathways, mrem/hr per μCi/ml.

k_o = units conversion factor, $1.14 \times 10^5 = 10^6$ pCi/μCi x 10^3ml/kg ÷ 8760 hr/yr.

U_W = 730 kg/yr, adult water consumption (fresh water site only).

U_F = 21 kg/yr, adult fish consumption (all sites).

U_I = 5 kg/yr, adult invertebrate consumption (salt water site only).

BF_i = Bioaccumulation factor for nuclide, i, in fish (fresh or salt water site, as applicable), pCi/kg per pCi/l, from Table A-1 of Regulatory Guide 1.109 (Ref. 4).

BI_i = Bioaccumulation factor for nuclide, i, in invertebrates (salt water only), pCi/kg per pCi/l, from Table A-1 of Regulatory Guide 1.109 (Ref. 4).

DF_i = Dose conversion factor for nuclide, i, for adults in pre-selected organ, τ, in mrem/pCi, from Table E-11 of Regulatory Guide 1.109 (Ref. 4).

D_W = Dilution factor from the near field area within one-quarter mile of the release point(s) to the potable water intake for the adult water consumption (fresh water site only).

Inserting the usage factors of Regulatory Guide 1.109 (Ref. 6) as appropriate into the equation gives the following expressions:

For Fresh Water sites: $A_{i\tau} = 1.14\text{x}10^5(730/D_w + 21BF_i)DF_i$

For Salt Water sites: $A_{i\tau} = 1.14\text{x}10^5(21BF_i + 5BI_i)DF_i$

As noted, all the factors required to calculate the values of $A_{i\tau}$ should be contained in the ODCM. The staff's method of calculating dilution factors for aquatic dispersion is provided in Regulatory Guide 1.113 (Ref. 10). The ODCM should include a detailed presentation of the calculation model and a tabulation of all values assigned to the parameters in expressions used to implement the Specification 3.11.1.2.

4.3.2 Special Reports

The Standard Technical Specifications 3.11.1.2, 3.11.1.3, 3.11.2.2, 3.11.2.3, 3.11.2.4 and 3.11.3.1 require that action be taken when the Specification cannot be met. The action is in the form of special reports, in lieu of licensee event reports, indicating the corrective action to be taken to reduce the dose impact due to the release of radioactive materials in liquid effluents.

These special reports should be prepared using the methodology provided in this manual to determine the dose impact. Such information in the special reports will be used by the staff in determining if the corrective action proposed by the licensee is adequate to bring the releases within the design objectives of Appendix I to 10 CFR Part 50. These special reports may also require submitting additional information as described in Section 3.4 of this manual.

4.4 SPECIFICATION ON RADIOACTIVITY CONTENTS IN LIQUID-CONTAINING TANKS

Standard Technical Specification 3.11.1.4 and Tables 3.3-11* and 4.3-11* list liquid-containing tanks outside containment that are to be analyzed periodically to verify that the radioactivity content (in curies, excluding tritium and dissolved or entrained noble gases) is below the specified value. Tanks included in this Specification are those that are not surrounded by liners, dikes or walls capable of holding the tank contents and do not have tank overflow and drains connected to the liquid radioactive waste management system. Indoor tanks are not included unless an analysis based on design basis fission product leakage from the fuel results in radionuclide concentrations in excess of the limits of 10 CFR Part 20, Appendix B, Table II, Column 2, where leaked fluid is capable of affecting the nearest existing or known future water supply** in an unrestricted area.

*See footnote on page 12.

**"Supply" means a well or surface water intake that is used as a water source for direct human consumption or indirectly through animals, crops or food processing. "Known future" water supply means potential wells or surface water intakes which are identified, or may be reasonably deduced from available information.

For those tanks that are determined to be included in Specification 3.11.1.4 and Tables 3.3-11 and 4.3-11, a curie limit should be determined based on the methodology presented in Appendices A or B of this manual, using the PWR-RATAFR Computer Code for pressurized water reactor plants, or the BWR-RATAFR Computer Code for boiling water reactor plants, respectively. The methodology is based on the calculated radionuclide inventory in the tank at 80% capacity using a design basis fission product source term of (1) 1% of the operating fission product inventory in the core being released to the primary coolant for a PWR, or (2) a fission product release consistent with a noble gas release rate of 100 μCi/MWt-sec at 30 minutes decay for a BWR. These Computer Codes determine the radionuclide inventory in a tank that would result in concentrations equal to the limits of 10 CFR Part 20, Appendix B, Table II, Column 2, at (1) the nearest potable water supply and (2) the nearest surface water supply in an unrestricted area.

By excluding tritium and dissolved or entrained noble gases from the surveillance analyses, since these can be estimated for any licensee event report, Specification 3.11.1.4 should include the lowest curie quantity of activation and mixed fission products determined for any tank listed in Specification 3.11.1.4 as the curie limit for all tanks included in that Specification.

Most operating reactors have required the use of temporary process and storage tanks during maintenance and service periods, or when temporary solidification equipment is used at the facility; therefore, the Specification 3.11.1.4 should indicate a "temporary tank." The curie limit for a temporary tank may be calculated by the above method, but should be limited to $\leq$ 10 curies, excluding tritium and dissolved or entrained gases. If the temporary tank is mobile and not used for more than a calendar quarter, it need not be included in Tables 3.3-11* and 4.3-11.*

4.5 SPECIFICATION ON THE USE OF LIQUID RADIOACTIVE WASTE MANAGEMENT SYSTEM

Standard Technical Specification 3.11.1.3 specifies that:

> "The liquid radwaste treatment system shall be OPERABLE. The appropriate subsystems shall be used to reduce the radioactive materials in liquid wastes prior to their discharge when the projected doses due to the liquid effluent releases to unrestricted areas (see Figure 3.11-1)* when averaged over 31 days, exceeds 0.06 mrem to the total body or 0.2 mrem to any organ."

The operability of the liquid radioactive waste management system ensures that this system will be available for use whenever liquid effluents require treatment prior to release to the environment. The term "liquid radwaste treatment system" involves all of the installed and available liquid radioactive waste management system equipment, as well as their controls, power instrumentation, and services that make the system functional. Equipment that is considered standby or redundant is also included, since their function is to assure operability. The specification also permits alternate treatment paths using alternate subsystems and equipment to be used in the event that the normal treatment is inoperable.

*See footnote on page 13.

This Specification requires maintenance and use of the liquid radioactive waste management system for conformance to 10 CFR Part 50.36a. Maintenance and use of the radioactive waste management system components are discussed in Section 2.2 of this manual.

To determine if use of the installed equipment is necessary, the licensee must project the cumulative liquid effluent releases over the ensuing 31 days. These releases should include all plant effluents from all liquid radioactive waste management and liquid waste disposal system components that are planned to be operated at the projected capacity and performance of each component used during the specified time. These releases should include a margin, based on operating data, for anticipated and unplanned operational occurrences and should use the methodology discussed in Section 4.3 of this manual. The impact from this projected cumulative release is to be compared to 0.06 mrem for the total body or 0.2 mrem for any organ. If the projection indicates these values will be exceeded, then the installed liquid radioactive waste management system components that will reduce those radioactive materials in liquid effluents and the projected impact, must be used.

The values for the projected impact, given above, correspond to approximately one forty-eighth of the design objective values of Appendix I, Section II.A of 10 CFR Part 50 in a month, and if continued at this rate for a year, they would correspond to less than one-fourth the values limited by Specification 3.11.1.2.b. The calculations of projected cumulative dose impact that could result from the proposed operation should use the methodology provided in Section 4.3 of this manual.

CHAPTER 5

GASEOUS EFFLUENTS

5.1 INSTRUMENTATION

Standard Technical Specification 3.3.3.9 requires that:

> "The radioactive gaseous process and effluent monitoring instrumentation channels shown in Table 3.3-12* shall be OPERABLE with their alarm/trip setpoints set to ensure that the limits of Specification 3.11.2.1 are not exceeded. The setpoints shall be determined in accordance with procedures as described in the ODCM, and shall be recorded in the station log."

Table 3.3-12* provides a list of the radioactive gaseous effluent monitoring instrumentation needed to comply with the requirements of General Design Criteria (GDC) 60, 63, and 64 of Appendix A to 10 CFR Part 50. The list includes instrumentation such as radioactivity monitoring and sampling devices, automatic control devices and essential flow and level devices that are components of the monitoring systems. The list uses common nomenclature for the effluent streams; however, the names may be revised as necessary, to conform with a particular plant's nomenclature. The list may include effluent streams which are not applicable to a given plant, or which may be duplicated and, therefore, should be tailored for the proposed Technical Specifications. Clarification of proposed Technical Specifications should be provided by a simple drawing or sketch, showing stream intersections, instrumentation and control features. Duplicate instrumentation (i.e., instruments that measure different sensor parameters or ranges) should be listed separately in Tables 3.3-12* and 4.3-12.* The channel logic should assure that the alarmed trip action is not negated by switching.

The plant procedures should contain a quality assurance program for instruments as recommended in Regulatory Guide 4.15 (Ref. 20).

5.1.1 Setpoint Determination to be Provided in the ODCM

The alarm/trip setpoint or automatic control trip setpoint for each instrument channel listed in Table 3.3-12* should be provided and should correspond to a value(s) which represents a safe margin of assurance that the instantaneous gaseous release limit of Specification 3.11.2.1(a) will not be exceeded. For channels with separate alarm and automatic control trips, the setpoint for the automatic control trip should be the established value referenced above; the corresponding setpoint for alarm/trip should be established such that an alarm trip will occur either in advance of the automatic control trip or simultaneously with the automatic control trip. For channels with alarm trips only, the setpoint for the alarm/trip should be the established value referenced above, provided that the manual or procedural response to the alarm represents a safe margin of assurance that the instantaneous gaseous release limit of 10 CFR Part 20 will not be exceeded. The alarm/trip setpoint in the ODCM should list the alarm setpoint for those channels where any trip actions are by

*This Table is to be included in the proposed Technical Specifications.

manual initiation. The method for calculating fixed or adjustable setpoints shall be provided in the ODCM and auditable records shall be maintained indicating the actual setpoints used at all times.

The alarm/trip setpoint for any gaseous effluent radiation monitor should be determined based on the instantaneous (see RELEASE RATE fundamental time units in Section 2.2 of this manual) concentration limits of 10 CFR Part 20, Appendix B, Table II, Column 1, and are to be applied at the point at which the discharge leaves the restricted area boundary into an unrestricted area, as defined by Figure 5.1-1.** The bases for each setpoint should consider the type of release at the monitor's location, e.g., long-term releases using the long-term atmospheric dispersion conditions or, if applicable (see Section 3.3 of this manual), short-term releases using the short-term atmospheric dispersion conditions. An isolation control valve or system shall be provided on the discharge line upstream of the release point to permit isolation prior to exceeding the specified release limits.

If the alarm/trip setpoints are based on predetermined factors accounting for atmospheric conditions, the elevation of the release point should be considered. The symbols used in the equations in this manual use a subscript (s) for a free-standing stack for elevated releases (or vents that take the plume out of the building wake) and a subscript (v) for vent for releases that are not completely elevated. Guidance on the staff's method for estimating atmospheric transport and dispersion of gaseous effluents in routine releases is provided in Regulatory Guide 1.111 (Ref. 8). The radiation monitor alarm/trip setpoints for each release point should be based on the radioactive noble gases in gaseous effluents. It is not considered to be practicable to apply instantaneous alarm/trip setpoints to integrating radiation monitors sensitive to radioiodines, radioactive materials in particulate form and radionuclides other than noble gases. Alarm/trip setpoints should also be provided in the main control room for flow measurement devices which are part of continuous monitoring or sampling systems and should alarm on loss-of-flow or departure from an established flow range. In all cases, conservative assumptions may be necessary in establishing these setpoints to account for system variables, such as the control and measurement system efficiency and detection capabilities during normal, anticipated, and unusual operating conditions, the variability in release flow and principal radionuclides, and the time lag between alarm/trip action and the final isolation of the radioactive effluent. The current spectrum of radionuclides used to calibrate radiation monitors should be maintained in the plant records. The instruments listed in Table 3.3-12* should also be included in Table 4.3-12,* to provide the instrument surveillance requirements, such as calibration, source checking, functional testing, and channel checking.

5.2 DOSE LIMIT FOR IMPLEMENTING 10 CFR PART 20

In preparing proposed Technical Specifications, Figure 5.1-1** should consist of a map of the site area showing the exclusion boundary, as defined in 10 CFR 100.3(a) (Ref. 15) and the unrestricted area boundary, as defined in 10 CFR 20.3(a)(17) (Ref. 14). Guidelines for this figure are contained in Section 2.1.1 of Regulatory Guide 1.70 (Ref. 21). Details on the release point locations and significant elevations should be given in Figure 5.1-1.**

*See footnote on page 20.

**This Figure is to be included in proposed Technical Specifications.

5.2.1 Implementation of 10 CFR Part 20 - Airborne Releases

The Standard Technical Specification 3.11.2.1 implements 10 CFR Part 20 as follows:

"The instantaneous dose rate in unrestricted areas (see Figure 5.1-1)** due to radioactive materials released in gaseous effluents from the site shall be limited to the following values:

a. The dose rate limit for noble gases shall be < 500 mrem/yr to the total body and < 3000 mrem/yr to the skin, and

b. The dose rate limit for all radioiodines and for all radioactive materials in particulate form and radionuclides other than noble gases with half lives greater than 8 days shall be < 1500 mrem/yr to any organ."

The ODCM should provide the mathematical relationships used to implement the above specification. The relationships presented below are acceptable for inclusion in the ODCM. If other methods are selected to implement the specification, it is expected that the alternative method will include the same general features considered below.

a. Release rate limit for noble gases:

$$\sum_i [V_i \dot{Q}_{is} + K_i ((\overline{\chi/Q})_v \dot{Q}_{iv})] < 500 \text{ mrem/yr, and}$$

$$\sum_i [(L_i (\overline{\chi/Q})_s + 1.1 B_i) \dot{Q}_{is} + (L_i + 1.1 M_i)((\overline{\chi/Q})_v \dot{Q}_{iv})] < 3000 \text{ mrem/yr}$$

where the terms are defined below.

b. Release rate limit for all radionuclides and radioactive materials in particulate form and radionuclides other than noble gases:

$$\sum_i P_i [W_s \dot{Q}_{is} + W_v \dot{Q}_{iv}] < 1500 \text{ mrem/yr}$$

where:

K_i = The total body dose factor due to gamma emissions for each identified noble gas radionuclide, in mrem/yr per $\mu Ci/m^3$.

L_i = The skin dose factor due to beta emissions for each identified noble gas radionuclide, in mrem/yr per $\mu Ci/m^3$.

M_i = The air dose factor due to gamma emissions for each identified noble gas radionuclide, in mrad/yr per $\mu Ci/m^3$ (unit conversion constant of 1.1 mrem/mrad converts air dose to skin dose).

P_i = The dose parameter for radionuclides other than noble gases for the inhalation pathway, in mrem/yr per $\mu Ci/m^3$ and for food and ground plane pathways, in m^2(mrem/yr per μCi/sec). The dose factors are based on the critical individual organ and most restrictive age group (infant).

V_i = The constant for each identified noble gas radionuclide accounting for the gamma radiation from the elevated finite plume, derived in accordance with the dose methodology in Regulatory Guide 1.109, Appendix B, Section 1, in mrem/yr per μCi/sec.

B_i = The constant for long-term releases (greater than 500 hrs/yr) for each identified noble gas radionuclide accounting for the gamma radiation from the elevated finite plume, derived in accordance with the dose methodology in Regulatory Guide 1.109, Appendix B, Section 1, in mrad/yr per μCi/sec.

** See footnote on page 21.

$\dot{Q}_{is}$ = The release rate of radionuclides, i, in gaseous effluents from free-standing stack, in μCi/sec (per unit, unless otherwise specified.)

$\dot{Q}_{iv}$ = The release rate of radionuclides, i, in gaseous effluent from all vent releases, in μCi/sec (per unit, unless otherwise specified).

$(\overline{\chi/Q})_s$ = _____ sec/m³. For free-standing stack releases. The highest calculated annual average relative concentration for any area at or beyond the unrestricted area boundary.

$(\overline{\chi/Q})_v$ = _____ sec/m³. For all vent releases. The highest calculated annual average relative concentration for any area at or beyond the unrestricted area boundary.

W_v = The highest calculated annual average dispersion parameter for estimating the dose to an individual at the controlling location due to all vent releases:

W_v = _____ sec/m³, for the inhalation pathway. The location is the unrestricted area boundary in the ___ sector.

W_v = ____ meters⁻², for the food and ground plane pathways. The location is the unrestricted area boundary in the ___ sector.

W_s = The highest calculated annual average dispersion parameter for estimating the dose to an individual at the controlling location due to free-standing stack releases:

W_s = _____ sec/m³, for the inhalation pathway. The location is the unrestricted area boundary in the ___ sector.

W_s = ____ meters⁻², for the food and ground plane pathways. The location is the unrestricted area boundary in the ___ sector."

SPECIAL NOTES: (1) If there are no free-standing stacks, the factors denoted by the subscript, s, need not be considered. (2) In all cases, the tritium releases use the first W parameter, based on relative concentration (sec/m³). (3) All radioiodines are assumed to be released in elemental form. If analysis includes the capability of determining elemental and nonelemental forms in all releases, the food pathway parameters may be adjusted accordingly.

The Specification is applicable to the location (unrestricted area boundary or beyond), characterized by the values of the parameters V_i, B_i or $(\overline{\chi/Q})$ which result in the maximum total body or skin dose commitment. In the event that the analyses indicates a different location for the total body and skin dose limitations, the location selected for consideration shall be that which minimizes the allowable release values.

The factors K_i, L_i, and M_i relate the radionuclide airborne concentrations to various dose rates assuming a semi-infinite cloud. These factors may be taken directly from Table B-1 of the Regulatory Guide 1.109 (Ref. 6), if the values therein are multiplied by 10^6 to convert picocuries^{-1} to microcuries^{-1} as used in the above equations. A tabulation of these factors should be included in the ODCM.

The B_i and V_i factors for the radionuclides are based on the finite plume model of Regulatory Guide 1.109 (Ref. 6). From Equation 6 of Section 6.2 of this Regulatory Guide, B_i can be expressed as:

$$B_i = \frac{K}{r_d} \sum_{jk\ell}\sum\sum \frac{f_{jk}\ A_{\ell i}\ \mu_a\ E_\ell I}{u_j} \left(\frac{mrad/yr}{\mu Ci/sec}\right)$$

Where:

I = the results of numerical integration over the plume spatial distribution of the airborne activity as defined by the meteorological condition of wind speed (u_j) and atmospheric stability class k for a particular wind direction.

K = a numerical constant representing unit conversions, presented below.

r_d = the distance from the release point to the receptor location, in meters.

u_j = the mean wind speed assigned to the jth wind speed class, in meters/sec.

f_{jk} = the joint frequency of occurrence of the jth wind speed class and kth stability class (dimensionless).

$A_{\ell i}$ = the number of photons of energy corresponding to the ℓth energy group emitted per transformation of the ith radionuclide, in number/transformation.

E_ℓ = the energy assigned to the ℓth energy group, in Mev.

μ_a = the energy absorption coefficient in air for photon energy E_ℓ, in meters^{-1}.

The constant K follows from Equation 6 of Section C.2.a of Regulatory Guide 1.109 (Ref. 6), as:

$$K = \frac{260\ mrad(radians)(m^3)(transformation)}{sec(Mev)(Ci)} \left(\frac{16\ sectors}{2\Pi\ radians}\right)\left(10^{-6}\ \frac{Ci}{\mu Ci}\right)\left(3.15x10^7\ \frac{sec}{yr}\right)$$

$$= 2.1x10^4\ mrad\ (m^3)(transformation)/yr(Mev)(\mu Ci).$$

The V_i factor is computed with conversion from air dose to tissue depth dose, thus:

$$V_i = 1.1 \frac{K}{r_d} \sum_{jk\ell}\sum\sum \frac{f_{jk}A_{\ell i}\mu_a\ E_\ell\ I}{u_j} [e^{-\mu_T T_d}] \left(\frac{mrem/yr}{\mu Ci/sec}\right)$$

where:

μ_T = the tissue energy absorption coefficient for photons of energy E_ℓ, in cm^2/gm.

T_d = the tissue density thickness taken to represent the total body dose ($5 gm/cm^2$).

1.1 = the ratio of the tissue to air absorption coefficients over the energy range of photons of interest. This ratio converts dose (mrad) to dose equivalent (mrem).

The parameter, P_i, contained in the radioiodine and particulates Specification 3.11.2.1.b includes pathway transport parameters of the ith radionuclide, the receptor's usage of the pathway media and the dosimetry of the exposure. Pathway usage rates and the internal dosimetry are functions of the receptor's age; however, the youngest age group, the infant, will always receive the maximum dose under the exposure conditions for Specification 3.11.2.1. For the infant exposure, separate values of P_i may be calculated using the PARTS computer program given in Appendix D of this manual for the inhalation pathway which uses a W parameter based on $(\overline{\chi/Q})$, and the food (milk) and ground pathway which uses a W parameter normally based on $(\overline{D/Q})$, except for tritium, for application in the ODCM. The following sections provide detail on calculating these P_i values for inclusion in the ODCM.

The values of P_i are independent of vent and stack release elevation. In the case of tritium, $(\overline{\chi/Q})$ is the W parameter for the food (milk) pathway as well as the inhalation pathway. As tritium is a weak beta emitter, the ground plane contribution is zero for tritium. (NOTE: The value for the P_i (food) for tritium is 2.4×10^3 mrem/yr per μCi/m^3.) If the controlling locations for vent and stack releases are different, the controlling location for vent releases should be used in Specification 3.11.2.1.

Omitting the subscripts for vent and stack releases, the dose rate from the ith radionuclide (except tritium) is:

$$P_i \text{ (inhalation)}(\overline{\chi/Q})\, Q + [P_i\text{(food)} + P_i\text{(ground plane)}]\, (\overline{D/Q})Q \text{ (mrem/yr)}$$

and for tritium, is:

$$P_i \text{ (inhalation)}(\overline{\chi/Q})Q + P_i\text{(food)}(\overline{\chi/Q})Q = 3.0 \times 10^3 (\overline{\chi/Q})Q \text{ (mrem/yr)}$$

5.2.1.1 Calculation of P_i (Inhalation)

$$P_i = K'(BR)\ DFA_i \text{ (mrem/yr per } \mu\text{Ci/m}^3)$$

where:

K' = a constant of unit conversion, 10^6 pCi/μCi.

BR = the breathing rate of the infant age group, in m^3/yr.

DFA_i = the maximum organ inhalation dose factor for the infant age group for the ith radionuclide, in mrem/pCi. The total body is considered as an organ in the selection of DFA_i.

The age group considered is the infant group. The infant's breathing rate is taken as 1400 m^3/yr from Table E-5 of Regulatory Guide 1.109 (Ref. 6). The inhalation dose factors for the infant, DFA_i are presented in Table E-10 of Regulatory Guide 1.109, in units of mrem/pCi.

Resolution of the units yields:

$$P_i \text{ (inhalation)} = 1.4 \times 10^9\ DFA_i$$

5.2.1.2 Calculation of P_i (Ground Plane)

$$P_i = K'K''DFG_i \quad (1-e^{-\lambda_i t})/\lambda_i \quad (m^2 \cdot mrem/yr \text{ per } \mu Ci/sec)$$

Where:

K' = a constant of unit conversion, 10^6 pCi/μCi.

K'' = a constant of unit conversion, 8760 hr/year.

λ_i = the decay constant for the ith radionuclide, sec^{-1}.

t = the exposure period, 3.15×10^7 sec (1 year).

DFG_i = the ground plane dose conversion factor for the ith radionuclide (mrem/hr per pCi/m^2).

The deposition rate onto the ground plane results in a ground plane concentration that is assumed to persist over a year with radiological decay the only operating removal mechanism for each radionuclide. The ground plane dose conversion factors for the ith radionuclide, DFG_i, are presented in Table E-6 of Regulatory Guide 1.109 (Ref. 6), in units of mrem/hr per pCi/m^2.

Resolution of the units yields:

P_i (Ground) = 8.76×10^9 DFG_i $(1-e^{-\lambda_i t})/\lambda_i$.

5.2.1.3 Calculation of P_i (Food)

$$P_i = K'r \frac{Q_F(U_{ap})}{Y_p(\lambda_i+\lambda_w)} F_m \; DFL_i \; [e^{-\lambda_i t_f}] \quad (m^2 \cdot mrem/yr \text{ per } \mu Ci/sec)$$

where:

K' = a constant of unit conversion, 10^6 pCi/μCi.

Q_F = the cow's consumption rate, in kg/day (wet weight).

U_{ap} = the infant's milk consumption rate, in liters/yr.

Y_p = the agricultural productivity by unit area, in kg/m^2

F_m = the stable element transfer coefficients, in days/liter.

r = fraction of deposited activity retained on cow's feed grass.

DFL_i = the maximum organ ingestion dose factor for the ith radionuclide, in mrem/pCi.

λ_i = the decay constant for the ith radionuclide, in sec^{-1}.

λ_w = the decay constant for removal of activity on leaf and plant surfaces by weathering, 5.73×10^{-7} sec^{-1} (corresponding to a 14 day half-time).

t_f = the transport time from pasture to cow, to milk, to infant, in sec.

A fraction of the airborne deposition is captured by the ground plant vegetation cover. The captured material is removed from the vegetation (grass) by both radiological decay and weathering processes.

The values of Q_F, U_{ap}, and Y_p are provided in Regulatory Guide 1.109 (Ref. 6), Tables E-3, E-5, and E-15, as 50 kg/day, 330 liters/day and 0.7 kg/m^2, respectively. The value t_f is provided in Regulatory Guide 1.109 (Ref. 6), Table E-15, as 2 days (1.73×10^5 seconds). The fraction, r, has a value of 1.0 for radioiodines and 0.2 for particulates, as presented in Regulatory Guide 1.109 (Ref. 6), Table E-15.

Table E-1 of Regulatory Guide 1.109 (Ref. 4) provides the stable element transfer coefficients, F_m, and Table E-14 provides the ingestion dose factors, DFL_i, for the infant's organs. The organ with the maximum value of DFL_i is to be used.

Resolution of the units yields:

$$P_i \text{ (food)} = 2.4 \times 10^{10} \frac{rF_m}{\lambda_i + \lambda_w} DFL_i \, [e^{-\lambda_i t_f}] \text{ (m}^2 \cdot \text{mrem/yr per } \mu\text{Ci/sec)}$$

for all radionuclides, except tritium.

The concentration of tritium in milk is based on its airborne concentration rather than the deposition rate.

$$P_i = K'K'''F_m Q_F U_{ap} DFL_i \, [0.75(0.5/H)] \text{ (mrem/yr per } \mu\text{Ci/m}^3)$$

where:

K''' = a constant of unit conversion, 10^3 gm/kg.

H = absolute humidity of the atmosphere, in gm/m^3.

0.75 = the fraction of total feed that is water.

0.5 = the ratio of the specific activity of the feed grass water to the atmospheric water.

From Table E-1 and E-14 of Regulatory Guide 1.109 (Ref. 6), the values of F_m and DFL_i for tritium are 1.0×10^{-2} day/liter and 3.08×10^{-7} mrem per pCi, respectively. Assuming an average absolute humidity of 8 grams/meter^3, the resolution of units yields:

$$P_i \text{ (food)} = 2.4 \times 10^3 \text{ mrem/yr per } \mu\text{Ci/m}^3$$

for tritium, only.

5.3 DOSE LIMIT FOR IMPLEMENTING 10 CFR PART 50

In preparing proposed Technical Specifications, Figure 5.1-1* should consist of a map of the site area showing the unrestricted area boundary for gaseous effluents as defined in Section 5.2 of this manual. Guidelines for this figure are contained in Regulatory Guide 1.70, Section 2.1.1 (Ref. 21).

*See footnote on page 21.

5.3.1 REQUIREMENTS FOR IMPLEMENTING 10 CFR PART 50

The Standard Technical Specifications 3.11.2.2 and 3.11.2.3 implement 10 CFR Part 50, Appendix I, as follows:

> "The air dose in unrestricted areas (see Figure 5.1-1)* due to noble gases released in gaseous effluents shall be limited to the following:
>
> a. During any calendar quarter, to ≤ 5 mrad for gamma radiation and ≤ 10 mrad for beta radiation;
>
> b. During any calendar year, to ≤ 10 mrad for gamma radiation and ≤ 20 mrad for beta radiation;
>
> (The dose design objectives may be reduced based on expected public occupancy of areas, e.g., beaches and visitor centers within the unrestricted area boundary. (For PWRs only) the dose design objectives may be reduced based on predicted noble gas releases from the turbine building, if effluent sampling is not provided.)"
>
> "The dose to an individual from radioiodines, radioactive materials in particulate form, and radionuclides other than noble gases with half-lives greater than 8 days in gaseous effluents released to unrestricted areas (see Figure 5.1-1)* shall be limited to the following:
>
> a. During any calendar quarter to ≤ 7.5 mrem; and
>
> b. During any calendar year to ≤ 15 mrem."

The ODCM should provide the mathematical relationships used to implement the Specifications. The relationships presented below are acceptable for inclusion in the ODCM. If other methods are selected to implement these Specifications, it is expected that the alternative method will include the same general features considered below.

The air dose in unrestricted area (see Figure 5.1-1)* due to noble gases released in gaseous effluents should be determined by the following expressions:

a. During any calendar quarter, for gamma radiation:

$$3.17 \times 10^{-8} \sum_i \left[M_i \, [(\overline{\chi/Q})_v \tilde{Q}_{iv} + (\overline{\chi/q})_v \tilde{q}_{iv}] + [B_i \tilde{Q}_{is} + b_i \tilde{q}_{is}] \right] \leq 5 \text{ mrad, and}$$

During any calendar quarter, for beta radiation:

$$3.17 \times 10^{-8} \sum_i N_i \, [(\overline{\chi/Q})_v \tilde{Q}_{iv} + (\overline{\chi/q})_v \tilde{q}_{iv} + (\overline{\chi/Q})_s \tilde{Q}_{is} + (\overline{\chi/Q})_s \tilde{q}_{is}] \leq 10 \text{ mrad, and}$$

b. During any calendar year, for gamma radiation:

$$3.17 \times 10^{-8} \sum_i \left[M_i \, [(\overline{\chi/Q})_v \tilde{Q}_{iv} + (\overline{\chi/q})_v \tilde{q}_{iv}] + [B_i \tilde{Q}_{is} + b_i \tilde{q}_{is}] \right] \leq 10 \text{ mrad, and}$$

During any calendar year, for beta radiation:

$$3.17 \times 10^{-8} \sum_i N_i \, [(\overline{\chi/Q})_v \tilde{Q}_{iv} + (\overline{\chi/q})_v \tilde{q}_{iv} + (\overline{\chi/Q})_s \tilde{Q}_{is} + (\overline{\chi/q})_s \tilde{q}_{is}] \leq 20 \text{ mrad}$$

where:

M_i = The air dose factor due to gamma emmissions for each identified noble gas radionculide, in mrad/yr per $\mu Ci/m^3$.

*See footnote on page 21.

N_i = The air dose factor due to beta emissions for each identified noble gas radionuclide, in mrad/yr per $\mu Ci/m^3$.

$(\overline{\chi/Q})_v$ = _______ sec/m^3. For vent releases. The highest calculated annual average relative concentration for area at or beyond the unrestricted area boundary for long term releases (greater than 500 hrs/year).

$(\overline{\chi/q})_v$ = _______ sec/m^3. For vent releases. The relative concentration for areas at or beyond the unrestricted area boundary for short term releases (equal to or less than 500 hrs/year).

$(\overline{\chi/Q})_s$ = _______ sec/m^3. For free-standing stack releases. The highest calculated annual average relative concentration for areas at or beyond the unrestricted area boundary for long term releases (greater than 500 hrs/year).

$(\overline{\chi/q})_s$ = _______ sec/m^3. For free-standing stack releases. The relative concentration for areas at or beyond the unrestricted area boundary for short term releases (equal to or less than 500 hrs/year).

$\tilde{q}_{is}$ = The average release of noble gas radionuclides in gaseous effluents, i, for short term releases (equal to or less than 500 hrs/year) from the free-standing stack, in μCi. Releases shall be cumulative over the calendar quarter or year as appropriate.

$\tilde{q}_{iv}$ = The average release of noble gas radionuclides in gaseous effluents, i, for short term releases (equal to or less than 500 hrs/year) from all vents, in μCi. Releases shall be cumulative over the calendar quarter or year as appropriate.

$\tilde{Q}_{is}$ = The average release of noble gas radionuclides in gaseous releases, i, for long term releases (greater than 500 hrs/year) from the free-standing stack, in μCi. Release shall be cumulative over the calendar quarter or year as appropriate.

$\tilde{Q}_{iv}$ = The average release of noble gas radionuclides in gaseous effluents, i, for long term releases (greater than 500 hrs/yr) from all vents, in μCi. Releases shall be cumulative over the calendar quarter or year as appropriate.

B_i = The constant for long term releases (greater than 500 hrs/yr) for each identified noble gas radionuclide accounting for the gamma radiation from the elevated finite plume, derived in accordance with the dose methodology in Regulatory Guide 1.109, Appendix B, Section 1, in mrad/yr per $\mu Ci/sec$.

b_i = The constant for short term releases (equal to or less than 500 hrs/yr) for each identified noble gas radionuclide accounting for the gamma radiation from the elevated finite plume, derived in accordance with the dose methodology in Regulatory Guide 1.109, Appendix B, Section 1, in mrad/yr per $\mu Ci/sec$.

3.17×10^{-8} = The inverse of the number of seconds in a year.

The dose to an individual from radioiodines, radioactive materials in particulate form, and radionuclides other than noble gases with half-lives greater than 8 days in gaseous effluents released to unrestricted areas (see Figure 5.1-1)* should be determined by the following expressions:

a. During any calendar quarter:

$$3.17 \times 10^{-8} \sum_i R_i \, [W_s\tilde{Q}_{is} + w_s\tilde{q}_{is} + W_v\tilde{Q}_{iv} + w_v\tilde{q}_{iv}] \leq 7.5 \text{ mrem, and}$$

*See footnote on page 21.

b. During any calendar year:

$$3.17 \times 10^{-8} \sum_i R_i \, [W_s \tilde{Q}_{is} + w_s \tilde{q}_{is} + W_v \tilde{Q}_{iv} + w_v \tilde{q}_{iv}] \leq 15 \text{ mrem}$$

where:

$\tilde{Q}_i$ = The releases of radionuclides, radioactive materials in particulate form, and radionuclides other than noble gases in gaseous effluents, i, for long term releases greater than 500 hrs/yr, in μCi. Releases shall be cumulative over the calendar quarter or year as appropriate.

$\tilde{q}_i$ = The releases of radionuclides, radioactive materials in particulate form and radionuclides other than noble gases in gaseous effluents, i, for short term releases equal to or less than 500 hrs/yr, in μCi. Releases shall be cumulative over the calendar quarter or year as appropriate.

W = The dispersion parameter for estimating the dose to an individual at the controlling location for long term releases (greater than 500 hrs/yr):

$W = (\overline{\chi/Q})$ for the inhalation pathway, in sec/m^3.

$W = (\overline{D/Q})$ for the food and ground plane pathways in meters^{-2}.

w = The dispersion parameter for estimating the dose to an individual at the controlling location for short term releases (equal to or less than 500 hrs/yr):

$w = (\overline{\chi/q})$ for the inhalation pathway in sec/m^3.

$w = (\overline{D/q})$ for the food and ground plane pathway in meters^{-2}.

3.17×10^{-8} = The inverse of the number of seconds in a year.

R_i = The dose factor for each identified radionuclide, i, in m^2(mrem/yr) per μCi/sec or mrem/yr per μCi/m^3.

For the direction sectors with existing pathways within 5 miles from the unit, use the values of R_i for these pathways. If no real pathway exists within 5 miles from the center of the building complex, use the cow-milk R_i assuming that this pathway exists at the 4.5 to 5.0 mile distance in the worst sector. If the R_i for an existing pathway within 5 miles is less than a cow-milk R_i at 4.5 to 5.0 miles, then use the value of the cow-milk R_i at 4.5 to 5.0 miles. The pathway values used for calculating dose contributions shall be consistent with the results of the land use census performed pursuant to Specification 3.12.2. The controlling value of R_i for each radionuclide shall be determined and provided in tabular form in the ODCM. The parameters W and w shall correspond to the applicable pathway location.

SPECIAL NOTES: (1) If there is no free-standing stack, the factors denoted by the subscript, s, need not be considered. (2) In all cases, the tritium releases use the first W or w parameter, based on relative concentration (sec/m^3). (3) All radioiodines are assumed to be released in elemental form. If analysis includes the capability of determining the elemental and non-elemental forms in all releases, the food pathway parameters may be adjusted accordingly.

The following information is provided to further clarify the application of these Specifications and provide more information regarding the individual factors. The ODCM should include a detailed presentation of the calculational model and a complete tabulation of all values assigned to each parameter.

The noble gas Specification 3.11.2.2 is to be evaluated at the location in the unrestricted area where analyses of annual average air doses were found to be maximum. In the event that the analyses indicate different locations for the beta and gamma limitations, the location selected for consideration shall be that which minimizes the allowable release values due to gamma radiation.

The radioiodine and particulate Specification 3.11.2.3 is applicable to the location in the unrestricted area where the combination of existing pathways and receptor age groups indicates the maximum potential exposures. The inhalation and ground plane exposure pathways shall be considered to exist at all locations. The grass-cow-milk, grass-cow-meat, and vegetation pathways are considered based on their existence at the various locations. Of the various age groups, the infant or child receives the largest dose; thus, only these two age groups will be discussed. It is the intent, however, that a licensee undertake annual surveys of the age groups and the land use at the various locations about the site, reports these results according to Specification 3.12.2 and determines the applicable parameters of R_i for tabulation in the ODCM. The new parameters shall be submitted to the NRC for review and approval prior to implementation.

The M_i and N_i factors of the noble gas relationship relate the airborne concentration of the noble gas to the air dose rates assuming a semi-infinite cloud. These factors may be taken directly from Table B-1 of the Regulatory Guide 1.109 (Ref. 6), and the values therein have been multiplied by 10^6 to convert picocuries^{-1} to microcuries^{-1}.

The factor, B_i, is defined in Section 5.2.1 of this manual. The corresponding short-term factor, b_i is computed following the same procedure replacing the meteorological variables, j, k, and ℓ, for long-term releases with variables for short-term releases using the methodology provided in Regulatory Guide 1.111 (Ref. 8), NUREG-0324 (Ref. 13), and NUREG-75/087 (Ref. 23). Such information should be provided in tabular form in the ODCM.

In developing the R_i values, separate expressions are written for each of the potential pathways. These expressions are similar to those developed in Section 5.2.1 of this manual for P_i, and are denoted by $R_i^G[D/Q]$, $R_i^I[\chi/Q]$, $R_i^C[D/Q]$, $R_i^M[D/Q]$ and $R_i^V[D/Q]$, where the superscripts G, I, C, M, and V refer to ground plane, inhalation, cow's milk, meat and vegetation, respectively. The 'argument' notation, [ ], indicates the appropriate dispersion parameter, W, to be applied with the R_i factor. Note that the argument is not included in the following expressions. In the case of tritium, the dispersion parameter, W, is always taken as $(\overline{\chi/Q})$. The R_i parameter is independent of long-term or short-term releases and should be provided in tabular form in the ODCM.

5.3.1.1 Inhalation Pathway Factor, $R_i^I[\chi/Q]$

$$R_i^I[\chi/Q] = K'(BR)_a\ (DFA_i)_a\ \text{(mrem/yr per } \mu\text{Ci/m}^3)$$

where:

K' = a constant of unit conversion, 10^6pCi/μCi.

$(BR)_a$ = the breathing rate of the receptor of age group (a), in m^3/yr.

$(DFA_i)_a$ = the maximum organ inhalation dose factor for the receptor of age group (a) for the ith radionuclide, in mrem/pCi. The total body is considered as an organ in the selection of $(DFA_i)_a$.

The breathing rates $(BR)_a$ for the various age groups are tabulated below, as given in Table E-5 of the Regulatory Guide 1.109 (Ref. 6).

Age Group (a)	Breathing Rate (m^3/yr)
Infant	1400
Child	3700
Teen	8000
Adult	8000

Inhalation dose factors $(DFA_i)_a$ for the various age groups are given in Tables E-7 through E-10 of Regulatory Guide 1.109 (Ref. 6).

5.3.1.2 Ground Plane Pathway Factor, R_i^G [D/Q]

$$R_i^G[D/Q] = K'K''(SF)DFG_i[(1-e^{-\lambda_i t})/\lambda_i] \text{ (m}^2\cdot\text{mrem/yr per } \mu\text{Ci/sec)}$$

where:

K' = a constant of unit conversion, 10^6 pCi/μCi.

K" = a constant of unit conversion, 8760 hr/year.

λ_i = the decay constant for the ith radionuclide, sec^{-1}.

t = the exposure time, 4.73×10^8 sec (15 years).

DFG_i = the ground plane dose conversion factor for the ith radionuclide (mrem/hr per pCi/m^2).

SF = the shielding factor (dimensionless).

A shielding factor of 0.7 is suggested in Table E-15 of Regulatory Guide 1.109 (Ref. 6). A tabulation of DFG_i values is presented in Table E-6 of Regulatory Guide 1.109 (Ref. 6).

5.3.1.3 Grass-Cow-Milk Pathway Factor, R_i^C [D/Q]

$$R_i^C[D/Q] = K' \frac{Q_F(U_{ap})}{\lambda_i+\lambda_w} F_m(r)(DFL_i)_a \left[\frac{f_p f_s}{Y_p} + \frac{(1-f_p f_s)e^{-\lambda_i t_h}}{Y_s} \right] e^{-\lambda_i t_f}$$

(m^2·mrem/yr per μCi/sec)

where:

K' = a constant of unit conversion, 10^6 pCi/μCi.

Q_F = the cow's consumption rate, in kg/day (wet weight).

U_{ap} = the receptor's milk consumption rate for age (a), in liters/yr.

Y_p = the agricultural productivity by unit area of pasture feed grass, in kg/m².

Y_s = the agricultural productivity by unit area of stored feed, in kg/m².

F_m = the stable element transfer coefficients, in days/liter.

r = fraction of deposited activity retained on cow's feed grass.

$(DFL_i)_a$ = the maximum organ ingestion dose factor for the ith radionuclide for the receptor in age group (a), in mrem/pCi.

λ_i = the decay constant for the ith radionuclide, in sec^{-1}.

λ_w = the decay constant for removal of activity on leaf and plant surfaces by weathering, 5.73×10^{-7} sec^{-1} (corresponding to a 14 day half-life).

t_f = the transport time from pasture to cow, to milk, to receptor, in sec.

t_h = the transport time from pasture, to harvest, to cow, to milk, to receptor, in sec.

f_p = fraction of the year that the cow is on pasture (dimensionless).

f_s = fraction of the cow feed that is pasture grass while the cow is on pasture (dimensionless).

SPECIAL NOTE: The above equation is applicable in the case that the milk animal is a goat.

Milk cattle are considered to be fed from two potential sources, pasture grass and stored feeds. Following the development in Regulatory Guide 1.109 (Ref. 6), the values of f_p and f_s will be considered unity, in lieu of site specific information provided in the annual land census report by the licensee.

Tabulated below are the appropriate parameter values and their reference to Regulatory Guide 1.109 (Ref. 6). In the case that the milk animal is a goat, rather than a cow, refer to Regulatory Guide 1.109 for the appropriate parameter values.

Parameter	Value	Table (Ref. 6)
r (dimensionless)	1.0 for radioiodine	E-15
	0.2 for particulates	E-15
F_m (days/liter)	Each stable element	E-1
U_{ap} (liters/yr) - Infant	330	E-5
- Child	330	E-5
- Teen	400	E-5
- Adult	310	E-5
$(DFL_i)_a$ (mrem/pCi)	Each radionuclide	E-11 to E-14
Y_p (kg/m²)	0.7	E-15
Y_s (kg/m²)	2.0	E-15
t_f (seconds)	1.73×10^5 (2 days)	E-15
t_h (seconds)	7.78×10^6 (90 days)	E-15
Q_F (kg/day)	50	E-3

The concentration of tritium in milk is based on the airborne concentration rather than the deposition. Therefore, the R_i^C is based on $[\chi/Q]$:

$$R_i^C[\chi/Q] \;=\; K'K'''F_m Q_F U_{ap}(DFL_i)_a\ [0.75(0.5/H)]\ \text{(mrem/yr per } \mu\text{Ci/m}^3)$$

where:

K''' = a constant of unit conversion, 10^3 gm/kg.

H = absolute humidity of the atmosphere, in gm/m^3.

0.75 = the fraction of total feed that is water.

0.5 = the ratio of the specific activity of the feed grass water to the atmospheric water.

and other parameters and values are given above. The value of H may be considered as 8 grams/meter^3, in lieu of site specific information (Ref. 6).

5.3.1.4 Grass-Cow-Meat Pathway Factor, $R_i^M[D/Q]$

The integrated concentration in meat follows in a similar manner to the development for the milk pathway, therefore:

$$R_i^M[D/Q] \;=\; K'\ \frac{Q_F(U_{ap})}{\lambda_i + \lambda_w}\ F_f(r)(DFL_i)_a \left[\frac{f_p f_s}{Y_p} + \frac{(1-f_p f_s)e^{-\lambda_i t_h}}{Y_s} \right] e^{-\lambda_i t_f}$$

$$\text{(m}^2\text{·mrem/yr per } \mu\text{Ci/sec)}$$

where:

F_f = the stable element transfer coefficients, in days/kg.

U_{ap} = the receptor's meat consumption rate for age (a), in kg/yr.

t_f = the transport time from pasture to receptor, in sec.

t_h = the transport time from crop field to receptor, in sec.

Tabulated below are the appropriate parameter values and their reference to Regulatory Guide 1.109 (Ref. 6).

