NUREG-0016
REVISION 1

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

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U.S. Nuclear Regulatory Commission

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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.,

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

where

P_i is the ith 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/μCi/gm)

	Containment Bldg**	Auxiliary Bldg**	Turbine Bldg***	Radwaste Bldg**
Annual Normalized* Iodine Release Rate				
Power Operation	1.2	11.1	3.8×10^3	4.6
Refueling/Maintainence 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 radiodine 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 μCi/gm.

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

TABLE 1-3

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

	Annual Normalized* Iodine Release Rate**
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 μCi/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

Demineralizer	Anions	Cs, Rb	Other Nuclides
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 μCi/sec. The dynamic adsorption coefficients for argon-41 in charcoal delay beds are 6.4 cm^3/gm and 16 cm^3/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 foward 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) DEEP BED PLANT WITH ULTRASONIC RESIN CLEANER	DEEP BED PLANT WITHOUT ULTRASONIC RESIN CLEANER OR A FILTER/DEMINERALIZER PLANT	FRACTION OF THE PRIMARY COOLANT ACTIVITY (PCA)
Equipment Drains			
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
Floor Drains			
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
Other Sources			
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	2×10^{-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

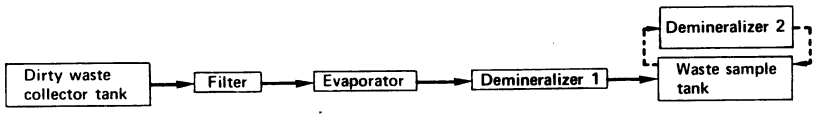
   Note: A DF of 1 is assumed by the BWR-GALE Code for tritium. Dissolved noble gases and water activation products are not considered in the liquid code.

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:

	Filter	Evaporator	Demineralizer 1	Demineralizer 2	Product
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		
Demineralizers	Anion	Cs, Rb	Other Nuclides
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)
Evaporators	All Nuclides Except Anions		Anions
Miscellaneous	10^4		10^3
Detergent wastes	10^2		10^2
Reverse Osmosis	All Nuclides		
Laundry wastes	30		
Other liquid wastes	10		
Filters	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)

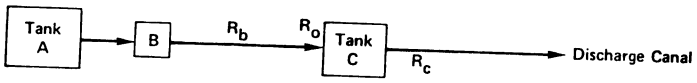
Collection time prior to processing is based on the input flow calculated above. Where redundant tanks are provided, assume the collection tank will be processed when filled to 80% capacity. If only one tank is provided, assume the tank will be processed when filled to 40% capacity. For example, if flow 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

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

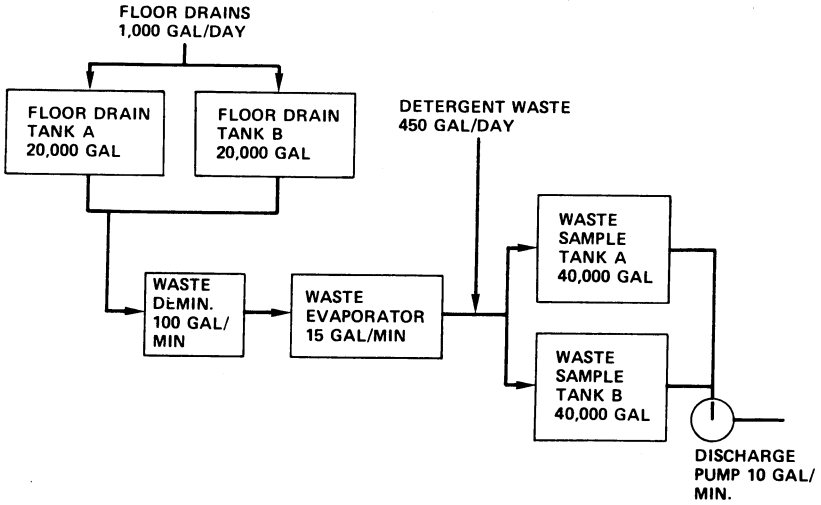
If so, then

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

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

Activated Carbon[a] Bed Depth	Removal Efficiencies[b] for Radioiodine %
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.

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

[b]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).

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.

	DYNAMIC ADSORPTION COEFFICIENT (cm^3/gm)			
	OPERATING 77°F DEW POINT 45°F	OPERATING 77°F DEW POINT 0°F	OPERATING 77°F DEW POINT -40°F	OPERATING 0°F DEW POINT -20°F
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.

	DYNAMIC ADSORPTION COEFFICIENT (cm^3/gm)			
	OPERATING 77°F DEW POINT 45°F	OPERATING 77°F DEW POINT 0°F	OPERATING 77°F DEW POINT - 40°F	OPERATING 0°F DEW POINT -20°F
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 10^3 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]

FACILITY[b]	DATE OF COMMERICAL OPERATION[c]	1972	1973	1974	1975	1976	1977
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

[a] From Semi-Annual Operating Reports for each facility, as submitted by respective licensees.

[b] Big 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.

[c] Plant capacity factors listed begin with the first full year of commercial operation.

[d] Not included due to extended maintenance outage to replace feedwater sparger.

[e] Not included due to extended operation at reduced power.

[f] Not included due to extended refueling outage.

[g] Not 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 μCi/gm)

ISOTOPE	REACTOR COOLANT	REACTOR STEAM
Noble Gases		
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)
Halogens		
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)
Cesium and Rubidium		
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.

**$1.1(-3) = 1.1 \times 10^{-3}$.

***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)

ISOTOPE	REACTOR COOLANT	REACTOR STEAM
Water Activation Products		
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)
Tritium*		
H-3	1(-2)	1(-2)
Other Nuclides		
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)

ISOTOPES	REACTOR COOLANT	REACTOR STEAM
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

PARAMETER	SYMBOL	UNITS	NOMINAL VALUE	RANGE MAXIMUM	RANGE MINIMUM
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 demineralizer flow rate to steam flow rate	NC**	-	0.75	0.99	0.5

*3.8(5) = 3.8×10^5

**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 coolan 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:

$$R = \frac{FA \cdot NA + NC \cdot FS \cdot NS \cdot NB}{WP}$$ 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.

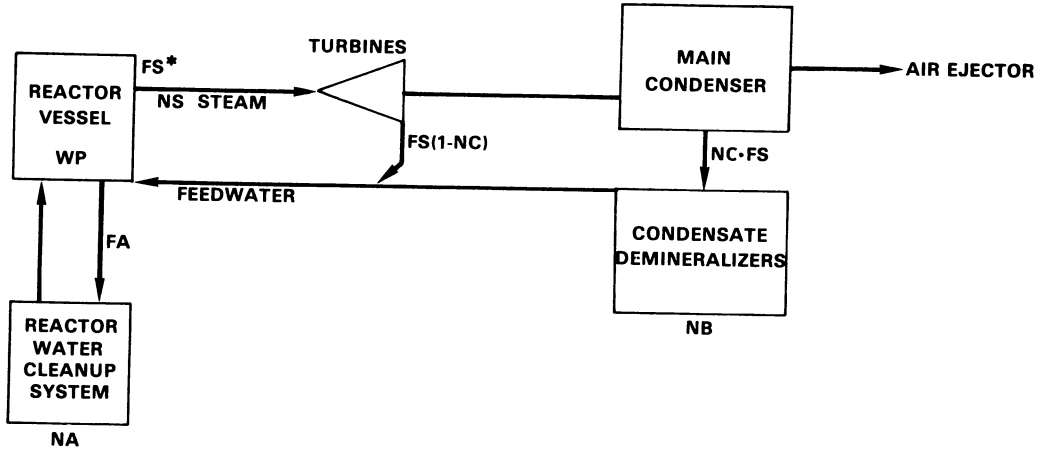
TABLE 2-5
ADJUSTMENT FACTORS FOR BOILING WATER REACTORS

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 μCi/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 μCi/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	3.4×10^5 - 4.2×10^5
Cleanup demineralizer flow (lbs/hr)	1.5×10^5	1.1×10^5 - 1.5×10^5
Steam flow rate (lbs/hr)	15.4×10^6	13.0×10^6 - 17.0×10^6
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:

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

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:

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

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

= (adjustment factor) x (standard I-131 concentration)

= $0.96 \times 4 \times 10^{-3}$ μCi/g = 3.8×10^{-3} μCi/gm

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:

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

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

= (adjustment factor) x (standard Cs-137 concentration)

= $0.96 \times 8 \times 10^{-5}$ μCi/g = 7.6×10^{-5} μCi/gm

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:

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

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

= (adjustment factor) x (standard Na-24 concentration)

= $0.92 \times 1 \times 10^{-2}$ μCi/gm = 9.2×10^{-3} μCi/gm

The noble gas concentrations in Table 2-2 are based on an offgas release rate of 50,000 μCi/sec measured at 30-minute decay. The value of 50,000 μCi/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 μCi/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*
(μCi/sec)

Facility	1977	1976	1975
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
	55,000	56,000	12,000

*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		
Plant	Partition Coefficient	Ref	Plant	Partition Coefficient	Ref
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	0.0082	5	Peach Bottom 3	0.0044	5
AVERAGE	0.015		Vermont Yankee	0.004	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 μCi/sec is divided by the measured reactor water concentration in μCi/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, μCi/sec

C_{RW} = measured reactor water iodine-131 concentration, μCi/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, μCi/sec

C_{RW} = measured reactor water iodine-131 concentration, μCi/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:

$$R_{BWR} = R_N^1 \times C_{BWR}$$

where

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

R_N^1 = normalized annual release of reactor water containing iodine-131 from Tables 2-9 and 2-10, Ci/yr/μCi/gm

C_{BWR} = calculated reactor water concentration for particular BWR, μCi/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:

$$R_{BWR} = R_N^1 \times C_{BWR} \times PC_{BWR}$$

where

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

R_N^1 = normalized annual release of reactor water from Table 2-8, Ci/yr/μCi/gm

C_{BWR} = calculated reactor water concentration for particular BWR, μCi/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 μCi/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 souce 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, hypoiodious 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

	CONTAINMENT	AUXILIARY	TURBINE	RADWASTE
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

Data Source	Normalized Release (Ci/yr/μCi/gm)
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

Data Source	Normalized Release (Ci/yr/μCi/gm)
Monticello (Ref. 15)	1.7×10^2
Oyster Creek (Ref. 15)	3.5×10^{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	4.1×10^{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 radiodine 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/μCi/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

NORMAL OPERATION

Data Source	Normalized Releases (Ci/yr/μCi/gm)
Monticello (Ref. 15)	11
Pilgrim (Ref. 16)	13
Brown Ferry (Ref. 5)	4.2
References 3 and 5***	21
	12.3**

EXTENDED SHUTDOWN

Data Source	Normalized Releases (Ci/yr/μCi/gm)
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***	20
	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 radiodine 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 in 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

Data Source	Normalized Release (Ci/yr/μCi/gm)
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**	5.3
AVERAGE	4.6

EXTENDED SHUTDOWN

Data Source	Normalized Release (Ci/yr/μCi/gm)
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**	4.4
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 radiodine 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*
(μCi/Kg)

Facility	1977	1976	1975
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	0.38	0.51	0.78
	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
(μCi/sec)

NUCLIDE	MILLSTONE-1	OYSTER CREEK	OYSTER CREEK	MONTICELLO	AVERAGE
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
(μCi/sec)

NUCLIDE	MILLSTONE-1	OYSTER CREEK	OYSTER CREEK	MONTICELLO	NINE MILE PT 1	AVERAGE
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
(μCi/sec)

NUCLIDE	MILLSTONE-1	OYSTER CREEK	MONTICELLO	AVERAGE
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} μCi/sec)

NUCLIDE	QUAD CITIES 1	QUAD CITIES 2	VERMONT YANKEE	OYSTER CREEK	MONTICELLO	AVERAGE
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:

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

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 carryover 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} μCi/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} μCi/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} μCi/sec)

NUCLIDE	OYSTER CREEK	VERMONT YANKEE	MONTICELLO	AVERAGE
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} μCi/sec)

NUCLIDE	VERMONT YANKEE	OYSTER CREEK	AVERAGE
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} μCi/sec)

NUCLIDE	MONTICELLO	AVERAGE
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 RADIO-IODINE RELEASE (Ci/yr)	1972 INTEGRATED THERMAL POWER (10^6 MWd)	1972 Ci/yr / 10^6 MWd	1973 RADIO-IODINE RELEASE (Ci/yr)	1973 INTEGRATED THERMAL POWER (10^6 MWd)	1973 Ci/yr / 10^6 MWd	1974 RADIO-IODINE RELEASE (Ci/yr)	1974 INTEGRATED THERMAL POWER (10^6 MWd)	1974 Ci/yr / 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]			c	5.5	1.32	4.2	8.2	1.09	7.5
Average			4.6			5.1			6.2

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

[a] Data from semiannual operating for 1972 through 1976 for facilities listed.
[b] Two-unit plants with a single stack.
[c] Not included in 1972 average because plants had not achieved a full year of operation.
[d] Augmented offgas system put in operation October 1975.
[e] Augmented offgas system put in operation late 1976.
[f] Augmented offgas system put in operation May 1975.
[g] Augmented offgas system put into operation 1977.
[h] Augmented offgas system put into operation late 1974.

