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REVISION 1

MASTER

**CALCULATION OF RELEASES OF
RADIOACTIVE MATERIALS IN GASEOUS
LIQUID EFFLUENTS FROM BOILING WATER
REACTORS
(BWR-GALE CODE)**

**F.P. Cardile, Editor
R.R. Bellamy, Editor**

**Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission**

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CALCULATION OF RELEASES OF RADIOACTIVE MATERIALS IN GASEOUS AND LIQUID EFFLUENTS FROM BOILING WATER REACTORS (BWR-GALE CODE)

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FOREWORD

The calculational procedures described in this NUREG report reflect current NRC staff practice. Therefore, the methods described herein will be used in the evaluation of applications for construction permits and operating licenses docketed after January 1, 1979, until this NUREG is revised as a result of additional staff review.

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CHAPTER 1. BWR-GALE CODE

1.1 INTRODUCTION

In promulgating Appendix I to 10 CFR Part 50, the U.S. Nuclear Regulatory Commission indicated its desire to use the best available data for improving the calculational models used by the Commission Staff to determine conformance with the requirements of the regulation. The first issue of this NUREG Report was published in April 1976. Revision 1 is being issued to update NUREG-0016 by incorporating more recent operating data now available and also by incorporating the results of a number of in-plant measurements programs at operating BWRs.

The BWR-GALE (Boiling Water Reactor Gaseous and Liquid Effluents) Code is a computerized mathematical model for calculating the release of radioactive material in gaseous and liquid effluents from boiling water reactors (BWRs). The calculations are based on data generated from operating reactors, field tests, laboratory tests, and plant-specific design considerations incorporated to reduce the quantity of radioactive materials that may be released to the environment.

The average quantity of radioactive material released to the environment from a nuclear power reactor during normal operation including anticipated operational occurrences is called the "source term," since it is the source or initial number used in calculating the environmental impact of radioactive releases. The calculations performed by the BWR-GALE Code are based on (1) standardized coolant activities derived from American Nuclear Society (ANS) 18.1 Working Group recommendations (Ref. 1), (2) release and transport mechanisms that result in the appearance of radioactive material in liquid and gaseous waste streams, (3) plant-specific design features used to reduce the quantities of radioactive materials ultimately released to the environs, and (4) information received on the operation of nuclear power plants.

In a BWR, water is converted to steam by heat from the fuel elements in the reactor. The steam expands through a turbine and then is condensed and returned to the reactor. The principal mechanisms that affect the concentrations of radioactive materials in the reactor coolant are (1) fission product leakage to the coolant from defects in the fuel cladding and fission product generation in tramp uranium, (2) corrosion products activated in the core, (3) radioactivity removed by the reactor coolant cleanup system, (4) radioactivity removed by the condensate demineralizers, (5) radioactivity removed through the steam-jet air ejectors, and (6) radioactivity removed due to reactor coolant leakage. These mechanisms are described briefly in the following paragraphs.

Fission products enter the coolant as a result of defects in the fuel cladding and from the tramp uranium on the cladding surfaces, while corrosion products are activated in the reactor core. These impurities must be continuously removed from the reactor coolant to prevent damage to the fuel elements and other reactor components. The removal is accomplished in two ways: (1) after passing through the turbine, the condensed steam is processed through the condensate cleanup system (e.g., demineralizers) and returned to the reactor for reuse and (2) a side stream of reactor coolant is continuously withdrawn, processed through the reactor water cleanup system (demineralizers), and returned to the reactor vessel. Both cleanup systems remove particulates and ionic impurities from the reactor coolant. The materials collected by the demineralizers are removed periodically by chemical regeneration or by replacement of resins. The liquid wastes are processed in the liquid waste treatment system, and the spent ion exchange resins are transferred to the solid waste treatment system and prepared for offsite shipment.

Radioactive gases are removed from the condensing steam in the main condenser by the steam-jet air ejectors. This source of gaseous waste is treated principally by delaying the release to permit radioactive decay. Treatment methods include holdup lines, long-term holdup using charcoal delay systems, and cryogenic distillation.

Additional radioactive material is released with the exhaust from the turbine gland sealing system when a sidestream of primary steam flows through the turbine gland seal. The steam is condensed and returned to the condenser hotwell for reuse in the reactor. However, noble gases, activation gases, radioactive particulates, and radioiodine that remain in the gaseous phase must be vented. The treatment provided this source of gaseous waste is normally a two-minute holdup line that permits decay of the short-lived noble and activation gases before they are released to the environment. Clean steam (nonradioactive steam) may be

used in place of primary steam to eliminate the turbine gland seal as a potential activity release point.

Following plant shutdowns, mechanical vacuum pumps are used to reestablish the main condenser vacuum. In addition, the mechanical vacuum pumps may be used during plant shutdowns to maintain a slight condenser vacuum and thereby prevent outleakage of radioactive gases from the main condenser. If required to meet the design objectives of Appendix I, the effluent from the mechanical vacuum pump effluent could be processed through charcoal adsorbers for removal of radioiodine prior to release to the environment.

In addition to the above release points, the BWR-GALE Code considers ventilation system releases from the turbine, containment, auxiliary (including the spent fuel pool area), and radwaste buildings due to leakage from contaminated systems. Such leakage from systems containing main steam or reactor coolant may have an appreciable effect on the radioactive source term. Leakage may occur through valve stems, pump seals, and flanged connections. The amount of airborne radioactive material released is a function of reactor coolant temperature, pressure, and activity at the point where the leak occurs. Included with the leaking steam or coolant are noble gases, iodine, and particulates that are released directly to the building atmosphere. In some cases, leakage may be reduced by special design features such as vacuum leakoff drains or "clean" steam on the valve bonnets in addition to normal precautions such as backseating valves and using all-welded systems. Leakage can also be reduced by the use of closed leakoff drains and by increased maintenance.

Liquid waste sources include liquid streams used to sluice (transfer), backwash, regenerate, and rinse demineralizer resins; laundry waste water; personnel shower wastes; laboratory drain wastes; decontamination wastes; and water collected in equipment drains and floor drains.

This chapter provides a step-by-step explanation of the BWR-GALE Code and a description of the parameters that have been built into the Code for use with all BWR source term calculations. These parameters, which apply generically to all BWRs, have been incorporated into the Code to eliminate the need for their entry on input data cards. This chapter also describes the entries required to be entered on input data cards used by the Code. Explanations of the data required, along with acceptable means for calculating such data, are given for each input data card. Chapter 2 gives the principal source term parameters developed for use with the BWR-GALE Code and explains the bases for each parameter. Chapter 3 contains a sample data input sheet and a FORTRAN listing of the BWR-GALE Code. Chapter 4 lists the information needed to generate source terms that an applicant is required to submit with the application.

1.2 DEFINITIONS

The following definitions apply to terms used in this report:

Activation Gases: The gases (including oxygen, nitrogen, and argon) that become radioactive due to irradiation in the core.

Anticipated Operational Occurrences - unplanned releases of radioactive materials from miscellaneous actions such as equipment failure, operator error, administrative error, that are not of consequence to be considered an accident.

Chemical Waste Stream: Liquids that contain relatively high concentrations of decontamination wastes or chemical compounds other than detergents. These liquids originate primarily from resin regenerants and laboratory waste.

Carryover Factor: Ratio of I-131 concentration in the condenser hotwell to its concentration in the reactor vessel. This value is used to express the partition coefficient between the steam and water phases in the reactor.

Decontamination Factor (DF): The ratio of the initial amount of a nuclide in a stream (specified in terms of concentration or activity of radioactive materials) to the final amount of that nuclide in a stream following treatment by a given process.

Detergent Waste Stream: Liquids that contain detergent, soaps, or similar organic materials. These liquids consist principally of laundry, personnel shower, and equipment decontamination wastes and normally have a low radioactivity content.

Effective Full Power Days: The number of days a plant would have to operate at 100% licensed power to produce the integrated thermal power output during a calendar year; i.e.,

$$\text{Effective Full Power Days} = \frac{\text{Integrated Thermal Power}}{\text{Licensed Power Level}} = \frac{\sum P_i T_i}{P_{\text{total}}}$$

where

- P_i is the i th power level, in MWt;
 P_{total} is the license power level, in MWt; and
 T_i is the time of operation at power level i , in days.

Fission Product: A nuclide produced either by fission or by subsequent radioactive decay or neutron activation of the nuclides formed in the fission process.

Gaseous Effluent Stream: Gaseous waste containing radioactive materials resulting from the operation of a nuclear power reactor.

High-Purity Waste Stream: Liquids, normally of low conductivity, consisting primarily of liquid waste collected from building equipment drains, valve and pump seal leakoffs, demineralizer backwash, ultrasonic resin cleaning, and resin transfer. These liquids are normally reused as primary coolant makeup water after processing.

Liquid Effluent Stream: Liquid wastes containing radioactive materials resulting from the operation of a nuclear power reactor.

Low-Purity Waste Stream: Liquids, normally of high conductivity and not of primary coolant quality, collected from building sumps, uncollected valve and pump seal leakoffs, miscellaneous vents, and floor drains.

Partition Coefficient (PC): The ratio of the concentration of a nuclide in the gas phase to the concentration of that nuclide in the liquid phase when the liquid and gas are at equilibrium.

Plant Capacity Factor: The ratio of the average net power to the rated power capacity.

Radioactive Halogens: The radioactive isotopes of fluorine, chlorine, bromine, and iodine. The radioactive isotopes of iodine are the principal halogen isotopes considered in dose calculations.

Radioactive Noble Gases: The radioactive isotopes of helium, neon, argon, krypton, xenon, and radon, which are characterized by their chemical inactivity. The radioactive isotopes of krypton and xenon are the principal noble gas isotopes considered in dose calculations.

Reactor Coolant: The fluid circulated through the reactor to remove heat. In a BWR, the fluid is allowed to boil in the reactor vessel to generate steam and power the turbine. The reactor coolant activity is considered to be constant over a range of power levels, coolant and cleanup flows, and reactor coolant volumes. The radionuclide distributions and concentrations for the reactor coolant and main steam are based on the values given in American National Standard, ANSI N237, Source Term Specification, (Ref. 1) but have been adjusted to plants with pumped forward heater drains. In addition, radioiodine and noble gas concentrations are based on a recent compilation of available operating data. Therefore, the concentration values in NUREG-0016, Rev. 1 differ slightly from the ANSI N237 values. Provisions are made in the BWR-GALE Code, in accordance with the recommendations of the standard, for adjusting reactor coolant concentrations should the plant be designed to parameters that are outside the ranges considered in the standard. The ANSI N237 radionuclide concentrations used are also representative of measured values based on the available operating data. The radionuclides are divided into the following categories:

1. Noble gases
2. Halogens (Br, I)
3. Cesium and Rubidium
4. Water activation products
5. Tritium

6. Other nuclides (as listed in Table 2-2 of Chapter 2 of this document)

Regenerant Solutions Waste Stream: Liquids containing regeneration chemical compounds that originate from regeneration of the condensate demineralizer resins.

Source Term: The calculated annual average quantity of radioactive material released to the environment from a nuclear power reactor during normal operation including anticipated operational occurrences. The source term is the isotopic distribution of radioactive materials used in evaluating the impact of radioactive releases on the environment. Normal operation includes routine outages for maintenance and scheduled refuelings.

Tramp Uranium: The uranium present on the exterior of the cladding of a fuel rod and core support structure surfaces.

1.3 GASEOUS SOURCE TERMS

The following sources are considered in calculating the release of radioactive materials (noble gases, particulates, carbon-14, tritium, argon-41 and iodine) in gaseous effluents from normal operation including anticipated operational occurrences:

1. Main condenser offgas system,
2. Turbine gland sealing system,
3. Mechanical vacuum pumps, and
4. Ventilation exhaust air from the containment, auxiliary, radwaste, and turbine buildings, and the spent fuel pool area

The releases of radioactive materials in gaseous effluents are based on measurements made at operating BWRs. The radioactive particulate and noble gas release rates are specified in the BWR-GALE Code and are modified only as needed to reflect treatment processes. Gaseous releases for building ventilation exhaust systems and the main condenser offgas system are based on the average of actual measurements. Radioiodine releases are related to the iodine-131 reactor water concentrations for the BWR being evaluated.

Chapter 2 provides iodine and particulate decontamination factors for removal equipment and parameters for calculating holdup times for noble gases and for calculating tritium releases.

1.4 LIQUID SOURCE TERMS

The following sources are considered in calculating the release of radioactive materials in liquid effluents from normal operations including anticipated operational occurrences:

1. Processed liquid wastes from the high-purity waste system,
2. Processed liquid wastes from the low-purity waste system,
3. Processed liquid wastes from the chemical waste system,
4. Processed liquid regenerant wastes, and
5. Detergent wastes.

The radioactivity input to the liquid radwaste treatment system is based on flow rates of the liquid waste streams and their radioactivity levels, expressed as a fraction of the primary reactor coolant activity (PCA). The primary coolant activity (PCA) is based on the recommendations of American National Standard (ANSI N237) Source Term Specification, (Ref. 1), with the changes as noted in Section 1.2 under the Reactor Coolant definition.

Radionuclide removal by the liquid radwaste treatment system is based on the following parameters:

1. Decay during collection and processing and
2. Removal by the proposed treatment systems, e.g., filtration, ion exchange, evaporation, reverse osmosis, and plateout.

For BWRs using a deep-bed condensate demineralizer, the inventory of radionuclides collected on the demineralizer resins is calculated by considering the flow rate of condensate at main steam activity that is processed through the demineralizers and radionuclide removal using the decontamination factors given in Chapter 2. The radioactivity content of the demineralizer regenerant solution is obtained by considering that all of the activity that is collected by the condensate demineralizers is removed from the resins at the interval dictated by the regeneration frequency.

Methods for calculating collection and processing times and the decontamination factors for radwaste treatment equipment are given in this chapter. The liquid radioactive source terms are adjusted to compensate for equipment downtime and anticipated operational occurrences.

For plants having an onsite laundry, a standard detergent source term, adjusted for the treatment provided, is added to the adjusted source term.

1.5 INSTRUCTIONS FOR COMPLETING BWR-GALE CODE INPUT DATA CARDS

1.5.1 PARAMETERS INCLUDED IN THE BWR-GALE CODE

The parameters listed below are built into the BWR-GALE Code since they are generally applicable to all BWR source term calculations and do not require entry on input data cards.

1.5.1.1 Plant Capacity Factor

0.80 (292 effective full power days per year)

1.5.1.2 Radionuclide Concentrations in the Reactor Coolant and Main Steam

See Chapter 2, Tables 2-2 through 2-5 of this document.

1.5.1.3 Noble Gas, Radioiodine, and Particulate Releases From Building Ventilation Systems Prior to Treatment

See Tables 1-1 and 1-2. For a discussion of the normalization techniques see Section 2.2.4.

1.5.1.4 Radioiodine Input Rate to Main Condenser Offgas System

6 Ci/yr per reactor downstream of main condenser air ejectors.

1.5.1.5 Main Condenser Vacuum Pump Release

Xe-133 -- 1300 Ci/yr

Xe-135 -- 500 Ci/yr

I-131 -- See Table 1-3

1.5.1.6 Charcoal Delay Systems

For a charcoal delay system used to treat the offgases from the main condenser air ejector, the BWR-GALE Code calculates the holdup times for Kr and Xe. Iodine releases from charcoal delay systems are negligible due to the large quantities of charcoal used in the system. The holdup times for noble gases are calculated by the Code using the following equation and the data entered on Cards 29-32.

$$T = 43.1 \frac{MK}{P}$$

where

K is the dynamic adsorption coefficient, in cm^3/gm
(see chart on page 2-35);

M is the mass of charcoal, in 10^3 lbs

T is the holdup time, in hr, and

P is the thermal power level (MWt) entered in Card 2.

TABLE 1-1
GASEOUS RELEASES FROM VENTILATION SYSTEMS PRIOR TO TREATMENT
(in Ci/yr per Reactor)

NUCLIDE	CONTAINMENT BUILDING	AUXILIARY BUILDING	TURBINE BUILDING	RADWASTE BUILDING
Kr-83m	**	**	**	**
Kr-85m	1	3	25	**
Kr-85	**	**	**	**
Kr-87	**	2	61	**
Kr-88	1	3	91	**
Kr-89	**	2	580	29
Xe-131m	**	**	**	**
Xe-133m	**	**	**	**
Xe-133	27	83	150	220
Xe-135m	15	45	400	530
Xe-135	33	94	330	280
Xe-137	45	135	1000	83
Xe-138	2	6	1000	2
Cr-51*	0.0002	0.0009	0.0009	0.0007
Mn-54	0.0004	0.001	0.0006	0.004
Fe-59	0.00009	0.0003	0.0001	0.0003
Co-58	0.0001	0.0002	0.001	0.0002
Co-60	0.001	0.004	0.001	0.007
Zn-65	0.001	0.004	0.006	0.0003
Sr-89	0.00003	0.00002	0.006	NA
Sr-90	0.000003	0.000007	0.00002	NA
Zr-95	0.0003	0.0007	0.00004	0.0008
Nb-95	0.001	0.009	0.000006	0.000004
Mo-99	0.006	0.06	0.002	0.000003
Ru-103	0.0002	0.004	0.00005	0.000001
Ag-110m	0.0000004	0.000002	NA	NA
Sb-124	0.00002	0.00003	0.0001	0.00007
Cs-134	0.0007	0.004	0.0002	0.0024
Cs-136	0.0001	0.0004	0.0001	NA
Cs-137	0.001	0.005	0.001	0.004
Ba-140	0.002	0.02	0.010	0.000004
Ce-141	0.0002	0.0007	0.010	0.000007

*Particulate release rates are prior to filtration.

**Less than 1 Ci/yr per reactor.

NA Not Analyzed; analysis for the isotope was not performed.

TABLE 1-2

RADIOIODINE RELEASES FROM BUILDING VENTILATION
SYSTEMS PRIOR TO TREATMENT
(Ci/yr/ μ Ci/gm)

	<u>Containment Bldg**</u>	<u>Auxiliary Bldg**</u>	<u>Turbine Bldg***</u>	<u>Radwaste Bldg**</u>
Annual Normalized* Iodine Release Rate				
Power Operation	1.2	11.1	3.8×10^3	4.6
Refueling/Maintenance Outages	4.7	0.5	4.1×10^2	1.4

*The normalized release rate, expressed in grams of water during the modes of operation, represents the effective leak rate for radioiodine. It is the combination of the reactor water leakage rate into the building and the partitioning of the radioiodine between the water phase in the leakage and the gas phase where it is measured. For the turbine building the effective leak rate also includes the carryover for radioiodine from reactor water to steam in the reactor vessel.

**To obtain the actual iodine release from these bldgs in Ci/yr, multiply the normalized release by the coolant concentration in μ Ci/gm.

***To obtain the actual iodine release from the turbine building in Ci/yr, multiply the normalized release by the coolant concentration in μ Ci/gm and by the iodine carryover from Table 2-4.

TABLE 1-3

RADIOIODINE RELEASES FROM MECHANICAL VACUUM PUMP
(Ci/yr/ μ Ci/gm)

	<u>Annual Normalized* Iodine Release Rate**</u>
Short-term outages	4.9×10^2
Refueling/Maintenance Outages	1.1×10^3

*The normalized release rate, expressed in grams of water during the modes of operation, represents the effective leak rate for radioiodine. It is the combination of the reactor water leakage rate, the partitioning of the radioiodine between the water phase in the leakage and the gas phase where it is measured and the carryover for radioiodine from reactor water to steam in the reactor vessel.

**To obtain the actual iodine release from the mechanical vacuum pump in Ci/yr, multiply the normalized release by the coolant concentration in μ Ci/gm and by the iodine carryover from Table 2-4.

1.5.1.7 Cryogenic Distillation System

For a cryogenic distillation system, the BWR-GALE Code uses a partition coefficient of 0.0001 for Xe and I and 0.00025 for Kr to calculate Xe, I, and Kr removal during separation by distillation. The Xe, I, and Kr separated by distillation are considered to be released following 90-day holdup. The calculated releases are the sum of the noble gases and radioiodine released from the overheads during distillation without holdup and the noble gases and iodine released following 90-day holdup.

1.5.1.8 Decontamination Factors for Condensate Demineralizers

<u>Demineralizer</u>	<u>Anions</u>	<u>Cs, Rb</u>	<u>Other Nuclides</u>
Deep bed	10	2	10
Powdex	10	2	10

1.5.1.9 Detergent Wastes

The radionuclides listed in Table 2-28 of Chapter 2 are assumed to be released unless treatment is provided or laundry is not processed on site.

1.5.1.10 Tritium Releases

Total tritium release equals 0.03 Ci/yr per MWt. The quantity of tritium released through the liquid pathway is 50% of the total quantity calculated to be available for release, and 50% is calculated to be released in gaseous effluents. Of that released in gaseous effluents, half is released from the turbine building ventilation system and half is released from the containment building ventilation system.

1.5.1.11 Argon-41 Releases

The argon-41 input to the main condenser offgas treatment system is 40 μ Ci/sec. The dynamic adsorption coefficients for argon-41 in charcoal delay beds are 6.4 cm³/gm and 16 cm³/gm for ambient and chilled temperature systems, respectively. The argon-41 release from purging or venting of the drywell is 15 Ci/yr.

1.5.1.12 Regeneration of Condensate Demineralizers

Flow rates and concentrations of radioactive materials routed to the liquid radwaste system from the chemical regeneration of the condensate demineralizers are based on the following parameters:

1. Liquid radioactivity flow to the demineralizer is based on the radioactivity of the main steam and the fraction of radioactivity which does not bypass the condensate demineralizers in the pumped forward flow.

2. All radionuclides removed from the condensate by the demineralizers are removed from the demineralizer resins during chemical regeneration. The regenerant waste radioactivity is adjusted for radionuclide decay during operation of the demineralizers.

1.5.1.13 Adjustment to Liquid Radwaste Source Terms for Anticipated Operational Occurrences

1. The calculated source term is increased by 0.1 Ci/yr per reactor using the same isotopic distribution as for the calculated source term to account for anticipated occurrences such as operator errors resulting in unplanned releases.

2. Evaporators are assumed to be unavailable for two consecutive days per week for maintenance. If a two-day holdup capacity or an alternative evaporator is available, no adjustment is needed. If less than a two-day capacity is available, the waste excess is assumed to be handled as follows:

- a. High-Purity or Low-Purity Waste--Processed through an alternative system (if available) using a discharge fraction consistent with the lower purity system.
- b. Chemical Waste--Discharged to the environment to the extent holdup capacity or an alternative evaporator is not available.

1.5.2 PARAMETERS REQUIRED FOR THE BWR-GALE CODE

The parameters described in the following sections must be entered on input data cards. Complete the cards designated below by "(SAR/ER)" from information given in the Safety Analysis and Environmental Reports. Complete the remaining cards (i.e., those not designated below as "(SAR/ER)" cards) using the principal source term parameters specified below and discussed in Chapter 2.

1.5.2.1 Card 1: Name of Reactor (SAR/ER)

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

1.5.2.2 Card 2: Thermal Power Level (SAR/ER)

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

1.5.2.3 Card 3: Total Steam Flow Rate (SAR/ER)

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

1.5.2.4 Card 4: Mass of Coolant in Reactor Vessel (SAR/ER)

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

1.5.2.5 Card 5: Cleanup Demineralizer Flow (SAR/ER)

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

1.5.2.6 Card 6: Condensate Demineralizer Regeneration Time

For deep-bed condensate demineralizers, use a 3.5-day regeneration frequency. If ultrasonic resin cleaning is used, assume 8-day regeneration frequency. Multiply the frequency by the total number of demineralizers and enter the calculated number of days in spaces 73-80. For filter/demineralizers (Powdex), enter 0.0 in spaces 73-80.

1.5.2.7 Card 7: Fraction of Feedwater Through Condensate Demineralizer (SAR/ER)

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

1.5.2.8 Cards 8-19: Liquid Radwaste Treatment System Input Parameters

Four liquid radwaste inlet streams are considered in the BWR-GALE Code (see Section 1.5.2.22 for detergent wastes):

1. High-Purity Waste, Cards 8-10
2. Low-Purity Waste, Cards 11-13
3. Chemical Waste, Cards 14-16
4. Regenerant Solutions Waste, Cards 17-19

Three input data cards are used to define the major parameters for each of the four waste streams. Essentially the same information is needed on the three input data cards used for each of the four streams. The instructions given in this section are applicable to all four waste streams, with the following exception: the inlet waste activity is not entered on Card 17 for the regenerant solutions wastes for systems using regenerable condensate demineralizers since that activity is calculated by the Code.

The entries required on the first card (8, 11, and 14) for the High-Purity, Low-Purity, and Chemical Waste Systems, respectively, are outlined below and described in more detail in Section 1.5.2.8.1.

1. Enter in spaces 18-41 the name of the waste inlet stream (e.g., high-purity wastes).

2. Enter in spaces 42-49 the flow rate (in gal/day) 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 the first card for the Regenerant Solutions Waste System (i.e., Card 17), enter in spaces 73-80 the flow rate of the regenerant solutions waste inlet stream. For the calculation of liquid effluents for regeneration of demineralizers other than the condensate demineralizers, see Appendix A.

The second card (9, 12, 15, and 18) for each waste stream contains the overall system decontamination factors for three categories of radionuclides, as follows:

1. Enter in spaces 21-28 the DF for anions.

2. Enter in spaces 34-41 the DF for cesium and rubidium.

3. Enter in spaces 47-54 the DF for other nuclides.

The following entries are required on the third card (10, 13, 16, and 19) for each waste stream:

1. Enter in spaces 29-33 the waste collection time (in days) prior to processing.

2. Enter in spaces 48-53 the sum of the waste processing and discharge time (in days).

3. Enter in spaces 72-77 the average fraction of wastes to be discharged after processing.

The following sections explain in more detail the use of the parameters in this document and the information given in the SAR/ER to make the data entries in Cards 8-19 listed above.

1.5.2.8.1 Liquid Waste Flow Rates and Activities (Cards 8, 11, 14, and 17)

Calculate flow rates and activities to complete the first card for each liquid radwaste inlet stream by using the waste volumes and activities given in Table 1-4. To the input flow rates and activity given in the table, add expected flows and activities more specific to the plant design as given in the SAR/ER. The inlet streams should be combined to form the four principal waste streams (high-purity, low-purity, chemical wastes, and regenerant wastes) considered in this document. Calculate the primary coolant activity (PCA) of each of the four principal inlet streams (except for the regenerant waste as indicated above) by determining the weighted average activity of the composite stream entering the waste collection tanks. For example, if inlet streams A, B, and C enter the low-purity waste collector tank at average rates and PCA as listed below:

Stream A 1,000 gal/day at 0.01 PCA

Stream B 2,000 gal/day at 0.1 PCA

Stream C 500 gal/day at 1.0 PCA

the composite A, B, C activity would be calculated as follows:

$$\frac{(1000 \text{ gal/day})(0.01 \text{ PCA}) + (2000 \text{ gal/day})(0.1 \text{ PCA}) + (500 \text{ gal/day})(1.0 \text{ PCA})}{(1000 \text{ gal/day} + 2000 \text{ gal/day} + 500 \text{ gal/day})} = 0.2 \text{ PCA}$$

The entries on Card 11 for this example would then be: spaces 18-41, "Low-Purity Waste"; spaces 42-49, "3500"; spaces 57-61, "0.2."

TABLE 1-4
BWR LIQUID WASTES

SOURCE	EXPECTED DAILY AVERAGE INPUT FLOW RATE (in gal/day)		FRACTION OF THE PRIMARY COOLANT ACTIVITY (PCA)
	DEEP BED PLANT WITH ULTRASONIC RESIN CLEANER	DEEP BED PLANT WITHOUT ULTRASONIC RESIN CLEANER OR A FILTER/DEMINERALIZER PLANT	
<u>Equipment Drains</u>			
Drywell	3,400	3,400	1.00
Containment, auxiliary building, and fuel pool	3,700	3,700	0.1
Radwaste building	1,100	1,100	0.1
Turbine building	3,000	3,000	0.001
Ultrasonic resin cleaner	15,000	-	0.05
Resin rinse*	2,500	5,000	0.002
<u>Floor Drains</u>			
Drywell	700	700	0.001
Containment, auxiliary building, and fuel handling	2,000	2,000	0.001
Radwaste building	1,000	1,000	0.001
Turbine building	2,000	2,000	0.001
<u>Other Sources</u>			
Cleanup phase separator decant	640	640	0.002
Laundry drains	1,000	1,000	-
Lab drains	500	500	0.02
Regenerants*	1,700	3,400	**
Condensate demineralizer backwash†	-	8,100	2 x 10 ⁻⁶
Chemical lab waste	100	100	0.02

* Deep-bed condensate demineralizers only.

** Calculated by BWR-GALE Code.

† Filter/demineralizer (Powdex) condensate demineralizers only.

The input flows and activities are entered in units of gal/day and fraction of PCA, respectively.

1.5.2.8.2 Decontamination Factors for Equipment Used in the Liquid Radwaste Treatment System (Cards 9, 12, 15, and 18)

The system decontamination factors (DFs) should be entered in the second card for each liquid radwaste inlet stream. The DFs represent the expected equipment performance averaged over the life of the plant. The following factors are to be considered in calculating overall decontamination factors for the various systems.

1. DFs are categorized by one of the following types of radionuclides:

- a. Anions
- b. Cs, Rb
- c. Other nuclides

Note: A DF of 1 is assumed by the BWR-GALE Code for tritium. Dissolved noble gases and water activation products are not considered in the liquid code.

2. The system DF for each inlet stream is the product of the individual equipment DFs in each of the subsystems.

3. Equipment that is used optionally (as required) and not included in the normal flow scheme should not be considered in calculating the overall system DF.

Table 1-5 shows the decontamination factors to be used for BWR liquid waste treatment systems.

The following example illustrates the calculation of the decontamination factor for a low-purity waste treatment system: Assume that low-purity wastes are collected, processed through a filter, an evaporator, and a mixed-bed polishing demineralizer; and collected for sampling. If required to meet discharge criteria, the contents of the waste sample (test) tank are processed through a mixed-bed demineralizer for additional radionuclide removal. This example may be summarized schematically as:

Extracting from Table 1-5 gives the following values for the example:

	<u>Filter</u>	<u>Evaporator</u>	<u>Demineralizer 1</u>	<u>Demineralizer 2</u>	<u>Product</u>
Anions	1	10^3	10	1	10^4
Cs, Rb	1	10^4	10	1	10^5
Other Nuclides	1	10^4	10	1	10^5

These values were obtained as follows:

- ° A DF of 1.0 was applied to all nuclides for the filter.
- ° A DF of 10^3 for anions and 10^4 for Cs, Rb, and other nuclides was applied for the radwaste evaporator.
- ° A DF of 10 was applied for anions, Cs, Rb, and other nuclides for the evaporator condensate polishing demineralizer.
- ° A DF of 1 was applied to the second demineralizer since this demineralizer's use is optional and it is not used for normal operations.
- ° The product of the DFs was obtained by combining the first four columns for each radionuclide.

TABLE 1-5
DECONTAMINATION FACTORS FOR BWR LIQUID WASTE TREATMENT SYSTEMS

TREATMENT SYSTEM	DECONTAMINATION FACTOR		
<u>Demineralizers</u>	<u>Anion</u>	<u>Cs, Rb</u>	<u>Other Nuclides</u>
Mixed-bed			
Reactor Coolant Cleanup	10	2	10
Condensate (deep bed)	10	2	10
High-purity waste	$10^2(10)^*$	10(10)	$10^2(10)$
Low-Purity Waste	$10^2(10)$	2(10)	$10^2(10)$
Cation bed (any system)	1(1)	10(10)	$10^2(10)$
Anion bed (any system)	$10^2(10)$	1(1)	1(1)
Powdex (any system)	10(10)	2(10)	10(10)
<u>Evaporators</u>	<u>All Nuclides Except Anions</u>		<u>Anions</u>
Miscellaneous	10^4		10^3
Detergent wastes	10^2		10^2
<u>Reverse Osmosis</u>	<u>All Nuclides</u>		
Laundry wastes	30		
Other liquid wastes	10		
<u>Filters</u>	DF of 1.0 for all nuclides		

* For an evaporator polishing demineralizer or for the second demineralizer in series, the DF is given in parentheses.

Thus in Card 9 the following would be entered: in spaces 21-28, "10,000"; in spaces 34-41, "100,000"; and in spaces 47-54, "100,000."

1.5.2.8.3 Collection Time for Liquid Wastes (Cards 10, 13, 16, 19 -- Spaces 29-33)

Collection time prior to processing is based on the input flow calculated above. Where redundant tanks are provided, assume the collection tank will be processed when filled to 80% capacity. If only one tank is provided, assume the tank will be processed when filled to 40% capacity. For example, if flow from a 1,000-gal/day floor drain is collected in two 20,000-gallon tanks prior to processing, collection time would be calculated as follows:

$$\text{Collection time } (T_c) = \frac{(20,000 \text{ gal})(0.8)}{1,000 \text{ gal/day}} = 16 \text{ days}$$

Then, for this example, "16" should be entered in spaces 29-33 on Card 13.

1.5.2.8.4 Processing and Discharge Time (Cards 10, 13, 16, 19 -- Spaces 48-53)

Decay during processing and discharge of liquid wastes is shown schematically as follows:

where

- A is the capacity of the initial tank in the flow scheme, in gal;
- B is the limiting process based on equipment flow capacity, dimensionless;
- C is the capacity of the final tank in the flow scheme prior to discharge, in gal;
- R_b is the equipment flow capacity of process B, in gal/day;
- R_c is the flow capacity of the Tank C discharge pump, in gal/day; and
- R_o is the rate of flow of additional wastes inputs to Tank C, in gal/day.

T_p , the process time credited for decay, is calculated as follows, in days:

$$T_p = \frac{0.8A}{R_b} \text{ for redundant tank, or } T_p = \frac{0.4A}{R_b} \text{ for a single tank}$$

T_d , the discharge time -- 50% credited for decay, is calculated as follows, in days:

$$T_d = \frac{0.8C}{R_c} \text{ for redundant tanks, or } T_d = \frac{0.4C}{R_c} \text{ for a single tank}$$

After performing the above two calculations, calculate whether credit may be taken for decay during processing and discharge by determining whether

$$0.8C > T_p(R_b + R_o) \text{ for redundant tanks, or } 0.4C > T_p(R_b + R_o) \text{ for a single tank}$$

If so, then

$$\text{Decay} = (T_p + 0.5T_d)$$

where "Decay" is the new processing and discharge time to be entered in spaces 48-53 of the third card for each input stream (Cards 10, 13, 16, and 19).

If, however, $0.8C$ or $0.4C$ (as appropriate) $\leq T_p(R_b + R_o)$, T_p is used for the holdup time during processing, since Tank C may be discharged before Tank A has been completely processed. In this case, the T_p value should be entered in spaces 48-53 of the third card.

For example, for the following input waste stream:

Decay time during processing and discharge would be calculated as follows:

$$\text{Process Time } (T_p) = \frac{(0.8)(20,000 \text{ gal})}{(15 \text{ gal/min})(1440 \text{ min/day})} = 0.7 \text{ day}$$

$$\text{Discharge Time } (T_d) = \frac{(0.8)(40,000 \text{ gal})}{(10 \text{ gal/min})(1440 \text{ min/day})} = 2 \text{ days}$$

Then, checking for decay credit, $0.8C/(R_b + R_o) = 1.45$ days, which is greater than T_p ; therefore, credit is taken for $(T_p + 0.5T_d)$ or 1.7 days for processing and discharge. The input on spaces 48-53 to the Code is 1.7 days for processing and discharge time.

1.5.2.8.5 Fraction of Wastes Discharged (Cards 10, 13, 16, and 19 -- Spaces 72-77)

The percent of the wastes discharged after processing may vary between 1% and 100% based on the capability of the system to process liquid waste during equipment downtime, waste volume surges, tritium control requirements, and tank surge capacity. A minimum value of 1% discharge for high-purity wastes and 10% discharge for other wastes is used when the radwaste system is designed for maximum waste recycle, the system capacity is sufficient to process wastes for reuse during equipment downtime and anticipated operational occurrences, and a discharge route is provided.

The BWR-GALE Code calculates the release of radioactive materials in liquid waste from the four inlet streams after processing. Releases included in each stream are:

1. High-Purity Waste - Combined releases from equipment drains and sumps.
2. Low-Purity Waste - Combined releases from floor drains and sumps.
3. Chemical Waste - Combined releases from laboratory and decontamination wastes and from demineralizer regenerant solutions according to the design of the condensate demineralizer system. If a filter/demineralizer (Powdex) system is used, the laboratory and decontamination wastes are combined with the low-purity waste or solidified in the solid waste system.
4. Detergent Waste System - Combined releases from laundry operations, equipment decontamination solutions, and personnel decontamination showers.

1.5.2.9 Card 20: Gland Seal Steam Flow

Enter in spaces 73-80 of Card 20 the steam flow (in 10^3 lbs/hr) to the turbine gland seal, as follows:

1. If main steam is used for the sealing steam, enter a flow rate 0.001 times the main steam flow entered previously on Card 3.

2. If clean (nonradioactive) steam from an auxiliary boiler is used for sealing steam, enter 0.0 in spaces 73-80.

1.5.2.10 Card 21: Gland Seal Holdup Time (SAR/ER)

Enter in spaces 73-80 the design holdup time (in hr) for gases vented from the gland seal condenser.

1.5.2.11 Card 22: Holdup Time for Condenser Air Ejector Offgas (SAR/ER)

Enter in spaces 73-80 the design holdup time (in hr) for offgases from the main condenser air ejector prior to being processed through the offgas treatment system, e.g., a 10-minute holdup time prior to cryogenic distillation.

1.5.2.12 Card 23: Containment Building Releases

1. If ventilation exhaust air is treated through charcoal adsorbers which satisfy the guidelines of Regulatory Guide 1.140 (Ref. 2), enter the appropriate removal efficiency in spaces 43-46 for radioiodine corresponding to the depth of charcoal as indicated in Table 1-6.

2. If ventilation exhaust air is treated through HEPA filters which satisfy the guidelines of Regulatory Guide 1.140 (Ref. 2), enter a removal efficiency of 99. for particulates in spaces 53-56.

3. If no treatment is provided for the ventilation exhaust air to remove radioiodine or if the charcoal adsorbers do not satisfy the guidelines of Regulatory Guide 1.140 (Ref. 2), enter 0.0 in spaces 43-46; if no treatment is provided to remove particulates or if the HEPA filters do not satisfy the guidelines of Regulatory Guide 1.140 (Ref. 2), enter 0.0 in spaces 53-56.

1.5.2.13 Card 24: Turbine Building Releases

1. If ventilation exhaust air is treated through charcoal adsorbers which satisfy the guidelines of Regulatory Guide 1.140 (Ref. 2), enter the appropriate removal efficiency in spaces 43-46 for radioiodine corresponding to the depth of charcoal as indicated in Table 1-6.

2. If ventilation exhaust air is treated through HEPA filters which satisfy the guidelines of Regulatory Guide 1.140 (Ref. 2), enter a removal efficiency of 99. for particulates in spaces 53-56.

3. If no treatment is provided for the ventilation exhaust air to remove radioiodine or if the charcoal adsorbers do not satisfy the guidelines of Regulatory Guide 1.140 (Ref. 2), enter 0.0 in spaces 43-46; if no treatment is provided to remove particulates or if the HEPA filters do not satisfy the guidelines of Regulatory Guide 1.140 (Ref. 2), enter 0.0 in spaces 53-56.

1.5.2.14 Card 25: Fraction of Radioiodine Released from Turbine Gland Seal Condenser Vent

1. If, prior to release, the offgases from the turbine gland seal condenser vent are processed through charcoal adsorbers which satisfy the guidelines of Regulatory Guide 1.140 (Ref. 2), enter the removal efficiency in spaces 73-80 for radioiodine corresponding to the depth of charcoal as indicated in Table 1-6.

2. If the offgases are released from the turbine gland seal condenser without treatment, if clean steam is used, or if charcoal adsorbers provided do not satisfy the guidelines of Regulatory Guide 1.140 (Ref. 2), enter 0.0 in spaces 73-80.

TABLE 1-6

ASSIGNED REMOVAL EFFICIENCIES FOR CHARCOAL ADSORBERS
FOR RADIOIODINE REMOVAL

<u>Activated Carbon^a Bed Depth</u>	<u>Removal Efficiencies^b for Radioiodine %</u>
2 inches. Air filtration system designed to operate inside reactor containment	90.
2 inches. Air filtration system designed to operate outside the reactor containment and relative humidity is controlled at 70%.	70.
4 inches. Air filtration system designed to operate outside the reactor containment and relative humidity is controlled at 70%	90.
6 inches. Air filtration system designed to operate outside the reactor containment and relative humidity is controlled to 70%.	99.

^aMultiple beds, e.g., two 2-inch beds in series, should be treated as a single bed of aggregate depth of 4 inches.

^bThe removal efficiencies assigned HEPA filters for particulate removal and charcoal adsorbers for radioiodine removal are based on the design, testing and maintenance criteria recommended in Regulatory Guide 1.140, "Design, Testing and Maintenance Criteria for Normal Ventilation Exhaust System Air Filtration and Adsorption Units of Light-Water-Cooled Nuclear Power Plants" (Ref. 2).

1.5.2.15 Card 26 Fraction of Radioiodine Released from the Condenser Air Ejector Offgas Treatment System

1. If, prior to release, the offgases are processed through charcoal adsorbers which satisfy the guidelines of Regulatory Guide 1.140 (Ref. 2), enter the removal efficiency in spaces 73-80 for radioiodine corresponding to the depth of charcoal as indicated in Table 1-6.
2. If the offgas is released without treatment or through charcoal adsorbers that do not satisfy the guidelines of Regulatory Guide 1.140 (Ref. 2), enter 0.0 in spaces 73-80.
3. Enter a 1. in spaces 73-80 if the offgas is processed through a charcoal delay system.
4. If the offgas is processed through a cryogenic distillation system (removal of iodine by the cryogenic distillation system is built into the Code -see Card 29), enter 0.0 in spaces 73-80.

1.5.2.16 Card 27: Auxiliary Building Releases

1. If ventilation exhaust air is treated through charcoal adsorbers which satisfy the guidelines of Regulatory Guide 1.140 (Ref. 2), enter the appropriate removal efficiency in spaces 43-46 for radioiodine corresponding to the depth of charcoal as indicated in Table 1-6.
2. If ventilation exhaust air is treated through HEPA filters which satisfy the guidelines of Regulatory Guide 1.140 (Ref. 2), enter a removal efficiency of 99. for particulates in spaces 53-56.
3. If no treatment is provided for the ventilation exhaust air to remove radioiodine or if the charcoal adsorbers do not satisfy the guidelines of Regulatory Guide 1.140 (Ref. 2), enter 0.0 in spaces 43-46; if no treatment is provided to remove particulates or if the HEPA filters do not satisfy the guidelines of Regulatory Guide 1.140 (Ref. 2), enter 0.0 in spaces 53-56.

1.5.2.17 Card 28: Radwaste Building Releases

1. If ventilation exhaust air is treated through charcoal adsorbers which satisfy the guidelines of Regulatory Guide 1.140 (Ref. 2), enter the appropriate removal efficiency in spaces 43-46 for radioiodine corresponding to the depth of charcoal as indicated in Table 1-6.
2. If ventilation exhaust air is treated through HEPA filters which satisfy the guidelines of Regulatory Guide 1.140 (Ref. 2), enter a removal efficiency of 99. for particulates in spaces 53-56.
3. If no treatment is provided for the ventilation exhaust air to remove radioiodine or if the charcoal adsorbers do not satisfy the guidelines of Regulatory Guide 1.140 (Ref. 2), enter 0.0 in spaces 43-46; if no treatment is provided to remove particulates or if the HEPA filters do not satisfy the guidelines of Regulatory Guide 1.140 (Ref. 2), enter 0.0 in spaces 53-56.

1.5.2.18 Card 29: Condenser Air Ejector Offgas Treatment System (SAR/ER)

1. Enter 1 in space 80 if a charcoal delay system is used to treat the offgas from the condenser air ejector.
2. Enter 2 in space 80 if the offgas from the condenser air ejector is processed by a cryogenic distillation system.
3. Enter a zero in space 80 if the offgas is not treated either through a charcoal delay system or by cryogenic distillation.

Note: Enter 0.0 on Cards 30, 31, and 32 if a charcoal delay system is not used to treat the offgases from the condenser air ejector.

1.5.2.19 Card 30: Dynamic Adsorption Coefficient for Krypton

Enter in spaces 73-80 the dynamic adsorption coefficient for Kr based on the system design and the dynamic adsorption coefficients noted below.

<u>DYNAMIC ADSORPTION COEFFICIENT (cm³/gm)</u>				
	<u>OPERATING 77°F</u> <u>DEW POINT 45°F</u>	<u>OPERATING 77°F</u> <u>DEW POINT 0°F</u>	<u>OPERATING 77°F</u> <u>DEW POINT -40°F</u>	<u>OPERATING 0°F</u> <u>DEW POINT -20°F</u>
Kr	18.5	25.	70.	105.

1.5.2.20 Card 31: Dynamic Adsorption Coefficient for Xenon

Enter in spaces 73-80 the dynamic adsorption coefficient for Xe based on the system design and dynamic adsorption coefficients noted below.