Parameter	Value	Table (Ref. 6)
r (dimensionless)	1.0 for radioiodine	E-15
	0.2 for particulates	E-15
F_f (days/kg)	Each stable element	E-1
U_{ap} (kg/yr) - Infant	0	E-5
- Child	41	E-5
- Teen	65	E-5
- Adult	110	E-5
$(DFL_i)_a$ (mrem/pCi)	Each radionuclide	E-11 to E-14
Y_p (kg/m^2)	0.7	E-15

Parameter	Value	Table (Ref. 6)
Y_s (kg/m^2)	2.0	E-15
t_f (seconds)	1.73×10^6 (20 days)	E-15
t_h (seconds)	7.78×10^6 (90 days)	E-15
Q_F (kg/day)	50	E-3

The concentration of tritium in meat is based on its airborne concentration rather than the deposition. Therefore, the R_i^M is based on $[\chi/Q]$:

$$R_i^M[\chi/Q] = K'K'''F_f Q_F U_{ap}(DFL_i)_a\ [0.75(0.5/H)]\ (\text{mrem/yr per } \mu\text{Ci/m}^3)$$

where all terms are defined above and Section 5.3.1.3 of this manual.

5.3.1.5 Vegetation Pathway Factor, $R_i^V[D/Q]$

The integrated concentration in vegetation consumed by man follows the expression developed in the derivation of the milk factor. Man is considered to consume two types of vegetation (fresh and stored) that differ only in the time period between harvest and consumption, therefore:

$$R_i^V[D/Q] = K' \left[\frac{(r)}{Y_v(\lambda_i + \lambda_w)}\right] (DFL_i)_a \left[U_a^L f_L e^{-\lambda_i t_L} + U_a^S f_g e^{-\lambda_i t_h}\right]$$

$$(\text{m}^2\cdot\text{mrem/yr per } \mu\text{Ci/sec})$$

where:

- K' = a constant of unit conversion, 10^6 pCi/μCi.
- U_a^L = the consumption rate of fresh leafy vegetation by the receptor in age group (a), in kg/yr.
- U_a^S = the consumption rate of stored vegetation by the receptor in age group (a), in kg/yr.
- f_L = the fraction of the annual intake of fresh leafy vegetation grown locally.
- f_g = the fraction of the annual intake of stored vegetation grown locally.
- t_L = the average time between harvest of leafy vegetation and its consumption, in seconds.
- t_h = the average time between harvest of stored vegetation and its consumption, in seconds.
- Y_v = the vegetation areal density, in kg/m^2.

and all other factors are defined in Section 5.3.1.3 of this manual.

Tabulated below are the appropriate parameter values and their reference to Regulatory Guide 1.109 (Ref. 6).

Parameter	Value	Table (Ref. 6)
r (dimensionless)	1.0 for radioiodines	E-1
	0.2 for particulates	E-1
$(DFL_i)_a$ (mrem/pCi)	Each radionuclide	E-11 to E-14
U_a^L (kg/yr) - Infant	0	E-5
- Child	26	E-5
- Teen	42	E-5
- Adult	64	E-5
U_a^S (kg/yr) - Infant	0	E-5
- Child	520	E-5
- Teen	630	E-5
- Adult	520	E-5
f_L (dimensionless)	site specific (default = 1.0)	
f_g (dimensionless)	site specific (default = 0.76) (see Ref. 6, page 28)	
t_L (seconds)	8.6×10^4 (1 day)	E-15
t_h (seconds)	5.18×10^6 (60 days)	E-15
Y_v (kg/m^2)	2.0	E-15

The concentration of tritium in vegetation is based on the airborne concentration rather than the deposition. Therefore, the R_i^V is based on $[\chi/Q]$:

$$R_i^V[\chi/Q] = K'K''' \quad U_a^L f_L + U_a^S f_g \quad (DFL_i)_a \quad [0.75(0.5/H)] \text{ (mrem/yr per } \mu Ci/m^3).$$

where all terms have been defined above and in Section 5.3.1.3 of this manual.

The staff has developed a computer code PARTS for calculating the R_i parameters, which is described in Appendix D of this manual.

5.4 SPECIFICATION ON THE USE OF GASEOUS RADIOACTIVE WASTE MANAGEMENT SYSTEM

Standard Technical Specification 3.11.2.4 specifies that:

"The gaseous radwaste treatment system shall be OPERABLE. The appropriate subsystems shall be used to reduce radioactive materials in gaseous waste prior to their discharge when the projected gaseous effluent releases from all release points to unrestricted areas (see Figure 5.1-1)* would result in a dose in any period of 31 days that exceeds 0.2 mrad for gamma radiation, 0.4 mrad for beta radiation, or 0.3 mrem to any organ for that same 31 day period."

The operability of the gaseous radioactive waste management system ensures that this system will be available for use whenever gaseous effluents require treatment prior to release to the environment. The term "gaseous radwaste treatment system" includes all of the installed and available gaseous radioactive waste management system equipment, as well as their controls, power, instrumentation and services that make the system functional. Equipment that is considered standby or redundant is also included, since the function is to assure operability. The action also permits alternate treatment paths using alternate subsystems and equipment to be used in the event that the normal treatment is inoperable.

*See footnote on page 21.

This Specification provides impetus to maintain and use the gaseous radioactive waste management system as required in 10 CFR 50.36a. Maintenance and use of the gaseous radioactive waste management system components are discussed in Section 2.2 of this manual. Since features; such as, free-standing stacks or elevated vents are not considered to be treatment systems, the NRC staff considers that BWR offgas systems must be used without bypassing normal treatment during reactor operation.

To determine if use of the installed equipment, other than in BWR offgas systems, is necessary, the licensee should calculate the expected dose to an individual in the unrestricted area by projecting the plant's cumulative gaseous effluent release over a 31-day period. These releases should include all potentially radioactive plant gaseous effluents from all gaseous radioactive waste management systems and ventilation exhaust treatment systems. Calculations should include a margin, based on operating data, for anticipated operational occurrences and should use the dose calculation models discussed in Section 5.3 of this manual. The dose impact from the projected 31-day release should be compared to 0.2 mrad for gamma radiation, 0.4 mrad for beta radiation, or 0.3 mrem to any organ. If the projection indicates these values will be exceeded, then installed radwaste treatment system components, which are capable of reducing the quantities or concentrations of radioactive materials in gaseous effluents and which are capable of reducing the projected impact to less than the values specified above, must be used. The values for the projected impact, given above, corresponds to approximately one forty-eighth of the annual design dose objective values of Appendix I, Section II.B and II.C of 10 CFR Part 50 in a month, and if continued for a year, these values would correspond to less than one-fourth the values limited by Specifications 3.11.2.2.b and 3.11.2.3.b. The calculation of projected cumulative dose impact that could result from the proposed operation may use the methodology provided in Section 5.3 of this manual.

5.5 SPECIFICATION ON EXPLOSIVE GAS MIXTURE LIMITATION

The Standard Technical Specifications for BWRs and PWRs contain Specification 3.11.2.6A and alternate Specification 3.11.2.6B for the limiting conditions for operation for systems designed to treat and store radioactive gases which also contain quantities of uncombined hydrogen and oxygen. Specification 3.11.2.6A applies to a system designed to withstand a hydrogen explosion. If all components of the system, from containment to the release point, are designed and tested to 20 times the normal operating pressure, the system is considered to be designed to withstand a hydrogen explosion. Alternate Specification 3.11.2.6B applies to a system not considered to be designed to withstand a hydrogen explosion.

The functional name, "waste gas holdup system," has been used in this manual to include the various system designs found in BWRs and PWRs which serve the same basic purpose, i.e., to remove radioactive waste gases from the reactor coolant, to treat and hold gases for radioactive decay, and to monitor and control the radioactive materials in the gaseous waste prior to final release.

The potentially explosive components of the waste gas holdup system may be effectively inerted by nitrogen or steam, treated and re-used in the plant or stored and released after delay. The treatment may involve hydrogen-oxygen recombiners, filters, holdup tanks, decay pipes, charcoal adsorbers, and cryogenic stills. The Specification is provided to ensure that the concentrations of potentially explosive gases contained in the system are maintained outside the explosive envelope for hydrogen and oxygen (i.e., less than 4% H_2 by volume or less than 4% O_2 by volume). The alternate Specification 3.11.2.6B provides an additional setpoint limitation to ensure that the automatic dilution, inerting or recombiner control is functioning to maintain the relative concentration of components of potentially explosive gas mixtures outside one-half the above flammability limits (i.e., 2% H_2 and/or O_2). Based on the design, the licensee should specify the gas to be measured: hydrogen, oxygen or both hydrogen and oxygen.

5.6 SPECIFICATIONS UNIQUE TO LWR DESIGN FEATURES

The Standard Technical Specifications contain several Specifications unique to certain design features of PWRs and BWRs; in general, these Specifications contain limiting conditions for operation. The following Sections describe these limitations and the method for determining the limiting values.

5.6.1 PWR Gas Storage Tank Specification 3.11.2.7

Specification 3.11.2.7 requires that the quantity of radioactive gas in each gas storage tank at a PWR be limited to a predetermined curie content. It is not applicable to PWRs that use adsorption units for gas holdup, but is applicable for compressed gas storage and for cryogenic storage systems. The purpose of this Specification is to assure that, in the event of an uncontrolled release of the tank contents, the resulting total body exposure to an individual at the nearest exclusion area boundary will not exceed 0.5 rem.

Determination of the curie limit should consider the following expression;

$$\sum Q_{iT} \leq \frac{500 \text{ mrem } (3.15 \times 10^7 \text{ sec/year})}{10^6 \ \mu\text{Ci/Ci} \ \sum_i K_i (\overline{\chi/Q})_{DBA} \ (\text{mrem}\cdot\text{sec}/\mu\text{Ci}\cdot\text{yr})}$$

where:

$\sum Q_{iT}$ = The sum quantity of all noble gas nuclides (i) in a gas storage tank based on a gas mixture resulting from gaseous wastes, in curies.

K_i = The total body dose factor due to gamma emissions for each identified noble gas radionuclide, in mrem/yr per $\mu Ci/m^3$. (See Section 5.2.1 of this manual.)

$(\overline{\chi/Q})_{DBA}$ = The relative concentration at the exclusion area boundary used for evaluation of design basis accidents for ground release conditions, in sec/m^3. Guidelines are provided in Standard Review Plan 2.3.4 (Ref. 23).

Normally the major radioactive nuclide constituent in PWR waste gas storage tanks is Xe-133. Radiation monitoring and sampling of these tanks should consider the Xe-133 (equivalent) concentration. Plant procedures shall not permit operation with communication between tanks.

Alternate Specification 3.11.2.7, "PWR Waste Gas Processing System," should be used for plants that use adsorption units for gas holdup prior to release. This Specification requires that the gross radioactivity in noble gases removed from the waste gas system by means of steam jet air ejectors (or other devices) and as measured prior to entering the adsorption systems at PWR plants shall be limited by a release rate alarm setpoint with indication in the main control room. The purpose of this pretreatment continuous radiation monitor setpoint is to provide reasonable assurance that the potential accident total body dose to an individual at the exclusion area boundary will not exceed a small fraction of the limits specified in 10 CFR Part 100 in the event this effluent is inadvertently discharged directly to the environment without treatment. Guidelines for determining the release rate limit are provided in Standard Review Plan 15.7.1 (Ref. 24), and guidance on the radiation monitoring instrumentation is given in Regulatory Guide 1.97 (Ref. 25).

5.6.2 BWR Main Condenser Evacuation System Specification 3.11.2.7

This Specification requires that the gross radioactivity in noble gases removed from the main condenser by means of steam jet air ejectors (or other devices) and as measured prior to entering the treatment, adsorption and delay systems at BWR plants shall be limited by a release rate alarm setpoint with indication in the main control room. The purpose of this pretreatment continuous radiation monitor setpoint is to provide reasonable assurance that the potential total body accident dose to an individual at the exclusion area boundary will not exceed a small fraction of the limits specified in 10 CFR Part 100 in the event this effluent including the radioactivity accumulated in the treatment system is inadvertently discharged directly to the environment without treatment.

The method for determining the specified rate limit, in μCi/sec, should use the following assumptions:

1. The release of radioactive material from the fuel is postulated to have an isotopic composition of noble gases determined from noble gas source term distribution for a 3500 MWt reactor. These values should be scaled linearly for reactors of higher and lower powers.

2. The assumptions related to the release of radioactive material from the system following the accident are:

   a. For systems which are not fully detonation-resistant or for those systems which are equipped with rupture discs that have not been isolated or loop seals which do not vent back to the main condenser, release occurs from a break just downstream of the main condenser evacuation system. Release from the main condenser evacuation system is assumed to be at ground level and a delay of five minutes is assumed to account for radioactive decay during transit from the release point to the exclusion area boundary.

NOBLE GAS SOURCE TERM

Isotope	Approx. Half-Life	Source Term, μCi/sec, at the main condenser evacuation system (SJAE) 0 Decay
Xe-140	13.7 s	1.1×10^6
Kr-90	33 s	9.8×10^5
Xe-139	41.0 s	9.8×10^5
Kr-89	3.2 m	4.6×10^5
Xe-137	3.8 m	5.3×10^5
Xe-138	14.0 m	3.1×10^5
Xe-135m	15.6 m	9.1×10^4
Kr-87	76 m	7.0×10^4
Kr-83m	1.86 hr	1.2×10^4
Kr-88	2.8 hr	7.0×10^4
Kr-85m	4.4 hr	1.1×10^4
Xe-135	9.2 hr	7.7×10^4
Xe-133m	2.3 d	1.0×10^3
Xe-133	5.27 d	2.9×10^4
Xe-131m	11.9 d	5.2×10^1
Kr-85	10.76 y	7.0×10^1
	Total	$\sim 4.7 \times 10^6$

b. For systems which are detonation-resistant (i.e., rupture discs have been isolated and loop seals are vented back to the main condenser), release from the main condenser evacuation system exits via the normal release point.

c. Activity release into the system continues for one hour following the accident at the Technical Specification limit unless positive means (such as automatic isolation) are provided to limit the releases from this source.

d. Radioiodines and activation gases may be ignored.

e. No deposition during downwind transport occurs.

f. The total radioactive inventory (neglecting radioiodines and activation gases) in any delay lines and from the process equipment is released within a two-hour period with no decay.

g. The total noble gas content of all charcoal delay beds is released over a period of two hours. A fractional release of the particulate inventory on the charcoal beds should be assumed. The rate of release is equal to the rate of absorption using the information contained in NUREG-0016 (Ref. 12).

h. The main condenser air inleakage is 6 scfm for three shell main condensers.

3. The relative concentration, $(\overline{\chi/Q})_{DBA}$, to be used is described in Section 5.6.1 of this manual.

Based on these assumptions, the applicant should backcalculate from a whole body dose of 2.5 rem to an individual at the exclusion area boundary to obtain the main condenser evacuation system rate limit, in μCi/sec, having a noble gas isotopic distribution proportional to the noble gas source term, given above. For licensed BWR facilities that have a Technical Specification limit, in μCi/sec, based on a 5 rem consequence criteria, a reevaluation of the specified limit is not required. Guidance on the radiation monitoring instrumentation is given in Regulatory Guide 1.97 (Ref. 25).

5.6.3 PWR Monitoring of Steam Generator Blowdown Flask Tank Vent

Standard Technical Specification 3.3.3.9, including Tables 3.3-12* and 4.3-12,* requires that PWRs continuously monitor the steam generator blowdown tank vent for gross noble gas radioactivity and continuously sample for radioactive iodines and particulates. Many PWRs with U-tube steam generators direct their blowdown to a blowdown treatment system without venting, so that item f in Tables 3.3-12 and 4.3-12 is not applicable. Others vent their flash tank to the main condenser, where the airborne radionuclides are either removed by condensing steam or drawn into the main condenser evacuation system, where they are then monitored prior to release to the atmosphere; therefore, this design provision makes item f not applicable. However, there are several operating PWR's that direct their blowdown to a flash tank which is vented directly to the atmosphere. Monitoring these releases presents serious difficulties, due to the presence of steam in the exhaust. In lieu of a flash tank vent radiation monitor, a determination of the release of radioiodine-131 via the flash tank vent can be made by calculating from a measured concentration in the secondary water by the following equation:

$$\dot{Q}_y = \bar{C}_y [R_{SGB}] f_{FT} (1 - SQ_{FTv})$$

where:

Q_y = The release rate of radioiodine-131, y, from the steam generator flash tank vent, in μCi/sec.

$\bar{C}_y$ = The concentration of radioiodine-131, y, in the secondary coolant water averaged over not more than one week, in μCi/ml.

R_{SGB} = The steam generator blowdown rate to the flash tank, in ml/sec.

f_{FT} = The fraction of blowdown flashed in the falsh tank determined from a heat balance taken around the flash tank at the applicable reactor power level.

SQ_{FTv} = The measured steam quality in the flash tank vent; or an assumed value of 0.85, based on NUREG-0017 (Ref. 11).

If this option is chosen, the applicant shall perform this calcuation every time measurements of secondary water radioiodine concentrations are required by Technical Specifications, and the calculated release shall be assumed at this calculated level until the next secondary water analysis is completed. These calculations shall be provided by the applicant in his semiannual effluent release report.

*See footnote on page 20.

REFERENCES

1. Title 10, "Energy," Chapter I, Code of Federal Regulations; Part 50, pages 250 to 327, U.S. Government Printing Office, Washington, D.C. 20402, January 1, 1977.

2. U.S. Nuclear Regulatory Commission, "Draft Radiological Effluent Technical Specifications for PWR's," USNRC NUREG-0472, Revision 1, Washington, D.C. 20555, October 1978.

3. U.S. Nuclear Regulatory Commission, "Draft Radiological Effluent Technical Specifications for PWR's," USNRC NUREG-0473, Revision 1, Washington, D.C. 20555, October 1978.

4. Regulatory Guide 1.16, "Reporting of Operating Information - Appendix A Technical Specifications," Revision 4, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555, August 1975.

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7. Regulatory Guide 1.110, "Cost-Benefit Analysis for Radwaste Systems for Light-Water-Cooled Nuclear Power Reactors," U.S. Nuclear Regulatory Commission, Washington, D.C. 20555, March 1976.

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9. Regulatory Guide 1.112, "Calculation of Releases of Radioactive Materials in Gaseous and Liquid Effluents from Light-Water-Cooled Power Reactors," U.S. Nuclear Regulatory Commission, Washington, D.C. 20555, April 1976.

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13. U.S. Nuclear Regulatory Commission, "XOQDOQ, Program for the Meteorological Evaluation of Routine Effluent Releases at Nuclear Power Stations," USNRC Report NUREG-0324, Washington, D.C. 20555, September 1977.

14. Title 10, "Energy," Chaper I, Code of Federal Regulations; Part 20, pages 144 to 172, U.S. Government Printing Office, Washington, D.C. 20402, January 1, 1977.

15. Title 10, "Energy," Chapter I, Code of Federal Regulations; Part 100, pages 409 to 421, U.S. Government Printing Office, Washington, D.C. 20402, January 1, 1977.

16. Title 40, "Protection of Environment," Chapter I, Code of Federal Regulations, Part 141, pages 169 to 182, U.S. Government Printing Office, Washington, D.C. 20402, January 1, 1977.

17. Regulatory Guide 1.21, "Measuring, Evaluating, and Reporting Radioactivity in Solid Wastes and Releases of Radioactive Materials in Liquid and Gaseous Effluents from Light-Water-Cooled Nuclear Power Plants," Revision 1, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555, June 1974.

18. Title 40, "Protection of Environment," Chapter I, Code of Federal Regulations, Part 190, Federal Register, Vol. 42, No. 9, pages 2858 to 2861, Washington, D.C. 20402, January 13, 1977.

19. "SKYSHINE, A Computer Program for Evaluating Effects of Structure Design on N-16 Gamma-Ray Dose Rates," Radiation Research Associates, Inc., Report RRA-T7209, Fort Worth, Texas, 76107, November 1972.

20. Regulatory Guide 4.15, "Quality Assurance for Radiological Monitoring Programs (Normal Operation) - Effluent Streams and the Environment," U.S. Nuclear Regulatory Commission, Washington, D.C. 20555, December 1977.

21. Regulatory Guide 1.70, "Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants, LWR Edition," Revision 2, USNRC Report NUREG-75/094, Washington, D.C. 20555, September 1975.

22. International Commission on Radiological Protection, Report of ICRP Committee II on Permissible Dose for Internal Radiation, ICRP Publication 2, Pergamon Press, New York 10022, 1959.

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25. Regulatory Guide 1.97, "Instrumentation for Light-Water-Cooled Nuclear Power Plants to Assess Plant Conditions During and Following an Accident," Revision 1, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555, August 1977.

APPENDIX A

RATAFR CODE FOR PRESSURIZED WATER REACTORS
Input Cards and Sample Calculation

1. Parameters Required for the PWR-RATAFR Code

   Complete the cards from information given in the Applicant's Safety Analysis and Environmental Reports and in Section 2 of this Appendix.

   a. CARD 1: Name of Reactor

      Enter in spaces (33-60) the name of the reactor.

   b. CARD 2: Thermal Power Level

      Enter in spaces (73-80) the maximum thermal power level (MWt) evaluated for safety considerations in the Safety Analysis Report.

   c. CARD 3: Mass of Coolant in Primary System

      Enter in spaces (73-80) the mass of coolant (10^3 lbs) in the primary system at operating temperature and pressure.

   d. CARD 4: Primary System Letdown Rate

      Enter in spaces (73-80) the average letdown rate (gpm) from the primary system to the purification demineralizers.

   e. CARD 5: Letdown Cation Demineralizer Flow Rate

      Enter in spaces (73-80) the annual average flow rate (gpm) through the cation demineralizers for the control of cesium in the primary coolant. The average flow rate is determined by multiplying the average letdown rate (value entered on Card 4) by the fraction of time cation demineralizers are in service to obtain the average cation demineralizer flow rate.

   f. CARD 6: Hydrological Travel Time

      Enter in spaces (73-80) the travel time (days) it takes for the liquid waste of a failed tank to reach the nearest potable water supply or nearest surface water in an unrestricted area.

   g. CARD 7: Hydrological Dilution Factor

      Enter in spaces (73-80) the dimensionless value of:
      The annual volume of water flowing past the potable water supply divided by the total volume of liquid waste in the failed tank (80% of design capacity).

   h. CARDS 8-16: Liquid Tank Parameters

      Tanks in two separate processing systems are considered in the PWR-RATAFR Code:
      (1) Shim Bleed Processing System, Cards 8-12;
      (2) Waste Drain Processing System, Cards 13-16.

In each of the processing systems considered, the Code can calculate the tank concentrations in either the collector tank or the evaporator bottoms tank. However, separate computer runs must be made for these two tank classifications. If it is desired, the Code can calculate concentrations in one tank of each of the processing systems in one computer run by making the appropriate entries in CARDS 8-16. If a tank in only one of the processing systems is to be considered, then the appropriate entries need only be made in CARDS 8-12 or 13-16, depending on which system contains the tank of interest.

Five input data cards define the major parameters for the failed tank in the shim bleed processing system. The first two cards (CARDS 8 and 9) describe the inputs to the tank. The shim bleed wastes are entered on CARD 8. For reactor designs which combine the shim bleed with other reactor grade wastes prior to processing, the other wastes are entered as equipment drain wastes on CARD 9.

Four input data cards define the major parameters for the failed tank in the waste drain processing system. The first card (CARD 13) describes the inputs to the tank. Essentially the same information is required on CARDS 8, 9 and 13, on CARDS 10 and 14, on CARDS 11 and 15, and on CARDS 12 and 16.

The following information explains the use of the parameters in this Appendix and information given in the SAR/ER to complete the input data cards.

For CARD 8, enter in spaces (42-49) the flow rate (gpd) of the inlet stream. The value of the shim bleed rate must always be entered, even if the tank being evaluated is not in this system, since it is used in determining the primary coolant concentrations. Do not enter inlet waste activity for the shim bleed since the activity for this waste stream is calculated by the Code.

The following information is required on CARDS 9 and 13 for both of the processing systems considered in the Code.

(1) Enter in spaces (17-40) the name of the waste stream (e.g., clean wastes).
(2) Enter in spaces (42-49) the flow rate (gpd) of the inlet stream.
(3) Enter in spaces (57-61) the activity of the inlet stream expressed as a fraction of primary coolant activity (PCA).

For CARDS 10 and 14, the following information is required:

(1) Enter in spaces (27-50) the name of the tank to be failed (e.g., shim bleed collector).

(2) Enter in spaces (65-73) the volume (gallons) of the tank to be failed. If a tank in either of the two processing streams is not being considered, leave spaces (65-73) blank for that tank.

For CARDS 11 and 15, enter a <u>1</u> in space (80) if the tank to be failed is an evaporator bottoms tank. Otherwise leave space (80) blank.

CARDS 12 and 16 for both waste streams contain the overall system "tank" factors. The "tank" factors indicate the type of processing the waste has undergone prior to its entry into the tank. The tank factors should be entered as follows:

(1) For a collector tank in either waste stream, without demineralizers upstream of the tank, values of TF=1.0 should be entered in the appropriate spaces.

(2) For a collector tank in either waste stream with demineralizers upstream of the tank, or for an evaporator bottoms tank in either waste stream, TF's based on the description given in Section 2.a(3) should be entered in the appropriate spaces.

The appropriate spaces for the TFs are:

(1) Enter in spaces (21-28) the TF for iodine.
(2) Enter in spaces (34-41) the TF for cesium and rubidium.
(3) Enter in spaces (47-54) the TF for other nuclides.

The following section explains the use of the parameters in this note and information given in the SAR/ER to complete data input CARDS 8-16.

2. Explanation of Parameters used in Filling out CARDS 8-16

a. Liquid Waste Flow Rates and Activities

(1) Shim Bleed Wastes and Equipment Drain Wastes

The flow rates of the shim bleed waste stream and equipment drain wastes processed with the shim bleed and the activity of the equipment drain wastes are based on information given in the SAR/ER. The activity of the shim bleed wastes is based on the primary coolant letdown system effluent activity and is calculated in the Code.

The activity of the combined inlet stream is calculated by the Code based on the weighted average of the composite stream entering the tanks.

(2) Waste Drain Tank Wastes

Flow rates and activities are calculated using the waste volumes and activities given in NUREG-0017, Table 1-2, "PWR Liquid Wastes" (Ref. 11).

These input flow rates are supplemented by the use of expected flows and activities more specific to the plant design as given in the SAR/ER. The individual streams are combined based on the radwaste treatment system described in the SAR/ER. Input activities are based on the weighted average activity of the composite stream entering the waste collection tanks. The input flow rates and activities are entered in units of gpd and fractions of PCA.

(3) Tank Factors

The tank factors indicate the type of processing the waste has undergone prior to its entry into the tank. The tank factors provide the capability to consider radionuclide removal by demineralizers or other treatment equipment prior to the tank. For evaporator bottoms tanks, the tank factors provide the capability to consider the effects of radionuclide concentration in the evaporator. Therefore, in determining the radionuclide concentration in the tank, the type of processing upstream of the tank must be considered and entered as tank factors on CARDS 12 and 16.

The following factors are considered in calculating overall tank factors for the systems.

(a) TFs are categorized by radionuclides.
Halogens
Cs, Rb
Other Nuclides
Note: TF of 1 is assumed for tritium.

(b) The system TF is the product of the individual equipment TF in each of the systems, e.g., the effect of the demineralizer removal, if any, is multiplied by the effect of the evaporator concentration, if any.

(c) Tank Factors for Demineralizers
The tank factors for demineralizers are entered in the same manner as decontamination factors (DFs) are entered in the PWR-GALE Code. Therefore, the values used for TFs for demineralizers are the same as those given in NUREG-0017, Table 1-3, "Decontamination Factors for PWR Liquid Waste Treatment Systems" (Ref. 11).

(d) Tank Failures for Evaporators
The tank factors for evaporators express the increase in concentration of radionuclides in the evaporator bottoms resulting from evaporator operation. The values entered on the CARDs are the ratio of the evaporator bottom stream flow to the evaporator inlet stream flow. Therefore, the TFs for evaporators are as follows:

Evaporator	All Nuclides
Waste Drain Stream	0.02
Shim Bleed Stream	0.02

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(12-75)

U.S. NUCLEAR REGULATORY COMMISSION

ADP TRANSCRIPTION SHEET

INPUT DATA PWR-RATAFR CODE

Line	Columns 1–8	Columns 10–15	Columns 17–80
1	CARD 1	REACTR	NAME OF REACTOR [ ] TYPE= PWR
2	CARD 2	POW1	THERMAL POWER LEVEL (MEGAWATTS) [ ]
3	CARD 3	PCVOL	MASS OF PRIMARY COOLANT (THOUSAND LBS) [ ]
4	CARD 4	LETDWN	PRIMARY SYSTEM LETDOWN RATE (GPM) [ ]
5	CARD 5	CBFLR	LETDOWN CATION DEMINERALIZER FLOW (GPM) [ ]
6	CARD 6	HYTRTM	HYDROLOGICAL TRAVEL TIME (DAYS) [ ]
7	CARD 7	HYDF	HYDROLOGICAL DILUTION FACTOR [ ]
8	CARD 8	SBLDR	SHIMBLEED RATE [ ]GPD
9	CARD 9	EDFLR	EQUIPMENT DRAINS INPUT [ ]GPD AT [ ] PCA
10	CARD 10	SBTANK	TANK'NAME [ ]TANK VOLUME [ ]GAL
11	CARD 11	KEVBTS	IS TANK IN SYSTEM A BOTTOMS TANK? 0 IF NO, 1 IF YES IN (80)
12	CARD 12		TFI=[ ]TFCS=[ ]TFO= [ ]
13	CARD 13	DWFLR	CLEAN WASTE INPUT [ ]GPD
14	CARD 14	DWTANK	TANK NAME [ ]TANK VOLUME [ ]GAL
15	CARD 15	KEVBTD	IS TANK IN SYSTEM A BOTTOMS TANK? 0 IF NO, 1 IF YES IN (80)
16	CARD 16		TFI=[ ]TFCS=[ ]TFO= [ ]
17			
18			
19			
20			
21			
22			
23			

```
 1.      CARD  1  NAME   NAME OF REACTOR   SAMPLE CASE PWR  4/78            TYPE =   PWR
 2.      CARD  2  POWTH  THERMAL POWER LEVEL (MEGAWATTS)                             3391.
 3.      CARD  3  PCVOL  MASS OF PRIMARY COOLANT (THOUSANDS LBS)                     561.
 4.      CARD  4  LETDWN PRIMARY SYSTEM LETDOWN RATE (GPM)                           75.
 5.      CARD  5  CBFLR  LETDOWN CATION DEMINERALIZER FLOW (GPM)                     7.5
 6.      CARD 6   HYTRTM HYDROLOGICAL TRAVEL TIME (DAYS)                             1.
 7.      CARD 7   HYDF   HYDROLOGICAL DILUTION FACTOR                                1000.
 8.      CARD  8         SHIMBLEED RATE            16200.   GPD
 9.      CARD  9         EQUIPMENT DRAINS INPUT     810.    GPD AT 1.0
10.      CARD 10         TANK NAME CONDENSATE HOLDUP         TANK VOLUME 250000.
11.      CARD 11         IS TANK IN SYSTEM A BOTTOMS TANK 0 IF NO  1 IF YES
12.      CARD 12         DFI=  1.0E03DFCS=  1.0E05DFO=   1.0E05
13.      CARD 13         DIRTY WASTES       INPUT   1375.   GPD AT .075 PCA
14.      CARD 14         TANK NAME WASTE HOLDUP              TANK VOLUME 250000.
15.      CARD 15         IS TANK IN SYSTEM A BOTTOMS TANK 0 IF NO  1 IF YES
16.      CARD 16         DFI=  1.0E03DFCS=  1.0E04DFO=   1.0E04
```

SAMPLE CASE PWR 4/78

	PWR
THERMAL POWER LEVEL (MEGAWATTS)	3391.0000
PLANT CAPACITY FACTOR	0.80
MASS OF PRIMARY COOLANT (THOUSANDS LBS)	561.0000
PERCENT FUEL WITH CLADDING DEFECTS	1.0000
PRIMARY SYSTEM LETDOWN RATE (GPM)	75.0000
LETDOWN CATION DEMINERALIZER FLOW (GPM)	7.5000
HYDROLOGICAL TRAVEL TIME (DAYS)	1.00
HYDROLOGICAL DILUTION FACTOR	1000.
SHIMBLEED RATE GPD	1.62E+04
EQUIPMENT DRAINS INPUT GPD	8.10E+02
DIRTY WASTES INPUT GPD	1.38E+03

FAILED TANK PARAMETERS

		TANK FACTORS		
FAILED TANK	VOLUME	I	CS	OTHERS
CONDENSATE HOLDUP	250000.	1.00E+03	1.00E+05	1.00E+05
WASTE HOLDUP	250000.	1.00E+03	1.00E+04	1.00E+04

SAMPLE CASE PWR 4/78 LIQUID TANK FAILURE
NAME OF TANK FAILED: CONDENSATE HOLDUP
VOLUME OF TANK FAILED: 200000. GAL. (80% OF TANK CAPACITY)
HYDROLOGICAL TRAVEL TIME (DAYS): 1.00
HYDROLOGICAL DILUTION FACTOR: 1000.

NUCLIDE	HALF-LIFE (DAYS)	PRIMARY COOLANT CONC. (UCI/ML)	10CFR20 LIMITS (UCI/ML)	FAILED TANK CONC. (UCI/ML)	CRITICAL RECEPTOR CONC. (UCI/ML)	FRACTION 10CFR20
CORROSION AND ACTIVATION PRODUCTS						
H 3	4.49E+03	1.00E+00	3.00E-03	1.00E+00	1.00E-03	0.3300
FISSION PRODUCTS						
I131	8.05E+00	2.18E+00	3.00E-07	2.00E-04	1.80E-07	0.6000
I133	8.75E-01	3.08E+00	1.00E-06	4.70E-05	2.10E-08	0.0210
ALL OTHERS		6.38E+00		2.40E-05	3.10E-09	0.0003
TOTAL EXCEPT TRITIUM		1.16E+01		2.70E-04	2.00E-07	0.6200

THE MAXIMUM QUANTITY OF TRITIUM IN THE TANK IS 2.3E+03 CURIES.

THE MAXIMUM QUANTITY OF CORROSION AND FISSION PRODUCTS (EXCLUDING TRITIUM) IN THE TANK IS 3.3E-01 CURIES.

SAMPLE CASE PWR 4/78 LIQUID TANK FAILURE
NAME OF TANK FAILED: WASTE HOLDUP
VOLUME OF TANK FAILED: 200000. GAL. (80% OF TANK CAPACITY)
HYDROLOGICAL TRAVEL TIME (DAYS): 1.00
HYDROLOGICAL DILUTION FACTOR: 1000.

NUCLIDE	HALF-LIFE (DAYS)	PRIMARY COOLANT CONC. (UCI/ML)	10CFR20 LIMITS (UCI/ML)	FAILED TANK CONC. (UCI/ML)	CRITICAL RECEPTOR CONC. (UCI/ML)	FRACTION 10CFR20
CORROSION AND ACTIVATION PRODUCTS						
H 3	4.49E+03	1.00E+00	3.00E-03	7.40E-02	7.40E-05	0.0250
FISSION PRODUCTS						
I131	8.05E+00	2.18E+00	3.00E-07	1.30E-05	1.20E-08	0.0400
ALL OTHERS		9.46E+00		6.70E-06	3.60E-09	0.0011
TOTAL EXCEPT TRITIUM		1.16E+01		2.00E-05	1.60E-08	0.0410

THE MAXIMUM QUANTITY OF TRITIUM IN THE TANK IS 2.3E+03 CURIES.

THE MAXIMUM QUANTITY OF CORROSION AND FISSION PRODUCTS (EXCLUDING TRITIUM) IN THE TANK IS 3.6E-01 CURIES.

APPENDIX B

RATAFR CODE FOR BOILING WATER REACTORS
Input Cards and Sample Calculation

1. Parameters Required for the BWR-RATAFR Code

   Complete the cards from information given in the Applicant's Safety Analysis and Environmental Reports and in Section 2 of this Appendix.

   a. CARD 1: Name or Reactor (SAR/ER)

      Enter in spaces (33-60) the name of the reactor.

   b. CARD 2: Thermal Power Level (SAR/ER)

      Enter in spaces (73-80) the maximum thermal power level (MWt) evaluated for safety considerations in the Safety Analysis Report.

   c. CARD 3: Total Steam Flow Rate (SAR/ER)

      Enter in spaces (73-80) the total steam flow rate from the reactor (10^6 lbs/hr).

   d. CARD 4: Mass of Coolant in Reactor Vessel (SAR/ER)

      Enter in spaces (73-80) the mass of water in the reactor vessel (10^6 lbs).

   e. CARD 5: Cleanup Demineralizer Flow (SAR/ER)

      Enter in spaces (73-80) the primary coolant flow rate (10^6 lbs/hr) through the reactor coolant cleanup system demineralizers.

   f. CARD 6: Condensate Demineralizer Regeneration Time

      For deep bed condensate demineralizers, use 3.5 day regeneration frequency per demineralizer. If ultrasonic resin cleaning is used, assume 7-day regeneration frequency per demineralizer. Multiply the frequency by the number of demineralizers, and enter the calculated number of days in spaces (73-80). For filter/demineralizers (Powdex), enter zero in spaces (73-80).

   g. CARD 7: Fraction of Feed Water Through Condensate Demineralizer (SAR/ER)

      Enter in spaces (73-80) the fraction of feedwater processed through the condensate demineralizers.

   h. CARD 8: Hydrological Travel Time

      Enter in spaces (73-80) the travel time (days) it takes for the liquid waste of a failed tank to reach the nearest potable water supply or nearest surface water in an unrestricted area.

   i. CARD 9: Hydrological Dilution Factor

      Enter in spaces (73-80) the dimensionless value of:
      The annual volume of water flowing past the potable water supply divided by the **total** volume of liquid waste in the failed tank (80% of design capacity).

j. <u>CARD 10-17: Liquid Tank Parameters</u>

Tanks in two separate processing systems are considered in the BWR-RATAFR Code:

(1) Waste Drain Processing System, CARDS 10-13.

(2) Regenerant Solutions Processing System, CARDS 14-17.

In each of the processing systems considered, the Code can calculate the tank concentrations in either the collector tank or the evaporator bottoms tank. However, separate computer runs must be made for these two tank classifications. If it is desired, the Code can calculate concentrations in one tank of each of the processing systems in one computer run by making the appropriate entries in CARDS 10-17. If a tank in only one of the processing systems is to be considered, then the appropriate entries need only be made in CARDS 10-13 or 14-17 depending on which system the tank of interest is in.

Four input data cards are used to define the major parameters for the failed tank in each of the processing systems. Essentially, the same information is required on the four input data cards used for each of the processing systems. The instructions given in this section are applicable to both processing streams, with the following exception. The inlet waste activity is not entered on CARD 14 for the regenerant solutions wastes for systems using regenerable condensate demineralizers, since the activity is calculated by the Code.

The following information explains the use of the parameters in this Appendix and information given in the SAR/ER to complete the input data cards.

The following information is required on CARDS 10 and 14 for both of the streams considered in the Code.

(1) Enter in spaces (18-40) the name of the waste stream (e.g., high-purity wastes).

(2) Enter in spaces (42-49) the flow rate (gpd) of the inlet stream.

(3) Enter in spaces (57-61) the activity of the inlet stream, expressed as a fraction of the primary coolant activity (PCA).

On CARD 14, do not enter the activity of the regenerant solutions waste inlet stream in spaces (57-61).

For CARDS 11 and 15, the following information is required:

(1) Enter in spaces (27-50) the name of the tank to be failed (e.g., High Purity Collector).

(2) Enter in spaces (65-73) the volume (gallons) of the tank to be failed. If a tank in either of the two processing streams is not being considered, leave spaces (65-73) blank for that tank.

For CARDS 12 and 16, enter a 1 in space (80) if the tank to be failed is an evaporator bottoms tank. Otherwise leave space (80) blank.

CARDS 13 and 17 for both waste streams contain the overall system "tank" factors. The "tank" factors indicate the type of processing the waste has undergone prior to its entry into the tank. The tank factors should be entered as follows:

(1) For a collector tank in either waste stream, without demineralizers upstream of the tank, values of TF = 1.0 should be entered in the appropriate spaces.

(2) For a collector tank in either waste stream with demineralizers upstream of the tank, or for an evaporator bottoms tank in either waste stream, TFs based on the description given in Section 2.b should be entered in the appropriate spaces.

The appropriate spaces for the TFs are:

(1) Enter in spaces (21-28) the TF for iodine.
(2) Enter in spaces (34-41) the TF for cesium and rubidium.
(3) Enter in spaces (47-54) the TF for other nuclides.

The following section explains the use of the parameters in this note and information given in the SAR/ER to complete data input CARDS 10-17.

2. Explanation of Parameters used in Filling out Cards 10-17

a. Liquid Waste Flow Rates and Activities

Flow rates and activities are calculated using the waste volumes and activities given in NUREG-0016, Table 1-2, "BWR Liquid Wastes" (Ref. 12).

These input flows are supplemented by the use of expected flows and activities more specific to the plant design as given in the SAR/ER. The inlet streams are combined to form the principal waste streams (drain wastes and regenerant wastes) considered in this guide, based on the radwaste treatment system described in the SAR/ER.

Input activities are based on the weighted average activity of the composite stream entering the waste collection tanks.

b. Tank Factors

The tank factors indicate the type of processing the waste stream has undergone prior to its entry into the tank. The tank factors provide the capability to consider radionuclide removal by demineralizers prior to the waste stream input into the tank. For evaporator bottoms tanks, the tank factors provide the capability to consider the effects of radionuclide concentration in the evaporator. Therefore, in determining the radionuclide concentration in a tank, the type of processing upstream of the tank must be considered and entered as tank factors on CARDS 13 and 17.

The following factors are considered in calculating overall tank factors for the systems:

(1) TFs are categorized by radionuclides.
Halogens
Cs, Rb
Other Nuclides
Note: TF of 1 is assumed for tritium.

(2) The system TF is the product of the individual equipment TF in each of the systems, e.g., the effect of the demineralizer removal, if any, is multiplied by the effect of the evaporator concentration, if any.

(3) Tank Factors for Demineralizers
The tank factors for demineralizers are entered in the same manner as decontamination factors (DFs) are entered in the BWR-GALE Code. Therefore, the values used for TFs for demineralizers are the same as those given in NUREG-0016, Table 1-3, "Decontamination Factors for BWR Liquid Waste Treatment Systems" (Ref. 11).

(4) Tank Factors for Evaporators
The tank factors for evaporators express the increase in concentration of radionuclides in the evaporator bottoms resulting from evaporator operation. The values entered on the cards are the ratio of the evaporator bottoms stream flow to the evaporator inlet stream flow. Therefore, the TFs for evaporators are entered as follows:

Evaporator	All Nuclides
Waste Drain Stream	0.01
Regenerant Waste Stream	0.05

NRC FORM 53A
(12-75)

U.S. NUCLEAR REGULATORY COMMISSION

ADP TRANSCRIPTION SHEET

INPUT DATA BWR-RATAFR CODE

```
CARD  1  REACTR NAME OF REACTOR [                          ]        TYPE =   BWR
CARD  2  POW1   THERMAL POWER LEVEL (MEGAWATTS)                            [      ]
CARD  3  STMFR  TOTAL STEAM FLOW (MILLION LBS/HR)                          [      ]
CARD  4  PCVOL  MASS OF WATER IN REACTOR VESSEL (MILLION LBS)              [      ]
CARD  5  LETDWN CLEAN-UP DEMINERALIZER FLOW (MILLION LBS/HR)               [      ]
CARD  6  REGENT CONDENSATE DEMINERALIZER REGENERATION TIME (DAYS)          [      ]
CARD  7  FFCDM  FRACTION FEEDWATER THROUGH CONDENSATE DEMIN                [      ]
CARD  8  HYTRTM HYDROLOGICAL TRAVEL TIME (DAYS)                            [      ]
CARD  9  HYDF   HYDROLOGICAL DILUTION FACTOR                               [      ]
CARD 10  CWFLR  HIGH PURITY WASTE INPUT [       ]GPD AT [    ]PCA
CARD 11  CWTANK TANK NAME                       ] TANK VOLUME [       ]GAL
CARD 12  KEVBTC IS TANK IN SYSTEM A BOTTOMS TANK? 0 IF NO, 1 IF YES IN (80)
CARD 13         TFI=[       ]TFCS=[       ]TFO= [       ]
CARD 14  RGWFR  REGENERANT WASTE INPUT [       ]GPD
CARD 15  RGTANK TANK NAME [                     ] TANK VOLUME [       ]GAL
CARD 16  KEVBTR IS TANK IN SYSTEM A BOTTOMS TANK? 0 IF NO, 1 IF YES IN (80)
CARD 17         DFI=[       ]DFCS=[       ]DFO= [       ]
```

```
 1.   CARD  1  NAME   NAME OF REACTOR  SAMPLE CASE BWR    4/78           TYPE =   BWR
 2.   CARD  2  POWTH  THERMAL POWER LEVEL (MEGAWATTS)                           3440.
 3.   CARD  3  GTO    TOTAL STEAM FLOW (MILLION LBS/HR)                         14.166
 4.   CARD  4  WL1Q   MASS OF WATER IN REACTOR VESSEL (MILLION LBS)             0.588
 5.   CARD  5  GDE    CLEAN-UP DEMINERALIZER FLOW (MILLION LBS/HR)              0.135
 6.   CARD  6  REGENT CONDENSATE DEMINERALIZER REGENERATION TIME (DAYS)         36.75
 7.   CARD  7  FFCDM  FRACTION FEED WATER THROUGH CONDENSATE DEMIN              1.
 8.   CARD 8   HYTRTM HYDROLOGICAL TRAVEL TIME (DAYS)                           2.0
 9.   CARD 9   HYDF   HYDROLOGICAL DILUTION FACTOR                              200000.
10.   CARD 10         HIGH PURITY WASTE  INPUT  27800.  GPD AT .164 PCA
11.   CARD 11         TANK NAME WASTE COLLECTION          TANK VOLUME 30000.    GAL
12.   CARD 12         IS TANK IN SYSTEM A BOTTOMS TANK 0 IF NO  1 IF YES              0
13.   CARD 13         DFI= 1.0E-00DFCS= 1.0E-00DFO = 1.0E-00
14.   CARD 14         REGENERATION SOLTNS INPUT 2550.        GPD
15.   CARD 15         TANK NAME CONCENTRATOR WASTE        TANK VOLUME 5000.     GAL
16.   CARD 16         IS TANK IN SYSTEM A BOTTOMS TANK 0 IF NO  1 IF YES              1
17.   CARD 17         DFI= 5.0E-02DFCS= 5.0E-02DFO = 5.0E-02
```

SAMPLE CASE BWR 4/78	BWR
THERMAL POWER LEVEL (MEGAWATTS)	3440.0000
PLANT CAPACITY FACTOR	0.80
TOTAL STEAM FLOW (MILLION LBS/HR)	14.1660
MASS OF WATER IN REACTOR VESSEL (MILLION LBS)	0.5880
OFF-GAS RELEASE RATE(UC/SEC)	350000.
FISSION PRODUCT CARRY-OVER FRACTION	0.0010
HALOGEN CARRY-OVER FRACTION	0.0200
CLEAN-UP DEMINERALIZER FLOW (MILLION LBS/HR)	0.1350
CONDENSATE DEMINERALIZER REGENERATION TIME (DAYS)	36.7500
FRACTION FEED WATER THROUGH CONDENSATE DEMIN	1.0000
HYDROLOGICAL TRAVEL TIME (DAYS)	2.00
HYDROLOGICAL DILUTION FACTOR	200000.
HIGH PURITY WASTE INPUT GPD	2.78E+04
REGENERATION SOLTNS INPU GPD	2.55E+03

FAILED TANK PARAMETERS

		TANK FACTORS		
FAILED TANK	VOLUME	I	CS	OTHERS
WASTE COLLECTION	30000.	1.00E+00	1.00E+00	1.00E+00
CONCENTRATOR WASTE	5000.	5.00E-02	5.00E-02	5.00E-02

SAMPLE CASE BWR 4/78 LIQUID TANK FAILURE
NAME OF TANK FAILED: WASTE COLLECTION
VOLUME OF TANK FAILED: 24000. GAL. (80% OF TANK CAPACITY)
HYDROLOGICAL TRAVEL TIME (DAYS): 2.00
HYDROLOGICAL DILUTION FACTOR: 200000.