TABLE 2-22 (continued)

RADIOIODINE-131 RELEASES FROM THE MAIN CONDENSER AIR EJECTORS

	1975			1976		
FACILITY	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 (μCi/sec)	Measured Reactor Water I-131 Concentration (μCi/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)
		10/7/75 to 10/21/74	14	1.4(-5)	7.7(-4)	4.6(5)
	Oyster Creek	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 Gland Seal I-133 Releases (μCi/sec)	Measured Reactor Water I-133 Concentration (μCi/gm)	Parameter (Ci/yr per Ci/gm) for 292 days/year
I-133	Vermont Yankeee	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} μCi/sec)

NUCLIDE	RELEASE RATE
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} μCi/sec)

NUCLIDE	RELEASE RATE
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)

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

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

Plant	Normalized Release (Ci/yr/μCi/gm)
Monticello	1.5(3)
Vermont Yankee	6.0(2)
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 μCi/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 μCi/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, (μCi/sec)

C_{RW} = measured reactor water iodine-131 concentration, (μCi/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/μCi/gm)

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

C_{BWR} = reactor water concentration for a particular BWR, (μCi/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, hypoiodious 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

	Time < 80 hrs[1/]	Time > 80 hrs[2/]
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 ft^3/min air inleakage to the main condenser per MWt of design reactor power with a minimum of 5 ft^3/min.

2.2.8.2 Bases

Air inleakage 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 inleakage to the main condenser.

Operational data for inleakage vary widely. At Oyster Creek and at Dresden Unit No. 2, air inleakage measurements during early phases of operation indicated leakage rates from 4 ft^3/min to 250 ft^3/min. (Refs. 21 and 22). Subsequent measurements at Dresden Unit 2 (Ref. 20), showed an air inleakage of 4.4 ft^3/min during operation at 1600 MWt. Air inleakage measurements reported for six TVA fossil plants, representing more than 50 years of cumulative experience, indicate leakage rates ranging from 4 to 25 ft^3/min per condenser shell and a statistical mean inleakage rate of 6.7 ft^3/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 ft^3/min for Unit No. 1 and 25 ft^3/min for Unit No. 2; measurements ranged from 6 ft^3/min to 55 ft^3/min and power level for both units during the test period was 2511 MWt.

The parameter for air inleakage was developed assuming that air inleakage 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 ft^3/min main condenser air inleakage for a plant with a design thermal power level of 3400 MWt. This is approximately equivalent to 0.0062 ft^3/min inleakage for each MWt of design thermal power. For BWRs of less than 800 MWt design thermal power level, a minimum condenser air inleakage of 5 ft^3/min should be used, independent of reactor design thermal power level.

CONDENSER AIR INLEAKAGE

Plant	Power Level	Reported Data	Extrapolated to 3400 MWt/ 3 shell
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	34
		AVERAGE	21 cfm

2.2.9 HOLDUP TIMES FOR CHARCOAL DELAY SYSTEMS

2.2.9.1 Parameter

T = 43.1 MK/P

where

K is the dynamic adsorption coefficient, in cm^3/gm (see chart below);

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

T is the holdup time, in hours; and

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

Dynamic adsorption coefficients (in cm^3/gm) are as follows:

	OPERATING 77°F DEW POINT 45°F	OPERATING 77°F DEW POINT -40°F	OPERATING 77°F DEW POINT 0°F	OPERATING 0°F DEW POINT -20°F
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 = MK/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.

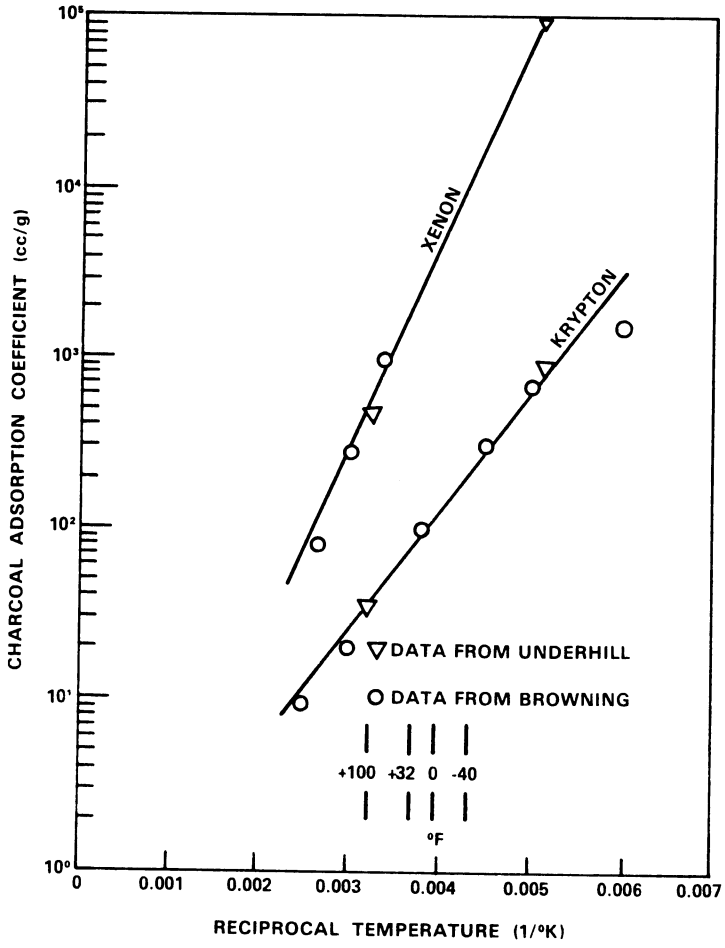


FIGURE 2-2
KRYPTON AND XENON K VALUES AS A FUNCTION OF RECIPROCAL TEMPERATURE

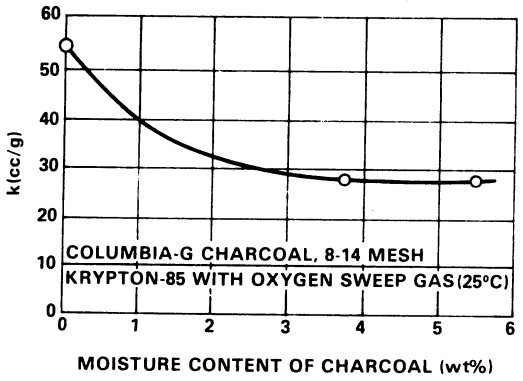


FIGURE 2-3
EFFECT OF MOISTURE CONTENT ON THE
DYNAMIC ADSORPTION COEFFICIENT

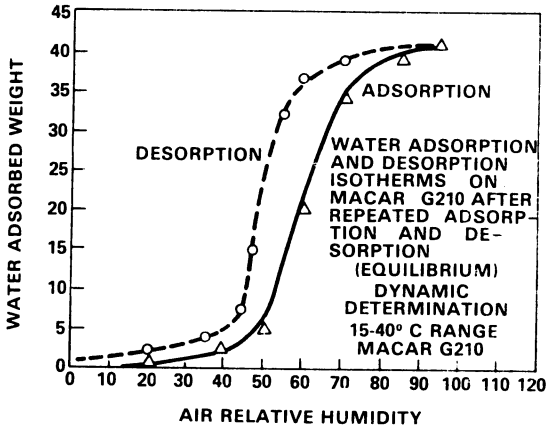


FIGURE 2-4
CHARCOAL MOISTURE AS A FUNCTION
OF RELATIVE HUMIDITY

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

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

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

2.2.10 DECONTAMINATION FACTORS FOR CRYOGENIC DISTILLATION

2.2.10.1 Parameter

NUCLIDES	DECONTAMINATION FACTOR
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:

ACTIVATED CARBON BED DEPTH[a]	ASSIGNED ACTIVATED CARBON REMOVAL EFFICIENCIES FOR RADIOIODINE
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%

[a]Multiple 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) DEEP BED PLANT WITH ULTRASONIC RESIN CLEANER	DEEP BED PLANT WITHOUT ULTRASONIC RESIN CLEANER OR A FILTER/DEMINERALIZER PLANT	FRACTION OF THE PRIMARY COOLANT ACTIVITY (PCA)
Equipment Drains			
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
Floor Drains			
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
Other Sources			
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	2×10^{-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

NUCLIDE	Ci/yr
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 Creek[a] (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

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

[b]Westinghouse Corporation WCAP-8253, "Source Term Data for Westinghouse Pressurized Water Reactors," May 1974.

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

[d]NUREG/CR-0140, "In-Plant Source Term Measurements at Ft. Calhoun Station, Unit 1," August 1978.

[e]NA, 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 elswhere (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.

	DECONTAMINATION FACTORS*		
DEMINERALIZER TYPE	ANION	Cs, Rb	OTHER NUCLIDES
Mixed Bed (H^+ OH^-)			
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)
Cation Bed (H^+)			
Dirty waste	1(1)	10(10)	10^2(10)
Powdex (any system)	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)					
									GASEOUS						#	LIQUID						#						
			1972	1973	1974	1975	1976	1977	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

REACTOR	1972	1973	1974	1975	1976	1977
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)

	SOURCE OF GASEOUS TRITIUM RELEASE (% OF TOTAL)			
PLANT	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

NUCLIDE	FEED ACTIVITY ($\mu Ci/cm^3$)	PRODUCT ACTIVITY ($\mu Ci/cm^3$)	MEMBRANE DF
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

DATE	TIME	FEED ACTIVITY (μCi/ml)	PRODUCT ACTIVITY (μCi/ml)	MEMBRANE DF
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

NUCLIDE	FEED ACTIVITY (μCi/ml)	PRODUCT ACTIVITY (μCi/ml)	MEMBRANE DF
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:

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

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*

UNPLANNED LIQUID RELEASES	
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:

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

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} cm^2, thermal neutron cross section for O-17; and

ϕ is the 3×10^{13} neutrons/cm^2-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/cm^2-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 CO_2.

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 μCi/sec. The dynamic adsorption coefficients for argon-41 in charcoal delay beds of a MCOTS are 6.4 cm^3/gm for an ambient temperature charcoal system and 16 cm^3/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 inleakage 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 μCi/sec to 37 μCi/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 μCi/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*
(μCi/sec)

PLANT	Argon-41 Release
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:

CARD	COLUMN	INPUT DATA
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.