<u>DYNAMIC ADSORPTION COEFFICIENT (cm³/gm)</u>				
	<u>OPERATING 77°F</u> <u>DEW POINT 45°F</u>	<u>OPERATING 77°F</u> <u>DEW POINT 0°F</u>	<u>OPERATING 77°F</u> <u>DEW POINT - 40°F</u>	<u>OPERATING 0°F</u> <u>DEW POINT -20°F</u>
Xe	330.	440.	1160.	2410.

1.5.2.21 Card 32: Mass of Charcoal in Charcoal Delay System (SAR/ER)

Enter in spaces 73-80 the mass of charcoal (in 10³ lbs) used in the charcoal delay system.

1.5.2.22 Card 33: Detergent Waste

1. If the plant does not have an onsite laundry, enter 0.0 in spaces 73-80.
2. If the plant has an onsite laundry and detergent wastes are released without treatment, enter 1.0 in spaces 73-80.
3. If detergent wastes are treated prior to discharge, enter the decontamination factor in spaces 73-80. The parameters in Chapter 2 are used in determining the DF for the treatment applied to detergent waste.

CHAPTER 2. PRINCIPAL PARAMETERS USED IN BWR SOURCE TERM CALCULATIONS AND THEIR BASES

2.1 INTRODUCTION

The principal parameters used in source term calculations have been compiled to standardize the calculation of radioactive source terms.

The following sections describe parameters used in the evaluation of radwaste treatment systems. The parameters have been derived from reactor operating experience where data were available. Where operating data were inconclusive or not available, information was drawn from laboratory and field tests and from engineering judgment. The bases for the source term parameters explain the reasons for choosing the numerical values listed. A list of references used in developing the parameters is also included.

The parameters in the BWR-GALE Code are updated periodically and published in revisions to this NUREG as additional operating data become available. The source term parameters used are believed to provide a realistic assessment of reactor and radwaste system operation.

2.2 PRINCIPAL PARAMETERS AND THEIR BASES

2.2.1 THERMAL POWER LEVEL

2.2.1.1 Parameter

The maximum thermal power level (MWt) evaluated for safety considerations in the Safety Analysis Report.

2.2.1.2 Bases

The power level used in the source term BWR-GALE Code is the maximum power level evaluated for safety considerations in the Safety Analysis Report. Using this value, the evaluation of the radwaste management systems need not be repeated when the applicant applies for a stretch power license at a later date. Past experience indicates that most utilities request approval to operate at maximum power soon after reaching commercial operation.

2.2.2 PLANT CAPACITY FACTOR

2.2.2.1 Parameter

A plant capacity factor of 80% is used, i.e., 292 effective full power days.

2.2.2.2 Bases

The source term calculations are based on a plant capacity factor of 80% averaged over the 30-year operating life of the plant, i.e., the plant operates at 100% power 80% of the time. The plant capacity factors experienced at BWRs are listed in Table 2-1 for the period 1972 through 1977.

The average plant capacity factors shown in Table 2-1 indicate that the 80% factor assumed is higher than the average factors experienced. However, it is expected that the major maintenance problems and extended refueling outages that have contributed to the lower plant capacity factors will be overcome and that the plants will achieve the 80% capacity factor when averaged over 30 years of operation.

2.2.3 RADIONUCLIDE CONCENTRATIONS IN THE REACTOR COOLANT

2.2.3.1 Parameter

As used in the BWR-GALE Code, Table 2-2 lists the expected radionuclide concentrations in the reactor coolant and steam for BWRs with design parameters within the ranges listed in Table 2-3. Should any design parameter be outside the ranges in Table 2-3, the BWR-GALE Code adjusts the concentrations in Table 2-2, using the factors in Tables 2-4 and 2-5. Figure 2-1 shows the graphical relationship of the design parameters.

TABLE 2-1
PLANT CAPACITY FACTORS AT OPERATING BWRs^a

<u>FACILITY^b</u>	<u>DATE OF COMMERICAL OPERATION^c</u>	<u>1972</u>	<u>1973</u>	<u>1974</u>	<u>1975</u>	<u>1976</u>	<u>1977</u>
Oyster Creek	12/69	77	65	66	58	70	58 ^e
Nine Mile Point-1	12/69	62	68	63	60	81	57 ^f
Millstone-1	03/71	55	34 ^d	63	68	66	84
Monticello	06/71	74	68	57	61	84	75
Dresden-3	11/71	67	54	47 ^e	33 ^f	60	76
Dresden-2	06/72		74	51	44 ^f	66	54
Vermont Yankee	11/72		44 ^e	59	81	73	80
Pilgrim-1	12/72		72	34 ^f	46 ^e	43 ^f	47 ^f
Quad Cities-1	02/73			51 ^f	65	52 ^f	55 ^e
Quad Cities-2	03/73			68	40 ^f	66	67
Cooper	07/74				60	57	70
Peach Bottom-2	07/74				57	61	45 ^f
Peach Bottom-3	12/74				59	67	54 ^f
Duane Arnold	02/75					55	67
Fitzpatrick	07/75					59	55 ^f
Brunswick-2	11/75					37 ^g	35 ^g
Hatch-1	12/75					65	57
AVERAGE		67	67	61	63	66	70

^aFrom Semi-Annual Operating Reports for each facility, as submitted by respective licensees.

^bBig Rock Point, Dresden 1, Humboldt Bay, and Lacrosse are not included since they are small reactors (< 700 Mwt) and are not considered to be typical of modern-day reactors. Browns Ferry 1, 2 are not included since they were not operating due to fire.

^cPlant capacity factors listed begin with the first full year of commercial operation.

^dNot included due to extended maintenance outage to replace feedwater sparger.

^eNot included due to extended operation at reduced power.

^fNot included due to extended refueling outage.

^gNot included due to extended maintenance outage to correct power monitor tube vibrations.

TABLE 2-2
RADIONUCLIDE CONCENTRATIONS
IN BOILING WATER REACTOR COOLANT AND MAIN STEAM*
(in $\mu\text{Ci/gm}$)

<u>ISOTOPE</u>	<u>REACTOR COOLANT</u>	<u>REACTOR STEAM</u>
<u>Noble Gases</u>		
Kr-83m		9.1(-4)**
Kr-85m		1.6(-3)
Kr-85		5.0(-6)
Kr-87		5.5(-3)
Kr-88		5.5(-3)
Kr-89		3.4(-2)
Kr-90		7.5(-2)
Kr-91		9.1(-2)
Kr-92		9.1(-2)
Kr-93		2.4(-2)
Kr-94		5.9(-3)
Kr-95		5.5(-4)
Kr-97		3.6(-6)
Xe-131m		3.9(-6)
Xe-133m		7.5(-5)
Xe-133		2.1(-3)
Xe-135m		7.0(-3)
Xe-135		6.0(-3)
Xe-137		3.9(-2)
Xe-138		2.3(-2)
Xe-139		7.5(-2)
Xe-140		8.0(-2)
Xe-141		6.5(-2)
Xe-142		1.9(-2)
Xe-143		3.2(-3)
Xe-144		1.5(-4)
<u>Halogens</u>		
Br-83	6(-3)	9(-5)***
Br-84	7(-3)	1(-4)
Br-85	3(-3)	5(-5)
I-131	3.7(-3)	6(-5)
I-132	6(-2)	9(-4)
I-133	5(-2)	8(-4)
I-134	1(-1)	2(-3)
I-135	5(-2)	8(-4)
<u>Cesium and Rubidium</u>		
Rb-89	5(-3)	5(-6)
Cs-134	3(-5)	3(-8)
Cs-136	2(-5)	2(-8)
Cs-137	8(-5)	8(-8)
Cs-138	1(-2)	1(-5)

*The reactor coolant concentration is specified at the nozzle where reactor water leaves the reactor vessel. Similarly, the reactor steam concentration is specified at time 0 at the nozzle.

**1.1(-3) = 1.1×10^{-3} .

***Halogen concentrations listed in reactor steam are based on a carryover of 0.015. For a carryover of 0.004 the halogen reactor steam concentrations would be reduced proportionately.

TABLE 2-2 (Continued)

<u>ISOTOPE</u>	<u>REACTOR COOLANT</u>	<u>REACTOR STEAM</u>
<u>Water Activation Products</u>		
N-13	5(-2)	7(-3)
N-16	6(+1)	5(+1)
N-17	9(-3)	2(-2)
O-19	7(-1)	2(-1)
F-18	4(-3)	4(-3)
<u>Tritium*</u>		
H-3	1(-2)	1(-2)
<u>Other Nuclides</u>		
Na-24	1(-2)	1(-5)
P-32	2(-4)	2(-7)
Cr-51	6(-3)	6(-6)
Mn-54	7(-5)	7(-8)
Mn-56	5(-2)	5(-5)
Fe-55	1(-3)	1(-6)
Fe-59	3(-5)	3(-8)
Co-58	2(-4)	2(-7)
Co-60	4(-4)	4(-7)
Ni-63	1(-6)	1(-9)
Ni-65	3(-4)	3(-7)
Cu-64	3(-2)	3(-5)
Zn-65	2(-4)	2(-7)
Zn-69	2(-3)	2(-6)
Sr-89	1(-4)	1(-7)
Sr-90	7(-6)	7(-9)
Sr-91	4(-3)	4(-6)
Sr-92	1(-2)	1(-5)
Y-91	4(-5)	4(-8)
Y-92	6(-3)	6(-6)
Y-93	4(-3)	4(-6)
Zr-95	8(-6)	8(-9)
Zr-97	6(-6)	6(-9)
Nb-95	8(-6)	8(-9)
Nb-98	4(-3)	4(-6)
Mo-99	2(-3)	2(-6)
Tc-99m	2(-2)	2(-5)
Tc-101	9(-2)	9(-5)
Tc-104	8(-2)	8(-5)
Ru-103	2(-5)	2(-8)
Ru-105	2(-3)	2(-6)
Ru-106	3(-6)	3(-9)
Ag-110m	1(-6)	1(-9)
Te-129m	4(-5)	4(-8)
Te-131m	1(-4)	1(-7)

* Measured values increased to account for liquid recycle.

TABLE 2-2 (Continued)

<u>ISOTOPES</u>	<u>REACTOR COOLANT</u>	<u>REACTOR STEAM</u>
Te-132	1(-5)	1(-8)
Ba139	1(-2)	1(-5)
Ba140	4(-4)	4(-7)
Ba-141	1(-2)	1(-5)
Ba-142	6(-3)	6(-6)
La-142	5(-3)	5(-6)
Ce-141	3(-5)	3(-8)
Ce-143	3(-5)	3(-8)
Ce-144	3(-6)	3(-9)
Pr-143	4(-5)	4(-8)
Nd-147	3(-6)	3(-9)
W-187	3(-4)	3(-7)
Np-239	8(-3)	8(-6)

TABLE 2-3
PARAMETERS USED TO DESCRIBE THE REFERENCE BOILING WATER REACTOR

<u>PARAMETER</u>	<u>SYMBOL</u>	<u>UNITS</u>	<u>NOMINAL VALUE</u>	<u>RANGE</u>	
				<u>MAXIMUM</u>	<u>MINIMUM</u>
Thermal power	P	MWt	3400	3800	3000
Weight of water in the reactor vessel	WP	lb	3.8(5)*	4.2(5)	3.4(5)
Cleanup demineralizer flow rate	FA	lb/hr	1.3(5)	1.5(5)	1.1(5)
Steam flow rate	FS	lb/hr	1.5(7)	1.7(7)	1.3(7)
Ratio of condensate demin- eralizer flow rate to steam flow rate	NC**	-	0.75	0.99	0.5

* $3.8(5) = 3.8 \times 10^5$

** For a BWR that is within the range indicated above, i.e. a BWR with pumped forward feedwater heater drains, the value for NC used in the BWR-GALE Code is 0.18 for iodine and 0.01 for Cs, Rb and other nuclides, as discussed on page 2-11. For a BWR that has a ratio of condensate demineralizer flow rate to steam flow rate equal to 1.0, i.e., full flow condensate demineralizers, a value of NC=1.0 is used in the BWR-GALE Code.

TABLE 2-4
VALUES USED IN DETERMINING ADJUSTMENT FACTORS FOR
BOILING WATER REACTORS

SYMBOL	DESCRIPTION	NOBLE GASES	HALOGENS	Cs, Rb	WATER ACTIVATION PRODUCTS	TRITIUM	OTHER NUCLIDES
NA	Fraction of material removed in the reactor water cleanup system	0.0	0.9	0.5	0.0	0.0	0.9 [*]
NB	Fraction of material removed by the condensate demineralizers	0.0	0.9	0.5	0.0	0.0	0.9 [*]
NS	Ratio of concentration in reactor steam to the concentration in reactor water	**	0.015 ⁺⁺⁺	0.001	***	1.0	0.001
R	Removal rate from the reactor water (hr ⁻¹).	**	0.40	0.17	***	††	0.31

* These represent effective removal terms and include other mechanisms such as plateout. Plateout would be applicable to nuclides such as Mo and corrosion products.

** All noble gases released from the core are transported rapidly out of the reactor water to the reactor steam and are stripped from the system in the main condenser. Therefore the concentration in the reactor water is negligible and the steam concentration is approximately equivalent to the ratio of the release rate and the steam flow rate.

*** Water activation products exhibit varying chemical and physical properties in reactor coolant which are not well defined. However, most are stripped off as gases. They are not effectively removed by the demineralizers of the systems, but their concentrations are controlled by decay.

† These values of R apply to the reference BWR whose parameters are given in Table 2-3 and have been used in developing Table 2-5. For BWRs not included in Table 2-3, the appropriate value for R is determined by the BWR-GALE Code using the following equation:

$$R = \frac{FA \cdot NA + NC \cdot FS \cdot NS \cdot NB}{WP} \text{ for halogens, Cs, Rb, and other nuclides}$$

where the symbols are defined in this table, Table 2-3 and Figure 2-1. The values for R for noble gases and water activation products are not used in the adjustment factors of Table 2-5.

†† The tritium concentrations in the reactor water and the steam are expected to be equal. They are controlled by loss of water from the main coolant system by evaporation or leakage.

+++ The value of 0.015 is used for BWRs which have Deep Bed Condensate Treatment. A value of 0.015 is also used for BWRs with Powdex Condensate Treatment and stainless steel condenser tubing. For BWRs which have Powdex Condensate Treatment systems and copper condenser tubing, a value of 0.004 should be used.

TABLE 2-5
ADJUSTMENT FACTORS FOR BOILING WATER REACTORS

NUCLIDES	REACTOR COOLANT	REACTOR STEAM
Noble gases*	1.0	1.0
Halogens**	$\frac{P}{WP} (110 \frac{lb}{MWt}) \frac{0.40 + \lambda}{R + \lambda}$	$\frac{P}{WP} (110 \frac{lb}{MWt}) \frac{0.40 + \lambda}{R + \lambda}$
Cs, Rb	$\frac{P}{WP} (110 \frac{lb}{MWt}) \frac{0.17 + \lambda}{R + \lambda}$	$\frac{P}{WP} (110 \frac{lb}{MWt}) \frac{0.17 + \lambda}{R + \lambda}$
Water activation products	1.0	1.0
Tritium***	1.0	1.0
Other nuclides	$\frac{P}{WP} (110 \frac{lb}{MWt}) \frac{0.31 + \lambda}{R + \lambda}$	$\frac{P}{WP} (110 \frac{lb}{MWt}) \frac{0.31 + \lambda}{R + \lambda}$

*Assumes that the ratio of power to steam flow is essentially the same for all BWRs.

** λ is the isotope's decay constant (hr^{-1}).

***The tritium concentrations in the reactor coolant and the steam are expected to be equal. They are controlled by loss of water from the main coolant system by evaporation or leakage. The concentration is therefore given by the ratio of the appearance rate in the coolant, which is about 100 Ci/yr, and the total loss from the system.

* SYMBOLS ARE DEFINED IN TABLES 2-3 AND 2-4

FIGURE 2-1
REMOVAL PATHS FOR THE REFERENCE
BOILING WATER REACTOR

2.2.3.2 Bases

The radionuclide concentrations, adjustment factors, and procedures for effecting adjustments are based on the values and methods in American National Standard ANSI N237, Source Term Specification, (Ref. 1) with the changes noted in Section 1.2 under the Reactor Coolant definitions. The values in Table 2-2 provide a set of typical radionuclide concentrations in the reactor coolant and steam for reactor designs within the parameters specified in Table 2-3. The values in Table 2-2 were those determined to be representative of radionuclide concentrations in a BWR over its lifetime based on the currently available data and models (Refs. 3 and 4). It is recognized that some systems will have design parameters that are outside the ranges specified in Table 2-3. For that reason a means of adjusting the concentrations to the actual design parameters has been provided in the BWR-GALE Code based on factors presented in Tables 2-4 and 2-5. The adjustment factors in Tables 2-4 and 2-5 are based on the following expression:

$$C = \frac{s}{w(\lambda + R)k}$$

where

- C is the specific activity, in $\mu\text{Ci/gm}$;
- k is a conversion factor, 454 gm/lbs;
- R is the removal rate of the isotope from the system due to demineralization, leakage, etc., in hr^{-1} ;
- s is the rate of release to and/or production of the isotope in the system, in $\mu\text{Ci/hr}$;
- w is the fluid weight, in lb; and
- λ is the decay constant, in hr^{-1} .

The following sample calculations illustrate the method by which the BWR-GALE Code will adjust the radionuclide concentrations in Table 2-2. As indicated in Table 2-5, adjustment factors will be calculated only for halogens, Cs, Rb, and other nuclides.

As an example, the sample case parameters shown below compare with the range of values in Table 2-3 as follows:

Parameter	Sample Case Value	Range Values
Thermal power level (MWt)	3758	3000-3800
Water weight in vessel (lbs)	4.9×10^5	$3.4 \times 10^5 - 4.2 \times 10^5$
Cleanup demineralizer flow (lbs/hr)	1.5×10^5	$1.1 \times 10^5 - 1.5 \times 10^5$
Steam flow rate (lbs/hr)	15.4×10^6	$13.0 \times 10^6 - 17.0 \times 10^6$
Condensate demineralizer flow fraction	0.75	0.5 - 0.99

Since in this example one of the parameters (water weight in vessel) is outside the range, adjusted values of the three types of radionuclide concentrations are calculated using the actual value of each parameter, as follows:

1. Halogens (I-131 is used as an example) -- Using the equation for halogens in Table 2-5, the adjustment factor A is calculated as follows:

$$A = \frac{P}{WP} (110) \frac{0.40 + \lambda}{R + \lambda} \quad (2-1)$$

where the terms in the equation are as defined in Tables 2-3 and 2-4.

In calculating A, the variable R is calculated first, using the equation given in Table 2-4:

$$R = \frac{FA NA + NC FS NS NB}{WP} \quad (2-2)$$

where the terms in the equation are as defined in Tables 2-3 and 2-4.

Using the sample case parameters given above, the halogen parameters given in Table 2-4, and the pumped forward parameter given in Table 2-3, and substituting in Equation (2-2) gives

$$R = \frac{1.5 \times 10^5 \times 0.9 + 0.18 \times 15.4 \times 10^6 \times 0.015 \times 0.9}{4.9 \times 10^5} = 0.35$$

Then, using this value of R in Equation (2-1):

$$A = \frac{3758}{4.9 \times 10^5} (110) \frac{0.40 + 3.6 \times 10^{-3}}{0.35 + 3.6 \times 10^{-3}} = 0.96$$

The adjusted I-131 concentration

$$\begin{aligned} &= (\text{adjustment factor}) \times (\text{standard I-131 concentration}) \\ &= 0.96 \times 4 \times 10^{-3} \text{ } \mu\text{Ci/g} = 3.8 \times 10^{-3} \text{ } \mu\text{Ci/gm} \end{aligned}$$

2. Cs, Rb (Cs-137 is used as an example) -- Using the equation for Cs and Rb in Table 2-5, the adjustment factor A is calculated as follows:

$$A = \frac{P}{WP} (110) \frac{0.17 + \lambda}{R + \lambda} \quad (2-3)$$

where the terms in the equation are as defined in Tables 2-3 and 2-4.

In calculating A, the variable R is calculated first, using Equation (2-2). The Cs and Rb parameters given in Table 2-4, the pumped forward parameter given in Table 2-3, and the sample case parameters are used in the equation.

$$R = \frac{1.5 \times 10^5 \times 0.5 + 0.01 \times 15.4 \times 10^6 \times 0.001 \times 0.5}{4.9 \times 10^5} = 0.15$$

Then, using this value of R in Equation (2-3) above:

$$A = \left(\frac{3758}{4.9 \times 10^5} \right) (110) \left(\frac{0.17 + 2.6 \times 10^{-6}}{0.15 + 2.6 \times 10^{-6}} \right) = 0.96$$

The adjusted Cs-137 concentration

$$\begin{aligned} &= (\text{adjustment factor}) \times (\text{standard Cs-137 concentration}) \\ &= 0.96 \times 8 \times 10^{-5} \text{ } \mu\text{Ci/g} = 7.6 \times 10^{-5} \text{ } \mu\text{Ci/gm} \end{aligned}$$

3. Other Nuclides (Na-24 is used as an example) -- Using the equation for other nuclides in Table 2-5, the adjustment factor A is calculated as follows:

$$A = \frac{P}{WP} (110) \frac{0.31 + \lambda}{R + \lambda} \quad (2-4)$$

where the terms in the equation are as defined in Tables 2-3 and 2-4.

In calculating A, the variable R is calculated first, using Equation (2-2). The other nuclide parameters given in Table 2-4, the pumped forward parameter given in Table 2-3, and the sample case parameters are used in the equation:

$$R = \frac{1.5 \times 10^5 \times 0.9 + 0.01 \times 15.4 \times 10^6 \times 0.001 \times 0.9}{4.9 \times 10^5} = 0.28$$

Then, using this value of R in Equation (2-4):

$$A = \left(\frac{3758}{4.9 \times 10^5} \right) (110) \left(\frac{0.31 + 4.62 \times 10^{-2}}{0.28 + 4.62 \times 10^{-2}} \right) = 0.92$$

The adjusted concentration of Na-24

$$= (\text{adjustment factor}) \times (\text{standard Na-24 concentration})$$

$$= 0.92 \times 1 \times 10^{-2} \text{ } \mu\text{Ci/gm} = 9.2 \times 10^{-3} \text{ } \mu\text{Ci/gm}$$

The noble gas concentrations in Table 2-2 are based on an offgas release rate of 50,000 $\mu\text{Ci/sec}$ measured at 30-minute decay. The value of 50,000 $\mu\text{Ci/sec}$ can be determined as discussed below. Recent data supplied by General Electric (Refs. 5,6,7) shows that improved (7 x 7R and 8 x 8) fuel which is in the process of being installed in both new and reload cores has shown considerable improvement over the 7 x 7 fuel which was previously used and still present in some BWRs.

The improvements in the fuel are primarily due to a reduction in zircaloy hydriding and pellet cladding interaction (PCI). However, there is not extensive experience of the improved fuel over complete burnup cycles to date. At the higher burnups, the probability for PCI failure increases even though the power generation rate in the fuel is diminished. This results because at the higher burnups the fuel-to-cladding gap closes due to fission product swelling of the fuel and because the cladding loses its ductility from neutron damage and hydrogen pickup (Ref. 8).

For these reasons, there is not sufficient justification to use the low values of noble gas release rates experienced at reactors having cores loaded with 100% of improved fuel. However, a review was performed of BWR operating experience with noble gas release rates for the period 1975-1977 (Refs. 9, 10) which include the time period during which the improved fuel was introduced. In order to account for the potential effects of increased releases at high burnups and also to account for the fact that the 7 x 7 fuel will be phased out (Ref. 6), only the experience at those reactors whose cores are loaded with greater than 50% of improved fuel was considered. A summary of these data is contained in Table 2-6. Based on this review, the noble gas release rate that will be used as an interim measure until more improved fuel experience is obtained is 50,000 $\mu\text{Ci/sec}$ at 30 minutes decay and normalized to 3400 MWt.

A carryover factor of 0.015 is used to calculate the halogen concentrations in the main steam in Table 2-2 for BWRs which have deep bed condensate treatment, or for BWRs with powdex filter/demineralizer condensate treatment and having stainless steel condenser tubing. For BWRs with powdex filter/demineralizer condensate treatment systems and copper condenser tubing a carryover factor of 0.004 is used to calculate the halogen concentrations in the main steam. This carryover factor is derived from data taken at operating reactors (Refs. 3, 4, 5, 11 and 12) which are listed in Table 2-7. The average of the data in Table 2-7 is 0.015 and 0.004 for halogen (iodine) carryover, respectively, for the two types of BWRs listed in that table.

The nominal value of the ratio of the condensate demineralizer flow rate to the steam flow rate is 0.75. This indicates that the nominal case is a design which utilizes a pumped forward model, that is, one in which the reactor steam flow is split with 75% flowing to the low pressure turbines and the main condenser, and 25% pumped forward to the feedwater. The fraction pumped forward to the feedwater does not undergo any treatment in the condensate demineralizers. We have determined that the iodine and Cs, Rb, and Other Nuclides of Table 2-2 preferentially go with the "pumped forward" fraction. The reason for this is that these nuclides show a tendency to go with the condensed steam in the moisture separator-reheater drains to the feedwater system. Based on data provided in Ref. 13 and 14 for Brunswick and Point Beach, the ratios used in the BWR-GALE Code are 82% bypass of condensate demineralizers for iodine and 99% bypass of condensate demineralizer for Cs, Rb, and Other Nuclides of Table 2-2. Since the remainder of the nuclides listed in Table 2-2 are not removed in the condensate demineralizers, we have not considered the magnitude of bypass for those nuclides.

TABLE 2-6
SUMMARY OF NOBLE GAS RELEASE
RATES FOR OPERATING BWRs*
($\mu\text{Ci/sec}$)

<u>Facility</u>	<u>1977</u>	<u>1976</u>	<u>1975</u>
Cooper	290	31	-
Dresden 3	215,000	-	-
Duane Arnold	NA	1,300	-
Fitzpatrick	1,190	-	-
Hatch 1	1,300	-	-
Millstone 1	NA	152,000	-
Monticello	91,000	137,000	-
Nine Mile Pt 1	60,000	64,000	-
Oyster Creek	113,000	79,000	-
Peach Bottom 2	12,000	10,000	-
Peach Bottom 3	6,900	-	-
Vermont Yankee	NA	11,000	12,000
	<u>55,000</u>	<u>56,000</u>	<u>12,000</u>

*Data in this table are based on measured noble gas release rates in references 9 and 10 and were adjusted to 30 minutes decay and to 3400 Mwt.

NA - Data not available.

TABLE 2-7
 REACTOR VESSEL HALOGEN CARRYOVER FACTORS
 (PARTITION COEFFICIENTS) OBSERVED AT OPERATING BWRs

BWRs which have Deep Bed Condensate
 Treatment; BWRs which have Powdex
 Systems with Stainless Steel
 Condenser Tubing

BWRs which have Powdex
 Treatment Systems with
 Copper Condenser Tubing

<u>Plant</u>	<u>Partition Coefficient</u>	<u>Ref</u>	<u>Plant</u>	<u>Partition Coefficient</u>	<u>Ref</u>
Oyster Creek	0.023	3, 4, 11			
Dresden 2	0.017	3, 12	Monticello	0.004	3
Dresden 3	0.021	3, 12	Browns Ferry 1	0.005	5
Millstone 1	0.012	3, 4	Browns Ferry 2	0.0023	5
Nine Mile Point 1	0.02	4	Browns Ferry 3	0.003	5
Quad Cities 1	0.013	3	Duane Arnold	0.004	5
Cooper	0.012	5	Hatch 1	0.0035	5
Fitzpatrick	0.018	5	Peach Bottom 2	0.004	5
Pilgrim 1	<u>0.0082</u>	5	Peach Bottom 3	0.0044	5
AVERAGE	0.015		Vermont Yankee	<u>0.004</u>	5
			AVERAGE	0.004	

The category "Other nuclides" includes Mo, Y, and Tc which are generally present in colloidal suspensions or as "crud." Although the actual removal mechanism for Y, Mo, and Tc is expected to be plateout or filtration, the quantitative effect of removal is expected to be commensurate with the removal of ionic impurities by ion exchange (within the accuracy of the calculations) and consequently plateout of these nuclides is included in the parameters for ion exchange.

2.2.4 GASEOUS RELEASES FROM BUILDING VENTILATION SYSTEMS

2.2.4.1 Parameter

The noble gas and radioactive particulate releases from ventilation systems for facilities with the BWR/6, Mark III containment design, prior to treatment, are shown in Table 2-12.

The iodine releases from ventilation systems for facilities with the BWR/6, Mark III containment design, prior to treatment, are calculated by the BWR-GALE Code using the data in Table 1-2, Tables 2-2 through 2-5, and 2-8 through 2-10.

2.2.4.2 Bases

The iodine-131 releases from building ventilation systems are based on measurements made at a number of operating reactors. These measurements were made during routine operation and during plant shutdowns. Extensive work on identifying sources of radioiodine at BWRs has been done by C. Pelletier, et al (Ref. 15) for the Electric Power Research Institute (EPRI), at three operating BWRs, Monticello, Vermont Yankee and Oyster Creek, and for the U.S. Nuclear Regulatory Commission at one operating BWR, Pilgrim (Ref. 16).

These measurements indicate that iodine-131 building vent releases are directly related to the reactor water iodine-131 concentration. As a result, the releases of iodine are expressed as "normalized" releases, that is, the absolute measured release rate in $\mu\text{Ci/sec}$ is divided by the measured reactor water concentration in $\mu\text{Ci/gm}$ to give a "normalized" release rate of reactor water containing iodine-131 in gm/sec , as shown in the following equation:

$$R_N = \frac{R_A}{C_{RW}}$$

where

R_N = normalized release rate of reactor water containing iodine-131, gm/sec

R_A = absolute (measured) iodine-131 release rate, $\mu\text{Ci/sec}$

C_{RW} = measured reactor water iodine-131 concentration, $\mu\text{Ci/gm}$.

The normalized reactor water release rate, expressed in gm/sec , represents an effective leak rate for reactor water containing iodine. It is the combination of the water leakage rate into the building and the effect of iodine partitioning between the water phase in the systems leakage and the vapor phase in the building atmosphere.

For the turbine building, the iodine releases are directly related to the partition coefficient for radioiodine from reactor water to steam, in addition to being directly related to the reactor water iodine-131 concentration. Therefore, for the turbine building, the normalized iodine release, R_N , is determined using the following expression:

$$R_N = \frac{R_A}{C_{RW} \times PC}$$

where

R_N = normalized release rate of reactor water containing iodine-131, gm/sec

R_A = absolute (measured) iodine-131 release rate, $\mu\text{Ci/sec}$

C_{RW} = measured reactor water iodine-131 concentration, $\mu\text{Ci/gm}$

PC = measured partition coefficient from the reactor water to reactor steam.

The normalized release rate is used to estimate the releases from BWRs since this expression for release rate is least variable with time and least variable from plant to plant for comparable time periods (Ref. 15). For this reason, it is useful in the determination of releases from BWRs.

Data on the normalized release rates from the three reactors used in the EPRI NP-495 study and the reactor in the NRC study are given for normal operation and shutdown periods in Tables 2-8, 2-9, and 2-10 for the turbine building, the reactor building and the radwaste building, respectively.

Also given in Tables 2-8, 2-9 and 2-10 are normalized values of the iodine release data based on References 3 and 5. The data and the plants included in these references are listed in Tables 2-10 through 2-15 of NUREG-0016, dated April 1976. These data are presented as one data point since the measurements used were of short duration compared to the lengthy measurements carried out in the EPRI NP-495 and the NRC study. Also given in Tables 2-8, 2-9, 2-10 are normalized values of iodine release data from Browns Ferry during 1977 (Ref. 5).

The data in Tables 2-8 through 2-10 are expressed as the total normalized release during power operation of 300 days and the total normalized release during extended shutdown of 65 days. Since the reactors used in the EPRI NP-495 study and the NRC study experienced several intermittent shutdowns of short duration during the power operation measurement period, the iodine releases during these short duration outages are included under power operation.

In order to obtain the releases in curies/yr from the reactor building and radwaste building of a particular BWR, the normalized release data in Tables 2-9 and 2-10, respectively, are multiplied in the BWR-GALE Code by the iodine reactor water concentration for that particular BWR using the following expression:

$$R_{BWR} = R_N^I \times C_{BWR}$$

where

R_{BWR} = calculated annual release for particular BWR, Ci/yr

R_N^I = normalized annual release of reactor water containing iodine-131 from Tables 2-9 and 2-10, Ci/yr/ μ Ci/gm

C_{BWR} = calculated reactor water concentration for particular BWR, μ Ci/gm

To obtain the release in curies/yr from the turbine building of a particular BWR, the normalized release data in Table 2-8 are multiplied in the BWR-GALE Code by the iodine reactor water concentration and the iodine carryover from the reactor water to reactor steam for that particular BWR using the following expression:

$$R_{BWR} = R_N^I \times C_{BWR} \times PC_{BWR}$$

where

R_{BWR} = calculated annual release for particular BWR, Ci/yr

R_N^I = normalized annual release of reactor water from Table 2-8, Ci/yr/ μ Ci/gm

C_{BWR} = calculated reactor water concentration for particular BWR, μ Ci/gm

PC_{BWR} = calculated carryover from the reactor water to reactor steam for the particular BWR (See Section 2.2.3.2 and Table 2-4)

The value for the iodine carryover for the reactor water to reactor steam can be determined for the particular BWR from Table 2-4.

To obtain the releases during extended shutdown, multiply the normalized release rates for the extended shutdown period by the same reactor water concentration as for power operation. Use of this reactor water concentration is acceptable since the normalization technique of EPRI-NP-495 based the extended shutdown normalized release rate on the reactor water concentrations prior to shutdown.

The value for the iodine-131 reactor water concentration can be determined as discussed below. Recent data supplied by General Electric (Refs. 5, 6, 7) shows that improved (7 x 7R and 8 x 8) fuel which is in the process of being installed in both new and reload cores has shown considerable improvement over the 7 x 7 fuel which was previously used and still present in some BWRs.

The improvements in the fuel are primarily due to a reduction in zircaloy hydriding and pellet cladding interaction (PCI). However, there is not extensive experience of the improved fuel over complete burnup cycles to date. At the higher burnups, the probability for PCI failure increases even though the power generation rate in the fuel is diminished. This results because at the higher burnups the fuel-to-cladding gap closes due to fission product swelling of the fuel and because the cladding loses its ductility from neutron damage and hydrogen pickup (Ref. 8).

For these reasons, there is not sufficient justification to use the low values of iodine-131 reactor water concentration experienced at reactors having cores loaded with 100% of improved fuel. However, a review was performed of BWR operating experience (Ref. 5) with iodine-131 reactor water concentrations for the period 1975-1977 which includes the time period during which the improved fuel was introduced. In order to account for the potential effects of increased releases at high burnups and also to account for the fact that the 7 x 7 fuel will be phased out (Ref. 6), only the experience at those reactors whose cores are loaded with greater than 50% of improved fuel was considered. A summary of these data is contained in Table 2-11. Based on this review, the iodine-131 reactor water concentration that will be used as an interim measure until more improved fuel experience is obtained is 0.0037 $\mu\text{Ci/gm}$.

The reactor building releases reported in References 13 and 14 are based on reactors with a BWR Mark I containment design. Equipment such as the reactor water cleanup (RWCU) pumps, the residual-heat removal system, and emergency core cooling systems have been placed in an auxiliary building in the BWR/6, Mark III containment design concept. Based on data gathered in Reference 15, the RWCU pumps are the major source of leakage in the reactor building. As a result of these measurements, the releases from the Mark III auxiliary building ventilation system are determined to be 90% of Mark I reactor building release, and releases from the Mark III containment building ventilation are determined to be 10% of Mark I releases during power operation. During shutdown, 90% of the releases are determined to be from the Mark III containment building ventilation system and 10% from the auxiliary building ventilation system. For the turbine building, based on data gathered in Ref. 15, 85% of the releases are determined to come from the ventilation system serving the main condenser area during power operation. The remainder of the releases come from miscellaneous areas such as the steam jet air ejector room, the turbine operating floor, the feedwater pump room, and the mechanical vacuum pump room. During the shutdown since there is potential for iodine release during maintenance of the turbines, the release from the ventilation system serving the main condenser area is approximately 50% of the total and the remainder of the releases come from the miscellaneous areas.

For the radwaste building, based on data gathered in Ref. 15, 10% of the releases are determined to come from the solid waste handling area and 90% of the releases are determined to come from the liquid waste handling area.

Within the building ventilation systems, charcoal adsorbers may be added on individual equipment cells and appropriate credit taken for iodine removal if the fraction of total iodine being assigned to that particular equipment cell is in accordance with Ref. 15.

Iodine released from BWR building ventilation systems appear in one of the following chemical forms: particulate, elemental, hypoiodous acid (HOI) and organic. Based on data in References 15 and 16 the fraction of the iodine appearing in each of the chemical forms for each building ventilation system is given below:

FRACTION OF IODINE APPEARING IN EACH CHEMICAL FORM
FROM BWR BUILDING VENTILATION SYSTEMS

	<u>CONTAINMENT</u>	<u>AUXILIARY</u>	<u>TURBINE</u>	<u>RADWASTE</u>
Particulate	0.11	0.2	0.2	0.002
Elemental	0.32	0.48	0.50	0.28
HOI	0.38	0.24	0.22	0.25
Organic	0.19	0.09	0.08	0.47

TABLE 2-8
ANNUAL IODINE NORMALIZED RELEASES*
FROM TURBINE BUILDING VENTILATION SYSTEMS

NORMAL OPERATION

<u>Data Source</u>	<u>Normalized Release (Ci/yr/μCi/gm)</u>
Monticello (Ref. 15)	3.1×10^3
Oyster Creek (Refs. 15, 16)	6.0×10^3
Vermont Yankee (Ref. 15)	0.35×10^3
Pilgrim (Ref. 16)	8.5×10^3
Browns Ferry (Ref. 5)	1.3×10^3
References 3 and 5***	3.3×10^3
AVERAGE	3.8×10^3

EXTENDED SHUTDOWN

<u>Data Source</u>	<u>Normalized Release (Ci/yr/μCi/gm)</u>
Monticello (Ref. 15)	1.7×10^2
Oyster Creek (Ref. 15)	$3.5 \times 10^{2**}$
Vermont Yankee (Ref. 15)	0.63×10^2
Browns Ferry (Ref. 5)	1.3×10^2
References 3 and 5***	1.4×10^3
AVERAGE	$4.1 \times 10^{2**}$

*The normalized release rate, expressed in grams of water during the modes of operation, represents the effective leak rate for radioiodine. It is the combination of the reactor water leakage rate into the buildings, the partitioning of the radiiodine between the water phase in the leakage and the gas phase where it is measured and the partition coefficient for radioiodine from reactor water to steam in the reactor vessel.

**Oyster Creek data in this table does not include effect of use of reheater protection system exhaust since the system design of this component is not typical of current BWRs (Nine Mile Point, Unit No. 1 is the only other BWR with this design). If a BWR uses this design, the additional release is 8.7×10^2 Ci/yr/ μ Ci/gm during the shutdown period (Ref. 15) and should be included in the total turbine building shutdown release.

***The data and the plants included in these references are listed in Tables 2-10 through 2-15 of NUREG-0016, dated April 1976.

TABLE 2-9
ANNUAL IODINE NORMALIZED RELEASES*
FROM REACTOR BUILDING VENTILATION SYSTEMS

<u>NORMAL OPERATION</u>	
<u>Data Source</u>	<u>Normalized Releases (Ci/yr/μCi/gm)</u>
Monticello (Ref. 15)	11
Pilgrim (Ref. 16)	13
Brown Ferry (Ref. 5)	4.2
References 3 and 5***	<u>21</u>
	12.3**
<u>EXTENDED SHUTDOWN</u>	
<u>Data Source</u>	<u>Normalized Releases (Ci/yr/μCi/gm)</u>
Monticello (Ref. 15)	0.47
Oyster Creek (Ref. 15)	1.3
Vermont Yankee (Ref. 15)	3.2
Browns Ferry (Ref. 5)	1.4
References 3 and 5***	<u>20</u>
	5.2

* The normalized release rate, expressed in grams of water during the modes of operation, represents the effective leak rate for radioiodine. It is the combination of the reactor water leakage rate into the buildings, and the partitioning of the radiiodine between the water phase in the leakage and the gas phase where it is measured.

**Oyster Creek and Vermont Yankee data are not included here since Monticello leakage is considered to be more typical of similar problems at other BWRs where the RWCU pump is upstream of the RWCU demineralizers.

*** The data and the plants included in these references are listed in Tables 2-10 through 2-15 of NUREG-0016, dated April 1976.

TABLE 2-10
ANNUAL IODINE NORMALIZED RELEASES*
FROM RADWASTE BUILDING VENTILATION SYSTEMS

NORMAL OPERATION

<u>Data Source</u>	<u>Normalized Release (Ci/yr/μCi/gm)</u>
Monticello (Ref. 15)	0.72
Oyster Creek (Refs. 15, 16)	6.8
Vermont Yankee (Ref. 15)	1.0
Pilgrim (Ref. 16)	12
Browns Ferry (Ref. 5)	2.0
References 3 and 5**	<u>5.3</u>
AVERAGE	4.6

EXTENDED SHUTDOWN

<u>Data Source</u>	<u>Normalized Release (Ci/yr/μCi/gm)</u>
Monticello (Ref. 15)	0.02
Oyster Creek (Ref. 15)	1.4
Vermont Yankee (Ref. 15)	0.4
Browns Ferry (Ref. 5)	0.6
References 3 and 5**	<u>4.4</u>
AVERAGE	1.4

*The normalized release rate, expressed in grams of water during the modes of operation, represents the effective leak rate for radioiodine. It is the combination of the reactor water leakage rate into the buildings, and the partitioning of the radiiodine between the water phase in the leakage and the gas phase where it is measured.

**The data and the plants included in these references are listed in Tables 2-10 through 2-15 of NUREG-0016, dated April 1976.

TABLE 2-11
SUMMARY OF IODINE-131 REACTOR WATER
CONCENTRATIONS IN BWR's*
($\mu\text{Ci/Kg}$)

<u>Facility</u>	<u>1977</u>	<u>1976</u>	<u>1975</u>
Browns Ferry 1	0.9	-	-
Browns Ferry 2	1.5	-	-
Browns Ferry 3	0.14	-	-
Brunswick 1	0.02	-	-
Brunswick 2	3.1	0.93	0.007
Cooper	0.072	0.09	0.013
Dresden 3	17.6	12.6	-
Duane Arnold	0.042	0.09	0.0023
Fitzpatrick	0.24	0.29	-
Hatch 1	0.9	0.11	-
Millstone Pt. 1	8.9	5.6	7.1
Monticello	5.9	9.0	8.7
Nine Mile Pt. 1	9.4	5.9	-
Oyster Creek	8.4	5.3	4.8
Peach Bottom 2	7.3	16.	0.045
Peach Bottom 3	1.1	0.83	0.063
Quad Cities 1	3.4	-	-
Vermont Yankee	<u>0.38</u>	<u>0.51</u>	<u>0.78</u>
	3.8	4.4	2.4

*Data in these tables are based on measured iodine-131 coolant concentrations in Ref. 5 and have been adjusted to the NSSS parameters listed in Table 2-3 of this report. These adjustments were made by considering the individual plant parameters and the nominal plant parameters (Table 2-3) and adjusting the actual coolant concentration using the equations in Table 2-5 of this report.

TABLE 2-12
GASEOUS AND PARTICULATE RELEASES FROM
BUILDING VENTILATION SYSTEMS
(in Ci/yr per Reactor)

NUCLIDE	CONTAINMENT BUILDING	AUXILIARY BUILDING	TURBINE BUILDING	RADWASTE BUILDING
Kr83m	**	**	**	**
Kr-85m	1	3	25	**
Kr-85	**	**	**	**
Kr-87	**	2	61	**
Kr-88	1	3	91	**
Kr-89	**	2	580	29
Xe-131m	**	**	**	**
Xe-133m	**	**	**	**
Xe-133	27	83	150	220
Xe-135m	15	45	400	530
Xe-135	33	94	330	280
Xe-137	45	135	1000	83
Xe-138	2	6	1000	2
Cr-51*	0.0002	0.0009	0.0009	0.0007
Mn-54	0.0004	0.001	0.0006	0.004
Fe-59	0.00009	0.0003	0.0001	0.0003
Co-58	0.0001	0.0002	0.001	0.0002
Co-60	0.001	0.004	0.001	0.007
Zn-65	0.001	0.004	0.006	0.0003
Sr-89	0.00003	0.00002	0.006	NA
Sr-90	0.000003	0.000007	0.00002	NA
Zr-95	0.0003	0.0007	0.00004	0.0008
Nb-95	0.001	0.009	0.000006	0.000004
Mo-99	0.006	0.06	0.002	0.000003
Ru-103	0.0002	0.004	0.00005	0.000001
Ag-110	0.0000004	0.000002	NA	NA
Sb-124	0.00002	0.00003	0.0001	0.00007
Cs-134	0.0007	0.004	0.0002	0.0024
Cs-136	0.0001	0.0004	0.0001	NA
Cs-137	0.001	0.005	0.001	0.004
Ba-140	0.002	0.02	0.010	0.000004
Ce-141	0.0002	0.0007	0.010	0.000007

*Particulate release rates are prior to filtration.

**Less than 1 Ci/yr per reactor.

NA Not Analyzed; analysis for the isotope was not performed.