NUCLIDE	HALF-LIFE (DAYS)	PRIMARY COOLANT CONC. (UCI/ML)	10CFR20 LIMITS (UCI/ML)	FAILED TANK CONC. (UCI/ML)	CRITICAL RECEPTOR CONC. (UCI/ML)	FRACTION 10CFR20
CORROSION AND ACTIVATION PRODUCTS						
FISSION PRODUCTS						
I131	8.05E+00	2.84E-02	3.00E-07	4.50E-03	1.90E-08	0.0630
I133	8.75E-01	1.07E-01	1.00E-06	1.30E-02	1.30E-08	0.0130
ALL OTHERS		1.81E+00		4.90E-02	3.30E-08	0.0008
TOTAL EXCEPT TRITIUM		1.95E+00		6.60E-02	6.50E-08	0.0770

THE MAXIMUM QUANTITY OF TRITIUM IN THE TANK IS 5.0E+03 CURIES.

THE MAXIMUM QUANTITY OF CORROSION AND FISSION PRODUCTS (EXCLUDING TRITIUM) IN THE TANK IS 1.5E+01 CURIES.

SAMPLE CASE BWR 4/78 LIQUID TANK FAILURE
NAME OF TANK FAILED: CONCENTRATOR WASTE
VOLUME OF TANK FAILED: 4000. GAL. (80% OF TANK CAPACITY)
HYDROLOGICAL TRAVEL TIME (DAYS): 2.00
HYDROLOGICAL DILUTION FACTOR: 200000.

NUCLIDE	HALF-LIFE (DAYS)	PRIMARY COOLANT CONC. (UCI/ML)	10CFR20 LIMITS (UCI/ML)	FAILED TANK CONC. (UCI/ML)	CRITICAL RECEPTOR CONC. (UCI/ML)	FRACTION 10CFR20
CORROSION AND ACTIVATION PRODUCTS						
P 32	1.43E+01	1.96E-04	2.00E-05	2.00E-02	8.90E-08	0.0045
CR 51	2.78E+01	4.91E-03	2.00E-03	9.50E-01	4.50E-06	0.0023
MN 54	3.03E+02	5.90E-05	1.00E-04	2.30E+02	1.10E-07	0.0011
FE 55	9.50E+02	9.83E-04	8.00E-04	3.90E-01	2.00E-06	0.0025
CO 58	7.13E+01	1.97E-04	9.00E-05	6.00E-02	2.90E-07	0.0032
CO 60	1.92E+03	3.93E-04	3.00E-05	1.60E-01	8.00E-07	0.0270
ZN 65	2.45E+02	1.97E-04	1.00E-04	7.40E-02	3.70E-07	0.0037
FISSION PRODUCTS						
SR 89	5.20E+01	5.73E-04	3.00E-06	1.60E-01	7.60E-07	0.2500
SR 90	1.03E+04	3.44E-05	3.00E-07	1.40E-02	7.10E-08	0.2400
Y 90	2.67E+00	0.0	2.00E-05	1.40E-02	4.20E-08	0.0021
Y 91	5.88E+01	2.29E-04	3.00E-05	1.10E-01	5.20E-07	0.0170
MO 99	2.79E+00	1.13E-02	4.00E-05	1.80E-02	5.60E-08	0.0014
RU103	3.96E+01	1.15E-04	8.00E-05	2.70E-02	1.30E-07	0.0017
RU106	3.67E+02	1.72E-05	1.00E-05	6.70E-03	3.30E-08	0.0033
TE129M	3.40E+01	2.29E-04	2.00E-05	5.00E-02	2.40E-07	0.0120
I131	8.05E+00	2.84E-02	3.00E-07	2.20E+01	9.40E-05	310.0000
CS134	7.49E+02	1.72E-04	9.00E-06	3.80E-02	1.90E-07	0.0210
CS137	1.10E+04	4.02E-04	2.00E-05	9.10E-02	4.60E-07	0.0230
BA140	1.28E+01	2.29E-03	2.00E-05	2.00E-01	8.90E-07	0.0440
LA140	1.67E+00	0.0	2.00E-05	2.30E-01	5.00E-07	0.0250
CE141	3.24E+01	1.72E-04	9.00E-05	4.00E-02	1.90E-07	0.0021
PR143	1.37E+01	2.29E-04	5.00E-05	2.40E-02	1.10E-07	0.0021
CE144	2.84E+02	1.72E-05	1.00E-05	6.50E-03	3.30E-08	0.0033
ALL OTHERS		1.90E+00		2.50E-01	2.90E-07	0.0046
TOTAL EXCEPT TRITIUM		1.95E+00		2.50E+01	1.10E-04	310.0000

THE MAXIMUM QUANTITY OF TRITIUM IN THE TANK IS 5.0E+03 CURIES.

THE MAXIMUM QUANTITY OF CORROSION AND FISSION PRODUCTS (EXCLUDING TRITIUM) IN THE TANK IS 1.2E+00 CURIES.