NRC FORM 53A
(12-75)

U.S. NUCLEAR REGULATORY COMMISSION
ADP TRANSCRIPTION SHEET

JOB TITLE BWR-GALE Code

OFFICE

PAGE 1 OF 2
DATE December 1978
PREPARED BY

```
CARD  1   NAME   NAME OF REACTOR (                         )        TYPE=    BWR
CARD  2   POWTH  THERMAL POWER LEVEL (MEGAWATTS)                        (      )
CARD  3   GTO    TOTAL STEAM FLOW (MILLION LBSH/HR)                     (      )
CARD  4   WLIQ   MASS OF WATER IN REACTOR VESSEL (MILLION LBS)          (      )
CARD  5   GDE    CLEAN-UP DEMINERALIZER FLOW (MILLION LBS HR)           (      )
CARD  6   REGENT CONDENSATE DEMINERALIZER REGENERATION TIME (DAYS)      (      )
CARD  7   FFCDM  FRACTION FEEDWATER THROUGH CONDENSATE DEMIN            (      )
CARD  8          HIGH PURITY WASTE INPUT (      )GPD AT (   )PCA
CARD  9          DFI(       )DFCS (       )DFO (      )
CARD 10          COLLECTION(     )DAYS PROCESS (     )DAYS FRACT DISCH (    )
CARD 11          LOW PURITY WASTE INPUT(       )GPD AT (    )PCA
CARD 12          DFI(       )DFCS (       )DFO (      )
CARD 13          COLLECTION(     )DAYS PROCESS (     )DAYS FRACT DISCH (    )
CARD 14          CHEMICAL WASTE INPUT    (     ) GPD AT(    ) PCA
CARD 15          DFI(       )DFCS (       )DFO (      )
CARD 16          COLLECTION(    )DAYS PROCESS(    )DAYS FRACT DISCH   (    )
CARD 17          REGENERANT SOLTNS WASTE INPUT-GPD                      (      )
CARD 18          DFI(       )DFCS (       )DFO (      )
CARD 19          COLLECTION(    )DAYS PROCESS  (    )DAYS FRACT DISCH (    )
CARD 20   GGS    GLAND SEAL STEAM FLOW (THOUSAND LBS/HR)                (      )
CARD 21   TIM 3  GLAND SEAL HOLD UP TIME (HOURS)                        (      )
CARD 22   TIM 4  AIR EJECTOR OFFGAS HOLDUP TIME (HOURS)                 (      )
```

NRC FORM 53A
(12 75)

JOB TITLE BWR - GALE Code

OFFICE

U. S. NUCLEAR REGULATORY COMMISSION
ADP TRANSCRIPTION SHEET

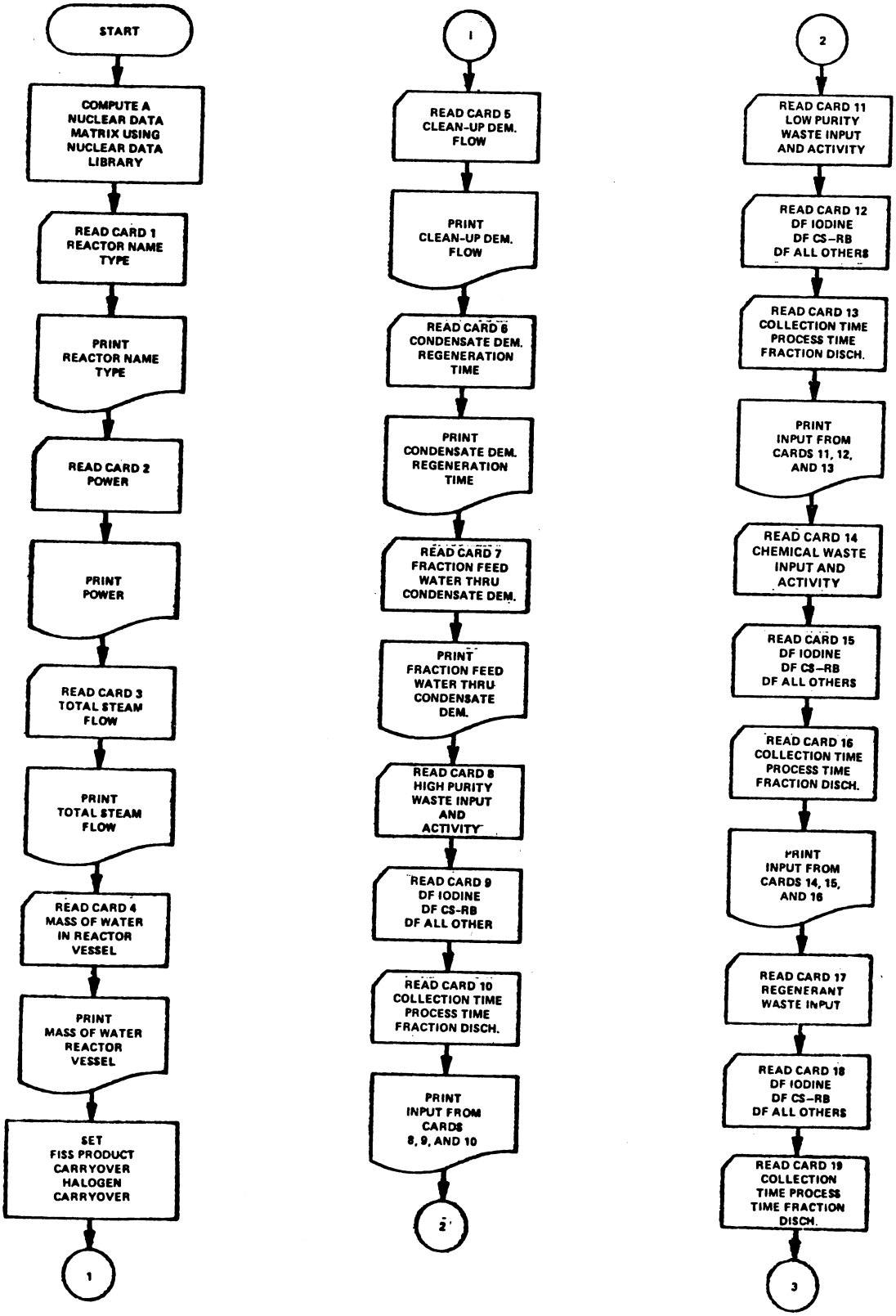
DATE December 1978

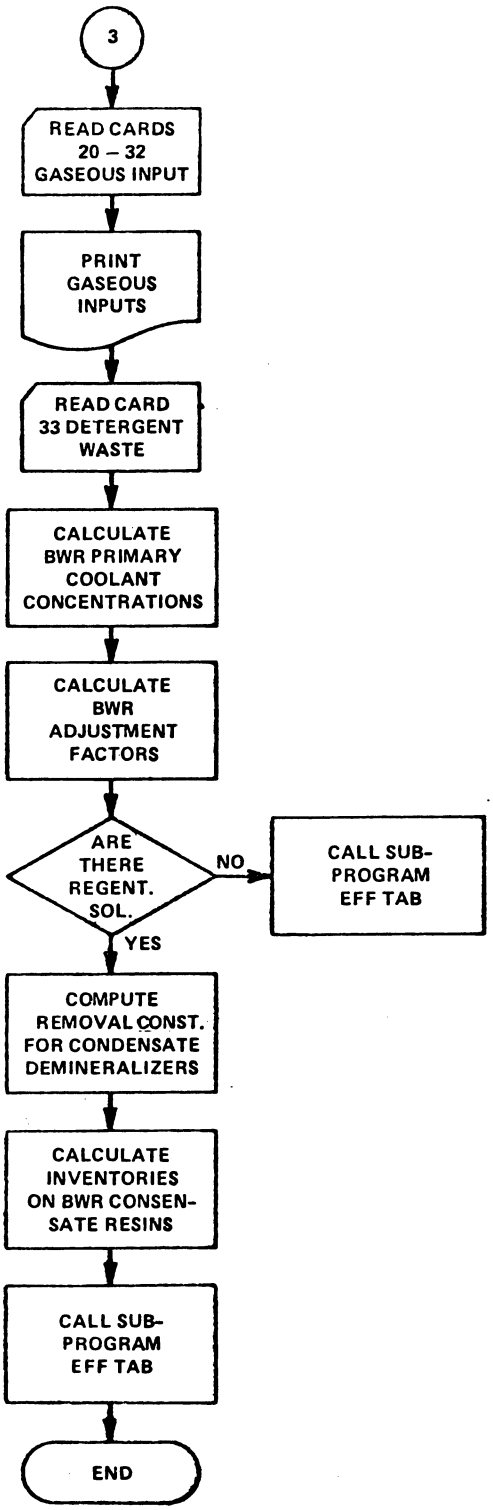
PREPARED BY

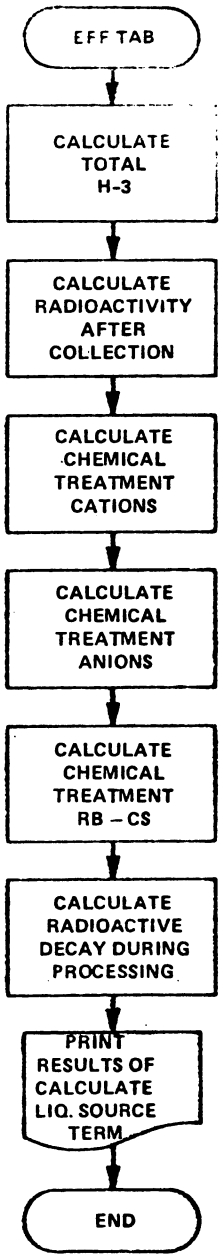
CARD 23		CONTAINMENT BLDG CHARCOAL?( ) HEPA?( )	
CARD 24		TURBINE BLDG CHARCOAL?( ) HEPA?( )	
CARD 25	FIL3	GLAND SEAL VENT IODINE PF	
CARD 26	FIL4	AIR EJECTOR OFFGAS IODINE PF	( )
CARD 27		AUXILIARY BLDG CHARCOAL?( ) HEPA?( )	( )
CARD 28		RADWASTE BLDG CHARCOAL?( ) HEPA?( )	
CARD 29	KCHAR	CHARCOAL DECAY SYSTEM 0=NO,1=YES,2=CRYGENIC DISTILL	( )
CARD 30	KKR	KRYPTON DYNAMIC ADSORPTION COEFFICIENT (CM3/GM)	( )
CARD 31	KXE	XENON DYNAMIC ADSORPTION COEFFICIENT (CM3/GM)	( )
CARD 32	KMASS	MASS OF CHARCOAL (THOUSAND LBS)	( )
CARD 33	PFLAUN	DETERGENT WASTE DECON FACTOR	( )

```
CARD  1  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  GGS    GLAND SEAL STEAM FLOW (THOUSAND LBS/HR)                 0.0
CARD 21  T1M3   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
```