TABLE 2-13

RELEASE RATES OF NOBLE GASES FROM
THE REACTOR BUILDING VENTILATION SYSTEM
 ($\mu\text{Ci/sec}$)

<u>NUCLIDE</u>	<u>MILLSTONE-1</u>	<u>OYSTER CREEK</u>	<u>OYSTER CREEK</u>	<u>MONTICELLO</u>	<u>AVERAGE</u>
Kr-85m	0.26	ND	ND	0.20	0.12
Kr-87	0.24	ND	ND	0.10	0.085
Kr-88	0.38	0.02	ND	0.20	0.15
Kr-89	ND	ND	ND	0.38	0.095
Xe-133	0.52	15	ND	2.0	4.4
Xe-135m	3.6	ND	2.5	3.5	2.4
Xe-135	3.0	2.1	14	1.8	5.2
Xe-137	ND	ND	ND	30	7.5
Xe-138	0.44	0.3	ND	0.4	0.29

ND - Not Detected. For averaging purposes a value of zero was assumed.

TABLE 2-14

RELEASE RATES OF NOBLE GASES FROM
THE TURBINE BUILDING VENTILATION SYSTEM
 ($\mu\text{Ci/sec}$)

<u>NUCLIDE</u>	<u>MILLSTONE-1</u>	<u>OYSTER CREEK</u>	<u>OYSTER CREEK</u>	<u>MONTICELLO</u>	<u>NINE MILE PT 1</u>	<u>AVERAGE</u>
Kr-85m	2.7	ND	2.3	0.10	0.097	1.0
Kr-87	5.3	ND	6.2	0.15	0.53	2.4
Kr-88	8.2	5.2	4.2	0.065	0.21	3.6
Kr-89	ND	ND	70	42	4.5	23
Xe-133	7.4	13	ND	5.0	3.5	5.8
Xe-135m	29	12	26	8.2	2.5	16
Xe-135	25	25	7.4	6.8	2.3	13
Xe-137	ND	ND	115	86	ND	40
Xe-138	63	26	97	11	4.3	40

ND - Not Detected. For averaging purposes a value of zero was assumed.

TABLE 2-15

RELEASE RATES OF NOBLE GASES FROM
THE RADWASTE BUILDING VENTILATION SYSTEM
($\mu\text{Ci/sec}$)

<u>NUCLIDE</u>	<u>MILLSTONE-1</u>	<u>OYSTER CREEK</u>	<u>MONTICELLO</u>	<u>AVERAGE</u>
Kr-89	ND	ND	3.0	1.0
Xe-133m	ND	ND	5.3	1.8
Xe-133	0.25	0.56	26	8.9
Xe-135m	ND	4	59	21
Xe-135	2.0	1.5	20	7.8
Xe-137	ND	ND	10	3.3
Xe-138	ND	ND	0.2	0.067

ND - Not Detected. For averaging purposes a value of zero was assumed.

TABLE 2-16

PARTICULATE RELEASE RATES FROM REACTOR BUILDING
VENTILATION SYSTEM, NORMAL OPERATION
($10^{-6}\mu\text{Ci/sec}$)

<u>NUCLIDE</u>	<u>QUAD CITIES 1</u>	<u>QUAD CITIES 2</u>	<u>VERMONT YANKEE</u>	<u>OYSTER CREEK</u>	<u>MONTICELLO</u>	<u>AVERAGE</u>
Co-60	210	0.9	37	610	140	200
Co-58	20	0.4	5.5	31	ND	11
Cr-51	140	0.5	13	39	ND	38
Mn-54	19	0.1	14	210	24	53
Fe-59	NA	NA	5	33	4.2	14
Zn-65	23	0.1	46	6.4	750	160
Sr-89	NA	NA	NA	6.8	NA	6.8
Sr-90	NA	NA	NA	0.3	NA	0.3
Zr-95	1.6	ND	1.5	0.5	115	24
Nb-95	2.7	ND	7.4	0.3	2200	440
Mo-99	NA	NA	4.4	140	7300	2500
Ru-103	NA	NA	ND	2.8	65	23
Ag-110m	0.2	ND	NA	NA	NA	0.1
Sb-124	NA	NA	ND	2.4	ND	0.8
Cs-134	48	0.1	12	16	760	170
Cs-136	2.3	ND	6.8	7.1	79	19
Cs-137	44	0.5	37	31	990	220
Ba-140	ND	ND	16	76	2600	540
Ce-141	NA	ND	ND	3.9	120	31

NA - Not Analyzed.

ND - Not Detected. For averaging purposes a value of zero was assumed.

The noble gas release rates for building ventilation systems are the average of measurements made at Oyster Creek (Ref 17), Millstone Unit No. 1 (Ref. 18), Monticello (Ref. 15), and Nine Mile Point (Ref. 19). These data are given in Tables 2-13 through 2-15 and are based on the fuel handling area being in the containment building. The noble gas release rates are divided between the containment and auxiliary buildings to reflect the BWR/6, Mark III design, in a manner similar to that for the iodine-131 release.

For the Mark III design during shutdown, 90% of the releases are assumed to be from the containment building and 10% from the auxiliary building ventilation system since the releases from the fuel handling area are considered to be the major source. For the BWR/6 Mark-III containment system design, the fuel building releases are considered to be part of the containment building releases.

The radioactive particulate release rates for building ventilation systems are the average of measurements made at Vermont Yankee, Oyster Creek, Dresden 2 & 3, Quad Cities 1 & 2, Monticello, and Nine Mile Point (Refs. 3, 5, 15 and 19). These data are given in Tables 2-16 through 2-21.

The calculated annual average rates given above are based on an 80% plant capacity factor, i.e., 80% normal operation at 100% power and 20% plant downtime. The releases for normal operation are weighted to account for the operating and shutdown modes. The particulate releases for the reactor building are divided between the containment and auxiliary buildings to reflect the BWR/6, Mark III containment design in a manner similar to that for the iodine-131 releases.

2.2.5 IODINE INPUT TO THE MAIN CONDENSER OFFGAS TREATMENT SYSTEM

2.2.5.1 Parameter

The iodine-131 input to the main condenser offgas treatment system, downstream of the air ejectors, is 6 Ci/yr.

2.2.5.2 Bases

Table 2-22 lists the measured iodine-131 releases and integrated thermal power outputs for BWRs with thermal ratings exceeding 1000 MWt, with more than one year of plant operation and without main condenser offgas treatment. The average ratio of the iodine-131 release in Ci/yr to the integrated thermal power in MWd for the years 1972 through 1976 is approximately 6.3×10^{-6} Ci/MWd per year. Based on a power rating of 3400 MWt and an 80% plant capacity factor, the iodine-131 release from the main condenser air ejector is approximately 6 Ci/yr.

2.2.6 TURBINE GLAND SEALING SYSTEM EXHAUST

2.2.6.1 Parameter

If main steam is used, the annual radioiodine releases from the gland seal condenser exhaust are:

$$\begin{aligned} \text{I-131} &= 8.1 \times 10^{-1} \text{ Ci/yr per } \mu\text{Ci/gm of I-131 in the reactor coolant.} \\ \text{I-133} &= 2.2 \times 10^{-1} \text{ Ci/yr per } \mu\text{Ci/gm of I-133 in the reactor coolant.} \end{aligned}$$

If the clean steam is supplied to the gland seal, the radioiodine source term is negligible (less than 10^{-4} Ci/yr). If sealing steam is supplied from a low-activity source, i.e., steam produced from demineralized condensate, consider the release to be zero.

2.2.6.2 Bases

Radioiodine measurements have been reported (Ref. 15) for two operating facilities that use main steam in the turbine gland seal system. The sample location necessitated including any radioiodines released from the mechanical vacuum pump during sampling. Table 2-23 summarizes this available data for radioiodines released from the gland seal condenser exhaust when the mechanical vacuum pump was not in operation or infrequently used. The radioiodine release rates are dependent on the radioiodine concentration in the reactor coolant and carry-over in the reactor.

It is assumed that there is no radioiodine source term when clean steam (non-radioactive steam from an auxiliary steam supply system) is used for the gland seal. Because of noble gas removal in the main steam condenser, radioiodine removal by the condensate demineralizers, and partitioning in the boiler, steam produced from demineralized condensate is considered to be clean steam. Data in Tables 2-24 and 2-25 show the release of radioactive particulates from the turbine gland seal to be negligible (less than 10^{-5} Ci/year).

TABLE 2-17

PARTICULATE RELEASE RATES FROM REACTOR BUILDING
VENTILATION SYSTEM, REFUELING SHUTDOWN

$(10^{-6} \mu\text{Ci/sec})$

NUCLIDE	QUAD CITIES 1	QUAD CITIES 2	VERMONT YANKEE	OYSTER CREEK	MONTICELLO	AVERAGE
Co-60	16	0.88	250	330	1.70	120
Co-58	2.3	0.35	41	19	ND	13
Cr-51	8.9	0.50	63	28	ND	20
Mn-54	2.6	0.061	20	140	47	42
Fe-59	ND	ND	21	5.0	3.4	6.0
Zn-65	58	0.11	770	1.4	73	180
Sr-89	NA	NA	NA	2.0	NA	2.0
Sr-90	NA	NA	NA	0.36	NA	0.36
Zr-95	0.31	ND	78	0.24	ND	16
Nb-95	0.40	0.021	ND	0.41	160	32
Mo-99	NA	NA	ND	13	4.4	5.8
Ru-103	NA	NA	NA	1.3	36	19
Ag-110m	0.11	NA	NA	NA	NA	0.11
Sb-124	ND	ND	NA	7.0	ND	1.8
Cs-134	6.2	0.14	82	13	170	54
Cs-136	1.0	NA	20	ND	21	11
Cs-137	14	0.54	240	23	200	95
Ba-140	ND	ND	14	1.1	200	43
Ce-141	ND	ND	NA	7.5	45	13

NA - Not Analyzed.

ND - Not Detected. For averaging purposes a value of zero was assumed.

TABLE 2-18

PARTICULATE RELEASE RATES FROM TURBINE BUILDING
VENTILATION SYSTEM, NORMAL OPERATION

$(10^{-6} \mu\text{Ci/sec})$

NUCLIDE	OYSTER CREEK	MONTICELLO	VERMONT YANKEE	DRESDEN 2	DRESDEN 3	AVERAGE
Co-60	61	15	4.1	4.5	6.0	18
Co-58	12	ND	2.0	ND	48	12
Cr-51	440	ND	NA	ND	160	150
Mn-54	30	7.5	1.9	ND	5	8.9
Fe-59	5.8	ND	ND	ND	ND	1.2
Zn-65	1.7	23	7.8	ND	ND	6.5
Sr-89	610	NA	NA	48	3.6	220
Sr-90	1.3	NA	NA	0.3	0.25	0.6
Zr-95	0.59	ND	ND	ND	4.0	0.92
Nb-95	0.33	ND	NA	ND	ND	0.1
Mo-99	91	150	NA	ND	ND	61
Ru-103	1.7	ND	ND	ND	ND	0.34
Sb-124	4.6	ND	ND	ND	ND	0.92
Cs-134	18	23	2.7	ND	3.0	9.3
Cs-136	1.1	16	ND	ND	ND	3.4
Cs-137	57	100	5.1	1.8	10	35
Ba-140	1400	16	83	120	65	340
Ce-141	29	1600	ND	5.5	5	328

NA - Not Analyzed.

ND - Not Detected. For averaging purposes a value of zero was assumed.

TABLE 2-19

PARTICULATE RELEASE RATES FROM TURBINE BUILDING
VENTILATION SYSTEM, REFUELING SHUTDOWN

$(10^{-6} \mu\text{Ci/sec})$

<u>NUCLIDE</u>	<u>OYSTER CREEK</u>	<u>VERMONT YANKEE</u>	<u>MONTICELLO</u>	<u>AVERAGE</u>
Co-60	290	2.5	5.8	100
Co-58	16	1	NA	8.5
Cr-51	51	ND	NA	26
Mn-54	110	NA	0.30	57
Fe-59	31	ND	ND	10
Zn-65	11	NA	10	10
Sr-89	2.5	NA	NA	2.5
Sr-90	0.25	NA	NA	0.25
Zr-95	0.06	ND	ND	0.02
Nb-95	0.40	ND	ND	0.13
Mo-99	125	NA	9.7	67
Ru-103	5.2	NA	ND	2.6
Sb-124	9.5	ND	NA	4.8
Cs-134	19	1.9	1.3	7.4
Cs-136	ND	ND	4.1	1.4
Cs-137	39	3.4	5.8	16
Ba-140	8.2	110	49	56
Ce-141	17	ND	9.1	8.7

NA - Not Analyzed.

ND - Not Detected. For averaging purposes a value of zero was assumed.

TABLE 2-20

PARTICULATE RELEASE RATE FROM RADWASTE BUILDING
VENTILATION SYSTEM, NORMAL OPERATION

$(10^{-6} \mu\text{Ci/sec})$

<u>NUCLIDE</u>	<u>VERMONT YANKEE</u>	<u>OYSTER CREEK</u>	<u>AVERAGE</u>
Co-60	6.0	580	290
Co-58	1.0	16	8
Cr-51	3.0	48	26
Mn-54	1.0	330	170
Fe-59	ND	26	13
Zn-65	1.0	21	11
Sr-89	NA	NA	NA
Sr-90	NA	NA	NA
Zr-95	ND	63	31
Mo-99	2.0	ND	1.0
Sb-124	ND	5.4	2.7
Cs-134	1.2	190	96
Cs-136	ND	ND	0
Cs-137	2.0	290	150
Ba-140	0.3	ND	0.15
Ce-141	ND	6.3	3.2

NA - Not Analyzed

ND - Not Detected. For averaging purposes a value of zero was assumed.

TABLE 2-21
 PARTICULATE RELEASE RATE FROM RADWASTE BUILDING
 VENTILATION SYSTEM, REFUELING SHUTDOWN
 (10⁻⁶ μ Ci/sec)

<u>NUCLIDE</u>	<u>MONTICELLO</u>	<u>AVERAGE</u>
Co-60	1.3	1.3
Co-58	0.21	0.21
Cr-51	ND	0
Mn-54	0.40	0.40
Fe-59	3.2	3.2
Zn-65	5.1	5.1
Sr-89	NA	NA
Sr-90	NA	NA
Nb-95	6.0	6.0
Mo-99	1.0	1.0
Ru-103	1.0	1.0
Ru-103	1.0	1.0
Sb-124	ND	0
Cs-134	1.0	1.0
Cs-136	ND	0
Cs-137	2.2	2.2
Ba-140	ND	0
Ce-141	1.2	1.2
Ce-144	4.0	4.0

NA - Not Analyzed.

ND - Not Detected. For averaging purposes a value of zero was assumed.

TABLE 2-22

RADIOIODINE-131 RELEASES FROM THE MAIN CONDENSER AIR EJECTORS^a

FACILITY	1972			1973			1974		
	RADIO- IODINE RELEASE (Ci/yr)	INTEGRATED THERMAL POWER (10 ⁶ MWd)	<u>Ci/yr</u> 10 ⁶ MWd	RADIO- IODINE RELEASE (Ci/yr)	INTEGRATED THERMAL POWER (10 ⁶ MWd)	<u>Ci/yr</u> 10 ⁶ MWd	RADIO- IODINE RELEASE (Ci/yr)	INTEGRATED THERMAL POWER (10 ⁶ MWd)	<u>Ci/yr</u> 10 ⁶ MWd
Oyster Creek	6.3	0.542	11.6	6.7	0.453	14.8	3.3	0.46	7.2
Nine Mile Point 1	0.89	0.417	2.1	1.9	0.457	4.2	0.7	0.43	1.6
Millstone 1	1.2	0.404	3.0	0.15	0.248	0.6	0.29	0.47	0.6
Dresden 2/3 ^b	5.1	1.05	4.9	9.8	1.18	8.3	4.0	0.91	4.4
Monticello	0.58	0.454	1.3	1.2	0.413	2.9	5.7	0.34	16.8
Pilgrim 1			c	0.46	0.523	0.9	1.4	0.25	5.6
Quad Cities 1/2 ^b			<u>c</u>	5.5	1.32	<u>4.2</u>	8.2	1.09	<u>7.5</u>
Average			4.6			5.1			6.2

Combined average for 1972 through 1976 = $6.3 \times 10^{-6} \frac{\text{Ci/yr}}{\text{MWd}}$

^aData from semiannual operating for 1972 through 1976 for facilities listed.

^bTwo-unit plants with a single stack.

^cNot included in 1972 average because plants had not achieved a full year of operation.

^dAugmented offgas system put in operation October 1975.

^eAugmented offgas system put in operation late 1976.

^fAugmented offgas system put in operation May 1975.

^gAugmented offgas system put into operation 1977.

^hAugmented offgas system put into operation late 1974.

TABLE 2-22 (continued)

RADIOIODINE-131 RELEASES FROM THE MAIN CONDENSER AIR EJECTORS

FACILITY	1975			1976		
	RADIO- IODINE RELEASE (Ci/yr)	INTEGRATED THERMAL POWER (10 ⁶ MWd)	Ci/yr 10 ⁶ MWd	RADIO- IODINE RELEASE (Ci/yr)	INTEGRATED THERMAL POWER (10 ⁶ MWd)	Ci/yr 10 ⁶ MWd
Oyster Creek	5.5	0.41	13.4	6.2	0.49	12.7
Nine Mile Point 1	2.1	0.4	5.3	2.1	0.55	3.8 ^g
Millstone 1	9.8	0.5	19.6	2.7	0.48	5.6
Dresden 2/3 ^b	0.75	0.71	1.06	1.9	1.14	1.7 ^e
Monticello	3.5	0.37	9.5	d		
Pilgrim 1	h					
Quad Cities 1/2 ^b	f					
Average			9.8			6.0

TABLE 2-23

RADIOIODINE RELEASE RATE FROM GLAND SEAL CONDENSER EXHAUST
FOR SYSTEMS USING MAIN STEAM FOR THE SEALING SYSTEM AT 7000 lbs/hr.

Nuclide	Facility	Sample Period	Days	Measured Gland Seal I-131 Release ($\mu\text{Ci/sec}$)	Measured Reactor Water I-131 Concentration ($\mu\text{Ci/gm}$)	Iodine-131 Release Ci/yr per Ci/gm for 292 days/year
I-131	Vermont Yankee	6/18/74 to 6/19/74	1	3.9(-4)	2.5(-2)	3.9(5)
		6/20/74 to 6/21/74	1	4.2(-4)	2.5(-2)	4.2(5)
		9/13/74 to 9/14/74	1	4.7(-4)	3.8(-2)	3.1(5)
		10/10/74 to 10/11/74	1	4.5(-4)	3.5(-2)	3.2(5)
		3/5/75 to 3/8/75	3	2.1(-5)	8.8(-4)	6.0(5)
	Oyster Creek	10/7/75 to 10/21/74	14	1.4(-5)	7.7(-4)	4.6(5)
		6/16/75 to 6/30/75	14	7.8(-5)	1.8(-3)	1.1(6)
		6/30/75 to 7/17/75	17	6.8(-5)	1.7(-3)	1.0(6)
Weighted Average According to Sample Days						8.1(5)

Nuclide	Facility	Sample Period	Days	Measured	Measured	Parameter	
				Gland Seal I-133 Releases (μCi/sec)	Reactor Water I-133 Concentration (μCi/gm)	(Ci/yr per Ci/gm) for 292 days/year	
I-133	Vermont Yankee	6/18/74 to 6/19/74	1	1.8(-4)	5.6(-2)	8.1(4)	
		6/20/74 to 6/21/74	1	1.9(-4)	5.6(-2)	8.6(4)	
		9/13/74 to 9/14/74	1	2.2(-4)	1.1(-2)	5.0(5)	
		10/10/74 to 10/11/74	1	1.7(-4)	1.0(-2)	4.3(5)	
	Oyster Creek	6/16/75 to 6/30/75	14	2.3(-4)	2.6(-2)	2.2(5)	
		6/30/75 to 7/17/75	17	2.0(-4)	2.4(-2)	2.1(5)	
	Weighted Average						
	According to Sample Days						2.2(5)

TABLE 2-24

PARTICULATE RELEASE RATE FROM VERMONT YANKEE MECHANICAL
VACUUM PUMP AND GLAND EXHAUST CONDENSER VENT,
SHORT-TERM SHUTDOWN

(10^{-6} μ Ci/sec)

<u>NUCLIDE</u>	<u>RELEASE RATE</u>
Cr-51	0.9
Co-60	0.5
Zn-65	0.3
Cs-134	0.8
Cs-136	1.1
Cs-137	3.3
Ba-140	2.1

TABLE 2-25

PARTICULATE RELEASE RATE FROM VERMONT YANKEE MECHANICAL
VACUUM PUMP AND GLAND EXHAUST CONDENSER VENT,
REFUELING SHUTDOWN

(10^{-6} μ Ci/sec)

<u>NUCLIDE</u>	<u>RELEASE RATE</u>
Cs-134	0.45
Cs-136	0.13
Cs-137	1.0
Ba-140	1.6

TABLE 2-26

NORMALIZED IODINE RELEASES FROM
MECHANICAL VACUUM PUMP
($\leq$ 80 HRS)

<u>Plant</u>	<u>Normalized Release</u> <u>(Ci/yr/μCi/gm)</u>
Monticello	8.3(2)
Vermont Yankee	<u>1.5(2)</u>
AVERAGE	4.9(2)

NORMALIZED IODINE RELEASES FROM
MECHANICAL VACUUM PUMP DURING REFUELING/MAINTENANCE
OUTAGES ($\geq$ 80 HRS)

<u>Plant</u>	<u>Normalized Release</u> <u>(Ci/yr/μCi/gm)</u>
Monticello	1.5(3)
Vermont Yankee	<u>6.0(2)</u>
AVERAGE	1.1(3)

^{1/} Assume (4) short-term outages per year.

2.2.7 MAIN CONDENSER MECHANICAL VACUUM PUMP

2.2.7.1 Parameter

Xe-133	1300 Ci/yr per reactor
Xe-135	500 Ci/yr per reactor

The iodine releases from the Main Condenser Mechanical Vacuum Pump are calculated by the BWR-GALE Code using the data in Tables 2-2, 2-4 and 2-26.

2.2.7.2 Bases

The release rates for Xe-133 and Xe-135 were derived from Dresden 1 and 2 operating data and adjusted to 50,000 $\mu\text{Ci/sec}$ (Ref. 5). These data indicate that approximately 300 Ci of Xe-133 and 120 Ci of Xe-135 were released with the mechanical vacuum pump effluent when the main condenser vacuum pumps were used to establish main condenser vacuum following a plant shutdown. At the point in the fuel cycle where the data were taken, the reactor was operating at an offgas rate of approximately 60,000 $\mu\text{Ci/sec}$. The annual release estimates for noble gases assumes four short-term shutdowns per year and one refueling/maintenance outage.

The release rates for iodine-131 are based on measurements made at operating reactors (Ref. 15). Investigations for the Electric Power Research Institute (EPRI) at three operating Boiling Water Reactors (BWRs), Monticello, Vermont Yankee, and Oyster Creek, have shown that iodine releases from the mechanical vacuum pump are at their highest levels for the first 80 hours after shutdown. In accordance with the EPRI study, the releases from the mechanical vacuum pump can be as much as a factor of 100 greater than releases measured during the pre-shutdown period. The normalized iodine-131 releases in Table 2-26 are based on data from Monticello and Vermont Yankee.

The annual iodine-131 release estimates assume four short term shutdowns per year and one refueling/maintenance outage per year.

To calculate releases from the mechanical vacuum pump, a normalized release rate is used. The normalized release rate is calculated by the BWR-GALE Code using the following expression:

$$R_N = \frac{R_A}{C_{RW} \times PC}$$

where

R_N = normalized release rate of reactor water containing iodine-131, (gm/sec)

R_A = absolute (measured) iodine-131 release rate, ($\mu\text{Ci/sec}$)

C_{RW} = measured reactor water iodine-131 concentration, ($\mu\text{Ci/gm}$)

PC = measured partition coefficient from reactor water to reactor steam.

To calculate the release in Ci/yr from the mechanical vacuum pump of a particular BWR, the normalized release data in Table 2-26 are multiplied by the iodine reactor water concentration and the iodine carryover from reactor water to reactor steam for the particular BWR using the following expression:

$$R_{MVP} = R'_N \times C_{BWR} \times PC_{BWR}$$

where:

R'_N = normalized release rate of reactor water containing iodine-131, (Ci/yr/ $\mu\text{Ci/gm}$)

R_{MVP} = calculated annual iodine release, (Ci/yr) from the mechanical vacuum pump

C_{BWR} = reactor water concentration for a particular BWR, ($\mu\text{Ci/gm}$)

PC_{BWR} = calculated carryover for particular BWR from Table 2-4.

Iodine released during the operation of the Mechanical Vacuum Pump at BWRs appear in one of the following chemical forms: particulate, elemental, hypoiodous acid (HOI), and organic. Based on data in Reference 15, the fraction of the iodine appearing in each of the chemical forms for the Mechanical Vacuum Pump is given below:

Fraction of Iodine Appearing In Each Chemical Form From
BWR Mechanical Vacuum Pump

	<u>Time < 80 hrs^{1/}</u>	<u>Time > 80 hrs^{2/}</u>
Particulate	0.004	0.01
Elemental	0.009	0.06
HOI	0.023	0.21
Organic	0.97	0.72

^{1/}Average of samples taken within the first 80 hrs after shutdown.

^{2/}Average of samples taken after the initial 80 hrs of a refueling maintenance outage.

Data in Tables 2-24 and 2-25 show the release of radioactive particulates from the mechanical vacuum pump to be negligible.

2.2.8 AIR INLEAKAGE TO THE MAIN CONDENSER

2.2.8.1 Parameter

0.0062 ft³/min air leakage to the main condenser per MWt of design reactor power with a minimum of 5 ft³/min.

2.2.8.2 Bases

Air leakage occurs in the main condensers of all power reactors. In a BWR, the amount of holdup time calculated for a charcoal bed offgas delay system is inversely proportional to the amount of air leakage to the main condenser.

Operational data for leakage vary widely. At Oyster Creek and at Dresden Unit No. 2, air leakage measurements during early phases of operation indicated leakage rates from 4 ft³/min to 250 ft³/min. (Refs. 21 and 22). Subsequent measurements at Dresden Unit 2 (Ref. 20), showed an air leakage of 4.4 ft³/min during operation at 1600 MWt. Air leakage measurements reported for six TVA fossil plants, representing more than 50 years of cumulative experience, indicate leakage rates ranging from 4 to 25 ft³/min per condenser shell and a statistical mean leakage rate of 6.7 ft³/min per condenser shell (Ref. 23). Measurements made in 1976 and 1977, at Quad Cities Units Nos. 1 and 2 (Ref. 24), showed average flow rates of 9.6 ft³/min for Unit No. 1 and 25 ft³/min for Unit No. 2; measurements ranged from 6 ft³/min to 55 ft³/min and power level for both units during the test period was 2511 MWt.

The parameter for air leakage was developed assuming that air leakage is proportional to the reactor design thermal power level. Available data, which were considered to represent long-term operational results, were converted by extrapolation to the common base of a 3400 MWt BWR with a 3 shell condenser. The use of data from Dresden Unit No. 2, Quad Cities Unit Nos. 1 and 2, and TVA fossil plants resulted in an average of 21 ft³/min main condenser air leakage for a plant with a design thermal power level of 3400 MWt. This is approximately equivalent to 0.0062 ft³/min leakage for each MWt of design thermal power. For BWRs of less than 800 MWt design thermal power level, a minimum condenser air leakage of 5 ft³/min should be used, independent of reactor design thermal power level.

CONDENSER AIR INLEAKAGE

<u>Plant</u>	<u>Power Level</u>	<u>Reported Data</u>	<u>Extrapolated to 3400 MWt/ 3 shell</u>
Dresden 2	1600 MWt	4.4 ft ³ /min	9.4
TVA Fossil Plants	700 MWe (average of 6)	6.7 ft ³ /min/shell	28.7
Quad Cities 1	2511 MWt	9.6 ft ³ /min	13
Quad Cities 2	2511 MWt	25 ft ³ /min	<u>34</u>
AVERAGE			21 cfm

2.2.9 HOLDUP TIMES FOR CHARCOAL DELAY SYSTEMS

2.2.9.1 Parameter

$$T = 43.1 \text{ MK/P}$$

where

K is the dynamic adsorption coefficient, in cm³/gm (see chart below);

M is the mass of charcoal adsorber, in 10³ lbs;

T is the holdup time, in hours; and

P is the thermal power level (MWt) entered in Card 2

Dynamic adsorption coefficients (in cm³/gm) are as follows:

	<u>OPERATING 77°F DEW POINT 45°F</u>	<u>OPERATING 77°F DEW POINT -40°F</u>	<u>OPERATING 77°F DEW POINT 0°F</u>	<u>OPERATING 0°F DEW POINT -20°F</u>
Kr	18.5	70	25	105
Xe	330	1160	440	2410

2.2.9.2 Bases

Charcoal delay systems are evaluated using the above equation and dynamic adsorption coefficients. $T = \text{MK}/\text{flow rate}$ is a standard equation for the calculation of delay times in charcoal adsorption systems (Ref. 25). The dynamic adsorption coefficients (K values) for Xe and Kr are dependent on operating temperature and moisture content (Ref. 26 and 27) in the charcoal, as indicated by the values in the above parameter. The K values represent a composite of data from operating reactor charcoal delay systems (Refs. 28 and 30) and reports concerning charcoal adsorption systems (Refs. 26-28, 31-33).

The factors influencing the selection of K values are

1. Operational data from KRB ($K_{Kr} = 20-30$, $K_{Xe} = 260-430$) (Ref. 28) and from KWL ($K_{Kr} = 30$, $K_{Xe} = 500$) (Ref. 29), and from Vermont Yankee (Ref. 31).
2. The effect of temperature on the dynamic adsorption coefficients, indicated in Figure 2-2 (Ref. 26).
3. The effect of moisture on the dynamic adsorption coefficients, shown in Figure 2-3. The affinity of charcoal for moisture, shown in Figure 2-4.
4. The variation in K values between researchers and between the types of charcoal used in these systems (Refs. 26, 34, and 35). Because of the variation in K values based on different types of charcoal and the data reported, average values taken from KRB and KWL data shown in Figure 2-2 are used.

FIGURE 2-2
KRYPTON AND XENON K VALUES AS A FUNCTION
OF RECIPROCAL TEMPERATURE

FIGURE 2-3
EFFECT OF MOISTURE CONTENT ON THE
DYNAMIC ADSORPTION COEFFICIENT

FIGURE 2-4
CHARCOAL MOISTURE AS A FUNCTION
OF RELATIVE HUMIDITY

The coefficient 43.1 adjusts the units and was calculated as follows:

$$T(\text{hr}) = \frac{M(10^3 \text{ lbs}) K(\text{cm}^3/\text{gm})(454 \text{ gm/lb})(3.53 \times 10^{-5} \text{ ft}^3/\text{cm}^3)}{(0.0062 \text{ ft}^3/\text{min/MWt}) (60 \text{ min/hr})P (\text{MWt})}$$

$$T = 43.1 \frac{MK}{P}$$

2.2.10 DECONTAMINATION FACTORS FOR CRYOGENIC DISTILLATION

2.2.10.1 Parameter

<u>NUCLIDES</u>	<u>DECONTAMINATION FACTOR</u>
I, Xe	1×10^4
Kr	4×10^3

The holdup times are calculated on the basis of gas residence time in the system prior to release.

2.2.10.2 Bases

A DF of 10^4 for iodine and xenon and a DF of 4×10^3 for krypton are used for a cryogenic distillation system. The values are based on data submitted in Amendment 11 to the PSAR for the Hope Creek Nuclear Generating Station, Units 1 and 2 (Ref. 36), which were derived from a proprietary report (Ref. 37) of Air Products and Chemical, Inc. The PSAR states that a maximum of 0.025% Kr (DF = 4×10^3) and 0.01% Xe (DF = 10^4) will escape from the system. These decontamination factors are considered reasonable.

2.2.11 RADIOIODINE REMOVAL EFFICIENCIES FOR CHARCOAL ADSORBERS AND PARTICULATE REMOVAL EFFICIENCIES FOR HEPA FILTERS

2.2.11.1 Parameter

Use a removal efficiency of 99% for particulate removal by HEPA filtration. For charcoal adsorbers, removal efficiencies for all forms of radioiodine are as follows:

<u>ACTIVATED CARBON BED DEPTH^a</u>	<u>ASSIGNED ACTIVATED CARBON REMOVAL EFFICIENCIES FOR RADIOIODINE</u>
2 inches. Air filtration system designed to operate inside primary containment.	90%
2 inches. Air filtration system designed to operate outside the primary containment and relative humidity is controlled to 70%.	70%
4 inches. Air filtration system designed to operate outside the primary containment and relative humidity is controlled to 70%.	90%
6 inches. Air filtration system designed to operate outside the primary containment and relative humidity is controlled to 70%.	99%

^aMultiple beds, e.g., two 2-inch beds in series, should be treated as a single bed of aggregate depth.

2.2.11.2 Bases

The removal efficiencies assigned HEPA filters for particulate removal and charcoal adsorbers for radioiodine removal are based on the design, testing and maintenance criteria recommended in Regulatory Guide 1.140, "Design, Testing and Maintenance Criteria for Normal Ventilation Exhaust System Air Filtration and Adsorption Units of Light-Water-Cooled Nuclear Power Plants" (Ref. 2).

2.2.12 LIQUID WASTE INPUTS

2.2.12.1 Parameter

The flow rates listed in Table 2-27 are used as inputs to the liquid radwaste treatment system. Flows that cannot be standardized are added to those listed in Table 2-27 to fit an individual application. Disposition of liquid streams to the appropriate collection tanks is based on the applicant's intended method of processing.

2.2.12.2 Bases

The liquid waste inputs are based on the values proposed by the ANS 55.3 Working Group in American National Standard, "Boiling Water Reactor Liquid Radioactive Waste Processing System," ANSI N197-1976 (Ref. 38). Activity inputs are based on the reactor coolant concentrations given in Parameter 2.2.3. The values given are those that were judged to be representative for a typical BWR design.

2.2.13 CHEMICAL WASTES FROM REGENERATION OF CONDENSATE DEMINERALIZERS

2.2.13.1 Parameter

1. Liquid flows to demineralizer at main steam activity.
2. All nuclides removed from the reactor coolant by the demineralizers are removed from the resins during regeneration.
3. Use a regeneration cycle of 3.5 days times the number of demineralizers. (For systems using ultrasonic resin cleaning, use 8 days times the number of demineralizers.)

2.2.13.2 Bases

Operating data from Dresden 2 and 3 indicate that one condensate demineralizer regeneration occurs every 3.5 days (Ref. 39) when ultrasonic cleaning is not used.

All material exchanged or filtered out by the resins between regenerations is contained in the regenerant waste streams; therefore, each regeneration will have approximately the same effectiveness (i.e., each regeneration removes all material collected since the previous regeneration, leaving a constant quantity of material on the resins after regeneration). Regeneration cycles are normally controlled by particulate buildup on resin beds, resulting in high pressure drops across the bed. If ultrasonic resin cleaning is used to remove insolubles between regenerations, operating data from Dresden 2 and 3 indicates that one condensate demineralizer regeneration occurs every 7.1 days (Ref. 40 and 41), from Pilgrim 1 at 8.2 days (Ref. 42) and from Nine Mile Point 1 at 10 days (Ref. 41).

2.2.14 DETERGENT WASTE

2.2.14.1 Parameter

For plants with an onsite laundry, use the radionuclide distribution given in Table 2-28 for untreated detergent wastes. The quantities shown in Table 2-28 are added to the adjusted liquid source term. They are reduced for any treatment provided using the appropriate decontamination factors.

2.2.14.2 Bases

In the evaluation of liquid radwaste treatment systems, it is assumed that detergent wastes (laundry drains, personnel and equipment decontamination drains, and cask cleaning drains) will total approximately 1000 gal/day per reactor. The radionuclide distribution given in Table 2-28 is based on data given in Table 2-29.

TABLE 2-27
BWR LIQUID WASTES

SOURCE	EXPECTED DAILY AVERAGE INPUT FLOW RATE (in gal/day)		FRACTION OF THE PRIMARY COOLANT ACTIVITY (PCA)
	DEEP BED PLANT WITH ULTRASONIC RESIN CLEANER	DEEP BED PLANT WITHOUT ULTRASONIC RESIN CLEANER OR A FILTER/DEMINERALIZER PLANT	
<u>Equipment Drains</u>			
Drywell	3,400	3,400	1.00
Containment, auxiliary building, and fuel pool	3,700	3,700	0.1
Radwaste building	1,100	1,100	0.1
Turbine building	3,000	3,000	0.001
Ultrasonic resin cleaner	15,000	-	0.05
Resin rinse*	2,500	5,000	0.002
<u>Floor Drains</u>			
Drywell	700	700	0.001
Containment, auxiliary building, and fuel handling	2,000	2,000	0.001
Radwaste building	1,000	1,000	0.001
Turbine building	2,000	2,000	0.001
<u>Other Sources</u>			
Cleanup phase separator decant	640	640	0.002
Laundry drains	1,000	1,000	-
Lab drains	500	500	0.02
Regenerants*	1,700	3,400	**
Condensate demineralizer backwash.	-	8,100	2 x 10 ⁻⁶
Chemical lab waste	100	100	0.02

* Deep-bed condensate demineralizers only.

** Calculated by BWR-GALE Code.

† Filter/demineralizer (Powdex) condensate demineralizers only.

TABLE 2-28

CALCULATED ANNUAL RELEASE OF RADIOACTIVE MATERIALS
IN UNTREATED DETERGENT WASTE FOR A BWR

<u>NUCLIDE</u>	<u>Ci/yr</u>
C-14	2.8(-4)
P-32	1.7(-4)
Cr-51	9.1(-3)
Mn-54	4.6(-3)
Fe-55	9.6(-3)
Fe-59	1.6(-4)
Co-57	1.3(-4)
Co-56	9.3(-3)
Co-60	1.6(-2)
Ni-63	2.5(-4)
Sr-89	1.1(-4)
Sr-90	5.8(-5)
Y-91	1.6(-4)
Zr-95	1.5(-3)
Nb-95	1.8(-3)
Mo-99	6(-5)
Ru-103	3.1(-4)
Ru-106	3(-4)
Ag-110m	6(-4)
Sb-124	6.5(-4)
I-131	2(-3)
Cs-134	1.1(-2)
Cs-136	5.6(-4)
Cs-137	1.6(-2)
Ba-140	9.1(-4)
Ce-141	2(-4)
Ce-144	3.5(-3)
TOTAL	0.09 Ci

TABLE 2-29
RADIONUCLIDE DISTRIBUTION OF DETERGENT WASTE
(MILLICURIES/MONTH)

NUCLIDE	Oyster ^a Creek (1971-1973)	Ginna ^b (1972-1973)	Zion ^c (1977)	Fort Calhoun ^d (1977)
C-14	1.2(-2)	NA ^e	2(-2)	4.2(-2)
P-32	1.5(-2)	NA	NA	NA
Cr-51	2.3(-1)	NA	1.3	NA
Mn-54	1.3	1.1(-1)	1.3(-1)	2.2(-2)
Fe-55	3.5(-1)	NA	1.9	1.6(-1)
Fe-59	2.9(-2)	NA	2.6(-1)	NA
Co-57	7.5(-3)	NA	1.7(-2)	NA
Co-58	3.5(-1)	4.1(-1)	2.3	1(-1)
Co-60	3.8	9(-1)	9.1(-1)	4(-2)
Ni-63	NA	NA	3.5(-1)	7.1(-2)
Sr-89	2.1(-2)	NA	7(-3)	1.4(-3)
Sr-90	2.5(-3)	NA	7.4(-3)	NA
Y-91	NA	NA	1.4(-2)	NA
Zr-95	8.3(-2)	1.4(-1)	1.4(-1)	NA
Nb-95	1.6(-2)	2(-1)	2.7(-1)	NA
Mo-99	NA	5(-3)	NA	NA
Ru-103	1.3(-2)	1.4(-2)	5.2(-2)	NA
Ru-106	NA	2.5(-1)	NA	NA)
Ag-110m	NA	5(-2)	NA	NA
Sb-124	6.1(-2)	NA	4.7(-2)	NA
I-131	4.3(-1)	6(-2)	1.7(-1)	1.6(-2)
Cs-134	1.7(-1)	1.4	1.4	1.0
Cs-136	NA	NA	4.7(-2)	NA
Cs-137	2.9(-1)	2.5	2.0	1.2
Ba-140	7.6(-2)	NA	NA	NA
Ce-141	3.3(-2)	1(-3)	NA	NA
Ce-144	7.3(-2)	5.3(-1)	NA	NA
TOTAL	7.4	6.6	11.3	2.7

^aU.S.E.P.A., EPA-520/5-76-003, "Radiological Surveillance Studies at the Oyster Creek BWR Nuclear Generating Station," June 1976.

^bWestinghouse Corporation WCAP-8253, "Source Term Data for Westinghouse Pressurized Water Reactors," May 1974.

^cEG&G Idaho, Inc. and Allied Chemical Corp., Idaho National Engineering Laboratory, "Draft Report, In-Plant-Measurements at Zion Station," 1976.

^dNUREG/CR-0140, "In-Plant Source Term Measurements at Ft. Calhoun Station, Unit 1," August 1978.

^eNA, Radionuclides were not analyzed.

2.2.15 TRITIUM RELEASES

2.2.15.1 Parameter

The total tritium release through liquid and gaseous pathways is 0.03 Ci/yr per Mwt. The quantity of tritium released through the liquid pathway is approximately 50% of the total quantity of tritium calculated to be available for release. The remainder of the tritium produced is assumed to be released as a gas from building ventilation exhaust systems. 50% of the tritium in gaseous effluents is released from the turbine building ventilation system and the remaining 50% of the tritium in gaseous effluents is released from the containment building ventilation system. For "zero liquid release" plants, assign all of the tritium calculated to be available for release to building ventilation exhaust systems.

2.2.15.2 Bases

Table 2-30 lists the measured liquid and gaseous tritium releases from BWRs for 1972 through 1977. Based on the total tritium release for each facility, the integrated thermal power produced during the year, and a plant capacity factor of 80%, the total annual release is approximately 0.03 Ci/Mwt through the combined liquid and gaseous pathways.

The tritium can be released either in liquid wastes or as a gas with ventilation effluents, the relative amounts being dependent on liquid recycle practices. Table 2-31 lists the percentage of total tritium which is released in liquid effluents (based on the data in Table 2-30). The weighted average* indicates that approximately 50% of the tritium available for release is released in liquid effluents.

Tritium in gaseous effluents is released largely through building ventilation exhaust systems. Based on measurements taken in 1974 and 1975 of tritium release rates in building ventilation systems at Monticello, Vermont Yankee, and Oyster Creek (Ref.15), Table 2-32 provides the distribution of tritium released from various sources within the plant. Based on data in Table 2-32, approximately 50% of the tritium in gaseous effluents is released through the turbine building ventilation systems. Assuming that miscellaneous sources (radwaste building ventilation, fuel pool area) are released via the reactor building vent, the remaining 50% of the tritium in gaseous effluents is released through the reactor building ventilation system. Although it is recognized that tritium should be released via the gaseous pathway from the fuel handling area, data is available only from operating reactors (Mark I containments) where the spent fuel pool area is inside containment. It is not possible with the present data base to identify what fraction of the tritium from the reactor building is associated with the spent fuel pool area. Accordingly, until sufficient data is available, tritium releases from the spent fuel pool area will be considered to be released from the containment building, even if the spent fuel pool is located elsewhere (BWR/6 Mark III's).

2.2.16 DECONTAMINATION FACTORS FOR DEMINERALIZERS

2.2.16.1 Parameter

The following are the expected decontamination factor (DFs) for demineralizers used on process or radwaste streams.

DEMINERALIZER TYPE	DECONTAMINATION FACTORS*		
	ANION	Cs, Rb	OTHER NUCLIDES
<u>Mixed Bed (H^+ OH^-)</u>			
Reactor Coolant	10	2	10
Condensate	10	2	10
Clean waste	$10^2(10)$	$10(10)$	$10^2(10)$
Dirty waste (floor drains)	$10^2(10)$	$2(10)$	$10^2(10)$
<u>Cation Bed (H^+)</u>			
Dirty waste	$1(1)$	$10(10)$	$10^2(10)$
<u>Powdex (any system)</u>	$10(10)$	$2(10)$	$10(10)$

*For an evaporator polishing demineralizer or for the second demineralizer in series, the DF is given in the parentheses.