APPENDIX C

RATAFR LISTING

This appendix contains the program listing in FORTRAN for the RATAFR Code, applicable to PWR's and BWR's using the input data cards from Appendix A or B of this manual. The nuclear data library and subroutines are available in card deck form from the Effluent Treatment Systems Branch, USNRC, (301)492-7775. The remainder of this appendix contains the RATAFR program listing.

```
C     RATAF CODE FOR CALCULATING CONSEQUENCES OF RADIOACTIVE LIQUID
C     TANK FAILURES.  MODIFIED MARCH 1976 TO CALCULATE TANK ISOTOPIC
C     CONCENTRATIONS TO PROVIDE AS INPUT FOR DETERMINING CONCENTRATIONS
C     AT POTABLE WATER SUPPLIES.  BASES FOR CODE IS THE LIQUID GALE
C     CODE OF JULY 1975.
C                                                                       00000080
      INTEGER*2 NAME(3),ELE(99),STA(2),LOC,NONC,KD
      REAL*4 LETDWA,LETDWN,MCH3,MQH3,MCCFP,MQCFP
      COMMON/LABEL/ ELE,STA
      COMMON/MATRIX/A(2500),LOC(2500),NONO(800),KD(800)                 00000190
      COMMON/FLEX/FLUX(10),MMN,MOUT,INDEX,QXN,AXN,ERR,NOBLND,MZERO      00000200
      COMMON/PROCSS/  NPROS,PRATE(8),NOPROS(8),NZPROS(8,20),PR(800)     00000210
      COMMON/EQ/XZERO(800), XZH(800),XTEMP(800),XNEW(10,800),           00000220
     1     B(800),D(800)                                                00000230
      COMMON/FLUXN/T(20),POWER(10),TOCAP(800),FISS(100),DIS(800),ILITE, 00000240
     1 IACT,IFP,ITOT,NON,INPT                                           00000250
      COMMON/CUT/NUCL(800),TITLE(20),Q(800),FG(800),CUTOFF(7),          00000260
     1 PCW,BURNUP,FLUX3,MSTAR,ALPHAN(100),SPONF(100),ABUND(500),        00000270
     2 BASIS(10),TCONST,TUNIT                                           00000280
      COMMON/MPC/MPCTAB,AMPC(800),WMPC(800)                             00008120
      COMMON/CONP/PWCONC(800)
      COMMON /CONB/BCONC(800)
      DIMENSION PCONC(800),DWCONC(800),CWCONC(800),CMCONC(800),
     1RINV(800)
      DIMENSION TKCONC(800),PER(800)
      DIMENSION PWCON(800),FRAC(800)
      DIMENSION SRTANK(6),DWTANK(6),CWTANK(6),RGTANK(6)
      DIMENSION WORD56(14),WORD24(6),REACTR(7)
      DATA PWR/' PWR'/,BWR/' BWR'/
C     BCONC CONTAINS PRIMARY COOLANT CONCENTRATIONS FOR BWR'S.
C     PWCONC CONTAINS PRIMARY COOLANT CONCENTRATIONS FOR PWR'S.
C                                                                       00000570
C     READ NUCLEAR DATA AND CONSTRUCT TRANSITION MATRIX                 00000580
   10 CALL NUDATA(NLIBE)
C                                                                       00000590
C                                                                       00000610
      DO 20 I=2,ITOT                                                    00000620
      NONO(I)=NONO(I)+NONO(I-1)                                         00000630
   20 KD(I)=KD(I)+NONO(I-1)                                             00000640
   30 CONTINUE
      INDEX=0                                                           00000680
      QXN=0.001                                                         00000730
      AXN=-ALOG(QXN)                                                    00003640
      TCONST=86400.                                                     00000740
      TRG=0.0
      TD=0.0
      TC=0.0
      REGENT=0.0
      HYTRTM=0.0
      HYDF=0.0
      DWFLR=0.0
      RGWFR=0.0
      EVAPS=1.0
      EVAPO=1.0
      EVAPC=1.0
      EVAPR=1.0
      DO 40 J=1,800                                                     00000840
```

```
      PCONC(J)=0.0                                                  00000850
      DWCONC(J)=0.0
      RINV(J)=0.0                                                   00000880
      CWCONC(J)=0.0                                                 00000890
      CMCONC(J)=0.0                                                 00000900
      TKCONC(J)=0.0
      PWCON(J)=0.0
      FRAC(J)=0.0
      PER(J)=0.0
      XZH(J)=0.0                                                    00000910
   40 CONTINUE                                                      00000920
C                                                                   00000930
C     READ DESCRIPTION OF REACTOR AND RADWASTE TREATMENT PLANT      00000940
C                                                                   00000950
      PRINT 9026                                                    00000970
      READ 9010,REACTR,TYPE                                         00000980
      PRINT 9010,REACTR,TYPE                                        00000990
      READ 9011,WORD56,POW1                                         00001000
      PRINT 9011,WORD56,POW1                                        00001010
      PF=0.80                                                       00001020
      PRINT 9027                                                    00001030
      IF(TYPE.EQ.BWR) GO TO 50                                      00001040
C     READ DATA FOR PWR NSSS PARAMETERS AND TANK PARAMETERS
      READ 9022,WORD56,PCVOL                                        00001050
      PRINT 9022,WORD56,PCVOL                                       00001060
  700 FAILDB=1.0
      FAILEA=0.12
      FAILRA=FAILDB/FAILEA
      PRINT 9028,FAILDB
      READ 9022,WORD56,LETDWN
      PRINT 9022,WORD56,LETDWN
      READ 9022,WORD56,CBFLR
      PRINT 9022,WORD56,CBFLR
      READ 9085,WORD56,HYTRTM
      PRINT 9085,WORD56,HYTRTM
      READ 9090,WORD56,HYDF
      PRINT 9090,WORD56,HYDF
      READ 9013,WORD24,SBLDR
      PRINT 9025,WORD24,SBLDR
      CWA=1.0
      READ 9013,WORD24,EDFLR,EDA
      PRINT 9025,WORD24,EDFLR
      READ 9023, SBTANK,SBTKSZ
      READ 9086,KEVBTS
      IF (KEVBTS.EQ.1) EVAPS=0.02
      READ 9014,DFICW,DFCSCW,DFCW
      READ 9013,WORD24,DWFLR,DWA
      IF (DWFLR.EQ.0.0)GO TO 4446
      PRINT 9025,WORD24,DWFLR
 4446 CONTINUE
      READ 9023,DWTANK,DWTKSZ
      READ 9086,KEVBTD
      IF (KEVBTD.EQ.1)EVAPD=0.02
      READ 9014,DFIDW,DFCSDW,DFDW
      K=1
      PRINT 9045                                                    00001520
      PRINT 9016                                                    00001560
      IF (SBTKSZ.EQ.0.0)GO TO 45
      PRINT 9024,SBTANK,SBTKSZ,DFICW,DFCSCW,DFCW
      GO TO 46
```

```
   45 K=2
   46 CONTINUE
      IF (DWTKSZ.EQ.0.0)GO TO 47
      PRINT 9024,DWTANK,DWTKSZ,DFIDW,DFCSDW,DFDW
   47 CONTINUE
C                                                                   00002300
C     CONVERSION OF UNITS                                           00002310
C                                                                   00002320
      DFRG=1.0
      DFIRG=1.0
      DFCSRG=1.0
      GO TO 240
C                                                                   00002470
C     READ DATA FOR BWR NSSS PARAMETERS AND TANK PARAMETERS
C                                                                   00002480
   50 READ 9022,WORD56,STMFR                                        00002490
      PRINT 9022,WORD56,STMFR                                       00002500
      READ 9022,WORD56,PCVOL                                        00002510
      PRINT 9022,WORD56,PCVOL                                       00002520
      OGDB=350000.
      PRINT 9052,OGDB
      OGEA=60000.
      OGRTIO=OGDB/OGEA
      FPEF=0.001                                                    00002530
      HEF=0.020
      PRINT 9030,FPEF,HEF                                           00002550
      READ 9022,WORD56,LETDWN                                       00002560
      PRINT 9022,WORD56,LETDWN                                      00002570
      READ 9022,WORD56,REGENT                                       00002650
      PRINT 9022,WORD56,REGENT                                      00002660
      READ 9022,WORD56,FFCDM                                        00002670
      PRINT 9022,WORD56,FFCDM                                       00002680
      READ 9085,WORD56,HYTRTM
      PRINT 9085,WORD56,HYTRTM
      READ 9090,WORD56,HYDF
      PRINT 9090,WORD56,HYDF
      K=1
      READ 9013,WORD24,CWFLR,CWA
      READ 9023,CWTANK,CWTKSZ
      READ 9086,KEVBTC
      IF (KEVBTC.EQ.1)EVAPC=0.01
      READ 9014,DFICW,DFCSCW,DFCW
      IF (CWTKSZ.EQ.0.)GO TO 52
      PRINT 9025,WORD24,CWFLR
      GO TO 54
   52 K=2
   54 CONTINUE
      READ 9013,WORD24,RGWFR
      READ 9023,RGTANK,RGTKSZ
      READ 9086,KEVBTR
      IF (KEVBTR.EQ.1)EVAPR=0.05
      READ 9014,DFIRG,DFCSRG,DFRG
      IF (RGTKSZ.EQ.0.0) GO TO 56
      PRINT 9025,WORD24,RGWFR
   56 CONTINUE
      PRINT 9045                                                    00002710
      PRINT 9016                                                    00002750
      IF (CWTKSZ.EQ.0.0)GO TO 58
      PRINT 9024,CWTANK,CWTKSZ,DFICW,DFCSCW,DFCW
   58 CONTINUE
```

```
      IF (RGTKSZ.EQ.0.0)GO TO 60
      PRINT 9024,RGTANK,RGTKSZ,DFIRG,DFCSRG,DFRG
   60 CONTINUE
   77 DO 78 I=1,ITOT
      B(I)=0.0
   78 CONTINUE
C                                                               00003290
      DFIDW=1.0
      DFCSDW=1.0
      DFDW=1.0
  240 CONTINUE                                                  00004850
C                                                               00004860
C     CALCULATE PRIMARY COOLANT CONCENTRATIONS FOR PWRS
C                                                               00004880
      IF(TYPE.EQ.BWR)GO TO 251
      AFPTES=0.0
      DO 242 I=1,ITOT
  242 PCONC(I)=PWCONC(I)
      POWA=POW1
      PCVOA=PCVOL*1E3
      LETDWA=LETDWN*500.53
      SBLDA=SBLDR*.3476
      CBFLA=CBFLR*500.53
C     CHECK TO SEE IF PRIMARY PLANT PARAMETERS ARE WITHIN SPECIFIED
C     RANGES
      IF(ABS(POWA-3400).GT.400.1)GO TO 243
      IF(ABS(PCVOA-5.5E5).GT.0.5001E5)GO TO 243
      IF(ABS(LETDWA-3.7E4).GT.0.5001E4)GO TO 243
      IF(ABS(SBLDA-625.).GT.375.1)GO TO 243
      IF(ABS(CBFLA-3750.).GT.3750.1)GO TO 243
      GO TO 247
C     CALCULATE PWR PRIMARY COOLANT ADJUSTMENT FACTORS
  243 AFPTES=1.0
      RHAL2=(LETDWA*0.9+0.1*SBLDA)/PCVOA
      RCSRB2=(LETDWA*0.5+0.5*(SBLDA+CBFLA*0.9))/PCVOA
      RCFP2=(LETDWA*0.9+C.1*(SBLDA+CBFLA*0.9))/PCVOA
      RK2=161.76*POWA/PCVOA
      DO 246 J=1,ITOT
      IF(PCONC(J).EQ.0.0) GO TO 246
      NZ=NUCL(J)/10000
      DL=DIS(J)*3600.
      IF (NZ.EQ.1) GO TO 246
      IF(NZ.EQ.53.OR.NZ.EQ.35)GO TO 244
      IF(NZ.EQ.37.OR.NZ.EQ.55)GO TO 245
      PCONC(J)=PCONC(J)*RK2*(0.0612+DL)/(RCFP2+DL)
      GO TO 246
  244 PCONC(J)=PCONC(J)*RK2*(0.0606+DL)/(RHAL2+DL)
      GO TO 246
  245 PCONC(J)=PCONC(J)*RK2*(0.0371+DL)/(RCSRB2+DL)
  246 CONTINUE
  247 PCVOL=PCVOL*1000.*0.7/62.4
      DO 279 I=1,ITOT
      IF (PCONC(I).EQ.0.0)GO TO 279
      FAIL1=FAILRA
      IF (I.LE.ILITE)FAIL1=1.0
      PCONC(I)=PCONC(I)/(DIS(I)*1.6283E13)*FAIL1
  279 CONTINUE
C                                                               00005480
      GO TO 400
C
```

```
C
  251 CONTINUE
C     CALCULATE BWR PRIMARY COOLANT CONCENTRATIONS
      DO 2251 I=1,ITOT
 2251 PCONC(I)=BCONC(I)
      POWA=POW1
      PCVOA=PCVOL*1E6
      LETDWA=LETDWN*1E6
      STMFA=STMFR*1E6
      FFCDA=FFCDM
C     CHECK TO SEE IF PLANT PARAMETERS ARE WITHIN SPECIFIED RANGES
      IF(ABS(POWA-3400).GT.400.1)GO TO 252
      IF(ABS(PCVOA-3.8E5).GT.0.4001E5)GO TO 252
      IF(ABS(LETDWA-1.3E5).GT.0.2001E5)GO TO 252
      IF(ABS(STMFA-1.5E7).GT.0.2001E7)GO TO 252
      IF(ABS(FFCDA-0.9).GT.0.1001)GO TO 252
      GO TO 256
C     CALCULATE BWR ADJUSTMENT FACTORS
  252 RHAL2=(LETDWA*0.9+FFCDA*STMFA*0.018)/PCVOA
      RCSRB2=(LETDWA*0.5+FFCDA*STMFA*5E-4)/PCVOA
      RCFP2=(LETDWA*0.9+FFCDA*STMFA*9E-4)/PCVOA
      RK2=111.76*POWA/PCVOA
      DO 255 J=1,ITOT
      IF(PCONC(J).EQ.0.0) GO TO 255
      NZ=NUCL(J)/10000
      DL=DIS(J)*3600
      IF (NZ.EQ.1) GO TO 255
      IF (NZ.EQ.53.OR.NZ.EQ.35)GO TO 253
      IF (NZ.EQ.37.OR.NZ.EQ.55)GO TO 254
      PCONC(J)=PCONC(J)*RK2*(0.3434+DL)/(RCFP2+DL)
      GO TO 255
  253 PCONC(J)=PCONC(J)*RK2*(0.1908+DL)/(RCSRB2+DL)
      GO TO 255
  254 PCONC(J)=PCONC(J)*RK2*(0.1908+DL)/(RCSRB2+DL)
  255 CONTINUE
  256 PCVOL=PCVOL*1000000./62.4
      LETDWN=LETDWN*2000.                                       00003340
      STMFR=STMFR*2851.                                         00003350
      DO 2255 J=1,ITOT
      OGRTI1=OGRTIO
      IF (J.LE.ILITE)OGRTI1=1.0
      IF(PCONC(J).GT.0.0)PCONC(J)=PCONC(J)/(DIS(J)*1.6283E13)*OGRTI1
 2255 CONTINUE
      IF(REGENT.GT.0.0) GO TO 257
      GO TO 400
C                                                               00005120
C     COMPUTE REMOVAL CONSTANT FOR CONDENSATE DEMINERALIZER IN BWR
  257 CCBDM=0.9*STMFR*FPEF/(PCVOL*7.48*60.)*FFCDM
      CSBDM=0.5*STMFR*FPEF/(PCVOL*7.48*60.)*FFCDM
      DO 258 I=1,ITOT
      NZ=NUCL(I)/10000
      PR(I)=CCBDM
      IF(NZ.EQ.53.OR.NZ.EQ.35)PR(I)=CCBDM*HEF/FPEF
      IF(NZ.EQ.37.OR.NZ.EQ.55)PR(I)=CSBDM
      XZHJ=PCCNC(I)*PR(I)*PCVOL*0.02832
      B(I)=XZHJ
      XZH(I)=XZHJ*86400.
  258 CONTINUE
      XZERO(I)=0.
C     CALCULATE INVENTORIES ON BWR CONDENSATE RESINS            00005130
```

```
  290 T(1)=REGENT                                                        00005420
      CALL SOLVE
      DO 295 I=1,ITOT
  295 RINV(I)=XTEMP(I)
C
C     THIS PORTION OF PROGRAM CALCULATES FAILED TANK CONCENTRATIONS
C
  400 CONTINUE
      RGWFRM=RGWFR*3785./1E6
      DO 410 I=1,ITOT
  410 D(I)=-DIS(I)
  420 DO 430 J=1,ITOT
      NZ=NUCL(J)/10000                                                   00008320
      IF(NZ.EQ.36.OR.NZ.EQ.54) GO TO 430
      IF (TYPE.EQ.PWR)GO TO 425
      CWCONC(J)=PCONC(J)*CWA                                             00008340
      IF (NZ.EQ.1) CWCONC(J)=PCONC(J)
      IF (RGWFR.EQ.0.0)GO TO 430
      RINV(J)=RINV(J)/(REGENT*RGWFRM)
      IF (NZ.EQ.1) RINV(J)=PCONC(J)
      GO TO 430
  425 DFCVCS=10.
      IF(NZ.EQ.1)DFCVCS=1.0
      IF(NZ.EQ.37.OR.NZ.EQ.55) DFCVCS=2.
      CWCONC(J)=PCONC(J)*(CWA*SBLDR/DFCVCS+EDA*EDFLR)/(SBLDR+EDFLR)
      DWCONC(J)=PCONC(J)*DWA                                             00008360
  430 CONTINUE
C                                                                        00008470
C     CALCULATE RADIOACTIVITY AFTER COLLECTION AT A CONSTANT RATE        00008480
      IF (TYPE.EQ.BWR)GO TO 432
      IF (SBLDR.GT.0.0)TC=SBTKSZ*0.8/((SBLDR+EDFLR)*EVAPS)
      GO TO 434
  432 CONTINUE
      IF (CWFLR.GT.0.0)TC=CWTKSZ*0.8/(CWFLR*EVAPC)
  434 CONTINUE
      IF (DWFLR.GT.0.0)TD=DWTKSZ*0.8/(DWFLR*EVAPD)
      IF (RGWFR.GT.0.0)TRG=(RGTKSZ*0.8-11900.*EVAPR)/(RGWFR*2.*EVAPR)
      IF (TRG.LT.0.0) TRG=0.
C                                                                        00008490
      CALL COLLECT(TC*86400.,CWCONC,ILITE,ITOT)                          00008500
      CALL COLLECT(TD*86400.,DWCONC,ILITE,ITOT)                          00008520
  440 IF (REGENT.LE.0.0)GO TO 450
      CALL STORAG(TRG*86400.,RINV,ILITE,ITOT)
  450 DO 500 I=1,ITOT
      NZ=NUCL(I)/10000                                                   00008580
      IF (NZ.EQ.1) GO TO 500
      IF (NZ.EQ.35.OR.NZ.EQ.53)GO TO 460
      IF (NZ.EQ.37.OR.NZ.EQ.55)GO TO 470
C                                                                        00008650
C     CHEMICAL TREATMENT FOR OTHER CATIONS                               00008660
C                                                                        00008670
      CWCONC(I)=CWCONC(I)/DFCW                                           00008680
      DWCONC(I)=DWCONC(I)/DFDW                                           00008700
      RINV  (I)=RINV  (I)/DFRG
      GO TO 500
C                                                                        00008790
C     CHEMICAL TREATMENT FOR ANIONS                                      00008800
C                                                                        00008810
  460 CWCONC(I)=CWCONC(I)/DFICW
      DWCONC(I)=DWCONC(I)/DFIDW                                          00008840
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      RINV  (I)=RINV  (I)/DFIRG
      GO TO 500
C                                                                 00008910
C     CHEMICAL TREATMENT FOR RB AND CS                            00008920
C                                                                 00008930
  470 CWCONC(I)=CWCONC(I)/DFCSCW
      DWCONC(I)=DWCONC(I)/DFCSDW                                  00008960
      RINV  (I)=RINV  (I)/DFCSRG
  500 CONTINUE
C
      STS=SBTKSZ*0.8
      DTS=DWTKSZ*0.8
      CTS=CWTKSZ*0.8
      RTS=RGTKSZ*0.8
C                                                                 00009410
      IF(REGENT.LT.0.001)GO TO 503
      DO 502 I=1,ITOT
      CMCONC(I)=RINV(I)
  502 CONTINUE
  503 CONTINUE
      IF (K.EQ.2) GO TO 508
      CTKSZ=STS
      IF (TYPE.EQ.BWR) CTKSZ=CTS
      DO 507 I=1,ITOT
  507 TKCONC(I)=CWCONC(I)
      GO TO 512
  508 DAN=1.6
      IF(TYPE.EQ.BWR)GO TO 510
      CTKSZ=DTS
      DO 509 I=1,ITOT
  509 TKCONC(I)=DWCONC(I)
      GO TO 512
  510 KATH=4.7
      CTKSZ=RTS
      DO 511 I=1,ITOT
  511 TKCONC(I)=CMCONC(I)
  512 CONTINUE
      DO 540 I=1,ITOT
      NZ=NUCL(I)/10000                                            00009600
      IF(NZ.EQ.36.OR.NZ.EQ.54) GO TO 540
      DISI=DIS(I)*1.6283E13                                       00009620
      TKCONC(I)=TKCONC(I)*DISI
      IF (TKCONC(I).GT.0.0) GO TO 535
      PWCON(I)=0.0
      GO TO 540
  535 V=DIS(I)*HYTRTM*86400.
      IF (V.GT.75.) V=75.
      PWCON(I)=(TKCONC(I)/HYDF)*EXP(-V)
  540 CONTINUE
      DO 545 I=1,ITOT
  545 FRAC(I)=PWCON(I)/WMPC(I)
  550 SAPRIM=0.0
      STANK=0.0
      SCRECN=0.0
      SFRACT=0.0
      PAPRIM=0.0                                                  00010010
      PTANK=0.0
      PCRECN=0.0
      PFRACT=0.0
      MCH3=TKCONC(3)/FRAC(3)
```

```
      MQH3=MCH3*CTKSZ*3785./1.0E6
      IF (MQH3.GT.5000.) MQH3=5000.
      IF (TYPE.EQ.BWR) GO TO 553
      IF (K.EQ.1) PRINT 9076,REACTR,SBTANK,STS,HYTRTM,HYDF
      IF (K.EQ.2) PRINT 9076,REACTR,DWTANK,DTS,HYTRTM,HYDF
      GO TO 555
  553 CONTINUE
      IF (K.EQ.1) PRINT 9076,REACTR,CWTANK,CTS,HYTRTM,HYDF
      IF (K.EQ.2) PRINT 9076,REACTR,RGTANK,RTS,HYTRTM,HYDF
  555 CONTINUE
      PRINT 9077
      PRINT 9081
      KOUNTR=1                                                          00010170
      I1=ILITE+IACT+1                                                   00010180
      L=1                                                               00010190
      DO 580 I=1,ITOT
      IF (I.EQ.I1)PRINT 9082
      NZ=NUCL(I)/10000                                                  00010220
      IF (NZ.EQ.36.OR.NZ.EQ.54)GO TO 580
      DISI=DIS(I)*1.6283E+13                                            00010250
      APRIM=PCONC(I)*DISI                                               00010260
      WMPC1=WMPC(I)
      TANK=TKCONC(I)
      CRECN=PWCON(I)
      FRACT=FRAC(I)
      NUCLI=NUCL(I)                                                     00010350
      L=L+1
      IF(NZ.EQ.1) GO TO 560
      SAPRIM=SAPRIM+APRIM                                               00010470
      STANK=STANK+TANK
      SCRECN=SCRECN+CRECN
      SFRACT=SFRACT+FRACT
  560 IF (FRACT.LT.0.001) GO TO 580
      IF (MOD(KOUNTR,50).NE.0) GO TO 570
      PRINT 9084,    REACTR
      PRINT 9077
  570 CALL NGAH(NUCL(I),NAME)
      THALF=8.0225E-6/DIS(I)                                            00010650
      ISUB=2
      IF (TANK.GT.1.) ISUB=1
      DIV=10.**(INT(ALOG10(TANK))-ISUB)
      TANK1=AINT(TANK/DIV+0.5)*DIV
      ISUB=2
      IF (CRECN.GT.1.0) ISUB=1
      DIV=10.**(INT(ALOG10(CRECN))-ISUB)
      CRECN1=AINT(CRECN/DIV+0.5)*DIV
      ISUB=2
      IF (FRACT.GT.1.0) ISUB=1
      DIV=10.**(INT(ALOG10(FRACT))-ISUB)
      FRACT1=AINT(FRACT/DIV+0.5)*DIV
      ISUBT=1
      PRINT 9078,    NAME,THALF,APRIM,WMPC1,TANK1,CRECN1,FRACT1
      KOUNTR=KOUNTR+1                                                   00010700
      IF(NZ.EQ.1) GO TO 580
      PAPRIM=PAPRIM+APRIM                                               00010720
      PTANK=PTANK+TANK
      PCRECN=PCRECN+CRECN
      PFRACT=PFRACT+FRACT
  580 CONTINUE
      PAPRIM=SAPRIM-PAPRIM                                              00010830
```

```
      PTANK=STANK-PTANK
      PCRECN=SCRECN-PCRECN
      PFRACT=SFRACT-PFRACT
      MCCFP=STANK/SFRACT
      MQCFP=MCCFP*CTKSZ*3785./1.0E6
      IF (MQCFP.GT.15.) MQCFP=15.
      ISUBP=2
      IF (PTANK.GT.1.0) ISUBP=1
      DIV=10.**(INT(ALOG10(PTANK))-ISUBP)
      PTANK=AINT(PTANK/DIV+0.5)*DIV
      ISUBP=2
      IF (PCRECN.GT.1.0) ISUBP=1
      DIV=10.**(INT(ALOG10(PCRECN))-ISUBP)
      PCRECN=AINT(PCRECN/DIV+0.5)*DIV
      IF (PFRACT.EQ.0.0) GO TO 585
      ISUBP=2
      IF (PFRACT.GT.1.0) ISUBP=1
      DIV=10.**(INT(ALOG10(PFRACT))-ISUBP)
      PFRACT=AINT(PFRACT/DIV+0.5)*DIV
  585 ISUBS=1
      IF (STANK.LT.1.0) ISUBS=2
      DIV=10.**(INT(ALOG10(STANK))-ISUBS)
      STANK=AINT(STANK/DIV+0.5)*DIV
      ISUBS=1
      IF (SCRECN.LT.1.0) ISUBS=2
      DIV=10.**(INT(ALOG10(SCRECN))-ISUBS)
      SCRECN=AINT(SCRECN/DIV+0.5)*DIV
      ISUBS=1
      IF (SFRACT.LT.1.0) ISUBS=2
      DIV=10.**(INT(ALOG10(SFRACT))-ISUBS)
      SFRACT=AINT(SFRACT/DIV+0.5)*DIV
      PRINT 9070,   PAPRIM,PTANK,PCRECN,PFRACT
      PRINT 9080,   SAPRIM,STANK,SCRECN,SFRACT
      PRINT 9100,     MQH3,MQCFP
      IF(TYPE.EQ.BWR)GO TO 600
      IF(K.EQ.2.OR.DWTKSZ.EQ.0.0)GO TO 30
      GO TO 610
  600 CONTINUE
      IF(K.EQ.2.OR.RGTKSZ.EQ.0.0)GO TO 30
  610 K=K+1
      GO TO 503
C                                                                       00005630
C     FORMATS                      FORMATS                      FORMATS 00005640
C                                                                       00005650
 9010 FORMAT(32X,7A4,16X,A4)                                            00005760
 9011 FORMAT(16X,13A4,A3,F9.4)                                          00005770
 9012 FORMAT(16X,14A4,F8.4)                                             00005780
 9013 FORMAT(16X,6A4,1X,F8.0,7X,F5.3)
 9014 FORMAT(20X,F8.0,2(5X,F8.0))
 9016 FORMAT('0',70X,'TANK FACTORS'/34X,'FAILED TANK',13X,'VOLUME',6X,
     1      'I',9X,'CS',7X,'OTHERS')
 9022 FORMAT(16X,14A4,F8.4)                                             00005890
 9023 FORMAT(26X,6A4,14X,F9.0)
 9024 FORMAT(30X,6A4,3X,F9.0,2X,3(1PE9.2,1X))
 9025 FORMAT(16X,6A4,' GPD',28X,1PE8.2)
 9026 FORMAT(1H1)                                                       00006010
 9027 FORMAT(16X,'PLANT CAPACITY FACTOR',T75,'0.80')                    00006020
 9028 FORMAT(16X,'PERCENT FUEL WITH CLADDING DEFECTS',T75,F6.4)         00006030
 9030 FORMAT(16X,'FISSION PRODUCT CARRY-OVER FRACTION',T75,F6.4/16X,    00006060
     1'HALOGEN CARRY-OVER FRACTION',T75,F6.4)                           00006070
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 9045 FORMAT(/,15X,'FAILED TANK PARAMETERS')
 9052 FORMAT(16X,'OFF-GAS RELEASE RATE(UC/SEC)',28X,F8.0)
 9076 FORMAT (1H1,20X,7A4,' LIQUID TANK FAILURE'/1H ,21X,'NAME OF TANK F
     1AILED:    ',6A4/1H ,21X,'VOLUME OF TANK FAILED:  ',F9.0,' GAL. (80
     2% OF TANK CAPACITY)'/1H ,21X,'HYDROLOGICAL TRAVEL TIME (DAYS):
     3',F8.2/1H ,21X,'HYDROLOGICAL DILUTION FACTOR:    ',F8.0)
 9077 FORMAT (1H0,28X,'PRIMARY',22X,'FAILED',7X,'CRITICAL'/29X,'COOLANT'
     1,7X,'10CFR20',9X,'TANK',8X,'RECEPTOR',6X,'FRACTION'/4X,'NUCLIDE',
     24X,'HALF-LIFE',5X,'CONC.',9X,'LIMITS',10X,'CONC.',7X,'CONC.',9X,
     3'10CFR20'/15X,'(DAYS)',2X,4(6X,'(UCI/ML)'))
 9078 FORMAT (4X,A2,I3,A1,4X,1PE9.2,4(5X,1PE9.2),3X,0PF12.4)
 9079 FORMAT (4X,'ALL OTHERS',14X,1PE9.2,19X,1PE9.2,5X,1PE9.2,3X,0PF12.4
     1)
 9080 FORMAT (4X,'TOTAL'/4X,'EXCEPT TRITIUM',10X,1PE9.2,19X,1PE9.2,5X,1P
     1E9.2,3X,0PF12.4)
 9081 FORMAT (4X,'CORROSION AND ACTIVATION PRODUCTS')
 9082 FORMAT (1H0,4X,'FISSION PRODUCTS')
 9084 FORMAT (1H1,20X,7A4,' LIQUID TANK FAILURE (CONTINUED)')
 9085 FORMAT(16X,14A4,F8.2)
 9086 FORMAT (79X,I1)
 9090 FORMAT(16X,14A4,F8.0)
 9100 FORMAT (1H0,3X,'THE MAXIMUM QUANTITY OF TRITIUM IN THE TANK IS ',1
     1PE7.1,' CURIES.'/1H0,3X,'THE MAXIMUM QUANTITY OF CORROSION AND FIS
     2SION PRODUCTS (EXCLUDING TRITIUM) IN THE TANK IS ',1PE7.1,' CURIES
     3.')
      END                                                               00006230
      BLOCK DATA
      COMMON /CONB/BCONC(800)
      COMMON/CONP/PWCONC(800)
      DATA BCONC/2*0,0.01,33*0,
     1                    9E-3,13*0,2E-4,53*0,5E-3,4*0,6E-5,0.0,5E-2,3*0,
     11E-3,3*0,3E-5,0.0,2E-4,2*0,4E-4,7*0,1E-6,0.0,3E-4,2*0,3E-2,4*0,
     22E-4,3*0,2E-3,98*0,3E-4,64*0,7E-3,63*0,3E-3,4*0,5E-3,2*0,3E-3,
     319*0,5E-3,1E-4,3*0,6E-6,5*0,4E-3,0.0,4E-5,3*0,1E-2,6E-3,4*0,4E-3,
     411*0,7E-6,0.0,7E-6,6*0,5E-6,5*0,4E-3,2*0,2E-3,2E-2,8*0,9E-2,7*0,
     52E-5,3*0,8E-2,6*0,2E-3,4*0,3E-6,21*0,1E-6,104*0,4E-5,13*0,1E-4,
     60.0,5E-3,5*0,1E-5,3E-2,4*0,2E-2,5*0,7E-2,2*0,3E-5,2*0,2E-2,8*0,
     72E-5,3*0,7E-5,4*0,1E-2,4*0,1E-2,3*0,4E-4,4*0,1E-2,0.0,3E-5,3*0,
     86E-3,5E-3,7*0,3E-5,4E-5,2*0,3E-6,10*0,3E-6,81*0/
      DATA PWCONC/2*0,1.0,101*0,
     1                          1.9E-3,4*0,3.1E-4,5*0,1.6E-3,3*0,1E-3,0.0,.016,
     12*0,2E-3,185*0,1.2E-3,63*0,4.8E-3,4*0,2.6E-3,2*0,3E-4,6*0,8.5E-5,
     28*0,.2,4*0,3.5E-4,3*0,1E-5,0.0,1.2E-6,3*0,6.5E-4,3.6E-4,6.4E-5,9*000010680
     3,3.4E-5,11*0,6E-5,0.,5E-5,15*0,.084,.048,16*0,4.5E-5,4.5E-5,14*0, 00010690
     41E-5,0.0,1E-5,103*0,2.9E-5,8*0,2.8E-4,8.5E-4,10*0,1.4E-3,1.6E-3,
     58*0,2.1E-3,3*0,2.5E-3,1.1E-3,.27,5*0,.027,.1,4*0,.38,5*0,.047,2*0,
     6.025,2*0,.19,8*0,.013,3*0,.018,.016,12*0,2.2E-4,1.5E-4,5*0,7E-5,
     712*0,4E-5,5E-5,2*0,3.3E-5,3.3E-5,91*0/
      END
      SUBROUTINE SOLVE                                                  00010990
      COMMON/EQ/XZERO(800), XZH(800),XTEMP(800),XNEW(10,800),           00011000
     1      B(800),D(800)                                               00011010
      COMMON/FLEX/FLUX(10),MMN,MOUT,INDEX,QXN,AXN,ERR,NOBLND,MZERO      00011020
      COMMON/PROCSS/  MPROS,PRATE(8),NOPROS(8),NZPROS(8,20),PR(800)     00011030
      COMMON/FLUXN/T(20),POWER(10),TOCAP(800),FISS(100),DIS(800),ILITE, 00011040
     1 IACT,IFP,ITOT,NON,INPT                                           00011050
      COMMON/OUT/NUCL(800),TITLE(20),Q(800),FG(800),CUTOFF(7),          00011060
     1 POW,BURNUP,FLUXB,MSTAR,ALPHAN(100),SPONF(100),ABUND(500),        00011070
     2 BASIS(10),TCONST,TUNIT                                           00011080
      DO 10 I=1,ITOT                                                    00011090
```

```
      D(I)=-DIS(I)
   10 XTEMP(I)=0.0
      DELT=T(1)*TCONST
      CALL DECAY(1,DELT,ITOT)
      CALL TERM(DELT,1,ILITE,ITOT)
      CALL EQUIL(1,ITOT)
      DO 30 I=1,ITOT
 30   XTEMP(I)=XNEW(1,I)
      RETURN
      END
      SUBROUTINE TERM(T,M,ILITE,ITOT)
C
C     TERM ADDS ONE TERM TO EACH ELEMENT OF THE SOLUTION VECTOR
C     CSUM(J) IS THE CURRENT APPROXIMATION TO XNEW(M,J)
C     CIMO(J) IS THE VECTOR CONTAINING THE LAST TERM ADDED TO EACH
C     ELEMENT OF CSUM(J)
C     CIMN(J) IS THE VECTOR CONTAINING 1/TON TIMES THE NEW TERM TO BE
C     ADDED TO  CSUM(J)
C     CIMN(J) IS GENERATED FROM CIMO(J) BY A RECURSION RELATION:
C           CIMN(J)= SUM OVER L OF (AP(J,L)*CIMO(L))
C     AP(I,J) IS THE REDUCED TRANSITION MATRIX FOR THE LONG-LIVED
C     NUCLIDES
C
      LOGICAL*1 LONG
      INTEGER*2 LOC,NONO,KD
      INTEGER*2 LOCP(2500)
      INTEGER*2 NONP(800)
      INTEGER*2 NQ,NQU,NQUEUE
      REAL*8 BATE,BATM
      REAL*8 CIMN(800),CSUM(800),CIMNI
      DIMENSION AP(2500),CIMB(800),CIMO(800)
      DIMENSION QUB(50)
      COMMON/SERIES/ XP(800),XPAR(800),LONG(800)
      COMMON/FLEX/FLUX(10),MMN,MOUT,INDEX,QXN,AXN,ERR,NOBLND,MZERO
      COMMON/EQ/XZERO(800),XZH(800),XTEMP(800),XNEW(10,800),
     1      B(800),D(800)
      COMMON/MATRIX/A(2500),LOC(2500),NONO(800),KD(800)
      COMMON/DEBUGG/AP
      COMMON/TERMD/DD(100),DXP(100),QUEUE(50),NQU(50),NQUEUE(50),NQ(800)
      NUL=0
      NN=0
C     FIRST CONSTRUCT REDUCED TRANSITION MATRIX FOR LONG-LIVED ISOTOPES
      DO 220 L=1,ITOT
      IF(.NOT.LONG(L)) GO TO 210
      NUM=NONO(L)
      IF(M.GT.MMN.OR.M.EQ.MZERO)  NUM=KD(L)
      CIMB(L)=B(L)
      IF(NUM.LE.NUL) GO TO 210
      NS=NN+1
      N=NUL
      NL=NUM-NUL
      DO 200 N1=1,NL
      N=N+1
      J=LOC(N)
      DJ=-D(J)
C
C      THIS IS A TEST TO SEE IF ONE OF THE ASSYMPTOTIC SOLUTIONS APPLIES
C
      IF(.NOT.LONG(J)) GO TO 10
      NN=NN+1
```

```
      AP(NN)=A(N)
      LOCP(NN)=J
      GO TO 200
C
C     GOING BACK UP THE CHAIN TO FIND A PARENT WHICH IS NOT IN
C     EQUILIBRIUM
C
   10 NSAVE=0
      QUE=A(N)/DJ
      DRB=1.0
      CIMB(L)=CIMB(L)+QUE*B(J)
      NQ(L)=0
      NQ(J)=L
   20 NUX=NONO(J)
      IF(M.GT.MMN.OR.M.EQ.MZERO)  NUX=KD(J)
      NUF=0
      IF(J.GT.1)  NUF=NONO(J-1)
      NX=NUX-NUF
      IF(NX.LT.1)  GO TO 190
      K=NUF
      DO 180 KK=1,NX
      K=K +1
      J1=LOC(K)
      DJ=-D(J1)
      KP=J
   30 IF(J1.EQ.NQ(KP))  GO TO 180
      KP=NQ(KP)
      IF(KP.NE.0)  GO TO 30
      AKDJQ=QUE*A(K)/DJ
      IF(.NOT.LONG(J1)) GO TO 160
      TRM=1.0-XP(J1)
      IF(TRM.LT.1.0E-6) GO TO 120
      NQ(J1)=J
      I=1
      KP=J1
   40 DD(I)=-D(KP)
      DXP(I)=XP(KP)
      KP=NQ(KP)
      IF(KP.EQ.0) GO TO 50
      I=I+1
      IF(I.LE.100) GO TO 40
C     IF QUEUE OF SHORT-LIVED NUCLIDES EXCEEDS 100 ISOTOPES, TERMINATE
C     CHAIN AND WRITE MESSAGE
      PRINT 9000,    M,L,J1,J,AKDJQ
 9000 FORMAT('1TOO LONG A QUEUE HAS BEEN FORMED IN TERM',4I5,E12.5)
      GO TO 190
   50 BATM=0.D0
      IM=I-1
      DO 110 I=2,IM
      DL=DD(I)
      XPL=DXP(I)
      BATE=0.D0
      I1=I-1
C     D R VONDY FORM OF BATEMAN EQUATIONS -- ORNL-TM-361
      DO 100 KB=1,I1
      XPJ=DXP(KB)
      IF(XPL+XPJ.LT.ERR) GO TO 100
      DK=DD(KB)
      PROD=(DL/DK-1.0)
      DKR=PROD
```

```
      IF( ABS(PROD).GT.1.E-4) GO TO 60                                  00012300
C     USE THIS FORM FOR TWO NEARLY EQUAL HALF-LIVES                     00012310
      PROD=T*DK*XPJ*(1.0-0.5*(DL-DJ)*T)                                 00012320
      GO TO 70                                                          00012330
   60 PROD=(XPJ-XPL)/PROD                                               00012340
      PRO1=XPJ/DKR                                                      00012350
   70 PI=1.0                                                            00012360
      S1=2./(DK*T)                                                      00012370
      DO 90 JK=1,I1                                                     00012380
      IF(JK.EQ.KB) GO TO 90                                             00012390
      S=1.0-DK/DD(JK)                                                   00012400
      IF( ABS(S).GT.1.E-4) GO TO 80                                     00012410
      IF(ABS(DKR).GT.1.0E-4)  PROD=PRO1                                 00012420
      S=S1                                                              00012430
   80 PI=PI*S                                                           00012440
      IF(ABS(PI).GT.1.E25)  GO TO 100                                   00012450
   90 CONTINUE                                                          00012460
      BATE=BATE+PROD/PI                                                 00012470
  100 CONTINUE                                                          00012480
C     IF SUMMATION IS NEGATIVE, SET EQUAL TO ZERO AND PRINT MESSAGE     00012490
      IF(BATE.LT.0.D0)  PRINT 9001,      L,IM,BATE,BATM                 00012500
 9001 FORMAT('1BATE IS NEGATIVE IN TERM. THERE ARE MORE THAN TWO SHORT-L00012510
     1IVED NUCLIDES IN A CHAIN WITH NEARLY EQUAL DIAGONAL ELEMENTS'/    00012520
     2' L,IM,BATE,BATM = ',2I5,1P2E12.5)                                00012530
      IF(BATE.LT.0.D0)  BATE=0.D0                                       00012540
      BATM=BATM+BATE                                                    00012550
  110 CONTINUE                                                          00012560
      DRA=AKDJQ*DJ*(TRM-BATM)/TRM                                       00012570
      GO TO 130                                                         00012580
  120 DRA=AKDJQ*AMAX1(DRB,0.0)*DJ                                       00012590
  130 IF(NS.GT.NN) GO TO 150                                            00012600
      DO 140 LJ=NS,NN                                                   00012610
      IF(LOCP(LJ).NE.J1)  GO TO 140                                     00012620
      AP(LJ)=AP(LJ)+DRA                                                 00012630
      GO TO 180                                                         00012640
  140 CONTINUE                                                          00012650
  150 NN=NN+1                                                           00012660
      AP(NN)=DRA                                                        00012670
      LOCP(NN)=J1                                                       00012680
      GO TO 180                                                         00012690
  160 IF(AKDJQ.LE.1.0E-06)  GO TO 180                                   00012700
      IF(NSAVE.GE.50) GO TO 180                                         00012710
  170 NSAVE=NSAVE+1                                                     00012720
      NQUEUE(NSAVE)=J1                                                  00012730
      QUEUE(NSAVE)=AKDJQ                                                00012740
      NQU(NSAVE)=J                                                      00012750
      QUB(NSAVE)=DRB-1./(DJ*T)                                          00012760
  180 CONTINUE                                                          00012770
  190 IF(NSAVE.LE.0) GO TO 200                                          00012780
      J=NQUEUE(NSAVE)                                                   00012790
      QUE=QUEUE(NSAVE)                                                  00012800
      NQ(J)=NQU(NSAVE)                                                  00012810
      DRB=QUB(NSAVE)                                                    00012820
      CIMB(L)=CIMB(L)+QUE*B(J)*AMAX1(DRB,0.0)                           00012830
      NSAVE=NSAVE-1                                                     00012840
      GO TO 20                                                          00012850
  200 CONTINUE                                                          00012860
  210 NUL=NONO(L)                                                       00012870
      NONP(L)=NN                                                        00012880
  220 CONTINUE                                                          00012890
```

```
C     FIND NORM OF MATRIX AND ESTIMATE ERROR AS DESCRIBED IN LAPIDUS
C     AND LUUS, OPTIMAL CONTROL OF ENGINEERING PROCESSES BLAISDELL 1967
C     FIND THE MINIMUM OF THE MAXIMUM ROW SUM AND THE MAXIMUM COLUMN SUM
      ASUM =0.0
      ASUMJ=0.0
      NUL=1
      DO 250 I=1,ITOT
      IF(.NOT.LONG(I)) GO TO 250
      DI=-D(I)*T
      AJ=DI
      NUM=NONP(I)
      IF(NUL.GT.NUM) GO TO 240
      DO 230 N=NUL,NUM
  230 AJ=AJ+AP(N)
  240 AI=DI+DI
      IF(AI.GT.ASUM )  ASUM =AI
      IF(AJ.GT.ASUMJ)  ASUMJ=AJ
  250 NUL=NONP(I)+1
      IF(ASUMJ.LT.ASUM)  ASUM=ASUMJ
C     USE ASUM TO DECIDE HOW MANY TERMS ARE REQUIRED AND ESTIMATE ERROR
      NLARGE=3.5*ASUM +5.
      XLARGE=NLARGE
      ERR1=EXP(ASUM )*(ASUM *2.71828/XLARGE)**NLARGE/SQRT(6.2832*XLARGE)
      IF(ERR1.GT.1.E-3)  PRINT 9002,     ERR1,ASUM ,NLARGE
 9002 FORMAT('OMAXIMUM ERROR GT 0.001, ='F10.6,', TRACE = 'F10.4,
     1  ' NLARGE = 'I6)
C     NEXT GENERATE MATRIX EXPONENTIAL SOLUTION
      DO 260 I=1,ITOT
      CSUM(I)=XTEMP(I)
      CIMN(I)=XTEMP(I)
  260 CONTINUE
      ERR3=0.001*EPR
      DO 310 NT=1,NLARGE
      DO 270 I=1,ITOT
      CIMO(I)=CIMN(I)
  270 CONTINUE
      TON=T/NT
      NUL=1
      DO 300 I=1,ITOT
      IF(.NOT.LONG(I)) GO TO 300
      NUM=NONP(I)
      CIMNI=0.0
      IF(NT.EQ.1) CIMNI=CIM3(I)
      IF(NUL.GT.NUM) GO TO 290
      DO 280 N=NUL,NUM
      J=LOCP(N)
  280 CIMNI=CIMNI+AP(N)*CIMO(J)
  290 CIMNI=CIMNI+D(I)*CIMO(I)
      CIMNI=TON*CIMNI
      IF(DABS(CIMNI).LT.ERR3)  CIMNI=0.D0
      CIMN(I)=CIMNI
      CSUM(I)=CSUM(I)+CIMNI
  300 NUL=NONP(I)+1
  310 CONTINUE
      DO 320 I=1,ITOT
      IF(CSUM(I).LT.ERR)  CSUM(I)=0.0
      IF(LONG(I)) XNEW(M,I)=CSUM(I)
  320 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE DECAY(M,T,ITOT)                                        00013500
C     DECAY TREATS SHORT-LIVED ISOTOPES AT BEGINNING OF CHAINS USING    00013510
C     BATEMAN EQUATIONS                                                 00013520
      LOGICAL*1 LONG                                                    00013530
      REAL*8 BATE                                                       00013540
      INTEGER*2 LOC,NONO,KD                                             00013550
      INTEGER*2 NQ,NQU,NQUEUE                                           00013560
      COMMON/DEBUGG/AP(2500)                                            00013570
      COMMON/SERIES/ XP(800),XPAR(800),LONG(800)                        00013580
      COMMON/FLEX/FLUX(10),MMN,MOUT,INDEX,QXN,AXN,ERR,NOBLND,MZERO      00013590
      COMMON/EQ/XZERO(800),XZH(800),XTEMP(800),XNEW(10,800),            00013600
     1      B(800),D(800)                                               00013610
      COMMON/MATRIX/A(2500),LOC(2500),NONO(800),KD(800)                 00013620
      COMMON/TERMD/DD(100),DXP(100),QUEUE(50),NQU(50),NQUEUE(50),NQ(800)00013630
      DO 10 I=1,ITOT                                                    00013640
      XPAR(I)=0.0                                                       00013650
      LONG(I)=.FALSE.                                                   00013660
      XPI=0.0                                                           00013670
      DT=D(I)*T                                                         00013680
      IF(DT.LT.-50.)  GO TO 10                                          00013690
      IF(ABS(DT).LE.AXN)  LONG(I)=.TRUE.                                00013700
      XPI=EXP(DT)                                                       00013710
   10 XP(I)=XPI                                                         00013720
      NUL=1                                                             00013730
      DO 160 L=1,ITOT                                                   00013740
      XTEM=0.0                                                          00013750
      DL=-D(L)                                                          00013760
      NUM=NONO(L)                                                       00013770
      IF(M.GT.MMN.OR.M.EQ.MZERO)  NUM=KD(L)                             00013780
      IF(NUM.LT.NUL) GO TO 150                                          00013790
      DO 140 N=NUL,NUM                                                  00013800
      J=LOC(N)                                                          00013810
      DJ=-D(J)                                                          00013820
      IF(LONG(J)) GO TO 140                                             00013830
C     USE THIS FORM FOR TWO NEARLY EQUAL HALF-LIVES                     00013840
      IF(ABS(DL/DJ-1.0).LE.1.0E-5)  XTEM=XTEM+XTEMP(J)*A(N)*XP(J)*T     00013850
      IF(ABS(DL/DJ-1.0).GT.1.0E-5)                                      00013860
     1                 XTEM=XTEM+XTEMP(J)*A(N)*(XP(J)-XP(L))/(DL-DJ)    00013870
     QUE=A(N)/DJ                                                        00013880
     NQ(L)=0                                                            00013890
     NQ(J)=L                                                            00013900
     NSAVE=0                                                            00013910
  20 NUX=NONO(J)                                                        00013920
     IF(M.GT.MMN.OR.M.EQ.MZERO)  NUX=KD(J)                              00013930
     NUF=1                                                              00013940
     IF(J.GT.1)  NUF=NONO(J-1)+1                                        00013950
     IF(NUF.GT.NUX)  GO TO 130                                          00013960
     DO 120 K=NUF,NUX                                                   00013970
     J1=LOC(K)                                                          00013980
     IF(LONG(J1)) GO TO 120                                             00013990
     KP=J                                                               00014000
  30 IF(J1.EQ.NQ(KP))  GO TO 120                                        00014010
     KP=NQ(KP)                                                          00014020
     IF(KP.NE.0)  GO TO 30                                              00014030
     DJ=-D(J1)                                                          00014040
     AKDJQ=A(K)/DJ*QUE                                                  00014050
     IF(AKDJQ.LE.1.0E-06)  GO TO 120                                    00014060
     NQ(J1)=J                                                           00014070
     I=1                                                                00014080
     KP=J1                                                              00014090
```

```
   40 DD(I)=-D(KP)
      DXP(I)=XP(KP)
      KP=NQ(KP)
      IF(KP.EQ.0) GO TO 50
      I=I+1
      IF(I.LE.100) GO TO 40
      PRINT 9000,    M,L,J1,J,AKDJQ
 9000 FORMAT('1',4I5,E12.5)
      GO TO 130
   50 BATE=0.D0
      I1=I-1
      XPL=XP(L)
C     D R VONDY FORM OF BATEMAN EQUATIONS -- ORNL-TM-361
      DO 100 KB=1,I1
      XPJ=DXP(KB)
      IF(XPL+XPJ.LT.ERR) GO TO 100
      DK=DD(KB)
      PROD=(DL/DK-1.0)
      DKR=PROD
      IF( ABS(PROD).GT.1.E-4) GO TO 60
      PROD=T*DK*XPJ*(1.0-0.5*(DL-DJ)*T)
      GO TO 70
   60 PROD=(XPJ-XPL)/PROD
      PRO1=XPJ/DKR
   70 PI=1.0
      S1=2./(DK*T)
      DO 90 JK=1,I1
      IF(JK.EQ.KB) GO TO 90
      S=1.0-DK/DD(JK)
      IF( ABS(S).GT.1.E-4) GO TO 80
C     USE THIS FORM FOR TWO NEARLY EQUAL HALF-LIVES
      IF(ABS(DKR).GT.1.0E-4)  PROD=PRO1
      S=S1
   80 PI=PI*S
      IF(ABS(PI).GT.1.E25)  GO TO 100
   90 CONTINUE
      BATE=BATE+PROD/PI
  100 CONTINUE
      IF(BATE.LT.0.D0)  PRINT 9001,     L,I,BATE,XTEM,XTEMP(J1),AKDJQ
 9001 FORMAT(' L,I,BATE,XTEM,XTEMP(J1),AKDJQ = ',2I5,1P4E12.5)
      IF(BATE.LT.0.D0)  BATE=0.D0
      XTEM=XTEM+XTEMP(J1)*AKDJQ*BATE
      IF(NSAVE.GE.50) GO TO 120
  110 NSAVE=NSAVE+1
      NQUEUE(NSAVE)=J1
      QUEUE(NSAVE)=AKDJQ
      NQU(NSAVE)=J
  120 CONTINUE
  130 IF(NSAVE.LE.0) GO TO 140
      J=NQUEUE(NSAVE)
      QUE=QUEUE(NSAVE)
      NQ(J)=NQU(NSAVE)
      NSAVE=NSAVE-1
      GO TO 20
  140 CONTINUE
      IF(LONG(L)) XPAR(L)=XTEM/XP(L)
  150 NUL=NONO(L)+1
      IF(.NOT.LONG(L)) XNEW(M,L)=XTEM+XTEMP(L)*XP(L)
  160 CONTINUE
      DO 170 I=1,ITOT
```

```
      IF(LONG(I)) XTEMP(I)=XTEMP(I)+XPAR(I)
      IF(.NOT.LONG(I)) XTEMP(I)=0.0
  170 CONTINUE
      RETURN
      END
      SUBROUTINE EQUIL(M,ITOT)
C
C     EQUIL PUTS SHORT-LIVED DAUGHTERS IN EQUILIBRIUM WITH PARENTS
C      EQUIL USES GAUSS-SEIDEL ITERATION TO GENERATE STEADY STATE
C     CONCENTRATIONS
C
      LOGICAL*1 LONG
      INTEGER*2 LOC,NONO,KD
      COMMON/EQ/XZERO(800),XZH(800),XTEMP(800),XNEW(10,800),
     1      B(800),D(800)
      COMMON/MATRIX/A(2500),LOC(2500),NONO(800),KD(800)
      COMMON/FLEX/FLUX(10),MMN,MOUT,INDEX,QXN,AXN,ERR,NOBLND,MZERO
      COMMON/SERIES/ XP(800),XPAR(800),LONG(800)
      DO 10 I=1,ITOT
      XPAR(I)=0.0
      IF(.NOT.LONG(I)) GO TO 10
      XTEMP(I)=XTEMP(I)*XP(I)
      XPAR(I)=AMAX1(XNEW(M,I)-XTEMP(I),0.0)
   10 CONTINUE
      ITER=1
   20 N=0
      BIG=0.0
      DO 60 I=1,ITOT
      NUM=NONO(I)-N
      DI=-D(I)
      IF(LONG(I)) GO TO 50
      XNW=B(I)
      IF(M.GT.MMN.OR.M.EQ.MZERO)  NUM=KD(I)-N
      IF(NUM.EQ.0)  GO TO 31
      DO 30 K=1,NUM
      N=N+1
      J=LOC(N)
      DJ=-D(J)
      XJ=XPAR(J)
      IF(LONG(J)) XJ=XJ+XTEMP(J)/(1.0-DJ/DI)
      XNW=XNW+A(N)*XJ
   30 CONTINUE
   31 XNW=XNW/DI
      IF(XNW.LT.1.0E-50)  GO TO 40
      ARG=ABS((XNW-XPAR(I))/XNW)
      IF(ARG.GT.BIG)  BIG=ARG
   40 XPAR(I)=XNW
   50 N=NONO(I)
   60 CONTINUE
      IF(BIG.LT.QXN  )   GOTO 70
      ITER=ITER+1
      IF(ITER.LT.100)  GO TO 20
      PRINT 9000
      STOP
   70 DO 80 I=1,ITOT
      IF(.NOT.LONG(I)) XNEW(M,I)=XNEW(M,I)+XPAR(I)
   80 CONTINUE
      RETURN
 9000 FORMAT(' GAUSS SEIDEL ITERATION DID NOT CONVERGE IN EQUIL')
      END
```

```
      SUBROUTINE NUDATA(NLIBE)                                          00015300
C     NUDATA VERSION TO HANDLE THREE TYPES OF NUCLEAR DATA LIBRARIES    00015310
C     HAS POINTER, NLIBE, = 1 FOR HTGR                                  00015320
C                         = 2 FOR LIGHT WATER REACTOR                   00015330
C                         = 3 FOR LMFBR                                 00015340
C                         = 4 FOR MSBR                                  00015350
      INTEGER*2 LOC,NONO,KD                                             00015360
      INTEGER*2 ELF(99),STA(2)                                          00015370
      INTEGER*2 KAP(800),MMAX(800)                                      00015380
      INTEGER*2 NAME(3)                                                 00015390
      DIMENSION COEFF(7,800),NPROD(7,800),CAPT(6),                      00015400
     1 NUCAL(6),NSORS(5),              YIELD(5,500),TYLD(5)             00015410
      DIMENSION Y(5)                                                    00015420
      DIMENSION SKIP(20)                                                00015430
      DIMENSION MSRS(20)                                                00015440
      COMMON/LABEL/ELE,STA                                              00015450
      COMMON/FLEX/FLUX(10),MMN,MOUT,INDEX,QXN,AXN,ERR,NOBLND,MZERO      00015460
      COMMON/EQ/XZERO(800),XZH(800),XTEMP(800),XNEW(10,800),            00015470
     1      B(800),D(800)                                               00015480
      COMMON/MPC/MPCTAB,AMPC(800),WMPC(800)                             00015490
      COMMON/FLUXN/T(20),POWER(10),TOCAP(800),FISS(100),DIS(800),ILITE, 00015500
     1 IACT,IFP,ITOT,NON,INPT                                           00015510
      COMMON/CUT/NUCL(800),TITLE(20),Q(800),FG(800),CUTOFF(7),          00015520
     1 POW,BURNUP,FLUXB,MSTAR,ALPHAN(100),SPONF(100),ABUND(500),        00015530
     2 BASIS(10),TCONST,TUNIT                                           00015540
      COMMON/MATRIX/A(2500),LOC(2500),NONO(800),KD(800)                 00015550
      EQUIVALENCE (XZERO(1),KAP(1)),(XZERO(401),MMAX(1)),               00015560
     1            ( XZH(1),COEFF(1,1)),(XNEW(1,401),NPROD(1,1))         00015570
      EQUIVALENCE (A1,DLAM)                                             00015580
      DATA NUCAL/-20030,-10000,10,11,-10,-9/                            00015590
      DATA MSRS/922330,922350,902320,922380,942390,922330,922350,942410,00015600
     1          922380,942390,942410,922350,942400,922380,942390,922330,00015610
     2          922350,902320,922380,942390/                            00015620
C                                                                       00015630
C     PROGRAM TO COMPUTE A MATRIX (TRANSITION MATRIX) FROM NUCLEAR DATA 00015640
C                                                                       00015650
      READ 9011,              (TITLE(I),I=1,18),NLIBE                   00015660
C     IF(NLIBE.LT.0) PROGRAM WILL READ TAPE IN CASDAR FORMAT            00015670
      IGWC=0                                                            00015680
      IF(NLIBE.GT.0)  GO TO  10                                         00015690
      IGWC=1                                                            00015700
      NLIBE=-NLIBE                                                      00015710
      PRINT 9000                                                        00015720
 9000 FORMAT(1H0,'WILL READ TAPE GENERATED BY CASDAR')                  00015730
   10 NI=4-NLIBE                                                        00015740
   20 READ 9001,     THERM,RES,FAST,ERR,NMO,NDAY,NYR,MPCTAB,INPT,IR     00015750
      PRINT 9005,      NMO,NDAY,NYR                                     00015760
      PRINT 9006                                                        00015770
      PRINT 9007                                                        00015780
      PRINT 9008                                                        00015790
      PRINT 9009                                                        00015800
      PRINT 9010                                                        00015810
      PRINT 9013                                                        00015820
      PRINT 9014                                                        00015830
C                                                                       00015840
C     THERM = RATIO OF THERMAL FLUX TO TOTAL FLUX                       00015850
C     RES =  RATIO OF RESONANCE FLUX TO TOTAL FLUX                      00015860
C     FAST = RATIO OF FAST FLUX TO TOTAL FLUX                           00015870
C     ERR = TRUNCATION ERROR LIMIT                                      00015880
C                                                                       00015890
```

```
C     READ DATA FOR LIGHT ELEMENTS
C
      K=5*(NLIBE-1)
      DO 30 K1=1,5
      K2=K+K1
   30 NSORS(K1)=MSRS(K2)
      PRINT 9018,    THERM,RES,FAST,(NSORS(K),K=1,5),NLIBE
      I=0
      NUTAPE=0
   40 I=I+1
   50 READ(8,9034,END=260)NUCL(I),DLAM,IU,FB1,FP,FP1,FT,FA,FSF,
     1Q(I),FG(I),ABUND(I),WMPC(I),AMPC(I)
      IF(IGWC.GT.0)  GO TO 70
      DO 60 N=1,NLIBE
   60 READ(8,9035) SIGTH,FNG1,FNA,FNP,RITH,FINA,FINP,SIGMEV,FN2N1,FFNA,
     1             FFNP,IT
      GO TO 90
   70 DO 80 N=1,NLIBE
   80 READ(8,9040) SIGTH,FNG1,FNA,FNP,RITH,FINA,FINP,SIGMEV,FN2N1,FFNA,
     1             FFNP,IT
   90 IF(N1.EQ.0) GO TO 110
      DO 100 N=1,N1
  100 READ(8,9036)  SKIP
  110 IF(IT.EQ.0) GO TO 50
  120 M=0
      CALL HALF(A1,IU)
      NUCLI=NUCL(I)
      IF(NUCLI.EQ.0)  GO TO 260
      CALL NOAH(NUCLI,NAME)
      IF(MOD(I-1,50) .EQ. 0) PRINT 9012,    (TITLE (N),N=1,18)
      IF(MOD(I-1,50) .EQ. 0) PRINT 9016
      SIGTH=THERM*SIGTH
      RITH=RES*RITH
      SIGMEV=FAST*SIGMEV
      SIGNA=SIGTH*FNA+RITH*FINA+SIGMEV*FFNA
      SIGNP=SIGTH*FNP+RITH*FINP+SIGMEV*FFNP
      FNG=1.0-FNA-FNP
      IF(FNG.LT.1.0E-4)FNG=0.
      FING=1.0-FINA-FINP
      IF(FING.LT.1.0E-4)FING=0.
      FN2N=1.0-FFNA-FFNP
      IF(FN2N.LT.1.0E-4)FN2N=0.
      SIGNG=SIGTH*FNG+RITH*FING
      SIGN2N=SIGMEV*FN2N
  130 PRINT 9033,     NAME,                DLAM,FB1,FP,FP1,FT,FA,SIGNG,
     1                FNG1,SIGN2N,FN2N1,SIGNA,SIGNP,Q(I),FG(I),ABUND(I)
C     TEST RADIOACTIVITY
C
  140 IF(A1.LE.ERR)  GO TO 180
      ABETA=1.0
C
C     TEST POSITRON EMISSION
C
      IF(FP .LT. ERR) GO TO 150
      M=M+1
      COEFF(M,I)=FP*A1
      NPROD(M,I)=NUCLI-10000
      ABETA=ABETA-FP
C
C     TEST POSITRON EMISSION TO EXCITED STATE OF PRODUCT NUCLIDE
```

```
C
      IF(FP1 .LT. ERR) GO TO 150
      M=M+1
      COEFF(M,I)=FP1*COEFF(M-1,I)
      NPROD(M,I)=NPROD(M-1,I)+1
      COEFF(M-1,I)=COEFF(M-1,I)-COEFF(M,I)
C
C     TEST ISOMERIC TRANSITION
C
  150 IF(FT .LT.ERR) GO TO 160
      M=M+1
      COEFF(M,I)=FT*A1
      NPROD(M,I)=NUCLI
      ABETA=ABETA-FT
C
C     TEST ALPHA EMISSION
C
  160 IF(FA .LT. ERR) GO TO 170
      M=M+1
      COEFF(M,I)=FA*A1
      NPROD(M,I)=NUCLI-20040
      M=M+1
      COEFF(M,I)=COEFF(M-1,I)
      NPROD(M,I)=20040
      ABETA=ABETA-FA
C
C     TEST NEGATRON EMISSION
C
  170 IF(ABETA.LT.1.E-4) GO TO 180
      M=M+1
      COEFF(M,I)=ABETA*A1
      NPROD(M,I)=NUCLI+10000
C
C     TEST NEGATRON EMISSION TO EXCITED STATE OF PRODUCT NUCLIDE
C
      IF(FB1 .LT. ERR)GO TO 180
      M=M+1
      COEFF(M,I)=FB1*COEFF(M-1,I)
      NPROD(M,I)=NPROD(M-1,I)+1
      COEFF(M-1,I)=COEFF(M-1,I)-COEFF(M,I)
C
C     COMPUTE NEUTRON CAPTURE CROSS SECTIONS IN THREE REGIONS
C
  180 KAP(I)=M
      DO 190 KI=1,6
  190 CAPT(KI) =0.0
      CAPT(1)=SIGNA
      CAPT(2)=SIGNP
      CAPT(4)=SIGNG*FNG1
      CAPT(3)=SIGNG-CAPT(4)
      CAPT(6)=SIGN2N*FN2N1
      CAPT(5)=SIGN2N-CAPT(6)
  200 TOCAP(I)=0.0
C     TOTAL NEUTRON CROSS SECTION FOR NUCLIDE(I)
      DO 220 K=1,6
      CAPKI=CAPT(K)
      IF(CAPKI.LT.ERR)  GO TO 220
      M=M+1
      NPROD(M,I)=NUCLI+NUCAL(K)
      COEFF(M,I)=CAPKI
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      TOCAP(I)=TOCAP(I)+CAPKI                                           00017100
      IF(K.NE.1) GO TO 210                                              00017110
      M=M+1                                                             00017120
      COEFF(M,I)=COEFF(M-1,I)                                           00017130
      NPROD(M,I)=20040                                                  00017140
  210 IF(K.NE.2) GO TO 220                                              00017150
      M=M+1                                                             00017160
      COEFF(M,I)=COEFF(M-1,I)                                           00017170
      NPROD(M,I)=10010                                                  00017180
  220 CONTINUE                                                          00017190
  230 IF(MOD(NUCLI,  10).EQ.0) GO TO 250                                00017200
      DO 240 K=1,M                                                      00017210
  240 NPROD(K,I)=NPROD(K,I)-1                                           00017220
  250 MMAX(I) =M                                                        00017230
      IF(M.GT.7)  PRINT 9039, M                                         00017240
      DIS(I)=A1                                                         00017250
      GO TO 40                                                          00017260
  260 ILITE = I-1                                                       00017270
      IACT=0                                                            00017280
C                                                                       00017290
C     READ DATA ON ACTINIDES                                            00017300
C                                                                       00017310
  270 READ(8,9034,END=450)NUCL(I),DLAM,IU,FB1,FP,FP1,FT,FA,FSF,         00017320
     1Q(I),FG(I),DUMMY,WMPC(I),AMPC(I)                                  00017330
      DO 280 N=1,NLIBE                                                  00017340
      READ(8,9037) SIGNG,RING,FNG1,SIGF,RIF,SIGFF,SIGN2N,FN2N1,SIGN3N,IT00017350
  280 CONTINUE                                                          00017360
      IF(N1.EQ.0) GO TO 300                                             00017370
      DO 290 N=1,N1                                                     00017380
  290 READ(8,9036)  SKIP                                                00017390
  300 IF(IT .EQ. 0) GO TO 270                                           00017400
  310 M=0                                                               00017410
      NUCLI=NUCL(I)                                                     00017420
      IF(NUCLI.EQ.0)  GO TO 450                                         00017430
      DO 320 K=1,5                                                      00017440
      IF(NUCLI.EQ.NSORS(K))  NSORS(K)=I                                 00017450
  320 CONTINUE                                                          00017460
      CALL HALF(A1,IU)                                                  00017470
      CALL NOAH(NUCLI,NAME)                                             00017480
      SIGNG=THERM*SIGNG+RES*RING                                        00017490
      SIGF =THERM*SIGF +RES*RIF +FAST*SIGFF                             00017500
      SIGN2N=SIGN2N*FAST                                                00017510
      SIGN3N=SIGN3N*FAST                                                00017520
      IF(MOD(IACT,50).EQ.0)  PRINT 9012,    (TITLE (N),N=1,18)          00017530
  330 IF(MOD(IACT,50).EQ.0) PRINT 9024                                  00017540
      PRINT 9026,     NAME,             DLAM,FB1,FP,FP1,FT,FA,FSF,SIGNG,00017550
     1                FNG1,SIGF,SIGN2N,SIGN3N,Q(I),FG(I)                00017560
  340 IACT=IACT+1                                                       00017570
C                                                                       00017580
C     TEST RADIOACTIVITY                                                00017590
C                                                                       00017600
      IF(A1.LT.ERR)  GO TO 380                                          00017610
      ABETA=1.0                                                         00017620
C     TEST POSITRON EMISSION                                            00017630
      IF(FP .LT. ERR) GO TO 350                                         00017640
      ABETA=ABETA-FP                                                    00017650
      M=M+1                                                             00017660
      COEFF(M,I)=FP*A1                                                  00017670
      NPROD(M,I)=NUCLI-10000                                            00017680
C     POSITRON EMISSION TO EXCITED STATE                                00017690
```

```
      IF(FP1 .LT. ERR)GO TO 350
      M=M+1
      COEFF(M,I)=FP1*COEFF(M-1,I)
      NPROD(M,I)=NPROD(M-1,I)+1
      COEFF(M-1,I)=COEFF(M-1,I)-COEFF(M,I)
C     ISOMERIC TRANSITION
 350  IF(FT .LT.ERR)GO TO 360
      M=M+1
      COEFF(M,I)=FT*A1
      NPROD(M,I)=NUCLI
      ABETA=ABETA-FT
C     ALPHA EMISSION
 360  IF(FA .LT.ERR)GO TO 370
      M=M+1
      COEFF(M,I)=FA*A1
      NPROD(M,I)=NUCLI-20040
      M=M+1
      COEFF(M,I)=COEFF(M-1,I)
      NPROD(M,I)=20040
      ABETA=ABETA-FA
C     BETA DECAY
 370  IF(ABETA.LT.1.E-4) GO TO 380
      M=M+1
      COEFF(M,I)=ABETA*A1
      NPROD(M,I)=NUCLI+10000
      IF(FB1 .LT. ERR)GO TO 380
      M=M+1
      COEFF(M,I)=COEFF(M-1,I)*FB1
      COEFF(M-1,I)=COEFF(M-1,I)-COEFF(M,I)
      NPROD(M,I)=NPROD(M-1,I)+1
C
C     NEUTRON CAPTURE CROSS SECTIONS
C
 380  KAP(I)=M
      DO 390 K=1,6
 390  CAPT(K  )=0.0
      CAPT(2)=SIGNG*FNG1
      CAPT(1)=SIGNG-CAPT(2)
      CAPT(4)=SIGN2N*FN2N1
      CAPT(3)=SIGN2N-CAPT(4)
 400  FISS(IACT)=SIGF
      TOCAP(I)=0.0
      DO 410 K=1,4
      CAPKI=CAPT(K)
      IF(CAPKI.LT.ERR)  GO TO 410
      M=M+1
      TOCAP(I)=TOCAP(I)+CAPKI
      COEFF(M,I)=CAPKI
      NPROD(M,I)=NUCLI+NUCAL(K+2)
 410  CONTINUE
      TOCAP(I)=TOCAP(I)+FISS(IACT)
C     N-3N CROSS SECTION
      A17=SIGN3N
      IF(A17.LT.ERR) GO TO 420
      M=M+1
      COEFF(M  ,I)= A17
      NPROD(M  ,I)= NUCLI-20
      TOCAP(I)=TOCAP(I)+A17
 420  IF(MOD(NUCLI,10).EQ.0) GO TO 440
      DO 430 K=1,M
```

```
  430 NPROD(K,I)=NPROD(K,I)-1
  440 MMAX(I)=M
      IF(M.GT.7)  PRINT 9039, M
      SPONF(IACT)=FSF*A1*6.023E23
      ALPHAN(IACT)=FA*A1*6.023E13*Q(I)**3.65
      DIS(I)=A1
      I=I+1
      GO TO 270
  450 IL=0
      DO 460 K=1,5
  460 TYLD(K)=0.0
C
C     READ DATA FOR FISSION PRODUCTS
C
  470 READ(8,9034,END=690)NUCL(I),DLAM,IU,FB1,FP,FP1,FT,FA,FSF,
     1Q(I),FG(I),DUMMY,WMPC(I),AMPC(I)
      DO 480 N=1,NLIBE
  480 READ(8,9038) SIGNG,RING,FNG1,Y,IT
      IF(N1.EQ.0) GO TO 500
      DO 490 N=1,N1
  490 READ(8,9036)  SKIP
  500 IF(IT .EQ. 0) GO TO 470
  510 M=0
      CALL HALF(A1,IU)
  520 NUCLI=NUCL(I)
      IF(NUCLI.EQ.0) GO TO 690
      CALL NOAH(NUCLI,NAME)
      IF(MOD(IL,50).EQ. 0)   PRINT 9012,    (TITLE (N),N=1,18)
      SIGNG=THERM*SIGNG+RES*RING
      IF(NLIBE.EQ.3) GO TO 540
  530 IF(MOD( IL        ,50).EQ.0)  PRINT 9019
      PRINT 9021,    NAME,                 DLAM,FB1,FP,FP1,FT,SIGNG,
     1     FNG1,Y,Q(I),FG(I)
      GO TO 550
  540 IF(MOD(IL,50).EQ.0) PRINT 9020
      PRINT 9022,    NAME  ,               DLAM,FB1,FP,FP1,FT,SIGNG,FNG1,
     1               Y(2),Y(4),Y(5),Q(I),FG(I)
C
C     TEST RADIOACTIVITY
C
  550 IF(A1.LT.ERR)  GO TO 600
      ABETA=1.0
C     POSITRON EMISSION
      A3=FP
      IF(A3.LT.ERR)  GO TO 570
      ABETA=ABETA-A3
      AP1=A3*FP1
      AP=A3-AP1
      IF(AP.LT.ERR)  GO TO 560
      M=M+1
      COEFF(M,I)=AP*A1
      NPROD(M,I)=NUCLI-10000
  560 IF(AP1.LT.ERR)  GO TO 570
      M=M+1
      COEFF(M,I)=AP1*A1
      NPROD(M,I)=NUCLI-9999
C     ISOMERIC TRANSITION
  570 IF(FT .LT. ERR) GO TO 580
      M=M+1
      COEFF(M,I)=FT*A1
```

```
      NPROD(M,I)=NUCLI
      ABETA=ABETA-FT
C     NEGATRON EMISSION
  580 IF(ABETA.LT.1.0E-4) GO TO 600
      A2=FB1
      AB1=ABETA*A2
      AB=ABETA-AB1
      IF(AB.LT.1.E-4) GO TO 590
      M=M+1
      COEFF(M,I)=AB*A1
      NPROD(M,I)=NUCLI+10000
  590 IF(AB1.LT.1.E-6) GO TO 600
      M=M+1
      COEFF(M,I)=AB1*A1
      NPROD(M,I)=NUCLI+10001
C
C     NEUTRON CAPTURE CROSS SECTIONS FOR FISSION PRODUCTS USING THREE
C     REGION APPROXIMATION
C
  600 KAP(I)=M
      DO 610 K=1,6
  610 CAPT(K)=0.0
      CAPT(2)=SIGNG*FNG1
      CAPT(1)=SIGNG-CAPT(2)
      TOCAP(I)=0.0
      DO 620 K=1,2
      CAPKI=CAPT(K)
      IF(CAPKI.LT.ERR)  GO TO 620
      M=M+1
      TOCAP(I)=TOCAP(I)+CAPKI
      COEFF(M,I)=CAPKI
      NPROD(M,I)=NUCLI+NUCAL(K+2)
  620 CONTINUE
  630 IF(MOD(NUCLI,10).EQ.0) GO TO 650
      DO 640 K=1,M
  640 NPROD(K,I)=NPROD(K,I)-1
  650 IL=IL+1
      DO 660 J=1,5
      YJ=Y(J)*0.010
      TYLD(J)=TYLD(J)+YJ
  660 YIELD(J,IL)=YJ
      IF(NLIBE.EQ.1.OR.NLIBE.EQ.4)  GO TO 680
  670 IF(NLIBE.EQ.3)  YIELD(1,IL)=YJ
      YIELD(3,IL)=YJ
  680 MMAX(I)=M
      IF(M.GT.7)  PRINT 9039, M
      DIS(I)=A1
      I=I+1
      GO TO 470
  690 IFP=IL
C
C     ALL DATA ON NUCLIDES HAS BEEN READ, BEGIN TO COMPUTE MATRIX COEFF
C
      ITOT=I-1
C
C     FIND PRODUCT NUCLIDES FOR REACTIONS OF LIGHT ELEMENTS
C
      NON=0
      DO 700 K=1,ITOT
  700 NONO(K)=0
```

```
      IF(ILITE.LT.1)  GO TO 760
      DO 750 I=1,ILITE
      NUCLI=NUCL(I)
      DO 720  J=1,ILITE
      KMAX=KAP(J)
      IF(KMAX.LT.1)  GO TO 720
      DO 710 M=1,KMAX
      IF(NUCLI.NE.NPROD(M,J)) GO TO 710
      NONO(I)=NONO(I)+1
      NON=NON+1
      IF(NON.GT.2500)  PRINT 9041,     NON,NUCL(I)
      A(NON)=COEFF(M,J)
      JT=J
      LOC(NON)=JT
  710 CONTINUE
  720 CONTINUE
      KD(I)=NONO(I)
      DO 740  J=1,ILITE
      K1=KAP(J)+1
      KMAX=MMAX(J)
      IF(KMAX.LT.K1)  GO TO 740
      DO 730 M=K1,KMAX
      IF(NUCLI.NE.NPROD(M,J)) GO TO 730
      NONO(I)=NONO(I)+1
      NON=NON+1
      IF(NON.GT.2500)  PRINT 9041,     NON,NUCL(I)
      A(NON)=COEFF(M,J)
      JT=J
      LOC(NON)=JT
  730 CONTINUE
  740 CONTINUE
  750 CONTINUE
C
C     NON ZERO MATRIX ELEMENTS FOR THE ACTINIDES
C
  760 IF(IACT.LT.1)  GO TO 820
      IO=ILITE+1
      I1=ILITE+IACT
      DO 810 I=IO,I1
      NUCLI=NUCL(I)
      DO 780 J=IO,I1
      MAX=KAP(J)
      IF(MAX.LT.1)  GO TO 780
      DO 770 M=1,MAX
      IF(NUCLI.NE.NPROD(M,J))  GO TO 770
      NONO(I)=NONO(I)+1
      NON=NON+1
      IF(NON.GT.2500)  PRINT 9041,     NON,NUCL(I)
      A(NON)=COEFF(M,J)
      JT=J
      LOC(NON)=JT
  770 CONTINUE
  780 CONTINUE
      KD(I)=NONO(I)
      DO 800 J=IO,I1
      M1=KAP(J)+1
      M2=MMAX(J)
      IF(M2.LT.M1)  GO TO 800
      DO 790 M=M1,M2
      IF(NUCLI.NE.NPROD(M,J)) GO TO 790
```

```
      NONO(I)=NONO(I)+1
      NON=NON+1
      IF(NON.GT.2500)  PRINT 9041,      NON,NUCL(I)
      A(NON)=COEFF(M,J)
      JT=J
      LOC(NON)=JT
  790 CONTINUE
  800 CONTINUE
  810 CONTINUE
C
C     MATRIX ELEMENTS FOR FISSION PRODUCTS
C
  820 IF(IFP.LT.1)  GO TO 900
      IM=ILITE+IACT
      IO=IM+1
      IF(ITOT.LT.IO)  GO TO 900
      DO 880 I=IO,ITOT
      NUCLI=NUCL(I)
      I2=MAX0(IO,I-10)
      I3=MIN0(ITOT,I+10)
      DO 840 J=I2,I3
      KMAX=KAP(J)
      IF(KMAX.LT.1)  GO TO 840
      DO 830 M=1,KMAX
      IF(NUCLI.NE.NPROD(M,J)) GO TO 830
      NONO(I)=NONO(I)+1
      NON=NON+1
      IF(NON.GT.2500)  PRINT 9041,      NON,NUCL(I)
      A(NON)=COEFF(M,J)
      JT=J
      LOC(NON)=JT
  830 CONTINUE
  840 CONTINUE
      KD(I)=NONO(I)
      DO 860 J=I2,I3
      K1=KAP(J)+1
      KMAX=MMAX(J)
      IF(KMAX.LT.K1)  GO TO 860
      DO 850 M=K1,KMAX
      IF(NUCLI.NE.NPROD(M,J)) GO TO 850
      NONO(I)=NONO(I)+1
      NON=NON+1
      IF(NON.GT.2500)  PRINT 9041,      NON,NUCL(I)
      A(NON)=COEFF(M,J)
      JT=J
      LOC(NON)=JT
  850 CONTINUE
  860 CONTINUE
      IF(IACT.LT.1)  GO TO 880
      DO 870 K=1,5
      IL=I-IM
      IF(YIELD(K,IL).LT.ERR)  GO TO 870
      NON=NON+1
      IF(NON.GT.2500)  PRINT 9041,      NON,NUCL(I)
      NONO(I)=NONO(I)+1
      KK=NSORS(K)
      LOC(NON)=KK
      KF=KK-ILITE
      A(NON)=YIELD(K,IL)*FISS(KF)
  870 CONTINUE
```

```
  880 CONTINUE                                                               00020700
      IF(IFP.LE.0) GO TO 900                                                 00020710
      IF(NLIBE.NE.3) GO TO 890                                               00020720
      PRINT 9027,    TYLD(2),TYLD(4),TYLD(5)                                 00020730
      GO TO 900                                                              00020740
  890 PRINT 9030,     (TYLD(I),I=1,5)                                        00020750
C                                                                            00020760
C     ALL MATRIX ELEMENTS ARE NOW COMPUTED                                   00020770
C     BEGIN TRANSIENT SOLUTION                                               00020780
C                                                                            00020790
C                                                                            00020800
C     TEMPORARILY WRITE CUT MATRIX ELEMENTS                                  00020810
C                                                                            00020820
  900 IF(IR .EQ. 0) RETURN                                                   00020830
      PRINT 9029                                                             00020840
      N=0                                                                    00020850
      DO 910 I=1,ITOT                                                        00020860
      NUM=NONO(I)                                                            00020870
      IF(NUM.LE.0)  GO TO 910                                                00020880
      N1=N+NUM                                                               00020890
      N=N+1                                                                  00020900
      PRINT 9028,    I,DIS (I),TOCAP(I),(A(K),LOC(K),K=N,N1)                 00020910
      N=N1                                                                   00020920
  910 CONTINUE                                                               00020930
      RETURN                                                                 00020940
  920 STOP                                                                   00020950
C                                                                            00020960
C     FORMATS     FORMATS     FORMATS     FORMATS                            00020970
C                                                                            00020980
 9001 FORMAT(4F10.5,6I2)                                                     00020990
 9002 FORMAT(I6,F5.3,I1,5F3.3,E5.2,F3.3,            13X,E5.2,F3.3,2E5.200021000
     1      ,F4.3,F3.3,F6.4)                                                 00021010
 9003 FORMAT(I6,F5.3,I1,3X,4F3.3,2E5.2,F3.3,5E5.2,F4.3,F3.3)                00021020
 9004 FORMAT(I6,F5.3,I1,5F3.3,2E5.2,F3.3,4E5.2,F3.3,F4.3,F3.3,2E5.2)        00021030
 9005 FORMAT(1H1,43X,'NUCLEAR TRANSMUTATION DATA   REVISED ',I2,'/',I2,'00021040
     1/',I2,/,'ONUCL = NUCLIDE = 10000 * ATOMIC NO + 10 * MASS NO + ISOM00021050
     2ERIC STATE (0 OR 1)',10X,'OLAM = DECAY CONSTANT (1/SEC).',/,' FB, 00021060
     3FP, FA, FT = FRACTIONAL DECAY BY BETA, POSITRON (OR ELECTRON CAPTU00021070
     4RE), ALPHA, INTERNAL TRANSITION.   FB = 1 - FP - FA - FT',/,' FB1,00021080
     5 FP1, FNG1, FN2N1 = FRACTION OF BETA, POSITRON, N-GAMMA, N-2N TRAN00021090
     6SITIONS TO EXCITED STATE OF PRODUCT NUCLIDE',/,' SIGTH, SIGNG, SIG00021100
     7F, SIGNA, SIGNP = THERMAL CROSS SECTIONS (BARNS) FOR ABSORPTION, N00021110
     8-GAMMA, FISSION, N-ALPHA, N-PROTON.')                                  00021120
 9006 FORMAT('   SIGNG = SIGTH * (1 - FNA -FNP).  SIGNA = SIGTH * FNA.  00021130
     1SIGNP = SIGTH * FNP.  FNA, FNP = FRACTION THERMAL N-ALPHA, N-PROTO00021140
     2N.',/,' RITH, RING, RIF, RINA, RINP = RESONANCE INTEGRAL FOR ABSOR00021150
     3PTION, N-GAMMA, FISSION, N-ALPHA, N-PROTON.',/,'  RING = RITH * (00021160
     41 - FINA - FINP). RINA = RITH * FINA. RINP = RITH * FINP.  FINA, F00021170
     5INP = FRACTION RESONANCE N-ALPHA, N-PROTON.',/,' SIGMEV, SIGFF, SI00021180
     6GN2N, SIGNAF, SIGNPF = FAST CROSS SECTIONS (BARNS) FOR ABSORPTION,00021190
     7FISSION, N-2N, N-ALPHA, N-PROTON.',/,'   SIGN2N = SIGMEV * (1 - FF00021200
     8NA - FFNP).  SIGNAF = SIGMEV * FFNA.  SIGNPF = SIGMEV * FFNP.  FFN00021210
     9A, FFNP = FRACTION FAST N-ALPHA, N-P.')                                00021220
 9007 FORMAT(' Y23, Y25, Y02, Y28, Y49 = FISSION YIELD (PERCENT) FROM 2300021230
     13-U, 235-U, 232-TH, 238-U, 239- PU.',/,' Q = HEAT PER DISINTEGRATI00021240
     2ON.  FG = FRACTION OF HEAT IN GAMMAS OF ENERGY GREATER THAN 0.2 ME00021250
     3V.',/,'0 EFFECTIVE CROSS SECTIONS FOR A VOLUME AVERAGED THERMAL (L00021260
     4T 0.876 EV) FLUX ARE AS FOLLOWS.',/,'    N-GAMMA  -  SIGNG * THERM00021270
     5 + RING * RES.',/,'    FISSION  -  SIGF * THERM + RIF * RES + SIGF00021280
     6F * FAST.',10X,'THERM = 1/V CORRECTION FOR THERMAL SPECTRUM AND TE00021290
```

```
      7MPERATURE.',/,'    N-2N     -  SIGN2N * FAST.',36X,'RES    = RATIO 00021300
      8OF RESONANCE FLUX PER LETHARGY UNIT TO THERMAL FLUX.')             00021310
 9008 FORMAT('   N-ALPHA   -  SIGNA * THERM + RINA * RES + SIGNAF * FAST00021320
      1.',7X,'FAST = 1.45 *  RATIO OF FAST (GT 1.0 MEV) TO THERMAL FLUX '00021330
      2/'    N-PROTON -  SIGNP * THERM + RINP * RES + SIGNPF * FAST.')   00021340
 9009 FORMAT(1H0,59X,'REFERENCES',/,'   HALF LIVES, DECAY SCHEMES, AND 00021350
      1THERMAL POWER',/,' C M LEDERER, J M HOLLANDER, AND I PERLMAN ''TAB00021360
      2LE OF ISOTOPES - SIXTH EDITION'' JOHN WILEY AND SONS, INC (1967)',00021370
      3/,' B S DZHELEPOV AND L K PEKER ''DECAY SCHEMES OF RADIOACTIVE NUC00021380
      4LEI'' PERGAMMON PRESS (1961)',/,' D T GOLDMAN AND JAMES R ROSSER '00021390
      5'CHART OF THE NUCLIDES'' NINTH EDITION  GENERAL ELECTRIC CO (JULY 00021400
      61966)',/,' E D ARNOLD ''PROGRAM SPECTRA'' APPENDIX A OF ORNL-3576 00021410
      7(APRIL 1964)')                                                    00021420
 9010 FORMAT('    CROSS SECTIONS AND FLUX SPECTRA',/,' B E PRINCE ''NEUT00021430
      1RON REACTION RATES IN THE MSRE SPECTRUM'' ORNL-4119, PP 79-83 (JUL00021440
      2Y 1967)',/,' B E PRINCE ''NEUTRON ENERGY SPECTRA IN MSRE AND MSBR'00021450
      3' ORNL-4191, PP 50-58 (DEC 1967)',/,' M D GOLDBERG ET AL ''NEUTRON00021460
      4 CROSS SECTIONS'' BNL-325, SECOND ED, SUPP NO 2 (MAY 1964 - AUG 1900021470
      566) ALSO EARLIER EDITIONS',/,' H T KERR, UNPUBLISHED ERC COMPILATI00021480
      6ON (FEB 1968)',/,' M K DRAKE ''A COMPILATION OF RESONANCE INTEGRAL00021490
      7S'' NUCLEONICS, VOL 24, NO 8, PP 108-111 (AUG 1966)',/,' BNWL STAF00021500
      8F ''INVESTIGATION OF N-2N CROSS SECTIONS'' BNWC-98, PP 44-98 (JUNE00021510
      9 1965)')                                                          00021520
 9011 FORMAT(18A4,I3)                                                    00021530
 9012 FORMAT(1H1,20X,18A4)                                               00021540
 9013 FORMAT(' H ALTER AND C E WEBER ''PRODUCTION OF H AND HE IN METALS 00021550
      1DURING REACTOR IRRADIATION'' J NUCL MATLS, VOL 16, PP 68-73 (1965)00021560
      2',/,' L L BENNETT ''RECOMMENDED FISSION PRODUCT CHAINS FOR USE IN 00021570
      3REACTOR EVALUATION STUDIES'' ORNL-TM-1658 (SEPT 1966)')            00021580
 9014 FORMAT('    FISSION PRODUCT YIELDS',/,' M E MEEK AND B F RIDER, ''00021590
      1SUMMARY OF FISSION PRODUCT YIELDS FOR U-235, U-238, PU-239, AND PU00021600
      2-241 AT THERMAL, FISSION SPECTRUM AND'/'     14 MEV NEUTRON ENERGI00021610
      3ES'' APED-5398-A(REV.),(OCT. 1968)'/' S KATCOFF '' FISSION PRODUCT00021620
      4YIELDS FROM NEUTRON INDUCED FISSION'' NUCLEONICS, VOL 18, NO 11,  00021630
      5(NOV 1960)'/' N D DUDEY '' REVIEW OF LOW-MASS ATOM PRODUCTION IN F00021640
      6AST REACTORS'' ANL-7434,(APRIL 1968) ')                           00021650
 9015 FORMAT(1H0,20X,'LIGHT ELEMENTS, MATERIALS OF CONSTRUCTION, AND ACT00021660
      1IVATION PRODUCTS  ',/,'0 NUCL    DLAM    FB1   FP    FP1   FT    F00021670
      2A    SIGTH   FNG1   FNA   FNP   RITH    FINA  FINP   SIGMEV  FN2N100021680
      3  FFNA  FFNP   Q    FG')                                          00021690
 9016 FORMAT(1H0,20X,'LIGHT ELEMENTS, MATERIALS OF CONSTRUCTION, AND ACT00021700
      1IVATION PRODUCTS  ',/,'0 NUCL    DLAM    FB1   FP    FP1   FT    F00021710
      2A    SIGNG   FNG1   SIGN2N   FN2N1  SIGNA   SIGNP    Q    FG ABU00021720
      3NDANCE')                                                          00021730
 9017 FORMAT(1H ,A2,I3,A1,1PE9.2,0P5F6.3,1PE9.2,0P3F6.3,1PE9.2,0P2F6.3, 00021740
      11PE9.2,0P4F6.3,0PF5.2)                                            00021750
 9018 FORMAT(1H0,10X,'THERM= 'F10.5,5X,'RES= 'F10.5,5X,'FAST= 'F10.5,   00021760
      1//,1X,'NEUTRON SOURCE= '5(I10,5X),5X,'NLIBE= 'I3)                 00021770
 9019 FORMAT(1H0,36X,'FISSION PRODUCTS',/,'0 NUCL    DLAM    FB1   FP    00021780
      1 FP1    FT     SIGNG ',      ' FNG1     Y23      Y25      Y02     Y00021790
      228       Y49      Q      FG')                                     00021800
 9020 FORMAT(1H0,36X,'FISSION PRODUCTS',/,'0 NUCL    DLAM    FB1   FP    00021810
      1 FP1    FT     SIGNG    FNG1    Y25     Y28     Y49     Q    FG')  00021820
 9021 FORMAT(1H ,A2,I3,A1,1PE9.2,0P4F6.3, 1PE9.2,0PF6.3,1P5E9.2,        00021830
      10P2F6.3)                                                          00021840
 9022 FORMAT(1H ,A2,I3,A1,1PE9.2,0P4F6.3,1PE9.2,0PF6.3,1P3E9.2,0P2F6.3) 00021850
 9023 FORMAT(1H0,32X, 'ACTINIDES AND THEIR DAUGHTERS',//                 00021860
      1' NUCL    DLAM    FB1   FP    FP1   FT    FA  FSF E+6  SIGNG     R00021870
      2ING   FNG1    SIGF    RIF     SIGFF    SIGN2N    SIGN3N    Q  FG')00021880
 9024 FORMAT(1H0,32X, 'ACTINIDES AND THEIR DAUGHTERS',//                 00021890
```