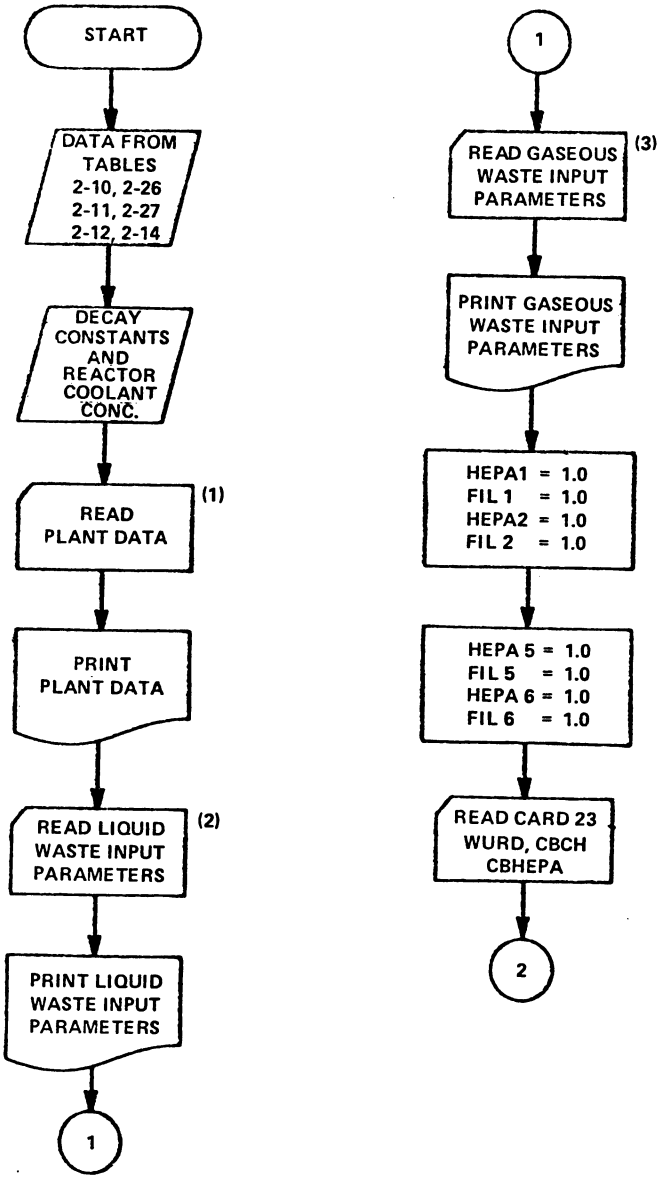
FLOW CHART FOR BWR LIQUID CODE



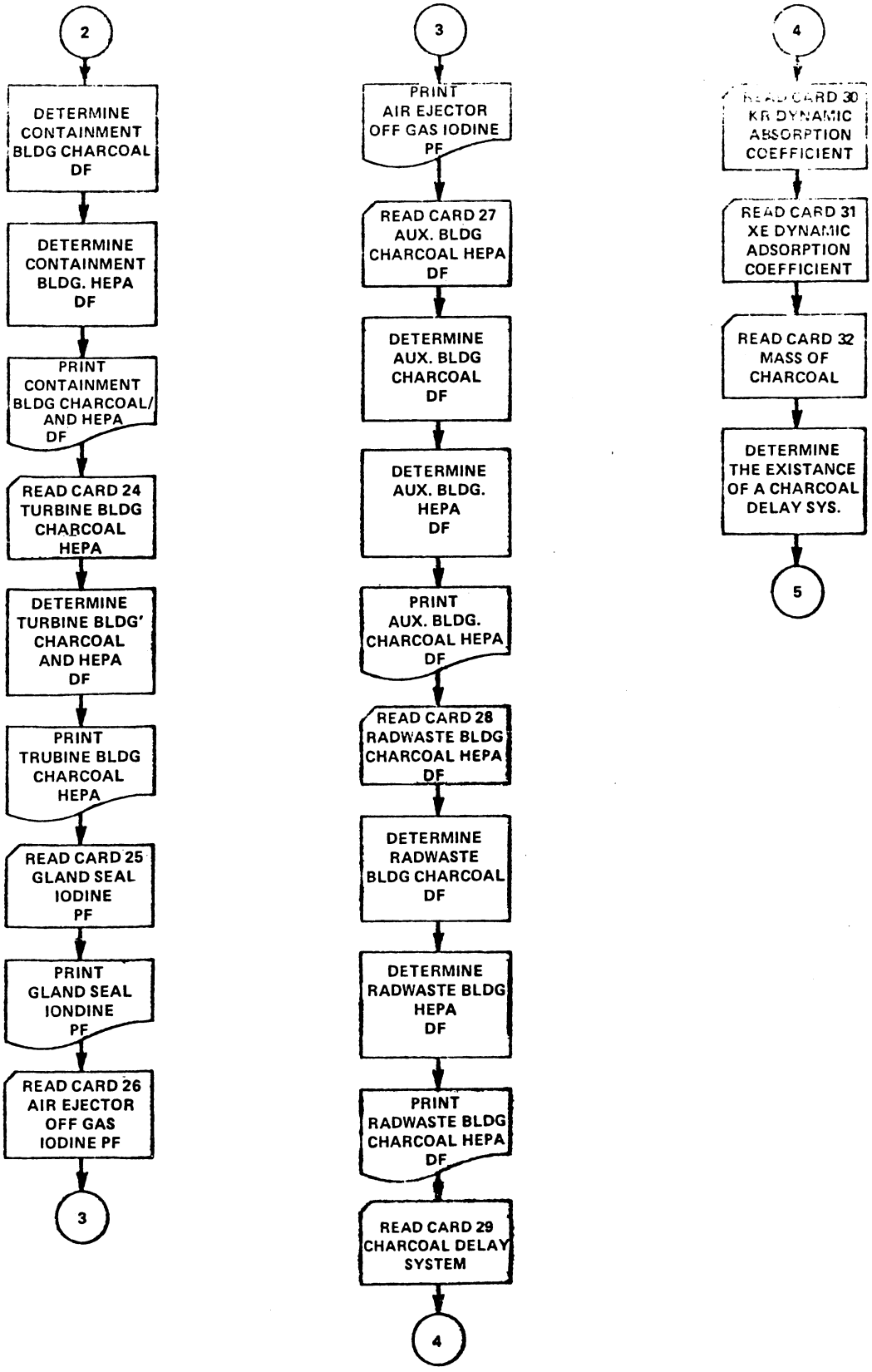

3
READ CARDS 20 – 32 GASEOUS INPUT
PRINT GASEOUS INPUTS
READ CARD 33 DETERGENT WASTE
CALCULATE BWR PRIMARY COOLANT CONCENTRATIONS
CALCULATE BWR ADJUSTMENT FACTORS
ARE THERE REGENT. SOL.
NO
CALL SUB-PROGRAM EFF TAB
YES
COMPUTE REMOVAL CONST. FOR CONDENSATE DEMINERALIZERS
CALCULATE INVENTORIES ON BWR CONSEN-SATE RESINS
CALL SUB-PROGRAM EFF TAB
END


EFF TAB
CALCULATE TOTAL H-3
CALCULATE RADIOACTIVITY AFTER COLLECTION
CALCULATE CHEMICAL TREATMENT CATIONS
CALCULATE CHEMICAL TREATMENT ANIONS
CALCULATE CHEMICAL TREATMENT RB – CS
CALCULATE RADIOACTIVE DECAY DURING PROCESSING
PRINT RESULTS OF CALCULATE LIQ. SOURCE TERM
END

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.


2
DETERMINE CONTAINMENT BLDG CHARCOAL DF
DETERMINE CONTAINMENT BLDG. HEPA DF
PRINT CONTAINMENT BLDG CHARCOAL/ AND HEPA DF
READ CARD 24 TURBINE BLDG CHARCOAL HEPA
DETERMINE TURBINE BLDG' CHARCOAL AND HEPA DF
PRINT TRUBINE BLDG CHARCOAL HEPA
READ CARD 25 GLAND SEAL IODINE PF
PRINT GLAND SEAL IONDINE PF
READ CARD 26 AIR EJECTOR OFF GAS IODINE PF
3
3
PRINT AIR EJECTOR OFF GAS IODINE PF
READ CARD 27 AUX. BLDG CHARCOAL HEPA DF
DETERMINE AUX. BLDG CHARCOAL DF
DETERMINE AUX. BLDG. HEPA DF
PRINT AUX. BLDG. CHARCOAL HEPA DF
READ CARD 28 RADWASTE BLDG CHARCOAL HEPA DF
DETERMINE RADWASTE BLDG CHARCOAL DF
DETERMINE RADWASTE BLDG HEPA DF
PRINT RADWASTE BLDG CHARCOAL HEPA DF
READ CARD 29 CHARCOAL DELAY SYSTEM
4
4
READ CARD 30 KR DYNAMIC ABSORPTION COEFFICIENT
READ CARD 31 XE DYNAMIC ADSORPTION COEFFICIENT
READ CARD 32 MASS OF CHARCOAL
DETERMINE THE EXISTANCE OF A CHARCOAL DELAY SYS.
5

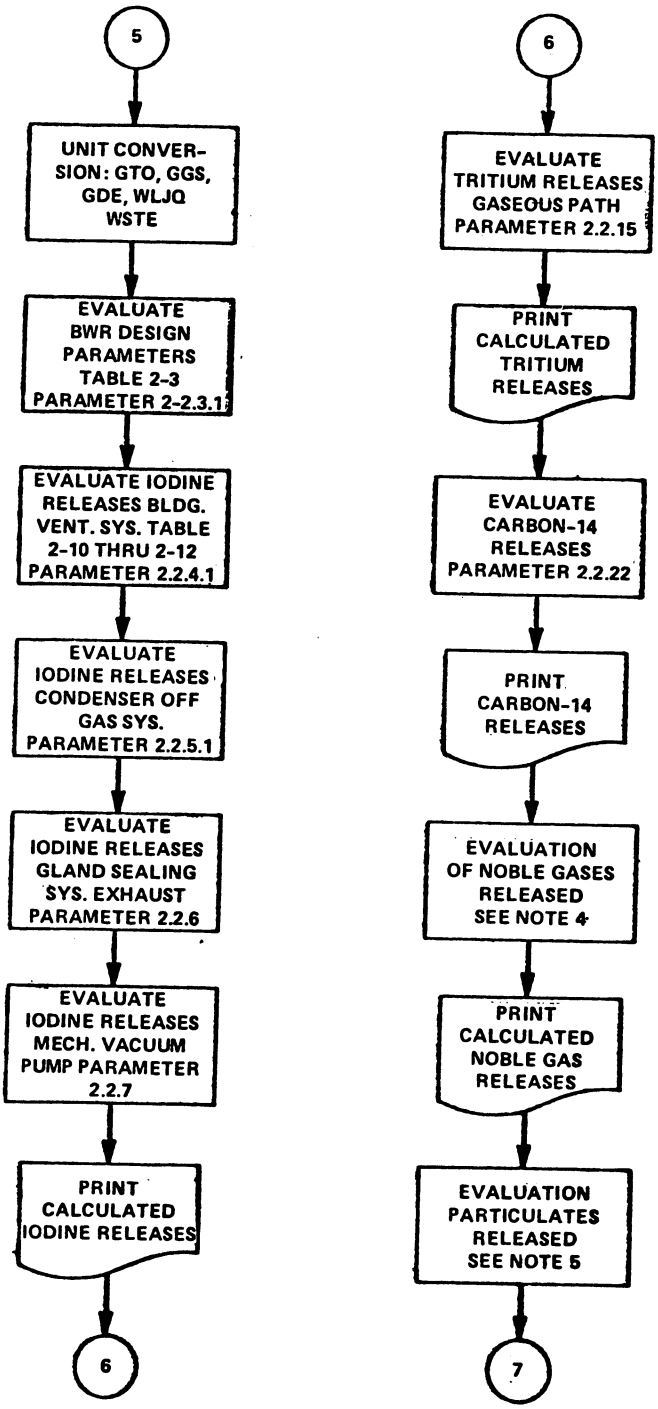


TABLE 2-14. PARAMETERS 2.2.9, 2.2.7, 2.2.10, 2.2.11, AND 2.2.23 ARE USED TO CALCULATE NOBLE GAS RELEASES FOR BWR'S.