TABLE 2-30
TRITIUM RELEASE DATA FROM OPERATING BWRs*

REACTOR NAME	POWER MWT	STARTUP DATE	NUCLEAR THERMAL OUTPUT 10 ⁶ MWDt						TRITIUM RELEASED (Ci/Yr)												TOTAL TRITIUM RELEASED (Ci/yr-MWt at 80% capacity)					
			1972	1973	1974	1975	1976	1977	GASEOUS #						LIQUID #						1972	1973	1974	1975	1976	1977
									1972	1973	1974	1975	1976	1977	1972	1973	1974	1975	1976	1977						
Oyster Creek	1930	1969	0.54	0.45	0.46	0.41	0.49	0.41	0.8	0.4	0.4	2.8	1.1	0.7	62	36.6	14.1	18	38	3.4	0.034	0.024	0.009	0.015	0.023	0.003
Nine Mile Point 1	1850	1969	0.42	0.46	0.44	0.40	0.55	0.38	18	26.8	**	20	19	33	28	46.5	18.7	28	2.5	0.5	0.032	0.047	0.012	0.035	0.011	0.026
Dresden 2/3	2577	1970/71	1.04	1.18	0.91	0.70	1.15	1.20	31	10	11	220	170	330	26	26	22.6	54	20	0.1	0.016	0.009	0.011	0.11	0.048	0.081
Millstone 1	2011	1970	0.40	0.25	0.47	0.50	0.48	0.62	4.2	1.7	2.8	17	29	33	21	3.7	24.1	80	20	7.5	0.018	0.006	0.017	0.057	0.030	0.019
Monticello	1670	1970	0.46	0.41	0.37	0.37	0.51	0.46	12	**	**	66	77	139	***	***	***	0	0	0	0.008	-	-	0.052	0.044	0.088
Vermont Yankee	1593	1972	0.06	0.18	0.34	0.47	0.42	0.46	+	1.0	0.9	7.1	14	28	+	0.2	***	0	1.6	0.1	-	0.002	0.001	0.004	0.011	0.018
Quad Cities 1/2	2511	1971/72	0.52	1.32	1.09	0.96	1.08	1.12	4.7	34++	29	280	300	40	4.7	24.5	34	54	24	19	0.005	0.013	0.017	0.10	0.088	0.016
Pilgrim 1	1998	1972	0.11	0.53	0.25	0.34	0.32	0.34	**	14	8	74	37	61	4.2	0.4	10.4	18	47	33	0.011	0.008	0.22	0.079	0.077	0.080
Peach Bottom 2/3	3293	1973/74				1.39	1.55	1.19				0.3	27	260				31	74	71				0.007	0.019	0.081
Browns Ferry 1-3	3293	73/74/76				0.36	0.37	2.24				5.1	0.6	23				10	4.0	22				0.012	0.004	0.006
Cooper	2381	1974				0.52	0.49	0.60				43	67	50				8.3	8.3	9.0				0.029	0.045	0.029
Hatch 1	2436	1974				0.41	0.57	0.51				1.8	1.4	1.2				6.1	9.0	14				0.006	0.005	0.009
Fitzpatrick	2436	1974				0.28	0.53	0.49			**	15	9.5				**	4.2	28				-	0.011	0.007	
Duane Arnold	1658	1974				0.31	0.33	0.39				19	16	15				0.3	0.3	0.2				0.018	0.014	0.011
Brunswick 1/2	2436	1975/76				0.20	0.33	0.66				2.0	22	19				3.2	5.9	7.4				0.008	0.025	0.012
WEIGHTED AVERAGE+++																					0.021	0.016	0.015	0.043	0.035	0.032

* Data from semiannual reports of reactor listed.

** No reported data.

*** No measurement made.

† Prior to first refueling.

†† Measured only during the July-December 1973 period.

††† Average weighted by nuclear thermal output.

Data for first half of 1977 have been extrapolated to the end of 1977 for Oyster Creek, Nine Mile Point-1, Millstone-1, Monticello, Browns Ferry 1, 2 and 3, Hatch-1, Fitzpatrick and Brunswick 1 and 2.

TABLE 2-31

TRITIUM RELEASE DATA FROM OPERATING BWR'S
PERCENT OF TOTAL TRITIUM RELEASED IN LIQUID EFFLUENTS

<u>REACTOR</u>	<u>1972</u>	<u>1973</u>	<u>1974</u>	<u>1975</u>	<u>1976</u>	<u>1977</u>
Oyster Creek	98.7	91.5	97.2	86.5	97.2	69.4
Nine Mile Point 1	60.9	63.4	**	58.3	11.6	1.6
Dresden 2/3	45.6	72.2	67.3	31.0	10.5	0
Millstone 1	83.3	68.5	89.6	82.5	40.8	18.6
Monticello	**	**	**	0	0	0
Vermont Yankee		16.7	**	0	10.3	0.4
Quad Cities 1/2	50.0	41.9	54.0	16.2	7.4	32.5
Pilgrim 1	**	2.8	56.8	19.6	56.0	35.1
Peach Bottom 2/3				99.0	73.3	21.5
Browns Ferry 1/2/3				66.2	87.3	47.7
Cooper				16.2	11.0	15.3
Hatch 1				77.2	86.5	92.1
Fitzpatrick				**	21.9	22.5
Duane Arnold				1.5	2.0	1.4
Brunswick 1/2				61.5	21.1	27.8
*Weighted Average	63.4	53.1	69.5	51.4	36.2	28.2

*Average weighted by thermal nuclear output

**Insufficient Data

*Prior to first refueling

TABLE 2-32

DISTRIBUTION OF TRITIUM RELEASE IN GASEOUS EFFLUENTS (Ref. 15)

PLANT	SOURCE OF GASEOUS TRITIUM RELEASE (% OF TOTAL)			
	REACTOR BUILDING	TURBINE BUILDING	MISCELLANEOUS	TOTAL
Monticello	68	29	3	100
Vermont Yankee	35	53	12	100
Oyster Creek	13	79	8	100
AVERAGE	39	54	7	100

2.2.16.2 Bases

The DFs for demineralizers used in the evaluation of liquid waste treatment systems are derived from the findings of a generic review in the nuclear industry by ORNL (Ref. 41). This reference contains operating and theoretical data that provides a basis for the numerical values assigned. The information contained in this report was projected to obtain a performance value expected over an extended period of operation. It was also considered that attempts to extend the service life of the resin will reduce the DFs below those expected under controlled operating conditions.

The following operating conditions were factored into the evaluation of demineralizer performance:

1. In general, the DF for waste treatment systems will vary with the quality of the water to be treated, increasing with increasing activity. Normally, when two demineralizers are used in series, the first demineralizer will have a higher DF than the second. However, the data in Reference 41 indicate that Cs and Rb will be more strongly exchanged in the second demineralizer in series than in the first, since the concentration of preferentially exchanged competing nuclides is reduced.

2. As indicated in Reference 41, compounds of Y, Mo, and Tc form colloidal particles that tend to plate out on solid surfaces. Mechanisms such as plateout on the relatively large surface area provided by demineralizer resin lead to removal of these nuclides to the degree stated above. An analysis of effluent release data indicates that these nuclides, although present in the primary coolant, are normally undetectable in the effluent streams.

2.2.17 DECONTAMINATION FACTORS FOR EVAPORATORS

2.2.17.1 Parameter

	ALL NUCLIDES EXCEPT ANIONS	ANIONS
Miscellaneous radwaste evaporator	10^4	10^3
Separate evaporator for detergent wastes	10^2	10^2

2.2.17.2 Bases

The decontamination factors for evaporators are derived from the findings of a generic review by ORNL of evaporators used in the nuclear industry (Ref. 43). The principal conclusions reached in the report are:

1. Decontamination factors of 10^4 can be expected for nonvolatile radioactive nuclides in a single-stage evaporator.
2. Decontamination factors for iodine are a factor of 10 less than the DFs for nonvolatile nuclides (10^3).
3. Decontamination factors for wastes containing detergents that tend to foam are a factor of 10 to 100 lower than DFs expected for nonfoaming wastes.

These conclusions have been extended to take into account the following factors:

1. For nonvolatile nuclides in a nonfoaming solution, a DF of 10^4 is used.
2. For iodine in a nonfoaming solution, a DF of 10^3 is used.
3. If an evaporator is used for detergent wastes, the DF for the evaporator is reduced to 100 to reflect carryover due to foaming, which will reduce the DF.

2.2.18 DECONTAMINATION FACTORS FOR REVERSE OSMOSIS

2.2.18.1 Parameter

Overall DF of 30 for laundry wastes and DF of 10 for other liquid radwastes.

2.2.18.2 Bases

Reverse osmosis processes are generally run as semibatch processes. The concentrated stream rejected by the membrane is recycled until a desired fraction of the batch is processed through the membrane. The ratio of the volume processed through the membrane to the inlet batch volume is the percent recovery. The DF normally specified for the process is the ratio of nuclide concentrations in the concentrated liquor stream to the concentrations in the effluent stream. This ratio is termed as the membrane DF. For source term calculations, the system DF should be used. The system DF is the ratio of the nuclide concentrations in the feed stream to those in the effluent stream. The relationship between the system DF and the membrane DF is nonlinear and is a function of the percent recovery. This relationship can be expressed as follows:

$$DF_s = \frac{F}{1 - [1 - F]^{1/DF_m}}$$

where

DF_m is the membrane DF;

DF_s is the system DF; and

F is the ratio of effluent volume to inlet volume (percent recovery).

Tables 2-33 through 2-35 give membrane DFs derived from operating data at Point Beach and Ginna (Refs. 45 and 46) and laboratory data on simulated radwaste liquids (Ref. 47). These data indicate that the overall membrane DF is approximately 100. The percent recovery for liquid radwaste processes using reverse osmosis is expected to be approximately 95%, i.e., 5% concentrated liquor. Using these values in the above equation, the system DF is approximately 30.

$$DF_s = \frac{0.95}{1 - (1 - .95)^{1/100}} = 30$$

The data used were derived mainly from tests on laundry wastes. The DF for other plant wastes, e.g., floor drain wastes, is expected to be lower because of the higher concentrations of iodine and cesium isotopes. As indicated by the data in Tables 2-33 and 2-35, the membrane DF for these isotopes is lower than the average membrane DF used in the evaluation for laundry waste.

2.2.19 DECONTAMINATION FACTORS FOR LIQUID RADWASTE FILTERS

2.2.19.1 Parameter

A DF of 1 for liquid radwaste filters is assigned for all radionuclides.

2.2.19.2 Bases

Reference 44 contains the findings of a generic review by ORNL of liquid radwaste filters used in the nuclear industry. Due to the various filter types and filter media employed, reported decontamination factors vary widely, with no discernible trend. The principal conclusion reached in the ORNL report is that no credit should be assigned liquid radwaste filters (DF of 1) until a larger data base is obtained.

2.2.20 ADJUSTMENT TO LIQUID RADWASTE SOURCE TERMS FOR ANTICIPATED OPERATIONAL OCCURRENCES

2.2.20.1 Parameter

1. Increase the calculated source term by 0.1 Ci/yr per reactor using the same isotopic distribution as for the calculated source term to account for anticipated operational occurrences such as operator errors that result in unplanned releases.

2. Assume evaporators to be unavailable for two consecutive days per week for maintenance. If a 2-day holdup capacity exists in the system (including surge tanks) or an alternative evaporator is available, no adjustment is needed. If less than a 2-day capacity is available, assume the waste excess is handled as follows:

TABLE 2-33

REVERSE OSMOSIS DECONTAMINATION FACTORS, GINNA STATION

<u>NUCLIDE</u>	<u>FEED ACTIVITY</u> <u>($\mu\text{Ci}/\text{cm}^3$)</u>	<u>PRODUCT ACTIVITY</u> <u>($\mu\text{Ci}/\text{cm}^3$)</u>	<u>MEMBRANE DF</u>
Ce-144	2.68×10^{-4}	$<2.2 \times 10^{-7}$	1200
Co-58	8.55×10^{-5}	$<3.4 \times 10^{-8}$	2500
Ru-103	5.83×10^{-5}	$<5.5 \times 10^{-8}$	1100
Cs-137	4.09×10^{-4}	6.6×10^{-6}	60
Cs-134	2.02×10^{-4}	3.2×10^{-6}	60
Nb-95	5.35×10^{-5}	$<5.3 \times 10^{-8}$	1000
Zr-95	2.36×10^{-5}	$<3.7 \times 10^{-8}$	640
Mn-54	8.82×10^{-5}	$<3.4 \times 10^{-8}$	2600
Co-60	9.62×10^{-4}	$<8.1 \times 10^{-8}$	12,000
Total isotopic	2.15×10^{-3}	9.8×10^{-6}	220
Gross β	1.63×10^{-3}	1.86×10^{-5}	88
Average*			200

*The average DF is calculated from the average of the reciprocals of the isotopic DFs.

TABLE 2-34
REVERSE OSMOSIS DECONTAMINATION FACTORS, POINT BEACH

<u>DATE</u>	<u>TIME</u>	<u>FEED ACTIVITY</u> ($\mu\text{Ci/ml}$)	<u>PRODUCT ACTIVITY</u> ($\mu\text{Ci/ml}$)	<u>MEMBRANE</u> <u>DF</u>
6/14/71	0840	1.1×10^{-5}	6.8×10^{-7}	16
	1225	6.3×10^{-5}	4.2×10^{-7}	150
	1530	8.8×10^{-5}	3.2×10^{-7}	280
6/15/71	1030	2.7×10^{-4}	3.1×10^{-6}	87
	1315	1.0×10^{-4}	1.7×10^{-6}	59
	1440	1.3×10^{-4}	1.1×10^{-7}	1200
	1510	1.6×10^{-4}	1.1×10^{-7}	1500
	1530	1.8×10^{-4}	5.7×10^{-7}	320

TABLE 2-35
EXPECTED REVERSE OSMOSIS DECONTAMINATION FACTORS
FOR SPECIFIC NUCLIDES

<u>NUCLIDE</u>	<u>FEED ACTIVITY</u> ($\mu\text{Ci/ml}$)	<u>PRODUCT ACTIVITY</u> ($\mu\text{Ci/ml}$)	<u>MEMBRANE</u> <u>DF</u>
Co-60	2.5×10^{-4}	5×10^{-7}	500
Mo-99	3.8×10^{-2}	1×10^{-3}	40
I-131, 132, 133, 134, 135	1.2×10^{-1}	4×10^{-3}	30
Cs-134, 137	4.3×10^{-2}	2×10^{-4}	200

a. High-purity or low-purity waste Processed through an alternative system (if available) using a discharge fraction consistent with the lower purity system.

b. Chemical Waste Discharged to the environment to the extent holdup capacity or an alternative evaporator is unavailable.

3. The following methods should be used for calculating holdup times and effective system DF:

a. Holdup Capacity If two or more holdup tanks are available, assume one tank is full (80% capacity) with the remaining tanks empty at the start of the two day outage. If there is only one holdup tank, assume that it is 40% full at the start of the two day outage with a usable capacity of 80%.

b. Effective System DF Should the reserve storage capacity be inadequate for waste holdup over a two-day evaporator outage, and should an alternate evaporator be unavailable to process the wastes from the out-of-service evaporator, the subsystem DF should be adjusted to show the effect of the evaporator outage.

For example, a DF of 10^5 was calculated for a radwaste demineralizer and radwaste evaporator in series. If an adjustment were required for the evaporator being out-of-service two days/week, with only one day holdup tank capacity, then the effective system DF can be calculated as follows:

1. For 6 days ($7 - 2 + 1$) out of 7 the system DF would be 10^5 .
2. For the remaining one day, the system DF would be 10^2 (only the demineralizer DF is considered). The effective DF is:

$$DF = \left[\left(\frac{6}{7} \right) (10^{-5}) + \left(\frac{1}{7} \right) (10^{-2}) \right]^{-1} = 7.0 \times 10^2$$

2.2.20.2 Bases

Reactor operating data over an 8 year period, January 1970 through December 1977, representing 127 reactor years of operation were evaluated to determine the frequency and extent of unplanned liquid releases. During the period evaluated, 50 unplanned liquid releases occurred; 28 due to operator errors, 13 due to component failures, 5 due to inadequate procedures or failure to follow procedures, and the remainder (4) due to miscellaneous causes such as design errors. Table 2-36 summarizes the findings of this evaluation. Based on the data provided in Table 2-36 it is estimated that 0.1 Ci/yr/reactor will be discharged in unplanned releases in liquid effluents. Tritium releases for BWR anticipated operational occurrences were less than 1% of the total normal operational release value, and was, therefore, judged to be negligible.

The availability for evaporators in waste treatment systems is expected to be in the range of 60 to 80%. Unavailability is attributed to scaling, fouling of surfaces, instrumentation failures, corrosion, and occasional upsets resulting in high carryovers requiring system cleaning. A value of two consecutive days unavailability per week was chosen as being representative of operating experience. For systems having sufficient tank capacity to collect and hold wastes during the assumed 2-day/week outage, no adjustments are required for the source term. If less capacity is available, the difference between the waste expected during two days of normal operation and the available holdup capacity is assumed to follow an alternative route for processing. Since processing through an alternative route implies mixing of wastes having different purities and different dispositions after treatment, it is assumed that the fraction of waste discharged following processing will be that normally assumed for the less pure of the two waste streams combined.

Since chemical and regenerant wastes are not amenable to processes other than evaporation, it is assumed that unless an alternative evaporation route is available, chemical and regenerant wastes in excess of the storage capacity are discharged without treatment.

2.2.21 GUIDELINES FOR ROUNDING OFF NUMERICAL VALUES

In calculating the estimated annual release of radioactive materials in liquid and gaseous wastes, round off all numerical values to two significant figures.

TABLE 2-36

FREQUENCY AND EXTENT OF UNPLANNED LIQUID RADWASTE
RELEASES FROM OPERATING PLANTS*

<u>UNPLANNED LIQUID RELEASES</u>	
Total number (unplanned releases)	50
Fraction due to personnel error	0.56
Fraction due to component failure	0.26
Fraction due to inadequate procedures or failure to follow procedures	0.10
Fraction due to other causes	0.08
Approximate activity (Ci)	10.62
Fraction of cumulative occurrences per reactor year (plants reporting releases >5 gals of liquid waste/reactor year)	0.15
Fraction of cumulative occurrences per reactor year (plants reporting activity released >0.01 mCi/reactor year)	0.27
Activity per release (Ci/release)	0.30
Activity released per reactor year (Ci/reactor/year)	0.10
Volume of release per reactor year (gal/reactor year)	1.66×10^4

* Values in this table are based on reported values in 1970-1977 Licensee Event Reports

2.2.22 CARBON-14 RELEASES

2.2.22.1 Parameter

The estimated annual quantity of carbon-14 released from a boiling water reactor is 9.5 Ci/yr. It is assumed that the carbon-14 reacts with oxygen in the reactor water and behaves like a noble gas fission product; thus all carbon-14 produced will be released through the main condenser offgas system.

2.2.22.2 Bases

The principal source of carbon-14 is the thermal neutron reaction with oxygen-17 in the reactor coolant. The production rate of carbon-14 from oxygen-17 is given by the equation:

$$Q = N_o \sigma_o \phi m t p s \quad (\text{Ci/yr})$$

where

- m is the 3.9×10^4 kg, mass of water in reactor core;
- N_o is the 1.3×10^{22} atoms O-17/kg natural water;
- p is the 0.80, plant capacity factor;
- s is the 1.03×10^{-22} Ci/atom, specific activity for C-14;
- t is the 3.15×10^7 sec/yr, maximum irradiation time per year;
- σ_o is the 2.4×10^{-25} cm², thermal neutron cross section for O-17; and
- ϕ is the 3×10^{13} neutrons/cm²-sec, average thermal neutron flux.

Based on the above parameters, $Q = 9.5$ Ci/yr.

Carbon-14 can also be produced by neutron activation of nitrogen-14 dissolved in the reactor coolant and present in air in the drywell. These sources contribute a small fraction of a curie per year to the annual production of carbon-14 due to the low concentration of nitrogen-14 in the reactor coolant (less than 1 ppm by weight), and the low neutron flux in the drywell (approximately 4×10^8 neutrons/cm²-sec).

The annual release of 9.5 Ci of carbon-14 is in good agreement with measurements at Nine Mile Point 1 reported by Kunz et al. (Ref. 48), who found that 8 curies per year of carbon-14 were released, principally in the form of CO₂.

2.2.23 ARGON-41 RELEASES

The argon-41 input to the main condenser offgas treatment system (MCOTS) downstream of the air ejectors, is 40 μ Ci/sec. The dynamic adsorption coefficients for argon-41 in charcoal delay beds of a MCOTS are 6.4 cm³/gm for an ambient temperature charcoal system and 16 cm³/gm for a chilled charcoal system. The holdup time for argon-41 in a charcoal delay system is determined using the equation in Section 2.2.9.1.

The argon-41 release from the purging or venting of the drywell is 15 Ci/yr.

2.2.23.2 Bases

Argon-41 is formed by neutron activation of stable naturally occurring argon-40. This reaction may occur with argon-40 present in the reactor coolant and also with argon-40 in the drywell air surrounding the reactor vessel.

Argon-40 will enter the reactor coolant as a part of air leakage at or downstream of the main condenser. Argon-41 produced by activation of the argon-40 in the reactor vessel will be transported to the main condenser offgas treatment system (MCOTS). Data in reference 49 and summarized in Table 2-37 indicates that the argon-41 input to the MCOTS during the measurements ranged from 5.6 μ Ci/sec to 37 μ Ci/sec. Due to the limited duration of these measurements, the mean value of the data is not used. Instead, in these evaluations a release rate of 40 μ Ci/sec is considered to be a value that is not likely to be exceeded, on the average, over the 30 year life of the plant.

Argon-41 will be held up in charcoal delay beds of the MCOTS in the same manner as discussed for xenon and krypton in Section 2.2.9.2. Values of the dynamic adsorption

coefficient are based on data contained in references 49, 50 and 51 for ambient and chilled temperature systems. Holdup times for argon-41 are determined using these k values and the delay equation in Section 2.2.9.1.

Argon-41 release from the drywell are based on data in reference 49 concerning the neutron flux in the drywell and on an assumed drywell purging frequency of 24 purges per year.

TABLE 2-37
 SUMMARY OF ARGON-41 RELEASES
TO THE MAIN CONDENSER OFFGAS TREATMENT SYSTEM*
 ($\mu\text{Ci/sec}$)

<u>PLANT</u>	<u>Argon-41 Release</u>
Browns Ferry 1	38
Browns Ferry 2	17
"	12
Browns Ferry 3	7.1
"	5.8
"	7.4
"	34
"	32
"	19
Hatch 1	12
"	16
Fitzpatrick	36

* Data in this table are based on measured argon-41 release rates in reference 49 and were adjusted to 3400 MWt.

CHAPTER 3. INPUT FORMAT, SAMPLE PROBLEM, AND FORTRAN LISTING OF THE BWR-GALE CODE

3.1 INTRODUCTION

This chapter contains additional information for using the BWR-GALE Code. Chapter 1 of this report described the entries required to be entered on input data cards, and Section 3.2 of this chapter contains sample input data sheets and flow charts to orient the user in making the entries described in Chapter 1.

Section 3.3 of this chapter contains a listing of the input data cards for a sample problem and the resultant output for that sample problem. Section 3.4 contains a discussion of the nuclear data library used and a FORTRAN listing of the BWR-GALE Code.

3.2 INPUT DATA SHEETS

The following pages (3-3 through 3-11) show (1) the form in which data should be entered on input data sheets and (2) a sample completed sheet and flow sheets for both the liquid and gas codes.

3.3 SAMPLE PROBLEM - INPUT AND OUTPUT

The following pages (3-12 through 3-18) show printouts of the input and output for a sample problem using the BWR-GALE Code.

3.4 LISTING OF BWR-GALE CODE

3.4.1 NUCLEAR DATA LIBRARY

Calculation of the releases of radioactive materials in liquid effluents using the GALE Code requires a library of nuclear data available from the Division of ADP Support, USNRC (301)492-7713. For convenience, the tape consists of five files, written in card image form. The contents of the five files are:

1. File 1: A FORTRAN listing of the liquid effluent code.
2. File 2: Nuclear data library for corrosion and activation products for use with the liquid effluent code.
3. File 3: Nuclear data library for fuel materials and their transmutation products for use with the liquid effluent code.
4. File 4: Nuclear data library for fission products for use with the liquid effluent code.
5. File 5: A FORTRAN listing of the gaseous effluent code.

The tape is written in the following format:

DCB = (RECFM = FB, LRECL = 80, BLKSIZE = 3200)

Use of the tape requires two data cards in addition to those described in Chapter 1 containing the plant parameters. For a low enrichment uranium-235 oxide-fueled light water reactor, these cards should always contain the following data:

<u>CARD</u>	<u>COLUMN</u>	<u>INPUT DATA</u>
1	1-72	Title
1	75	The value 2
2	1-10	The value 0.632
2	11-20	The value 0.333
2	21-30	The value 2.0
2	31-40	The value 1.0E-25
2	41-46	The date (month, day, year)
2	48	The value 1
2	50	The value 0
2	52	The value 0

A description of the information contained in the nuclear data library can be found in the report ORNL-4628, "ORIGEN - The ORNL Isotope Generation and Depletion Code," dated May 1973.

3.4.2 FORTRAN PROGRAM LISTING

The remainder of this chapter (pages 3-19 through 3-58) provides the program listing for the BWR-GALE Code.

JOB TITLE BWR-GALE Code

PREPARED BY _____

[illegible]

[illegible]

CARD	NAME	NAME OF REACTOR	SAMPLE BWR CASE 1	TYPE =	BWR
CARD 2	POWTH	THERMAL POWER LEVEL (MEGAWATTS)			3400.
CARD 3	GTO	TOTAL STEAM FLOW (MILLION LBS/HR)			15.
CARD 4	WL1Q	MASS OF WATER IN REACTOR VESSEL (MILLION LBS)			0.38
CARD 5	GDE	CLEAN-UP DEMINERALIZER FLOW (MILLION LBS/HR)			0.13
CARD 6	REGENT	CONDENSATE DEMINERALIZER REGENERATION TIME (DAYS)			56.
CARD 7	FFCDM	FRACTION FEED WATER THROUGH CONDENSATE DEMIN			1.00
CARD 8		HIGH PURITY WASTE INPUT 28640. GPD AT .15 PCA			
CARD 9		DFI= 1.0E03DFCS= 1.0E02DFO = 1.0E03			
CARD 10		COLLECTION 1.0 DAYS PROCESS 0.07 DAYS FRACT DISCH			0.01
CARD 11		LOW PURITY WASTE INPUT 5700. GPD AT .13			
CARD 12		DFI= 1.0E03DFCS= 1.0E04DFO = 1.0E04			
CARD 13		COLLECTION 3.10 DAYS PROCESS 0.6 DAYS FRACT DISCH			1.0
CARD 14		CHEMICAL WASTE INPUT 600. GPD AT .02 PCA			
CARD 15		DFI= 1.0E03DFCS= 1.0E04DFO = 1.0E04			
CARD 16		COLLECTION 3.1 DAYS PROCESS .60 DAYS FRACT DISCH			1.0
CARD 17		REGENERATION SOLTNS INPUT GPD			1700.
CARD 18		DFI= 1.0E04DFCS= 1.0E05DFO = 1.0E05			
CARD 19		COLLECTION 9.4 DAYS PROCESS .44 DAYS FRACT DISCH			1.0
CARD 20	GGG	GLAND SEAL STEAM FLOW (THOUSAND LBS/HR)			0.0
CARD 21	TIM3	GLAND SEAL HOLDUP TIME (HOURS)			0.0
CARD 22	TIM4	AIR EJECTOR OFFGAS HOLDUP TIME (HOURS)			.167
CARD 23		CONTAINMENT BLDG. CHARCOAL 90.0 HEPA?99.0			
CARD 24		TURBINE BLDG. CHARCOAL 00.0 HEPA?00.0			
CARD 25	FIL3	GLAND SEAL VENT, IODINE PF			00.0
CARD 26	FIL4	AIR EJECTOR OFFGAS IODINE PF			1.0
CARD 27		AUXILIARY BLDG. CHARCOAL 00.0 HEPA?00.0			
CARD 28		RADWASTE BLDG. CHARCOAL 00.0 HEPA?99.0			
CARD 29	KCHAR	CHARCOAL DELAY SYSTEM 0=NO,1=YES,2=CRYOGENIC DISTILL			1
CARD 30	KKR	KRYPTON DYNAMIC ADSORPTION COEFFICIENT (CM3/GM)			105.0
CARD 31	KXE	XENON DYNAMIC ADSORPTION COEFFICIENT (CM3/GM)			2410.0
CARD 32	KMASS	MASS OF CHARCOAL (THOUSAND LBS)			48.
CARD 33	PFLAUN	DETERGENT WASTE DECONTAMINATION FACTOR			1.0

FLOW CHART FOR BWR LIQUID CODE

FLOWCHART FOR BWR GAS CODE

- (1) SEE SAMPLE INPUT CARDS 1 THRU 7.
- (2) SEE SAMPLE INPUT CARDS 8 THRU 19.
- (3) SEE SAMPLE INPUT CARDS 20 THRU 22.

TABLE 2-14. PARAMETERS 2.2.9, 2.2.7, 2.2.10, 2.2.11, AND 2.2.23 ARE USED TO CALCULATE NOBLE GAS RELEASES FOR BWR'S.

TABLE 2-14, PARAMETER 2.2.11 ARE USED TO
CALCULATE PARTICULATE RELEASES

SAMPLE BWR CASE 1	
THERMAL POWER LEVEL (MEGAWATTS)	3400.00000
PLANT CAPACITY FACTOR	0.80
TOTAL STEAM FLOW (MILLION LBS/HR)	15.00000
MASS OF WATER IN REACTOR VESSEL (MILLION LBS)	0.38000
FISSION PRODUCT CARRY-OVER FRACTION	0.0010
HALOGEN CARRY-OVER FRACTION	0.0200
CLEAN-UP DEMINERALIZER FLOW (MILLION LBS/HR)	0.13000
CONDENSATE DEMINERALIZER REGENERATION TIME (DAYS)	56.00000
FRACTION FEED WATER THROUGH CONDENSATE DEMIN	1.00000

LIQUID WASTE INPUTS

STREAM	FLOW RATE (GAL/DAY)	FRACTION OF PCA	FRACTION DISCHARGED	COLLECTION TIME (DAYS)	DECAY TIME (DAYS)	DECONTAMINATION FACTORS		
						I	CS	OTHERS
HIGH PURITY WASTE	2.86E+04	0.150	0.010	1.000	0.070	1.00E+03	1.00E+02	1.00E+03
LOW PURITY WASTE	5.70E+03	0.130	1.000	3.100	0.600	1.00E+03	1.00E+04	1.00E+04
CHEMICAL WASTE	6.00E+02	0.020	1.000	3.100	0.600	1.00E+03	1.00E+04	1.00E+04
REGENERANT SOLS	1.70E+03		1.000	9.400	0.440	1.00E+04	1.00E+05	1.00E+05

GASEOUS WASTE INPUTS

GLAND SEAL STEAM FLOW (THOUSAND LBS/HR)	0.0
GLAND SEAL HOLDUP TIME (HOURS)	0.0
AIR EJECTOR OFFGAS HOLDUP TIME (HOURS)	0.16700
CONTAINMENT BLDG IODINE RELEASE FRACTION	0.10000
TURBINE BLDG. PARTICULATE RELEASE FRACTION	0.01000
IODINE RELEASE FRACTION	1.00000
PARTICULATE RELEASE FRACTION	1.00000
GLAND SEAL VENT, IODINE PF	1.00000
AIR EJECTOR OFFGAS IODINE PF	0.0
AUXILIARY BLDG. IODINE RELEASE FRACTION	1.00000
PARTICULATE RELEASE FRACTION	1.00000
RADWASTE BLDG. IODINE RELEASE FRACTION	1.00000
PARTICULATE RELEASE FRACTION	0.01000
THERE IS A CHARCOAL DELAY SYSTEM	
KRYPTON HOLDUP TIME (DAYS)	2.66823
XENON HOLDUP TIME (DAYS)	61.24234
KRYPTON DYNAMIC ADSORPTION COEFFICIENT (CM3/GM)	105.00000
XENON DYNAMIC ADSORPTION COEFFICIENT (CM3/GM)	2410.00000
MASS OF CHARCOAL (THOUSAND LBS)	48.00000

SAMPLE BWR CASE 1

LIQUID EFFLUENTS

NUCLIDE	HALF-LIFE (DAYS)	CONCENTRATION IN PRIMARY		ANNUAL RELEASES TO DISCHARGE CANAL			ADJUSTED TOTAL (CI/YR)	DETERGENT WASTES (CI/YR)	TOTAL (CI/YR)
		COOLANT (MICRO CI/ML)	HIGH PURITY (CURIES)	LOW PURITY (CURIES)	CHEMICAL (CURIES)	TOTAL LWS (CURIES)			
CORROSION AND ACTIVATION PRODUCTS									
NA 24	6.25E-01	9.18E-03	0.00030	0.00014	0.00000	0.00044	0.00155	0.0	0.00160
P 32	1.43E+01	1.81E-04	0.00001	0.00002	0.00003	0.00006	0.00020	0.0	0.00020
CR 51	2.78E+01	5.44E-03	0.00032	0.00053	0.00177	0.00262	0.00918	0.0	0.00920
MN 54	3.03E+02	6.35E-05	0.00000	0.00001	0.00004	0.00006	0.00019	0.00100	0.00120
MN 56	1.07E-01	4.74E-02	0.00028	0.00001	0.00000	0.00028	0.00099	0.0	0.00099
FE 55	9.50E+02	9.07E-04	0.00005	0.00009	0.00068	0.00082	0.00289	0.0	0.00290
FE 59	4.50E+01	2.72E-05	0.00000	0.00000	0.00001	0.00002	0.00006	0.0	0.00006
CO 58	7.13E+01	1.81E-04	0.00001	0.00002	0.00010	0.00013	0.00044	0.00400	0.00440
CO 60	1.92E+03	3.63E-04	0.00002	0.00004	0.00028	0.00033	0.00117	0.00870	0.00990
CU 64	5.33E-01	2.76E-02	0.00084	0.00032	0.00001	0.00116	0.00406	0.0	0.00410
ZN 65	2.45E+02	1.81E-04	0.00001	0.00002	0.00013	0.00015	0.00054	0.0	0.00054
ZN 69M	5.75E-01	1.84E-03	0.00006	0.00002	0.00000	0.00008	0.00029	0.0	0.00029
ZN 69	3.96E-02	0.0	0.00006	0.00003	0.00000	0.00009	0.00031	0.0	0.00031
ZR 95	6.50E+01	0.0	0.0	0.0	0.0	0.0	0.0	0.00140	0.00140
NB 95	3.50E+01	0.0	0.0	0.0	0.0	0.0	0.0	0.00200	0.00200
W187	9.76E-01	2.74E-04	0.00001	0.00001	0.00000	0.00002	0.00007	0.0	0.00007
NP239	2.35E+00	6.37E-03	0.00032	0.00036	0.00002	0.00070	0.00246	0.0	0.00250
FISSION PRODUCTS									
BR 83	1.00E-01	3.45E-03	0.00002	0.00000	0.00000	0.00002	0.00007	0.0	0.00007
SR 89	5.20E+01	9.07E-05	0.00001	0.00001	0.00004	0.00006	0.00020	0.0	0.00020
SR 90	1.03E+04	6.35E-06	0.00000	0.00000	0.00000	0.00001	0.00002	0.0	0.00002
Y 90	2.67E+00	0.0	0.00000	0.00000	0.00000	0.00001	0.00002	0.0	0.00002
SR 91	4.03E-01	3.69E-03	0.00009	0.00003	0.00000	0.00012	0.00042	0.0	0.00042
Y 91M	3.47E-02	0.0	0.00006	0.00002	0.00000	0.00007	0.00026	0.0	0.00026
Y 91	5.88E+01	3.63E-05	0.00000	0.00001	0.00003	0.00004	0.00014	0.0	0.00014
SR 92	1.13E-01	9.47E-03	0.00006	0.00000	0.00000	0.00006	0.00021	0.0	0.00021
Y 92	1.47E-01	5.64E-03	0.00014	0.00001	0.00000	0.00015	0.00051	0.0	0.00051
Y 93	4.25E-01	3.69E-03	0.00010	0.00003	0.00000	0.00012	0.00044	0.0	0.00044
ZR 95	6.50E+01	7.25E-06	0.00000	0.00000	0.00000	0.00000	0.00002	0.0	0.00002
NB 95	3.50E+01	7.26E-06	0.00000	0.00000	0.00000	0.00001	0.00002	0.0	0.00002
NB 98	3.54E-02	3.89E-03	0.00000	0.00000	0.00000	0.00000	0.00001	0.0	0.00001
MO 99	2.79E+00	1.82E-03	0.00009	0.00011	0.00001	0.00022	0.00076	0.0	0.00076
TC 99M	2.50E-01	1.86E-02	0.00037	0.00015	0.00001	0.00053	0.00185	0.0	0.00180
RU103	3.96E+01	1.81E-05	0.00000	0.00000	0.00001	0.00001	0.00004	0.00014	0.00018
RH103M	3.96E-02	0.0	0.00000	0.00000	0.00001	0.00001	0.00004	0.0	0.00004
RU105	1.85E-01	1.87E-03	0.00002	0.00000	0.00000	0.00002	0.00008	0.0	0.00008
RH105M	5.21E-04	0.0	0.00002	0.00000	0.00000	0.00002	0.00008	0.0	0.00008
RH105	1.50E+00	0.0	0.00001	0.00001	0.00000	0.00002	0.00007	0.0	0.00007
RU106	3.67E+02	2.72E-06	0.00000	0.00000	0.00000	0.00000	0.00001	0.00240	0.00240
AG110M	2.53E+02	9.07E-07	0.00000	0.00000	0.00000	0.00000	0.00000	0.00044	0.00044
TE129M	3.40E+01	3.63E-05	0.00000	0.00000	0.00001	0.00002	0.00007	0.0	0.00007
TE129	4.79E-02	0.0	0.00000	0.00000	0.00001	0.00001	0.00004	0.0	0.00004
TE131M	1.25E+00	9.13E-05	0.00000	0.00000	0.00000	0.00001	0.00003	0.0	0.00002
I131	8.05E+00	1.60E-03	0.00009	0.00137	0.02165	0.02311	0.08113	0.00006	0.08100
I132	9.58E-02	3.48E-02	0.00017	0.00002	0.00000	0.00019	0.00068	0.0	0.00068
I133	8.75E-01	2.26E-02	0.00088	0.00535	0.00012	0.00634	0.02226	0.0	0.02200
I134	3.67E-02	7.05E-02	0.00006	0.00000	0.00000	0.00006	0.00021	0.0	0.00021
CS134	7.49E+02	2.72E-05	0.00002	0.00000	0.00001	0.00003	0.00011	0.01300	0.01300
I135	2.79E-01	2.46E-02	0.00045	0.00074	0.00001	0.00120	0.00422	0.0	0.00420
CS136	1.30E+01	7.26E-05	0.00004	0.00001	0.00001	0.00005	0.00019	0.0	0.00019

SAMPLE BWR CASE 1

LIQUID EFFLUENTS (CONTINUED)

NUCLIDE	HALF-LIFE (DAYS)	CONCENTRATION IN PRIMARY COOLANT	ANNUAL RELEASES TO DISCHARGE CANAL				ADJUSTED TOTAL (CI/YR)	DETERGENT WASTES (CI/YR)	TOTAL (CI/YR)
		(MICRO CI/ML)	HIGH PURITY (CURIES)	LOW PURITY (CURIES)	CHEMICAL (CURIES)	TOTAL LWS (CURIES)			
CS137	1.10E+04	1.81E-05	0.00001	0.00000	0.00001	0.00002	0.00007	0.02400	0.02400
BA137M	1.77E-03	0.0	0.00001	0.00000	0.00001	0.00002	0.00007	0.0	0.00007
CS138	2.24E-02	9.88E-03	0.00002	0.00000	0.00000	0.00002	0.00008	0.0	0.00008
BA139	5.76E-02	9.62E-03	0.00002	0.00000	0.00000	0.00002	0.00007	0.0	0.00007
BA140	1.28E+01	3.63E-04	0.00002	0.00003	0.00005	0.00011	0.00037	0.0	0.00037
LA140	1.67E+00	0.0	0.00000	0.00002	0.00006	0.00008	0.00029	0.0	0.00029
LA141	1.62E-01	0.0	0.00001	0.00000	0.00000	0.00001	0.00003	0.0	0.00003
CE141	3.24E+01	2.72E-05	0.00000	0.00000	0.00001	0.00002	0.00006	0.0	0.00006
LA142	6.39E-02	4.80E-03	0.00001	0.00000	0.00000	0.00001	0.00005	0.0	0.00005
PR143	1.37E+01	3.63E-05	0.00000	0.00000	0.00001	0.00001	0.00004	0.0	0.00004
CE144	2.84E+02	2.72E-06	0.00000	0.00000	0.00000	0.00000	0.00001	0.00520	0.00520
ALL OTHERS		1.98E-01	0.00001	0.00000	0.00001	0.00002	0.00006	0.0	0.00006
TOTAL (EXCEPT TRITIUM)		5.29E-01	0.00513	0.00953	0.02517	0.03983	0.13983	0.06234	0.20000
TRITIUM RELEASE			26	CURIES PER YEAR					

SAMPLE BWR CASE 1		BWR
THERMAL POWER LEVEL (MEGAWATTS)		3400.00000
PLANT CAPACITY FACTOR		0.80
TOTAL STEAM FLOW (MILLION LBS/HR)		15.00000
MASS OF WATER IN REACTOR VESSEL (MILLION LBS)		0.38000
CLEAN-UP DEMINERALIZER FLOW (MILLION LBS/HR)		0.13000
CONDENSATE DEMINERALIZER REGENERATION TIME (DAYS)		56.00000
FRACTION FEED WATER THROUGH CONDENSATE DEMIN		1.00000
REACTOR VESSEL HALOGEN CARRYOVER FACTOR		0.01500

LIQUID WASTE INPUTS

STREAM	FLOW RATE (GAL/DAY)	FRACTION OF PCA	FRACTION DISCHARGED	COLLECTION TIME (DAYS)	DECAY TIME (DAYS)	DECONTAMINATION FACTORS		
						I	CS	OTHERS
HIGH PURITY WASTE	2.86E+04	0.150	0.010	1.000	0.070	1.00E+03	1.00E+02	1.00E+03
LOW PURITY WASTE	5.70E+03	0.130	1.000	3.100	0.600	1.00E+03	1.00E+04	1.00E+04
CHEMICAL WASTE	6.00E+02	0.020	1.000	3.100	0.600	1.00E+03	1.00E+04	1.00E+04
REGENERANT SOLS	1.70E+03		1.000	9.400	0.440	1.00E+04	1.00E+05	1.00E+05

GASEOUS WASTE INPUTS

GLAND SEAL STEAM FLOW (THOUSAND LBS/HR)	0.0
GLAND SEAL HOLDUP TIME (HOURS)	0.0
AIR EJECTOR OFFGAS HOLDUP TIME (HOURS)	0.16700
CONTAINMENT BLDG IODINE RELEASE FRACTION	0.10000
TURBINE BLDG. PARTICULATE RELEASE FRACTION	0.01000
TURBINE BLDG. IODINE RELEASE FRACTION	1.00000
TURBINE BLDG. PARTICULATE RELEASE FRACTION	1.00000
GLAND SEAL VENT, IODINE PF	1.00000
AIR EJECTOR OFFGAS IODINE PF	0.0
AUXILIARY BLDG. IODINE RELEASE FRACTION	1.00000
AUXILIARY BLDG. PARTICULATE RELEASE FRACTION	1.00000
RADWASTE BLDG. IODINE RELEASE FRACTION	1.00000
RADWASTE BLDG. PARTICULATE RELEASE FRACTION	0.01000
THERE IS A CHARCOAL DELAY SYSTEM	
KRYPTON HOLDUP TIME (DAYS)	2.66823
XENON HOLDUP TIME (DAYS)	61.24234
KRYPTON DYNAMIC ADSORPTION COEFFICIENT (CM3/GM)	105.00000
XENON DYNAMIC ADSORPTION COEFFICIENT (CM3/GM)	2410.00000
MASS OF CHARCOAL (THOUSAND LBS)	48.00000

SAMPLE BWR CASE 1

GASEOUS RELEASE RATE (CURIES PER YEAR)									
NUCLIDE	COOLANT CONC. (MICROCURIES/G)	CONTAINMENT BLDG.	TURBINE BLDG.	AUXILIARY BLDG.	RADWASTE BLDG.	GLAND SEAL	AIR EJECTOR	MECH VAC PUMP	TOTAL
I-131	1.785E-03	1.1E-03	1.1E-01	2.1E-02	1.1E-02	0.0	0.0	8.2E-02	2.3E-01
I-133	2.499E-02	1.5E-02	1.6E+00	2.9E-01	1.5E-01	0.0	0.0	9.2E-01	3.0E+00

H-3 RELEASED FROM TURBINE BLDG. VENTILATION SYSTEM 2.6E+01

H-3 RELEASED FROM CONTAINMENT BLDG. VENTILATION SYSTEM 2.6E+01

TOTAL H-3 RELEASED VIA GASEOUS PATHWAY 5.2E+01

C-14 RELEASED VIA MAIN CONDENSER OFFGAS SYSTEM = 9.5 CI/YR

SAMPLE BWR CASE 1

GASEOUS RELEASE RATE

(CURIES PER YEAR)