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     1' NUCL     DLAM     FB1    FP     FP1    FT    FA     FSF E+6  SIGNG    F00021900
     2NG21     SIGF     SIGN2N     SIGN3N     Q     FG')                      00021910
 9025 FORMAT(1H ,A2,I3,A1,1PE9.2,0P5F6.3,6PF6.1,1P2E9.2,0PF6.3,1P5E9.2,     00021920
     1         0PF6.3,F5.2)                                                 00021930
 9026 FORMAT(1H ,A2,I3,A1,1PE9.2,0P5F6.3,6PF9.1,1PE9.2,0PF6.3,1P3E9.2,      00021940
     1         0PF7.3,F5.2)                                                 00021950
 9027 FORMAT('0SUM OF YIELDS OF ALL FISSION PRODUCTS =',15X,1P3E9.2)        00021960
 9028 FORMAT(I5,2X,1PE10.3,3X,E10.3,5(2X,E10.3,3X,I5)/(30X,5(2X,E10.3,      00021970
     1    3X,I5)))                                                          00021980
 9029 FORMAT('1NON-ZERO MATRIX ELEMENTS AND THEIR LOCATIONS'/               00021990
     1'  I        DIS(I)        CAP(I)       A(I,J)        J     A(I,J)     00022000
     2J       A(I,J)        J        A(I,J)        J        A(I,J)        J  ') 00022010
 9030 FORMAT(64HOSUM OF YIELDS OF ALL FISSION PRODUCTS                      00022020
     1         ,1P5F9.2)                                                    00022030
 9031 FORMAT(5I10)                                                          00022040
 9032 FORMAT(I6,F5.3,I1,5F3.3,E5.2,3F3.3,E5.2,2F3.3,E5.2,3F3.3,F4.3,F3.300022050
     1,F6.4)                                                                00022060
 9033 FORMAT(1H ,A2,I3,A1,1PE9.2,0P5F6.3,1PE9.2,0PF6.3,1PE9.2,0PF6.3,       00022070
     1      1P2E9.2,0P2F6.3,F7.3)                                           00022080
 9034 FORMAT(I7,F9.3,I1,5F5.3,1PE9.2,0P2F5.3,F7.3,2E6.0)                    00022090
 9035 FORMAT(7X,F9.2,3F5.3,F9.2,2F5.3,F9.2,3F5.3, 5X,I1)                    00022100
 9036 FORMAT(20A4)                                                          00022110
 9037 FORMAT(7X,2F9.2,F5.3,4F9.2,F4.3,F9.2,I1)                              00022120
 9038 FORMAT(7X,2F9.2,F5.3,5F9.2, 4X,I1)                                    00022130
 9039 FORMAT('0  WARNING, MOUT OF RANGE IN NUDATA, =' I5)                   00022140
 9040 FORMAT(   7X,F9.2,3F8.6,F4.2,2F3.1,F9.2,3F5.3,5X,I1)                  00022150
 9041 FORMAT('0 NUN HAS EXCEEDED 2500, EQUAL TO '2I6)                       00022160
      END                                                                   00022170
      SUBROUTINE COLLECT(TMB,CWASTE,ILITE,ITOT)                             00022180
      COMMON/EQ/XZERO(800), XZH(800),XTEMP(800),XNEW(10,800),               00022190
     1      B(800),D(800)                                                   00022200
      DIMENSION CWASTE(800)                                                 00022210
      IF(TMB.LT.1) RETURN                                                   00022220
      DO 10 I=1,ITOT                                                        00022230
      B(I)=CWASTE(I)                                                        00022240
 10   XTEMP(I)=0.0                                                          00022250
      CALL DECAY(1,TMB,ITOT)                                                00022260
      CALL TERM(TMB,1,0,ITOT)                                               00022270
      CALL EQUIL(1,ITOT)                                                    00022280
      DO 20 I=1,ITOT                                                        00022290
 20   CWASTE(I)=XNEW(1,I)/TMB                                               00022300
      RETURN                                                                00022310
      END                                                                   00022320
      SUBROUTINE STORAG(TMB,CWASTE,ILITE,ITOT)                              00022330
      COMMON/EQ/XZERO(800), XZH(800),XTEMP(800),XNEW(10,800),               00022340
     1      B(800),D(800)                                                   00022350
      DIMENSION CWASTE(ITOT)                                                00022360
      IF(TMB.LT.1)  RETURN                                                  00022370
      DELT=TMB                                                              00022380
      DO 10 I=1,ITOT                                                        00022390
      B(I)=0.0                                                              00022400
 10   XTEMP(I)=CWASTE(I)                                                    00022410
      CALL DECAY(1,DELT,ITOT)                                               00022420
      CALL TERM(TMB,1,ILITE,ITOT)                                           00022430
      CALL EQUIL(1,ITOT)                                                    00022440
      DO 20 I=1,ITOT                                                        00022450
 20   CWASTE(I)=XNEW(1,I)                                                   00022460
      RETURN                                                                00022470
      END                                                                   00022480
C     PROGRAM BLOCK DATA                                                    00022490
```

```
      BLOCK DATA
      INTEGER*2 ELE(99),STA(2)
      COMMON/LABEL/  ELE,STA
      DATA ELE/' H','HE','LI','BE',' B',' C',' N',' O',' F','NE','NA','M
     1G','AL','SI',' P',' S','CL','AR',' K','CA','SC','TI',' V','CR','MN
     2','FE','CO','NI','CU','ZN','GA','GE','AS','SE','BR','KR','RB','SR'
     3,' Y','ZR','NB','MO','TC','RU','RH','PD','AG','CD','IN','SN','SB',
     4'TE',' I','XE','CS','BA','LA','CE','PR','ND','PM','SM','EU','GD','
     5TB','DY','HO','ER','TM','YB','LU','HF','TA',' W','RE','OS','IR','P
     6T','AU','HG','TL','PB','BI','PO','AT','RN','FR','RA','AC','TH','PA
     7',' U','NP','PU','AM','CM','BK','CF','ES'/
      DATA STA/'  ','M '/
      END
      SUBROUTINE  HALF(A,I)
C     SUBROUTINE HALF CONVERTS HALF-LIFE TO DECAY CONSTANT (1/SEC)
      DIMENSION C(9)
      DATA C/6.9315E-01,1.1552E-02,1.9254E-04,8.0226E-06,2.1965E-08,0.0,
     1       2.1965E-11,2.1965E-14,2.1965E-17/
      IF(A.GT.0.0)  GO TO 10
      IF(I.EQ.6)  GO TO 20
      A=9.99
      RETURN
   10 A=C(I)/A
      RETURN
   20 A=0.0
      RETURN
      END
      SUBROUTINE NOAH(NUCLI,NAME)
C     SUBROUTINE NOAH CONVERTS SIX DIGIT IDENTIFIER TO ALPHAMERIC SYMBOL
      INTEGER*2 NAME(3)
      INTEGER*2 ELE(99),STA(2)
      COMMON/LABEL/  ELE,STA
      IS=MOD(NUCLI,10)+1
      NZ  =NUCLI/10000
      MW=NUCLI/10-NZ  *1000
      NAME(1)=ELE(NZ)
      NAME(2)=MW
      NAME(3)=STA(IS)
      RETURN
      END
```

APPENDIX D

COMPUTER PROGRAMS FOR DOSE PARAMETERS

The following computer programs provide the NRC staff method for calculating various parameters used in the Technical Specifications.

PARTS, a computer program to calculate technical specification dose parameters for the iodine and particulate portions of gaseous effluents; available from the Radiological Assessment Branch of the Nuclear Regulatory Commission, Washington, D.C. 20555.

RABFIN, a computer program to calculate technical specification dose parameters for the noble gas portion of gaseous effluents; available from the Radiological Assessment Branch of the Nuclear Regulatory Commission, Washington, D.C. 20555.

LADTAP, a computer program to calculate the doses from radioactive effluents released to the hydrosphere; the program and a modification to calculate the technical specification dose parameters for radionuclides in liquid effluents is available from the Radiological Assessment Branch of the Nuclear Regulatory Commission, Washington, D.C. 20555.

The remainder of this Appendix contains the PARTS program listing, and modifying the routines to the LADTAP Code.

LADTAP MODIFICATIONS

An option has been added to the staff's code LADTAP to tabulate the $A_{i\tau}$ factors of Section 4.3.1 of this manual. Listed below are the routines which have been modified, the changes are indicated by the 'CHANGE 1' notation in columns 73-80.

To execute this option the standard LADTAP input is prepared with the following departures:

1. The 50 mile population (card 3 of the LADTAP input deck) should be set negative.
2. The release of all nuclides should be set to one Ci/yr.

Only the input data defining the ALARA determination of LADTAP is necessary. Following the input data deck structure of Enclosure 1 to the LADTAP program, data beyond card number 7 need not be prepared for the option.

PARTS INPUT DECK TABLE

Card No.	Format	Variable	Columns	Description
1	20 A4	Name	1-80	Plant Title Card, Name, Docket No. and Plant Type
2	F 5.2	H	1-5	Humidity absolute (default value = 8.0 gr/m^3)
	F 5.2	YL	6-10	Yield of leafy vegetables for human consumption (default value = 2.0 Kg/m^2)
	F 5.2	YV	11-15	Yield of produce other than leafy vegetables (default value = 2.0 Kg/m^2)
	F 5.2	YP	16-20	Agricultural productivity of animal pasture feed (default value = 0.70 Kg/m^2 wet weight)
	F 5.2	YC	21-25	Agricultural crop productivity of animal feed other than pasture grass (default value = 2.0 Kg/m^2 wet weight)
	F 5.2	QC	26-30	Milk cow and beef cattle consumption rate for feed or forage (default value = 50 Kg/day wet weight)
	F 5.2	QG	31-35	Goat consumption rate for feed or forage (default value = 6 Kg/day wet weight)
	E 8.2	DOQ	41-48	Annual average relative deposition rate (D/Q), determined for a specific plant airborne release and site location ($meters^{-2}$) (Optional Use For Reference & Information Only)
3	I1	IAGE	1	Identification of Controlling Age Group (1 is Infant, 2 is Child, 3 is Teen and 4 is Adult)
	I1	IORG	2	Identification of Controlling Organ (1 is Thyroid, 2 is the critical organ)
	6A4	ZLOC	3-26	Receptor Location identification, Name, Compass Sector and Distance
	F 5.0	GF	27-31	Fraction of yr. humans are exposed to ground surface radiation (default value = 1.0)
	F 5.0	ZIN	32-36	Annual occupancy factor for the inhalation pathway (default value = 1.0)
	F 5.0	FV	37-41	Fraction of yr. leafy vegetables are grown (default value = 1.0)
	F 5.0	FP	42-46	Fraction of yr. cows are on pasture (default value = 1.0)
	F 5.0	FG	47-51	Fraction of produce from local garden (default value = 0.76)
	F 5.0	FPF	52-56	Fraction of daily intake of cows derived from pasture while on pasture (default value - 1.0)
	F 5.0	FGT	57-61	Fraction of yr. goats are on pasture (default value = 1.0)
	F 5.0	FPG	62-66	Fraction of daily intake of goat from pasture while on pasture (default value = 1.0)
	F 5.0	FB	67-71	Fraction of yr. beef cattle are on pasture (default value 1.0)
	F 5.0	FBF	72-76	Fraction of daily intake of beef cattle derived from pasture while on pasture (default value = 1.0)

```
      BLOCK DATA BLKDAT                                                  BLKDAT    2
      COMMON/ELEMEN/IELEM(100)                                           BLKDAT    3
      INTEGERIELEM                                                       BLKDAT    4
      COMMON/POPUL/PERA,PERT,PERC,US                                     BNL01     1
      DATA IELEM/                                                        BLKDAT    5
     1'H ','HE','LI','BE','B ','C ','N ','O ','F ','NE','NA','MG','AL',  BLKDAT    6
     2'SI','P ','S ','CL','AR','K ','CA','SC','TI','V ','CR','MN','FE',  BLKDAT    7
     3'CO','NI','CU','ZN','GA','GE','AS','SE','BR','KR','RB','SR','Y ',  BLKDAT    8
     4'ZR','NB','MO','TC','RU','RH','PD','AG','CD','IN','SN','SB','TE',  BLKDAT    9
     5'I ','XE','CS','BA','LA','CE','PR','ND','PM','SM','EU','GD','TB',  BLKDAT   10
     6'DY','HO','ER','TM','YB','LU','HF','TA','W ','RE','OS','IR','PT',  BLKDAT   11
     7'AU','HG','TL','PB','BI','PO','AT','RN','FR','RA','AC','TH','PA',  BLKDAT   12
     8'U ','NP','PU','AM','CM','BK','CF','ES','FM'/                      BLKDAT   13
      DATA PERA/0.66/                                                    BLKDAT   15
      DATA PERT/0.14/                                                    BLKDAT   16
      DATA PERC/0.20/                                                    BLKDAT   17
      DATA US/2.6E+08/                                                   BLKDAT   18
      END                                                                BLKDAT   19
```

```
      PROGRAM LADTAP(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT,TAPE10)       BNL01      2
      COMMON Q(200),PL,CFS,NSUR,LT,RECO(200),LIST(200,4),LCT,LZ ,CON,KIT LADTAP     3
     + ,POP                                                              LADTAP     4
      COMMON/POPUL/PERA,PERT,PERC,US                                     LADTAP     5
      DIMENSION FACCF(100),FACCI(100),FACCA(100),SACCF(100),SACCI(100),  LADTAP     6
     + SACCA(100)                                                        LADTAP     7
      DIMENSION ITITLE(20)                                               BNL01      3
      DATA FACCF/                                                        LADTAP     8
     +9.0E-01,1.0E+00,5.0E-01,2.0E+00,2.2E-01,4.6E+03,1.5E+05,9.2E-01,   LADTAP     9
     +1.0E+01,1.0E+00,1.0E+02,5.0E+01,1.0E+01,2.5E+00,1.0E+05,7.5E+02,   LADTAP    10
     +5.0E+01,1.0E+00,1.0E+03,4.0E+01,2.0E+00,1.0E+03,1.0E+01,2.0E+02,   LADTAP    11
     +4.0E+02,1.0E+02,5.0E+01,1.0E+02,5.0E+01,2.0E+03,3.3E+02,3.3E+03,   LADTAP    12
     +1.0E+02,1.7E+02,4.2E+02,1.0E+00,2.0E+03,3.0E+01,2.5E+01,3.3E+00,   LADTAP    13
     +3.0E+04,1.0E+01,1.5E+01,1.0E+01,1.0E+01,1.0E+01,2.3E+00,2.0E+02,   LADTAP    14
     +1.0E+05,3.0E+03,1.0E+00,4.0E+02,1.5E+01,1.0E+00,2.0E+03,4.0E+00,   LADTAP    15
     +2.5E+01,1.0E+00,2.5E+01,2.5E+01,2.5E+01,2.5E+01,2.5E+01,2.5E+01,   LADTAP    16
     +2.5E+01,2.5E+01,2.5E+01,2.5E+01,2.5E+01,2.5E+01,2.5E+01,3.3E+00,   LADTAP    17
     +3.0E+04,1.2E+03,1.2E+02,1.0E+01,1.0E+01,1.0E+02,3.3E+01,1.0E+03,   LADTAP    18
     +1.0E+04,1.0E+02,1.5E+01,5.0E+02,1.5E+01,1.0E+00,4.0E+02,5.0E+01,   LADTAP    19
     +2.5E+01,3.0E+01,1.1E+01,2.0E+00,1.0E+01,3.5E+00,2.5E+01,2.5E+01,   LADTAP    20
     +2.5E+01,2.5E+01,1.0E+01,1.0E+01/                                   LADTAP    21
      DATA FACCI/                                                        LADTAP    22
     +9.0E-01,1.0E+00,4.0E+01,1.0E+01,5.0E+01,9.1E+03,1.5E+05,9.2E-01,   LADTAP    23
     +1.0E+02,1.0E+00,2.0E+02,1.0E+02,6.3E+01,2.5E+01,2.0E+04,1.0E+02,   LADTAP    24
     +1.0E+02,1.0E+00,8.3E+02,3.3E+02,1.0E+03,3.0E+03,3.0E+03,2.0E+03,   LADTAP    25
     +9.0E+04,3.2E+03,2.0E+02,1.0E+02,4.0E+02,1.0E+04,6.7E+02,3.3E+01,   LADTAP    26
     +4.0E+01,1.7E+02,3.3E+02,1.0E+00,1.0E+03,1.0E+02,1.0E+03,6.7E+00,   LADTAP    27
     +1.0E+02,1.0E+01,5.0E+00,3.0E+02,3.0E+02,3.0E+02,7.7E+02,2.0E+03,   LADTAP    28
     +1.0E+05,1.0E+03,1.0E+01,1.0E+05,5.0E+00,1.0E+00,1.0E+02,2.0E+02,   LADTAP    29
     +1.0E+03,1.0E+03,1.0E+03,1.0E+03,1.0E+03,1.0E+03,1.0E+03,1.0E+03,   LADTAP    30
     +1.0E+03,1.0E+03,1.0E+03,1.0E+03,1.0E+03,1.0E+03,1.0E+03,6.7E+00,   LADTAP    31
     +6.7E+02,1.0E+01,6.0E+01,3.0E+02,3.0E+02,3.0E+02,5.0E+01,1.0E+05,   LADTAP    32
     +1.5E+04,1.0E+02,2.4E+01,2.0E+04,5.0E+00,1.0E+00,1.0E+02,2.5E+02,   LADTAP    33
     +1.0E+03,5.0E+02,1.1E+02,6.0E+01,4.0E+02,1.0E+02,1.0E+03,1.0E+03,   LADTAP    34
     +1.0E+03,1.0E+03,1.0E+02,1.0E+02/                                   LADTAP    35
      DATA FACCA/                                                        LADTAP    36
     +9.0E-01,1.0E+00,3.0E+00,2.0E+01,2.2E+00,4.6E+03,1.3E+04,9.2E-01,   LADTAP    37
     +2.0E+00,1.0E+00,5.0E+02,1.0E+02,4.2E+02,1.3E+02,5.0E+05,1.0E+02,   LADTAP    38
     +5.0E+01,1.0E+00,6.7E+02,1.3E+02,1.0E+04,5.0E+02,1.0E+02,4.0E+03,   LADTAP    39
     +1.0E+04,1.0E+03,2.0E+02,5.0E+01,2.0E+03,2.0E+04,1.7E+03,3.3E+01,   LADTAP    40
     +3.0E+03,1.0E+03,5.0E+01,1.0E+00,1.0E+03,5.0E+02,5.0E+03,1.0E+03,   LADTAP    41
     +8.0E+02,1.0E+03,4.0E+01,2.0E+03,2.0E+02,2.0E+02,2.0E+02,1.0E+03,   LADTAP    42
     +1.0E+05,1.0E+02,1.5E+03,1.0E+02,4.0E+01,1.0E+00,5.0E+02,5.0E+02,   LADTAP    43
     +5.0E+03,4.0E+03,5.0E+03,5.0E+03,5.0E+03,5.0E+03,5.0E+03,5.0E+03,   LADTAP    44
     +5.0E+03,5.0E+03,5.0E+03,5.0E+03,5.0E+03,5.0E+03,5.0E+03,1.0E+03,   LADTAP    45
     +8.0E+02,1.2E+03,2.4E+02,2.0E+02,2.0E+02,2.0E+02,3.3E+01,1.0E+03,   LADTAP    46
     +1.0E+05,2.0E+02,2.4E+01,2.0E+03,4.0E+01,1.0E+00,8.0E+01,2.5E+03,   LADTAP    47
     +5.0E+03,1.5E+03,1.1E+03,5.0E-01,3.0E+02,3.5E+02,5.0E+03,5.0E+03,   LADTAP    48
     +5.0E+03,5.0E+03,1.0E+03,1.0E+03/                                   LADTAP    49
      DATA SACCF/                                                        LADTAP    50
     +9.0E-01,1.0E+00,5.0E-01,2.0E+02,2.2E-01,1.8E+03,6.0E+04,9.6E-01,   LADTAP    51
     +3.6E+00,1.0E+00,6.7E-02,7.7E-01,1.0E+01,1.0E+01,2.9E+04,1.7E+00,   LADTAP    52
     +1.3E-02,1.0E+00,1.1E+01,5.0E-01,2.0E+00,1.0E+03,1.0E+01,4.0E+02,   LADTAP    53
     +5.5E+02,3.0E+03,1.0E+02,1.0E+02,6.7E+02,2.0E+03,3.3E+02,3.3E+03,   LADTAP    54
     +3.3E+02,4.0E+03,1.5E-02,1.0E+00,8.3E+00,2.0E+00,2.5E+01,2.0E+02,   LADTAP    55
     +3.0E+04,1.0E+01,1.0E+01,3.0E+00,1.0E+01,1.0E+01,3.3E+03,3.0E+03,   LADTAP    56
     +1.0E+05,3.0E+03,4.0E+01,1.0E+01,1.0E+01,1.0E+00,4.0E+01,1.0E+01,   LADTAP    57
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      +2.5E+01,1.0E+01,2.5E+01,2.5E+01,2.5E+01,2.5E+01,2.5E+01,2.5E+01,  LADTAP     58
      +2.5E+01,2.5E+01,2.5E+01,2.5E+01,2.5E+01,2.5E+01,2.5E+01,2.0E+02,  LADTAP     59
      +3.0E+04,3.0E+01,4.8E+00,1.0E+01,1.0E+01,1.0E+02,3.3E+01,1.7E+03,  LADTAP     60
      +1.0E+04,3.0E+02,1.5E+01,3.0E+02,1.0E+01,1.0E+00,3.0E+01,5.0E+01,  LADTAP     61
      +2.5E+01,1.0E+04,1.0E+01,1.0E+01,1.0E+01,3.0E+00,2.5E+01,2.5E+01,  LADTAP     62
      +2.5E+01,2.5E+01,1.0E+01,1.0E+01/                                  LADTAP     63
       DATA SACCI/                                                       LADTAP     64
      +9.3E-01,1.0E+00,5.0E-01,2.0E+02,4.4E-01,1.4E+03,1.7E+04,9.6E-01,  LADTAP     65
      +3.6E+00,1.0E+00,1.9E-01,7.7E-01,6.0E+01,3.3E+01,3.0E+04,4.4E-01,  LADTAP     66
      +1.9E-02,1.0E+00,6.6E+00,1.3E+01,1.0E+04,1.0E+03,5.0E+01,2.0E+03,  LADTAP     67
      +4.0E+02,2.0E+04,1.0E+03,2.5E+02,1.7E+03,5.0E+04,6.7E+02,1.7E+04,  LADTAP     68
      +3.3E+02,1.0E+03,3.1E+00,1.0E+00,1.7E+01,2.0E+01,1.0E+03,8.0E+01,  LADTAP     69
      +1.0E+02,1.0E+01,5.0E+01,1.0E+03,2.0E+03,2.0E+03,3.3E+03,2.5E+05,  LADTAP     70
      +1.0E+05,1.0E+03,5.0E+00,1.0E+05,5.0E+01,1.0E+00,2.5E+01,1.0E+02,  LADTAP     71
      +1.0E+03,6.0E+02,1.0E+03,1.0E+03,1.0E+03,1.0E+03,1.0E+03,1.0E+03,  LADTAP     72
      +1.0E+03,1.0E+03,1.0E+03,1.0E+03,1.0E+03,1.0E+03,1.0E+03,2.0E+01,  LADTAP     73
      +1.7E+04,3.0E+01,6.0E+01,2.0E+03,2.0E+03,2.0E+03,3.3E+01,3.3E+04,  LADTAP     74
      +1.5E+04,1.0E+03,2.4E+01,5.0E+03,5.0E+01,1.0E+00,2.0E+01,1.0E+02,  LADTAP     75
      +1.0E+03,2.0E+03,1.0E+01,1.0E+01,1.0E+01,2.0E+02,1.0E+03,1.0E+03,  LADTAP     76
      +1.0E+03,1.0E+03,1.0E+01,1.0E+01/                                  LADTAP     77
       DATA SACCA/                                                       LADTAP     78
      +9.3E-01,1.0E+00,3.0E+00,1.0E+03,2.2E+00,1.8E+03,1.0E+04,9.6E-01,  LADTAP     79
      +1.4E+00,1.0E+00,9.5E-01,7.7E-01,5.0E+02,6.7E+01,3.0E+03,4.4E-01,  LADTAP     80
      +7.6E-02,1.0E+00,2.6E+01,5.0E+00,1.0E+05,2.0E+03,1.0E+02,2.0E+03,  LADTAP     81
      +5.5E+03,7.3E+02,1.0E+03,2.5E+02,1.0E+03,1.0E+03,1.7E+03,3.3E+02,  LADTAP     82
      +1.7E+03,1.0E+03,1.5E+00,1.0E+00,1.7E+01,1.0E+01,5.0E+03,1.0E+03,  LADTAP     83
      +5.0E+02,1.0E+01,4.0E+03,2.0E+03,2.0E+03,2.0E+03,2.0E+02,1.0E+03,  LADTAP     84
      +1.0E+05,1.0E+02,1.5E+03,1.0E+03,1.0E+03,1.0E+00,5.0E+01,5.0E+02,  LADTAP     85
      +5.0E+03,6.0E+02,5.0E+03,5.0E+03,5.0E+03,5.0E+03,5.0E+03,5.0E+03,  LADTAP     86
      +5.0E+03,5.0E+03,5.0E+03,5.0E+03,5.0E+03,5.0E+03,5.0E+03,2.0E+03,  LADTAP     87
      +1.0E+03,3.0E+01,2.4E+02,2.0E+03,2.0E+03,2.0E+03,3.3E+01,1.0E+03,  LADTAP     88
      +1.0E+05,5.0E+03,2.4E+01,2.0E+03,4.0E+03,1.0E+00,2.0E+01,1.0E+02,  LADTAP     89
      +5.0E+03,3.0E+03,6.0E+00,6.7E+01,6.0E+00,1.0E+03,5.0E+03,5.0E+03,  LADTAP     90
      +5.0E+03,5.0E+03,6.0E+01,6.0E+01/                                  LADTAP     91
    10 FORMAT(2X,19A4,A2)                                                BNL01       4
    20 FORMAT(8F10.0)                                                    LADTAP     95
    24 FORMAT(I10,2E10.2,I10)                                            LADTAP     96
    25 FORMAT(1H0,2X,'DISCHARGE=',1PE8.2,' CFS',10X,'SOURCE TERM MULTIPLI LADTAP     97
      +ER=',E8.2)                                                        LADTAP     98
    26 FORMAT(1H0,2X,'FRESHWATER SITE')                                  LADTAP     99
    27 FORMAT(1H0,2X,'SALTWATER SITE')                                   LADTAP    100
    30 FORMAT(1H0,'  50-MILE POPULATION=',1PE8.2,5X,'FRACTION ---  ADULT= LADTAP    101
      +',0PF4.2,/,49X,'TEENAGER=',F4.2,/,49X,'CHILD=',F4.2)              LADTAP    102
    28 FORMAT(1H1)                                                       LADTAP    103
       PL=15.0                                                           LADTAP    104
       IPRNT=1                                                           LADTAP    105
       JSB=1                                                             LADTAP    106
    22 READ(5,10)ITITLE                                                  LADTAP    107
       IF(EOF(5).NE.0)GOTO500                                            LADTAP    108
       PRINT 28                                                          LADTAP    109
       READ 24,LT,CFS,UML,LCT                                            LADTAP    110
       IF(UML.EQ.0.) UML=1.                                              LADTAP    111
       READ 20,POP,TR                                                    LADTAP    112
       IF(TR.GT.0.) READ 20,PERA,PERT,PERC                               LADTAP    113
       PRINT 10,ITITLE                                                   LADTAP    114
       PRINT 25,CFS,UML                                                  LADTAP    115
       IF(POP.GT.0) PRINT 30,POP,PERA,PERT,PERC                          LADTAP    116
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      IF(LT.EQ.0) PRINT 26                                          LADTAP   117
      IF(LT.GT.0) PRINT 27                                          LADTAP   118
      IF(JSB.EQ.1) CALL REDDF(IPRNT)                                LADTAP   119
      JSB=JSB+2                                                     LADTAP   120
      CALL PLOP(DOSE,4)                                             LADTAP   121
      CALL SOURCE(UML)                                              LADTAP   122
      IF(LT.EQ.0) CALL ALARA(FACCF,FACCI,FACCA)                     LADTAP   123
      IF(LT.GT.0) CALL ALARA(SACCF,SACCI,SACCA)                     LADTAP   124
      IF(LT.EQ.0) CALL WHY(FACCF,1,1)                               LADTAP   125
      IF(LT.EQ.0) CALL WHY(FACCF,1,2)                               LADTAP   126
      IF(LT.EQ.0) CALL WHY(FACCI,2,1)                               LADTAP   127
      IF(LT.EQ.0) CALL WHY(FACCI,2,2)                               LADTAP   128
      IF(LT.GT.0) CALL WHY(SACCF,1,1)                               LADTAP   129
      IF(LT.GT.0) CALL WHY(SACCF,1,2)                               LADTAP   130
      IF(LT.GT.0) CALL WHY(SACCI,2,1)                               LADTAP   131
      IF(LT.GT.0) CALL WHY(SACCI,2,2)                               LADTAP   132
      CALL WATER                                                    LADTAP   133
      CALL ACTIVE                                                   LADTAP   134
      CALL FLOOD                                                    LADTAP   135
      IF(LT.EQ.0) CALL WHO(FACCF,FACCI,FACCA)                       LADTAP   136
      IF(LT.GT.0) CALL WHO(SACCF,SACCI,SACCA)                       LADTAP   137
      CALL PLOP(DOSE,3)                                             LADTAP   138
      GO TO 22                                                      LADTAP   139
  500 STOP                                                          LADTAP   140
      END                                                           LADTAP   141
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      SUBROUTINE REDDF(IPRNT)                                           REDDF      2
      COMMON/SURCE/IZ(300),IMASS(300),META(300),NLIBA,NLIBT,NLIBC,NLIBI REDDF      5
      COMMON/ELEMEN/IELEM(100)                                          REDDF      6
      COMMON Q(200),PL,CFS,NSUR,LT,RECD(200),LIST(200,4),LCT,LZ ,CON,KIT REDDF     7
     + ,POP                                                             REDDF      8
      COMMON/DFLIB/DFL(300,7),DFA(300,7),EXG(300,2),TAU(300),EXS(300,2), REDDF     9
     +EFF(300,8)                                                        REDDF     10
      DIMENSION LS(20)                                                  BNL01      5
   10 FORMAT(1H1)                                                       REDDF     12
   11 FORMAT(/,/)                                                       REDDF     13
   12 FORMAT(2X,19A4,A2)                                                BNL01      6
   13 FORMAT('  CHILD DOSE FACTORS')                                    REDDF     15
   14 FORMAT('  ADULT DOSE FACTORS')                                    REDDF     16
   15 FORMAT('  TEENAGER DOSE FACTORS')                                 REDDF     17
   16 FORMAT(1X,2I3,A1,5E8.0)                                           REDDF     18
   17 FORMAT(10E8.0)                                                    REDDF     19
   18 FORMAT('  ADULT HEADING GOES HERE')                               REDDF     20
   19 FORMAT(I4,A2,I4,A1,1P12E9.2,/,56X,1P7E9.2,/,10X,1P8E10.2)         REDDF     21
   20 FORMAT('  TEENAGER HEADING GOES HERE')                            REDDF     22
   21 FORMAT(I4,A2,I4,A1,1P7E9.2,/,11X,1P7E9.2)                         REDDF     23
   22 FORMAT('  INFANT DOSE FACTORS')                                   REDDF     24
   23 FORMAT('  DOSE FACTOR LIBRARY CONTAINS',I4,' ENTRIES')            REDDF     25
   24 FORMAT(1X,9E8.2)                                                  REDDF     26
C** READ ADULT DOSE FACTOR LIBRARY                                      REDDF     27
      READ (10,12)LS                                                    REDDF     28
      K=0                                                               REDDF     29
   39 K=K+1                                                             REDDF     30
      READ(10,16)IZ(K),IMASS(K),META(K),TAU(K),EXG(K,2),EXS(K,2),EXG(K,1 REDDF    31
     +),EXS(K,1)                                                        REDDF     32
      TAU(K)=TAU(K)*3600.                                               REDDF     33
      IF(IZ(K))45,45,40                                                 REDDF     34
   40 READ(10,17)(DFL(K,J),J=1,7)                                       REDDF     35
      READ(10,17)(DFA(K,J),J=1,7)                                       REDDF     36
      READ(10,24)(EFF(K,J),J=1,8)                                       REDDF     37
      GOTO 39                                                           REDDF     38
   45 NLIBA=K-1                                                         REDDF     39
      K=K-1                                                             REDDF     40
C** READ TEENAGER DOSEFACTOR LIBRARY                                    REDDF     41
      READ(10,12)LS                                                     REDDF     42
   49 K=K+1                                                             REDDF     43
      READ(10,16)IZ(K),IMASS(K),META(K)                                 REDDF     44
      IF(IZ(K))55,55,50                                                 REDDF     45
   50 READ(10,17)(DFL(K,J),J=1,7)                                       REDDF     46
      READ(10,17)(DFA(K,J),J=1,7)                                       REDDF     47
      GOTO 49                                                           REDDF     48
   55 NLIBT=K-1                                                         REDDF     49
      K=K-1                                                             REDDF     50
C** READ CHILD DOSE FACTOR LIBRARY                                      REDDF     51
      READ(10,12)LS                                                     REDDF     52
   59 K=K+1                                                             REDDF     53
      READ(10,16)IZ(K),IMASS(K),META(K)                                 REDDF     54
      IF(IZ(K))65,65,60                                                 REDDF     55
   60 READ(10,17)(DFL(K,J),J=1,7)                                       REDDF     56
      READ(10,17)(DFA(K,J),J=1,7)                                       REDDF     57
      GOTO 59                                                           REDDF     58
   65 NLIBC=K-1                                                         REDDF     59
      K=K-1                                                             REDDF     60
```

```
      READ(10,12)LS
   66 K=K+1
      READ(10,16)IZ(K),IMASS(K),META(K)
      IF(IZ(K))68,68,67
   67 READ(10,17)(DFL(K,J),J=1,7)
      READ(10,17)(DFA(K,J),J=1,7)
      GO TO 66
   68 NLIBI=K-1
      IF(IPRNT.GT.0)GOTO 1000
C** PRINT OUT ADULT DOSE FACTORS
      PRINT 10
      PRINT 11
      PRINT 14
      PRINT 18
      DO 70 K=1,NLIBA
      KK=IZ(K)
   70 PRINT 19, IZ(K),IELEM(KK),IMASS(K),META(K),TAU(K),(EXG(K,J),J=1,2)
     1,(EXS(K,J),J=1,2),(DFL(K,J),J=1,7),(DFA(K,J),J=1,7),(EFF(K,J),J=1,
     28)
      K1=NLIBA+1
C** PRINT OUT TEENAGER DOSE FACTORS
      PRINT 10
      PRINT 11
      PRINT 15
      PRINT 20
      DO 80 K=K1,NLIBT
      KK=IZ(K)
   80 PRINT 21,IZ(K),IELEM(KK),IMASS(K),META(K),(DFL(K,J),J=1,7),(DFA(K,
     1J),J=1,7)
      K1=NLIBT+1
C** PRINT OUT CHILD DOSE FACTORS
      PRINT 10
      PRINT 11
      PRINT 13
      PRINT 20
      DO 90 K=K1,NLIBC
      KK=IZ(K)
   90 PRINT 21,IZ(K),IELEM(KK),IMASS(K),META(K),(DFL(K,J),J=1,7),(DFA(K,
     1J),J=1,7)
      K1=NLIBC+1
C** PRINT OUT INFANT DOSE FACTORS
      PRINT 10
      PRINT 11
      PRINT 22
      PRINT 20
      DO 100 K=K1,NLIBI
      KK=IZ(K)
  100 PRINT 21,IZ(K),IELEM(KK),IMASS(K),META(K),(DFL(K,J),J=1,7),(DFA(K,
     CJ),J=1,7)
      PRINT 23,NLIBC
 1000 RETURN
      END
```