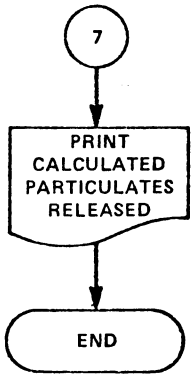


TABLE 2-14, PARAMETER 2.2.11 ARE USED TO CALCULATE PARTICULATE RELEASES

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
	PARTICULATE RELEASE FRACTION	0.01000
TURBINE BLDG.	IODINE RELEASE FRACTIOM	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 COOLANT (MICRO CI/ML)	ANNUAL RELEASES TO DISCHARGE CANAL: HIGH PURITY (CURIES)	LOW PURITY (CURIES)	CHEMICAL (CURIES)	TOTAL LWS (CURIES)	ADJUSTED TOTAL (CI/YR)	DETERGENT WASTES (CI/YR)	TOTAL (CI/YR)
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	9.96E-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

NUCLIDE	HALF-LIFE (DAYS)	CONCENTRATION IN PRIMARY COOLANT (MICRO CI/ML)	ANNUAL RELEASES TO DISCHARGE CANAL HIGH PURITY (CURIES)	LOW PURITY (CURIES)	CHEMICAL (CURIES)	TOTAL LWS (CURIES)	ADJUSTED TOTAL (CI/YR)	DETERGENT WASTES (CI/YR)	TOTAL (CI/YR)
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
	PARTICULATE RELEASE FRACTION	0.01000
TURBINE BLDG.	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

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

NUCLIDE	COOLANT CONC. (MICROCURIES/G)	GASEOUS RELEASE RATE (CURIES PER YEAR) 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

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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      C      GALE CODE FOR CALCULATING LIQUID  EFFLUENTS FROM LWRS.  MODIFIED  0000000
      C     OCT. 1978 TO IMPLEMENT APPENDIX I TO 10 CFR PART 50.  REACTOR      0000005
      C     WATER CONCENTRATIONS CALCULATED USING METHODS OF DRAFT STANDARD    0000010
      C     ANS 237 'RADIOACTIVE MATERIALS IN PRINCIPAL FLUID STREAMS OF       0000015
      C     LIGHT WATER COOLED NUCLEAR POWER PLANTS'  DRAFT DATED MAY 20, 1974 0000020
      C     MODIFIED EDITION OF ORIGEN PROGRAM TO COMPUTE EFFLUENTS FROM BWR   0000025
      C     AND PWR RADWASTE SYSTEMS                                          0000030
      C                                                                       0000035
            LOGICAL DISCHG,POWRIT                                             0000040
            INTEGER*2 LOC,NON0,KD                                             0000045
            REAL*4 LETDWN,NOGEN                                               0000050
            REAL*4 LETDWA                                                     0000055
            REAL KKR,KXE,KNO,KMASS                                            0000060
            INTEGER*2 NAME(3)                                                 0000065
            COMMON/MATRIX/A(2500),LOC(2500),NON0(800),KD(800)                 0000070
            COMMON/FLEX/FLUX(10),MMN,MOUT,INDEX,QXN,AXN,ERR,NOBLND,MZERO      0000075
            COMMON/PROCSS/  MPROS,PRATE(8),NOPROS(8),NZPROS(8,20),PR(800)     0000080
            COMMON/EQ/XZERO(800), XZH(800),XTEMP(800),XNEW(10,800),           0000085
           1      B(800),D(800)                                               0000090
            COMMON/FLUXN/T(20),POWER(10),TOCAP(800),FISS(100),DIS(800),ILITE, 0000095
           1 IACT,IFP,ITOT,NON,INPT                                           0000100
            COMMON/OUT/NUCL(800),TITLE(20),Q(800),FG(800),CUTOFF(7),          0000105
           1 POW,BURNUP,FLUXB,MSTAR,ALPHAN(100),SPONF(100),ABUND(500),        0000110
           2 BASIS(10),TCONST,TUNIT                                           0000115
            COMMON/CONC/PCONC(800),DWCONC(800),CWCONC(800),CMCONC(800),       0000120
           1     SCON(800),RINV(800)                                          0000125
            COMMON/COOL/REACTR,POW1,TYPE,PCVOL,LETDWN,NDGAS,SCVOL,STMVOL,NOGEN 0000130
           1             ,NPURGE,NVCSPG,SBLDR,GASDLA,STLKR,BLWDWN,EJCTR,WLKRAT, 0000135
           2             GASLKR,CONDLR,DFMBDM,DFCBDM,NZMBDM,NZCBDM,NE,PF,     0000140
           3             STMFR,FPEF,HEF,FFCDM,DFMBCS,CBFLR,DFI,DFCS,DF,       0000145
           4             EDFLR,DFIED,DFCSED,DFED,DWFLR,DFIDW,DFCSDW,DFDW,DILUT 0000150
           5            ,SBA,EDA,DWA,CWFLR,CMWFR,CWA,CMA,DFCM,DFICM,DFCSCM,   0000155
           6             DFCW,DFICW,DFCSCW,MHOLD,MHOLDE,MHOLDW,MHOLCM,MHOLDC  0000160
           7            ,BDTFR,DFIBD,DFCSBD,DFBD,MHOLDB,REGENT,              0000165
           8              SBFD,DFMO,DFY,EDFD,DFMOED,DFYED,DWFD,DFMODW,DFYDW,  0000170
           9              DFMOBD,DFYBD,CWFD,DFMOCW,DFYCW,CMFD,DFMOCM,DFYCM    0000175
           A   ,TS,TE,TD,TB,TC,TCM,TSTORC,TSTORD,TSTORB,TMSC,DWFL2,DW2,DWF2,  0000180
           B  T2,TSTOR2,DFID2,DFCSD2,DFMOD2,DFYD2,DFD2,PFLAUN                 0000185
            COMMON/APCOOL/RGWFR,DFIRG,DFCSRG,DFRG,TRG,TSTORR,RGFD             0000190
            COMMON/BDTES/RFNRT                                                0000195
            COMMON /CONB/BCONC(800)                                           0000200
            DIMENSION WORD13(4), WORD15(4),WORD18(5),WORD23(6),WORD28(7),     0000205
           1          WORD33(9),WORD10(3),WORD8(2),WORD40(10)                 0000210
            DIMENSION REACTR(7),NZMBDM(26),NZCBDM(26)                         0000215
            DIMENSION FACT(10),XCOMP(20),INUCL(20)                            0000220
            DIMENSION WORD56(14)                                              0000225
            DATA YES/'YES'/                                                   0000230
      C     FOLLOWINFISOTOPES(WITH THEIR CONCENTRATIONS IN UCI/GM) ARE        0000235
      C     ALSO PRESENT IN THE PRIMARY COOLANT BUT ARE NOT CONSIDERED        0000240
      C     SIGNIFICANT IN EFFLUENT CALCULATIONS:N-13,.05;N-16,60;N-17,.009;  0000245
      C     O-19,.7;F-18,.004.                                                0000250
      C     READ NUCLEAR DATA AND CONSTRUCT TRANSITION MATRIX                 0000255
      C                                                                       0000260
       10   CALL NUDATA(NLIBE)                                                0000265
      C                                                                       0000270
            DO 20 I=2,ITOT                                                    0000275
            NON0(I)=NON0(I)+NON0(I-1)                                         0000280
       20   KD(I)=KD(I)+NON0(I-1)                                             0000285
       30   DISCHG=.FALSE.                                                    0000290
            POWRIT=.FALSE.                                                    0000295
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```
      KT=0                                                              0000300
      INDEX=0                                                           0000305
      FLXB=0.0                                                          0000310
      PWRH=0.0                                                          0000315
      BURN=0.0                                                          0000320
      BDTFR=1.0                                                         0000325
      QXN=0.001                                                         0000330
      AXN=-ALOG(QXN)                                                    0000335
      NE=ITOT                                                           0000340
      TCONST=86400.                                                     0000345
      MMN=0                                                             0000350
      MZERO=21                                                          0000355
      EDA=0.0                                                           0000360
      TMSC=0.0                                                          0000365
      TE=0.0                                                            0000370
      TS=0.0                                                            0000375
      T2=0.0                                                            0000380
      TSTOR2=0.0                                                        0000385
      DWFL2=0.0                                                         0000390
      DW2=0.0                                                           0000395
      DWF2=0.0                                                          0000400
      DO 40 J=1,800                                                     0000405
      PCONC(J)=0.0                                                      0000410
      DWCONC(J)=0.0                                                     0000415
      SCON(J)=0.0                                                       0000420
      RINV(J)=0.0                                                       0000425
      CWCONC(J)=0.0                                                     0000430
      CMCONC(J)=0.0                                                     0000435
      XZH(J)=0.0                                                        0000440
   40 CONTINUE                                                          0000445
C                                                                       0000450
C     READ DESCRIPTION OF REACTOR AND RADWASTE TREATMENT PLANT          0000455
C                                                                       0000460
      PRINT 9026                                                        0000465
      READ 9010,REACTR,TYPE                                             0000470
      PRINT 9010,REACTR,TYPE                                            0000475
      READ 9022,WORD56,POW1                                             0000480
      PRINT 9022,WORD56,POW1                                            0000485
      PF=0.80                                                           0000490
      PRINT 9027                                                        0000495
C                                                                       0000500
C     READ DATA FOR BWR LIQUID CODE                                     0000505
C                                                                       0000510
   50 READ 9022,WORD56,STMFR                                            0000515
      PRINT 9022,WORD56,STMFR                                           0000520
      READ 9022,WORD56,PCVOL                                            0000525
      PRINT 9022,WORD56,PCVOL                                           0000530
      FPEF=0.001                                                        0000535
      HEF=0.020                                                         0000540
      PRINT 9030,FPEF,HEF                                               0000545
      READ 9022,WORD56,LETDWN                                           0000550
      PRINT 9022,WORD56,LETDWN                                          0000555
      PC = 0.015                                                        0000560
      READ 9022,WORD56,REGENT                                           0000565
      IF(REGENT.EQ.0.0) PC = 0.004                                      0000570
      PRINT 9022,WORD56,REGENT                                          0000575
      READ 9022,WORD56,FFCDM                                            0000580
      PRINT 9022,WORD56,FFCDM                                           0000585
      PRINT 9045                                                        0000590
      READ 9013,WORD18,CWFLR,WORD8,CWA                                  0000595
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      READ 9014,DFICW,DFCSCW,DFCW                                                0000600
      READ 9015,TC,TSTORC,CWFD                                                   0000605
      PRINT 9016                                                                 0000610
      PRINT 9017,WORD18,CWFLR,CWA,CWFD,TC,TSTORC,DFICW,DFCSCW,DFCW               0000615
      READ 9013,WORD18,DWFLR,WORD8,DWA                                           0000620
      READ 9014,DFIDW,DFCSDW,DFDW                                                0000625
      READ 9015,TD,TSTORD,DWFD                                                   0000630
      PRINT 9017,WORD18,DWFLR,DWA,DWFD,TD,TSTORD,DFIDW,DFCSDW,DFDW               0000635
      READ 9013,WORD18,CMWFR,WORD8,CMA                                           0000640
      READ 9014,DFICM,DFCSCM,DFCM                                                0000645
      READ 9015,TCM,TSTORB,CMFD                                                  0000650
      PRINT 9017,WORD18,CMWFR,CMA,CMFD,TCM,TSTORB,DFICM,DFCSCM,DFCM              0000655
      READ 9037,RGWFR                                                            0000660
      READ 9014,DFIRG,DFCSRG,DFRG                                                0000665
      READ 9015,TRG,TSTORR,RGFD                                                  0000670
      PRINT 9038,RGWFR,RGFD,TRG,TSTORR,DFIRG,DFCSRG,DFRG                         0000675
C                                                                                0000680
C     READ DATA FOR BWR GAS CODE                                                 0000685
C                                                                                0000690
      PRINT 9046                                                                 0000695
      READ 9022,WORD56,GGS                                                       0000700
      PRINT 9022,WORD56,GGS                                                      0000705
      READ 9022,WORD56,TIM3                                                      0000710
      PRINT 9022,WORD56,TIM3                                                     0000715
      READ 9022,WORD56,TIM4                                                      0000720
      PRINT 9022,WORD56,TIM4                                                     0000725
      HEPA1=1.0                                                                  0000730
      FIL1=1.0                                                                   0000735
      HEPA2=1.0                                                                  0000740
      FIL2=1.0                                                                   0000745
      HEPA5=1.0                                                                  0000750
      FIL5=1.0                                                                   0000755
      HEPA6=1.0                                                                  0000760
      FIL6=1.0                                                                   0000765
      FILGS = 1.0                                                                0000770
      FILEJ = 1.0                                                                0000775
      READ 9060,WORD15,CBCH,CBHEPA                                               0000780
      IF(CBCH.GT.0.0)FIL1 = (1.0 - CBCH/100.)                                    0000785
      IF(CBHEPA.GT.0.0)HEPA1 = (1.0 - CBHEPA/100.)                               0000790
      PRINT 9061,WORD15,FIL1,HEPA1                                               0000795
      READ 9062,WORD15,TBCH,TBHEPA                                               0000800
      IF(TBCH.GT.0.0)FIL2 = (1.0 - TBCH/100.)                                    0000805
      IF(TBHEPA.GT.0.0)HEPA2 = (1.0 - TBHEPA/100.)                               0000810
      PRINT 9063,WORD15,FIL2,HEPA2                                               0000815
      READ 9022,WORD56,FIL3                                                      0000820
      IF(FIL3.GT.0.0) FILGS = (1.0 - FIL3/100.)                                  0000825
      PRINT 9022,WORD56,FILGS                                                    0000830
      READ 9022,WORD56,FIL4                                                      0000835
      IF(FIL4.EQ.1.0) FILEJ = (1.0 - FIL4)                                       0000840
      IF(FIL4.GT.1.0) FILEJ = (1.0 - FIL4/100.)                                  0000845
      IF(FIL4.EQ.0.0) FILEJ = 1.0                                                0000850
      PRINT 9022,WORD56,FILEJ                                                    0000855
      READ 9060,WORD15,AXCH,AXHEPA                                               0000860
      IF(AXCH.GT.0.0)FIL5 = (1.0 - AXCH/100.)                                    0000865
      IF(AXHEPA.GT.0.0)HEPA5 = (1.0 - AXHEPA/100.)                               0000870
      PRINT 9061,WORD15,FIL5,HEPA5                                               0000875
      READ 9060,WORD15,RWCH,RWHEPA                                               0000880
      IF(RWCH.GT.0.0)FIL6 = (1.0 - RWCH/100.)                                    0000885
      IF(RWHEPA.GT.0.0)HEPA6 = (1.0 - RWHEPA/100.)                               0000890
      PRINT 9061,WORD15,FIL6,HEPA6                                               0000895
```