NUCLIDE	COOLANT CONC. (MICROCURIES/G)	CONTAINMENT BLDG.	TURBINE BLDG.	AUXILIARY BLDG.	RADWASTE BLDG.	GLAND SEAL	AIR EJECTOR	MECH VAC PUMP	TOTAL
AR-41	0.0	1.5E+01	0.0	0.0	0.0	0.0	2.3E+01	0.0	3.8E+01
KR-83M	9.100E-03	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
KR-85M	1.600E-03	1.0E+00	2.5E+01	3.0E+00	0.0	0.0	3.0E+00	0.0	3.2E+01
KR-85	5.000E-06	0.0	0.0	0.0	0.0	0.0	2.4E+02	0.0	2.4E+02
KR-87	5.500E-03	0.0	6.1E+01	2.0E+00	0.0	0.0	0.0	0.0	6.3E+01
KR-88	5.500E-03	1.0E+00	9.1E+01	3.0E+00	0.0	0.0	0.0	0.0	9.5E+01
KR-89	3.400E-02	0.0	5.8E+02	2.0E+00	2.9E+01	0.0	0.0	0.0	6.1E+02
XE-131M	3.900E-06	0.0	0.0	0.0	0.0	0.0	5.0E+00	0.0	5.1E+00
XE-133M	7.500E-05	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
XE-133	2.100E-03	2.7E+01	1.5E+02	8.3E+01	2.2E+02	0.0	3.2E+01	1.3E+03	1.8E+03
XE-135M	7.000E-03	1.5E+01	4.0E+02	4.5E+01	5.3E+02	0.0	0.0	0.0	9.9E+02
XE-135	6.000E-03	3.3E+01	3.3E+02	9.4E+01	2.8E+02	0.0	0.0	5.0E+02	1.2E+03
XE-137	3.900E-02	4.5E+01	1.0E+03	1.4E+02	8.3E+01	0.0	0.0	0.0	1.3E+03
XE-138	2.300E-02	2.0E+00	1.0E+03	6.0E+00	2.0E+00	0.0	0.0	0.0	1.0E+03
TOTAL NOBLE GASES									7.4E+03

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0.0 APPEARING IN THE TABLE INDICATES RELEASE IS LESS THAN 1.0 CI/YR FOR NOBLE GAS

SAMPLE BWR CASE 1

AIRBORNE PARTICULATE RELEASE RATE

(CURIES PER YEAR)

NUCLIDE	CONTAINMENT BLDG.	TURBINE BLDG.	AUXILIARY BLDG.	RADWASTE BLDG.	MECH VAC. PUMP	TOTAL
CR-51	2.0E-06	9.0E-04	9.0E-04	7.0E-06	1.0E-06	1.8E-03
MN-54	4.0E-06	6.0E-04	1.0E-03	4.0E-05	0.0	1.6E-03
CO-58	1.0E-06	1.0E-03	2.0E-04	2.0E-06	0.0	1.2E-03
FE-59	9.0E-07	1.0E-04	3.0E-04	3.0E-06	0.0	4.0E-04
CO-60	1.0E-05	1.0E-03	4.0E-03	7.0E-05	5.6E-07	5.1E-03
ZN-65	1.0E-05	6.0E-03	4.0E-03	3.0E-06	3.4E-07	1.0E-02
SR-89	3.0E-07	6.0E-03	2.0E-05	0.0	0.0	6.0E-03
SR-90	3.0E-08	2.0E-05	7.0E-06	0.0	0.0	2.7E-05
NB-95	1.0E-05	6.0E-06	9.0E-03	4.0E-08	0.0	9.0E-03
ZR-95	3.0E-06	4.0E-05	7.0E-04	8.0E-06	0.0	7.5E-04
MO-99	6.0E-05	2.0E-03	6.0E-02	3.0E-08	0.0	6.2E-02
RU-103	2.0E-06	5.0E-05	4.0E-03	1.0E-08	0.0	4.1E-03
AG-110M	4.0E-09	0.0	2.0E-06	0.0	0.0	2.0E-06
SB-124	2.0E-07	1.0E-04	3.0E-05	7.0E-07	0.0	1.3E-04
CS-134	7.0E-06	2.0E-04	4.0E-03	2.4E-05	3.2E-06	4.2E-03
CS-136	1.0E-06	1.0E-04	4.0E-04	0.0	1.9E-06	5.0E-04
CS-137	1.0E-05	1.0E-03	5.0E-03	4.0E-05	8.9E-06	6.1E-03
BA-140	2.0E-05	1.0E-02	2.0E-02	4.0E-08	1.1E-05	3.0E-02
CE-141	2.0E-06	1.0E-02	7.0E-04	7.0E-08	0.0	1.1E-02

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1. C GALE CODE FOR CALCULATING LIQUID EFFLUENTS FROM LWRS. MODIFIED 0000000
2. C OCT. 1978 TO IMPLEMENT APPENDIX I TO 10 CFR PART 50. REACTOR 0000005
3. C WATER CONCENTRATIONS CALCULATED USING METHODS OF DRAFT STANDARD 0000010
4. C ANS 237 'RADIOACTIVE MATERIALS IN PRINCIPAL FLUID STREAMS OF 0000015
5. C LIGHT WATER COOLED NUCLEAR POWER PLANTS' DRAFT DATED MAY 20, 1974 0000020
6. C MODIFIED EDITION OF ORIGEN PROGRAM TO COMPUTE EFFLUENTS FROM BWR 0000025
7. C AND PWR RADWASTE SYSTEMS 0000030
8. C 0000035
9. LOGICAL DISCHG,POWRIT 0000040
10. INTEGER*2 LOC,NON0,KD 0000045
11. REAL*4 LETDWN,NOGEN 0000050
12. REAL*4 LETDWA 0000055
13. REAL KKR,KXE,KNO,KMASS 0000060
14. INTEGER*2 NAME(3) 0000065
15. COMMON/MATRIX/A(2500),LOC(2500),NON0(800),KD(800) 0000070
16. COMMON/FLEX/FLUX(10),MMN,MOUT,INDEX,QXN,AXN,ERR,NOBLND,MZERO 0000075
17. COMMON/PROCSS/ MPROS,PRATE(8),NOPROS(8),NZPROS(8,20),PR(800) 0000080
18. COMMON/EQ/XZERO(800), XZH(800),XTEMP(800),XNEW(10,800), 0000085
19. 1 B(800),D(800) 0000090
20. COMMON/FLUXN/T(20),POWER(10),TOCAP(800),FISS(100),DIS(800),ILITE, 0000095
21. 1 IACT,IFP,ITOT,NON,INPT 0000100
22. COMMON/OUT/NUCL(800),TITLE(20),Q(800),FG(800),CUTOFF(7), 0000105
23. 1 POW,BURNUP,FLUXB,MSTAR,ALPHAN(100),SPONF(100),ABUND(500), 0000110
24. 2 BASIS(10),TCONST,TUNIT 0000115
25. COMMON/CONC/PCONC(800),DWCONC(800),CWCONC(800),CMCONC(800), 0000120
26. 1 SCON(800),RINV(800) 0000125
27. COMMON/COOL/REACTR,POW1,TYPE,PCVOL,LETDWN,NDGAS,SCVOL,STMVOL,NOGEN 0000130
28. 1 ,NPURGE,NVCSGP,SBLDR,GASDLA,STLKR,BLWDWN,EJCTR,WLKRAT, 0000135
29. GASLKR,CONDLR,DFMBDM,DFCBDM,NZMBDM,NZCBDM,NE,PF, 0000140
30. 3 STMFR,FPEF,HEF,FFCDM,DFMBCS,CBFLR,DFI,DFCS,DF, 0000145
31. 4 EDFLR,DFIED,DFCSED,DFED,DWFLR,DFIDW,DFCSDW,DFDW,DILUT 0000150
32. 5 ,SBA,EDA,DWA,CWFLR,CMWFR,CWA,CMA,DFCM,DFICM,DFCSCM, 0000155
33. 6 DFCW,DFICW,DFCSCW,MHOLD,MHOLDE,MHOLDW,MHOLCM,MHOLDC 0000160
34. 7 ,BDTFR,DFIBD,DFCSBD,DFBD,MHOLDB,REGENT, 0000165
35. 8 SBF,DFMO,DFY,EDFD,DFMOED,DFYED,DWFD,DFMODW,DFYDW, 0000170
36. 9 DFM0BD,DFYBD,CWFD,DFMOCW,DFYCW,CMFD,DFMOCM,DFYCM 0000175
37. A ,TS,TE,TD,TB,TC,TCM,TSTORC,TSTORD,TSTORB,TMSC,DWFL2,DW2,DWF2, 0000180
38. B T2,TSTOR2,DFID2,DFCSD2,DFMOD2,DFYD2,DFD2,PFLAUN 0000185
39. COMMON/APCOOL/RGWFR,DFIRG,DFCSRG,DFRG,TRG,TSTORR,RGFD 0000190
40. COMMON/BDTES/RFNRT 0000195
41. COMMON /CONB/BCONC(800) 0000200
42. DIMENSION WORD13(4), WORD15(4),WORD18(5),WORD23(6),WORD28(7), 0000205
43. 1 WORD33(9),WORD10(3),WORD8(2),WORD40(10) 0000210
44. DIMENSION REACTR(7),NZMBDM(26),NZCBDM(26) 0000215
45. DIMENSION FACT(10),XCOMP(20),INUCL(20) 0000220
46. DIMENSION WORD56(14) 0000225
47. DATA YES/'YES'/ 0000230
48. C FOLLOWINFISOTOPES(WITH THEIR CONCENTRATIONS IN UCI/GM) ARE 0000235
49. C ALSO PRESENT IN THE PRIMARY COOLANT BUT ARE NOT CONSIDERED 0000240
50. C SIGNIFICANT IN EFFLUENT CALCULATIONS:N-13,.05;N-16,60;N-17,.009; 0000245
51. C 0-19,.7;F-18,.004. 0000250
52. C READ NUCLEAR DATA AND CONSTRUCT TRANSITION MATRIX 0000255
53. C 0000260
54. 10 CALL NUDATA(NLIBE) 0000265
55. C 0000270
56. DO 20 I=2,ITOT 0000275
57. NON0(I)=NON0(I)+NON0(I-1) 0000280
58. 20 KD(I)=KD(I)+NON0(I-1) 0000285
59. DISCHG=.FALSE. 0000290
60. POWRIT=.FALSE. 0000295

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61.	KT=0	0000300
62.	INDEX=0	0000305
63.	FLXB=0.0	0000310
64.	PWRH=0.0	0000315
65.	BURN=0.0	0000320
66.	BDTFR=1.0	0000325
67.	QXN=0.001	0000330
68.	AXN=-ALOG(QXN)	0000335
69.	NE=ITOT	0000340
70.	TCONST=86400.	0000345
71.	MMN=0	0000350
72.	MZERO=21	0000355
73.	EDA=0.0	0000360
74.	TMSC=0.0	0000365
75.	TE=0.0	0000370
76.	TS=0.0	0000375
77.	T2=0.0	0000380
78.	TSTOR2=0.0	0000385
79.	DWFL2=0.0	0000390
80.	DW2=0.0	0000395
81.	DWF2=0.0	0000400
82.	DO 40 J=1,800	0000405
83.	PCONC(J)=0.0	0000410
84.	DWCONC(J)=0.0	0000415
85.	SCONC(J)=0.0	0000420
86.	RINV(J)=0.0	0000425
87.	CWCONC(J)=0.0	0000430
88.	CMCONC(J)=0.0	0000435
89.	XZH(J)=0.0	0000440
90.	40 CONTINUE	0000445
91.	C	0000450
92.	C READ DESCRIPTION OF REACTOR AND RADWASTE TREATMENT PLANT	0000455
93.	C	0000460
94.	PRINT 9026	0000465
95.	READ 9010,REACTR,TYPE	0000470
96.	PRINT 9010,REACTR,TYPE	0000475
97.	READ 9022,WORD56,POW1	0000480
98.	PRINT 9022,WORD56,POW1	0000485
99.	PF=0.80	0000490
100.	PRINT 9027	0000495
101.	C	0000500
102.	C READ DATA FOR BWR LIQUID CODE	0000505
103.	C	0000510
104.	50 READ 9022,WORD56,STMFR	0000515
105.	PRINT 9022,WORD56,STMFR	0000520
106.	READ 9022,WORD56,PCVOL	0000525
107.	PRINT 9022,WORD56,PCVOL	0000530
108.	FPEF=0.001	0000535
109.	HEF=0.020	0000540
110.	PRINT 9030,FPEF,HEF	0000545
111.	READ 9022,WORD56,LETDWN	0000550
112.	PRINT 9022,WORD56,LETDWN	0000555
113.	PC = 0.015	0000560
114.	READ 9022,WORD56,REGENT	0000565
115.	IF(REGENT.EQ.0.0) PC = 0.004	0000570
116.	PRINT 9022,WORD56,REGENT	0000575
117.	READ 9022,WORD56,FFCDM	0000580
118.	PRINT 9022,WORD56,FFCDM	0000585
119.	PRINT 9045	0000590
120.	READ 9013,WORD18,CWFLR,WORD8,CWA	0000595

121.	READ 9014,DFICW,DFCSCW,DFCW	0000600
122.	READ 9015,TC,TSTORC,CWFD	0000605
123.	PRINT 9016	0000610
124.	PRINT 9017,WORD18,CWFLR,CWA,CWFD,TC,TSTORC,DFICW,DFCSCW,DFCW	0000615
125.	READ 9013,WORD18,DWFLR,WORD8,DWA	0000620
126.	READ 9014,DFIDW,DFCSDW,DFDW	0000625
127.	READ 9015,TD,TSTORD,DWFD	0000630
128.	PRINT 9017,WORD18,DWFLR,DWA,DWFD,TD,TSTORD,DFIDW,DFCSDW,DFDW	0000635
129.	READ 9013,WORD18,CMWFR,WORD8,CMA	0000640
130.	READ 9014,DFICM,DFCSCM,DFCM	0000645
131.	READ 9015,TCM,TSTORB,CMFD	0000650
132.	PRINT 9017,WORD18,CMWFR,CMA,CMFD,TCM,TSTORB,DFICM,DFCSCM,DFCM	0000655
133.	READ 9037,RGWFR	0000660
134.	READ 9014,DFIRG,DFCSRG,DFRG	0000665
135.	READ 9015,TRG,TSTORR,RGFD	0000670
136.	PRINT 9038,RGWFR,RGFD,TRG,TSTORR,DFIRG,DFCSRG,DFRG	0000675
137.		0000680
138.	C READ DATA FOR BWR GAS CODE	0000685
139.	C	0000690
140.		0000695
141.	PRINT 9046	0000700
142.	READ 9022,WORD56,GG5	0000705
143.	PRINT 9022,WORD56,GG5	0000710
144.	READ 9022,WORD56,TIM3	0000715
145.	PRINT 9022,WORD56,TIM3	0000720
146.	READ 9022,WORD56,TIM4	0000725
147.	PRINT 9022,WORD56,TIM4	0000730
148.	HEPA1=1.0	0000735
149.	FIL1=1.0	0000740
150.	HEPA2=1.0	0000745
151.	FIL2=1.0	0000750
152.	HEPA5=1.0	0000755
153.	FIL5=1.0	0000760
154.	HEPA6=1.0	0000765
155.	FIL6=1.0	0000770
156.	FILGS = 1.0	0000775
157.	FILEJ = 1.0	0000780
158.	READ 9060,WORD15,CBCH,CBHEPA	0000785
159.	IF(CBCH.GT.0.0)FIL1 = (1.0 - CBCH/100.)	0000790
160.	IF(CBHEPA.GT.0.0)HEPA1 = (1.0 - CBHEPA/100.)	0000795
161.	PRINT 9061,WORD15,FIL1,HEPA1	0000800
162.	READ 9062,WORD15,TBCH,TBHEPA	0000805
163.	IF(TBCH.GT.0.0)FIL2 = (1.0 - TBCH/100.)	0000810
164.	IF(TBHEPA.GT.0.0)HEPA2 = (1.0 - TBHEPA/100.)	0000815
165.	PRINT 9063,WORD15,FIL2,HEPA2	0000820
166.	READ 9022,WORD56,FIL3	0000825
167.	IF(FIL3.GT.0.0) FILGS = (1.0 - FIL3/100.)	0000830
168.	PRINT 9022,WORD56,FILGS	0000835
169.	READ 9022,WORD56,FIL4	0000840
170.	IF(FIL4.EQ.1.0) FILEJ = (1.0 - FIL4)	0000845
171.	IF(FIL4.GT.1.0) FILEJ = (1.0 - FIL4/100.)	0000850
172.	IF(FIL4.EQ.0.0) FILEJ = 1.0	0000855
173.	PRINT 9022,WORD56,FILEJ	0000860
174.	READ 9060,WORD15,AXCH,AXHEPA	0000865
175.	IF(AXCH.GT.0.0)FIL5 = (1.0 - AXCH/100.)	0000870
176.	IF(AXHEPA.GT.0.0)HEPA5 = (1.0 - AXHEPA/100.)	0000875
177.	PRINT 9061,WORD15,FIL5,HEPA5	0000880
178.	READ 9060,WORD15,RWCH,RWHEPA	0000885
179.	IF(RWCH.GT.0.0)FIL6 = (1.0 - RWCH/100.)	0000890
180.	IF(RWHEPA.GT.0.0)HEPA6 = (1.0 - RWHEPA/100.)	0000895
	PRINT 9061,WORD15,FIL6,HEPA6	

181.	READ 9021,KCHAR	0000900
182.	READ 9022,WORD56,KKR	0000905
183.	READ 9022,WORD56,KXE	0000910
184.	READ 9022,WORD56,KMASS	0000915
185.	READ 9020,WORD56,PFLAUN	0000920
186.	IF(KCHAR.EQ.0) GO TO 54	0000925
187.	IF(KCHAR.EQ.1) GO TO 55	0000930
188.	PRINT 9023	0000935
189.	GO TO 56	0000940
190.	54 PRINT 9024	0000945
191.	GO TO 56	0000950
192.	55 CHTI1 = 1.8 * (KMASS * KKR)/POW1	0000955
193.	CHTI2 = 1.8 * (KMASS * KXE)/POW1	0000960
194.	PRINT 9025,CHTI1,CHTI2,KKR,KXE,KMASS	0000965
195.	56 CONTINUE	0000970
196.	IF(PFLAUN.EQ.0.0) GO TO 99	0000975
197.	GO TO 98	0000980
198.	99 CONTINUE	0000985
199.	PRINT 9048	0000990
200.	98 CONTINUE	0000995
201.	PRINT 9026	0001000
202.	57 DO 58 I=1,ITOT	0001005
203.	B(I)=0.0	0001010
204.	58 CONTINUE	0001015
205.	DFIED=1.	0001020
206.	DFCSED=1.	0001025
207.	DFED=1.	0001030
208.	DFID2=1.	0001035
209.	DFCSD2=1.	0001040
210.	DFD2=1.	0001045
211.	C	0001050
212.	C CALCULATE BWR PRIMARY COOLANT CONCENTRATIONS	0001055
213.	DO 2251 I=1,ITOT	0001060
214.	2251 PCONC(I)=BCONC(I)	0001065
215.	POWA=POW1	0001070
216.	PCVOA=PCVOL*1E6	0001075
217.	LETDWA=LETDOWN*1E6	0001080
218.	STMFA=STMFR*1E6	0001085
219.	FFCDA=FFCDM	0001090
220.	C CHECK TO SEE IF PLANT PARAMETERS ARE WITHIN SPECIFIED RANGES	0001095
221.	IF(FFCDA.LT.0.99) FFCDA=0.18	0001100
222.	IF(ABS(POWA-3400).GT.400.1)GO TO 252	0001105
223.	IF(ABS(PCVOA-3.8E5).GT.0.4001E5)GO TO 252	0001110
224.	IF(ABS(LETDWA-1.3E5).GT.0.2001E5)GO TO 252	0001115
225.	IF(ABS(STMFA-1.5E7).GT.0.2001E7)GO TO 252	0001120
226.	IF(FFCDA.GT.0.99) GO TO 252	0001125
227.	GO TO 256	0001130
228.	C CALCULATE BWR ADJUSTMENT FACTORS	0001135
229.	252 RHAL2=(LETDWA*0.9+FFCDA*STMFA*PC*0.9)/PCVOA	0001140
230.	IF(FFCDA.GT.0.99) GO TO 299	0001145
231.	FFCDA = 0.01	0001150
232.	299 CONTINUE	0001155
233.	RCSR2=(LETDWA*0.5+FFCDA*STMFA*5E-4)/PCVOA	0001160
234.	RCFP2=(LETDWA*0.9+FFCDA*STMFA*9E-4)/PCVOA	0001165
235.	RK2=111.76*POWA/PCVOA	0001170
236.	DO 255 J=1,ITOT	0001175
237.	IF(PCONC(J).EQ.0.0) GO TO 255	0001180
238.	NZ=NUCL(J)/10000	0001185
239.	DL=DIS(J)*3600	0001190
240.	IF (NZ.EQ.53.OR.NZ.EQ.35)GO TO 253	0001195

241.	IF (NZ.EQ.37.OR.NZ.EQ.55)GO TO 254	0001200
242.	PCONC(J)=PCONC(J)*RK2*(0.3114+DL)/(RCFP2+DL)	0001205
243.	GO TO 255	0001210
244.	253 PCONC(J)=PCONC(J)*RK2*(0.3612+DL)/(RHAL2+DL)	0001215
245.	GO TO 255	0001220
246.	254 PCONC(J)=PCONC(J)*RK2*(0.1730+DL)/(RCSR2+DL)	0001225
247.	255 CONTINUE	0001230
248.	256 PCVOL=PCVOL*1000000./62.4	0001235
249.	LETDWN=LETDWN*2000.	0001240
250.	STMFR=STMFR*2851.	0001245
251.	DO 2255 J=1,ITOT	0001250
252.	IF (PCONC(J).GT.0.0)PCONC(J)=PCONC(J)/(DIS(J)*1.6283E13)	0001255
253.	2255 CONTINUE	0001260
254.	IF(REGENT.GT.0.0) GO TO 257	0001265
255.	CALL EFFTAB	0001270
256.	GO TO 30	0001275
257.	C	0001280
258.	C COMPUTE REMOVAL CONSTANT FOR CONDENSATE DEMINERALIZER IN BWR	0001285
259.	257 FFCDM = FFCDA	0001290
260.	IF(FFCDM.EQ.0.1) GO TO 300	0001295
261.	GO TO 301	0001300
262.	300 FFCDM = 0.01	0001305
263.	301 CONTINUE	0001310
264.	CCBDM=0.9*STMFR*FPEF/(PCVOL*7.48*60.)*FFCDM	0001315
265.	CSBDM=0.5*STMFR*FPEF/(PCVOL*7.48*60.)*FFCDM	0001320
266.	IF(FFCDM.EQ.0.01) GO TO 304	0001325
267.	CCBDI = CCBDM	0001330
268.	GO TO 305	0001335
269.	304 CONTINUE	0001340
270.	FFCDM = 0.1	0001345
271.	CCBDI = 0.9*STMFR*FPEF/(PCVOL*7.48*60.)*FFCDM	0001350
272.	305 CONTINUE	0001355
273.	DO 258 I=1,ITOT	0001360
274.	NZ=NUCL(I)/10000	0001365
275.	PR(I)=CCBDM	0001370
276.	IF(NZ.EQ.53.OR.NZ.EQ.35)PR(I)=CCBDI*HEF/FPEF	0001375
277.	IF(NZ.EQ.37.OR.NZ.EQ.55)PR(I)=CSBDM	0001380
278.	XZHJ=PCONC(I)*PR(I)*PCVOL*0.02832	0001385
279.	B(I)=XZHJ	0001390
280.	XZH(I)=XZHJ*86400.	0001395
281.	258 CONTINUE	0001400
282.	XZERO(I)=0.	0001405
283.	C CALCULATE INVENTORIES ON BWR CONDENSATE RESINS	0001410
284.	290 T(I)=REGENT	0001415
285.	CALL SOLVE	0001420
286.	DO 295 I=1,ITOT	0001425
287.	295 RINV(I)=XTEMP(I)	0001430
288.	CALL EFFTAB	0001435
289.	GO TO 30	0001440
290.	C	0001445
291.	C FORMATS FORMATS FORMATS	0001450
292.	C	0001455
293.	9000 FORMAT(20A4)	0001460
294.	9001 FORMAT(10E8.2)	0001465
295.	9002 FORMAT(8E10.3)	0001470
296.	9003 FORMAT(5(I6,E9.2),I5)	0001475
297.	9004 FORMAT(16I5)	0001480
298.	9005 FORMAT('0MMN OR MOUT EXCEEDS DIMENSIONS')	0001485
299.	9006 FORMAT('0MOUT SHOULD NOT EXCEED MMN BY MORE THAN 10'/)	0001490
300.	9007 FORMAT(8(E8.2,I2))	0001495

301.	9008	FORMAT(20I4)	0001500
302.	9009	FORMAT(10A4,F7.0,A3,F10.3)	0001505
303.	9010	FORMAT(32X,8A4,12X,A4)	0001510
304.	9012	FORMAT(16X,14A4,F8.4)	0001515
305.	9013	FORMAT(15X,4A4,A2,8X,F8.0,1X,A4,A2,F5.3)	0001520
306.	9014	FORMAT(20X,F8.0,2(5X,F8.0))	0001525
307.	9015	FORMAT(27X,F6.2,14X,F6.2,18X,F6.2)	0001530
308.	9016	FORMAT('0',30X,'FRACTION FRACTION COLLECTION DECAY'/8X,'STREAM	0001535
309.	1	FLOW RATE OF PCA DISCHARGED TIME TIME',10X,'DECONTA	0001540
310.	2	MINATION FACTORS'/20X,'(GAL/DAY)',23X,'(DAYS) (DAYS)',7X,	0001545
311.	3	'I',8X,'CS',6X,'OTHERS')	0001550
312.	9017	FORMAT(2X,4A4,A2,1PE9.2,1X,4(0PF8.3,2X),3(1PE9.2,1X))	0001555
313.	9020	FORMAT(16X,14A4,F8.4)	0001560
314.	9021	FORMAT(79X,I1)	0001565
315.	9022	FORMAT(16X,13A4,A2,F10.5)	0001570
316.	9023	FORMAT(16X,'THERE IS A CRYOGENIC DISTILLATION COLUMN'/20X,'IODINE	0001575
317.	1	AND XENON DECONTAMINATION FACTOR',T71,'10000.'/20X,'KRYPTON DECONT	0001580
318.	2	AMINATION FACTOR',T72,'4000.'/20X,'KRYPTON AND XENON HOLDUP TIME (	0001585
319.	3	DAYS)',T74,'90.')	0001590
320.	9024	FORMAT(16X,'THERE IS NO CHARCOAL DELAY SYSTEM')	0001595
321.	9025	FORMAT(16X,'THERE IS A CHARCOAL DELAY SYSTEM'/20X,'KRYPTON HOLDUP	0001600
322.	1	TIME (DAYS)',T72,F9.5/20X,'XENON HOLDUP TIME (DAYS)',T72,F9.5/	0001605
323.	2	20X,'KRYPTON DYNAMIC ADSORPTION COEFFICIENT (CM3/GM)',T72,F9.5/	0001610
324.	3	20X,'XENON DYNAMIC ADSORPTION COEFFICIENT(CM3/GM)',T71,F10.5/20X,	0001615
325.	4	'MASS OF CHARCOAL(THOUSAND LBS)',T72,F9.5)	0001620
326.	9026	FORMAT(1H1)	0001625
327.	9027	FORMAT(16X,'PLANT CAPACITY FACTOR',T75,'0.80')	0001630
328.	9028	FORMAT(16X,'PERCENT FUEL WITH CLADDING DEFECTS',T75,F6.4)	0001635
329.	9029	FORMAT(16X,'MASS OF WATER IN STEAM GENERATORS (THOUSAND LBS)',T73,	0001640
330.	1	F8.4)	0001645
331.	9030	FORMAT(16X,'FISSION PRODUCT CARRY-OVER FRACTION',T75,F6.4/16X,	0001650
332.	1	'HALOGEN CARRY-OVER FRACTION',T75,F6.4)	0001655
333.	9032	FORMAT(2X,7A4,F7.0,3A4,A1,F5.3,3A4,A3,I2,2A4)	0001660
334.	9034	FORMAT(2X,'BLOWDOWN',10X,1PE9.2,14X,0PF5.3,2X,2(F8.3,2X),	0001665
335.	1	3(1PE9.2,1X))	0001670
336.	9035	FORMAT(2X,'UNTREATED BLOWDOWN',1PE9.2,11X,' 1.000 0.0	0001675
337.	1	0.0 1.00E 00 1.00E 00 1.00E 00')	0001680
338.	9036	FORMAT(16X,'THERE IS NOT A CONDENSATE DEMINERALIZER')	0001685
339.	9037	FORMAT(72X,F8.2)	0001690
340.	9038	FORMAT(2X,'REGENERANT SOLS ',1PE9.2,14X,0PF5.3,2X,2(F8.3,2X),	0001695
341.	1	3(1PE9.2,1X))	0001700
342.	9039	FORMAT(16X,'THERE IS A CRYOGENIC OFFGAS SYSTEM')	0001705
343.	9040	FORMAT(16X,'THERE IS NO CRYOGENIC OFFGAS SYSTEM')	0001710
344.	9041	FORMAT(16X,'PRIMARY TO SECONDARY LEAK RATE (LBS/DAY)',T73,'100.')	0001715
345.	9045	FORMAT (/,'0 LIQUID WASTE INPUTS')	0001720
346.	9046	FORMAT (/,'0 GASEOUS WASTE INPUTS')	0001725
347.	9048	FORMAT('0',15X,'THERE IS NOT AN ON-SITE LAUNDRY')	0001730
348.	9051	FORMAT(16X,'BLOWDOWN RATE (THOUSAND LBS/HR)',25X,F8.4)	0001735
349.	9052	FORMAT(16X,'THERE IS CONTINUOUS STRIPPING OF FULL LETDOWN FLOW')	0001740
350.	9053	FORMAT (16X,'THERE IS NOT CONTINUOUS STRIPPING OF FULL LETDWN FLOW'	0001745
351.	1	)	0001750
352.	9054	FORMAT(16X,'FLOW RATE THROUGH GAS STRIPPER (GPM)',20X,F8.4)	0001755
353.	9055	FORMAT(36X,F8.4,35X,I1)	0001760
354.	9056	FORMAT(15X,4A4,A2,8X,F8.0)	0001765
355.	9060	FORMAT(16X,4A4,10X,F4.0,6X,F4.0)	0001770
356.	9061	FORMAT (16X,4A4,'IODINE RELEASE FRACTION',16X,F10.5/32X,'PARTICULA	0001775
357.	1	TE RELEASE FRACTION',10X,F10.5)	0001780
358.	9062	FORMAT(16X,4A4,10X,F4.0,6X,F4.0)	0001785
359.	9063	FORMAT(16X,4A4,'IODINE RELEASE FRACTION',16X,F10.5/32X,'PARTICULAT	0001790
360.	1	TE RELEASE FRACTION',10X,F10.5)	0001795

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361. 9064 FORMAT(16X,'STEAM LEAK TO TURBINE BLDG (LBS/HR)',19X,F10.5) 0001800
362. 9065 FORMAT(16X,4A4,6X,A3) 0001805
363. 9066 FORMAT(16X,4A4,4X,'PARTICULATE RELEASE FRACTION',6X,F10.5) 0001810
364. 9067 FORMAT(16X,5A4,10X,A3,6X,A3) 0001815
365. 9068 FORMAT(16X,5A4,'IODINE RELEASE FRACTION',11X,F10.5/36X,'PARTICULAT 0001820
366. 1E RELEASE FRACTION',6X,F10.5) 0001825
367. 9069 FORMAT(16X,5A4,9X,F8.2,9X,A3,6X,A3) 0001830
368. 9070 FORMAT(16X,5A4,'RATE(CFM)',27X,F8.2/16X,5A4,'IODINE RELEASE FRACTI 0001835
369. 10N',11X,F10.5/36X,'PARTICULATE RELEASE FRACTION',6X,F10.5) 0001840
370. 9071 FORMAT(16X,5A4,10X,A3,6X,A3,19X,F3.0) 0001845
371. 9072 FORMAT(16X,'FREQUENCY OF CNTMT BLDG HIGH VOL PURGE (TIMES/YR)', 0001850
372. 1T74,F6.0) 0001855
373. 9073 FORMAT(16X,'THERE IS NOT A CNTMT BLDG LOW VOL PURGE') 0001860
374. 9075 FORMAT(16X,'THERE IS CONTINUOUS LOW VOL PURGE OF VOL. CONTROL TK') 0001865
375. END 0001870
376. SUBROUTINE EFFTAB 0001875
377. INTEGER*2 NAME(3) 0001880
378. INTEGER*2 LOC,NON0,KD 0001885
379. REAL*4 LETDWN,NOGEN 0001890
380. REAL*4 LETDWA 0001895
381. DIMENSION NZMBDM(26),NZCBDM(26),REACTR(7) 0001900
382. DIMENSION TURBDR(800),DWCON2(800),EDCONC(800) 0001905
383. DIMENSION LAUNDY(12),WLAUND(12) 0001910
384. COMMON/EQ/XZERO(800), XZH(800),XTEMP(800),XNEW(10,800), 0001915
385. 1 B(800),D(800) 0001920
386. COMMON/FLUXN/T(20),POWER(10),TOCAP(800),FISS(100),DIS(800),ILITE, 0001925
387. 1 IACT,IFP,ITOT,NON,INPT 0001930
388. COMMON/OUT/NUCL(800),TITLE(20),Q(800),FG(800),CUTOFF(7), 0001935
389. 1 POW,BURNUP,FLUXB,MSTAR,ALPHAN(100),SPONF(100),ABUND(500), 0001940
390. 2 BASIS(10),TCONST,TUNIT 0001945
391. COMMON/COOL/REACTR,POW1,TYPE,PCVOL,LETDWN,NDGAS,SCVOL,STMVOL,NOGEN 0001950
392. 1 ,NPURGE,NVCS PG,SBLDR,GASDLA,STLKR,BLWDWN,EJCTR,WLKRAT, 0001955
393. 2 GASLKR,CONDLR,DFMBDM,DFCBDM,NZMBDM,NZCBDM,NE,PF, 0001960
394. 3 STMFR,FEFF,HEF,FFCDM,DFMBCS,CBFLR,DFI,DFCS,DF, 0001965
395. 4 EDFLR,DFIED,DFCSED,DFED,DWFLR,DFIDW,DFCSDW,DFDW,DILUT 0001970
396. 5 ,SBA,EDA,DWA,CWFLR,CMWFR,CWA,CMA,DFCM,DFICM,DFCSCM, 0001975
397. 6 DFCW,DFICW,DFCSW,MHOLD,MHOLDE,MHOLDW,MHOLCM,MHOLDC 0001980
398. 7 ,BDTFR,DFIBD,DFCSBD,DFBD,MHOLDB,REGENT, 0001985
399. 8 SBFD,DFMO,DFY,EDFD,DFMOED,DFYED,DWFD,DFMODW,DFYDW, 0001990
400. 9 DFM0BD,DFYBD,CWFD,DFMOCW,DFYCW,CMFD,DFMOCM,DFYCM 0001995
401. A ,TS,TE,TD,TB,TC,TCM,TSTORC,TSTORD,TSTORB,TMSC,DWFL2,DW2,DWF2, 0002000
402. B T2,TSTOR2,DFID2,DFCSD2,DFMOD2,DFYD2,DFD2,PFLAUN 0002005
403. COMMON/APCOOL/RGWFR,DFIRG,DFCSRG,DFRG,TRG,TSTORR,RGFD 0002010
404. COMMON/BDTES/RFRRT 0002015
405. COMMON/FLEX/FLUX(10),MMN,MOUT,INDEX,QXN,AXN,ERR,NOBLND,MZERO 0002020
406. COMMON/CONC/PCONC(800),DWCONC(800),CWCONC(800),CMCONC(800), 0002025
407. 1 SCON(800),RINV(800) 0002030
408. COMMON/MPC/MPCTAB,AMPC(800),WMPC(800) 0002035
409. EQUIVALENCE (XZERO(1),TURBDR(1)),(XZH(1),DWCON2(1)) 0002040
410. DATA LAUNDY/250540,270580,270600,400950,410950,441030,441060, 0002045
411. 1 471101,551310,551340,551370,581440/ 0002050
412. DATA WLAUND/0.001,0.004,0.0087,0.0014,0.002,0.00014,0.0024, 0002055
413. 1 0.00044,0.000062,0.013,0.024,0.0052/ 0002060
414. DO 10 I=1,ITOT 0002065
415. D(I)=-DIS(I) 0002070
416. 10 H3BWR = 0.03 * POW1 0002075
417. TRITPR = H3BWR * 0.5 0002080
418. TRITCO=.01 0002085
419. 20 DO 30 J=1,ITOT 0002090
420. CWCONC(J)=0.0 0002095

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421.		EDCONC(J)=0.0	0002100
422.		DWCONC(J)=0.0	0002105
423.		DWCON2(J)=0.0	0002110
424.		CMCONC(J)=0.0	0002115
425.		NZ=NUCL(J)/10000	0002120
426.		IF(NZ.EQ.36.OR.NZ.EQ.54) GO TO 30	0002125
427.		CWCONC(J)=PCONC(J)*CWA	0002130
428.		EDCONC(J)=PCONC(J)*EDA	0002135
429.		DWCONC(J)=PCONC(J)*DWA	0002140
430.		DWCON2(J)=PCONC(J)*DW2	0002145
431.		CMCONC(J)=PCONC(J)*CMA	0002150
432.	30	CONTINUE	0002155
433.	C		0002160
434.	C	CALCULATE RADIOACTIVITY AFTER COLLECTION AT A CONSTANT RATE	0002165
435.	C		0002170
436.		CALL COLECT(TC*86400.,CWCONC,ILITE,ITOT)	0002175
437.		CALL COLECT(TE*86400.,EDCONC,ILITE,ITOT)	0002180
438.		CALL COLECT(TD*86400.,DWCONC,ILITE,ITOT)	0002185
439.		CALL COLECT(T2*86400.,DWCON2,ILITE,ITOT)	0002190
440.		CALL COLECT(TCM*86400.,CMCONC,ILITE,ITOT)	0002195
441.	40	IF(REGENT.LE.0.0) GO TO 50	0002200
442.		CALL STORAG(TRG*86400.,RINV,ILITE,ITOT)	0002205
443.	50	DO 100 I=1,ITOT	0002210
444.		NZ=NUCL(I)/10000	0002215
445.		TURBDR(I)=1991.*5.*SCON(I)	0002220
446.		IF(NZ.EQ.1) GO TO 100	0002225
447.		IF(NZ.EQ.35.OR.NZ.EQ.53) GO TO 60	0002230
448.		IF(NZ.EQ.37.OR.NZ.EQ.55) GO TO 70	0002235
449.	C		0002240
450.	C	CHEMICAL TREATMENT FOR OTHER CATIONS	0002245
451.	C		0002250
452.		CWCONC(I)=CWCONC(I)/DFCW	0002255
453.		EDCONC(I)=EDCONC(I)/DFED	0002260
454.		DWCONC(I)=DWCONC(I)/DFDW	0002265
455.		DWCON2(I)=DWCON2(I)/DFD2	0002270
456.		CMCONC(I)=CMCONC(I)*(1.0-BDTR*(1.0-CMFD/DFCM))	0002275
457.	C	TO TREAT PWR TURBINE BUILDING FLOOR DRAINS THROUGH DIRTY WASTE	0002280
458.	C	SYSTEM, DELETE C FOR COMMENT ON CARDS BELOW, UNTIL NEXT MESSAGE	0002285
459.		RINV(I)=RINV(I)/DFRG	0002290
460.		TURBDR(I)=1991.*5.*SCON(I)*FPEF	0002295
461.	C	TURBDR(I)=1991.*5.*SCON(I)*FPEF/DFDW	0002300
462.		GO TO 100	0002305
463.	C		0002310
464.	C	CHEMICAL TREATMENT FOR ANIONS	0002315
465.	C		0002320
466.	60	CWCONC(I)=CWCONC(I)/DFICW	0002325
467.		EDCONC(I)=EDCONC(I)/DFIED	0002330
468.		DWCONC(I)=DWCONC(I)/DFIDW	0002335
469.		DWCON2(I)=DWCON2(I)/DFID2	0002340
470.		CMCONC(I)=CMCONC(I)*(1.0-BDTR*(1.0-CMFD/DFICM))	0002345
471.		RINV(I)=RINV(I)/DFIRG	0002350
472.		TURBDR(I)=1991.*5.*SCON(I)*HEF	0002355
473.	C	TURBDR(I)=1991.*5.*SCON(I)*HEF/DFIDW	0002360
474.		GO TO 100	0002365
475.	C		0002370
476.	C	CHEMICAL TREATMENT FOR RB AND CS	0002375
477.	C		0002380
478.	70	CWCONC(I)=CWCONC(I)/DFCSCW	0002385
479.		EDCONC(I)=EDCONC(I)/DFCSED	0002390
480.		DWCONC(I)=DWCONC(I)/DFCSDW	0002395

481.		DWCON2(I)=DWCON2(I)/DFCSD2	0002400
482.		CMCONC(I)=CMCONC(I)*(1.0-BDTRF*(1.0-CMFD/DFCSCM))	0002405
483.		RINV(I)=RINV(I)/DFC5RG	0002410
484.		TURBDR(I)=1991.*5.*SCON(I)*FPEF	0002415
485.	C	TURBDR(I)=1991.*5.*SCON(I)*FPEF/DFCSDW	0002420
486.	100	CONTINUE	0002425
487.	C		0002430
488.	C	COMPUTE RADIOACTIVE DECAY DURING PROCESSING AND SAMPLING	0002435
489.	C		0002440
490.		CALL STORAG(TSTORC*86400.,CWCONC,ILITE,ITOT)	0002445
491.		CALL STORAG(TS *86400.,EDCONC,ILITE,ITOT)	0002450
492.		CALL STORAG(TSTORD*86400.,DWCONC,ILITE,ITOT)	0002455
493.		CALL STORAG(TSTOR2*86400.,DWCON2,ILITE,ITOT)	0002460
494.		CALL STORAG(TSTORB*86400.,CMCONC,ILITE,ITOT)	0002465
495.		CALL STORAG(TSTORR*86400.,RINV,ILITE,ITOT)	0002470
496.		CALL STORAG(21600.,TURBDR,ILITE,ITOT)	0002475
497.		DO 130 I=1,ITOT	0002480
498.		NZ=NUCL(I)/10000	0002485
499.		ABLOW=0.0	0002490
500.		IF(REGENT.LT.0.001) GO TO 110	0002495
501.		ABLOW=RINV(I)*365.5*RGFD/REGENT	0002500
502.	110	CONTINUE	0002505
503.	120	ABLOW=ABLOW+CMWFR*1.382*CMCONC(I)	0002510
504.	130	CMCONC(I)=ABLOW	0002515
505.	133	CWFR=CWFLR*1.382*CWFD	0002520
506.		DWFR=DWFLR*DWFD*1.382	0002525
507.		TLR=(CWFR+DWFR)+1.382*(CMFD*CMWFR+RGFD*RGWFR)	0002530
508.		TRITRL=TRITCO*TLR	0002535
509.		IF(TRITRL.GT.0.5*TRITPR)TRITRL=0.5*TRITPR	0002540
510.		RTRITR=TRITRL+0.5	0002545
511.		ITRITR=RTRITR	0002550
512.	136	TOTAL=0.0	0002555
513.		DO 140 I=1,ITOT	0002560
514.		NZ=NUCL(I)/10000	0002565
515.		IF(NZ.EQ.36.OR.NZ.EQ.54) GO TO 140	0002570
516.		DISI=DIS(I)*1.6283E13	0002575
517.		CWCONC(I)=DISI*(CWCONC(I)*CWFR+EDCONC(I)*EDFLR)	0002580
518.		DWCONC(I)=(DWCONC(I)*DWFR+DWCON2(I)*DWFR2)*DISI	0002585
519.		CMCONC(I)=CMCONC(I)*DISI	0002590
520.		TURBDR(I)=TURBDR(I)*DISI	0002595
521.		IF(NUCL(I).EQ.10030) GO TO 140	0002600
522.		TOTAL =TOTAL +CWCONC(I)+DWCONC(I)+CMCONC(I)+TURBDR(I)	0002605
523.	140	CONTINUE	0002610
524.		AOI=0.1	0002615
525.		AOR=(AOI+TOTAL)/TOTAL	0002620
526.	150	SCNORM=0.0	0002625
527.		SAPRIM=0.0	0002630
528.		SSEC=0.0	0002635
529.		SCWAST=0.0	0002640
530.		SDWAST=0.0	0002645
531.		SABLOW=0.0	0002650
532.		STB=0.0	0002655
533.		STOTAL =0.0	0002660
534.		SPER=0.0	0002665
535.		PAPRIM=0.0	0002670
536.		PSEC=0.0	0002675
537.		PCWAST=0.0	0002680
538.		PDWAST=0.0	0002685
539.		PABLOW=0.0	0002690
540.		PTB=0.0	0002695