```
      SUBROUTINE SOURCE(UML)                                            SOURCE     2
      COMMON Q(200),PL,CFS,NSUR,LT,RECO(200),LIST(200,4),LCT,LZ ,CON,KIT SOURCE     5
     + ,POP                                                             SOURCE     6
      COMMON/DFL16/DFL(300,7),DFA(300,7),EXG(300,2),TAU(300),EXS(300,2), SOURCE     7
     +EFF(300,8)                                                        SOURCE     8
      COMMON/SORCE/IZ(300),IMASS(300),META(300),NLIBA,NLIBT,NLIBC,NLIBI SOURCE     9
      COMMON/ELEMEN/IELEM(100)                                          SOURCE    10
      DIMENSION IM(5),NUM(12),ISUR(20)                                  BNL01      7
      DATA NUM/' ','0','1','2','3','4','5','6','7','8','9','M'/         SOURCE    12
   11 FORMAT(8E10.0)                                                    SOURCE    13
   12 FORMAT(2X,19A4,A2)                                                BNL01      8
   13 FORMAT('  GRIEF ',A2,5A1,1PE10.2)                                 SOURCE    15
   21 FORMAT(2X,A2,5A1,1X,E10.0)                                        SOURCE    16
   22 FORMAT(1H ,I4,A2,I4,A1,1X,1P12F9.2)                               SOURCE    17
   23 FORMAT(1H0,'TOTAL NUMBER IN SOURCE TERM IS ',I4,5X,'TOTAL RELEASE SOURCE    18
     +IS ',1PE10.4)                                                     SOURCE    19
   30 FORMAT(1H ,'NUCLIDE  CURIE/YEAR    BONE    LIVER  TOTAL BODY  THYR SOURCE    20
     +OID  KIDNEY    LUNG     GI-LLI     SKIN  TOTAL BODY   RECON')     SOURCE    21
   31 FORMAT(1H0,21X,'______________________INGESTION DOSE FACTORS_______ SOURCE    22
     +____________ ______SHORELINE______')                              SOURCE    23
   35 FORMAT(1H ,45X,'(MREM/PCI INTAKE)',22X,'(MREM/HR)/(PCI/M**2)')    SOURCE    24
   32 FORMAT(1H1,30X,'*   *   *   TEENAGER DOSE FACTORS   *   *   *')   SOURCE    25
   33 FORMAT(1H0,30X,'*   *   *   CHILD DOSE FACTORS   *   *   *')      SOURCE    26
   34 FORMAT(1H0,30X,'*   *   *   INFANT DOSE FACTORS   *   *   *')     SOURCE    27
   36 FORMAT(1H0,30X,'*  *  *  ADULT DOSE FACTORS  *  *  *')            SOURCE    28
      READ 12,ISUR                                                      SOURCE    29
      PRINT 12,ISUR                                                     SOURCE    30
      I=0                                                               SOURCE    31
      QT=0.                                                             SOURCE    32
   75 I=I+1                                                             SOURCE    33
      READ 21,IA,IM,QQ                                                  SOURCE    34
      IF(QQ)101,101,76                                                  SOURCE    35
   76 K=-1                                                              SOURCE    36
      MASS=0                                                            SOURCE    37
      MET=NUM(1)                                                        SOURCE    38
      DO 90 JJ=1,5                                                      SOURCE    39
      J=6-JJ                                                            SOURCE    40
      IF(IM(J).EQ.NUM(1))GOTO 90                                        SOURCE    41
      IF(IM(J).NE.NUM(12))GOTO 78                                       SOURCE    42
      MET=NUM(12)                                                       SOURCE    43
      GOTO 90                                                           SOURCE    44
   78 K=K+1                                                             SOURCE    45
      DO 80 L=2,11                                                      SOURCE    46
   80 IF(NUM(L).EQ.IM(J))GOTO 85                                        SOURCE    47
      PRINT 13,IA,IM,QQ                                                 SOURCE    48
      I=I-1                                                             SOURCE    49
      GOTO 75                                                           SOURCE    50
   85 MASS=MASS+(L-2)*10.**K                                            SOURCE    51
   90 CONTINUE                                                          SOURCE    52
C** FIND Z OF NUCLIDE                                                   SOURCE    53
      DO 91 IK=1,100                                                    SOURCE    54
   91 IF(IELEM(IK).EQ.IA)GOTO 92                                        SOURCE    55
      PRINT 13,IA,IM,QQ                                                 SOURCE    56
      I=I-1                                                             SOURCE    57
      GOTO 75                                                           SOURCE    58
C** FINE NUCLIDE IN ADULT LIBRARY                                       SOURCE    59
   92 DO 95 LL=1,NLIBA                                                  SOURCE    60
```

```
      IF(IZ(LL).NE.IK)GOTO 95                                   SOURCE   61
      IF(IMASS(LL).NE.MASS)GOTO 95                              SOURCE   62
      IF(META(LL).NE.MET)GOTO 95                                SOURCE   63
      GOTO 96                                                   SOURCE   64
   95 CONTINUE                                                  SOURCE   65
      I=I-1                                                     SOURCE   66
      PRINT 13,IA,IM,QQ                                         SOURCE   67
      GOTO 75                                                   SOURCE   68
   96 LIST(I,1)=LL                                              SOURCE   69
C** FIND NUCLIDE IN TEENAGER LIBRARY                             SOURCE   70
      K1=NLIBA+1                                                SOURCE   71
      DO 97 LL=K1,NLIBT                                         SOURCE   72
      IF(IZ(LL).NE.IK)GOTO 97                                   SOURCE   73
      IF(IMASS(LL).NE.MASS)GOTO 97                              SOURCE   74
      IF(META(LL).NE.MET)GOTO 97                                SOURCE   75
      GOTO 98                                                   SOURCE   76
   97 CONTINUE                                                  SOURCE   77
      LIST(I,2)=LIST(I,1)                                       SOURCE   78
      GOTO 99                                                   SOURCE   79
   98 LIST(I,2)=LL                                              SOURCE   80
      DFL(LL,5)=DFL(LIST(I,1),5)                                SOURCE   81
      DFA(LL,5)=DFA(LIST(I,1),5)                                SOURCE   82
C** FIND NUCLIDE IN CHILD DOSE FACTOR LIBRARY                    SOURCE   83
   99 K1=NLIBT+1                                                SOURCE   84
      DO 106 LL=K1,NLIBC                                        SOURCE   85
      IF(IZ(LL).NE.IK)GOTO 106                                  SOURCE   86
      IF(IMASS(LL).NE.MASS)GOTO 106                             SOURCE   87
      IF(META(LL).NE.MET)GOTO 106                               SOURCE   88
      GOTO 107                                                  SOURCE   89
  106 CONTINUE                                                  SOURCE   90
      LIST(I,3)=LIST(I,2)                                       SOURCE   91
      GOTO 108                                                  SOURCE   92
  107 LIST(I,3)=LL                                              SOURCE   93
      DFL(LL,5)=DFL(LIST(I,1),5)                                SOURCE   94
      DFA(LL,5)=DFA(LIST(I,1),5)                                SOURCE   95
  108 CONTINUE                                                  SOURCE   96
C** FIND NUCLIDE IN INFANT DOSE FACTOR LIBRARY                   SOURCE   97
      K1=NLIBC+1                                                SOURCE   98
      DO 110 LL=K1,NLIBI                                        SOURCE   99
      IF(IZ(LL).NE.IK)GO TO 110                                 SOURCE  100
      IF(IMASS(LL).NE.MASS)GO TO 110                            SOURCE  101
      IF(META(LL).NE.MET)GO TO 110                              SOURCE  102
      GO TO 115                                                 SOURCE  103
  110 CONTINUE                                                  SOURCE  104
      LIST(I,4)=LIST(I,3)                                       SOURCE  105
      GO TO 120                                                 SOURCE  106
  115 LIST(I,4)=LL                                              SOURCE  107
      DFL(LL,5)=DFL(LIST(I,1),5)                                SOURCE  108
      DFA(LL,5)=DFA(LIST(I,1),5)                                SOURCE  109
  120 CONTINUE                                                  SOURCE  110
      QT=QT+QQ                                                  SOURCE  111
      Q(I)=QQ*UML                                               SOURCE  112
      GOTO 75                                                   SOURCE  113
  101 NSOR=I-1                                                  SOURCE  114
C** PRINT OUT SOURCE TERM                                        SOURCE  115
C**CALCULATES ANY RECONCENTRATION OF RADIONUCLIDES               SOURCE  116
      CALL RECON                                                SOURCE  117
```

```
         PRINT 36                                                       SOURCE   118
         PRINT 31                                                       SOURCE   119
         PRINT 35                                                       SOURCE   120
         PRINT 30                                                       SOURCE   121
         DO 105 I=1,NSUR                                                SOURCE   122
         LL=LIST(I,1)                                                   SOURCE   123
         IK=IZ(LL)                                                      SOURCE   124
     105 PRINT 22,IK,IELEM(IK),IMASS(LL),META(LL),Q(I),(DFL(LL,J),J=1,7), SOURCE   125
        +EXG(LL,1),EXG(LL,2),RECU(I)                                    SOURCE   126
         DO 210 JT=2,4                                                  SOURCE   127
         IF(JT.EQ.4) PRINT 34                                           SOURCE   128
         IF(JT.EQ.3) PRINT 33                                           SOURCE   129
         IF(JT.EQ.2) PRINT 32                                           SOURCE   130
         PRINT 31                                                       SOURCE   131
         PRINT 35                                                       SOURCE   132
         PRINT 30                                                       SOURCE   133
         DO 200 I=1,NSUR                                                SOURCE   134
         LL=LIST(I,1)                                                   SOURCE   135
         IK=IZ(LL)                                                      SOURCE   136
         LA=LIST(I,JT)                                                  SOURCE   137
         IF(LA.EQ.LL) GO TO 200                                         SOURCE   138
         PRINT 22,IK,IELEM(IK),IMASS(LL),META(LL),Q(I),(DFL(LA,J),J=1,7) SOURCE   139
     200 CONTINUE                                                       SOURCE   140
     210 CONTINUE                                                       SOURCE   141
         QT=QT*UML                                                      SOURCE   142
         PRINT 23,NSOR,QT                                               SOURCE   143
         RETURN                                                         SOURCE   144
         END                                                            SOURCE   145
```

```
      SUBROUTINE RECON                                                    RECON    2
      COMMON Q(200),PL,CFS,NSUR,LT,RECO(200),LIST(200,4),LCT,LZ ,CON,KIT  RECON    3
     + ,PUP                                                               RECON    4
      COMMON/DFLIB/DFL(300,7),DFA(300,7),EXG(300,2),TAU(300),EXS(300,2),  RECON    5
     +EFF(300,8)                                                          RECON    6
      COMMON/SORCE/IZ(300),IMASS(300),META(300),NLIBA,NLIBT,NLIBC,NLIBI   RECON    7
      REAL MAKE                                                           RECON    8
   10 FORMAT(I10,5F10.2)                                                  RECON    9
   15 FORMAT(1H0,'NO RECONCENTRATION OF NUCLIDES ')                       RECON   10
   16 FORMAT(1H0,'RECONCENTRATION--  MAKE-UP=',1PE8.2,5X,'CYCLE TIME=',   RECON   11
     +E8.2,' HR',5X,'VOL OF POND=',E8.2,' FT**3',/,20X,'TURNOVER RATE=',  RECON   12
     +E8.2,' /HR',5X,'COOLANT FLOW=',E8.2,' CFS')                         RECON   13
   17 FORMAT(1H0,'RECONCENTRATION--   CYCLE TIME=',F10.2,' HR',5X,'RECYC  RECON   14
     +LE FRACTION=',F10.2)                                                RECON   15
      READ(5,10)M,MAKE,CT,VOL,TR,RF                                       RECON   16
      IF(M.EQ.0)WRITE(6,15)                                               RECON   17
      IF(M.EQ.1)WRITE(6,16)MAKE,CT,VOL,TR,CFS                             RECON   18
      IF(M.EQ.2)WRITE(6,17)CT,RF                                          RECON   19
      IF(M.EQ.0)GO TO 100                                                 RECON   20
      IF(M-1)20,20,30                                                     RECON   21
   20 DO 50 J=1,NSUR                                                      RECON   22
      MO=LIST(J,1)                                                        RECON   23
      ARGU=TAU(MO)*CT                                                     RECON   24
      IF(ARGU.GT.100.)ARGU=100.                                           RECON   25
   50 RECO(J)=1./(1.-((CFS-MAKE)*EXP(-ARGU))/(CFS+VOL*TR/3600.))          RECON   26
      RETURN                                                              RECON   27
   30 TOTC=PL*365.25*24./CT                                               RECON   28
      N=1+INT(TOTC)                                                       RECON   29
      DO 60 J=1,NSUR                                                      RECON   30
      MO=LIST(J,1)                                                        RECON   31
      ARGU=TAU(MO)*CT                                                     RECON   32
      IF(ARGU.GT.100.)ARGU=100.                                           RECON   33
      STEW=RF*EXP(-ARGU)                                                  RECON   34
      TEST=TOTC*ALOG(STEW)                                                RECON   35
      IF(TEST.LT.-11.51)GO TO 40                                          RECON   36
      STEW=STEW**N                                                        RECON   37
      GO TO 60                                                            RECON   38
   40 STEW=1.0E-05                                                        RECON   39
   60 RECO(J)=(1.-STEW)/(1.-(RF*EXP(-ARGU)))                              RECON   40
      RETURN                                                              RECON   41
  100 DO 70 J=1,NSOR                                                      RECON   42
   70 RECO(J)=1.                                                          RECON   43
      RETURN                                                              RECON   44
      END                                                                 RECON   45
```

```
      SUBROUTINE ALARA (ACCF,ACCI,ACCA)                                 ALARA       2
      COMMON Q(200),PL,CFS,NSUR,LT,RECO(200),LIST(200,4),LCT,LZ ,CON,KIT ALARA      3
     + ,POP                                                             ALARA       4
      DIMENSION ACCF(100),ACCI(100),ACCA(100)                           ALARA       5
      DIMENSION LUCA (3)                                                ALARA       6
C                                                                       ALARA       7
C                                                                       ALARA       8
C     PRINTS HEADINGS FOR THE APPENDIX I INDIVIDUAL                     ALARA       9
C      DOSE TABLES AND THE SELECTED LOCATION DOSE                       ALARA      10
C      TABLES-ALSO CALLS SUBROUTINE OUT WITH                            ALARA      11
C      THE CORRECT USAGE PARAMETERS FOR A                               ALARA      12
C      PARTICULAR AGE GROUP                                             ALARA      13
C                                                                       ALARA      14
C                                                                       ALARA      15
   10 FORMAT(1H1,35X,'*     *     *  AS LOW AS REASONABLY ACHIEVABLE  *  ALARA      16
     C *    *')                                                         ALARA      17
   20 FORMAT(1H ,55X,'MREM PER YEAR')                                   ALARA      18
   25 FORMAT(1H1)                                                       ALARA      19
   40 FORMAT(1H0,'PATHWAY                    SKIN            BONE         LI ALARA   20
     1VER     TOTAL BODY        THYROID          KIDNEY           LUNG  ALARA      21
     2      GI-LLI')                                                    ALARA      22
   50 FORMAT(1H0,17X,'____________________________________________DOSE ALARA      23
     +__(MREM PER YEAR INTAKE)______________________________________') ALARA      24
   60 FORMAT(1H0,20X,'A D U L T    D O S E S ')                         ALARA      25
   70 FORMAT(1H0,20X,'C H I L D   D O S E S ')                          ALARA      26
   80 FORMAT(1H0,20X,'T E E N A G E R    D O S E S ')                   ALARA      27
   90 FORMAT(1H0,20X,'I N F A N T    D O S E S ')                       ALARA      28
  160 FORMAT(1H0,'LOCATION IS ',3A4)                                    ALARA      29
C                                                                       ALARA      30
  100 FORMAT(I10,7E10.0)                                                ALARA      31
  110 FORMAT(7E10.0)                                                    ALARA      32
  130 FORMAT(1H1,35X,'*     *     *  SELECTED LOCATION  *     *     *') ALARA      33
  140 FORMAT(I10,3E10.0,3A4)                                            ALARA      34
      CON=1.0                                                           ALARA      35
      KK=0                                                              ALARA      36
  150 CONTINUE                                                          ALARA      37
      DATA TDF,TDC,TDA,TDW,TDS,TDSW,TDB/0.0,0.0,0.0,510.,0.0,0.0,0.0/   ALARA      38
      DATA CHF,CHC,CHA,CHW,CHS,CHSW,CHB/6.9,0.0,0.0,510.,14.,0.0,0.0/   ALARA      39
      IF(LT.GT.0) CHC=1.7                                               ALARA      40
      DATA TAF,TAC,TAA,TAW,TAS,TASW,TAB/16.,0.0,0.0,510.,67.,0.0,0.0/   ALARA      41
      IF(LT.GT.0) TAC=3.8                                               ALARA      42
      DATA FIUS,CRUS,ALUS,WUSE,SHU,SWU,BUSE/21.,0.,0.,730.,12.,0.,0./   ALARA      43
C                                                                       ALARA      44
      IF(LT.GT.0)CRUS=5.0                                               ALARA      45
      IF(KK.EQ.0)READ 100,N,SWF,DILU,SHD,DWD,T,TD                       ALARA      46
      IF(KK.GT.0) READ 140,N,DILU,T,SWF,(LOCA(J),J=1,3)                 ALARA      47
      IF (N.EQ.0)GO TO 120                                              ALARA      48
      READ 110,FIUS,CRUS,ALUS,WUSE,SHU,SWU,BUSE                         ALARA      49
      READ 110,TAF,TAC,TAA,TAW,TAS,TASW,TAB                             ALARA      50
      READ 110,CHF,CHC,CHA ,CHW,CHS,CHSW,CHB                            ALARA      51
      READ 110,TDF,TDC,TDA,TDW,TDS,TDSW,TDB                             ALARA      52
  120 CONTINUE                                                          ALARA      53
      IF(DILU.EQ.0.)GO TO 200                                           ALARA      54
      IF(KK.GT.0) PRINT 130                                             ALARA      55
      IF(KK.EQ.0)PRINT 10                                               ALARA      56
      IF(KK.GT.1)SHD=DILU                                               ALARA      57
       SHD=SHD                                                          ALARA      58
```

```
      BOIL=DILU                                                         ALARA    59
      IF(KK.GT.1)DWD=DILU                                               ALARA    60
      IF(KK.GT.1) PRINT 160,LUCA                                        ALARA    61
      IF(KK.GT.1) TD=T                                                  ALARA    62
C                                                                       ALARA    63
      PRINT 60                                                          ALARA    64
      PRINT 50                                                          ALARA    65
      PRINT 40                                                          ALARA    66
      CALL OUT(1,ACCF,ACCI,ACCA,T,FIUS,CRUS,ALUS,HUSE,SHU,SWU,BUSE,DILU, ALARA    67
     +DWD,SHD,SWD,BOIL,SWF,KK,N,TD)                                     ALARA    68
      IF(KK.GT.0.AND.LCT.GT.0)PRINT 130                                 ALARA    69
      IF(KK.GT.1) PRINT 160,LUCA                                        ALARA    70
      IF(KK.EQ.0.AND.LCT.GT.0)PRINT 10                                  ALARA    71
      PRINT 80                                                          ALARA    72
      PRINT 50                                                          ALARA    73
      PRINT 40                                                          ALARA    74
      CALL OUT(2,ACCF,ACCI,ACCA,T,TAF,TAC,TAA,TAW,TAS,TASW,TAB,DILU,DWD, ALARA    75
     +SHD,SWD,BOIL,SWF,KK,N,TD)                                         ALARA    76
      IF(KK.GT.0.AND.LCT.GT.0)PRINT 130                                 ALARA    77
      IF(KK.GT.1) PRINT 160,LUCA                                        ALARA    78
      IF(KK.EQ.0.AND.LCT.GT.0)PRINT 10                                  ALARA    79
      PRINT 70                                                          ALARA    80
      PRINT 50                                                          ALARA    81
      PRINT 40                                                          ALARA    82
      CALL OUT(3,ACCF,ACCI,ACCA,T,CHF,CHC,CHA,CHW,CHS,CHSW,CHB,DILU,DWD, ALARA    83
     +SHD,SWD,BOIL,SWF,KK,N,TD)                                         ALARA    84
      IF(TDW.EQ.0..OR.LT.GT.0) GO TO 145                                ALARA    85
      IF(KK.GT.0.AND.LCT.GT.0)PRINT 130                                 ALARA    86
      IF(KK.GT.1) PRINT 160,LUCA                                        ALARA    87
      IF(KK.EQ.0.AND.LCT.GT.0)PRINT 10                                  ALARA    88
      PRINT 90                                                          ALARA    89
      PRINT 50                                                          ALARA    90
      PRINT 40                                                          ALARA    91
      CALL OUT(4,ACCF,ACCI,ACCA,T,TDF,TDC,TDA,TDW,TDS,TDSW,TDB,DILU,DWD, ALARA    92
     +SHD,SWD,BOIL,SWF,KK,N,TD)                                         ALARA    93
  145 KK=KK+2                                                           ALARA    94
      GO TO 150                                                         ALARA    95
  200 CONTINUE                                                          ALARA    96
      RETURN                                                            ALARA    97
      END                                                               ALARA    98
```

```
      SUBROUTINE OUT(KOP,ACCF,ACCI,ACCA,T,FIUS,CRUS,ALUS,WUSE,SHU,SWU,BU OUT     2
     +SE,DILU,DWD,SHD,SWD,BDIL,SWF,KK,N,TD)                              OUT     3
      COMMON D(200),PL,CFS,NSUR,LT,RECD(200),LIST(200,4),LCT,LZ ,CON,KIT OUT     4
     + ,POP                                                              OUT     5
      DIMENSION W(3),X(3),Y(3),Z(3),H(3),FDOSE(8),CDOSE(8),ADUSE(8),SDOS OUT     6
     1E(8),SWDO(8),BDOSE(8),TDOSE(8),A(3),B(3),C(3),WDOSE(8)             OUT     7
      DIMENSION ACCF(100),ACCI(100),ACCA(100),DOSE(200,8)                OUT     8
C                                                                        OUT     9
C                                                                        OUT    10
C       CONTROLS THE CALLING OF THE CALCULATIONAL SUBROUTINES WITH THE   OUT    11
C       APPROPRIATE USAGE PARAMETERS FOR THE PARTICULAR AGE GROUP        OUT    12
C                                                                        OUT    13
C                                                                        OUT    14
      DATA Y/'TOTA','L   ','    '/                                       OUT    15
      DATA X/'INVE','RTEB','RATE'/                                       OUT    16
      DATA Z/'ALGA','E   ','    '/                                       OUT    17
      DATA C/'BOAT','ING ','    '/                                       OUT    18
      DATA H/'DRIN','KING','    '/                                       OUT    19
      DATA W/'FISH','    ','    '/                                       OUT    20
      DATA A/'SHOR','ELIN','E   '/                                       OUT    21
      DATA B/'SWIM','MING','    '/                                       OUT    22
   10 FORMAT(1H ,3A4,15X,1P7E15.2)                                       BNL01   9
   20 FORMAT(1H ,3A4,1P8E15.2)                                           OUT    24
      T2=T+24.                                                           OUT    25
      T3=TD+12.                                                          OUT    26
      LZ=0                                                               OUT    27
      KIT=0                                                              OUT    28
      CALL AQUA(W,DILU,FIUS,T2,FDOSE,KOP,ACCF)                           OUT    29
      PRINT 10,W,(FDOSE(J),J=2,8)                                        OUT    30
      CALL AQUA(X,DILU,CRUS,T2,CDOSE,KOP,ACCI)                           OUT    31
      IF(CRUS.GT.0.0) PRINT 10,X,(CDOSE(J),J=2,8)                        OUT    32
      CALL AQUA(Z,DILU,ALUS,T2,ADOSE,KOP,ACCA)                           OUT    33
      IF(ALUS.GT.0.0) PRINT 10,Z,(ADOSE(J),J=2,8)                        OUT    34
      CALL DRINK(DWD,T3,WUSE,WDOSE,KOP)                                  OUT    35
      IF(LT.EQ.0) PRINT 10,H,(WDOSE(J),J=2,8)                            OUT    36
      CALL SHORE(A,SWF,SHD,T,SHU,SDOSE)                                  OUT    37
      PRINT 20,A,SDOSE                                                   OUT    38
      GEOM=1.                                                            OUT    39
      CALL SWIM(B,SWD,T,SWU,GEOM,SWDO)                                   OUT    40
      IF(SWU.GT.0.0) PRINT 20,B,SWDO                                     OUT    41
      GEOM=2.                                                            OUT    42
      CALL SWIM(C,BDIL,T,BUSE,GEOM,BDOSE)                                OUT    43
      IF(BUSE.GT.0.) PRINT 20,C,BDOSE                                    OUT    44
      DO 40 J=1,8                                                        OUT    45
   40 TDOSE(J)=FDOSE(J)+CDOSE(J)+ADOSE(J)+SDOSE(J)+WDOSE(J)+SWDO(J)+BDOS OUT    46
     1E(J)                                                               OUT    47
      PRINT 20,Y,TDOSE                                                   OUT    48
   60 FORMAT(1H0,12X,'USAGE (KG/YR,HR/YR)            DILUTION      TIME(HR OUT    49
     +)',10X,'SHOREWIDTH FACTOR=',F3.1)                                  OUT    50
   70 FORMAT(1H ,3A4,7X,F8.1,10X,F10.1,3X,F10.2)                         OUT    51
      PRINT 60,SWF                                                       OUT    52
      PRINT 70,W,FIUS, DILU,T2                                           OUT    53
      IF(CRUS.GT.0.) PRINT 70,X,CRUS,DILU,T2                             OUT    54
      IF(ALUS.GT.0.) PRINT 70,Z,ALUS,DILU,T2                             OUT    55
      IF(WUSE.GT.0..AND.LT.EQ.0) PRINT 70,H,WUSE,DWD,T3                  OUT    56
      IF(SHU.GT.0.0) PRINT 70,A,SHU,SHD,T                                OUT    57
      IF(SWU.GT.0.0) PRINT 70,B,SWU,SWD,T                                OUT    58
```

```
      IF(BUSE.GT.0.0) PRINT 70,C,BUSE,BOIL,T                            OUT     59
      KIT=10                                                            OUT     60
   80 CONTINUE                                                          OUT     61
      IF(LCT.GT.0)CALL PERDOS(W,TDOSE,DOSE)                             OUT     62
      RETURN                                                            OUT     63
      END                                                               OUT     64
```

```
      SUBROUTINE WHO(ACCF,ACCI,ACCA)
      COMMON Q(200),PL,CFS,NSUR,LT,RECO(200),LIST(200,4),LCT,LZ ,CON,KIT
     + ,POP
      DIMENSION EXT(8),EXI(8),TDOSE(8),TYPE(3),A(3),B(3),C(3),D(3),W(3),
     CX(3),Z(3),ACCF(100),ACCI(100),ACCA(100)
C
C
C      CONTROLS THE CALLING  OF THE CALCULATIONAL SUBROUTINES FOR THE
C      PRIMARY AND SECONDARY BIOTA DOSES
C
C
      DATA CSWF/2.0/
      DATA RAT,RAC,HERON,DUCK/6.,14.,11.,5./
      DATA RATMAS,RACMAS,HERMAS,DUCMAS/1000.,12000.,4600.,1000./
      DATA RATUSE,RACUSE,HERUSE,DUCUSE/100.,200.,600.,100./
C      BIOTA TYPES
      DATA A/'MUSK','RAT ','    '/
      DATA B/'RACC','OON ','    '/
      DATA C/'HERO','N   ','    '/
      DATA D/'DUCK','    ','    '/
      DATA W/'FISH','    ','    '/
      DATA X/'INVE','RTEB','RATE'/
      DATA Z/'ALGA','E   ','    '/
   70 FORMAT(1H0,'_______________________________________________________')
   20 FORMAT(1H ,3A4,1P3E15.2)
   60 FORMAT('DILUTION=',1PE10.2,10X,'TRANSIT TIME=',E10.2,' HR')
   10 FORMAT(1H1,'*     *     *  DOSE TO BIOTA  *     *     *')
   30 FORMAT(1H0,20X,'MRADS PER YEAR')
   40 FORMAT(1H0,19X,'INTERNAL        EXTERNAL         TOTAL')
   50 FORMAT(8E10.0)
      CON=1.
      PRINT 10
      PRINT 30
   80 READ 50,DILU,T
      IF(DILU.EQ.0.)GO TO 100
      KIT=0
      LZ=0
      PRINT 70
      PRINT 60,DILU,T
      PRINT 40
      CALL CRITTR(W,DILU,T,TDOSE,ACCF)
      CALL SHORE(TYPE,CSWF,DILU,T,4380.,EXT)
      CALL SWIM(TYPE,DILU,T,8760.,1.,EXI)
      TEXT=EXT(2)+EXI(2)
      TOT=TEXT+TDOSE(1)
      PRINT 20,W,TDOSE(1),TEXT,TOT
      CALL CRITTR(X,DILU,T,TDOSE,ACCI)
      CALL SHORE(TYPE,CSWF,DILU,T,8760.,EXT)
      CALL SWIM (TYPE,DILU,T,8760.,1.,EXI)
      TEXT=EXT(2)+EXI(2)
      TOT=TEXT+TDOSE(1)
      PRINT 20,X,TDOSE(1),TEXT,TOT
      CALL CRITTR(Z,DILU,T,TDOSE,ACCA)
      CALL SWIM(TYPE,DILU,T,8760.,1.,EXI)
      TOT=EXI(2)+TDOSE(1)
      PRINT 20,Z,TDOSE(1),EXI(2),TOT
      CALL EAT(A,RAT,RATMAS,RATUSE,DILU,T,TDOSE,ACCA)
```

```
      CALL SHORE(TYPE,CSWF,DILU,T,2922.,EXT)                WHO   59
      CALL SWIM(TYPE,DILU,T,2922.,1.,EXI)                   WHO   60
      TEXT=EXT(2)+EXI(2)                                    WHO   61
      TOT=TEXT+TDUSE(1)                                     WHO   62
      PRINT 20,A,TDUSE(1),TEXT,TOT                          WHO   63
      CALL EAT(B,RAC,RACMAS,RACUSE,DILU,T,TDOSE,ACCI)       WHO   64
      CALL SHORE(TYPE,CSWF,DILU,T,2191.,EXT)                WHO   65
      TOT=EXT(2)+TDUSE(1)                                   WHO   66
      PRINT 20,B,TDUSE(1),EXT(2),TOT                        WHO   67
      CALL EAT(C,HERON,HERMAS,HERUSE,DILU,T,TDOSE,ACCF)     WHO   68
      CALL SHORE(TYPE,CSWF,DILU,T,2922.,EXT)                WHO   69
      CALL SWIM(TYPE,DILU,T,2920.,2.,EXI)                   WHO   70
      TEXT=EXT(2)+EXI(2)                                    WHO   71
      TOT=TEXT+TDUSE(1)                                     WHO   72
      PRINT 20,C,TDUSE(1),TEXT,TOT                          WHO   73
      CALL EAT(D,DUCK,DUCMAS,DUCUSE,DILU,T,TDOSE,ACCA)      WHO   74
      CALL SHORE(TYPE,CSWF,DILU,T,4383.,EXT)                WHO   75
      TEXT=EXT(2)+EXI(2)*3./2.                              WHO   76
      TOT=TEXT+TDUSE(1)                                     WHO   77
      PRINT 20,D,TDUSE(1),TEXT,TOT                          WHO   78
      KIT=70                                                WHO   79
      IF(LCT.GT.0) CALL PERDOS(A,TDUSE,DOSE)                WHO   80
      GO TO 80                                              WHO   81
  100 CONTINUE                                              WHO   82
      RETURN                                                WHO   83
       END                                                  WHO   84
```

```
      SUBROUTINE WHY(ACC,I,N)
      COMMON/POPUL/PERA,PERT,PERC,US
      COMMON Q(200),PL,CFS,NSUR,LT,RECO(200),LIST(200,4),LCT,LZ ,CON,KIT
     + ,PUP
      DIMENSION ACC(100),X(3),W(3),CATH(20),DILU(20),T(20),TDOSE(8),DOSE
     +(200,8),A(3),B(3),C(3),TYPE(3),CONC(200)
      DIMENSION D(3),PD(7)
C
C
C      CONTROLS THE CALCULATION OF THE SPORT
C      AND COMMERCIAL FISH AND INVERTEBRATE
C      POPULATION DOSES-ACTUAL CALCULATIONS
C      DONE BY SUBROUTINES PAFD AND CENT
C
C
      DATA X/'INVE','R   ','    '/
      DATA W/'FISH','    ','    '/
      DATA A/'ADUL','T   ','    '/
      DATA B/'TEEN','AGER','    '/
      DATA C/'CHIL','D   ','    '/
      DATA D/'TOTA','L   ','    '/
   15 FORMAT(1H ,6A4,1P8E10.2)
   20 FORMAT(1H0,'PATHWAY        AGE GROUP     USAGE      BONE      LIVER
     + TOTAL BODY  THYROID   KIDNEY      LUNG    GI-LLI')
   30 FORMAT(1H0,34X,'----------------------------DOSE (MAN-REM)--------
     +-------------------')
   60 FORMAT(1H0,' DILUTION    CATCH    TIME(HR)-INCLUDES FOOD PROCESSING
     + TIME OF ',1PE8.2,' HR',5X,'POPULATION=',E8.2)
   61 FORMAT(1H ,53X,'MAN-REM')
   64 FORMAT(1H1,35X,'*  *  *  INVERTEBRATE CONSUMPTION POPULATION DOSES
     +  *  *  *')
   65 FORMAT(1H1,35X,'*  *  *  FISH CONSUMPTION POPULATION DOSES  *  *
     +*')
   66 FORMAT(1H0,'__________SPORTFISH HARVEST__________')
   67 FORMAT(1H0,'__________COMMERCIAL HARVEST__________')
   68 FORMAT(1H0,'__________NEPA DOSES__________')
   69 FORMAT(1H0,'NOTE--TOTAL NEPA DOSE MUST INCLUDE SPORT CATCH, DOSES
     +BELOW ARE FOR COMMERCIAL CATCH ONLY')
   70 FORMAT(8E10.2)
   71 FORMAT(1H ,1P8E10.2)
   75 FORMAT(1H0,'AVERAGE INDIVIDUAL CONSUMPTION (KG/YR)    ADULT=',
     +1PE8.2,5X,'TEEN=',E8.2,5X,'CHILD=',E8.2)
      P(AMT,AU,TU,CU)=AMT/(AU*PERA+TU*PERT+CU*PERC)
      AUSE(PEO,AU)=PEO*PERA*AU
      TUSE(PEO,TU)=PEO*PERT*TU
      CUSE(PEO,CU)=PEO*PERC*CU
      CUN=1000.
      LN=0
      IF(N.EQ.1) NN=1
      IF(N.EQ.2) NN=2
      IF(I.EQ.1.AND.LT.EQ.0) HARV=44.0E+06
      IF(I.EQ.2.AND.LT.EQ.0) HARV=2.30E+06
      IF(I.EQ.1.AND.LT.GT.0) HARV=6.58E+08
      IF(I.EQ.2.AND.LT.GT.0) HARV=4.10E+08
      IF(N.EQ.1) FPT=168.
      IF(N.EQ.2) FPT=240.
      J=1
```

```
   80 READ 70,CATH(J),DILU(J),T(J)
      T(J)=T(J)+FPT
      J=J+1
      M=J-1
      IF(DILU(M).EQ.0.) GO TO 85
      GO TO 80
   85 M=M-1
      IF(M.EQ.0) GO TO 100
      IF(I.EQ.1)PRINT 65
      IF(I.EQ.2)PRINT 64
      PRINT 61
      IF(N.EQ.1)PRINT66
      IF(N.EQ.2)PRINT 67
      PRINT 30
      PRINT 20
      GO TO (21,22),I
      GO TO 100
   21 AU=6.9
      TU=5.2
      DO 17 J=1,3
   17 TYPE(J)=W(J)
      CU=2.2
      GO TO 86
   22 AU=1.
      TU=0.75
      CU=0.33
      DO 16 J=1,3
   16 TYPE(J)=X(J)
      GO TO 86
   86 AMT=0.
      IF(N.EQ.1) NL=1
      IF(N.EQ.2) NL=2
      DO 87 IN=1,M
   87 AMT=AMT+CATH(IN)
      IF(N.EQ.1)PEO=P(AMT,AU,TU,CU)
      IF(N.EQ.2)PEO=POP
   88 LZ=0
      KIT=0
      USE=AUSE(PEO,AU)
      CALL CENT(T,CATH,DILU,M,CONC,AMT,HARV,NL)
      CALL PAFD(TYPE,ACC,CONC,1,USE,TDOSE,NN,LM)
      PRINT 15,TYPE,A,USE,(TDOSE(JK),JK=1,7)
      DO 89 J=1,7
   89 PD(J)=TDOSE(J)
      SUM=USE
      USE=TUSE(PEO,TU)
      CALL PAFD(TYPE,ACC,CONC,2,USE,TDOSE,NN,LM)
      PRINT 15,TYPE,B,USE,(TDOSE(JK),JK=1,7)
      DO 91 J=1,7
   91 PD(J)=PD(J)+TDOSE(J)
      SUM=SUM+USE
      USE=CUSE(PEO,CU)
      CALL PAFD(TYPE,ACC,CONC,3,USE,TDOSE,NN,LM)
      PRINT 15,TYPE,C,USE,(TDOSE(JK),JK=1,7)
      DO 92 J=1,7
   92 PD(J)=PD(J)+TDOSE(J)
      SUM=SUM+USE
```

```
            PRINT 15,TYPE,D,SUM,(PD(J),J=1,7)                            WHY     116
            IF(LM.GT.0)GO TO 100                                         WHY     117
            PRINT 60,FPT,PFD                                             WHY     118
            DO 90 J=1,M                                                  WHY     119
         90 PRINT 71,DILU(J),CATH(J),T(J)                                WHY     120
            PRINT 75,AU,TU,CU                                            WHY     121
            KIT=30                                                       WHY     122
            IF(LCT.GT.0)CALL PERDOS(W,TDOSE,DOSE)                        WHY     123
            IF(N.EQ.1)GO TO 100                                          WHY     124
            LM=10                                                        WHY     125
            NL=1                                                         WHY     126
            PRINT 68                                                     WHY     127
            PRINT 69                                                     WHY     128
            PRINT 30                                                     WHY     129
            PRINT 20                                                     WHY     130
            PED=P(AMT,AU,TU,CU)                                          WHY     131
            GO TO 88                                                     WHY     132
        100 CONTINUE                                                     WHY     133
            RETURN                                                       WHY     134
            END                                                          WHY     135
```

CARD NR.	SEVERITY	DETAILS	DIAGNOSIS OF PROBLEM
73	I		AN IF STATEMENT MAY BE MORE EFFICIENT THAN A 2 OR 3 BRANCH COMPUTED GO TO STATEMENT.
74	I		THERE IS NO PATH TO THIS STATEMENT.

```
      SUBROUTINE WATER                                                  WATER    2
      COMMON Q(200),PL,CFS,NSUR,LT,RECO(200),LIST(200,4),LCT,LZ ,CON,KIT WATER    3
     + ,PUP                                                             WATER    4
      COMMON/POPUL/PERA,PERT,PERC,US                                    WATER    5
      COMMON/SORCE/IZ(300),IMASS(300),META(300),NLIBA,NLIBT,NLIBC,NLIBI WATER    6
      DIMENSION TDOSE(8),A(3),B(3),C(3),D(3),TRI(3)                     WATER    7
      DIMENSION TYPE(3)                                                 WATER    8
      DIMENSION PD(8),CUM(8),E(3)                                       WATER    9
      DATA TRI/'WATE','R   ','    '/                                    WATER   10
      DATA D/'TOTA','L   ','    '/                                      WATER   11
      DATA E/'CUMU','L TO','TAL '/                                      WATER   12
      DATA A/'ADUL','T   ','    '/                                      WATER   13
      DATA B/'TEEN','AGER','    '/                                      WATER   14
      DATA C/'CHIL','D   ','    '/                                      WATER   15
      DATA TYPE/'DRIN','KING','    '/                                   WATER   16
   10 FORMAT(1H ,6A4,1P8E10.2)                                          WATER   17
   20 FORMAT(1H0,'PATHWAY          AGE GROUP     USAGE      BONE      LIVER WATER   18
     + TOTAL BODY  THYROID    KIDNEY      LUNG    GI-LLI')              WATER   19
   30 FORMAT(1H1,35X,'*  *  *  POPULATION WATER CONSUMPTION DOSES  *  * WATER   20
     + *')                                                              WATER   21
   35 FORMAT(1H0,34X,'----------------------------DOSE (MAN-REM)-------- WATER   22
     +--------------------')                                            WATER   23
   50 FORMAT(1H0,'______________________________________________________ WATER   24
     +_____________________________________________________________')  WATER   25
   55 FORMAT(1H0,'POPULATION=',1PE8.2,5X,'DILUTION=',E8.2,5X,'TRANSIT TI WATER   26
     +ME=',E8.2,' HR (INCLUDING 24 HR FOR TREATMENT FACILITY)')         WATER   27
   60 FORMAT(8E10.0)                                                    WATER   28
   65 FORMAT(1H0,'__________HYDROSPHERE TRITIUM DOSE__________')        WATER   29
   66 FORMAT(1H0,'-----CUMULATIVE TOTAL-----')                          WATER   30
   80 FORMAT(1H0,'AVERAGE INDIVIDUAL CONSUMPTION (L/YR)     ADULT=',    WATER   31
     +1PE8.2,5X,'TEEN=',E8.2,5X,'CHILD=',E8.2)                          WATER   32
      DATA AU/370./                                                     WATER   33
      DATA TU/260./                                                     WATER   34
      DATA CU/260./                                                     WATER   35
      AUSE(P,AU)=P*PERA*AU                                              WATER   36
      TUSE(P,TU)=P*PERT*TU                                              WATER   37
      CUSE(P,CU)=P*PERC*CU                                              WATER   38
      CON=1000.                                                         WATER   39
      DO 56 JM=1,8                                                      WATER   40
   56 CUM(JM)=0.0                                                       WATER   41
      EUS=0.0                                                           WATER   42
      PRINT 30                                                          WATER   43
   40 READ 60,P,DILU,T,GAL,GUS                                          WATER   44
      PRINT 50                                                          WATER   45
      IF(P.EQ.0..AND.GUS.GT.0.) P=GAL/GUS                               WATER   46
      IF(DILU.EQ.0)GO TO 100                                            WATER   47
      PRINT 35                                                          WATER   48
      PRINT 20                                                          WATER   49
      DO 41 JM=2,8                                                      WATER   50
   41 PD(JM)=0.0                                                        WATER   51
      T=T+24.                                                           WATER   52
      USE=AUSE(P,AU)                                                    WATER   53
      KIT=0                                                             WATER   54
      LZ=0                                                              WATER   55
      CALL DRINK(DILU,T,USE,TDOSE,1)                                    WATER   56
      PRINT 10,TYPE,A,USE,(TDOSE(JK),JK=2,8)                            WATER   57
      DO 42 JM=2,8                                                      WATER   58
```

```
      SUBROUTINE ACTIVE                                                 ACTIVE     2
      COMMON Q(200),PL,CFS,NSUR,LT,RECD(200),LIST(200,4),LCT,LZ ,CON,KIT ACTIVE     3
     + ,POP                                                             ACTIVE     4
      DIMENSION S(3),SW(3),D(3),A(3),B(3),C(3),TDOSE(8)                 ACTIVE     5
      DIMENSION LOCA(3)                                                 ACTIVE     6
      DATA S/'SHOR','ELIN','E   '/                                      ACTIVE     7
      DATA SW/'SWIM','MING','    '/                                     ACTIVE     8
      DATA D/'BOAT','ING ','    '/                                      ACTIVE     9
      DATA A/'TOTA','L PO','PUL '/                                      ACTIVE    10
   80 FORMAT(1H0,'LOCATION= ',3A4)                                      ACTIVE    11
   15 FORMAT(1H0,'DILUTION=',E8.2,10X,'TRANSIT TIME=',E8.2,' HR',10X,'SW ACTIVE    12
     +F=',F3.1)                                                         ACTIVE    13
   10 FORMAT(1H ,6A4,1P7E15.2)                                          BNL01     10
   16 FORMAT(1H1,35X,'*    *    *   RECREATION POPULATION DOSES    *    * ACTIVE    15
     +*')                                                               ACTIVE    16
   20 FORMAT(1H0,'PATHWAY           AGE GROUP           USAGE          SKIN ACTIVE    17
     +          TOTAL BODY         THYROID')                            ACTIVE    18
   30 FORMAT(1H1,'*    *    *  POPULATION DOSES  *    *    *')          ACTIVE    19
   40 FORMAT(1H ,48X,'_______________DOSE(MAN-REM)_______________')     ACTIVE    20
   50 FORMAT(1H0,'________________________________________________________ ACTIVE    21
     +_______________________________________________________')         ACTIVE    22
   60 FORMAT(1H0,'DILUTION=',E8.2,10X,'TRANSIT TIME=',E8.2,' HR')       ACTIVE    23
   70 FORMAT(4E10.0,3A4)                                                ACTIVE    24
   75 FORMAT(3E10.0,3A4)                                                ACTIVE    25
      PRINT 16                                                          ACTIVE    26
      CON=1000.                                                         ACTIVE    27
      JL=10                                                             ACTIVE    28
  100 READ 70,SHU,DILU,T,SWF,(LOCA(J),J=1,3)                            ACTIVE    29
      PRINT 50                                                          ACTIVE    30
      IF(DILU.EQ.0.)GO TO 110                                           ACTIVE    31
      LZ=0                                                              ACTIVE    32
      PRINT 40                                                          ACTIVE    33
      KIT=0.                                                            ACTIVE    34
      PRINT 20                                                          ACTIVE    35
      CALL SHORE(S,SWF,DILU,T,SHU,TDOSE)                                ACTIVE    36
      PRINT 10,S,A,SHU,(TDOSE(J),J=1,3)                                 ACTIVE    37
      PRINT 80,LOCA                                                     ACTIVE    38
      PRINT 15,DILU,T,SWF                                               ACTIVE    39
      KIT=40                                                            ACTIVE    40
      IF(JL.LT.0)GO TO 100                                              ACTIVE    41
      IF(LCT.GT.0)CALL PERDOS(W,TDOSE,DOSE)                             ACTIVE    42
      JL=-10                                                            ACTIVE    43
      GO TO 100                                                         ACTIVE    44
  110 READ 75,SWU,DILU,T,(LOCA(J),J=1,3)                                ACTIVE    45
      PRINT 50                                                          ACTIVE    46
      IF(DILU.EQ.0.)GO TO 120                                           ACTIVE    47
      LZ=0                                                              ACTIVE    48
      KIT=0.                                                            ACTIVE    49
      PRINT 40                                                          ACTIVE    50
      PRINT 20                                                          ACTIVE    51
      GEOM=1.                                                           ACTIVE    52
      CALL SWIM(SW,DILU,T,SWU,GEOM,TDOSE)                               ACTIVE    53
      PRINT 10,SW,A,SWU,(TDOSE(J),J=1,3)                                ACTIVE    54
      PRINT 80,LOCA                                                     ACTIVE    55
      PRINT 60,DILU,T                                                   ACTIVE    56
      KIT=40                                                            ACTIVE    57
      IF(JL.GT.0)GO TO 110                                              ACTIVE    58
```