```
      READ 9021,KCHAR                                                   0000900
      READ 9022,WORD56,KKR                                              0000905
      READ 9022,WORD56,KXE                                              0000910
      READ 9022,WORD56,KMASS                                            0000915
      READ 9020,WORD56,PFLAUN                                           0000920
      IF(KCHAR.EQ.0) GO TO 54                                           0000925
      IF(KCHAR.EQ.1) GO TO 55                                           0000930
      PRINT 9023                                                        0000935
      GO TO 56                                                          0000940
   54 PRINT 9024                                                        0000945
      GO TO 56                                                          0000950
   55 CHTI1 = 1.8 * (KMASS * KKR)/POW1                                  0000955
      CHTI2 = 1.8 * (KMASS * KXE)/POW1                                  0000960
      PRINT 9025,CHTI1,CHTI2,KKR,KXE,KMASS                              0000965
   56 CONTINUE                                                          0000970
      IF(PFLAUN.EQ.0.0) GO TO 99                                        0000975
      GO TO 98                                                          0000980
   99 CONTINUE                                                          0000985
      PRINT 9048                                                        0000990
   98 CONTINUE                                                          0000995
      PRINT 9026                                                        0001000
   57 DO 58 I=1,ITOT                                                    0001005
      B(I)=0.0                                                          0001010
   58 CONTINUE                                                          0001015
      DFIED=1.                                                          0001020
      DFCSED=1.                                                         0001025
      DFED=1.                                                           0001030
      DFID2=1.                                                          0001035
      DFCSD2=1.                                                         0001040
      DFD2=1.                                                           0001045
C                                                                       0001050
C     CALCULATE BWR PRIMARY COOLANT CONCENTRATIONS                      0001055
      DO 2251 I=1,ITOT                                                  0001060
 2251 PCONC(I)=BCONC(I)                                                 0001065
      POWA=POW1                                                         0001070
      PCVOA=PCVOL*1E6                                                   0001075
      LETDWA=LETDWN*1E6                                                 0001080
      STMFA=STMFR*1E6                                                   0001085
      FFCDA=FFCDM                                                       0001090
C     CHECK TO SEE IF PLANT PARAMETERS ARE WITHIN SPECIFIED RANGES      0001095
      IF(FFCDA.LT.0.99) FFCDA=0.18                                      0001100
      IF(ABS(POWA-3400).GT.400.1)GO TO 252                              0001105
      IF(ABS(PCVOA-3.8E5).GT.0.4001E5)GO TO 252                         0001110
      IF(ABS(LETDWA-1.3E5).GT.0.2001E5)GO TO 252                        0001115
      IF(ABS(STMFA-1.5E7).GT.0.2001E7)GO TO 252                         0001120
      IF(FFCDA.GT.0.99) GO TO 252                                       0001125
      GO TO 256                                                         0001130
C     CALCULATE BWR ADJUSTMENT FACTORS                                  0001135
  252 RHAL2=(LETDWA*0.9+FFCDA*STMFA*PC*0.9)/PCVOA                       0001140
      IF(FFCDA.GT.0.99) GO TO 299                                       0001145
      FFCDA = 0.01                                                      0001150
  299 CONTINUE                                                          0001155
      RCSRB2=(LETDWA*0.5+FFCDA*STMFA*5E-4)/PCVOA                        0001160
      RCFP2=(LETDWA*0.9+FFCDA*STMFA*9E-4)/PCVOA                         0001165
      RK2=111.76*POWA/PCVOA                                             0001170
      DO 255 J=1,ITOT                                                   0001175
      IF(PCONC(J).EQ.0.0) GO TO 255                                     0001180
      NZ=NUCL(J)/10000                                                  0001185
      DL=DIS(J)*3600                                                    0001190
      IF (NZ.EQ.53.OR.NZ.EQ.35)GO TO 253                                0001195
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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)/(RCSRB2+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(1)=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
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 9008 FORMAT(20I4)                                                              0001500
 9009 FORMAT(10A4,F7.0,A3,F10.3)                                                0001505
 9010 FORMAT(32X,8A4,12X,A4)                                                    0001510
 9012 FORMAT(16X,14A4,F8.4)                                                     0001515
 9013 FORMAT(15X,4A4,A2,8X,F8.0,1X,A4,A2,F5.3)                                  0001520
 9014 FORMAT(20X,F8.0,2(5X,F8.0))                                               0001525
 9015 FORMAT(27X,F6.2,14X,F6.2,18X,F6.2)                                        0001530
 9016 FORMAT('0',30X,'FRACTION  FRACTION  COLLECTION  DECAY'/8X,'STREAM         0001535
     1     FLOW RATE   OF PCA  DISCHARGED   TIME      TIME',10X,'DECONTA       0001540
     2MINATION FACTORS'/20X,'(GAL/DAY)',23X,'(DAYS)    (DAYS)',7X,            0001545
     3'I',8X,'CS',6X,'OTHERS')                                                  0001550
 9017 FORMAT(2X,4A4,A2,1PE9.2,1X,4(0PF8.3,2X),3(1PE9.2,1X))                     0001555
 9020 FORMAT(16X,14A4,F8.4)                                                     0001560
 9021 FORMAT(79X,I1)                                                            0001565
 9022 FORMAT(16X,13A4,A2,F10.5)                                                 0001570
 9023 FORMAT(16X,'THERE IS A CRYOGENIC DISTILLATION COLUMN'/20X,'IODINE         0001575
     1AND XENON DECONTAMINATION FACTOR',T71,'10000.'/20X,'KRYPTON DECONT       0001580
     2AMINATION FACTOR',T72,'4000.'/20X,'KRYPTON AND XENON HOLDUP TIME (       0001585
     3DAYS)',T74,'90.')                                                         0001590
 9024 FORMAT(16X,'THERE IS NO CHARCOAL DELAY SYSTEM')                           0001595
 9025 FORMAT(16X,'THERE IS A CHARCOAL DELAY SYSTEM'/20X,'KRYPTON HOLDUP         0001600
     1TIME (DAYS)',T72,F9.5/20X,'XENON HOLDUP TIME (DAYS)',T72,F9.5/            0001605
     220X,'KRYPTON DYNAMIC ADSORPTION COEFFICIENT (CM3/GM)',T72,F9.5/           0001610
     320X,'XENON DYNAMIC ADSORPTION COEFFICIENT(CM3/GM)',T71,F10.5/20X,         0001615
     4'MASS OF CHARCOAL(THOUSAND LBS)',T72,F9.5)                                0001620
 9026 FORMAT(1H1)                                                               0001625
 9027 FORMAT(16X,'PLANT CAPACITY FACTOR',T75,'0.80')                            0001630
 9028 FORMAT(16X,'PERCENT FUEL WITH CLADDING DEFECTS',T75,F6.4)                 0001635
 9029 FORMAT(16X,'MASS OF WATER IN STEAM GENERATORS (THOUSAND LBS)',T73,        0001640
     1F8.4)                                                                     0001645
 9030 FORMAT(16X,'FISSION PRODUCT CARRY-OVER FRACTION',T75,F6.4/16X,            0001650
     1'HALOGEN CARRY-OVER FRACTION',T75,F6.4)                                   0001655
 9032 FORMAT(2X,7A4,F7.0,3A4,A1,F5.3,3A4,A3,I2,2A4)                             0001660
 9034 FORMAT(2X,'BLOWDOWN',10X,1PE9.2,14X,0PF5.3,2X,2(F8.3,2X),                 0001665
     13(1PE9.2,1X))                                                             0001670
 9035 FORMAT(2X,'UNTREATED BLOWDOWN',1PE9.2,11X,'   1.000     0.0              0001675
     10.0     1.00E 00  1.00E 00  1.00E 00')                                    0001680
 9036 FORMAT(16X,'THERE IS NOT A CONDENSATE DEMINERALIZER')                     0001685
 9037 FORMAT(72X,F8.2)                                                          0001690
 9038 FORMAT(2X,'REGENERANT SOLS   ',1PE9.2,14X,0PF5.3,2X,2(F8.3,2X),           0001695
     13(1PE9.2,1X))                                                             0001700
 9039 FORMAT(16X,'THERE IS A CRYOGENIC OFFGAS SYSTEM')                          0001705
 9040 FORMAT(16X,'THERE IS NO CRYOGENIC OFFGAS SYSTEM')                         0001710
 9041 FORMAT(16X,'PRIMARY TO SECONDARY LEAK RATE (LBS/DAY)',T73,'100.')         0001715
 9045 FORMAT   (/,'0 LIQUID WASTE INPUTS')                                      0001720
 9046 FORMAT   (/,'0 GASEOUS WASTE INPUTS')                                     0001725
 9048 FORMAT('0',15X,'THERE IS NOT AN ON-SITE LAUNDRY')                         0001730
 9051 FORMAT(16X,'BLOWDOWN RATE (THOUSAND LBS/HR)',25X,F8.4)                    0001735
 9052 FORMAT(16X,'THERE IS CONTINUOUS STRIPPING OF FULL LETDOWN FLOW')          0001740
 9053 FORMAT (16X,'THERE IS NOT CONTINOUS STRIPPING OF FULL LETDWN FLOW'        0001745
     1)                                                                         0001750
 9054 FORMAT(16X,'FLOW RATE THROUGH GAS STRIPPER (GPM)',20X,F8.4)               0001755
 9055 FORMAT(36X,F8.4,35X,I1)                                                   0001760
 9056 FORMAT(15X,4A4,A2,8X,F8.0)                                                0001765
 9060 FORMAT(16X,4A4,10X,F4.0,6X,F4.0)                                          0001770
 9061 FORMAT (16X,4A4,'IODINE RELEASE FRACTION',16X,F10.5/32X,'PARTICULA        0001775
     1TE RELEASE FRACTION',10X,F10.5)                                           0001780
 9062 FORMAT(16X,4A4,10X,F4.0,6X,F4.0)                                          0001785
 9063 FORMAT(16X,4A4,'IODINE RELEASE FRACTIOM',16X,F10.5/32X,'PARTICULAT        0001790
     1E RELEASE FRACTION',10X,F10.5)                                            0001795
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      9064 FORMAT(16X,'STEAM LEAK TO TURBINE BLDG (LBS/HR)',19X,F10.5)          0001800
      9065 FORMAT(16X,4A4,6X,A3)                                               0001805
      9066 FORMAT(16X,4A4,4X,'PARTICULATE RELEASE FRACTION',6X,F10.5)          0001810
      9067 FORMAT(16X,5A4,10X,A3,6X,A3)                                        0001815
      9068 FORMAT(16X,5A4,'IODINE RELEASE FRACTION',11X,F10.5/36X,'PARTICULAT  0001820
     1E RELEASE FRACTION',6X,F10.5)                                            0001825
      9069 FORMAT(16X,5A4,9X,F8.2,9X,A3,6X,A3)                                 0001830
      9070 FORMAT(16X,5A4,'RATE(CFM)',27X,F8.2/16X,5A4,'IODINE RELEASE FRACTI  0001835
     1ON',11X,F10.5/36X,'PARTICULATE RELEASE FRACTION',6X,F10.5)               0001840
      9071 FORMAT(16X,5A4,10X,A3,6X,A3,19X,F3.0)                               0001845
      9072 FORMAT (16X,'FREQUENCY OF CNTMT BLDG HIGH VOL PURGE (TIMES/YR)',    0001850
     1T74,F6.0)                                                                0001855
      9073 FORMAT (16X,'THERE IS NOT A CNTMT BLDG LOW VOL PURGE')              0001860
      9075 FORMAT(16X,'THERE IS CONTINUOUS LOW VOL PURGE OF VOL. CONTROL TK')  0001865
           END                                                                 0001870
           SUBROUTINE EFFTAB                                                   0001875
           INTEGER*2 NAME(3)                                                   0001880
           INTEGER*2 LOC,NON0,KD                                               0001885
           REAL*4 LETDWN,NOGEN                                                 0001890
           REAL*4 LETDWA                                                       0001895
           DIMENSION NZMBDM(26),NZCBDM(26),REACTR(7)                           0001900
           DIMENSION TURBDR(800),DWCON2(800),EDCONC(800)                       0001905
           DIMENSION  LAUNDY(12),WLAUND(12)                                    0001910
           COMMON/EQ/XZERO(800), XZH(800),XTEMP(800),XNEW(10,800),             0001915
          1      B(800),D(800)                                                0001920
           COMMON/FLUXN/T(20),POWER(10),TOCAP(800),FISS(100),DIS(800),ILITE,   0001925
          1 IACT,IFP,ITOT,NON,INPT                                             0001930