541.	PTOTAL =0.0	0002700
542.	PPER=0.0	0002705
543.	PNORM=0.0	0002710
544.	TLAUND=0.0	0002715
545.	CTOTAL=0.0	0002720
546.	PRINT 9001, REACTR	0002725
547.	PRINT 9006	0002730
548.	PRINT 9010	0002735
549.	KOUNTR=1	0002740
550.	I1=ILITE+IACT+1	0002745
551.	L=1	0002750
552.	DO 180 I=1,ITOT	0002755
553.	IF(I.EQ.I1) PRINT 9011	0002760
554.	NZ=NUCL(I)/10000	0002765
555.	IF(NZ.EQ.36.OR.NZ.EQ.54) GO TO 180	0002770
556.	IF(NZ.EQ.1) GO TO 180	0002775
557.	DISI=DIS(I)*1.6283E+13	0002780
558.	APRIM=PCONC(I)*DISI	0002785
559.	ASEC=0.0	0002790
560.	CWASTE=CWCONC(I)	0002795
561.	DWASTE=DWCONC(I)	0002800
562.	ABLOW=CMCONC(I)	0002805
563.	TB=TURBDR(I)	0002810
564.	TOTAL=CWASTE+DWASTE+ABLOW+TB	0002815
565.	TOTALN=TOTAL*AOR	0002820
566.	NUCLI=NUCL(I)	0002825
567.	XLAUND=0.0	0002830
568.	TOTALG=TOTALN	0002835
569.	IF(NUCLI.NE.LAUNDY(L)) GO TO 155	0002840
570.	XLAUND=WLAUND(L)*PFLAUN	0002845
571.	TOTALG=TOTALN+WLAUND(L)*PFLAUN	0002850
572.	L=L+1	0002855
573.	155 CONTINUE	0002860
574.	IF (TOTALG.LT.1E-5) GO TO 156	0002865
575.	ISUB=2	0002870
576.	IF (TOTALG.GT.1.)ISUB=1	0002875
577.	DIV=10.*(INT(ALOG10(TOTALG))-ISUB)	0002880
578.	TOTALG=AIN(TOTALG/DIV+0.5)*DIV	0002885
579.	156 CONTINUE	0002890
580.	IF(NUCL(I).EQ.10030) TOTALN=TOTAL	0002895
581.	IF(NZ.EQ.1) GO TO 160	0002900
582.	SAPRIM=SAPRIM+APRIM	0002905
583.	SSEC=SSEC+ASEC	0002910
584.	SABLOW=SABLOW+ABLOW	0002915
585.	SCWAST=SCWAST+CWASTE	0002920
586.	SDWAST=SDWAST+DWASTE	0002925
587.	STB=STB+TB	0002930
588.	STOTAL=STOTAL+TOTAL	0002935
589.	SCNORM=SCNORM+TOTALN	0002940
590.	TLAUND=TLAUND+XLAUND	0002945
591.	CTOTAL=CTOTAL+TOTALG	0002950
592.	160 IF(TOTALG.LT.1.E-5) GO TO 180	0002955
593.	IF(MOD(KOUNTR,50).NE.0) GO TO 170	0002960
594.	PRINT 9000, REACTR	0002965
595.	PRINT 9006	0002970
596.	170 CALL NOAH(NUCL(I),NAME)	0002975
597.	THALF=8.0225E-6/DIS(I)	0002980
598.	PRINT 9007, NAME,THALF,APRIM,CWASTE,DWASTE,	0002985
599.	1 ABLOW,TOTAL,TOTALN,XLAUND,TOTALG	0002990
600.	KOUNTR=KOUNTR+1	0002995

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601. IF(NZ.EQ.1) GO TO 180
602. PAPRIM=PAPRIM+APRIM
603. PSEC=PSEC+ASEC
604. PCWAST=PCWAST+CWASTE
605. PDWAST=PDWAST+DWASTE
606. PABLOW=PABLOW+ABLOW
607. PTB=PTB+TB
608. PTOTAL=PTOTAL+TOTAL
609. PNORM=PNORM+TOTALN
610. 180 CONTINUE
611. PAPRIM=SAPRIM-PAPRIM
612. PSEC=SSEC-PSEC
613. PCWAST=SCWAST-PCWAST
614. PDWAST=SDWAST-PDWAST
615. PABLOW=SABLOW-PABLOW
616. PTB=STB-PTB
617. PTOTAL=STOTAL-PTOTAL
618. PNORM=SCNORM-PNORM
619. ISUBC=2
620. IF (CTOTAL.GT.1.)ISUBC=1
621. DIV=10.**((INT(ALOG10(CTOTAL))-ISUBC)
622. CTOTAL=AINT(CTOTAL/DIV+0.5)*DIV
623. IF (PNORM.LT.1E-5) GO TO 184
624. DIV=10.**((INT(ALOG10(PNORM))-2)
625. PNORMT=AINT(PNORM/DIV+0.5)*DIV
626. 184 PNORMT=PNORM
627. PRINT 9008, PAPRIM,PCWAST,PDWAST,PABLOW,PTOTAL,PNORM,PNORMT
628. PRINT 9009, SAPRIM,SCWAST,SDWAST,SABLOW,STOTAL,SCNORM,TLAUND,
629. 1 CTOTAL
630. 195 PRINT 9012, ITRITR
631. 9000 FORMAT(1H1,20X,7A4,' LIQUID EFFLUENTS (CONTINUED)')
632. 9001 FORMAT(1H1,20X,7A4,' LIQUID EFFLUENTS')
633. 9003 FORMAT(1X,A2,I3,A1,2X,1PE9.2,2(2X,E9.2,2X),5(1X,0PF9.5,1X),2(1X,0P
634. 1 F9.5,1X),0PF10.5)
635. 9006 FORMAT(1H0,17X,'CONCENTRATION ANNUAL RELEASES TO DISCHARGE CAN
636. 1AL'/18X,' IN PRIMARY ',43(' '), ' ADJUSTED DETERGENT TOTAL
637. 2 '/' NUCLEIDE HALF-LIFE COOLANT HIGH PURITY LOW PURITY CHEMICA
638. 3L TOTAL LWS TOTAL WASTES '/10X,'(DAYS) (MICRO C
639. 4I/ML)',3(' (CURIES) '), ' (CURIES) (CI/YR) (CI/YR) (CI/Y
640. 5R)')
641. 9007 FORMAT(1X,A2,I3,A1,2X,1PE9.2, 2X,E9.2,2X ,4(1X,0PF9.5,1X),2(1X,0P
642. 1F9.5,1X),1X,0PF9.5)
643. 9008 FORMAT(1X,'ALL OTHERS',9X,1PE9.2,2X,4(1X,0PF9.5,1X),1X,0PF9.5,4X,
644. 1 '0.0',6X,0PF9.5)
645. 9009 FORMAT(' TOTAL',/,' (EXCEPT TRITIUM) ',1PE9.2,2X,4(1X,0PF9.5,1X),
646. 1 2(1X,0PF9.5,1X),1X,0PF9.5)
647. 9010 FORMAT(' CORROSION AND ACTIVATION PRODUCTS')
648. 9011 FORMAT('0FISSION PRODUCTS')
649. 9012 FORMAT (1H0,1X,'TRITIUM RELEASE',12X,I3,' CURIES PER YEAR')
650. RETURN
651. END
652. BLOCK DATA
653. COMMON /CONB/BCONC(800)
654. DATA BCONC/2*0.0,0.01,33*0.0,
655. 1 1E-2,13*0.0,2E-4,53*0.0,6E-3,4*0.0,7E-5,0.0,5E-2,3*0.0,
656. 21E-3,3*0.0,3E-5,0.0,2E-4,2*0.0,4E-4,7*0.0,1E-6,0.0,3E-4,2*0.0,3E-2
657. 3,4*0.0,2E-4,3*0.0,2E-3,98*0.0,3E-4,64*0.0,7E-3,63*0.0,6E-3,4*0.0,7
658. 4E-3,2*0.0,3E-3,19*0.0,5E-3,1E-4,3*0.0,7E-6,5*0.0,4E-3,0.0,4E-5,3*0
659. 5.0,1E-2,6E-3,4*0.0,4E-3,11*0.0,8E-6,0.0,8E-6,6*0.0,6E-6,5*0.0,4E-3
660. 6,2*0.0,2E-3,2E-2,8*0.0,9E-2,7*0.0,2E-5,3*0.0,8E-2,6*0.0,2E-3,4*0.0

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661.      7,3E-6,21*0.,1E-6,104*0.0,4E-5,13*0.,1E-4,0.,3.7E-3,5*0.,1E-5,6E- 0003300
662.      82,4*0.0,5E-2,5*0.0,1E-1,2*0.0,3E-5,2*0.0,5E-2,8*0.0,8E-5,3*0.0,2E- 0003305
663.      95,4*0.0,1E-2,4*0.0,1E-2,3*0.0,4E-4,4*0.0,1E-2,0.0,3E-5,3*0.0,6E-3, 0003310
664.      115E-3,7*0.0,3E-5,4E-5,2*0.0,3E-6,10*0.0,3E-6,81*0.0/ 0003315
665.      END 0003320
666.      SUBROUTINE SOLVE 0003325
667.      COMMON/EQ/XZERO(800), XZH(800),XTEMP(800),XNEW(10,800), 0003330
668.      1 B(800),D(800) 0003335
669.      COMMON/FLEX/FLUX(10),MMN,MOUT,INDEX,QXN,AXN,ERR,NOBLND,MZERO 0003340
670.      COMMON/PROCSS/ MPROS,PRATE(8),NOPROS(8),NZPROS(8,20),PR(800) 0003345
671.      COMMON/FLUXN/T(20),POWER(10),TOCAP(800),FISS(100),DIS(800),ILITE, 0003350
672.      1 IACT,IFP,ITOT,NON,INPT 0003355
673.      COMMON/OUT/NUCL(800),TITLE(20),Q(800),FG(800),CUTOFF(7), 0003360
674.      1 POW,BURNUP,FLUXB,MSTAR,ALPHAN(100),SPONF(100),ABUND(500), 0003365
675.      2 BASIS(10),TCONST,TUNIT 0003370
676.      DO 10 I=1,ITOT 0003375
677.      D(I)=-DIS(I) 0003380
678.      10 XTEMP(I)=0.0 0003385
679.      DELT=T(1)*TCONST 0003390
680.      CALL DECAY(1,DELT,ITOT) 0003395
681.      CALL TERM(DELT,1,ILITE,ITOT) 0003400
682.      CALL EQUIL(1,ITOT) 0003405
683.      DO 30 I=1,ITOT 0003410
684.      30 XTEMP(I)=XNEW(1,I) 0003415
685.      RETURN 0003420
686.      END 0003425
687.      SUBROUTINE TERM(T,M,ILITE,ITOT) 0003430
688.      C 0003435
689.      C TERM ADDS ONE TERM TO EACH ELEMENT OF THE SOLUTION VECTOR 0003440
690.      C CSUM(J) IS THE CURRENT APPROXIMATION TO XNEW(M,J) 0003445
691.      C CIM0(J) IS THE VECTOR CONTAINING THE LAST TERM ADDED TO EACH 0003450
692.      C ELEMENT OF CSUM(J) 0003455
693.      C CIMN(J) IS THE VECTOR CONTAINING 1/TON TIMES THE NEW TERM TO BE 0003460
694.      C ADDED TO CSUM(J) 0003465
695.      C CIMN(J) IS GENERATED FROM CIM0(J) BY A RECURSION RELATION: 0003470
696.      C CIMN(J)= SUM OVER L OF (AP(J,L)*CIM0(L)) 0003475
697.      C AP(I,J) IS THE REDUCED TRANSITION MATRIX FOR THE LONG-LIVED 0003480
698.      C NUCLIDES 0003485
699.      C 0003490
700.      LOGICAL*1 LONG 0003495
701.      INTEGER*2 LOC,NON0,KD 0003500
702.      INTEGER*2 LOCP(2500) 0003505
703.      INTEGER*2 NONP(800) 0003510
704.      INTEGER*2 NQ,NQU,NQUEUE 0003515
705.      REAL*8 BATE,BATM 0003520
706.      REAL*8 CIMN(800),CSUM(800),CIMNI 0003525
707.      DIMENSION AP(2500),CIMB(800),CIM0(800) 0003530
708.      DIMENSION QUB(50) 0003535
709.      COMMON/SERIES/ XP(800),XPAR(800),LONG(800) 0003540
710.      COMMON/FLEX/FLUX(10),MMN,MOUT,INDEX,QXN,AXN,ERR,NOBLND,MZERO 0003545
711.      COMMON/EQ/XZERO(800),XZH(800),XTEMP(800),XNEW(10,800), 0003550
712.      1 B(800),D(800) 0003555
713.      COMMON/MATRIX/A(2500),LOC(2500),NON0(800),KD(800) 0003560
714.      COMMON/DEBUGG/AP 0003565
715.      COMMON/TERMD/DD(100),DXP(100),QUEUE(50),NQU(50),NQUEUE(50),NQ(800) 0003570
716.      NUL=0 0003575
717.      NN=0 0003580
718.      C FIRST CONSTRUCT REDUCED TRANSITION MATRIX FOR LONG-LIVED ISOTOPES 0003585
719.      DO 220 L=1,ITOT 0003590
720.      IF(.NOT.LONG(L)) GO TO 210 0003595

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721.		NUM=NONO(L)	0003600
722.		IF(M.GT.MMN.OR.M.EQ.MZERO) NUM=KD(L)	0003605
723.		CIMB(L)=B(L)	0003610
724.		IF(NUM.LE.NUL) GO TO 210	0003615
725.		NS=NN+1	0003620
726.		N=NUL	0003625
727.		NL=NUM-NUL	0003630
728.		DO 200 N1=1,NL	0003635
729.		N=N+1	0003640
730.		J=LOC(N)	0003645
731.		DJ=-D(J)	0003650
732.	C		0003655
733.	C	THIS IS A TEST TO SEE IF ONE OF THE ASSYMPTOTIC SOLUTIONS APPLIES	0003660
734.	C		0003665
735.		IF(.NOT.LONG(J)) GO TO 10	0003670
736.		NN=NN+1	0003675
737.		AP(NN)=A(N)	0003680
738.		LOCP(NN)=J	0003685
739.		GO TO 200	0003690
740.	C		0003695
741.	C	GOING BACK UP THE CHAIN TO FIND A PARENT WHICH IS NOT IN	0003700
742.	C	EQUILIBRIUM	0003705
743.	C		0003710
744.	10	NSAVE=0	0003715
745.		QUE=A(N)/DJ	0003720
746.		DRB=1.0	0003725
747.		CIMB(L)=CIMB(L)+QUE*B(J)	0003730
748.		NQ(L)=0	0003735
749.		NQ(J)=L	0003740
750.	20	NUX=NONO(J)	0003745
751.		IF(M.GT.MMN.OR.M.EQ.MZERO) NUX=KD(J)	0003750
752.		NUF=0	0003755
753.		IF(J.GT.1) NUF=NONO(J-1)	0003760
754.		NX=NUX-NUF	0003765
755.		IF(NX.LT.1) GO TO 190	0003770
756.		K=NUF	0003775
757.		DO 180 KK=1,NX	0003780
758.		K=K +1	0003785
759.		J1=LOC(K)	0003790
760.		DJ=-D(J1)	0003795
761.		KP=J	0003800
762.	30	IF(J1.EQ.NQ(KP)) GO TO 180	0003805
763.		KP=NQ(KP)	0003810
764.		IF(KP.NE.0) GO TO 30	0003815
765.		AKDJQ=QUE*A(K)/DJ	0003820
766.		IF(.NOT.LONG(J1)) GO TO 160	0003825
767.		TRM=1.0-XP(J1)	0003830
768.		IF(TRM.LT.1.0E-6) GO TO 120	0003835
769.		NQ(J1)=J	0003840
770.		I=1	0003845
771.		KP=J1	0003850
772.	40	DD(I)=-D(KP)	0003855
773.		DXP(I)=XP(KP)	0003860
774.		KP=NQ(KP)	0003865
775.		IF(KP.EQ.0) GO TO 50	0003870
776.		I=I+1	0003875
777.		IF(I.LE.100) GO TO 40	0003880
778.	C	IF QUEUE OF SHORT-LIVED NUCLIDES EXCEEDS 100 ISOTOPES, TERMINATE	0003885
779.	C	CHAIN AND WRITE MESSAGE	0003890
780.		PRINT 9000, M,L,J1,J,AKDJQ	0003895

781.	9000	FORMAT('1T00 LONG A QUEUE HAS BEEN FORMED IN TERM',4I5,E12.5)	0003900
782.		GO TO 190	0003905
783.	50	BATM=0.D0	0003910
784.		IM=I-1	0003915
785.		DO 110 I=2,IM	0003920
786.		DL=DD(I)	0003925
787.		XPL=DXP(I)	0003930
788.		BATE=0.D0	0003935
789.		I1=I-1	0003940
790.	C	D R VONDY FORM OF BATEMAN EQUATIONS -- ORNL-TM-361	0003945
791.		DO 100 KB=1,I1	0003950
792.		XPJ=DXP(KB)	0003955
793.		IF(XPL+XPJ.LT.ERR) GO TO 100	0003960
794.		DK=DD(KB)	0003965
795.		PROD=(DL/DK-1.0)	0003970
796.		DKR=PROD	0003975
797.		IF(ABS(PROD).GT.1.E-4) GO TO 60	0003980
798.	C	USE THIS FORM FOR TWO NEARLY EQUAL HALF-LIVES	0003985
799.		PROD=T*DK*XPJ*(1.0-0.5*(DL-DJ)*T)	0003990
800.		GO TO 70	0003995
801.	60	PROD=(XPJ-XPL)/PROD	0004000
802.		PRO1=XPJ/DKR	0004005
803.	70	PI=1.0	0004010
804.		S1=2./(DK*T)	0004015
805.		DO 90 JK=1,I1	0004020
806.		IF(JK.EQ.KB) GO TO 90	0004025
807.		S=1.0-DK/DD(JK)	0004030
808.		IF(ABS(S).GT.1.E-4) GO TO 80	0004035
809.		IF(ABS(DKR).GT.1.0E-4) PROD=PRO1	0004040
810.		S=S1	0004045
811.	80	PI=PI*S	0004050
812.		IF(ABS(PI).GT.1.E25) GO TO 100	0004055
813.	90	CONTINUE	0004060
814.		BATE=BATE+PROD/PI	0004065
815.	100	CONTINUE	0004070
816.	C	IF SUMMATION IS NEGATIVE, SET EQUAL TO ZERO AND PRINT MESSAGE	0004075
817.		IF(BATE.LT.0.D0) PRINT 9001, L,IM,BATE,BATM	0004080
818.	9001	FORMAT('1BATE IS NEGATIVE IN TERM. THERE ARE MORE THAN TWO SHORT-L	0004085
819.		IVED NUCLIDES IN A CHAIN WITH NEARLY EQUAL DIAGONAL ELEMENTS'/	0004090
820.		2' L,IM,BATE,BATM = ',2I5,1P2E12.5)	0004095
821.		IF(BATE.LT.0.D0) BATE=0.D0	0004100
822.		BATM=BATM+BATE	0004105
823.	110	CONTINUE	0004110
824.		DRA=AKDJQ*DJ*(TRM-BATM)/TRM	0004115
825.		GO TO 130	0004120
826.	120	DRA=AKDJQ*AMAX1(DRB,0.0)*DJ	0004125
827.	130	IF(NS.GT.NN) GO TO 150	0004130
828.		DO 140 LJ=NS,NN	0004135
829.		IF(LOCP(LJ).NE.J1) GO TO 140	0004140
830.		AP(LJ)=AP(LJ)+DRA	0004145
831.		GO TO 180	0004150
832.	140	CONTINUE	0004155
833.	150	NN=NN+1	0004160
834.		AP(NN)=DRA	0004165
835.		LOCP(NN)=J1	0004170
836.		GO TO 180	0004175
837.	160	IF(AKDJQ.LE.1.0E-06) GO TO 180	0004180
838.		IF(NSAVE.GE.50) GO TO 180	0004185
839.	170	NSAVE=NSAVE+1	0004190
840.		NQUEUE(NSAVE)=J1	0004195

841.		QUEUE(NSAVE)=AKDJQ	0004200
842.		NQU(NSAVE)=J	0004205
843.		QUB(NSAVE)=DRB-1./(DJ*XT)	0004210
844.	180	CONTINUE	0004215
845.	190	IF(NSAVE.LE.0) GO TO 200	0004220
846.		J=NQUEUE(NSAVE)	0004225
847.		QUE=QUEUE(NSAVE)	0004230
848.		NQ(J)=NQU(NSAVE)	0004235
849.		DRB=QUB(NSAVE)	0004240
850.		CIMB(L)=CIMB(L)+QUE*B(J)*AMAX1(DRB,0.0)	0004245
851.		NSAVE=NSAVE-1	0004250
852.		GO TO 20	0004255
853.	200	CONTINUE	0004260
854.	210	NUL=NONO(L)	0004265
855.		NONP(L)=NN	0004270
856.	220	CONTINUE	0004275
857.	C	FIND NORM OF MATRIX AND ESTIMATE ERROR AS DESCRIBED IN LAPIDUS	0004280
858.	C	AND LUUS, OPTIMAL CONTROL OF ENGINEERING PROCESSES BLAISDELL 1967	0004285
859.	C	FIND THE MINIMUM OF THE MAXIMUM ROW SUM AND THE MAXIMUM COLUMN SUM	0004290
860.		ASUM =0.0	0004295
861.		ASUMJ=0.0	0004300
862.		NUL=1	0004305
863.		DO 250 I=1,ITOT	0004310
864.		IF(.NOT.LONG(I)) GO TO 250	0004315
865.		DI=-D(I)*T	0004320
866.		AJ=DI	0004325
867.		NUM=NONP(I)	0004330
868.		IF(NUL.GT.NUM) GO TO 240	0004335
869.		DO 230 N=NUL,NUM	0004340
870.	230	AJ=AJ+AP(N)	0004345
871.	240	AI=DI+DI	0004350
872.		IF(AI.GT.ASUM) ASUM =AI	0004355
873.		IF(AJ.GT.ASUMJ) ASUMJ=AJ	0004360
874.	250	NUL=NONP(I)+1	0004365
875.		IF(ASUMJ.LT.ASUM) ASUM=ASUMJ	0004370
876.	C	USE ASUM TO DECIDE HOW MANY TERMS ARE REQUIRED AND ESTIMATE ERROR	0004375
877.		NLARGE=3.5*ASUM +5.	0004380
878.		XLARGE=NLARGE	0004385
879.		ERR1=EXP(ASUM)*(ASUM *2.71828/XLARGE)**NLARGE/SQRT(6.2832*XLARGE)	0004390
880.		IF(ERR1.GT.1.E-3) PRINT 9002, ERR1,ASUM ,NLARGE	0004395
881.	9002	FORMAT('OMAXIMUM ERROR GT 0.001, ='F10.6,', TRACE = 'F10.4,	0004400
882.	1	' , NLARGE = 'I6)	0004405
883.	C	NEXT GENERATE MATRIX EXPONENTIAL SOLUTION	0004410
884.		DO 260 I=1,ITOT	0004415
885.		CSUM(I)=XTEMP(I)	0004420
886.		CIMN(I)=XTEMP(I)	0004425
887.	260	CONTINUE	0004430
888.		ERR3=0.001*ERR	0004435
889.		DO 310 NT=1,NLARGE	0004440
890.		DO 270 I=1,ITOT	0004445
891.		CIM0(I)=CIMN(I)	0004450
892.	270	CONTINUE	0004455
893.		TON=T/NT	0004460
894.		NUL=1	0004465
895.		DO 300 I=1,ITOT	0004470
896.		IF(.NOT.LONG(I)) GO TO 300	0004475
897.		NUM=NONP(I)	0004480
898.		CIMNI=0.0	0004485
899.		IF(NT.EQ.1) CIMNI=CIMB(I)	0004490
900.		IF(NUL.GT.NUM) GO TO 290	0004495

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901.      DO 280 N=NUL,NUM                      0004500
902.      J=LOCP(N)                            0004505
903.      280 CIMNI=CIMNI+AP(N)*CIM0(J)        0004510
904.      290 CIMNI=CIMNI+D(I)*CIM0(I)        0004515
905.      CIMNI=TON*CIMNI                      0004520
906.      IF(DABS(CIMNI).LT.ERR3) CIMNI=0.D0  0004525
907.      CIMN(I)=CIMNI                      0004530
908.      CSUM(I)=CSUM(I)+CIMNI              0004535
909.      300 NUL=NONP(I)+1                  0004540
910.      310 CONTINUE                        0004545
911.      DO 320 I=1,ITOT                    0004550
912.      IF(CSUM(I).LT.ERR) CSUM(I)=0.0      0004555
913.      IF(LONG(I)) XNEW(M,I)=CSUM(I)      0004560
914.      320 CONTINUE                      0004565
915.      RETURN                             0004570
916.      END                                0004575
917.      SUBROUTINE DECAY(M,T,ITOT)          0004580
918.      C DECAY TREATS SHORT-LIVED ISOTOPES AT BEGINNING OF CHAINS USING
919.      C BATEMAN EQUATIONS                0004585
920.      LOGICAL*1 LONG                     0004590
921.      REAL*8 BATE                        0004600
922.      INTEGER*2 LOC,NON0,KD              0004605
923.      INTEGER*2 NQ,NQU,NQUEUE           0004610
924.      COMMON/DEBUGG/AP(2500)            0004615
925.      COMMON/SERIES/ XP(800),XPAR(800),LONG(800) 0004620
926.      COMMON/FLEX/FLUX(10),MMN,MOUT,INDEX,QXN,AXN,ERR,NOBLND,MZERO 0004625
927.      COMMON/EQ/XZERO(800),XZH(800),XTEMP(800),XNEW(10,800), 0004630
928.      1 B(800),D(800)                  0004635
929.      COMMON/MATRIX/A(2500),LOC(2500),NON0(800),KD(800) 0004640
930.      COMMON/TERMD/DD(100),DXP(100),QUEUE(50),NQU(50),NQUEUE(50),NQ(800) 0004645
931.      DO 10 I=1,ITOT                    0004650
932.      XPAR(I)=0.0                      0004655
933.      LONG(I)=.FALSE.                  0004660
934.      XPI=0.0                          0004665
935.      DT=D(I)*T                        0004670
936.      IF(DT.LT.-50.) GO TO 10          0004675
937.      IF(ABS(DT).LE.AXN) LONG(I)=.TRUE. 0004680
938.      XPI=EXP(DT)                      0004685
939.      10 XP(I)=XPI                     0004690
940.      NUL=1                            0004695
941.      DO 160 L=1,ITOT                  0004700
942.      XTEM=0.0                         0004705
943.      DL=-D(L)                         0004710
944.      NUM=NON0(L)                      0004715
945.      IF(M.GT.MMN.OR.M.EQ.MZERO) NUM=KD(L) 0004720
946.      IF(NUM.LT.NUL) GO TO 150         0004725
947.      DO 140 N=NUL,NUM                 0004730
948.      J=LOC(N)                         0004735
949.      DJ=-D(J)                         0004740
950.      IF(LONG(J)) GO TO 140            0004745
951.      C USE THIS FORM FOR TWO NEARLY EQUAL HALF-LIVES 0004750
952.      IF(ABS(DL/DJ-1.0).LE.1.0E-5) XTEM=XTEM+XTEMP(J)*A(N)*XP(J)*T 0004755
953.      IF(ABS(DL/DJ-1.0).GT.1.0E-5)    0004760
954.      1 XTEM=XTEM+XTEMP(J)*A(N)*(XP(J)-XP(L))/(DL-DJ) 0004765
955.      QUE=A(N)/DJ                      0004770
956.      NQ(L)=0                          0004775
957.      NQ(J)=L                          0004780
958.      NSAVE=0                          0004785
959.      20 NUX=NON0(J)                   0004790
960.      IF(M.GT.MMN.OR.M.EQ.MZERO) NUX=KD(J) 0004795

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961.		NUF=1	0004800
962.		IF(J.GT.1) NUF=NON0(J-1)+1	0004805
963.		IF(NUF.GT.NUX) GO TO 130	0004810
964.		DO 120 K=NUF,NUX	0004815
965.		J1=LOC(K)	0004820
966.		IF(LONG(J1)) GO TO 120	0004825
967.		KP=J	0004830
968.	30	IF(J1.EQ.NQ(KP)) GO TO 120	0004835
969.		KP=NQ(KP)	0004840
970.		IF(KP.NE.0) GO TO 30	0004845
971.		DJ=-D(J1)	0004850
972.		AKDJQ=A(K)/DJ*QUE	0004855
973.		IF(AKDJQ.LE.1.0E-06) GO TO 120	0004860
974.		NQ(J1)=J	0004865
975.		I=1	0004870
976.		KP=J1	0004875
977.	40	DD(I)=-D(KP)	0004880
978.		DXP(I)=XP(KP)	0004885
979.		KP=NQ(KP)	0004890
980.		IF(KP.EQ.0) GO TO 50	0004895
981.		I=I+1	0004900
982.		IF(I.LE.100) GO TO 40	0004905
983.		PRINT 9000, M,L,J1,J,AKDJQ	0004910
984.	9000	FORMAT('1',4I5,E12.5)	0004915
985.		GO TO 130	0004920
986.	50	BATE=0.D0	0004925
987.		I1=I-1	0004930
988.		XPL=XP(L)	0004935
989.	C	D R VONDY FORM OF BATEMAN EQUATIONS -- ORNL-TM-361	0004940
990.		DO 100 KB=1,I1	0004945
991.		XPJ=DXP(KB)	0004950
992.		IF(XPL+XPJ.LT.ERR) GO TO 100	0004955
993.		DK=DD(KB)	0004960
994.		PROD=(DL/DK-1.0)	0004965
995.		DKR=PROD	0004970
996.		IF(ABS(PROD).GT.1.E-4) GO TO 60	0004975
997.		PROD=T*DK*XPJ*(1.0-0.5*(DL-DJ)*T)	0004980
998.		GO TO 70	0004985
999.	60	PROD=(XPJ-XPL)/PROD	0004990
1000.		PRO1=XPJ/DKR	0004995
1001.	70	PI=1.0	0005000
1002.		S1=2./(DK*T)	0005005
1003.		DO 90 JK=1,I1	0005010
1004.		IF(JK.EQ.KB) GO TO 90	0005015
1005.		S=1.0-DK/DD(JK)	0005020
1006.		IF(ABS(S).GT.1.E-4) GO TO 80	0005025
1007.	C	USE THIS FORM FOR TWO NEARLY EQUAL HALF-LIVES	0005030
1008.		IF(ABS(DKR).GT.1.0E-4) PROD=PRO1	0005035
1009.		S=S1	0005040
1010.	80	PI=PI*S	0005045
1011.		IF(ABS(PI).GT.1.E25) GO TO 100	0005050
1012.	90	CONTINUE	0005055
1013.		BATE=BATE+PROD/PI	0005060
1014.	100	CONTINUE	0005065
1015.		IF(BATE.LT.0.D0) PRINT 9001, L,I,BATE,XTEM,XTEMP(J1),AKDJQ	0005070
1016.	9001	FORMAT(' L,I,BATE,XTEM,XTEMP(J1),AKDJQ = ',2I5,1P4E12.5)	0005075
1017.		IF(BATE.LT.0.D0) BATE=0.D0	0005080
1018.		XTEM=XTEM+XTEMP(J1)*AKDJQ*BATE	0005085
1019.		IF(NSAVE.GE.50) GO TO 120	0005090
1020.	110	NSAVE=NSAVE+1	0005095

1021.		NQUEUE(NSAVE)=J1	0005100
1022.		QUEUE(NSAVE)=AKDJQ	0005105
1023.		NQU(NSAVE)=J	0005110
1024.	120	CONTINUE	0005115
1025.	130	IF(NSAVE.LE.0) GO TO 140	0005120
1026.		J=NQUEUE(NSAVE)	0005125
1027.		QUE=QUEUE(NSAVE)	0005130
1028.		NQ(J)=NQU(NSAVE)	0005135
1029.		NSAVE=NSAVE-1	0005140
1030.		GO TO 20	0005145
1031.	140	CONTINUE	0005150
1032.		IF(LONG(L)) XPAR(L)=XTEM/XP(L)	0005155
1033.	150	NUL=NONO(L)+1	0005160
1034.		IF(.NOT.LONG(L)) XNEW(M,L)=XTEM+XTEMP(L)*XP(L)	0005165
1035.	160	CONTINUE	0005170
1036.		DO 170 I=1,ITOT	0005175
1037.		IF(LONG(I)) XTEMP(I)=XTEMP(I)+XPAR(I)	0005180
1038.		IF(.NOT.LONG(I)) XTEMP(I)=0.0	0005185
1039.	170	CONTINUE	0005190
1040.		RETURN	0005195
1041.		END	0005200
1042.		SUBROUTINE EQUIL(M,ITOT)	0005205
1043.	C		0005210
1044.	C	EQUIL PUTS SHORT-LIVED DAUGHTERS IN EQUILIBRIUM WITH PARENTS	0005215
1045.	C	EQUIL USES GAUSS-SEIDEL ITERATION TO GENERATE STEADY STATE	0005220
1046.	C	CONCENTRATIONS	0005225
1047.	C		0005230
1048.		LOGICAL*1 LONG	0005235
1049.		INTEGER*2 LOC, NONO, KD	0005240
1050.		COMMON/EQ/XZERO(800), XZH(800), XTEMP(800), XNEW(10,800),	0005245
1051.	1	B(800), D(800)	0005250
1052.		COMMON/MATRIX/A(2500), LOC(2500), NONO(800), KD(800)	0005255
1053.		COMMON/FLEX/FLUX(10), MMN, MOUT, INDEX, QXN, AXN, ERR, NOBLND, MZERO	0005260
1054.		COMMON/SERIES/ XP(800), XPAR(800), LONG(800)	0005265
1055.		DO 10 I=1, ITOT	0005270
1056.		XPAR(I)=0.0	0005275
1057.		IF(.NOT.LONG(I)) GO TO 10	0005280
1058.		XTEMP(I)=XTEMP(I)*XP(I)	0005285
1059.		XPAR(I)=AMAX1(XNEW(M,I)-XTEMP(I), 0.0)	0005290
1060.	10	CONTINUE	0005295
1061.		ITER=1	0005300
1062.	20	N=0	0005305
1063.		BIG=0.0	0005310
1064.		DO 60 I=1, ITOT	0005315
1065.		NUM=NONO(I)-N	0005320
1066.		DI=-D(I)	0005325
1067.		IF(LONG(I)) GO TO 50	0005330
1068.		XNW=B(I)	0005335
1069.		IF(M.GT.MMN.OR.M.EQ.MZERO) NUM=KD(I)-N	0005340
1070.		IF(NUM.EQ.0) GO TO 31	0005345
1071.		DO 30 K=1, NUM	0005350
1072.		N=N+1	0005355
1073.		J=LOC(N)	0005360
1074.		DJ=-D(J)	0005365
1075.		XJ=XPAR(J)	0005370
1076.		IF(LONG(J)) XJ=XJ+XTEMP(J)/(1.0-DJ/DI)	0005375
1077.		XNW=XNW+A(N)*XJ	0005380
1078.	30	CONTINUE	0005385
1079.	31	XNW=XNW/DI	0005390
1080.		IF(XNW.LT.1.0E-50) GO TO 40	0005395

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1081.      ARG=ABS((XNW-XPAR(I))/XNW)                0005400
1082.      IF(ARG.GT.BIG) BIG=ARG                    0005405
1083.      40  XPAR(I)=XNW                          0005410
1084.      50  N=NONO(I)                             0005415
1085.      60  CONTINUE                             0005420
1086.      IF(BIG.LT.QXN ) GOTO 70                  0005425
1087.      ITER=ITER+1                               0005430
1088.      IF(ITER.LT.100) GO TO 20                 0005435
1089.      PRINT 9000                                0005440
1090.      STOP                                       0005445
1091.      70  DO 80 I=1,ITOT                        0005450
1092.      IF(.NOT.LONG(I)) XNEW(M,I)=XNEW(M,I)+XPAR(I) 0005455
1093.      80  CONTINUE                             0005460
1094.      RETURN                                    0005465
1095.      9000 FORMAT(' GAUSS SEIDEL ITERATION DID NOT CONVERGE IN EQUIL') 0005470
1096.      END                                       0005475
1097.      SUBROUTINE NUDATA(NLIBE)                  0005480
1098.      C  NUDATA VERSION TO HANDLE THREE TYPES OF NUCLEAR DATA LIBRARIES 0005485
1099.      C  HAS POINTER, NLIBE, = 1 FOR HTGR        0005490
1100.      C  = 2 FOR LIGHT WATER REACTOR           0005495
1101.      C  = 3 FOR LMFBR                          0005500
1102.      C  = 4 FOR MSBR                            0005505
1103.      INTEGER*2 LOC,NON0,KD                     0005510
1104.      INTEGER*2 ELE(99),STA(2)                   0005515
1105.      INTEGER*2 KAP(800),MMAX(800)               0005520
1106.      INTEGER*2 NAME(3)                         0005525
1107.      DIMENSION COEFF(7,800),NPROD(7,800),CAPT(6), 0005530
1108.      1  NUCAL(6),NSORS(5), YIELD(5,500),TYLD(5) 0005535
1109.      DIMENSION Y(5)                             0005540
1110.      DIMENSION SKIP(20)                         0005545
1111.      DIMENSION MSRS(20)                         0005550
1112.      COMMON/LABEL/ELE,STA                       0005555
1113.      COMMON/FLEX/FLUX(10),MMN,MOUT,INDEX,QXN,AXN,ERR,NOBLND,MZERO 0005560
1114.      COMMON/EQ/XZERO(800),XZH(800),XTEMP(800),XNEW(10,800), 0005565
1115.      1  B(800),D(800)                           0005570
1116.      COMMON/MPC/MPCTAB,AMPC(800),WMPC(800)       0005575
1117.      COMMON/FLUXN/I(20),POWER(10),TOCAP(800),FISS(100),DIS(800),ILITE, 0005580
1118.      1  IACT,IFP,ITOT,NON,INPT                  0005585
1119.      COMMON/OUT/NUCL(800),TITLE(20),Q(800),FG(800),CUTOFF(7), 0005590
1120.      1  POW,BURNUP,FLUXB,MSTAR,ALPHAN(100),SPONF(100),ABUND(500), 0005595
1121.      2  BASIS(10),ICONST,TUNIT                  0005600
1122.      COMMON/MATRIX/A(2500),LOC(2500),NON0(800),KD(800) 0005605
1123.      EQUIVALENCE (XZERO(1),KAP(1)),(XZERO(401),MMAX(1)), 0005610
1124.      1  ( XZH(1),COEFF(1,1)),(XNEW(1,401),NPROD(1,1)) 0005615
1125.      EQUIVALENCE (A1,DLAM)                      0005620
1126.      DATA NUCAL/-20030,-10000,10,11,-10,-9/    0005625
1127.      DATA MSRS/922330,922350,902320,922380,942390,922330,922350,942410, 0005630
1128.      1  922380,942390,942410,922350,942400,922380,942390,922330, 0005635
1129.      2  922350,902320,922380,942390/           0005640
1130.      C                                           0005645
1131.      C  PROGRAM TO COMPUTE A MATRIX (TRANSITION MATRIX) FROM NUCLEAR DATA 0005650
1132.      C                                           0005655
1133.      READ 9011, (TITLE(I),I=1,18),NLIBE        0005660
1134.      C  IF(NLIBE.LT.0) PROGRAM WILL READ TAPE IN CASDAR FORMAT 0005665
1135.      IGWC=0                                       0005670
1136.      IF(NLIBE.GT.0) GO TO 10                    0005675
1137.      IGWC=1                                       0005680
1138.      NLIBE=-NLIBE                                0005685
1139.      PRINT 9000                                  0005690
1140.      9000 FORMAT(1H0,'WILL READ TAPE GENERATED BY CASDAR') 0005695

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1141.	10	N1=4-NLIBE	0005700
1142.	20	READ 9001, THERM, RES, FAST, ERR, NMO, NDAY, NYR, MPCTAB, INPT, IR	0005705
1143.		PRINT 9005, NMO, NDAY, NYR	0005710
1144.		PRINT 9006	0005715
1145.		PRINT 9007	0005720
1146.		PRINT 9008	0005725
1147.		PRINT 9009	0005730
1148.		PRINT 9010	0005735
1149.		PRINT 9013	0005740
1150.		PRINT 9014	0005745
1151.	C		0005750
1152.	C	THERM = RATIO OF THERMAL FLUX TO TOTAL FLUX	0005755
1153.	C	RES = RATIO OF RESONANCE FLUX TO TOTAL FLUX	0005760
1154.	C	FAST = RATIO OF FAST FLUX TO TOTAL FLUX	0005765
1155.	C	ERR = TRUNCATION ERROR LIMIT	0005770
1156.	C		0005775
1157.	C	READ DATA FOR LIGHT ELEMENTS	0005780
1158.	C		0005785
1159.		K=5*(NLIBE-1)	0005790
1160.		DO 30 K1=1,5	0005795
1161.		K2=K+K1	0005800
1162.	30	NSORS(K1)=MSRS(K2)	0005805
1163.		PRINT 9018, THERM, RES, FAST, (NSORS(K), K=1,5), NLIBE	0005810
1164.		I=0	0005815
1165.		NUTAPE=0	0005820
1166.	40	I=I+1	0005825
1167.	50	READ(8,9034,END=260)NUCL(I),DLAM,IU,FB1,FP,FP1,FT,FA,FSF,	0005830
1168.		1Q(I),FG(I),ABUND(I),WMPC(I),AMPC(I)	0005835
1169.		IF(IGWC.GT.0) GO TO 70	0005840
1170.		DO 60 N=1,NLIBE	0005845
1171.	60	READ(8,9035) SIGTH,FNG1,FNA,FNP,RITH,FINA,FINP,SIGMEV,FN2N1,FFNA,	0005850
1172.		1 FFPN,IT	0005855
1173.		GO TO 90	0005860
1174.	70	DO 80 N=1,NLIBE	0005865
1175.	80	READ(8,9040) SIGTH,FNG1,FNA,FNP,RITH,FINA,FINP,SIGMEV,FN2N1,FFNA,	0005870
1176.		1 FFPN,IT	0005875
1177.	90	IF(N1.EQ.0) GO TO 110	0005880
1178.		DO 100 N=1,N1	0005885
1179.	100	READ(8,9036) SKIP	0005890
1180.	110	IF(IT.EQ.0) GO TO 50	0005895
1181.	120	M=0	0005900
1182.		CALL HALF(A1,IU)	0005905
1183.		NUCLI=NUCL(I)	0005910
1184.		IF(NUCLI.EQ.0) GO TO 260	0005915
1185.		CALL NOAH(NUCLI,NAME)	0005920
1186.		IF(MOD(I-1,50).EQ.0) PRINT 9012, (TITLE(N),N=1,18)	0005925
1187.		IF(MOD(I-1,50).EQ.0) PRINT 9016	0005930
1188.		SIGTH=THERM*SIGTH	0005935
1189.		RITH=RES*RITH	0005940
1190.		SIGMEV=FAST*SIGMEV	0005945
1191.		SIGNA=SIGTH*FNA+RITH*FINA+SIGMEV*FFNA	0005950
1192.		SIGNP=SIGTH*FNP+RITH*FINP+SIGMEV*FFNP	0005955
1193.		FNG=1.0-FNA-FNP	0005960
1194.		IF(FNG.LT.1.0E-4)FNG=0.	0005965
1195.		FING=1.0-FINA-FINP	0005970
1196.		IF(FING.LT.1.0E-4)FING=0.	0005975
1197.		FN2N=1.0-FFNA-FFNP	0005980
1198.		IF(FN2N.LT.1.0E-4)FN2N=0.	0005985
1199.		SIGNG=SIGTH*FNG+RITH*FING	0005990
1200.		SIGN2N=SIGMEV*FN2N	0005995

1201.	130	PRINT 9033, NAME, DLAM,FB1,FP,FP1,FT,FA,SIGNG,	0006000
1202.	1	FNG1,SIGN2N,FN2N1,SIGNA,SIGNP,Q(I),FG(I),ABUND(I)	0006005
1203.	C	TEST RADIOACTIVITY	0006010
1204.	C		0006015
1205.	140	IF(A1.LE.ERR) GO TO 180	0006020
1206.		ABETA=1.0	0006025
1207.	C		0006030
1208.	C	TEST POSITRON EMISSION	0006035
1209.	C		0006040
1210.		IF(FP .LT. ERR) GO TO 150	0006045
1211.		M=M+1	0006050
1212.		COEFF(M,I)=FP*A1	0006055
1213.		NPROD(M,I)=NUCLI-10000	0006060
1214.		ABETA=ABETA-FP	0006065
1215.	C		0006070
1216.	C	TEST POSITRON EMISSION TO EXCITED STATE OF PRODUCT NUCLIDE	0006075
1217.	C		0006080
1218.		IF(FP1 .LT. ERR) GO TO 150	0006085
1219.		M=M+1	0006090
1220.		COEFF(M,I)=FP1*COEFF(M-1,I)	0006095
1221.		NPROD(M,I)=NPROD(M-1,I)+1	0006100
1222.		COEFF(M-1,I)=COEFF(M-1,I)-COEFF(M,I)	0006105
1223.	C		0006110
1224.	C	TEST ISOMERIC TRANSITION	0006115
1225.	C		0006120
1226.	150	IF(FT .LT.ERR) GO TO 160	0006125
1227.		M=M+1	0006130
1228.		COEFF(M,I)=FT*A1	0006135
1229.		NPROD(M,I)=NUCLI	0006140
1230.		ABETA=ABETA-FT	0006145
1231.	C		0006150
1232.	C	TEST ALPHA EMISSION	0006155
1233.	C		0006160
1234.	160	IF(FA .LT. ERR) GO TO 170	0006165
1235.		M=M+1	0006170
1236.		COEFF(M,I)=FA*A1	0006175
1237.		NPROD(M,I)=NUCLI-20040	0006180
1238.		M=M+1	0006185
1239.		COEFF(M,I)=COEFF(M-1,I)	0006190
1240.		NPROD(M,I)=20040	0006195
1241.		ABETA=ABETA-FA	0006200
1242.	C		0006205
1243.	C	TEST NEGATRON EMISSION	0006210
1244.	C		0006215
1245.	170	IF(ABETA.LT.1.E-4) GO TO 180	0006220
1246.		M=M+1	0006225
1247.		COEFF(M,I)=ABETA*A1	0006230
1248.		NPROD(M,I)=NUCLI+10000	0006235
1249.	C		0006240
1250.	C	TEST NEGATRON EMISSION TO EXCITED STATE OF PRODUCT NUCLIDE	0006245
1251.	C		0006250
1252.		IF(FB1 .LT. ERR)GO TO 180	0006255
1253.		M=M+1	0006260
1254.		COEFF(M,I)=FB1*COEFF(M-1,I)	0006265
1255.		NPROD(M,I)=NPROD(M-1,I)+1	0006270
1256.		COEFF(M-1,I)=COEFF(M-1,I)-COEFF(M,I)	0006275
1257.	C		0006280
1258.	C	COMPUTE NEUTRON CAPTURE CROSS SECTIONS IN THREE REGIONS	0006285
1259.	C		0006290
1260.	180	KAP(I)=M	0006295