```
   42 PD(JM)=PD(JM)+TDOSE(JM)                                          WATER     59
      DO 57 JM=2,8                                                     WATER     60
   57 CUM(JM)=CUM(JM)+TDOSE(JM)                                        WATER     61
      TUS=USE                                                          WATER     62
      USE=TUSE(P,TU)                                                   WATER     63
      CALL DPINK(DILU,T,USE,TDOSE,2)                                   WATER     64
      PRINT 10,TYPE,B,USE,(TDOSE(JK),JK=2,8)                           WATER     65
      DO 43 JM=2,8                                                     WATER     66
   43 PD(JM)=PD(JM)+TDOSE(JM)                                          WATER     67
      DO 58 JM=2,8                                                     WATER     68
   58 CUM(JM)=CUM(JM)+TDOSE(JM)                                        WATER     69
      TUS=TUS+USE                                                      WATER     70
      USE=CUSE(P,CU)                                                   WATER     71
      CALL DPINK(DILU,T,USE,TDOSE,3)                                   WATER     72
      PRINT 10,TYPE,C,USE,(TDOSE(JK),JK=2,8)                           WATER     73
      DO 44 JM=2,8                                                     WATER     74
   44 PD(JM)=PD(JM)+TDOSE(JM)                                          WATER     75
      DO 59 JM=2,8                                                     WATER     76
   59 CUM(JM)=CUM(JM)+TDOSE(JM)                                        WATER     77
      TUS=TUS+USE                                                      WATER     78
      EUS=FUS+TUS                                                      WATER     79
      PRINT 10,TYPE,D,TUS,(PD(JM),JM=2,8)                              WATER     80
      KIT=20                                                           WATER     81
      PRINT 55,P,DILU,T                                                WATER     82
      PRINT 80,AU,TU,CU                                                WATER     83
      IF(LCT.GT.0) CALL PERDUS(TYPE,TDOSE,DOSE)                        WATER     84
      GO TO 40                                                         WATER     85
  100 CONTINUE                                                         WATER     86
      IF(PD(2).GT.0.0) PRINT 66                                        WATER     87
      IF(PD(2).GT.0.0) PRINT 20                                        WATER     88
      IF(PD(2).GT.0.0) PRINT 10,TYPE,E,EUS,(CUM(JM),JM=2,8)            WATER     89
      PRINT 65                                                         WATER     90
      PRINT 20                                                         WATER     91
      USE=2.2                                                          WATER     92
      DO 70 I=1,NSOR                                                   WATER     93
      M=LIST(I,1)                                                      WATER     94
      IF(M.EQ.1) CALL TRTIUM(Q(M),POP,H3B,H3T)                         WATER     95
      IF(M.EQ.1)PRINT 10,TRI,D,USE,H3B,H3T,H3B,H3B,H3B,H3B,H3B         WATER     96
   70 CONTINUE                                                         WATER     97
      RETURN                                                           WATER     98
      END                                                              WATER     99
```

```
      IF(LCT.GT.0)CALL PERDUS(W,TDOSE,DOSE)                 ACTIVE      59
      JL=10                                                 ACTIVE      60
      GO TO 110                                             ACTIVE      61
  120 READ 75,BUSE,DILU,T,(LOCA(J),J=1,3)                   ACTIVE      62
      PRINT 50                                              ACTIVE      63
      IF(DILU.EQ.0.)GO TO 130                               ACTIVE      64
      LZ=0                                                  ACTIVE      65
      KIT=0.                                                ACTIVE      66
      GEOM=2.0                                              ACTIVE      67
      PRINT 40                                              ACTIVE      68
      PRINT 20                                              ACTIVE      69
      CALL SWIM(D,DILU,T,BUSE,GEOM,TDOSE)                   ACTIVE      70
      PRINT 10,D,A,BUSE,(TDOSE(J),J=1,3)                    ACTIVE      71
      PRINT 80,LOCA                                         ACTIVE      72
      PRINT 60,DILU,T                                       ACTIVE      73
C                                                           ACTIVE      74
C                                                           ACTIVE      75
      GO TO 120                                             ACTIVE      76
  130 CONTINUE                                              ACTIVE      77
      RETURN                                                ACTIVE      78
      END                                                   ACTIVE      79
```

```
      SUBROUTINE AQUA (CRITR,DILU,USE,T,TDOSE,JJ,ACC)                    AQUA      2
      COMMON/DFLIB/DFL(300,7),DFA(300,7),EXG(300,2),TAU(300),EXS(300,2), AQUA      3
     +EFF(300,8)                                                         AQUA      4
      COMMON Q(200),PL,CFS,NSUR,LT,RECU(200),LIST(200,4),LCT,LZ ,CON,KIT AQUA      5
     + ,POP                                                              AQUA      6
      COMMON/SORCE/IZ(300),IMASS(300),META(300),NLIBA,NLIBT,NLIBC,NLIBI  AQUA      7
      DIMENSION ACC(100),TDOSE(8),DOSE(200,8),CRITR(3)                   AQUA      8
      DO 8 J=1,8                                                         AQUA      9
    8 TDOSE(J)=0.0                                                       AQUA     10
      IF(USE.EQ.0.)GO TO 50                                              AQUA     11
      DO 10 I=1,NSUR                                                     AQUA     12
      DOSE(I,1)=0.                                                       CHANGE1   1
      LL=LIST(I,JJ)                                                      AQUA     13
      LM=LIST(I,1)                                                       AQUA     14
      MO=IZ(LM)                                                          AQUA     15
      ARGU=TAU(LM)*T                                                     AQUA     16
      IF(ARGU.GT.20.)GO TO 20                                            AQUA     17
      FACT=1119.*Q(I)*RECU(I)/CFS/DILU*EXP(-ARGU)*USE*ACC(MO)/CON        AQUA     18
      GO TO 30                                                           AQUA     19
   20 FACT=0.0                                                           AQUA     20
   30 DO 40 J=2,8                                                        AQUA     21
      L=J-1                                                              AQUA     22
      DOSE(I,J)=DFL(LL,L)*FACT                                           AQUA     23
   40 TDOSE(J)=TDOSE(J)+DOSE(I,J)                                        AQUA     24
   10 CONTINUE                                                           AQUA     25
      IF(LCT.GT.0) CALL PERDOS(CRITR,TDOSE,DOSE)                         AQUA     26
   50 CONTINUE                                                           AQUA     27
      RETURN                                                             AQUA     28
      END                                                                AQUA     29
```

```
      SUBROUTINE DRINK(DWD,T,USE,TDOSE,JJ)                            DRINK      2
      COMMON Q(200),PL,CFS,NSUR,LT,RECO(200),LIST(200,4),LCT,LZ ,CON,KIT DRINK   3
     + ,PUP                                                           DRINK      4
      COMMON/SORCE/IZ(300),IMASS(300),META(300),NLIBA,NLIBT,NLIBC,NLIBI DRINK    5
      COMMON/DFLIB/DFL(300,7),DFA(300,7),EXG(300,2),TAU(300),EXS(300,2), DRINK   6
     +EFF(300,8)                                                      DRINK      7
      COMMON/TRANS/DILW                                               CHANGE1    2
      DIMENSION TDOSE(8),DOSE(200,8),TYPE(3)                          DRINK      8
      DATA TYPE/'DRIN','KING','    '/                                 DRINK      9
      DILW = DWD                                                      CHANGE1    3
      DO 8 J=1,8                                                      DRINK     10
    8 TDOSE(J)=0.0                                                    DRINK     11
      IF(USE.EQ.0.)GO TO 50                                           DRINK     12
      IF(LT.GT.0) GO TO 50                                            DRINK     13
      DO 10 I=1,NSUR                                                  DRINK     14
      DOSE(I,1)=0.                                                    CHANGE1    4
      LL=LIST(I,JJ)                                                   DRINK     15
      LM=LIST(I,1)                                                    DRINK     16
      MU=IZ(LM)                                                       DRINK     17
      ARGU=TAU(LM)*T                                                  DRINK     18
      IF(ARGU.GT.20.) GO TO 20                                        DRINK     19
      FACT=1119.*Q(I)*RECO(I)/CFS/DWD*EXP(-ARGU)*USE/CON              DRINK     20
      GO TO 30                                                        DRINK     21
   20 FACT=0.0                                                        DRINK     22
   30 DO 40 J=2,8                                                     DRINK     23
      L=J-1                                                           DRINK     24
      DOSE(I,J)=DFL(LL,L)*FACT                                        DRINK     25
   40 TDOSE(J)=TDOSE(J)+DOSE(I,J)                                     DRINK     26
   10 CONTINUE                                                        DRINK     27
      IF (LCT.GT.0) CALL PERDOS(TYPE,TDOSE,DOSE)                      DRINK     28
      IF(CON.GT.10.)CALL PLOP(DOSE,7)                                 DRINK     29
   50 CONTINUE                                                        DRINK     30
      RETURN                                                          DRINK     31
      END                                                             DRINK     32
```

```
      SUBROUTINE SHURE(TYPE,SWF,DILU,T,USE,TDUSE)                       SHURE      2
      COMMON Q(200),PL,CFS,NSUR,LT,RECU(200),LIST(200,4),LCT,LZ ,CON,KIT SHURE     3
     + ,POP                                                             SHURE      4
      COMMON/DFLIB/DFL(300,7),DFA(300,7),EXG(300,2),TAU(300),EXS(300,2), SHURE     5
     +EFF(300,8)                                                        SHURE      6
      COMMON/SURCE/IZ(300),IMASS(300),META(300),NLIBA,NLIBT,NLIBC,NLIBI SHURE      7
      DIMENSION TYPE(3),TDUSE(8),DOSE(200,8)                            SHURE      8
      DO 8 J=1,8                                                        SHURE      9
    8 TDUSE(J)=0.0                                                      SHURE     10
      IF(USE.EQ.0.)GO TO 50                                             SHURE     11
      DO 10 I=1,NSUR                                                    SHURE     12
      LM=LIST(I,1)                                                      SHURE     13
      MO=IZ(LM)                                                         SHURE     14
      ARGU=TAU(LM)*PL*8760.                                             SHURE     15
      IF(ARGU.GT.100.)ARGU=100                                          SHURE     16
      TP=TAU(LM)*T                                                      SHURE     17
      IF(TP.GT.100)TP=100                                               SHURE     18
      FACT=110000.*(.693/TAU(LM)/24.)*Q(I)*RECU(I)/CFS/DILU*EXP(-TP)*SWF SHURE    19
     C*(1.-EXP(-ARGU))*USE/CON                                          SHURE     20
      DO 20 J=1,8                                                       CHANGE1    5
      IF(J.GT.2)GOTO 15                                                 CHANGE1    6
      DOSE(I,J)=FACT*EXG(LM,J)                                          SHURE     22
      TDOSE(J)=TDUSE(J)+DOSE(I,J)                                       CHANGE1    7
      GOTO 20                                                           CHANGE1    8
   15 DOSE(I,J)=DOSE(I,2)                                               CHANGE1    9
   20 CONTINUE                                                          CHANGE1   10
   10 CONTINUE                                                          SHURE     24
      IF(USE.GT.1000..AND.CON.LT.10.) GO TO 50                          SHURE     25
      IF(LCT.GT.0)CALL PERDOS(TYPE,TDUSE,DOSE)                          SHURE     26
   50 CONTINUE                                                          SHURE     27
      DO 40 J=3,8,1                                                     SHURE     28
   40 TDOSE(J)=TDUSE(2)                                                 SHURE     29
      IF(CON.GT.10..AND.USE.GT.0.)CALL PLOP(DOSE,5)                     SHURE     30
      RETURN                                                            SHURE     31
      END                                                               SHURE     32
```

```
      SUBROUTINE SWIM(TYPE,DILU,T,USE,GEOM,TDOSE)                        SWIM       2
      COMMON Q(200),PL,CFS,NSOR,LT,RECU(200),LIST(200,4),LCT,LZ ,CON,KIT SWIM       3
     + ,PUP                                                              SWIM       4
      COMMON/DFLIB/DFL(300,7),DFA(300,7),EXG(300,2),TAU(300),EXS(300,2), SWIM       5
     +EFF(300,8)                                                         SWIM       6
      COMMON/SORCE/IZ(300),IMASS(300),META(300),NLIBA,NLIBT,NLIBC,NLIBI  SWIM       7
      DIMENSION TDOSE(8),DOSE(200,8)                                     SWIM       8
      DO 8 J=1,8                                                         SWIM       9
    8 TDOSE(J)=0.0                                                       SWIM      10
      IF(USE.EQ.0.)GO TO 50                                              SWIM      11
      IF(DILU.EQ.0.)GO TO 50                                             SWIM      12
      DO 10 I=1,NSOR                                                     SWIM      13
      LM=LIST(I,1)                                                       SWIM      14
      NU=IZ(LM)                                                          SWIM      15
      ARGU=TAU(LM)*T                                                     SWIM      16
      IF(ARGU.GT.20.)GO TO 20                                            SWIM      17
      FACT=1119.*Q(I)*RECU(I)/CFS/DILU*EXP(-ARGU)/GEOM*USE/CON           SWIM      18
      GO TO 30                                                           SWIM      19
   20 FACT=0.0                                                           SWIM      20
   30 DOSE(I,1)=EXS(LM,1)*FACT                                           SWIM      21
      DOSE(I,2)=EXS(LM,2)*FACT                                           SWIM      22
      DO 15 J=3,8                                                        CHANGE1   11
   15 DOSE(I,J)=DOSE(I,2)                                                CHANGE1   12
      TDOSE(1)=TDOSE(1)+DOSE(I,1)                                        SWIM      23
   10 TDOSE(2)=TDOSE(2)+DOSE(I,2)                                        SWIM      24
      IF(INT(GEOM).EQ.2) GO TO 50                                        SWIM      25
      IF(USE.GT.1000..AND.CON.LT.10.) GO TO 50                           SWIM      26
      IF(LCT.GT.0) CALL PERDOS(TYPE,TDOSE,DOSE)                          SWIM      27
      IF(CON.GT.10.)CALL PLUP(DOSE,5)                                    SWIM      28
   50 CONTINUE                                                           SWIM      29
      DO 40 J=3,8,1                                                      SWIM      30
   40 TDOSE(J)=TDOSE(2)                                                  SWIM      31
      RETURN                                                             SWIM      32
      END                                                                SWIM      33
```

```
      SUBROUTINE CRITTR(CRITR,DILU,T,TDOSE,ACC)                         CRITTR       2
      COMMON Q(200),PL,CFS,NSUR,LT,RECO(200),LIST(200,4),LCT,LZ ,CON,KIT CRITTR       3
     + ,PUP                                                             CRITTR       4
      COMMON/SURCE/IZ(300),IMASS(300),META(300),NLIBA,NLIBT,NLIBC,NLIBI CRITTR       5
      COMMON/DFLIB/DFL(300,7),DFA(300,7),EXG(300,2),TAU(300),EXS(300,2), CRITTR       6
     +EFF(300,8)                                                        CRITTR       7
      DIMENSION TDOSE(8),ACC(100),CRITR(3),DOSE(200,8)                  CRITTR       8
      DO 8 J=1,8                                                        CRITTR       9
    8 TDOSE(J)=0.0                                                      CRITTR      10
      DO 10 I=1,NSUR                                                    CRITTR      11
      LM=LIST(I,1)                                                      CRITTR      12
      MO=IZ(LM)                                                         CRITTR      13
      ARGU=TAU(LM)*T                                                    CRITTR      14
      IF(ARGU.GT.40.)GO TO 9                                            CRITTR      15
      FACT=21.*Q(I)*RECO(I)/CFS/DILU*EXP(-ARGU)*EFF(LM,2)               CRITTR      16
      GO TO 11                                                          CRITTR      17
    9 FACT=0.0                                                          CRITTR      18
   11 DOSE(I,1)=FACT*ACC(MO)                                            CRITTR      19
   10 TDOSE(1)=TDOSE(1)+DOSE(I,1)                                       CRITTR      20
      IF(LCT.GT.0) CALL PERDOS(CRITR,TDOSE,DOSE)                        CRITTR      21
      RETURN                                                            CRITTR      22
      END                                                               CRITTR      23
```

```
      SUBROUTINE EAT(BIOT,RAD,MASS,CONS,DILU,T,TDOSE,ACC)                 EAT    2
      COMMON Q(200),PL,CFS,NSUR,LT,RECO(200),LIST(200,4),LCT,LZ ,CON,KIT EAT    3
     + ,PUP                                                               EAT    4
      COMMON/DFLIB/DFL(300,7),DFA(300,7),EXG(300,2),TAU(300),EXS(300,2), EAT    5
     +EFF(300,8)                                                          EAT    6
      COMMON/SORCE/IZ(300),IMASS(300),META(300),NLIBA,NLIBT,NLIBC,NLIBI  EAT    7
      REAL MASS                                                           EAT    8
      DIMENSION BIOT(4),STAN(9),ACC(100),TDOSE(8),DOSE(200,8)            EAT    9
      DATA STAN/0.,1.4,2.,3.,5.,7.,10.,20.,30./                          EAT   10
      TDOSE(1)=0.0                                                        EAT   11
      TDOSE(2)=0.0 .                                                      EAT   12
      DO 10 J=2,8                                                         EAT   13
      IF(RAD.LE.1.4)GO TO 50                                              EAT   14
      JOT=J-1                                                             EAT   15
      PT=(STAN(JOT)+STAN(J))/2.                                           EAT   16
      JEB=J+1                                                             EAT   17
      TP=(STAN(J)+STAN(JEB))/2.                                           EAT   18
      IF(RAD.GE.PT.AND.RAD.LT.TP)GO TO 50                                 EAT   19
   10 CONTINUE                                                            EAT   20
   50 L=J-1                                                               EAT   21
      DO 20 I=1,NSOR                                                      EAT   22
      MO=LIST(I,1)                                                        EAT   23
      MT=IZ(MO)                                                           EAT   24
      ARGU=TAU(MO)*T                                                      EAT   25
      IF(ARGU.GT.40.)GO TO 9                                              EAT   26
      IF(EFF(MO,8).EQ.0.) GO TO 9                                         EAT   27
      FACT=2.86E+07*Q(I)*RECO(I)/CFS/DILU*EXP(-ARGU)*CONS/MASS/EFF(MO,8) EAT   28
     +*DFL(MO,3)*EFF(MO,L)                                                EAT   29
      GO TO 8                                                             EAT   30
    9 FACT=0.0                                                            EAT   31
    8 CONTINUE                                                            EAT   32
      DOSE(I,1)=FACT*ACC(MT)                                              EAT   33
   20 TDOSE(1)=TDOSE(1)+DOSE(I,1)                                         EAT   34
      IF(LCT.GT.0)CALL PERDOS(BIOT,TDOSE,DOSE)                            EAT   35
  100 CONTINUE                                                            EAT   36
      RETURN                                                              EAT   37
      END                                                                 EAT   38
```

```
      SUBROUTINE PAFD(TYPE,ACC,CONC,JJ,USE,TDOSE,NN,LM)                 PAFD   2
      COMMON/SORCE/IZ(300),IMASS(300),META(300),NLIBA,NLIBT,NLIBC,NLIBI PAFD   3
      COMMON Q(200),PL,CFS,NSUR,LT,RECO(200),LIST(200,4),LCT,LZ ,CON,KIT PAFD  4
     + ,POP                                                             PAFD   5
      COMMON/DFLIB/DFL(300,7),DFA(300,7),EXG(300,2),TAU(300),EXS(300,2), PAFD  6
     +EFF(300,8)                                                        PAFD   7
      DIMENSION TYPE(3),ACC(100),CONC(200)                              PAFD   8
      DIMENSION DOSE(200,8),TDOSE(8)                                    PAFD   9
      DO 50 KJ=1,NSUR                                                   PAFD  10
      ML=LIST(KJ,1)                                                     PAFD  11
      LL=LIST(KJ,JJ)                                                    PAFD  12
      MU=IZ(ML)                                                         PAFD  13
      FACT=CONC(KJ)*ACC(MU)/CON*1100.                                   PAFD  14
      DO 60 J=1,7                                                       PAFD  15
      IF(KJ.EQ.1)TDOSE(J)=0.                                            PAFD  16
      DOSE(KJ,J)=FACT*DFL(LL,J)*USE                                     PAFD  17
   60 TDOSE(J)=TDOSE(J)+DOSE(KJ,J)                                      PAFD  18
   50 CONTINUE                                                          PAFD  19
      IF(LM.EQ.0.AND.NN.EQ.1)CALL PLOP(DOSE,6)                          PAFD  20
      IF(LM.EQ.0.AND.NN.EQ.2)CALL PLOP(DOSE,6)                          PAFD  21
      IF(LCT.GT.0)CALL PERDOS(TYPE,TDOSE,DOSE)                          PAFD  22
      RETURN                                                            PAFD  23
      END                                                               PAFD  24
```

```
      SUBROUTINE CENT(T,CATH,DILU,J,CONC,AMT,HARV,N)                    CENT       2
      COMMON Q(200),PL,CFS,NSUR,LT,RECO(200),LIST(200,4),LCT,LZ ,CON,KTT CENT      3
     + ,POP                                                             CENT       4
      COMMON/SORCE/IZ(300),IMASS(300),META(300),NLIBA,NLIBT,NLIBC,NLIBI  CENT      5
      COMMON/DFLIB/DFL(300,7),DFA(300,7),EXG(300,2),TAU(300),EXS(300,2), CENT      6
     +EFF(300,8)                                                        CENT       7
      DIMENSION  CATH(20),DILU(20),T(20),CONC(200)                      CENT       8
      DO 20 K=1,J                                                       CENT       9
      DO 40 KK=1,NSUR                                                   CENT      10
      IF(K.EQ.1)CONC(KK)=0.0                                            CENT      11
      LM=LIST(KK,1)                                                     CENT      12
      MU=IZ(LM)                                                         CENT      13
      ARGU=TAU(LM)*T(K)                                                 CENT      14
      IF(ARGU.GT.20.)GO TO 40                                           CENT      15
      IF(N.EQ.2) CONC(KK)=CONC(KK)+CATH(K)*Q(KK)*RECO(KK)/CFS/DILU(K)*  CENT      16
     +EXP(-ARGU)/HARV                                                   CENT      17
      IF(N.EQ.1)CONC(KK)=CONC(KK)+CATH(K)*Q(KK)*RECO(KK)/CFS/DILU(K)*EXP CENT     18
     +(-ARGU)/AMT                                                       CENT      19
   40 CONTINUE                                                          CENT      20
   20 CONTINUE                                                          CENT      21
      RETURN                                                            CENT      22
      END                                                               CENT      23
```

```
      SUBROUTINE TRTIUM(CIYR,P,H3B,H3T)                                  TRTIUM    2
      COMMON Q(200),PL,CFS,NSUR,LT,RECO(200),LIST(200,4),LCT,LZ ,CON,KIT TRTIUM    3
     + ,POP                                                              TRTIUM    4
      COMMON/POPUL/PERA,PERT,PERC,US                                     TRTIUM    5
      COMMON/DFLIB/DFL(300,7),DFA(300,7),EXG(300,2),TAU(300),EXS(300,2), TRTIUM    6
     +EFF(300,8)                                                         TRTIUM    7
      DATA HYDRO/2.7E+19/                                                TRTIUM    8
      DATA CONSUM/800./                                                  TRTIUM    9
      ARGU=TAU(1)*PL*8760.                                               TRTIUM   10
      IF(ARGU.GT.40.)ARGU=40.                                            TRTIUM   11
      H3CON=CIYR*1.0E+12*(1.-EXP(-ARGU))/(TAU(1)*8760.*HYDRO)            TRTIUM   12
      H3B=H3CON*CONSUM*DFL(1,3)/CON*US                                   TRTIUM   13
      H3T=H3CON*CONSUM*DFL(1,4)/CON*US                                   TRTIUM   14
      RETURN                                                             TRTIUM   15
      END                                                                TRTIUM   16
```

```
      SUBROUTINE FLOOD                                                  FLOOD
      COMMON D(200),PL,CFS,NSUR,LT,RECD(200),LIST(200,4),LCT,LZ ,CON,KIT FLOOD
     + ,PUP                                                             FLOOD
      COMMON/POPUL/PERA,PERT,PERC,US                                    FLOOD
      REAL IRRIG                                                        FLOOD
      DIMENSION TYPE(3),A(3),B(3),C(3),TDOSE(8)                         FLOOD
      DIMENSION D(3),VEG(3),LV(3),MLK(3),MET(3),AALD(7),AAND(7),TALD(7), FLOOD
     +TAND(7),CALD(7),CAND(7)                                           FLOOD
      DIMENSION DILU(20),T(20),PROD(20),CONC(200)                       FLOOD
      DIMENSION GOOD(7),BAD(7)                                          FLOOD
      DATA D/'TOTA','L   ','    '/                                      FLOOD
      DATA TYPE/'IRRI',' FOO','D   '/                                   FLOOD
      DATA VEG/'VEGE','TATI','ON  '/                                    FLOOD
      DATA LV/'LEAF','Y VE','GE  '/                                     FLOOD
      DATA MLK/'MILK','    ','    '/                                    FLOOD
      DATA MET/'MEAT','    ','    '/                                    FLOOD
      DATA A/'ADUL','T   ','    '/                                      FLOOD
      DATA B/'TEEN','AGER','    '/                                      FLOOD
      DATA C/'CHIL','D   ','    '/                                      FLOOD
   10 FORMAT(1H1,35X,'*    *    *  IRRIGATED FOOD PATHWAY  *    *    *') FLOOD
   40 FORMAT(1H0,22X,'BONE          LIVER     TOTAL BODY        THYROID FLOOD
     C         KIDNEY            LUNG          GI-LLI')                 FLOOD
   41 FORMAT(1H0,19X,'_______________________________________INDIVIDUAL FLOOD
     + DOSES(MREM PER YEAR INTAKE)_____________________________')       FLOOD
   42 FORMAT(1H0,16X,'_______________POPULATION DOSES(MAN-REM)__________ FLOOD
     +_____')                                                           FLOOD
   43 FORMAT(1H0,15X,'NOTE- INDIVIDUAL DOSES CALCULATED WITH DILUTION=', FLOOD
     +1PE8.2,' AND TRANSIT TIME=',E8.2,' HRS.')                         FLOOD
   50 FORMAT(2I10,6E10.0)                                               FLOOD
   60 FORMAT(1H ,3A4,1P7E15.2)                                          FLOOD
   80 FORMAT(8E10.2)                                                    FLOOD
   84 FORMAT(17X,1P5E10.2)                                              FLOOD
   85 FORMAT(1H0,'INDEX FOR FOOD PATHWAY DOES NOT EXIST')               FLOOD
   90 FORMAT(1H0,'$   $   $  ALARA DOSES   $   $   $')                  FLOOD
   91 FORMAT(1H0,'*   *   *  NEPA DOSES   *   *   *')                   FLOOD
   96 FORMAT(1H0,3A4,5X,'IRRIGATION RATE=',1PE8.2,' L/M**2/MON',5X,'YIEL FLOOD
     +D=',1PE8.2,' KG/M**2',5X,'GROWING PERIOD=',E8.2,' DAYS',/,17X,    FLOOD
     +'TOTAL 50 MILE GROW=',E8.2,' KG/YR',5X,'TOTAL CROP IRRIGATION=',E8 FLOOD
     +.2,/,/,17X,'  DILUTION  HARVEST  TRANSIT TIME')                   FLOOD
   97 FORMAT(1H0,'INDIVIDUAL CONSUMPTION RATES    ADULT=',1PE8.2,' KG', FLOOD
     +5X,'TEEN=',E8.2,5X,'CHILD=',E8.2,5X,'FOOD PROCESS TIME=',E8.2,' HR FLOOD
     +')                                                                FLOOD
   98 FORMAT(1H ,'POPULATION CONSUMPTION RATES    ADULT=',1PE8.2,' KG', FLOOD
     +5X,'TEEN=',E8.2,5X,'CHILD=',E8.2,5X,'FOOD PROCESS TIME=',E8.2,' HR FLOOD
     +')                                                                FLOOD
  100 READ 50,N,KZ,IRRIG,YIELD,GROW,TFMG                                FLOOD
      TTIG=0.0                                                          FLOOD
      IF(N.EQ.0) GO TO 200                                              FLOOD
      IF(KZ.GT.0)READ 80,ACON,TCON,CCON,AC,TC,CC,HOLD,HLD1              FLOOD
      J=1                                                               FLOOD
  104 READ 80,DILU(J),PROD(J),T(J)                                      FLOOD
      M=J-1                                                             FLOOD
      IF(DILU(J).EQ.0.) GO TO 105                                       FLOOD
      J=J+1                                                             FLOOD
      GO TO 104                                                         FLOOD
  105 CONTINUE                                                          FLOOD
      TM=T(1)                                                           FLOOD
```

```
      DL=DILU(1)
      DO 107 J=1,M
      IF(DILU(J).LT.DL) DL=DILU(J)
  107 IF(DILU(J).LT.DL) TM=T(J)
      PRINT 10
      DO 106 J=1,M
  106 TTIG=TTIG+PROD(J)
      IF(KZ.GT.0)GO TO 160
      GO TO (120,130,140,150),N
      PRINT 85
      RETURN
  120 AC=190.
      TC=240..
      CC=200.
      ACON=520.
      TCON=630.
      CCON=520.
      HLD1=1440.
      HOLD=340.
      GO TO 160
  130 AC=30.
      TC=20.
      CC=10.
      ACON=64.
      TCON=42.
      CCON=26.
      HOLD=50.
      HLD1=24.
      GO TO 160
  140 AC=110.
      TC=200.
      CC=170.
      ACON=310.
      TCON=400.
      CCON=330.
      HOLD=96.
      HLD1=48.
      GO TO 160
  150 AC=95.
      TC=59.
      CC=37.
      ACON=110.
      TCON=65.
      CCON=41.
      HOLD=480.
      HLD1=480.
  160 CONTINUE
      IF(N.EQ.1) PRINT 60,VEG
      IF(N.EQ.2) PRINT 60,LV
      IF(N.EQ.3) PRINT 60,MLK
      IF(N.EQ.4) PRINT 60,MET
      IF(N.GT.4) PRINT 85
      P=TFMG/(AC*PERA+TC*PERT+CC*PERC)
      TP=TTIG/(AC*PERA+TC*PERT+CC*PERC)
      IF(P.GT.PUP)P=PUP
      KIT=0
      LZ=0
```

```
          CALL CENT(T,PROD,DILU,M,CONC,AMT,TFMG,2)                         FLOOD   116
          CALL FOOD(TYPE,CONC,HOLD,HLD1,ACON,IRRIG,YIELD,GROW,TFMG,TTIG,TP FLOOD   117
         +,AC,TDOSE,AALD,AAND,N,1,P,TM,DL)                                 FLOOD   118
          PRINT 41                                                         FLOOD   119
          PRINT40                                                          FLOOD   120
          PRINT 60,A,(TDOSE(J),J=1,7)                                      FLOOD   121
          CALL FOOD(TYPE,CONC,HOLD,HLD1,TCON,IRRIG,YIELD,GROW,TFMG,TTIG,TP FLOOD   122
         +,TC,TDOSE,TALD,TAND,N,2,P,TM,DL)                                 FLOOD   123
          PRINT 60,B,(TDOSE(J),J=1,7)                                      FLOOD   124
          CALL FOOD(TYPE,CONC,HOLD,HLD1,CCON,IRRIG,YIELD,GROW,TFMG,TTIG,TP FLOOD   125
         +,CC,TDOSE,CALD,CAND,N,3,P,TM,DL)                                 FLOOD   126
          PRINT 60,C,(TDOSE(J),J=1,7)                                      FLOOD   127
          PRINT 43,DL,TM                                                   FLOOD   128
          PRINT 42                                                         FLOOD   129
          PRINT 91                                                         FLOOD   130
          PRINT 40                                                         FLOOD   131
          PRINT 60,A,(AAND(JM),JM=1,7)                                     FLOOD   132
          PRINT 60,B,(TAND(JM),JM=1,7)                                     FLOOD   133
          PRINT 60,C,(CAND(JM),JM=1,7)                                     FLOOD   134
          DO 165 JM=1,7                                                    FLOOD   135
      165 GOOD(JM)=AAND(JM)+TAND(JM)+CAND(JM)                              FLOOD   136
          PRINT 60,D,(GOOD(JM),JM=1,7)                                     FLOOD   137
          PRINT 90                                                         FLOOD   138
          PRINT 40                                                         FLOOD   139
          PRINT 60,A,(AALD(JM),JM=1,7)                                     FLOOD   140
          PRINT 60,B,(TALD(JM),JM=1,7)                                     FLOOD   141
          PRINT 60,C,(CALD(JM),JM=1,7)                                     FLOOD   142
          DO 166 JM=1,7                                                    FLOOD   143
      166 BAD(JM)=AALD(JM)+TALD(JM)+CALD(JM)                               FLOOD   144
          PRINT 60,D,(BAD(JM),JM=1,7)                                      FLOOD   145
          PRINT 96,TYPE,IRRIG,YIELD,GROW,TFMG,TTIG                         FLOOD   146
          DO 170 J=1,M                                                     FLOOD   147
      170 PRINT 84,DILU(J),PROD(J),T(J)                                    FLOOD   148
          PRINT 97,ACON,TCON,CCON,HLD1                                     FLOOD   149
          PRINT 98,AC,TC,CC,HOLD                                           FLOOD   150
          KIT=30                                                           FLOOD   151
          IF(LCT.GT.0) CALL PERDOS(TYPE,TDOSE,DUSE)                        FLOOD   152
          GO TO 100                                                        FLOOD   153
      200 CONTINUE                                                         FLOOD   154
          RETURN                                                           FLOOD   155
          END                                                              FLOOD   156
```

CARD NR. SEVERITY DETAILS DIAGNOSIS OF PROBLEM

67 I THERE IS NO PATH TO THIS STATEMENT.

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      SUBROUTINE FOOD(TYPE,CONC,HOLD,HLD1,CONSUM,IRRIG,YIELD,GROW,
     +TEMG,TTIG,TP,C,IDOSE,ALD,AND,N,JJ,P,TM,DL)
      COMMON Q(200),PL,CFS,NSUR,LT,RFCO(200),LIST(200,4),LCT,LZ ,CON,KIT
     + ,POP
      COMMON/POPUL/PERA,PERT,PERC,US
      COMMON/DFLIB/DFL(300,7),DFA(300,7),EXG(300,2),TAU(300),EXS(300,2),
     +EFF(300,8)
      COMMON/SORCE/IZ(300),IMASS(300),META(300),NLIBA,NLIBT,NLIBC,NLIBI
      REAL IPRIG
      DIMENSION ALD(7),AND(7),TYPE(3),TDOSE(8),DOSE(200,8),POOL(200,8)
      DIMENSION CONC(200)
      DIMENSION SOIL(100),ZMET(100),ZMLK(100)
      DATA Q1,Q2,Q3,Q4/50.,60.,50.,50./
      DATA FRAC/0.25/
      DATA ZMET/
     +2.1E-02,2.0E-02,1.0E-02,1.0E-03,8.0E-04,3.1E-02,7.7E-02,1.6E-02,
     +1.5E-01,2.0E-02,3.0E-02,5.0E-03,1.5E-03,4.0E-05,4.6E-02,1.0E-01,
     +8.0E-02,2.0E-02,1.2E-02,4.0E-03,1.6E-02,3.1E-02,2.3E-03,2.4E-03,
     +8.0E-04,4.0E-02,1.3E-02,5.3E-03,8.0E-03,3.0E-02,1.3E 00,2.0E 01,
     +2.0E-03,1.5E-02,2.6E-02,2.0E-02,3.1E-02,6.0E-04,4.6E-03,3.4E-02,
     +2.8E-01,8.0E-03,4.0E-01,4.0E-01,1.5E-03,4.0E-03,1.7E-02,5.3E-04,
     +8.0E-03,8.0E-02,4.0E-03,7.7E-02,2.9E-03,2.0E-02,4.0E-03,3.2E-03,
     +2.0E-04,1.2E-03,4.7E-03,3.3E-03,4.8E-03,5.0E-03,4.8E-03,3.6E-03,
     +4.4E-03,5.3E-03,4.4E-03,4.0E-03,4.4E-03,4.0E-03,4.4E-03,4.0E-01,
     +1.6E 00,1.3E-03,8.0E-03,4.0E-01,1.5E-03,4.0E-03,8.0E-03,2.6E-01,
     +4.0E-02,2.9E-04,1.3E-02,1.2E-02,8.0E 00,2.0E-02,2.0E-02,3.4E-02,
     +6.0E-02,2.0E-04,8.0E 02,3.4E-04,2.0E-04,1.4E-05,2.0E-04,2.0E-04,
     +2.0E-04,2.0E-04,2.0E-04,2.0E-04/
      DATA SOIL/
     14.8    ,5.0E-02,8.3E-04,4.2E-04,1.2E-01,5.5    ,7.5    ,1.6    ,
     26.5E-04,1.4E-01,5.2E-02,1.3E-01,1.8E-04,1.5E-04,1.1E+00,5.9E-01,
     35.0E+00,6.0E-01,3.7E-01,3.6E-02,1.1E-03,5.4E-05,1.3E-03,2.5E-04,
     42.9E-02,6.6E-04,9.4E-03,1.9E-02,1.2E-01,4.0E-01,2.5E-04,1.0E-01,
     51.0E-02,1.3E-00,7.6E-01,3.0E-00,1.3E-01,1.7E-02,2.6E-03,1.7E-04,
     69.4E-03,1.2E-01,2.5E-01,5.0E-02,1.3E+01,5.0E-00,1.5E-01,3.0E-01,
     72.5E-01,2.5E-03,1.1E-02,1.3E-00,2.0E-02,1.0E+01,1.0E-02,5.0E-03,
     82.5E-03,2.5E-03,2.5E-03,2.4E-03,2.5E-03,2.5E-03,2.5E-03,2.6E-03,
     92.6E-03,2.5E-03,2.6E-03,2.5E-03,2.6E-03,2.5E-03,2.6E-03,1.7E-04,
     A6.3E-03,1.8E-02,2.5E-01,5.0E-02,1.3E+01,5.0E-01,2.5E-03,3.8E-01,
     B2.5E-01,6.8E-02,1.5E-01,1.5E-01,2.5E-01,3.5E-00,1.0E-02,3.1E-04,
     C2.5E-03,4.2E-03,2.5E-03,2.5E-03,2.5E-03,2.5E-04,2.5E-04,2.5E-03,
     D2.5E-03,2.5E-03,2.5E-03,2.5E-03/
      DATA ZMLK/
     +1.3E-02,2.0E-02,5.0E-02,1.0E-04,2.7E-03,1.2E-02,2.2E-02,2.0E-02,
     +1.4E-02,2.0E-02,4.0E-02,1.0E-02,5.0E-04,1.0E-04,2.5E-02,1.8E-02,
     +5.0E-02,2.0E-02,1.0E-02,8.0E-03,5.0E-06,5.0E-06,1.0E-03,2.2E-03,
     +2.5E-04,1.2E-03,1.0E-03,6.7E-03,1.4E-02,3.9E-02,5.0E-05,5.0E-04,
     +6.0E-03,4.5E-02,5.0E-02,2.0E-02,3.0E-02,8.0E-04,1.0E-05,5.0E-06,
     +2.5E-03,7.5E-03,2.5E-02,1.0E-06,1.0E-02,1.0E-02,5.0E-02,1.2E-04,
     +1.0E-04,2.5E-03,1.5E-03,1.0E-03,6.0E-03,2.0E-02,1.2E-02,4.0E-04,
     +5.0E-06,6.0E-04,5.0E-06,5.0E-06,5.0E-06,5.0E-06,5.0E-06,5.0E-06,
     +5.0E-06,5.0E-06,5.0E-06,5.0E-06,5.0E-06,5.0E-06,5.0E-06,5.0E-06,
     +2.5E-02,5.0E-04,2.5E-02,5.0E-03,5.0E-03,5.0E-03,5.0E-03,3.8E-02,
     +2.2E-02,6.2E-04,5.0E-04,3.0E-04,5.0E-02,2.0E-02,5.0E-02,8.0E-03,
     +5.0E-06,5.0E-06,5.0E-06,5.0E-04,5.0E-06,2.0E-06,5.0E-06,5.0E-06,
     +5.0E-06,5.0E-06,5.0E-06,5.0E-06/
      IF(JJ.EQ.1) TERM=PERA
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      IF(JJ.EQ.3)TERM=PERC
      IF(JJ.EQ.2)TERM=PERT
      DO 8 J=1,8
    8 TDOSE(J)=0.0
      IF(N.EQ.0)GO TO 50
      TRANS=1.
      DO 10 I=1,NSOR
      MO=LIST(I,1)
      MT=IZ(MO)
      LL=LIST(I,JJ)
      CNC1=0.0
      ARGU=TAU(MO)*TM
      IF(ARGU.GT.20.) GO TO 25
      CNC1=Q(I)*PECO(I)/CFS/OL*EXP(-ARGU)*1100.
   25 CONTINUE
      IF(JJ.EQ.1) CONC(I)=CONC(I)*1100.
      DECAY=0.693/14.+24.*TAU(MO)
      ARGU=DECAY*GROW
      IF(ARGU.GT.20.) ARGU=20.
      LEAF=FRAC*TRANS/YIELD*(1.-EXP(-ARGU))/(DECAY*30.)
      ARG1=TAU(MO)*PL*8766.
      IF(ARG1.GT.20.) ARG1=20.
      ROOT=SOIL(MT)*(1.-EXP(-ARG1))/(TAU(MO)*240.*730.)
      PCON=CONC(I)*IRRIG*(LEAF+ROOT)
      PCN1=CNC1*IRRIG*(LEAF+ROOT)
      IF(MO.EQ.1) PCON=CONC(I)
      IF(MO.EQ.1) PCN1=CNC1
      ARGU=TAU(MO)*HOLD
      ARG1=TAU(MO)*HLD1
      IF(ARGU.GT.60.) ARGU=60.
      IF(ARG1.GT.60.) ARG1=60.
      IF(N.GT.2)GO TO 30
      FCN1=PCN1*EXP(-ARG1)
      FCON=PCON*EXP(-ARGU)
      GO TO 40
   30 IF(N.EQ.3)FCON=(Q1*PCON+Q2*CONC(I))*ZMLK(MT)*EXP(-ARGU)
      IF(N.EQ.3) FCN1=(Q1*PCN1+Q2*CNC1)*ZMLK(MT)*EXP(-ARG1)
      IF(N.EQ.4)FCON=(Q3*PCON+Q4*CONC(I))*ZMET(MT)*EXP(-ARGU)
      IF(N.EQ.4) FCN1=(Q3*PCN1+Q4*CNC1)*ZMET(MT)*EXP(-ARG1)
      IF(N.EQ.3.AND.MO.EQ.1) FCON=(0.0028*CONC(I)/0.28)*(38.+60.)
      IF(N.EQ.3.AND.MO.EQ.1) FCN1=(0.0028*CNC1/0.28)*(38.+60.)
      IF(N.EQ.4.AND.MO.EQ.1) FCON=(0.0041*CONC(I)/0.32)*(28.+50.)
      IF(N.EQ.4.AND.MO.EQ.1) FCN1=(0.0041*CNC1/0.32)*(28.+50.)
      GO TO 40
C
   40 DO 60 J=1,7
      IF(I.EQ.1) ALD(J)=0.
      IF(I.EQ.1) AND(J)=0.
      DOSE(I,J)=DFL(LL,J)*FCN1*CONSUM
      FACT=TERM*P*C
      FCT1=TERM*TP*C
      POOL(I,J)=DFL(LL,J)*FCON*FACT/1000.
      POL1=DFL(LL,J)*FCON*FCT1*TFMG/TTIG/1000.
      ALD(J)=ALD(J)+POOL(I,J)
      AND(J)=AND(J)+POL1
   60 TDOSE(J)=TDOSE(J)+DOSE(I,J)
   10 CONTINUE
```

```
      CALL PLOP(POOL,6)                                          FOOD  116
      IF(LCT.GT.0)CALL PERDUS(TYPE,TDOSE,DOSE)                   FOOD  117
   50 CONTINUE                                                   FOOD  118
      RETURN                                                     FOOD  119
      END                                                        FOOD  120
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```
      SUBROUTINE PERDOS(SPECIE,TDOSE,DOSE)                              PERDOS    2
      COMMON D(200),PL,CFS,NSOR,LT,RECO(200),LIST(200,4),LCT,LZ ,CON,KIT PERDOS    3
     + ,POP                                                             PERDOS    4
      COMMON/ELEMEN/IELEM(100)                                          PERDOS    8
      COMMON/SORCE/IZ(300),IMASS(300),META(300),NLIBA,NLIBT,NLIBC,NLIBI PERDOS    9
      DIMENSION SPECIE(3),TDOSE(8),DOSE(200,8),PATH(8,3),SET(12),A1(7,8, PERDOS   10
     +20),A2(7,8,20),A3(7,8,20),ISOT(7,8,20),IMET(7,8,20),NADS(7,8)     PERDOS   11
      DIMENSION B1(7,8,20),B2(7,8,20),B3(7,8,20)                        PERDOS   12
      COMMON/TRANS/DILW                                                 CHANGE1   13
      DIMENSION DOS(8,100,8)                                            CHANGE1   14
C                                                                       PERDOS   13
      DATA SET/1H1,1H2,1H3,1H4,1H5,1H6,1H7,1H8,1H9,1H0,1H ,1H%/         BNL01    11
   10 FORMAT(1H0,'PATHWAY                    SKIN          BONE        LI PERDOS   15
     +VER     TOTAL BOCY        THYROID          KIDNEY          LUNG   PERDOS   16
     +        GI-LLI')                                                  PERDOS   17
   15 FORMAT(1H0,'PATHWAY                    BODY')                     PERDOS   18
      DATA BLAK/'    '/                                                 PERDOS   19
  110 FORMAT(1H0,'AGE GROUP         TOTAL BODY         THYROID')        PERDOS   20
  115 FORMAT(1H0,'AGE GROUP         SKIN            TOTAL BODY')        PERDOS   21
  120 FORMAT(1H0,'*     *     *  ISOTOPE CONTRIBUTION  *     *     *')  PERDOS   22
  130 FORMAT(1H0,'AGE GROUP                    BONE          LIVER     TOTAL PERDOS   23
     +BODY        THYROID          KIDNEY           LUNG           GI-LLI') PERDOS   24
      IF(LZ.GT.0) GO TO 50                                              PERDOS   25
      DO 65 J=1,7                                                       PERDOS   26
      DO 66 K=1,8                                                       PERDOS   27
   66 NADS(J,K)=1                                                       PERDOS   28
   65 CONTINUE                                                          PERDOS   29
      DO 70 J=1,7                                                       PERDOS   30
      DO 80 K=1,8                                                       PERDOS   31
      DO 90 I=1,20                                                      PERDOS   32
      A1(J,K,I)=BLAK                                                    PERDOS   33
      A2(J,K,I)=BLAK                                                    PERDOS   34
      A3(J,K,I)=BLAK                                                    PERDOS   35
      ISOT(J,K,I)=BLAK                                                  PERDOS   36
      B1(J,K,I)=BLAK                                                    PERDOS   37
      B2(J,K,I)=BLAK                                                    PERDOS   38
      B3(J,K,I)=BLAK                                                    PERDOS   39
      IMET(J,K,I)=BLAK                                                  PERDOS   40
   90 CONTINUE                                                          PERDOS   41
   80 CONTINUE                                                          PERDOS   42
   70 CONTINUE                                                          PERDOS   43
   50 IF(KIT.EQ.40) GO TO 300                                           PERDOS   44
      IF(KIT.EQ.30)GO TO 300                                            PERDOS   45
      IF(KIT.EQ.10)GO TO 200                                            PERDOS   46
      IF(KIT.EQ.50)GO TO 300                                            PERDOS   47
      IF(KIT.EQ.20) GO TO 300                                           PERDOS   48
      IF(KIT.EQ.70) GO TO 200                                           PERDOS   49
      LZ=LZ+1                                                           PERDOS   50
      PATH(LZ,1)=SPECIE(1)                                              PERDOS   51
      PATH(LZ,2)=SPECIE(2)                                              PERDOS   52
      PATH(LZ,3)=SPECIE(3)                                              PERDOS   53
      DO 20 J=1,NSOR                                                    PERDOS   54
      MO=LIST(J,1)                                                      PERDOS   55
      MI=IZ(MO)                                                         PERDOS   56
      IHUN = IMASS(MO)/100                                              CHANGE1   15
      ITEN =(IMASS(MO)-IHUN*100)/10                                     CHANGE1   16
      IUNIT= IMASS(MO)-IHUN*100-ITEN*10                                 CHANGE1   17
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      IF(IHUN.GT.0.AND.ITEN.EQ.0) ITEN = 10                              CHANGE1   18
      IF(IHUN.EQ.0.AND.ITEN.EQ.0) ITEN = 11                              CHANGE1   19
      IF(IHUN.EQ.0) IHUN = 11                                            CHANGE1   20
      IF(IUNIT.EQ.0) IUNIT = 10                                          CHANGE1   21
      C1=SET(IHUN)                                                       CHANGE1   22
      C2=SET(ITEN)                                                       CHANGE1   23
      C3=SET(IUNIT)                                                      CHANGE1   24
      DO 30 JJ=1,8                                                       PERDOS    57
      DOS(LZ,J,JJ)=101.94*CFS*DOSE(J,JJ)                                 CHANGE1   25
      L=NADS(LZ,JJ)                                                      CHANGE1   26
      IF(L.GT.20)GOTO 30                                                 CHANGE1   27
      IF(TDOSE(JJ).LT.1.E-10)GOTO 30                                     CHANGE1   28
      PER=DOSE(J,JJ)/TDOSE(JJ)*100.                                      PERDOS    60
      IF(PER.LT.1.)GOTO 30                                               CHANGE1   29
      ITEN=INT(PER/10.)                                                  PERDOS    62
      IUNIT=INT(PER)-ITEN*10                                             PERDOS    63
      IF(ITEN.EQ.0)ITEN=11                                               PERDOS    64
      IF(IUNIT.EQ.0)IUNIT=10                                             PERDOS    65
      A1(LZ,JJ,L)=SET(ITEN)                                              PERDOS    66
      A2(LZ,JJ,L)=SET(IUNIT)                                             PERDOS    67
      A3(LZ,JJ,L)=SET(12)                                                PERDOS    68
      ISOT(LZ,JJ,L)=IELEM(MT)                                            PERDOS    69
      B1(LZ,JJ,L)=C1                                                     CHANGE1   30
      B2(LZ,JJ,L)=C2                                                     CHANGE1   31
      B3(LZ,JJ,L)=C3                                                     CHANGE1   32
      IMET(LZ,JJ,L)=META(MO)                                             CHANGE1   33
      NADS(LZ,JJ)=NADS(LZ,JJ)+1                                          PERDOS    81
C                                                                        CHANGE1   34
   30 CONTINUE                                                           PERDOS    83
   20 CONTINUE                                                           PERDOS    84
      RETURN                                                             PERDOS    85
C *  *  INDIVIDUAL PERCENTAGE                                            PERDOS    86
  200 CONTINUE                                                           PERDOS    87
  210 FORMAT(1H0,3A4,8(4X,A2,1X,4A1,1X,3A1))                             PERDOS    88
  220 FORMAT(1H ,12X,8(4X,A2,1X,4A1,1X,3A1))                             PERDOS    89
      PRINT 120                                                          PERDOS    90
      IF(KIT.EQ.10) PRINT 10                                             PERDOS    91
      IF(KIT.EQ.70) PRINT 15                                             PERDOS    92
      DO 240 K=1,LZ                                                      PERDOS    93
      LOW=NADS(K,1)                                                      PERDOS    94
      DO 250 JS=1,8                                                      PERDOS    95
      IF(NADS(K,JS).GT.LOW)LOW=NADS(K,JS)                                PERDOS    96
  250 CONTINUE                                                           PERDOS    97
      IF(LOW.GT.20)LOW=20                                                CHANGE1   35
      PRINT 210,(PATH(K,KL),KL=1,3),(ISOT(K,J,1),B1(K,J,1),B2(K,J,1),B3( PERDOS    98
     +K,J,1),IMET(K,J,1),A1(K,J,1),A2(K,J,1),A3(K,J,1),J=1,8)            PERDOS    99
      DO 260 KJ=2,LOW                                                    PERDOS   100
      PRINT 220,(ISOT(K,J,KJ),B1(K,J,KJ),B2(K,J,KJ),B3(K,J,KJ),IMET(K,J, PERDOS   101
     +KJ),A1(K,J,KJ),A2(K,J,KJ),A3(K,J,KJ),J=1,8)                        PERDOS   102
  260 CONTINUE                                                           PERDOS   103
  240 CONTINUE                                                           PERDOS   104
      IF(POP.GE.0.)RETURN                                                CHANGE1   36
      PRINT 599                                                          CHANGE1   37
  599 FORMAT(1H1,32X,'TABLE 4.11-2'/24X,'LIQUID EFFLUENT DOSE PARAMETERS CHANGE1   38
     +'//37X,'A(I),MREM/HR PER UCI/ML'/16X,'RADIONUCLIDE',6X,'TOTAL BODY CHANGE1   39
     +',5X,'CRITICAL ORGAN'/)                                            CHANGE1   40
      DO 503 J=1,NSOR                                                    CHANGE1   41
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      MO=LIST(J,1)                                                      CHANGE1     42
      MT=IZ(MO)                                                         CHANGE1     43
      DOS1 = DOS(1,J,4) + DOS(2,J,4)                                    CHANGE1     44
      CDOS = 0.                                                         CHANGE1     45
      DO 510 JJ=2,8                                                     CHANGE1     46
      DOS2 = DOS(1,J,JJ) + DOS(2,J,JJ)                                  CHANGE1     47
      IF(DOS2.GT.CDOS) CDOS = DOS2                                      CHANGE1     48
  510 CONTINUE                                                          CHANGE1     49
      PRINT 505,IELEM(MT),IMASS(MO),META(MO),DOS1,CDOS                  CHANGE1     50
  505 FORMAT(1H ,18X,A2,I4,A1,9X,1PE8.2,9X,E8.2)                        CHANGE1     51
  503 CONTINUE                                                          CHANGE1     52
      PRINT 506                                                         CHANGE1     53
  506 FORMAT(////////////////)                                          CHANGE1     54
      PRINT 507,(PATH(2,KL), KL=1,3),DILW                               CHANGE1     55
  507 FORMAT(2X,3A4,' DILUTION IN ADDITION TO THAT FOR FISH=',F5.1)     CHANGE1     56
      STOP                                                              CHANGE1     57
C  *  *  IRRIGATED FOODS AND POD.                                       PERDOS     106
  320 FORMAT(1H ,12X,2(4X,A2,1X,4A1,1X,3A1))                            PERDOS     107
  300 CONTINUE                                                          PERDOS     108
  310 FORMAT(1H ,12X,7(4X,A2,1X,4A1,1X,3A1))                            PERDOS     109
  380 FORMAT(1H0,'ADULT')                                               PERDOS     110
  390 FORMAT(1H0,'TEENAGER')                                            PERDOS     111
  395 FORMAT(1H0,'CHILD')                                               PERDOS     112
      PRINT 120                                                         PERDOS     113
      IF(KIT.EQ.20) PRINT 130                                           PERDOS     114
      IF(KIT.EQ.50) PRINT 110                                           PERDOS     115
      IF(KIT.EQ.30)PRINT 130                                            PERDOS     116
      IF(KIT.EQ.40) PRINT 115                                           PERDOS     117
      DO 340 K=1,LZ                                                     PERDOS     118
      IF(K.EQ.1)PRINT 380                                               PERDOS     119
      IF(K.EQ.2)PRINT 390                                               PERDOS     120
      IF(K.EQ.3) PRINT 395                                              PERDOS     121
      LOW=NADS(K,1)                                                     PERDOS     122
      DO 350 JS=1,7                                                     PERDOS     123
      IF(NADS(K,JS).GT.LOW)LOW=NADS(K,JS)                               PERDOS     124
  350 CONTINUE                                                          PERDOS     125
      IF(LOW.GT.20)LOW=20                                               CHANGE1     58
      DO 360 KJ=1,LOW                                                   PERDOS     126
      IF(KIT.EQ.30) PRINT 310,(ISOT(K,J,KJ),B1(K,J,KJ),B2(K,J,KJ),B3(K,J PERDOS     127
     +,KJ),IMET(K,J,KJ),A1(K,J,KJ),A2(K,J,KJ),A3(K,J,KJ),J=1,7)         PERDOS     128
      IF(KIT.EQ.20) PRINT 310,(ISOT(K,J,KJ),B1(K,J,KJ),B2(K,J,KJ),B3(K,J PERDOS     129
     +,KJ),IMET(K,J,KJ),A1(K,J,KJ),A2(K,J,KJ),A3(K,J,KJ),J=2,8)         PERDOS     130
      IF(KIT.EQ.50)PRINT 320,(ISOT(K,J,KJ),B1(K,J,KJ),B2(K,J,KJ),B3(K,J PERDOS     131
     +,KJ),IMET(K,J,KJ),A1(K,J,KJ),A2(K,J,KJ),A3(K,J,KJ),J=3,4)         PERDOS     132
      IF(KIT.EQ.40) PRINT 320,(ISOT(K,J,KJ),B1(K,J,KJ),B2(K,J,KJ),B3(K,J PERDOS     133
     +,KJ),IMET(K,J,KJ),A1(K,J,KJ),A2(K,J,KJ),A3(K,J,KJ),J=1,2)         PERDOS     134
  360 CONTINUE                                                          PERDOS     135
  340 CONTINUE                                                          PERDOS     136
      RETURN                                                            PERDOS     137
      END                                                               PERDOS     138
```

```
      SUBROUTINE PLUP(DOSE,N)                                          PLUP    2
      INTEGERIELEM                                                     PLUP    3
      LOGICALMETA                                                      PLUP    4
      COMMON/SORCE/IZ(300),IMASS(300),META(300),NLIBA,NLIBT,NLIBC,NLIBI PLUP   5
      COMMON/ELEMEN/IELEM(100)                                         PLUP    6
      COMMON Q(200),PL,CFS,NSUR,LT,RECU(200),LIST(200,4),LCT,LZ ,CON,KIT PLUP  7
     + ,POP                                                            PLUP    8
      DIMENSION DOSE(200,8),CUBEAD(200,8)                              PLUP    9
   10 FORMAT(1H1,20X,'*  *  *  COST-BENEFIT ANALYSIS  *  *  *')        PLUP   10
   11 FORMAT(1H0,'  NUCLIDE       RELEASE     ______MAN-REM DOSE______  __ PLUP   11
     +__MAN-REM PER CURIE____')                                        PLUP   12
   12 FORMAT(1H ,13X,'I    CI/YR    I TOTAL BODY I    THYROID   I TOTAL BOD BNL01  12
     +Y I    THYROID  I')                                              BNL01  13
   13 FORMAT(1H ,I4,A2,I4,A1,'  I  ',1PE8.2,'  I  ',E8.2,'  I  ',E8.2, BNL01  14
     +'  I  ',E8.2,'  I  ',E8.2,'  I')                                 BNL01  15
   14 FORMAT(1H0,'  TOTAL',20X,1PE8.2,5X,E8.2)                         PLUP   17
      IF(N.EQ.6.OR.N.EQ.7)GO TO 15                                     PLUP   16
      IF(N.EQ.5)GO TO 20                                               PLUP   19
      IF(N.EQ.3) GO TO 100                                             PLUP   20
      IF(N.EQ.4) GO TO 50                                              PLUP   21
   15 DO 30 J=1,NSUR                                                   PLUP   22
      CUBEAD(J,1)=CUBEAD(J,1)+DOSE(J,N-3)                              PLUP   23
      CUBEAD(J,2)=CUBEAD(J,2)+DOSE(J,N-2)                              PLUP   24
   30 CONTINUE                                                         PLUP   25
      RETURN                                                           PLUP   26
   20 DO 40 J=1,NSUR                                                   PLUP   27
      CUBEAD(J,1)=CUBEAD(J,1)+DOSE(J,2)                                PLUP   28
      CUBEAD(J,2)=CUBEAD(J,2)+DOSE(J,2)                                PLUP   29
   40 CONTINUE                                                         PLUP   30
      RETURN                                                           PLUP   31
   50 DO 60 J=1,200                                                    PLUP   32
      CUBEAD(J,1)=0.                                                   PLUP   33
      CUBEAD(J,2)=0.                                                   PLUP   34
   60 CONTINUE                                                         PLUP   35
      TOB=0.0                                                          PLUP   36
      TOT=0.0                                                          PLUP   37
      RETURN                                                           PLUP   38
  100 PRINT 10                                                         PLUP   39
      PRINT 11                                                         PLUP   40
      PRINT 12                                                         PLUP   41
      DO 110 J=1,NSUR                                                  PLUP   42
      LL=LIST(J,1)                                                     PLUP   43
      IK=IZ(LL)                                                        PLUP   44
      CIB=CUBEAD(J,1)/Q(J)                                             PLUP   45
      CIT=CUBEAD(J,2)/Q(J)                                             PLUP   46
      PRINT 13,IK,IELEM(IK),IMASS(LL),META(LL),Q(J),CUBEAD(J,1),CUBEAD(J PLUP  47
     +,2),CIB,CIT                                                      PLUP   48
      TOB=TOB+CUBEAD(J,1)                                              PLUP   49
      TOT=TOT+CUBEAD(J,2)                                              PLUP   50
  110 CONTINUE                                                         PLUP   51
      PRINT 14,TOB,TOT                                                 PLUP   52
      RETURN                                                           PLUP   53
      END                                                              PLUP   54
```