           COMMON/OUT/NUCL(800),TITLE(20),Q(800),FG(800),CUTOFF(7),            0001935
          1 POW,BURNUP,FLUXB,MSTAR,ALPHAN(100),SPONF(100),ABUND(500),          0001940
          2 BASIS(10),TCONST,TUNIT                                             0001945
           COMMON/COOL/REACTR,POW1,TYPE,PCVOL,LETDWN,NDGAS,SCVOL,STMVOL,NOGEN  0001950
          1             ,NPURGE,NVCSPG,SBLDR,GASDLA,STLKR,BLWDWN,EJCTR,WLKRAT,  0001955
          2             GASLKR,CONDLR,DFMBDM,DFCBDM,NZMBDM,NZCBDM,NE,PF,        0001960
          3             STMFR,FPEF,HEF,FFCDM,DFMBCS,CBFLR,DFI,DFCS,DF,          0001965
          4             EDFLR,DFIED,DFCSED,DFED,DWFLR,DFIDW,DFCSDW,DFDW,DILUT   0001970
          5            ,SBA,EDA,DWA,CWFLR,CMWFR,CWA,CMA,DFCM,DFICM,DFCSCM,      0001975
          6             DFCW,DFICW,DFCSCW,MHOLD,MHOLDE,MHOLDW,MHOLCM,MHOLDC     0001980
          7            ,BDTFR,DFIBD,DFCSBD,DFBD,MHOLDB,REGENT,                  0001985
          8              SBFD,DFMO,DFY,EDFD,DFMOED,DFYED,DWFD,DFMODW,DFYDW,     0001990
          9              DFMOBD,DFYBD,CWFD,DFMOCW,DFYCW,CMFD,DFMOCM,DFYCM       0001995
          A    ,TS,TE,TD,TB,TC,TCM,TSTORC,TSTORD,TSTORB,TMSC,DWFL2,DW2,DWF2,    0002000
          B  T2,TSTOR2,DFID2,DFCSD2,DFMOD2,DFYD2,DFD2,PFLAUN                   0002005
           COMMON/APCOOL/RGWFR,DFIRG,DFCSRG,DFRG,TRG,TSTORR,RGFD               0002010
           COMMON/BDTES/RFNRT                                                  0002015
           COMMON/FLEX/FLUX(10),MMN,MOUT,INDEX,QXN,AXN,ERR,NOBLND,MZERO        0002020
           COMMON/CONC/PCONC(800),DWCONC(800),CWCONC(800),CMCONC(800),         0002025
          1     SCON(800),RINV(800)                                            0002030
           COMMON/MPC/MPCTAB,AMPC(800),WMPC(800)                               0002035
           EQUIVALENCE  (XZERO(1),TURBDR(1)),(XZH(1),DWCON2(1))                0002040
           DATA LAUNDY/250540,270580,270600,400950,410950,441030,441060,       0002045
          1             471101,531310,551340,551370,581440/                  0002050
           DATA WLAUND/0.001,0.004,0.0087,0.0014,0.002,0.00014,0.0024,         0002055
          1            0.00044,0.000062,0.013,0.024,0.0052/                   0002060
           DO 10 I=1,ITOT                                                      0002065
      10   D(I)=-DIS(I)                                                        0002070
        15 H3BWR = 0.03 * POW1                                                0002075
           TRITPR = H3BWR * 0.5                                               0002080
           TRITCO=.01                                                         0002085
      20   DO 30 J=1,ITOT                                                      0002090
           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-BDTFR*(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-BDTFR*(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
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481.            DWCON2(I)=DWCON2(I)/DFCSD2                                      0002400
482.            CMCONC(I)=CMCONC(I)*(1.0-BDTFR*(1.0-CMFD/DFCSCM))               0002405
483.            RINV(I)=RINV(I)/DFCSRG                                          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
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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=AINT(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 TO180                                  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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      IF(NZ.EQ.1) GO TO 180                                                     0003000
      PAPRIM=PAPRIM+APRIM                                                       0003005
      PSEC=PSEC+ASEC                                                            0003010
      PCWAST=PCWAST+CWASTE                                                      0003015
      PDWAST=PDWAST+DWASTE                                                      0003020
      PABLOW=PABLOW+ABLOW                                                       0003025
      PTB=PTB+TB                                                                0003030
      PTOTAL=PTOTAL+TOTAL                                                       0003035
      PNORM=PNORM+TOTALN                                                        0003040
  180 CONTINUE                                                                  0003045
      PAPRIM=SAPRIM-PAPRIM                                                      0003050
      PSEC=SSEC-PSEC                                                            0003055
      PCWAST=SCWAST-PCWAST                                                      0003060
      PDWAST=SDWAST-PDWAST                                                      0003065
      PABLOW=SABLOW-PABLOW                                                      0003070
      PTB=STB-PTB                                                               0003075
      PTOTAL=STOTAL-PTOTAL                                                      0003080
      PNORM=SCNORM-PNORM                                                        0003085
      ISUBC=2                                                                   0003090
      IF (CTOTAL.GT.1.)ISUBC=1                                                  0003095
      DIV=10.**(INT(ALOG10(CTOTAL))-ISUBC)                                      0003100
      CTOTAL=AINT(CTOTAL/DIV+0.5)*DIV                                           0003105
      IF (PNORM.LT.1E-5) GO TO 184                                              0003110
        DIV=10.**(INT(ALOG10(PNORM))-2)                                         0003115
      PNORMT=AINT(PNORM/DIV+0.5)*DIV                                            0003120
  184 PNORMT=PNORM                                                              0003125
      PRINT 9008,   PAPRIM,PCWAST,PDWAST,PABLOW,PTOTAL,PNORM,PNORMT             0003130
      PRINT 9009,    SAPRIM,SCWAST,SDWAST,SABLOW,STOTAL,SCNORM,TLAUND,          0003135
     1               CTOTAL                                                     0003140
      PRINT 9012,   ITRITR                                                      0003145
 9000 FORMAT(1H1,20X,7A4,' LIQUID EFFLUENTS (CONTINUED)')                       0003150
 9001 FORMAT(1H1,20X,7A4,' LIQUID EFFLUENTS')                                   0003155
 9003 FORMAT(1X,A2,I3,A1,2X,1PE9.2,2(2X,E9.2,2X),5(1X,0PF9.5,1X),2(1X,0P        0003160
     1  F9.5,1X),0PF10.5)                                                      0003165
 9006 FORMAT(1H0,17X,'CONCENTRATION     ANNUAL RELEASES TO DISCHARGE CAN        0003170
     1AL'/18X,' IN PRIMARY  ',43('-'),'  ADJUSTED   DETERGENT    TOTAL         0003175
     2 '/' NUCLIDE HALF-LIFE  COOLANT    HIGH PURITY LOW PURITY  CHEMICA       0003180
     3L  TOTAL LWS    TOTAL      WASTES          '/10X,'(DAYS)  (MICRO C       0003185
     4I/ML)',3('  (CURIES) '), ' (CURIES)    (CI/YR)    (CI/YR)    (CI/Y      0003190
     5R)')                                                                      0003195
 9007 FORMAT(1X,A2,I3,A1,2X,1PE9.2,  2X,E9.2,2X ,4(1X,0PF9.5,1X),2(1X,0P        0003200
     1F9.5,1X),1X,0PF9.5)                                                       0003205
 9008 FORMAT(1X,'ALL OTHERS',9X,1PE9.2,2X,4(1X,0PF9.5,1X),1X,0PF9.5,4X,         0003210
     1       '0.0',6X,0PF9.5)                                                   0003215
 9009 FORMAT(' TOTAL'/,' (EXCEPT TRITIUM)   ',1PE9.2,2X,4(1X,0PF9.5,1X),        0003220
     1       2(1X,0PF9.5,1X),1X,0PF9.5)                                         0003225
 9010 FORMAT(' CORROSION AND ACTIVATION PRODUCTS')                              0003230
 9011 FORMAT('0FISSION PRODUCTS')                                               0003235
 9012 FORMAT (1H0,1X,'TRITIUM RELEASE',12X,I3,'   CURIES PER YEAR')             0003240
      RETURN                                                                    0003245
      END                                                                       0003250
      BLOCK DATA                                                                0003255
      COMMON /CONB/BCONC(800)                                                   0003260
      DATA BCONC/2*0.0,0.01,33*0.0,                                             0003265
     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,            0003270
     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        0003275
     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        0003280
     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        0003285
     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        0003290
     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        0003295
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     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-
     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-
     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,
    115E-3,7*0.0,3E-5,4E-5,2*0.0,3E-6,10*0.0,3E-6,81*0.0/
      END
      SUBROUTINE SOLVE
      COMMON/EQ/XZERO(800), XZH(800),XTEMP(800),XNEW(10,800),
     1      B(800),D(800)
      COMMON/FLEX/FLUX(10),MMN,MOUT,INDEX,QXN,AXN,ERR,NOBLND,MZERO
      COMMON/PROCSS/  MPROS,PRATE(8),NOPROS(8),NZPROS(8,20),PR(800)
      COMMON/FLUXN/T(20),POWER(10),TOCAP(800),FISS(100),DIS(800),ILITE,
     1 IACT,IFP,ITOT,NON,INPT
      COMMON/OUT/NUCL(800),TITLE(20),Q(800),FG(800),CUTOFF(7),
     1 POW,BURNUP,FLUXB,MSTAR,ALPHAN(100),SPONF(100),ABUND(500),
     2 BASIS(10),TCONST,TUNIT
      DO 10 I=1,ITOT
      D(I)=-DIS(I)
   10 XTEMP(I)=0.0
      DELT=T(1)*TCONST
      CALL DECAY(1,DELT,ITOT)
      CALL TERM(DELT,1,ILITE,ITOT)
      CALL EQUIL(1,ITOT)
      DO 30 I=1,ITOT
   30 XTEMP(I)=XNEW(1,I)
      RETURN
      END
      SUBROUTINE TERM(T,M,ILITE,ITOT)
C
C     TERM ADDS ONE TERM TO EACH ELEMENT OF THE SOLUTION VECTOR
C     CSUM(J) IS THE CURRENT APPROXIMATION TO XNEW(M,J)
C     CIM0(J) IS THE VECTOR CONTAINING THE LAST TERM ADDED TO EACH
C     ELEMENT OF CSUM(J)
C     CIMN(J) IS THE VECTOR CONTAINING 1/TON TIMES THE NEW TERM TO BE
C     ADDED TO  CSUM(J)
C     CIMN(J) IS GENERATED FROM CIM0(J) BY A RECURSION RELATION:
C          CIMN(J)= SUM OVER L OF (AP(J,L)*CIM0(L))
C     AP(I,J) IS THE REDUCED TRANSITION MATRIX FOR THE LONG-LIVED
C     NUCLIDES
C
      LOGICAL*1 LONG
      INTEGER*2 LOC,NON0,KD
      INTEGER*2 LOCP(2500)
      INTEGER*2 NONP(800)
      INTEGER*2 NQ,NQU,NQUEUE
      REAL*8 BATE,BATM
      REAL*8 CIMN(800),CSUM(800),CIMNI
      DIMENSION AP(2500),CIMB(800),CIM0(800)
      DIMENSION QUB(50)
      COMMON/SERIES/ XP(800),XPAR(800),LONG(800)
      COMMON/FLEX/FLUX(10),MMN,MOUT,INDEX,QXN,AXN,ERR,NOBLND,MZERO
      COMMON/EQ/XZERO(800),XZH(800),XTEMP(800),XNEW(10,800),
     1      B(800),D(800)
      COMMON/MATRIX/A(2500),LOC(2500),NON0(800),KD(800)
      COMMON/DEBUGG/AP
      COMMON/TERMD/DD(100),DXP(100),QUEUE(50),NQU(50),NQUEUE(50),NQ(800)
      NUL=0
      NN=0
C     FIRST CONSTRUCT REDUCED TRANSITION MATRIX FOR LONG-LIVED ISOTOPES
      DO 220 L=1,ITOT
      IF(.NOT.LONG(L)) GO TO 210
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721.            NUM=NON0(L)
722.            IF(M.GT.MMN.OR.M.EQ.MZERO)  NUM=KD(L)                          0003600
723.            CIMB(L)=B(L)                                                   0003605
724.            IF(NUM.LE.NUL) GO TO 210                                       0003610
725.            NS=NN+1                                                        0003615
726.            N=NUL                                                          0003620
727.            NL=NUM-NUL                                                     0003625
728.            DO 200 N1=1,NL                                                 0003630
729.            N=N+1                                                          0003635
730.            J=LOC(N)                                                       0003640
731.            DJ=-D(J)                                                       0003645
732.      C                                                                    0003650
733.      C      THIS IS A TEST TO SEE IF ONE OF THE ASSYMPTOTIC SOLUTIONS APPLIES 0003655
734.      C                                                                    0003660
735.            IF(.NOT.LONG(J)) GO TO 10                                      0003665
736.            NN=NN+1                                                        0003670
737.            AP(NN)=A(N)                                                    0003675