1261.		DO 190 KI=1,6	0006300
1262.	190	CAPT(KI) =0.0	0006305
1263.		CAPT(1)=SIGNA	0006310
1264.		CAPT(2)=SIGNP	0006315
1265.		CAPT(4)=SIGNG*FNG1	0006320
1266.		CAPT(3)=SIGNG-CAPT(4)	0006325
1267.		CAPT(6)=SIGN2N*FN2N1	0006330
1268.		CAPT(5)=SIGN2N-CAPT(6)	0006335
1269.	200	TOCAP(I)=0.0	0006340
1270.	C	TOTAL NEUTRON CROSS SECTION FOR NUCLIDE(I)	0006345
1271.		DO 220 K=1,6	0006350
1272.		CAPKI=CAPT(K)	0006355
1273.		IF(CAPKI.LT.ERR) GO TO 220	0006360
1274.		M=M+1	0006365
1275.		NPROD(M,I)=NUCLI+NUCAL(K)	0006370
1276.		COEFF(M,I)=CAPKI	0006375
1277.		TOCAP(I)=TOCAP(I)+CAPKI	0006380
1278.		IF(K.NE.1) GO TO 210	0006385
1279.		M=M+1	0006390
1280.		COEFF(M,I)=COEFF(M-1,I)	0006395
1281.		NPROD(M,I)=20040	0006400
1282.	210	IF(K.NE.2) GO TO 220	0006405
1283.		M=M+1	0006410
1284.		COEFF(M,I)=COEFF(M-1,I)	0006415
1285.		NPROD(M,I)=10010	0006420
1286.	220	CONTINUE	0006425
1287.	230	IF(MOD(NUCLI, 10).EQ.0) GO TO 250	0006430
1288.		DO 240 K=1,M	0006435
1289.	240	NPROD(K,I)=NPROD(K,I)-1	0006440
1290.	250	MMAX(I) =M	0006445
1291.		IF(M.GT.7) PRINT 9039, M	0006450
1292.		DIS(I)=A1	0006455
1293.		GO TO 40	0006460
1294.	260	ILITE = I-1	0006465
1295.		IACT=0	0006470
1296.	C		0006475
1297.	C	READ DATA ON ACTINIDES	0006480
1298.	C		0006485
1299.	270	READ(8,9034,END=450)NUCL(I),DLAM,IU,FB1,FP,FP1,FT,FA,FSF,	0006490
1300.		IQ(I),FG(I),DUMMY,WMPG(I),AMPC(I)	0006495
1301.		DO 280 N=1,NLIBE	0006500
1302.		READ(8,9037) SIGNG,RING,FNG1,SIGF,RIF,SIGFF,SIGN2N,FN2N1,SIGN3N,IT	0006505
1303.	280	CONTINUE	0006510
1304.		IF(N1.EQ.0) GO TO 300	0006515
1305.		DO 290 N=1,N1	0006520
1306.	290	READ(8,9036) SKIP	0006525
1307.	300	IF(IT.EQ. 0) GO TO 270	0006530
1308.	310	M=0	0006535
1309.		NUCLI=NUCL(I)	0006540
1310.		IF(NUCLI.EQ.0) GO TO 450	0006545
1311.		DO 320 K=1,5	0006550
1312.		IF(NUCLI.EQ.NSORS(K)) NSORS(K)=I	0006555
1313.	320	CONTINUE	0006560
1314.		CALL HALF(A1,IU)	0006565
1315.		CALL NOAH(NUCLI,NAME)	0006570
1316.		SIGNG=THERM*SIGNG+RES*RING	0006575
1317.		SIGF =THERM*SIGF +RES*RIF +FAST*SIGFF	0006580
1318.		SIGN2N=SIGN2N*FAST	0006585
1319.		SIGN3N=SIGN3N*FAST	0006590
1320.		IF(MOD(IACT,50).EQ.0) PRINT 9012, (TITLE (N),N=1,18)	0006595

1321.	330	IF(MOD(IACT,50).EQ.0) PRINT 9024	0006600
1322.		PRINT 9026, NAME, DLAM,FB1,FP,FP1,FT,FA,FSF,SIGNG,	0006605
1323.	1	FNG1,SIGF,SIGN2N,SIGN3N,Q(I),FG(I)	0006610
1324.	340	IACT=IACT+1	0006615
1325.	C		0006620
1326.	C	TEST RADIOACTIVITY	0006625
1327.	C		0006630
1328.		IF(A1.LT.ERR) GO TO 380	0006635
1329.		ABETA=1.0	0006640
1330.	C	TEST POSITRON EMISSION	0006645
1331.		IF(FP .LT. ERR) GO TO 350	0006650
1332.		ABETA=ABETA-FP	0006655
1333.		M=M+1	0006660
1334.		COEFF(M,I)=FP*A1	0006665
1335.		NPROD(M,I)=NUCLI-10000	0006670
1336.	C	POSITRON EMISSION TO EXCITED STATE	0006675
1337.		IF(FP1 .LT. ERR)GO TO 350	0006680
1338.		M=M+1	0006685
1339.		COEFF(M,I)=FP1*COEFF(M-1,I)	0006690
1340.		NPROD(M,I)=NPROD(M-1,I)+1	0006695
1341.		COEFF(M-1,I)=COEFF(M-1,I)-COEFF(M,I)	0006700
1342.	C	ISOMERIC TRANSITION	0006705
1343.	350	IF(FT .LT.ERR)GO TO 360	0006710
1344.		M=M+1	0006715
1345.		COEFF(M,I)=FT*A1	0006720
1346.		NPROD(M,I)=NUCLI	0006725
1347.		ABETA=ABETA-FT	0006730
1348.	C	ALPHA EMISSION	0006735
1349.	360	IF(FA .LT.ERR)GO TO 370	0006740
1350.		M=M+1	0006745
1351.		COEFF(M,I)=FA*A1	0006750
1352.		NPROD(M,I)=NUCLI-20040	0006755
1353.		M=M+1	0006760
1354.		COEFF(M,I)=COEFF(M-1,I)	0006765
1355.		NPROD(M,I)=20040	0006770
1356.		ABETA=ABETA-FA	0006775
1357.	C	BETA DECAY	0006780
1358.	370	IF(ABETA.LT.1.E-4) GO TO 380	0006785
1359.		M=M+1	0006790
1360.		COEFF(M,I)=ABETA*A1	0006795
1361.		NPROD(M,I)=NUCLI+10000	0006800
1362.		IF(FB1 .LT. ERR)GO TO 380	0006805
1363.		M=M+1	0006810
1364.		COEFF(M,I)=COEFF(M-1,I)*FB1	0006815
1365.		COEFF(M-1,I)=COEFF(M-1,I)-COEFF(M,I)	0006820
1366.		NPROD(M,I)=NPROD(M-1,I)+1	0006825
1367.	C		0006830
1368.	C	NEUTRON CAPTURE CROSS SECTIONS	0006835
1369.	C		0006840
1370.	380	KAP(I)=M	0006845
1371.		DO 390 K=1,6	0006850
1372.	390	CAPT(K)=0.0	0006855
1373.		CAPT(2)=SIGNG*FNG1	0006860
1374.		CAPT(1)=SIGNG-CAPT(2)	0006865
1375.		CAPT(4)=SIGN2N*FN2N1	0006870
1376.		CAPT(3)=SIGN2N-CAPT(4)	0006875
1377.	400	FISS(IACT)=SIGF	0006880
1378.		TOCAP(I)=0.0	0006885
1379.		DO 410 K=1,4	0006890
1380.		CAPKI=CAPT(K)	0006895

1381.		IF(CAPKI.LT.ERR) GO TO 410	0006900
1382.		M=M+1	0006905
1383.		TOCAP(I)=TOCAP(I)+CAPKI	0006910
1384.		COEFF(M,I)=CAPKI	0006915
1385.		NPROD(M,I)=NUCLI+NUCAL(K+2)	0006920
1386.	410	CONTINUE	0006925
1387.		TOCAP(I)=TOCAP(I)+FISS(IACT)	0006930
1388.	C	N-3N CROSS SECTION	0006935
1389.		A17=SIGN3N	0006940
1390.		IF(A17.LT.ERR) GO TO 420	0006945
1391.		M=M+1	0006950
1392.		COEFF(M,I)= A17	0006955
1393.		NPROD(M,I)= NUCLI-20	0006960
1394.		TOCAP(I)=TOCAP(I)+A17	0006965
1395.	420	IF(MOD(NUCLI,10).EQ.0) GO TO 440	0006970
1396.		DO 430 K=1,M	0006975
1397.	430	NPROD(K,I)=NPROD(K,I)-1	0006980
1398.	440	MMAX(I)=M	0006985
1399.		IF(M.GT.7) PRINT 9039, M	0006990
1400.		SPONF(IACT)=FSF*A1*6.023E23	0006995
1401.		ALPHAN(IACT)=FA*A1*6.023E13*Q(I)**3.65	0007000
1402.		DIS(I)=A1	0007005
1403.		I=I+1	0007010
1404.		GO TO 270	0007015
1405.	450	IL=0	0007020
1406.		DO 460 K=1,5	0007025
1407.	460	TYLD(K)=0.0	0007030
1408.	C		0007035
1409.	C	READ DATA FOR FISSION PRODUCTS	0007040
1410.	C		0007045
1411.	470	READ(8,9034,END=690)NUCL(I),DLAM,IU,FB1,FP,FP1,FT,FA,FSF,	0007050
1412.		1Q(I),FG(I),DUMMY,WMP(C(I),AMPC(I)	0007055
1413.		DO 480 N=1,NLIBE	0007060
1414.	480	READ(8,9038) SIGNG,RING,FNG1,Y,IT	0007065
1415.		IF(N1.EQ.0) GO TO 500	0007070
1416.		DO 490 N=1,N1	0007075
1417.	490	READ(8,9036) SKIP	0007080
1418.	500	IF(IT.EQ.0) GO TO 470	0007085
1419.	510	M=0	0007090
1420.		CALL HALF(A1,IU)	0007095
1421.	520	NUCLI=NUCL(I)	0007100
1422.		IF(NUCLI.EQ.0) GO TO 690	0007105
1423.		CALL NOAH(NUCLI,NAME)	0007110
1424.		IF(MOD(IL,50).EQ.0) PRINT 9012, (TITLE(N),N=1,18)	0007115
1425.		SIGNG=THERM*SIGNG+RES*RING	0007120
1426.		IF(NLIBE.EQ.3) GO TO 540	0007125
1427.	530	IF(MOD(IL,50).EQ.0) PRINT 9019	0007130
1428.		PRINT 9021, NAME, DLAM,FB1,FP,FP1,FT,SIGNG,	0007135
1429.		1 FNG1,Y,Q(I),FG(I)	0007140
1430.		GO TO 550	0007145
1431.	540	IF(MOD(IL,50).EQ.0) PRINT 9020	0007150
1432.		PRINT 9022, NAME, DLAM,FB1,FP,FP1,FT,SIGNG,FNG1,	0007155
1433.		1 Y(2),Y(4),Y(5),Q(I),FG(I)	0007160
1434.	C		0007165
1435.	C	TEST RADIOACTIVITY	0007170
1436.	C		0007175
1437.	550	IF(A1.LT.ERR) GO TO 600	0007180
1438.		ABETA=1.0	0007185
1439.	C	POSITRON EMISSION	0007190
1440.		A3=FP	0007195

1441.		IF(A3.LT.ERR) GO TO 570	0007200
1442.		ABETA=ABETA-A3	0007205
1443.		AP1=A3*FP1	0007210
1444.		AP=A3-AP1	0007215
1445.		IF(AP.LT.ERR) GO TO 560	0007220
1446.		M=M+1	0007225
1447.		COEFF(M,I)=AP*A1	0007230
1448.		NPROD(M,I)=NUCLI-10000	0007235
1449.	560	IF(AP1.LT.ERR) GO TO 570	0007240
1450.		M=M+1	0007245
1451.		COEFF(M,I)=AP1*A1	0007250
1452.		NPROD(M,I)=NUCLI-9999	0007255
1453.	C	ISOMERIC TRANSITION	0007260
1454.	570	IF(FT.LT.ERR) GO TO 580	0007265
1455.		M=M+1	0007270
1456.		COEFF(M,I)=FT*A1	0007275
1457.		NPROD(M,I)=NUCLI	0007280
1458.		ABETA=ABETA-FT	0007285
1459.	C	NEGATRON EMISSION	0007290
1460.	580	IF(ABETA.LT.1.0E-4) GO TO 600	0007295
1461.		A2=FB1	0007300
1462.		AB1=ABETA*A2	0007305
1463.		AB=ABETA-AB1	0007310
1464.		IF(AB.LT.1.E-4) GO TO 590	0007315
1465.		M=M+1	0007320
1466.		COEFF(M,I)=AB*A1	0007325
1467.		NPROD(M,I)=NUCLI+10000	0007330
1468.	590	IF(AB1.LT.1.E-6) GO TO 600	0007335
1469.		M=M+1	0007340
1470.		COEFF(M,I)=AB1*A1	0007345
1471.		NPROD(M,I)=NUCLI+10001	0007350
1472.	C		0007355
1473.	C	NEUTRON CAPTURE CROSS SECTIONS FOR FISSION PRODUCTS USING THREE	0007360
1474.	C	REGION APPROXIMATION	0007365
1475.	C		0007370
1476.	600	KAP(I)=M	0007375
1477.		DO 610 K=1,6	0007380
1478.	610	CAPT(K)=0.0	0007385
1479.		CAPT(2)=SIGNG*FNG1	0007390
1480.		CAPT(1)=SIGNG-CAPT(2)	0007395
1481.		TOCAP(I)=0.0	0007400
1482.		DO 620 K=1,2	0007405
1483.		CAPKI=CAPT(K)	0007410
1484.		IF(CAPKI.LT.ERR) GO TO 620	0007415
1485.		M=M+1	0007420
1486.		TOCAP(I)=TOCAP(I)+CAPKI	0007425
1487.		COEFF(M,I)=CAPKI	0007430
1488.		NPROD(M,I)=NUCLI+NUCAL(K+2)	0007435
1489.	620	CONTINUE	0007440
1490.	630	IF(MOD(NUCLI,10).EQ.0) GO TO 650	0007445
1491.		DO 640 K=1,M	0007450
1492.	640	NPROD(K,I)=NPROD(K,I)-1	0007455
1493.	650	IL=IL+1	0007460
1494.		DO 660 J=1,5	0007465
1495.		YJ=Y(J)*0.010	0007470
1496.		TYLD(J)=TYLD(J)+YJ	0007475
1497.	660	YIELD(J,IL)=YJ	0007480
1498.		IF(NLIBE.EQ.1.OR.NLIBE.EQ.4) GO TO 680	0007485
1499.	670	IF(NLIBE.EQ.3) YIELD(1,IL)=YJ	0007490
1500.		YIELD(3,IL)=YJ	0007495

1501.	680	MMAX(I)=M	0007500
1502.		IF(M.GT.7) PRINT 9039, M	0007505
1503.		DIS(I)=A1	0007510
1504.		I=I+1	0007515
1505.		GO TO 470	0007520
1506.	690	IFP=IL	0007525
1507.	C		0007530
1508.	C	ALL DATA ON NUCLIDES HAS BEEN READ, BEGIN TO COMPUTE MATRIX COEFF	0007535
1509.	C		0007540
1510.		ITOT=I-1	0007545
1511.	C		0007550
1512.	C	FIND PRODUCT NUCLIDES FOR REACTIONS OF LIGHT ELEMENTS	0007555
1513.	C		0007560
1514.		NON=0	0007565
1515.		DO 700 K=1,ITOT	0007570
1516.	700	NON0(K)=0	0007575
1517.		IF(ILITE.LT.1) GO TO 760	0007580
1518.		DO 750 I=1,ILITE	0007585
1519.		NUCLI=NUCL(I)	0007590
1520.		DO 720 J=1,ILITE	0007595
1521.		KMAX=KAP(J)	0007600
1522.		IF(KMAX.LT.1) GO TO 720	0007605
1523.		DO 710 M=1,KMAX	0007610
1524.		IF(NUCLI.NE.NPROD(M,J)) GO TO 710	0007615
1525.		NON0(I)=NON0(I)+1	0007620
1526.		NON=NON+1	0007625
1527.		IF(NON.GT.2500) PRINT 9041, NON,NUCL(I)	0007630
1528.		A(NON)=COEFF(M,J)	0007635
1529.		JT=J	0007640
1530.		LOC(NON)=JT	0007645
1531.	710	CONTINUE	0007650
1532.	720	CONTINUE	0007655
1533.		KD(I)=NON0(I)	0007660
1534.		DO 740 J=1,ILITE	0007665
1535.		K1=KAP(J)+1	0007670
1536.		KMAX=MMAX(J)	0007675
1537.		IF(KMAX.LT.K1) GO TO 740	0007680
1538.		DO 730 M=K1,KMAX	0007685
1539.		IF(NUCLI.NE.NPROD(M,J)) GO TO 730	0007690
1540.		NON0(I)=NON0(I)+1	0007695
1541.		NON=NON+1	0007700
1542.		IF(NON.GT.2500) PRINT 9041, NON,NUCL(I)	0007705
1543.		A(NON)=COEFF(M,J)	0007710
1544.		JT=J	0007715
1545.		LOC(NON)=JT	0007720
1546.	730	CONTINUE	0007725
1547.	740	CONTINUE	0007730
1548.	750	CONTINUE	0007735
1549.	C		0007740
1550.	C	NON ZERO MATRIX ELEMENTS FOR THE ACTINIDES	0007745
1551.	C		0007750
1552.	760	IF(IACT.LT.1) GO TO 820	0007755
1553.		IO=ILITE+1	0007760
1554.		I1=ILITE+IACT	0007765
1555.		DO 810 I=IO,I1	0007770
1556.		NUCLI=NUCL(I)	0007775
1557.		DO 780 J=IO,I1	0007780
1558.		MAX=KAP(J)	0007785
1559.		IF(MAX.LT.1) GO TO 780	0007790
1560.		DO 770 M=1,MAX	0007795

1561.		IF(NUCLI.NE.NPROD(M,J)) GO TO 770	0007800
1562.		NON0(I)=NON0(I)+1	0007805
1563.		NON=NON+1	0007810
1564.		IF(NON.GT.2500) PRINT 9041, NON,NUCL(I)	0007815
1565.		A(NON)=COEFF(M,J)	0007820
1566.		JT=J	0007825
1567.		LOC(NON)=JT	0007830
1568.	770	CONTINUE	0007835
1569.	780	CONTINUE	0007840
1570.		KD(I)=NON0(I)	0007845
1571.		DO 800 J=I0,I1	0007850
1572.		M1=KAP(J)+1	0007855
1573.		M2=MMA(X(J)	0007860
1574.		IF(M2.LT.M1) GO TO 800	0007865
1575.		DO 790 M=M1,M2	0007870
1576.		IF(NUCLI.NE.NPROD(M,J)) GO TO 790	0007875
1577.		NON0(I)=NON0(I)+1	0007880
1578.		NON=NON+1	0007885
1579.		IF(NON.GT.2500) PRINT 9041, NON,NUCL(I)	0007890
1580.		A(NON)=COEFF(M,J)	0007895
1581.		JT=J	0007900
1582.		LOC(NON)=JT	0007905
1583.	790	CONTINUE	0007910
1584.	800	CONTINUE	0007915
1585.	810	CONTINUE	0007920
1586.	C		0007925
1587.	C	MATRIX ELEMENTS FOR FISSION PRODUCTS	0007930
1588.	C		0007935
1589.	820	IF(IFP.LT.1) GO TO 900	0007940
1590.		IM=ILITE+IACT	0007945
1591.		I0=IM+1	0007950
1592.		IF(ITOT.LT.I0) GO TO 900	0007955
1593.		DO 880 I=I0,ITOT	0007960
1594.		NUCLI=NUCL(I)	0007965
1595.		I2=MAX0(I0,I-10)	0007970
1596.		I3=MIN0(ITOT,I+10)	0007975
1597.		DO 840 J=I2,I3	0007980
1598.		KMAX=KAP(J)	0007985
1599.		IF(KMAX.LT.1) GO TO 840	0007990
1600.		DO 830 M=1,KMAX	0007995
1601.		IF(NUCLI.NE.NPROD(M,J)) GO TO 830	0008000
1602.		NON0(I)=NON0(I)+1	0008005
1603.		NON=NON+1	0008010
1604.		IF(NON.GT.2500) PRINT 9041, NON,NUCL(I)	0008015
1605.		A(NON)=COEFF(M,J)	0008020
1606.		JT=J	0008025
1607.		LOC(NON)=JT	0008030
1608.	830	CONTINUE	0008035
1609.	840	CONTINUE	0008040
1610.		KD(I)=NON0(I)	0008045
1611.		DO 860 J=I2,I3	0008050
1612.		K1=KAP(J)+1	0008055
1613.		KMAX=MMA(X(J)	0008060
1614.		IF(KMAX.LT.K1) GO TO 860	0008065
1615.		DO 850 M=K1,KMAX	0008070
1616.		IF(NUCLI.NE.NPROD(M,J)) GO TO 850	0008075
1617.		NON0(I)=NON0(I)+1	0008080
1618.		NON=NON+1	0008085
1619.		IF(NON.GT.2500) PRINT 9041, NON,NUCL(I)	0008090
1620.		A(NON)=COEFF(M,J)	0008095

1621.		JT=J	0008100
1622.		LOC(NON)=JT	0008105
1623.	850	CONTINUE	0008110
1624.	860	CONTINUE	0008115
1625.		IF(IACT.LT.1) GO TO 880	0008120
1626.		DO 870 K=1,5	0008125
1627.		IL=I-IM	0008130
1628.		IF(YIELD(K,IL).LT.ERR) GO TO 870	0008135
1629.		NON=NON+1	0008140
1630.		IF(NON.GT.2500) PRINT 9041, NON,NUCL(I)	0008145
1631.		NON0(I)=NON0(I)+1	0008150
1632.		KK=NSORS(K)	0008155
1633.		LOC(NON)=KK	0008160
1634.		KF=KK-ILITE	0008165
1635.		A(NON)=YIELD(K,IL)*FISS(KF)	0008170
1636.	870	CONTINUE	0008175
1637.	880	CONTINUE	0008180
1638.		IF(IFP.LE.0) GO TO 900	0008185
1639.		IF(NLIBE.NE.3) GO TO 890	0008190
1640.		PRINT 9027, TYLD(2),TYLD(4),TYLD(5)	0008195
1641.		GO TO 900	0008200
1642.	890	PRINT 9030, (TYLD(I),I=1,5)	0008205
1643.	C		0008210
1644.	C	ALL MATRIX ELEMENTS ARE NOW COMPUTED	0008215
1645.	C	BEGIN TRANSIENT SOLUTION	0008220
1646.	C		0008225
1647.	C		0008230
1648.	C	TEMPORARILY WRITE OUT MATRIX ELEMENTS	0008235
1649.	C		0008240
1650.	900	IF(IR.EQ. 0) RETURN	0008245
1651.		PRINT 9029	0008250
1652.		N=0	0008255
1653.		DO 910 I=1,ITOT	0008260
1654.		NUM=NON0(I)	0008265
1655.		IF(NUM.LE.0) GO TO 910	0008270
1656.		N1=N+NUM	0008275
1657.		N=N+1	0008280
1658.		PRINT 9028, I,DIS (I),TOCAP(I),(A(K),LOC(K),K=N,N1)	0008285
1659.		N=N1	0008290
1660.	910	CONTINUE	0008295
1661.		RETURN	0008300
1662.	920	STOP	0008305
1663.	C		0008310
1664.	C	FORMATS FORMATS FORMATS FORMATS	0008315
1665.	C		0008320
1666.	9001	FORMAT(4F10.5,6I2)	0008325
1667.	9002	FORMAT(I6,F5.3,I1,5F3.3,E5.2,F3.3, 13X,E5.2,F3.3,2E5.2	0008330
1668.	1	,F4.3,F3.3,F6.4)	0008335
1669.	9003	FORMAT(I6,F5.3,I1,3X,4F3.3,2E5.2,F3.3,5E5.2,F4.3,F3.3)	0008340
1670.	9004	FORMAT(I6,F5.3,I1,5F3.3,2E5.2,F3.3,4E5.2,F3.3,F4.3,F3.3,2E5.2)	0008345
1671.	9005	FORMAT(1H1,43X,'NUCLEAR TRANSUTATION DATA REVISED ',I2,'/',I2,'	0008350
1672.		1/',I2,'/','0NUCL = NUCLIDE = 10000 * ATOMIC NO + 10 * MASS NO + ISOM	0008355
1673.		2ERIC STATE (0 OR 1)',10X,'DLAM = DECAY CONSTANT (1/SEC).',/,', FB,	0008360
1674.		3FP, FA, FT = FRACTIONAL DECAY BY BETA, POSITRON (OR ELECTRON CAPTU	0008365
1675.		4RE), ALPHA, INTERNAL TRANSITION. FB = 1 - FP - FA - FT',/,', FB1,	0008370
1676.		5 FP1, FNG1, FN2N1 = FRACTION OF BETA, POSITRON, N-GAMMA, N-2N TRAN	0008375
1677.		6SITIONS TO EXCITED STATE OF PRODUCT NUCLIDE',/,', SIGH, SIGNG, SIG	0008380
1678.		7F, SIGNA, SIGNP = THERMAL CROSS SECTIONS (BARNS) FOR ABSORPTION, N	0008385
1679.		8-GAMMA, FISSION, N-ALPHA, N-PROTON.')	0008390
1680.	9006	FORMAT(' SIGNG = SIGH * (1 - FNA -FNP). SIGNA = SIGH * FNA.	0008395

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1681. 1SIGNP = SIGTH * FNP. FNA, FNP = FRACTION THERMAL N-ALPHA, N-PROTO 0008400
1682. 2N.',/, ' RITH, RING, RIF, RINA, RINP = RESONANCE INTEGRAL FOR ABSOR 0008405
1683. 3PTION, N-GAMMA, FISSION, N-ALPHA, N-PROTON.',/, ' RING = RITH * ( 0008410
1684. 41 - FINA - FINP). RINA = RITH * FINA. RINP = RITH * FINP. FINA, F 0008415
1685. 5INP = FRACTION RESONANCE N-ALPHA, N-PROTON.',/, ' SIGMEV, SIGFF, SI 0008420
1686. 6GN2N, SIGNAF, SIGNPF = FAST CROSS SECTIONS (BARNs) FOR ABSORPTION, 0008425
1687. 7FISSION, N-2N, N-ALPHA, N-PROTON.',/, ' SIGN2N = SIGMEV * (1 - FF 0008430
1688. 8NA - FFNP). SIGNAF = SIGMEV * FFNA. SIGNPF = SIGMEV * FFNP. FFN 0008435
1689. 9A, FFNP = FRACTION FAST N-ALPHA, N-P.') 0008440
1690. 9007 FORMAT(' Y23, Y25, Y02, Y28, Y49 = FISSION YIELD (PERCENT) FROM 23 0008445
1691. 13-U, 235-U, 232-TH, 238-U, 239- PU.',/, ' Q = HEAT PER DISINTEGRATI 0008450
1692. 20N. FG = FRACTION OF HEAT IN GAMMAS OF ENERGY GREATER THAN 0.2 ME 0008455
1693. 3V.',/, '0 EFFECTIVE CROSS SECTIONS FOR A VOLUME AVERAGED THERMAL (L 0008460
1694. 4T 0.876 EV) FLUX ARE AS FOLLOWS.',/, ' N-GAMMA - SIGNG * THERM 0008465
1695. 5 + RING * RES.',/, ' FISSION - SIGF * THERM + RIF * RES + SIGF 0008470
1696. 6F * FAST.',10X, 'THERM = 1/V CORRECTION FOR THERMAL SPECTRUM AND TE 0008475
1697. 7MPERATURE.',/, ' N-2N - SIGN2N * FAST.',36X, 'RES = RATIO 0008480
1698. 80F RESONANCE FLUX PER LETHARGY UNIT TO THERMAL FLUX.') 0008485
1699. 9008 FORMAT(' N-ALPHA - SIGNA * THERM + RINA * RES + SIGNAF * FAST 0008490
1700. 1.',7X, 'FAST = 1.45 * RATIO OF FAST (GT 1.0 MEV) TO THERMAL FLUX ' 0008495
1701. 2/' N-PROTON - SIGNP * THERM + RINP * RES + SIGNPF * FAST.') 0008500
1702. 9009 FORMAT(1H0,59X, 'REFERENCES',/, ' HALF LIVES, DECAY SCHEMES, AND 0008505
1703. 1THERMAL POWER',/, ' C M LEDERER, J M HOLLANDER, AND I PERLMAN 'TAB 0008510
1704. 2LE OF ISOTOPES - SIXTH EDITION' JOHN WILEY AND SONS, INC (1967)', 0008515
1705. 3/, ' B S DZHELEPOV AND L K PEKER 'DECAY SCHEMES OF RADIOACTIVE NUC 0008520
1706. 4LEI' PERGAMMON PRESS (1961)',/, ' D T GOLDMAN AND JAMES R ROSSER ' 0008525
1707. 5'CHART OF THE NUCLIDES' NINTH EDITION - GENERAL ELECTRIC CO (JULY 0008530
1708. 61966)',/, ' E D ARNOLD 'PROGRAM SPECTRA' APPENDIX A OF ORNL-3576 0008535
1709. 7(APRIL 1964)') 0008540
1710. 9010 FORMAT(' CROSS SECTIONS AND FLUX SPECTRA',/, ' B E PRINCE 'NEUT 0008545
1711. 1IRON REACTION RATES IN THE MSRE SPECTRUM' ORNL-4119, PP 79-83 (JUL 0008550
1712. 2Y 1967)',/, ' B E PRINCE 'NEUTRON ENERGY SPECTRA IN MSRE AND MSBR' 0008555
1713. 3' ORNL-4191, PP 50-58 (DEC 1967)',/, ' M D GOLDBERG ET AL 'NEUTRON 0008560
1714. 4 CROSS SECTIONS' BNL-325, SECOND ED, SUPP NO 2 (MAY 1964 - AUG 19 0008565
1715. 566) ALSO EARLIER EDITIONS',/, ' H T KERR, UNPUBLISHED ERC COMPILATI 0008570
1716. 6ON (FEB 1968)',/, ' M K DRAKE 'A COMPILATION OF RESONANCE INTEGRAL 0008575
1717. 7S' NUCLEONICS, VOL 24, NO 8, PP 108-111 (AUG 1966)',/, ' BNWL STAF 0008580
1718. 8F 'INVESTIGATION OF N-2N CROSS SECTIONS' BNWC-98, PP 44-98 (JUNE 0008585
1719. 9 1965)') 0008590
1720. 9011 FORMAT(18A4,I3) 0008595
1721. 9012 FORMAT(1H1,20X,18A4) 0008600
1722. 9013 FORMAT(' H ALTER AND C E WEBER 'PRODUCTION OF H AND HE IN METALS 0008605
1723. 1DURING REACTOR IRRADIATION' J NUCL MATLS, VOL 16, PP 68-73 (1965) 0008610
1724. 2',/, ' L L BENNETT 'RECOMMENDED FISSION PRODUCT CHAINS FOR USE IN 0008615
1725. 3REACTOR EVALUATION STUDIES' ORNL-TM-1658 (SEPT 1966)') 0008620
1726. 9014 FORMAT(' FISSION PRODUCT YIELDS',/, ' M E MEEK AND B F RIDER, ' 0008625
1727. 1SUMMARY OF FISSION PRODUCT YIELDS FOR U-235, U-238, PU-239, AND PU 0008630
1728. 2-241 AT THERMAL, FISSION SPECTRUM AND',/, ' 14 MEV NEUTRON ENERGI 0008635
1729. 3ES' APED-5398-A(REV.), (OCT. 1968)'/ ' S KATCOFF 'FISSION PRODUCT 0008640
1730. 4YIELDS FROM NEUTRON INDUCED FISSION' NUCLEONICS, VOL 18, NO 11, 0008645
1731. 5(NOV 1960)'/ ' N D DUDEY 'REVIEW OF LOW-MASS ATOM PRODUCTION IN F 0008650
1732. 6AST REACTORS' ANL-7434, (APRIL 1968) ' 0008655
1733. 9015 FORMAT(1H0,20X, 'LIGHT ELEMENTS, MATERIALS OF CONSTRUCTION, AND ACT 0008660
1734. 1IVATION PRODUCTS ',/, '0 NUCL DLAM FB1 FP FP1 FT F 0008665
1735. 2A SIGTH FNG1 FNA FNP RITH FINA FINP SIGMEV FN2N1 0008670
1736. 3 FFNA FFNP Q FG') 0008675
1737. 9016 FORMAT(1H0,20X, 'LIGHT ELEMENTS, MATERIALS OF CONSTRUCTION, AND ACT 0008680
1738. 1IVATION PRODUCTS ',/, '0 NUCL DLAM FB1 FP FP1 FT F 0008685
1739. 2A SIGNG FNG1 SIGN2N FN2N1 SIGNA SIGNP Q FG ABU 0008690
1740. 3NDANCE') 0008695

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1741. 9017 FORMAT(1H ,A2,I3,A1,1PE9.2,0P5F6.3,1PE9.2,0P3F6.3,1PE9.2,0P2F6.3, 0008700
1742. 11PE9.2,0P4F6.3,0PF5.2) 0008705
1743. 9018 FORMAT(1H0,10X,'THERM= 'F10.5,5X,'RES= 'F10.5,5X,'FAST= 'F10.5, 0008710
1744. 1//,1X,'NEUTRON SOURCE= '5(I10,5X),5X,'NLIBE= 'I3) 0008715
1745. 9019 FORMAT(1H0,36X,'FISSION PRODUCTS',/, '0 NUCL DLAM FB1 FP 0008720
1746. 1 FP1 FT SIGNG ' , ' FNG1 Y23 Y25 Y02 Y 0008725
1747. 228 Y49 Q FG') 0008730
1748. 9020 FORMAT(1H0,36X,'FISSION PRODUCTS',/, '0 NUCL DLAM FB1 FP 0008735
1749. 1 FP1 FT SIGNG FNG1 Y25 Y28 Y49 Q FG') 0008740
1750. 9021 FORMAT(1H ,A2,I3,A1,1PE9.2,0P4F6.3, 1PE9.2,0PF6.3,1P5E9.2, 0008745
1751. 10P2F6.3) 0008750
1752. 9022 FORMAT(1H ,A2,I3,A1,1PE9.2,0P4F6.3,1PE9.2,0PF6.3,1P3E9.2,0P2F6.3) 0008755
1753. 9023 FORMAT(1H0,32X, 'ACTINIDES AND THEIR DAUGHTERS',// 0008760
1754. 1' NUCL DLAM FB1 FP FP1 FT FA FSF E+6 SIGNG R 0008765
1755. 2ING FNG1 SIGF RIF 'SIGFF SIGN2N SIGN3N Q FG') 0008770
1756. 9024 FORMAT(1H0,32X, 'ACTINIDES AND THEIR DAUGHTERS',// 0008775
1757. 1' NUCL DLAM FB1 FP FP1 FT FA FSF E+6 SIGNG F 0008780
1758. 2NG21 SIGF SIGN2N SIGN3N Q FG') 0008785
1759. 9025 FORMAT(1H ,A2,I3,A1,1PE9.2,0P5F6.3,6PF6.1,1P2E9.2,0PF6.3,1P5E9.2, 0008790
1760. 1 0PF6.3,F5.2) 0008795
1761. 9026 FORMAT(1H ,A2,I3,A1,1PE9.2,0P5F6.3,6PF9.1,1PE9.2,0PF6.3,1P3E9.2, 0008800
1762. 1 0PF7.3,F5.2) 0008805
1763. 9027 FORMAT('0SUM OF YIELDS OF ALL FISSION PRODUCTS =' ,15X,1P3E9.2) 0008810
1764. 9028 FORMAT(I5,2X,1PE10.3,3X,E10.3,5(2X,E10.3,3X,I5)/(30X,5(2X,E10.3, 0008815
1765. 1 3X,I5))) 0008820
1766. 9029 FORMAT('1NON-ZERO MATRIX ELEMENTS AND THEIR LOCATIONS'/ 0008825
1767. 1' I DIS(I) CAP(I) A(I,J) J A(I,J) 0008830
1768. 2J A(I,J) J A(I,J) J A(I,J) J ' ) 0008835
1769. 9030 FORMAT(64H0SUM OF YIELDS OF ALL FISSION PRODUCTS 0008840
1770. 1 ,1P5E9.2) 0008845
1771. 9031 FORMAT(5I10) 0008850
1772. 9032 FORMAT(I6,F5.3,I1,5F3.3,E5.2,3F3.3,E5.2,2F3.3,E5.2,3F3.3,F4.3,F3.3 0008855
1773. 1,F6.4) 0008860
1774. 9033 FORMAT(1H ,A2,I3,A1,1PE9.2,0P5F6.3,1PE9.2,0PF6.3,1PE9.2,0PF6.3, 0008865
1775. 1 1P2E9.2,0P2F6.3,F7.3) 0008870
1776. 9034 FORMAT(I7,F9.3,I1,5F5.3,1PE9.2,0P2F5.3,F7.3,2E6.0) 0008875
1777. 9035 FORMAT(7X,F9.2,3F5.3,F9.2,2F5.3,F9.2,3F5.3, 5X,I1) 0008880
1778. 9036 FORMAT(20A4) 0008885
1779. 9037 FORMAT(7X,2F9.2,F5.3,4F9.2,F4.3,F9.2,I1) 0008890
1780. 9038 FORMAT(7X,2F9.2,F5.3,5F9.2, 4X,I1) 0008895
1781. 9039 FORMAT('0 WARNING, MOUT OF RANGE IN NUDATA, =' I5) 0008900
1782. 9040 FORMAT( 7X,F9.2,3F8.6,F4.2,2F3.1,F9.2,3F5.3,5X,I1) 0008905
1783. 9041 FORMAT('0 NON HAS EXCEEDED 2500, EQUAL TO '2I6) 0008910
1784. END 0008915
1785. SUBROUTINE COLECT(TMB,CWASTE,ILITE,ITOT) 0008920
1786. COMMON/EQ/XZERO(800), XZH(800),XTEMP(800),XNEW(10,800), 0008925
1787. 1 B(800),D(800) 0008930
1788. DIMENSION CWASTE(800) 0008935
1789. IF(TMB.LT.1) RETURN 0008940
1790. DO 10 I=1,ITOT 0008945
1791. B(I)=CWASTE(I) 0008950
1792. 10 XTEMP(I)=0.0 0008955
1793. CALL DECAY(1,TMB,ITOT) 0008960
1794. CALL TERM(TMB,1,0,ITOT) 0008965
1795. CALL EQUIL(1,ITOT) 0008970
1796. DO 20 I=1,ITOT 0008975
1797. 20 CWASTE(I)=XNEW(1,I)/TMB 0008980
1798. RETURN 0008985
1799. END 0008990
1800. SUBROUTINE STORAG(TMB,CWASTE,ILITE,ITOT) 0008995

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1801.		COMMON/EQ/XZERO(800), XZH(800),XTEMP(800),XNEW(10,800),	0009000
1802.	1	B(800),D(800)	0009005
1803.		DIMENSION CWASTE(ITOT)	0009010
1804.		IF(TMB.LT.1) RETURN	0009015
1805.		DELT=TMB	0009020
1806.		DO 10 I=1,ITOT	0009025
1807.		B(I)=0.0	0009030
1808.	10	XTEMP(I)=CWASTE(I)	0009035
1809.		CALL DECAY(1,DELT,ITOT)	0009040
1810.		CALL TERM(TMB,1,ILITE,ITOT)	0009045
1811.		CALL EQUIL(1,ITOT)	0009050
1812.		DO 20 I=1,ITOT	0009055
1813.	20	CWASTE(I)=XNEW(1,I)	0009060
1814.		RETURN	0009065
1815.		END	0009070
1816.	C	PROGRAM BLOCK DATA	0009075
1817.		BLOCK DATA	0009080
1818.		INTEGER*2 ELE(99),STA(2)	0009085
1819.		COMMON/LABEL/ ELE,STA	0009090
1820.		DATA ELE/' H','HE','LI','BE','B','C','N','O','F','NE','NA','M	0009095
1821.		1G','AL','SI','P','S','CL','AR','K','CA','SC','TI','V','CR','MN	0009100
1822.		2','FE','CO','NI','CU','ZN','GA','GE','AS','SE','BR','KR','RB','SR'	0009105
1823.		3','Y','ZR','NB','MO','TC','RU','RH','PD','AG','CD','IN','SN','SB'	0009110
1824.		4'TE','I','XE','CS','BA','LA','CE','PR','ND','PM','SM','EU','GD','	0009115
1825.		5TB','DY','HO','ER','TM','YB','LU','HF','TA','W','RE','OS','IR','P	0009120
1826.		6T','AU','HG','TL','PB','BI','PO','AT','RN','FR','RA','AC','TH','PA	0009125
1827.		7','U','NP','PU','AM','CM','BK','CF','ES'/	0009130
1828.		DATA STA/' ','M'/'	0009135
1829.		END	0009140
1830.		SUBROUTINE HALF(A,I)	0009145
1831.	C	SUBROUTINE HALF CONVERTS HALF-LIFE TO DECAY CONSTANT (1/SEC)	0009150
1832.		DIMENSION C(9)	0009155
1833.		DATA C/6.9315E-01,1.1552E-02,1.9254E-04,8.0226E-06,2.1965E-08,0.0,	0009160
1834.	1	2.1965E-11,2.1965E-14,2.1965E-17/	0009165
1835.		IF(A.GT.0.0) GO TO 10	0009170
1836.		IF(I.EQ.6) GO TO 20	0009175
1837.		A=9.99	0009180
1838.		RETURN	0009185
1839.	10	A=C(I)/A	0009190
1840.		RETURN	0009195
1841.	20	A=0.0	0009200
1842.		RETURN	0009205
1843.		END	0009210
1844.		SUBROUTINE NOAH(NUCLI,NAME)	0009215
1845.	C	SUBROUTINE NOAH CONVERTS SIX DIGIT IDENTIFIER TO ALPHAMERIC SYMBOL	0009220
1846.		INTEGER*2 NAME(3)	0009225
1847.		INTEGER*2 ELE(99),STA(2)	0009230
1848.		COMMON/LABEL/ ELE,STA	0009235
1849.		IS=MOD(NUCLI,10)+1	0009240
1850.		NZ =NUCLI/10000	0009245
1851.		MW=NUCLI/10-NZ *1000	0009250
1852.		NAME(1)=ELE(NZ)	0009255
1853.		NAME(2)=MW	0009260
1854.		NAME(3)=STA(IS)	0009265
1855.		RETURN	0009270
1856.		END	0009275