S C O P E 2 L O A D M A P LOADER VERSION 1.0 10/18/78 15.17.49 PAGE 1

PROGRAM WILL BE ENTERED AT LADTAP (340) SCM LENGTH 156366 LCM LENGTH 0

BLOCK	ADDRESS	LENGTH
/ELEMEN/	100	144
/POPUL/	244	4
BLKDAT	250	0
LADTAP	250	1623
/SURCE/	2073	1610
/OFLIB/	3703	17644
REDUF	23547	1306
SOURCE	25055	724
RECON	26001	244
ALARA	26245	1000
OUT	27245	3714
WHO	33161	626
WHY	34007	4516
WATER	40525	637
ACTIVE	41364	513
AQUA	42077	3242
/TRANS/	45341	1
DRINK	45342	3252
SHORE	50614	3311
SWIM	54125	3266
CRITTR	57413	3213
EAT	62626	3264
PAFO	66112	3240
CENT	71352	121
TRTIUM	71473	40
FLOOD	71533	1743
FOOD	73476	7410
PEROUS	103106	40467
PLOP	143575	3333
/FCL.C./	147130	23
/Q8.IO./	147153	134
Q8NTRY=	147307	1
COMIO=	147310	44
EOF	147354	20
FECMSK=	147374	41
FLTIN=	147435	154
FLTOUT=	147611	314
FMTAP=	150125	372
FORSYS=	150517	556
FORUTL=	151275	16
GETFIT=	151313	43
INCOM=	151356	257
INPC=	151635	173
KODER=	152030	467
KRAKER=	152517	454
OUTC=	153173	171
OUTCOM=	153364	203
GOTOER=	153567	14
ALOG	153603	77
EXP	153702	100
SYSAID=	154002	1
SYS=1ST	154003	62

S C O P E   2   L O A D   M A P


```
XTUI=      154065       10
 //        154075     2271
```

LADTAP TEST DECK FOR LIQUID EFFLUENT T/S IN FRESH WATER

DISCHARGE=2.00E+01 CFS   SOURCE TERM MULTIPLIER=1.00E+00

FRESHWATER SITE
TECH SPEC NUCLIDES

NO RECONCENTRATION OF NUCLIDES

* * * ADULT DOSE FACTORS * * *

NUCLIDE	CURIE/YEAR	INGESTION DOSE FACTORS (MREM/PCI INTAKE) BONE	LIVER	TOTAL BODY	THYROID	KIDNEY	LUNG	GI-LLI	SHORELINE (MREM/HR)/(PCI/M**2) SKIN	TOTAL BODY	RECON
1H 3	1.00E+00	0.	1.34E-07	1.34E-07	1.34E-07	1.34E-07	1.34E-07	1.34E-07	-0.	0.	1.00E+00
15P 32	1.00E+00	1.93E-04	1.21E-05	7.47E-06	0.	0.	0.	2.17E-05	-0.	0.	1.00E+00
24CR 51	1.00E+00	0.	0.	2.66E-09	1.59E-09	5.87E-10	3.53E-09	6.69E-07	2.60E-10	2.20E-10	1.00E+00
25MN 54	1.00E+00	0.	4.57E-06	8.73E-07	0.	1.36E-06	0.	1.40E-05	6.80E-09	5.80E-09	1.00E+00
26FE 55	1.00E+00	6.20E-06	2.79E-05	7.33E-06	0.	0.	3.23E-05	1.09E-05	-0.	0.	1.00E+00
26FE 59	1.00E+00	4.34E-06	1.03E-05	3.92E-06	0.	0.	2.86E-06	3.40E-05	9.40E-09	8.00E-09	1.00E+00
27CO 58	1.00E+00	0.	7.46E-07	1.67E-06	0.	0.	0.	1.51E-05	8.20E-09	7.00E-09	1.00E+00
27CO 60	1.00E+00	0.	2.15E-06	4.72E-06	0.	0.	0.	4.02E-05	2.00E-08	1.70E-08	1.00E+00
30ZN 65	1.00E+00	4.65E-06	1.54E-05	6.97E-06	0.	1.03E-05	0.	9.70E-06	4.60E-09	4.00E-09	1.00E+00
30ZN 69M	1.00E+00	1.70E-07	4.09E-07	3.73E-08	0.	2.48E-07	0.	2.49E-05	3.40E-09	2.90E-09	1.00E+00
37RB 86	1.00E+00	0.	2.11E-05	9.84E-06	0.	0.	0.	4.16E-06	7.20E-10	6.30E-10	1.00E+00
38SR 89	1.00E+00	3.09E-04	0.	8.85E-06	0.	0.	0.	4.94E-05	6.50E-13	5.60E-13	1.00E+00
38SR 90	1.00E+00	7.61E-03	0.	1.86E-03	0.	0.	0.	1.02E-04	-0.	0.	1.00E+00
39Y 90	1.00E+00	9.63E-09	0.	2.58E-10	0.	0.	0.	1.02E-04	2.60E-12	2.20E-12	1.00E+00
39Y 91	1.00E+00	1.41E-07	0.	3.78E-09	0.	0.	0.	7.76E-05	2.70E-11	2.40E-11	1.00E+00
40ZR 95	1.00E+00	3.04E-08	9.76E-09	6.61E-09	0.	1.54E-08	0.	3.03E-05	5.80E-09	5.00E-09	1.00E+00
40ZR 97	1.00E+00	1.68E-09	3.39E-10	1.56E-10	0.	5.12E-10	0.	1.05E-04	6.40E-09	5.50E-09	1.00E+00
41NB 95	1.00E+00	6.23E-09	3.46E-09	1.36E-09	0.	3.43E-09	0.	2.10E-05	6.00E-09	5.10E-09	1.00E+00
42MO 99	1.00E+00	0.	4.31E-06	8.20E-07	0.	9.77E-06	0.	9.99E-06	2.20E-09	1.90E-09	1.00E+00
44RU 103	1.00E+00	1.85E-07	-0.	7.98E-08	-0.	7.07E-07	-0.	2.16E-05	4.20E-09	3.60E-09	1.00E+00
44RU 106	1.00E+00	2.75E-06	-0.	3.48E-07	-0.	5.32E-06	-0.	1.78E-04	1.80E-09	1.50E-09	1.00E+00
47AG 110M	1.00E+00	1.60E-07	1.48E-07	8.80E-08	-0.	2.91E-07	-0.	6.04E-05	2.10E-08	1.80E-08	1.00E+00
48CD 113M	1.00E+00	-0.	3.19E-06	1.02E-07	-0.	3.50E-06	-0.	2.56E-05	2.60E-12	2.30E-12	1.00E+00
50SN 123	1.00E+00	3.11E-05	5.16E-07	7.60E-07	4.38E-07	-0.	-0.	6.33E-05	6.46E-08	-0.	1.00E+00
50SN 126	1.00E+00	8.46E-05	1.68E-06	2.41E-06	4.92E-07	-0.	-0.	2.43E-05	1.00E-08	9.00E-09	1.00E+00
51SB 124	1.00E+00	2.81E-06	5.30E-08	1.11E-06	6.79E-09	-0.	2.18E-06	7.95E-05	1.50E-08	1.30E-08	1.00E+00
51SB 125	1.00E+00	2.23E-06	2.40E-08	4.48E-07	1.98E-09	-0.	2.33E-04	1.97E-05	3.50E-09	3.10E-09	1.00E+00
52TE 125M	1.00E+00	2.68E-06	9.73E-07	3.59E-07	8.07E-07	1.09E-05	-0.	1.07E-05	4.80E-11	3.50E-11	1.00E+00
52TE 127M	1.00E+00	6.78E-06	2.37E-06	8.26E-07	1.73E-06	2.75E-05	-0.	2.27E-05	1.30E-12	1.10E-12	1.00E+00
52TE 129M	1.00E+00	1.15E-05	4.30E-06	1.82E-06	3.95E-06	4.80E-05	-0.	5.79E-05	9.00E-10	7.70E-10	1.00E+00
52TE 131M	1.00E+00	1.74E-06	8.47E-07	7.06E-07	1.34E-06	8.58E-06	-0.	8.40E-05	9.90E-09	8.40E-09	1.00E+00
52TE 132	1.00E+00	2.53E-05	1.64E-06	1.53E-06	1.80E-06	1.58E-05	-0.	7.71E-05	2.00E-09	1.70E-09	1.00E+00
53I 131	1.00E+00	4.16E-06	5.96E-06	3.41E-06	1.95E-03	1.02E-05	-0.	1.57E-06	3.40E-09	2.80E-09	1.00E+00
53I 133	1.00E+00	1.43E-06	2.48E-06	7.57E-07	4.77E-04	4.33E-06	-0.	2.18E-06	4.50E-09	3.70E-09	1.00E+00
55CS 134	1.00E+00	6.22E-05	1.48E-04	1.21E-04	-0.	4.80E-05	1.59E-05	2.59E-06	1.40E-08	1.20E-08	1.00E+00
55CS 136	1.00E+00	6.51E-06	2.57E-05	1.85E-05	-0.	1.43E-05	1.96E-06	2.92E-06	1.70E-08	1.50E-08	1.00E+00
55CS 137	1.00E+00	7.98E-05	1.09E-04	7.15E-05	-0.	3.71E-05	1.23E-05	2.10E-06	4.90E-09	4.20E-09	1.00E+00
56BA 140	1.00E+00	2.03E-05	2.55E-08	1.34E-06	-0.	8.68E-09	1.46E-08	4.18E-05	2.40E-09	2.10E-09	1.00E+00
57LA 140	1.00E+00	2.50E-09	1.26E-09	3.34E-10	-0.	-0.	-0.	9.25E-05	1.70E-08	1.50E-08	1.00E+00
58CE 141	1.00E+00	9.37E-09	6.34E-09	7.18E-10	-0.	2.94E-09	-0.	2.42E-05	6.20E-10	5.50E-10	1.00E+00
58CE 143	1.00E+00	1.65E-09	1.22E-06	1.35E-10	-0.	5.38E-10	-0.	4.56E-05	2.50E-09	2.20E-09	1.00E+00
58CE 144	1.00E+00	4.89E-07	2.04E-07	2.62E-08	-0.	1.21E-07	-0.	1.65E-04	3.70E-10	3.20E-10	1.00E+00
59PR 143	1.00E+00	9.21E-09	3.70E-09	4.57E-10	-0.	2.13E-09	-0.	4.03E-05	-0.	-0.	1.00E+00
93NP 239	1.00E+00	1.20E-09	1.18E-10	6.46E-11	-0.	3.65E-10	-0.	2.40E-05	1.10E-09	9.50E-10	1.00E+00

* * * TEENAGER DOSE FACTORS * * *

NUCLIDE		CURIE/YEAR	BONE	LIVER	TOTAL BODY	THYROID	KIDNEY	LUNG	GI-LLI	SKIN	TOTAL BODY	RECON
			INGESTION DOSE FACTORS (MREM/PCI INTAKE)							SHORELINE (MREM/HR)/(PCI/M**2)		
1H	3	1.00E+00	0.	1.06E-07	1.06E-07	1.06E-07	1.34E-07	1.06E-07	1.06E-07			
27CO	58	1.00E+00	0.	9.92E-07	2.20E-06	0.	0.	0.	1.34E-05			
27CO	60	1.00E+00	0.	2.76E-06	6.30E-06	0.	0.	0.	3.31E-05			
38SR	89	1.00E+00	4.60E-04	0.	1.32E-05	0.	0.	0.	4.99E-05			
38SR	90	1.00E+00	1.04E-02	0.	2.57E-03	0.	0.	0.	2.20E-04			
39Y	90	1.00E+00	3.30E-08	0.	8.87E-10	0.	0.	3.75E-05	1.09E-04			
39Y	91	1.00E+00	1.96E-07	0.	5.23E-09	0.	0.	0.	7.53E-05			
40ZR	95	1.00E+00	3.72E-08	1.24E-08	8.66E-09	0.	1.54E-08	0.	2.68E-05			
41NB	95	1.00E+00	7.24E-09	4.36E-09	2.46E-09	0.	3.43E-09	0.	1.78E-05			
44RU	103	1.00E+00	2.37E-07	0.	1.06E-07	0.	7.07E-07	0.	1.85E-05			
44RU	106	1.00E+00	4.00E-06	0.	5.03E-07	0.	5.32E-06	0.	1.81E-04			
50SN	123	1.00E+00	4.38E-05	7.22E-07	1.08E-06	5.78E-07	-0.	0.	6.31E-05			
52TE	125M	1.00E+00	3.83E-06	1.37E-06	5.08E-07	1.06E-06	1.09E-05	0.	1.07E-05			
52TE	129M	1.00E+00	1.66E-05	6.15E-06	2.61E-06	5.30E-06	4.80E-05	0.	5.80E-05			
52TE	132	1.00E+00	3.55E-06	2.22E-06	2.10E-06	2.36E-06	1.58E-05	0.	8.00E-05			
53I	131	1.00E+00	5.57E-06	7.87E-06	4.69E-06	2.27E-03	1.02E-05	0.	1.49E-06			
53I	133	1.00E+00	2.03E-06	3.44E-06	1.06E-06	6.25E-04	4.33E-06	0.	2.50E-06			
55CS	134	1.00E+00	8.05E-05	1.94E-04	9.06E-05	0.	4.80E-05	2.35E-05	2.24E-06			
55CS	137	1.00E+00	1.07E-04	1.44E-04	5.05E-05	0.	3.71E-05	1.91E-05	1.92E-06			
56BA	140	1.00E+00	2.83E-05	3.48E-08	1.82E-06	0.	8.68E-09	2.33E-08	4.14E-06			
57LA	140	1.00E+00	3.48E-09	1.72E-09	4.55E-10	0.	-0.	0.	9.48E-05			
58CE	141	1.00E+00	1.26E-08	8.46E-09	9.70E-10	0.	2.94E-09	0.	2.29E-05			
58CE	144	1.00E+00	7.22E-07	2.96E-07	3.83E-08	0.	1.21E-07	0.	1.70E-04			

* * * CHILD DOSE FACTORS * * *

NUCLIDE		CURIE/YEAR	BONE	LIVER	TOTAL BODY	THYROID	KIDNEY	LUNG	GI-LLI	SKIN	TOTAL BODY	RECON
			INGESTION DOSE FACTORS (MREM/PCI INTAKE)							SHORELINE (MREM/HR)/(PCI/M**2)		
1H	3	1.00E+00	0.	2.03E-07	2.03E-07	2.03E-07	1.34E-07	2.03E-07	2.03E-07			
27CO	58	1.00E+00	0.	1.85E-06	5.58E-06	0.	0.	0.	1.10E-05			
27CO	60	1.00E+00	0.	5.17E-06	1.55E-05	0.	0.	0.	2.86E-05			
38SR	89	1.00E+00	1.38E-03	0.	3.95E-05	0.	0.	0.	5.15E-05			
38SR	90	1.00E+00	1.72E-02	0.	4.36E-03	0.	0.	0.	2.29E-04			
39Y	90	1.00E+00	4.21E-08	0.	1.13E-09	0.	0.	0.	1.20E-04			
39Y	91	1.00E+00	5.65E-07	0.	1.56E-08	0.	0.	0.	7.77E-05			
40ZR	95	1.00E+00	1.04E-07	2.42E-08	2.20E-08	0.	1.54E-08	0.	2.50E-05			
41NB	95	1.00E+00	1.95E-08	8.32E-09	6.11E-09	0.	3.43E-09	0.	1.44E-05			
44RU	103	1.00E+00	6.78E-07	0.	2.74E-07	0.	7.07E-07	0.	1.78E-05			
44RU	106	1.00E+00	1.19E-05	0.	1.48E-06	0.	5.32E-06	0.	1.85E-04			
50SN	123	1.00E+00	1.31E-04	1.64E-06	3.22E-06	1.73E-06	-0.	0.	6.50E-05			
52TE	125M	1.00E+00	1.14E-05	3.09E-06	1.52E-06	3.20E-06	1.09E-05	0.	1.10E-05			
52TE	129M	1.00E+00	4.95E-05	1.38E-05	7.65E-06	1.58E-05	4.80E-05	0.	5.96E-05			
52TE	132	1.00E+00	1.02E-05	4.50E-06	5.42E-06	6.62E-06	1.58E-05	0.	7.89E-05			
53I	131	1.00E+00	1.63E-05	1.67E-05	1.26E-05	5.43E-03	1.02E-05	0.	1.43E-06			
53I	133	1.00E+00	5.98E-06	7.38E-06	2.90E-06	1.78E-03	4.33E-06	0.	2.99E-06			
55CS	134	1.00E+00	2.24E-04	3.77E-04	8.02E-05	0.	4.80E-05	4.19E-05	2.04E-06			
55CS	137	1.00E+00	3.12E-04	3.02E-04	4.50E-05	0.	3.71E-05	3.54E-05	1.84E-06			
56BA	140	1.00E+00	8.26E-05	7.25E-08	4.85E-06	0.	8.68E-09	4.32E-08	4.21E-06			
57LA	140	1.00E+00	1.01E-08	3.52E-09	1.19E-09	0.	-0.	0.	1.00E-04			
58CE	141	1.00E+00	3.76E-08	1.88E-08	2.80E-09	0.	2.94E-09	0.	2.36E-05			
58CE	144	1.00E+00	2.14E-06	6.70E-07	1.14E-07	0.	1.21E-07	0.	1.74E-04			

* * * INFANT DOSE FACTORS * * *

NUCLIDE	CURIE/YEAR	INGESTION DOSE FACTORS (MREM/PCI INTAKE) BONE	LIVER	TOTAL BODY	THYROID	KIDNEY	LUNG	GI-LLI	SHORELINE (MREM/HR)/(PCI/M**2) SKIN	TOTAL BODY	RECON
1H 3	1.00E+00	0.	3.07E-07	3.07E-07	3.07E-07	1.34E-07	3.07E-07	3.07E-07			
27CO 58	1.00E+00	0.	3.78E-06	9.26E-06	0.	0.	0.	9.79E-06			
27CO 60	1.00E+00	0.	1.07E-05	2.56E-05	0.	0.	0.	2.64E-05			
38SR 89	1.00E+00	2.93E-03	0.	8.42E-05	0.	0.	0.	5.48E-05			
38SR 90	1.00E+00	2.51E-02	0.	6.40E-03	0.	0.	0.	2.43E-04			
39Y 90	1.00E+00	8.97E-08	0.	2.41E-09	0.	0.	0.	1.29E-04			
39Y 91	1.00E+00	1.25E-06	0.	3.33E-08	0.	0.	0.	8.27E-05			
40ZR 95	1.00E+00	2.11E-07	5.32E-08	3.78E-08	0.	1.54E-08	0.	2.36E-05			
41NB 95	1.00E+00	3.89E-08	1.75E-08	1.03E-08	0.	3.43E-09	0.	1.40E-05			
44RU 103	1.00E+00	1.41E-06	0.	4.85E-07	0.	7.07E-07	0.	1.76E-05			
44RU 106	1.00E+00	2.54E-05	0.	3.12E-06	0.	5.32E-06	0.	1.97E-04			
50SN 123	1.00E+00	2.79E-04	4.33E-06	6.86E-06	4.33E-06	-0.	0.	6.91E-05			
52TE 125M	1.00E+00	2.43E-05	8.19E-06	3.24E-06	8.00E-06	1.00E-05	0.	1.17E-05			
52TE 129M	1.00E+00	1.05E-04	3.61E-05	1.60E-05	3.95E-05	4.80E-05	0.	6.33E-05			
52TE 132	1.00E+00	2.13E-05	1.05E-05	9.76E-06	1.55E-05	1.58E-05	0.	8.08E-05			
53I 131	1.00E+00	3.42E-05	4.07E-05	2.38E-05	1.31E-02	1.02E-05	0.	1.53E-06			
53I 133	1.00E+00	1.26E-05	1.84E-05	5.58E-06	4.35E-03	4.33E-06	0.	3.27E-06			
55CS 134	1.00E+00	4.58E-04	8.24E-04	6.97E-05	0.	4.80E-05	9.42E-05	1.96E-06			
55CS 137	1.00E+00	6.53E-04	7.31E-04	4.20E-05	0.	3.71E-05	8.81E-05	1.89E-06			
56BA 140	1.00E+00	1.74E-04	1.75E-07	8.99E-06	0.	8.68E-09	1.07E-07	4.43E-06			
57LA 140	1.00E+00	2.12E-08	8.37E-09	2.16E-09	0.	-0.	0.	1.04E-04			
58CE 141	1.00E+00	8.00E-08	4.91E-08	5.75E-09	0.	2.94E-09	0.	2.38E-05			
58CE 144	1.00E+00	4.49E-06	1.77E-06	2.42E-07	0.	1.21E-07	0.	1.85E-04			

TOTAL NUMBER IN SOURCE TERM IS 44 TOTAL RELEASE IS 4.4000E+01

* * * AS LOW AS REASONABLY ACHIEVABLE * * *

ADULT DOSES

PATHWAY	SKIN	BONE	LIVER	TOTAL BODY	THYROID	KIDNEY	LUNG	GI-LLI
	DOSE (MREM PER YEAR INTAKE)							
FISH		2.27E+04	2.12E+03	1.45E+03	4.26E+01	3.06E+02	7.50E+01	3.66E+03
DRINKING		3.46E+02	1.65E+01	8.73E+01	8.98E+01	1.02E+01	1.23E+01	6.99E+01
SHORELINE	8.01E+00	6.49E+00	6.49E+00	6.49E+00	6.49E+00	6.49E+00	6.49E+00	6.49E+00
TOTAL	8.01E+00	2.30E+04	2.14E+03	1.54E+03	1.39E+02	3.23E+02	9.38E+01	3.74E+03

	USAGE (KG/YR,HR/YR)	DILUTION	TIME(HR)
FISH	21.0	1.0	24.00
DRINKING	730.0	1.0	12.00
SHORELINE	12.0	1.0	-0.00

SHOREWIDTH FACTOR=1.0

* * * ISOTOPE CONTRIBUTION * * *

PATHWAY	SKIN	BONE	LIVER	TOTAL BODY	THYROID	KIDNEY	LUNG	GI-LLI
FISH		P 32 95%	P 32 63%	P 32 57%	SN 123 3%	ZN 65 7%	FE 55 5%	P 32 66%
		SR 90 1%	ZN 65 1%	ZN 65 1%	SN 126 4%	TE 125M 1%	CS 134 49%	NB 95 19%
		SN 126 1%	RB 86 2%	RB 86 1%	TE 127M 1%	TE 127M 4%	CS 136 5%	SN 123 6%
			CS 134 16%	SR 90 4%	TE 129M 4%	TE 129M 7%	CS 137 38%	SN 126 2%
			CS 136 2%	CS 134 19%	TE 132 1%	TE 132 1%		
			CS 137 12%	CS 136 2%	I 131 73%	CS 134 36%		
				CS 137 11%	I 133 .8%	CS 136 10%		
						CS 137 28%		
DRINKING		P 32 2%	P 32 2%	SR 90 87%	I 131 84%	ZN 65 4%	FE 55 10%	P 32 1%
		SR 89 3%	MN 54 1%	CS 134 5%	I 133 14%	MO 99 3%	SB 125 77%	FE 59 1%
		SR 90 89%	FE 55 6%	CS 137 3%		RU 106 2%	CS 134 5%	CO 60 2%
			FE 59 2%			CD 113M 1%	CS 137 4%	SR 89 2%
			ZN 65 3%			TE 125M 4%		SR 90 5%
			RB 86 5%			TE 127M 11%		Y 90 5%
			TE 129M 1%			TE 129M 19%		Y 91 4%
			I 131 1%			TE 131M 2%		ZR 95 1%
			CS 134 36%			TE 132 5%		ZR 97 3%
			CS 136 6%			I 131 3%		NB 95 1%
			CS 137 27%			I 133 1%		RU 103 1%
						CS 134 19%		RU 106 10%
						CS 136 5%		AG 110M 3%
						CS 137 14%		CD 113M 1%
								SN 123 3%
								SN 126 1%
								SB 124 4%
								SB 125 1%
								TE 127M 1%
								TE 129M 3%
SHORELINE	MN 54 1%	MN 54 1%						
	CO 60 27%	CO 60 28%						
	AG 110M 4%	AG 110M 4%						
	SN 123 6%	SN 126 34%						
	SN 126 31%	SB 125 3%						
	SB 125 2%	CS 134 9%						
	CS 134 8%	CS 137 13%						
	CS 137 12%							

TABLE 4.11-2
LIQUID EFFLUENT DOSE PARAMETERS

RADIONUCLIDE	A(I),MREM/HR PER UCI/ML TOTAL BODY	CRITICAL ORGAN
H 3	1.14E+01	1.14E+01
P 32	1.71E+06	4.41E+07
CR 51	1.46E+00	3.66E+02
MN 54	9.07E+02	1.45E+04
FE 55	2.36E+03	1.04E+04
FE 59	1.25E+03	1.08E+04
CO 58	3.36E+02	3.04E+03
CO 60	9.58E+02	8.16E+03
ZN 65	3.39E+04	7.49E+04
ZN 69M	5.55E+01	3.70E+04
RB 86	4.62E+04	9.91E+04
SR 89	1.36E+03	4.75E+04
SR 90	2.89E+05	1.18E+06
Y 90	3.08E-02	1.22E+04
Y 91	5.37E-01	1.10E+04
ZR 95	5.99E-01	2.75E+03
ZR 97	8.40E-03	5.65E+03
NB 95	9.59E+01	1.48E+06
MO 99	7.55E+01	9.19E+02
RU 103	8.47E+00	2.29E+03
RU 106	3.73E+01	1.91E+04
AG 110M	7.80E+00	5.35E+03
CD 113M	5.74E+01	1.44E+04
SN 123	5.50E+03	4.58E+05
SN 126	1.75E+04	6.15E+05
SB 124	9.45E+01	6.77E+03
SB 125	3.84E+01	2.00E+04
TE 125M	3.70E+02	1.12E+04
TE 127M	8.55E+02	2.85E+04
TE 129M	1.86E+03	5.91E+04
TE 131M	4.33E+02	5.15E+04
TE 132	1.30E+03	6.55E+04
I 131	3.84E+02	2.20E+05
I 133	5.45E+01	3.43E+04
CS 134	5.89E+05	7.21E+05
CS 136	8.55E+04	1.19E+05
CS 137	3.48E+05	5.31E+05
BA 140	1.21E+02	3.77E+03
LA 140	3.59E-02	9.93E+03
CE 141	6.08E-02	2.05E+03
CE 143	8.93E-03	3.02E+03
CE 144	2.24E+00	1.41E+04
PR 143	6.31E-02	5.56E+03
NP 239	5.79E-03	2.15E+03

DRINKING DILUTION IN ADDITION TO THAT FOR FISH= 1.0

ADDENDUM

Setpoint Calculations

The radiological effluent Technical Specifications require alarm/trip setpoints for radiation monitors and flow measurement devices for each effluent line. Setpoint values are to be calculated to assure that alarm and trip actions occur prior to exceeding the limits of 10 CFR 20 at the release point to the unrestricted area. The calculated alarm and trip action setpoints to be specified in the ODCM for each radioactive liquid effluent line monitor and flow measurement device must satisfy the following equation:

$$\frac{cf}{F+f} \leq C$$

where:

C = the effluent concentration limit (Specification 3.11.1) implementing 10 CFR 20 for the site, in μCi/ml

c = the setpoint, in μCi/ml, of the radioactivity monitor measuring the radioactivity concentration in the effluent line prior to dilution and subsequent release; the setpoint, which is proportional to the volumetric flow of the effluent line and inversely proportional to the volumetric flow of the dilution stream plus the effluent stream, represents a value which, if exceeded, would result in concentrations exceeding the limits of 10 CFR 20 in the unrestricted area

f = the flow setpoint as measured at the radiation monitor location, in volume per unit time, but in the same units as F, below

F = the dilution water flow setpoint as measured prior to the release point, in volume per unit time.

[Note that if no dilution is provided, $c \leq C$. Also, note that when (F) is large compared to (f), then $F+f \approx F$.]

The equation is satisfied when the following alarm/trip setpoints are provided for each effluent line in the ODCM:

$$f \leq \frac{CF}{c} \text{ (in ml/sec; for example).}$$

$$F \leq \frac{cf}{C} \text{ (in ml/sec; for example).}$$

$$c \leq \frac{CF}{f} \text{ (in μCi/ml; for example).}$$

Some plants may be operated using a fixed value for one or more of these three variables, c, f or F.

Example 1

By using a constant capacity radwaste system discharge pump (on the undiluted stream) the value of (f) is fixed; therefore, the setpoints to be given in the ODCM are:

f = ______________________ ml/sec (fixed)

$F >$ ______________________ ml/sec = cf/C

c = ______________________ xF μCi/ml $\leq$ CF/f

If C = 3×10^{-8} μCi/ml, f = 4000 ml/sec and F > 4×10^{6} ml/sec, the radiation monitor setpoint is calculated as follows:

$$c \leq CF/f$$

$$= \frac{(3\times10^{-8})F}{4000} = 7.5\times10^{-12}F\ \mu Ci/ml.$$

If F is measured at some value in excess of the limiting value (the limiting value is 4×10^{6} ml/sec in this example), then c may be established proportionately. If F = 8×10^{6} ml/sec, the alarm setpoint is:

$$c = 7.5\times10^{-12}F\ (\mu Ci/ml\ per\ ml/sec)(ml/sec)$$

$$= 7.5\times10^{-12}(8\times106) = 6\times10^{-5}\ \mu Ci/ml.$$

In this case, the alarm setpoint for the radioactive liquid effluent line monitor can be established at 6×10^{-5} μCi/ml, provided that an automatic isolation/control trip action occurs to satisfy the condition:

$$c/F < 7\times5\times10^{-12}\ \mu Ci/ml\ per\ ml/sec.$$

Example 2

By using a constant capacity dilution pump (on the dilution stream prior to a mixing box), the value of (F) is fixed; therefore, the setpoints to be given in the ODCM are:

$f <$ ______________________ ml/sec = CF/c

F = ______________________ ml/sec (fixed)

c = ______________________ x(1/f)μCi/ml $\leq$ CF/f

If C = 3×10^{-8} μCi/ml, F = 4×10^{6} ml/sec and f < 4000 ml/sec, the radiation monitor setpoint is calculated as follows:

$$c \leq CF/f$$

$$= \frac{(3\times10^{-8}\ X\ 4\times10^{6})}{f} = 0.12(1/f)\ \mu Ci/ml.$$

If f is measured at some value less than the limiting value (the limiting value is 4000 ml/sec in this example), then c may be established proportionately. If f = 1000 ml/sec, the alarm setpoint is:

$$c = 0.12(1/f)(\mu Ci/sec)(sec/ml)$$

$$= \frac{0.12}{1000} = 1.2\times10^{-4}\ \mu Ci/ml.$$

In this case, the alarm setpoint for the radioactive liquid effluent line monitor can be established at 1.2×10^{-4} μCi/ml, <u>provided</u> that an automatic isolation/control trip action occurs to satisfy the condition:

$$cf > 0.12 \ \mu Ci/sec.$$

<u>Value of c</u>

A detailed description of the method to be used to obtain the value of (c) should be provided in the ODCM. Since (c) is dependent on the radionuclide distribution, yields, calibration and the monitor's parameters, each of these variables should be considered and the fixed or adjustable setpoint method of determination described in the ODCM for each effluent monitor. This may be accomplished by tabulation. Changes to the ODCM shall be provided in the SEMIANNUAL RADIOACTIVE EFFLUENT RELEASE REPORT.

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This guidance manual provides the NRC staff methodology for calculating parameters for limiting conditions of operation required in the radiological effluent Technical Specifications for light-water-cooled nuclear power plants. It provides guidance in using the model specifications reported in NUREG-0472 (Rev. 1)*and NUREG-0473 (Rev. 1),* applicable to operating PWR and BWR licensees, and users of the Standard Technical Specifications packages available for various vendor designs. The manual addresses the implementation of the Regulations and current NRC staff positions as related to the radioactive waste management systems, effluent control and radiological monitoring programs and provides equations, references, computer codes, and guidelines pertinent to these limiting conditions for operation.

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