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1. C GALE CODE FOR CALCULATING GASEOUS EFFLUENTS FROM LWRS. MODIFIED 0000000
2. C AUG. 1978 TO IMPLEMENT APPENDIX I TO 10 CFR PART 50. REACTOR 0000005
3. C WATER CONCENTRATIONS CALCULATED USING METHODS OF DRAFT STANDARD 0000010
4. C ANS 237 'RADIOACTIVE MATERIALS IN PRINCIPAL FLUID STREAMS OF 0000015
5. C LIGHT WATER COOLED NUCLEAR POWER PLANTS' DRAFT DATED MAY 20, 1974 0000020
6. COMMON MSIG,NSIG 0000025
7. DIMENSION NAME(8) 0000030
8. DIMENSION DECON(14),DECOH(14) 0000035
9. DIMENSION EX3(14),EX4(14),EXC(14),EJT(14) 0000040
10. DIMENSION PCBB(19),PAXBB(19),PTBB(19),PRWBB(19) 0000045
11. DIMENSION CBB(14),AXB(14),TBB(14),RADBB(14) 0000050
12. DIMENSION PCBL(19),PTBL(19),PAXBL(19),PRWBL(19),PTOTB(19) 0000055
13. DIMENSION WURD(4),WORD(14) 0000060
14. DIMENSION PVPL(19),VPR(14),PVPR(19) 0000065
15. DIMENSION XB(14),X1(14) 0000070
16. DIMENSION CBL(14),AXB(14),TBL(14),RADBL(14),SGL(14) 0000075
17. DIMENSION TOT(14) 0000080
18. DIMENSION EJT(2),EXCI(2) 0000085
19. DIMENSION TOTI(2),VPRI(2) 0000090
20. DIMENSION RNR(2),RNR5(2),RBWRR(2),RBWRRS(2),RADBLI(2) 0000095
21. DIMENSION RNT(2),RNTS(2),RBWRT(2),RBWRTS(2),TBLI(2) 0000100
22. DIMENSION DECONI(2),DECOHI(2) 0000105
23. DIMENSION EX3I(2),EX4I(2),CBWR1(2) 0000110
24. DIMENSION RBWR(2),RN(2),CBWR(2),RBWRS(2),RNS(2) 0000115
25. DIMENSION AUXMK1(2),AUXBLN(2),CBLN(2),AUXM1S(2),CBLN(2),AUXBLS(2) 0000120
26. DIMENSION CBLI(2),AUXLI(2),SGLI(2) 0000125
27. DIMENSION WARD(5) 0000130
28. DIMENSION RNMVP(2),RNMVPS(2) 0000135
29. DIMENSION RMVP(2),RMVPS(2) 0000140
30. REAL KKR,KXE,KNO,KMASS,KAR 0000145
31. REAL*8 NUCLID(14)/' AR-41 ',' KR-83M ',' KR-85M ',' KR-85 ',' K 0000150
32. 1R-87 ',' KR-88 ',' KR-89 ',' XE-131M ',' XE-133M ',' XE-133 ',' XE 0000155
33. 2-135M ',' XE-135 ',' XE-137 ',' XE-138 '/ 0000160
34. REAL*8 BPART(19)/' CR-51 ',' MN-54 ',' CO-58 ',' FE-59 ',' CO 0000165
35. 1-60 ',' ZN-65 ',' SR-89 ',' SR-90 ',' NB-95 ',' ZR-95 ',' MO 0000170
36. 2-99 ',' RU-103 ',' AG-110M ',' SB-124 ',' CS-134 ',' CS-136 ',' CS- 0000175
37. 3137 ',' BA-140 ',' CE-141 '/ 0000180
38. REAL*8 HAL(2)/' I-131 ',' I-133 '/ 0000185
39. DATA PCBB/.2,.4,.1,.09,1.,1.,.03,.003,1.,.3,6.,.2,.0004,.02,.7,.1, 0000190
40. 11.,2.,.2/ 0000195
41. DATA PAXBB/.9,1.,.2,.3,4.,.4.,.02,.007,9.,.7,60.,.4.,.002,.03,4.,.4, 0000200
42. 15,20.,.7/ 0000205
43. DATA PTBB/.9,.6,1.,.1,1.,.6.,.6.,.02,.006,.04,2.,.05,0.,.1,.2,.1,1., 0000210
44. 110.,10./ 0000215
45. DATA PRWBB/.7,4.,.2,.3,7.,.3,0.,.0.,.004,.8.,.003,.001,0.,.07,2,4,0. 0000220
46. 1,4.,.004,.007/ 0000225
47. DATA CBB/15,0,0,0,1,0,2*0,0,1,0,3*0,0,27,0,15,0,33,0,45,0,2,0/ 0000230
48. DATA AXBB/2*0,0,3,0,0,0,2,0,3,0,2,0,2*0,0,83,0,45,0,94,0,135,0,6,0 0000235
49. 1/ 0000240
50. DATA TBB/2*0,0,25,0,0,0,61,0,91,0,580,0,2*0,0,150,0,400,0,330,0,10 0000245
51. 200,0,1000,0/ 0000250
52. DATA RADBB/6*0,0,29,0,2*0,0,220,0,530,0,280,0,83,0,2,0/ 0000255
53. DATA PVPR/.001,3*0.,.00056,.00034,8*0.,.0032,.0019,.0089,.011,1*0. 0000260
54. 1/ 0000265
55. DATA XB/0.0E-0,9.1E-3,1.6E-3,5.0E-6,5.5E-3,5.5E-3,3.4E-2,3.9E-6,7. 0000270
56. 15E-5,2.1E-3,7.0E-3,6.0E-3,3.9E-2,2.3E-2/ 0000275
57. DATA DECON/1.052E-04,1.035E-04,4.375E-05,2.040E-09,1.520E-04,6.880 0000280
58. 1E-05,3.632E-03,6.800E-07,3.548E-06,1.520E-06,7.357E-04,2.090E-05,3 0000285
59. 2.024E-03,6.800E-04/ 0000290
60. DATA VPR/9*0,0,1300,0,0,0,500,0,2*0,0/ 0000295

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61.	C		0000300
62.	C	DECONI DEFINES THE DECAY CONSTANT FOR IODINES	0000305
63.	C		0000310
64.		DATA DECONI/9.970E-07,9.170E-06/	0000315
65.	C		0000320
66.	C	CBWR DEFINES THE REACTOR WATER CONCENTRATIONS FOR IODINES	0000325
67.	C		0000330
68.		DATA CBWR/3.7E-3,5.0E-2/	0000335
69.	C		0000340
70.	C	RN DEFINES THE NORMALIZED ANNUAL RELEASES DURING POWER OPERATIONS FOR	0000345
71.	C	THE REACTOR BLDG.	0000350
72.	C		0000355
73.	C		0000360
74.		DATA RN/12.3,12.3/	0000365
75.	C		0000370
76.	C	RNS DEFINES THE NORMALIZED ANNUAL RELEASES DURING SHUTDOWNS FOR THE	0000375
77.	C	REACTOR BLDG.	0000380
78.	C		0000385
79.		DATA RNS/5.2,5.2/	0000390
80.	C		0000395
81.	C	RNT DEFINES THE NORMALIZED ANNUAL RELEASES DURING POWER OPERATION FOR	0000400
82.	C	THE TURBINE BLDG.	0000405
83.	C		0000410
84.		DATA RNT/3.8E3,3.8E3/	0000415
85.	C		0000420
86.	C	RNTS DEFINES THE NORMALIZED ANNUAL RELEASES DURING SHUTDOWNS FOR	0000425
87.	C	THE TURBINE BLDG.	0000430
88.	C		0000435
89.		DATA RNTS/4.1E2,4.1E2/	0000440
90.	C		0000445
91.	C	RNR DEFINES THE NORMALIZED RELEASES FROM THE RADWASTE BLDG. DURING	0000450
92.	C	POWER OPERATIONS	0000455
93.	C		0000460
94.		DATA RNR/4.6,4.6/	0000465
95.	C		0000470
96.	C	RNRS DEFINES THE NORMALIZED RELEASES FROM THE RADWASTE BLDG.	0000475
97.	C	DURING SHUTDOWNS	0000480
98.	C		0000485
99.		DATA RNRS/1.4,1.4/	0000490
100.	C		0000495
101.	C	RNMVP DEFINES NORMALIZED RELEASES FROM THE MECHANICAL VACUUM PUMP	0000500
102.		DATA RNMVP/4.9E2,4.9E2/	0000505
103.		DATA RNMVPS/1.1E3,1.1E3/	0000510
104.		49 FORMAT(16X,'REACTOR VESSEL HALOGEN CARRYOVER FACTOR',15X,F10.5)	0000515
105.		51 FORMAT(16X,'PLANT CAPACITY FACTOR',T74,'0.80')	0000520
106.		52 FORMAT(32X,8A4,12X,A4)	0000525
107.		53 FORMAT(16X,13A4,A2,F10.5)	0000530
108.		55 FORMAT(15X,4A4,A2,8X,F8.0,7X,F5.3)	0000535
109.		56 FORMAT(20X,F8.0,2(5X,F8.0))	0000540
110.		57 FORMAT(27X,F6.2,14X,F6.2,18X,F6.2)	0000545
111.		58 FORMAT (30X,'FRACTION FRACTION COLLECTION DECAY'/8X,'STREAM	0000550
112.		1 FLOW RATE OF PCA DISCHARGED TIME TIME',5X,' DECONTAM	0000555
113.		2INATION FACTORS'/20X,'(GAL/DAY)',23X,'(DAYS) (DAYS)',7X,	0000560
114.		3'I',8X,'CS',8X,'OTHERS')	0000565
115.		59 FORMAT(2X,4A4,A2,1PE9.2,1X,4(0PF8.3,2X),3(1PE9.2,1X))	0000570
116.		60 FORMAT(79X,I1)	0000575
117.		61 FORMAT(16X,'THERE IS A CRYOGENIC DISTILLATION COLUMN'/20X,'IODINE	0000580
118.		1AND XENON DECONTAMINATION FACTOR',T70,'10000.'/20X,'KRYPTON DECONT	0000585
119.		2AMINATION FACTOR',T71,'4000.'/20X,'KRYPTON AND XENON HOLDUP TIME	0000590
120.		3(DAYS)',T73,'90.')	0000595


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121. 62 FORMAT(16X,'THERE IS NO CHARCOAL DELAY SYSTEM') 0000600
122. 63 FORMAT(16X,'THERE IS A CHARCOAL DELAY SYSTEM'/20X,'KRYPTON HOLDUP 0000605
123. 1TIME (DAYS)',T72,F9.5/20X,'XENON HOLDUP TIME (DAYS)',T72,F9.5/ 0000610
124. 220X,'KRYPTON DYNAMIC ADSORPTION COEFFICIENT (CM3/GM)',T72,F9.5/ 0000615
125. 320X,'XENON DYNAMIC ADSORPTION COEFFICIENT (CM3/GM)',T71,F10.5/20X, 0000620
126. 4'MASS OF CHARCOAL(THOUSAND LBS)',T72,F9.5) 0000625
127. 68 FORMAT(70X,F10.5) 0000630
128. 77 FORMAT(16X,'FRACTION IODINE BYPASSING CONDENSATE DEMINERALIZER', 0000635
129. 17X,T72,F9.5) 0000640
130. 71 FORMAT(2X,'REGENERANT SOLS ',1PE9.2,14X,0PF5.3,2X,2(F8.3,2X), 0000645
131. 13(1PE9.2,1X)) 0000650
132. 903 FORMAT(16X,16A4) 0000655
133. 904 FORMAT (/, ' LIQUID WASTE INPUTS') 0000660
134. 905 FORMAT (/, ' GASEOUS WASTE INPUTS') 0000665
135. 906 FORMAT(1H1) 0000670
136. 907 FORMAT('0',15X,'THERE IS NOT AN ON-SITE LAUNDRY') 0000675
137. 214 FORMAT(1H0,131H-----) 0000680
138. 1-----) 0000685
139. 2-----) 0000690
140. 232 FORMAT(1H0,5X,'TOTAL NOBLE GASES', 99X,1PE7.1) 0000695
141. 230 FORMAT(1H0,4X,A8,5X,1PE9.3,8X,1PE7.1,1X,6(4X,1PE7.1,1X),7X,1PE7.1) 0000700
142. 231 FORMAT(1H0,'0.0 APPEARING IN THE TABLE INDICATES RELEASE IS LESS 0000705
143. 1THAN 1.0 CI/YR FOR NOBLE GAS') 0000710
144. 245 FORMAT (1H0,49X,'AIRBORNE PARTICULATE RELEASE RATE'/1H0,63X,'(CURI 0000715
145. 1ES PER YEAR)'/1H0,32X,'CONTAINMENT',3X,'TURBINE',6X,'AUXILIARY',4X 0000720
146. 2,'RADWASTE MECH VAC.'/1H,4X,'NUCLIDE',24X,'BLDG.',7X,'BLDG.',7X, 0000725
147. 3'BLDG.',8X,'BLDG.',6X,'PUMP',10X,'TOTAL') 0000730
148. 235 FORMAT(1H0,63X,'GASEOUS RELEASE RATE'/1H0,63X,'(CURIES PER YEAR)'/ 0000735
149. 11H0,16X,'COOLANT CONC.',3X,'CONTAINMENT',3X,'TURBINE',4X,'AUXILIAR 0000740
150. 2Y',3X,'RADWASTE',5X,'GLAND',7X,'AIR',6X,'MECH VAC'/1H,4X,'NUCLIDE' 0000745
151. 3,3X,'(MICROCURIES/G)',6X,'BLDG.',7X,'BLDG.',7X,'BLDG.',6X,'BLDG.', 0000750
152. 48X,'SEAL',5X,'EJECTOR',7X,'PUMP',11X,'TOTAL') 0000755
153. 925 FORMAT(16X,4A4,10X,F4.0,6X,F4.0) 0000760
154. 927 FORMAT(16X,4A4,10X,F4.0,6X,F4.0) 0000765
155. 926 FORMAT (16X,4A4,'IODINE RELEASE FRACTION',16X,F10.5/32X,'PARTICULA 0000770
156. 1TE RELEASE FRACTION',10X,F10.5) 0000775
157. 928 FORMAT(16X,4A4,'IODINE RELEASE FRACTION',16X,F10.5/32X,'PARTICULAT 0000780
158. 1E RELEASE FRACTION',10X,F10.5) 0000785
159. 920 FORMAT (1H0,4X,A8,22X,5(1PE7.1,5X),3X,1PE7.1) 0000790
160. 960 FORMAT(1H0,30X,'H-3 RELEASED FROM TURBINE BLDG. VENTILATION SYSTEM 0000795
161. 1',5X,1PE7.1) 0000800
162. 962 FORMAT(1H0,30X,'H-3 RELEASED FROM CONTAINMENT BLDG. VENTILATION SY 0000805
163. 1STEM',5X,1PE7.1) 0000810
164. 963 FORMAT(1H0,30X,'C-14 RELEASED VIA MAIN CONDENSER OFFGAS SYSTEM = 0000815
165. 19.5 CI/YR') 0000820
166. 964 FORMAT(1H0,30X,'TOTAL H-3 RELEASED VIA GASEOUS PATHWAY',5X,1PE7.1) 0000825
167. 2 FORMAT(I2) 0000830
168. C 0000835
169. C GENERIC PLANT INFORMATION 0000840
170. C 0000845
171. READ(1,2) N 0000850
172. ICOUNT = 0 0000855
173. 80 ICOUNT = ICOUNT + 1 0000860
174. IF(ICOUNT.EQ.N) GO TO 1003 0000865
175. READ(1,52)NAME,TYPE 0000870
176. WRITE(6,906) 0000875
177. WRITE(6,52)NAME,TYPE 0000880
178. READ(1,53)WORD,POWTH 0000885
179. WRITE(6,53)WORD,POWTH 0000890
180. OPFRA=0.80 0000895

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181.	WRITE(6,51)	0000900
182.	READ(1,53)WORD,GTO	0000905
183.	WRITE(6,53)WORD,GTO	0000910
184.	READ(1,53)WORD,WLIQ	0000915
185.	WRITE(6,53)WORD,WLIQ	0000920
186.	READ(1,53)WORD,GDE	0000925
187.	WRITE(6,53)WORD,GDE	0000930
188.	PC = 0.015	0000935
189.	READ(1,53)WORD,REGENT	0000940
190.	IF(REGENT.EQ.0.0) PC = 0.004	0000945
191.	WRITE(6,53)WORD,REGENT	0000950
192.	READ(1,53)WORD,FFCDM	0000955
193.	WRITE(6,53)WORD,FFCDM	0000960
194.	WRITE(6,49) PC	0000965
195.		0000970
196.	C READ DATA FOR BWR LIQUID CODE	0000975
197.	C	0000980
198.	C	0000985
199.	WRITE(6,904)	0000990
200.	READ(1,55)WARD,CWFLR,CWA	0000995
201.	READ(1,56)DFICW,DFCSCW,DFCW	0001000
202.	READ(1,57)TC,TSTORC,CWFD	0001005
203.	WRITE(6,58)	0001010
204.	WRITE(6,59)WARD,CWFLR,CWA,CWFD,TC,TSTORC,DFICW,DFCSCW,DFCW	0001015
205.	READ(1,55)WARD,DWFLR,DWA	0001020
206.	READ(1,56)DFIDW,DFCSDW,DFDW	0001025
207.	READ(1,57)TD,TSTORD,DWFD	0001030
208.	WRITE(6,59)WARD,DWFLR,DWA,DWFD,TD,TSTORD,DFIDW,DFCSDW,DFDW	0001035
209.	READ(1,55)WARD,CMWFR,CMA	0001040
210.	READ(1,56)DFICM,DFCSCM,DFCM	0001045
211.	READ(1,57)TCM,TSTORB,CMFD	0001050
212.	WRITE(6,59)WARD,CMWFR,CMA,CMFD,TCM,TSTORB,DFICM,DFCSCM,DFCM	0001055
213.	READ(1,68)RGWFR	0001060
214.	READ(1,56)DFIRG,DFCSRG,DFRG	0001065
215.	READ(1,57)TRG,TSTORR,RGFD	0001070
216.	WRITE(6,71)RGWFR,RGFD,TRG,TSTORR,DFIRG,DFCSRG,DFRG	0001075
217.	C	0001080
218.	C READ DATA FOR BWR GAS CODE	0001085
219.	C	0001090
220.	WRITE(6,905)	0001095
221.	READ(1,53)WORD,GG5	0001100
222.	WRITE(6,53)WORD,GG5	0001105
223.	READ(1,53)WORD,TIM3	0001110
224.	WRITE(6,53)WORD,TIM3	0001115
225.	READ(1,53)WORD,TIM4	0001120
226.	WRITE(6,53)WORD,TIM4	0001125
227.	HEPA1=1.0	0001130
228.	FIL1=1.0	0001135
229.	HEPA2=1.0	0001140
230.	FIL2=1.0	0001145
231.	HEPA5=1.0	0001150
232.	FIL5=1.0	0001155
233.	HEPA6=1.0	0001160
234.	FIL6=1.0	0001165
235.	FILGS = 1.0	0001170
236.	FILEJ = 1.0	0001175
237.	READ(1,925)WURD,CBCH,CBHEPA	0001180
238.	IF(CBCH.GT.0.0)FIL1 = (1.0 - CBCH/100.)	0001185
239.	IF(CBHEPA.GT.0.0)HEPA1 = (1.0 - CBHEPA/100.)	0001190
240.	WRITE(6,926)WURD,FIL1,HEPA1	0001195
	READ(1,927)WURD,TBCH,TBHEPA	

241.	IF(TBCH.GT.0.0)FIL2 = (1.0 - TBCH/100.)	0001200
242.	IF(TBHEPA.GT.0.0)HEPA2 = (1.0 - TBHEPA/100.)	0001205
243.	WRITE(6,928) WURD,FIL2,HEPA2	0001210
244.	READ(1,53) WORD,FIL3	0001215
245.	IF(FIL3.GT.0.0) FILGS = (1.0 - FIL3/100.)	0001220
246.	WRITE(6,53) WORD,FILGS	0001225
247.	READ(1,53) WORD,FIL4	0001230
248.	IF(FIL4.EQ.1.0) FILEJ = (1.0 - FIL4)	0001235
249.	IF(FIL4.GT.1.0) FILEJ = (1.0 - FIL4/100.)	0001240
250.	IF(FIL4.EQ.0.0) FILEJ = 1.0	0001245
251.	WRITE(6,53) WORD,FILEJ	0001250
252.	READ(1,925) WURD,AXCH,AXHEPA	0001255
253.	IF(AXCH.GT.0.0)FIL5 = (1.0 - AXCH/100.)	0001260
254.	IF(AXHEPA.GT.0.0)HEPA5 = (1.0 - AXHEPA/100.)	0001265
255.	WRITE(6,926) WURD,FIL5,HEPA5	0001270
256.	READ(1,925) WURD,RWCH,RWHEPA	0001275
257.	IF(RWCH.GT.0.0)FIL6 = (1.0 - RWCH/100.)	0001280
258.	IF(RWHEPA.GT.0.0)HEPA6 = (1.0 - RWHEPA/100.)	0001285
259.	WRITE(6,926) WURD,FIL6,HEPA6	0001290
260.	READ(1,60)KCHAR	0001295
261.	READ(1,53)WORD,KKR	0001300
262.	READ(1,53)WORD,KXE	0001305
263.	READ(1,53)WORD,KMASS	0001310
264.	IF(KXE.LT.1161.) XKAR = 6.4	0001315
265.	IF(KXE.GT.1161.) XKAR = 16.0	0001320
266.	IF(KCHAR.EQ.0) GO TO 90	0001325
267.	IF(KCHAR.EQ.1) GO TO 91	0001330
268.	WRITE(6,61)	0001335
269.	CHTI1=90.	0001340
270.	CHTI2=90.	0001345
271.	CHT3=90.	0001350
272.	GO TO 92	0001355
273.	90 WRITE(6,62)	0001360
274.	CHTI1=0.	0001365
275.	CHTI2=0.	0001370
276.	CHT3=0.	0001375
277.	GO TO 92	0001380
278.	91 CHTI1 = 1.8 * (KMASS * KKR)/POWTH	0001385
279.	CHTI2 = 1.8 * (KMASS * KXE)/POWTH	0001390
280.	CHT3 = 1.8 * (KMASS * XKAR)/POWTH	0001395
281.	WRITE(6,63)CHTI1,CHTI2,KKR,KXE,KMASS	0001400
282.	92 CONTINUE	0001405
283.	READ(1,53) WORD,PFLAUN	0001410
284.	IF(PFLAUN.LE.0.0) WRITE(6,907)	0001415
285.	C	0001420
286.	C	0001425
287.	C	0001430
288.	GTO=GTO*1000000.	0001435
289.	GDE=GDE*1000000.	0001440
290.	GGG=GGG*1000.	0001445
291.	WLIQ=WLIQ*1000000.	0001450
292.	WSTE=WSTE*1000000.	0001455
293.	C	0001460
294.	IOT=1	0001465
295.	IF(FFCDM.LT.0.99) FFCDM = 0.18	0001470
296.	IF(ABS(POWTH-3400).GT.400.1) GO TO 210	0001475
297.	IF(ABS(WLIQ-3.8E5).GT.0.4001E5)GO TO 210	0001480
298.	IF(ABS(GDE-1.3E5).GT.0.2001E5)GO TO 210	0001485
299.	IF(ABS(GTO-1.5E7).GT.0.2001E7)GO TO 210	0001490
300.	IF(FFCDM.GT.0.99) GO TO 210	0001495

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301.      GO TO 211                                0001500
302.      210 RHAL2=(GDE*0.9+FFCDM*GTO*PC*0.9)/WLIQ 0001505
303.      IOT=2                                    0001510
304.      211 CONTINUE                             0001515
305.      C                                         0001520
306.      C                                         0001525
307.      C CALCULATION OF IODINE RELEASES FROM BLDG. VENTILATION SYSTEMS 0001530
308.      C                                         0001535
309.      DO 88 I = 1,2                             0001540
310.      CBWR1(I) = CBWR(I)                       0001545
311.      DECOHI(I) = DECONI(I) * 3600.             0001550
312.      EX3I(I) = DECOHI(I) * TIM3               0001555
313.      IF(EX3I(I).GT.75.) EX3I(I) = 75.          0001560
314.      EX4I(I) = DECOHI(I) * TIM4               0001565
315.      IF(EX4I(I).GT.75.) EX4I(I) = 75.          0001570
316.      IF(IOT.EQ.1) GO TO 2002                   0001575
317.      CBWR(I) =CBWR1(I) * ((111.76 * POWTH/WLIQ) * ((0.4038+ DECOHI(I))/C 0001580
318.      1RHAL2 + DECOHI(I)))                      0001585
319.      C                                         0001590
320.      C CALCULATION OF IODINE RELEASES FROM RX. BLDG. DURING NORMAL OPERATIONS 0001595
321.      C                                         0001600
322.      2002 CONTINUE                             0001605
323.      RBWR(I) = RN(I) * CBWR(I)                 0001610
324.      AUXBLN(I) = RBWR(I) * 0.9                 0001615
325.      CBLN(I) = RBWR(I) * 0.1                   0001620
326.      C                                         0001625
327.      C CALCULATION OF IODINE RELEASES FROM RX. BLDG. DURING SHUTDOWNS 0001630
328.      C                                         0001635
329.      RBWRS(I) = RNS(I) * CBWR(I)               0001640
330.      AUXBLS(I) = RBWRS(I) * 0.1                0001645
331.      CBLS(I) = RBWRS(I) * 0.9                  0001650
332.      CBLI(I) = (CBLN(I) + CBLS(I)) * FIL1      0001655
333.      AUXLI(I) = (AUXBLN(I) + AUXBLS(I)) * FIL5 0001660
334.      C                                         0001665
335.      C CALCULATION OF IODINE RELEASES FROM TURBINE BLDG.DURING OPERATION 0001670
336.      C                                         0001675
337.      RBWRT(I) = RNT(I) * CBWR(I) * PC          0001680
338.      RBWRTS(I) = RNTS(I) * CBWR(I) * PC        0001685
339.      TBLI(I) = (RBWRT(I) + RBWRTS(I)) * FIL2    0001690
340.      C                                         0001695
341.      RBWRR(I) = RNR(I) * CBWR(I)               0001700
342.      RBWRRS(I) = RNRS(I) * CBWR(I)              0001705
343.      RADBLI(I) = (RBWRR(I) + RBWRRS(I)) * FIL6 0001710
344.      C                                         0001715
345.      IF(GGS.EQ.0.0) GO TO 87                    0001720
346.      SGLI(1) = 8.1E-1 * CBWR(1) * FILGS        0001725
347.      SGLI(2) = 2.2E-1 * CBWR(2)* FILGS         0001730
348.      GO TO 99                                    0001735
349.      87 SGLI(1) = 0.0                           0001740
350.      SGLI(2) = 0.0                              0001745
351.      C                                         0001750
352.      99 EXCI(I) = 0.0                           0001755
353.      IF(KCHAR.EQ.2) EXCI(I) = DECOHI(I) * CHTI1 * 24. 0001760
354.      IF(EXCI(I).GT.75.) EXCI(I) = 75.           0001765
355.      IF(KCHAR.EQ.2) DFCR = 0.00010              0001770
356.      EJTI(1) = 6.0 * EXP(-EX4I(I))*(DFCR+EXP(-EXCI(I)))*FILEJ 0001775
357.      EJTI(2) = EJTI(1) * CBWR(2)/CBWR(1)        0001780
358.      RMVP(I) = (RNMVP(I) * CBWR(I) * PC) * 4.0   0001785
359.      IF(I.EQ.2) GO TO 899                        0001790
360.      RMVPS(I) = RNMVPS(I) * CBWR(I) * PC        0001795

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361.	899	RMVPS(2) = RNMVP(I) * CBWR(I) * PC	0001800
362.		VPRI(I) = RMVP(I) + RMVPS(I)	0001805
363.		TEST = 0.0001	0001810
364.		IF(SGLI(I).LE.TEST) SGLI(I) = 0.0	0001815
365.		IF(EJTI(I).LE.TEST) EJTI(I) = 0.0	0001820
366.	88	CONTINUE	0001825
367.		MSIG = 1	0001830
368.		NSIG = 2	0001835
369.		CALL SIGF2(SGLI)	0001840
370.		CALL SIGF2(EJTI)	0001845
371.		DO 89 I = 1,2	0001850
372.		TOTI(I) = AUXLI(I)+TBLI(I)+SGLI(I)+EJTI(I)+CBLI(I)+RADBLI(I)+VPRI(I)	0001855
373.		1I)	0001860
374.	89	CONTINUE	0001865
375.		WRITE(6,906)	0001870
376.		WRITE(6,903) NAME	0001875
377.		WRITE(6,214)	0001880
378.		WRITE(6,235)	0001885
379.		WRITE(6,214)	0001890
380.		DO 79 I = 1,2	0001895
381.		WRITE(6,230) HAL(I),CBWR(I),CBLI(I),TBLI(I),AUXLI(I),RADBLI(I),SGL	0001900
382.		1I(I),EJTI(I),VPRI(I),TOTI(I)	0001905
383.		CBWR(I) = CBWR1(I)	0001910
384.	79	CONTINUE	0001915
385.		WRITE(6,214)	0001920
386.	C		0001925
387.	C	CALCULATION OF TRITIUM RELEASES	0001930
388.	C		0001935
389.		TRITRP = 0.03 * POWTH	0001940
390.		GASH3 = TRITRP * 0.5	0001945
391.		TBH3 = GASH3 * 0.5	0001950
392.		CBH3 = GASH3 - TBH3	0001955
393.		TH3 = TBH3 + CBH3	0001960
394.		DIV = 10.*(INT(ALOG10(TBH3))-1)	0001965
395.		TBH = INT(TBH3/DIV+0.5)*DIV	0001970
396.		DIV = 10.*(INT(ALOG10(CBH3))-1)	0001975
397.		CBH = INT(CBH3/DIV+0.5)*DIV	0001980
398.		DIV = 10.*(INT(ALOG10(TH3))-1)	0001985
399.		TH = INT(TH3/DIV+1.0)*DIV	0001990
400.		WRITE(6,960) TBH	0001995
401.		WRITE(6,962) CBH	0002000
402.		WRITE(6,964) TH	0002005
403.		WRITE(6,963)	0002010
404.	C		0002015
405.	C	CALCULATION OF NOBLE GAS RELEASES	0002020
406.	C		0002025
407.		WRITE(6,906)	0002030
408.		WRITE(6,903) NAME	0002035
409.		WRITE(6,214)	0002040
410.		WRITE(6,235)	0002045
411.		WRITE(6,214)	0002050
412.		DO 5 I = 1,14	0002055
413.		DECOH(I)=DECON(I)*3600.	0002060
414.		EX3(I)=DECOH(I)*TIM3	0002065
415.		IF(EX3(I).GT.75.)EX3(I)=75.	0002070
416.		EX4(I)=DECOH(I)*TIM4	0002075
417.		IF(EX4(I).GT.75.)EX4(I)=75.	0002080
418.		X1(I)=XB(I)	0002085
419.		CBL(I)=CBB(I)	0002090
420.		AXBL(I)=AXBB(I)	0002095

421.	TBL(I)=TBB(I)	0002100
422.	RADBL(I)=RADDB(I)	0002105
423.	SGL(I)=GG5*X1(I)*EXP(-EX3(I))*3.977*OPFRA	0002110
424.	IF(I.GT.1) GO TO 98	0002115
425.	EXC(I) = DECOH(I) * CHT3 * 24.	0002120
426.	GO TO 101	0002125
427.	98 EXC(I)=DECOH(I)*CHTI1*24.	0002130
428.	IF(I.GT.7)EXC(I)=DECOH(I)*CHTI2*24.	0002135
429.	101 CONTINUE	0002140
430.	IF(EXC(I).GT.75.)EXC(I)=75.	0002145
431.	DFCR=0.0	0002150
432.	IF(KCHAR.EQ.2) DFCR=0.00025	0002155
433.	IF(KCHAR.EQ.2.AND.I.GT.7) DFCR=0.0001	0002160
434.	IF(I.GT.1) GO TO 105	0002165
435.	EJT(I) = 1E3 * EXP(-EX4(I)) * (DFCR + EXP(-EXC(I)))	0002170
436.	GO TO 2001	0002175
437.	105 EJT(I)=GT0*X1(I)*EXP(-EX4(I))*(DFCR+EXP(-EXC(I)))*3.977*OPFRA	0002180
438.	GO TO 2001	0002185
439.	2001 TEST=1.	0002190
440.	IF(SGL(I).LE.TEST) SGL(I)=0.0	0002195
441.	IF(EJT(I).LE.TEST) EJT(I)=0.0	0002200
442.	5 CONTINUE	0002205
443.	DO 2003 I=1,14	0002210
444.	TOT(I)=AXB(I)+TBL(I)+SGL(I)+EJT(I)+CBL(I)+RADBL(I)+VPR(I)	0002215
445.	2003 CONTINUE	0002220
446.	MSIG = 2	0002225
447.	NSIG = 14	0002230
448.	CALL SIGF2(TBL)	0002235
449.	CALL SIGF2(SGL)	0002240
450.	CALL SIGF2(EJT)	0002245
451.	GASTOT=0.0	0002250
452.	DO 2004 I=1,14	0002255
453.	WRITE(6,230)NUCLID(I),XB(I),CBL(I),TBL(I),AXB(I),RADBL(I),	0002260
454.	1 SGL(I),EJT(I),VPR(I),TOT(I)	0002265
455.	GASTOT=GASTOT+TOT(I)	0002270
456.	2004 CONTINUE	0002275
457.	DIV=10.*(INT(ALOG10(GASTOT))-1)	0002280
458.	GASTOT=AIN(TGASTOT/DIV+0.5)*DIV	0002285
459.	WRITE(6,232) GASTOT	0002290
460.	WRITE(6,214)	0002295
461.	WRITE(6,231)	0002300
462.	WRITE(6,906)	0002305
463.	WRITE(6,903)NAME	0002310
464.	WRITE(6,214)	0002315
465.	WRITE(6,245)	0002320
466.	WRITE(6,214)	0002325
467.	DO 9 I = 1,19	0002330
468.	PCBL(I) = PCBB(I)*1E-3*HEPA1	0002335
469.	PTBL(I) = PTBB(I)*1E-3*HEPA2	0002340
470.	PAXBL(I) = PAXBB(I)*1E-3*HEPA5	0002345
471.	PVPL(I) = PVPR(I) * 1E-3	0002350
472.	PRWBL(I) = PRWBB(I)*1E-3*HEPA6	0002355
473.	PTOTB(I) = PCBL(I) + PTBL(I) + PAXBL(I) + PRWBL(I) + PVPL(I)	0002360
474.	9 CONTINUE	0002365
475.	MSIG = 3	0002370
476.	NSIG = 20	0002375
477.	CALL SIGF2(PTOTB)	0002380
478.	DO 10 I =1,19	0002385
479.	WRITE (6,920) BPART(I),PCBL(I),PTBL(I),PAXBL(I),PRWBL(I),PVPL(I),	0002390
480.	1PTOTB(I)	0002395

481.	10	CONTINUE	0002400
482.		WRITE(6,214)	0002405
483.		GO TO 80	0002410
484.	1003	CONTINUE	0002415
485.		STOP	0002420
486.		END	0002425
487.		SUBROUTINE SIGF2(RLPT)	0002430
488.		COMMON MSIG,NSIG	0002435
489.		DIMENSION RLPT(NSIG)	0002440
490.		IF(MSIG.EQ.2) GO TO 25	0002445
491.		IF(MSIG.EQ.3) GO TO 30	0002450
492.		DO 20 I=1,NSIG	0002455
493.	C	THIS PART OF SUBROUTINE IS FOR IODINE	0002460
494.		ISUB=2	0002465
495.		IF(RLPT(I).EQ.0.) GO TO 20	0002470
496.		IF(RLPT(I).GT.1.0)ISUB=1	0002475
497.		DIV=10.*(INT(ALOG10(RLPT(I)))-ISUB)	0002480
498.		RLPT(I)=AINT(RLPT(I)/DIV+0.5)*DIV	0002485
499.	20	CONTINUE	0002490
500.		GO TO 50	0002495
501.	25	CONTINUE	0002500
502.		DO 35 I = 1,NSIG	0002505
503.	C	THIS PART OF SUBROUTINE IS FOR NOBLE GASES	0002510
504.		IF(RLPT(I).EQ.0.) GO TO 35	0002515
505.		DIV=10.*(INT(ALOG10(RLPT(I)))-1)	0002520
506.		IF (RLPT(I).LT.10.) DIV=1.00	0002525
507.		RLPT(I)=AINT(RLPT(I)/DIV+0.5)*DIV	0002530
508.	35	CONTINUE	0002535
509.		GO TO 50	0002540
510.	30	CONTINUE	0002545
511.		DO 40 I = 1,NSIG	0002550
512.	C	THIS PART OF SUBROUTINE IS FOR PARTICULATES	0002555
513.		IF (RLPT(I).EQ.0.) GO TO 40	0002560
514.		DIV=10.*(INT(ALOG10(RLPT(I)))-2)	0002565
515.		RLPT(I)=AINT(RLPT(I)/DIV+0.5)*DIV	0002570
516.	40	CONTINUE	0002575
517.	50	CONTINUE	0002580
518.		RETURN	0002585
519.		END	0002590

CHAPTER 4. DATA NEEDED FOR NRC RADIOACTIVE SOURCE TERM CALCULATIONS FOR BOILING WATER REACTORS (BWRs)

This chapter lists the information needed to generate source terms for BWRs. The information is provided by the applicant and should be consistent with the contents of the Safety Analysis Report (SAR) and the Environmental Report (ER) of the proposed boiling water reactor. This information is the basic data required to calculate the releases of radioactive material in liquid and gaseous effluents (the source terms). All data is on a per-reactor basis.

4.1 GENERAL

1. The maximum core thermal power (MWt) evaluated for safety considerations in the SAR. (Note: All of the following responses should be adjusted to this power level.)
2. The quantity of tritium released in liquid and gaseous effluents (Ci/yr per reactor).

4.2 NUCLEAR STEAM SUPPLY SYSTEM

1. Total steam flow rate (in lb/hr).
2. Mass of reactor coolant (in lb) in the reactor vessel at full power.

4.3 REACTOR COOLANT CLEANUP SYSTEM

1. Average flow rate (in lbs/hr).
2. Demineralizer type (deep bed or powdered resin) and size of resin capacity (in ft³).
3. Regeneration or replacement frequency.
4. Regenerant volume (in gal/event) and activity (if applicable).

4.4 CONDENSATE DEMINERALIZERS

1. Average flow rate (in lbs/hr).
2. Demineralizer type (deep bed or powdered resin).
3. Number and size (in ft³) of resin capacity of demineralizers.
4. Regeneration or replacement frequency.
5. Indicate whether ultrasonic resin cleaning is used and waste liquid volume associated with its use.
6. Regenerant volume (in gal/event) and activity.

4.5 LIQUID WASTE PROCESSING SYSTEMS

1. For each liquid waste processing system, provide in tabular form the following information:
 - a. Sources, flow rates (in gal/day), and expected activities (fraction of primary coolant activity, i.e., PCA) for all inputs to each system.
 - b. Holdup times associated with collection, processing, and discharge of all liquid streams.
 - c. Capacities of all tanks (in gal) and processing equipment (in gal/day) considered in calculating holdup times.
 - d. Decontamination factors for each processing step.

- e. Fraction of each processing stream expected to be discharged over the life of the plant.
 - f. For waste demineralizer regeneration, the time between regenerations, regenerant volumes and activities, treatment of regenerants, and fractions of regenerant discharged. Include parameters used in making these determinations.
 - g. Liquid source term by radionuclide (in Ci/yr) for normal operation, including anticipated operational occurrences.
2. Provide piping and instrumentation diagrams and process flow diagrams for the liquid radwaste systems, along with all other systems influencing the source term calculations.

4.6 MAIN CONDENSER AND TURBINE GLAND SEAL AIR REMOVAL SYSTEMS

1. The main condenser tubing material of construction, i.e., stainless steel or copper.
2. The holdup time (in hr) for offgases from the main condenser air ejector prior to processing by the offgas treatment system.
3. A description and the expected performance of the gaseous waste treatment systems for the offgases from the condenser air ejector and mechanical vacuum pump. The iodine source term from the condenser.
4. The mass of charcoal (in tons) in the charcoal delay system used to treat the offgases from the main condenser air ejector, the operating and dew point temperatures of the delay system, and the dynamic adsorption coefficients for Xe and Kr.
5. A description of the cryogenic distillation system, the fraction of gases partitioned during distillation, the holdup in the system, storage following distillation, and the expected system leakage rate.
6. The steam flow (in lbs/hr) to the turbine gland seal and the source of the steam (primary or auxiliary).
7. The design holdup time (in hr) for gas vented from the gland seal condenser, the iodine partition factor for the condenser, and the fraction of radioiodine released through the system vent. A description of the treatment system used to reduce radioiodine and particulate releases from the gland seal system.
8. Piping and instrumentation diagrams and process flow diagrams for the gaseous waste treatment system, along with all other systems influencing the source term calculations.

4.7 VENTILATION AND EXHAUST SYSTEMS

For each plant building housing the main condenser evacuation system, the turbine gland seal system exhaust, or any system that contains radioactive materials, provide the following:

1. Provisions incorporated to reduce radioactivity releases through the ventilation or exhaust systems.
2. Decontamination factors assumed and the bases (include charcoal adsorbers, HEPA filters, and mechanical devices).
3. Release rates for radioiodines, noble gases, and radioactive particulates (in Ci/yr); and the bases.
4. Release point description including height above grade, height above and location relative to adjacent structures, expected average temperature difference between gaseous effluents and ambient air, flow rate, exit velocity, and size and shape of flow orifice, whether deflectors or diffusers are used.
5. For the containment building, indicate the expected purge and venting frequencies and duration and the continuous purge rate (if used).

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APPENDIX A

LIQUID SOURCE TERM CALCULATIONAL PROCEDURE FOR REGENERANT WASTES FROM DEMINERALIZERS OTHER THAN CONDENSATE DEMINERALIZERS

Often in BWR radwaste systems, demineralizers other than the condensate demineralizers may undergo regeneration, for example, the radwaste demineralizer in the high purity waste system. The BWR-GALE Code can calculate the liquid effluent resulting from periodic regeneration of non-condensate demineralizers by following the procedure outlined below.

1. Input to Cards 1-7 and Cards 17-33

A separate computer run for calculating the regeneration waste effluent from non-condensate demineralizers is required. Cards 1-7 should be filled out as indicated for the specific plant in Sections 1.5.2.1 through 1.5.2.7 of this report. Also Cards 17 through 33 may be left blank. (except that values of 1.0 must be entered for Card 18 entries).

2. Input to Cards 8-16

The only liquid source term data cards completed (Cards 8-16) should be the three card sets used in the input data for the stream in which the demineralizer to be regenerated is located.

a. Input Flow and Activity (Cards 8, 11, or 14)

The input flow rate and input activity should be the average daily input flow rate and input activity processed through the demineralizer to be regenerated. For example, if the demineralizer to be regenerated is used to process a BWR high purity stream, the total input flow rate and weighted activity would be 30,000 gallons per day at 0.15 PCA from Table 1-4.

Note that it is not the flow rate and activity which is due to the regenerant wastes which is entered, it is the normal flow rate and activity through the component to be regenerated which is entered.

b. Regeneration Frequency (Card 9, 12, or 15)

Enter the time between regenerations in days as the "collection time." If a regeneration frequency is stated by the applicant, it may be used; otherwise the following frequency may be used:

TABLE A-1

<u>Demineralizer Service</u>	<u>Regeneration Frequency</u>
Reactor Coolant Cleanup System	180 days
Equipment Drain Wastes	25,000 gal/ft ³ *
Floor Drain Wastes	2,000 gal/ft ³ *

* Calculated values based on 12,000 gm CaCO₃ ion exchange capacity per ft³ of resin and 5 umho/cm and 50 umho/cm average conductivity of equipment and floor drain liquid wastes.

By inputting the normal flow rate and activity in Item a and the regeneration frequency as the collection time in Item b the BWR-GALE Code will accumulate all of the activity processed through the demineralizer during its normal operation and decay the activity as a function of the time over which it was collected.

c. Process Time and Fraction Discharged

Use the same "process time" and "fraction discharged" as indicated for the stream in which the regeneration wastes are processed as indicated in Section 1.5.2.8.2 of this document.

d. Decontamination Factors (Card 10, 13 or 16)

The decontamination factors entered should consider radionuclide removal by the equipment used to process the regenerant wastes using the normal source term procedures of 1.5.2.8.2. In addition, the decontamination factors entered should be used to adjust the source term for the fraction of the activity in the process stream flowing through the demineralizer during normal operation which was not removed by the demineralizer.

e. Sample Case

A waste demineralizer is used to process equipment drain waste and is to be regenerated. The normal flow rate and activity for the demineralizer is 30,000 gpd at 0.15 PCA. The demineralizer resin volume is 180 ft³. The regenerant wastes will be processed through an evaporator and discharged.

Fill in the Cards 8-10 in the following manner:

Card 8

Spaces 18-41 enter - waste demin regen

Spaces 42-49 enter - 30,000

Spaces 57-61 enter - 0.15

Card 9

The wastes will be processed through an evaporator which will provide the following DF's according to Table 1-5 of Section 1.5.2.8.2:

I - 10³₄
Cs, Rb - 10⁴₄
Others - 10⁴

While in operation, referring to Table 1-5 of Section 1.5.2.8.2, demineralizer DF's were:

I - 10²
Cs, Rb - 2₂
Others - 10²

Therefore, for "I" and "Others," 99% of the activity processed through the demineralizer was removed by the resins and no adjustment is needed. Only 50% of the Cs and Rb in the waste stream was removed by the resins, however, so the DF entered for Cs should be adjusted. Thus, the DFs entered on Card 9 would be:

I - 10³
Cs, Rb - 2₄ × 10⁴
Others - 10⁴

Card 10

Spaces 29-32 "Collection Time." Using the value from Table A-1 of 25,000 gal/ft³, the regeneration frequency would be:

$$\frac{(180 \text{ ft}^3)(25,000 \text{ gal/ft}^3)}{(30,000 \text{ gal/day})} = 150 \text{ days}$$

Enter 150 days in spaces 29-32.

Use the same "process time" and "fraction discharged" as is indicated for the stream in which the regeneration wastes are processed as indicated in Section 1.5.2.8.2 of this report.

3. Components in Service

- a. If the waste is processed through a component other than a regenerable demineralizer prior to processing by the regenerable demineralizer, the activity in the steam entering the demineralizer will be less than the activity entered as described above. To compensate for this difference, the DF's for the regenerant waste calculation should be adjusted in a manner similar to that described above. The product of the DF's should be used.
- b. If two regenerable demineralizers are used in series, follow the procedure in A above. Adjust the DF for nuclides removed from the waste stream, by using the product of the DF's for two demineralizer in series, i.e., consider the two demineralizers as one larger demineralizer.

4. Use of Computer Calculated Result

Combine the values printed out in the individual liquid source term columns for the system in which the demineralizer is being regenerated (not the adjusted total value) with the normal liquid source term run values. Do not use the adjusted total value from the right hand column as the source term run to which the regenerant waste run will be added has already been adjusted.

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