738.            LOCP(NN)=J                                                     0003680
739.            GO TO 200                                                      0003685
740.      C                                                                    0003690
741.      C     GOING BACK UP THE CHAIN TO FIND A PARENT WHICH IS NOT IN        0003695
742.      C     EQUILIBRIUM                                                    0003700
743.      C                                                                    0003705
744.       10   NSAVE=0                                                        0003710
745.            QUE=A(N)/DJ                                                    0003715
746.            DRB=1.0                                                        0003720
747.            CIMB(L)=CIMB(L)+QUE*B(J)                                       0003725
748.            NQ(L)=0                                                        0003730
749.            NQ(J)=L                                                        0003735
750.       20   NUX=NON0(J)                                                    0003740
751.            IF(M.GT.MMN.OR.M.EQ.MZERO)  NUX=KD(J)                          0003745
752.            NUF=0                                                          0003750
753.            IF(J.GT.1)  NUF=NON0(J-1)                                      0003755
754.            NX=NUX-NUF                                                     0003760
755.            IF(NX.LT.1)  GO TO 190                                         0003765
756.            K=NUF                                                          0003770
757.            DO 180 KK=1,NX                                                 0003775
758.            K=K +1                                                         0003780
759.            J1=LOC(K)                                                      0003785
760.            DJ=-D(J1)                                                      0003790
761.            KP=J                                                           0003795
762.       30   IF(J1.EQ.NQ(KP))  GO TO 180                                    0003800
763.            KP=NQ(KP)                                                      0003805
764.            IF(KP.NE.0)  GO TO 30                                          0003810
765.            AKDJQ=QUE*A(K)/DJ                                              0003815
766.            IF(.NOT.LONG(J1)) GO TO 160                                    0003820
767.            TRM=1.0-XP(J1)                                                 0003825
768.            IF(TRM.LT.1.0E-6) GO TO 120                                    0003830
769.            NQ(J1)=J                                                       0003835
770.            I=1                                                            0003840
771.            KP=J1                                                          0003845
772.       40   DD(I)=-D(KP)                                                   0003850
773.            DXP(I)=XP(KP)                                                  0003855
774.            KP=NQ(KP)                                                      0003860
775.            IF(KP.EQ.0) GO TO 50                                           0003865
776.            I=I+1                                                          0003870
777.            IF(I.LE.100) GO TO 40                                          0003875
778.      C     IF QUEUE OF SHORT-LIVED NUCLIDES EXCEEDS 100 ISOTOPES, TERMINATE 0003880
779.      C     CHAIN AND WRITE MESSAGE                                        0003885
780.            PRINT 9000,    M,L,J1,J,AKDJQ                                  0003890
                                                                               0003895
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781.      9000 FORMAT('1TOO 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.          1IVED 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
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841.            QUEUE(NSAVE)=AKDJQ                                                    0004200
842.            NQU(NSAVE)=J                                                          0004205
843.            QUB(NSAVE)=DRB-1./(DJ*T)                                              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=NON0(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('0MAXIMUM 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      0004585
919.        C   BATEMAN EQUATIONS                                                   0004590
920.            LOGICAL*1 LONG                                                      0004595
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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      NUF=1                                                                 0004800
      IF(J.GT.1)  NUF=NONO(J-1)+1                                           0004805
      IF(NUF.GT.NUX)  GO TO 130                                             0004810
      DO 120 K=NUF,NUX                                                      0004815
      J1=LOC(K)                                                             0004820
      IF(LONG(J1)) GO TO 120                                                0004825
      KP=J                                                                  0004830
30    IF(J1.EQ.NQ(KP))  GO TO 120                                           0004835
      KP=NQ(KP)                                                             0004840
      IF(KP.NE.0)  GO TO 30                                                 0004845
      DJ=-D(J1)                                                             0004850
      AKDJQ=A(K)/DJ*QUE                                                     0004855
      IF(AKDJQ.LE.1.0E-06)  GO TO 120                                       0004860
      NQ(J1)=J                                                              0004865
      I=1                                                                   0004870
      KP=J1                                                                 0004875
40    DD(I)=-D(KP)                                                          0004880
      DXP(I)=XP(KP)                                                         0004885
      KP=NQ(KP)                                                             0004890
      IF(KP.EQ.0) GO TO 50                                                  0004895
      I=I+1                                                                 0004900
      IF(I.LE.100) GO TO 40                                                 0004905
      PRINT 9000,    M,L,J1,J,AKDJQ                                         0004910
9000  FORMAT('1',4I5,E12.5)                                                 0004915
      GO TO 130                                                             0004920
50    BATE=0.D0                                                             0004925
      I1=I-1                                                                0004930
      XPL=XP(L)                                                             0004935
C     D R VONDY FORM OF BATEMAN EQUATIONS -- ORNL-TM-361                    0004940
      DO 100 KB=1,I1                                                        0004945
      XPJ=DXP(KB)                                                           0004950
      IF(XPL+XPJ.LT.ERR) GO TO 100                                          0004955
      DK=DD(KB)                                                             0004960
      PROD=(DL/DK-1.0)                                                      0004965
      DKR=PROD                                                              0004970
      IF( ABS(PROD).GT.1.E-4) GO TO 60                                      0004975
      PROD=T*DK*XPJ*(1.0-0.5*(DL-DJ)*T)                                     0004980
      GO TO 70                                                              0004985
60    PROD=(XPJ-XPL)/PROD                                                   0004990
      PRO1=XPJ/DKR                                                          0004995
70    PI=1.0                                                                0005000
      S1=2./(DK*T)                                                          0005005
      DO 90 JK=1,I1                                                         0005010
      IF(JK.EQ.KB) GO TO 90                                                 0005015
      S=1.0-DK/DD(JK)                                                       0005020
      IF( ABS(S).GT.1.E-4) GO TO 80                                         0005025
C     USE THIS FORM FOR TWO NEARLY EQUAL HALF-LIVES                         0005030
      IF(ABS(DKR).GT.1.0E-4)  PROD=PRO1                                     0005035
      S=S1                                                                  0005040
80    PI=PI*S                                                               0005045
      IF(ABS(PI).GT.1.E25)  GO TO 100                                       0005050
90    CONTINUE                                                              0005055
      BATE=BATE+PROD/PI                                                     0005060
100   CONTINUE                                                              0005065
      IF(BATE.LT.0.D0)  PRINT 9001,     L,I,BATE,XTEM,XTEMP(J1),AKDJQ       0005070
9001  FORMAT(' L,I,BATE,XTEM,XTEMP(J1),AKDJQ = ',2I5,1P4E12.5)              0005075
      IF(BATE.LT.0.D0)  BATE=0.D0                                           0005080
      XTEM=XTEM+XTEMP(J1)*AKDJQ*BATE                                        0005085
      IF(NSAVE.GE.50) GO TO 120                                             0005090
110   NSAVE=NSAVE+1                                                         0005095
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```
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=NON0(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,NON0,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),NON0(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=NON0(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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      ARG=ABS((XNW-XPAR(I))/XNW)                                        0005400
      IF(ARG.GT.BIG)  BIG=ARG                                           0005405
   40 XPAR(I)=XNW                                                       0005410
   50 N=NON0(I)                                                         0005415
   60 CONTINUE                                                          0005420
      IF(BIG.LT.QXN  )   GOTO 70                                        0005425
      ITER=ITER+1                                                       0005430
      IF(ITER.LT.100)  GO TO 20                                         0005435
      PRINT 9000                                                        0005440
      STOP                                                              0005445
   70 DO 80 I=1,ITOT                                                    0005450
      IF(.NOT.LONG(I)) XNEW(M,I)=XNEW(M,I)+XPAR(I)                      0005455
   80 CONTINUE                                                          0005460
      RETURN                                                            0005465
 9000 FORMAT(' GAUSS SEIDEL ITERATION DID NOT CONVERGE IN EQUIL')       0005470
      END                                                               0005475
      SUBROUTINE NUDATA(NLIBE)                                          0005480
C     NUDATA VERSION TO HANDLE THREE TYPES OF NUCLEAR DATA LIBRARIES     0005485
C     HAS POINTER, NLIBE, = 1 FOR HTGR                                  0005490
C                         = 2 FOR LIGHT WATER REACTOR                   0005495
C                         = 3 FOR LMFBR                                 0005500
C                         = 4 FOR MSBR                                  0005505
      INTEGER*2 LOC,NON0,KD                                             0005510
      INTEGER*2 ELE(99),STA(2)                                          0005515
      INTEGER*2 KAP(800),MMAX(800)                                      0005520
      INTEGER*2 NAME(3)                                                 0005525
      DIMENSION COEFF(7,800),NPROD(7,800),CAPT(6),                      0005530
     1 NUCAL(6),NSORS(5),           YIELD(5,500),TYLD(5)                0005535
      DIMENSION Y(5)                                                    0005540
      DIMENSION SKIP(20)                                                0005545
      DIMENSION MSRS(20)                                                0005550
      COMMON/LABEL/ELE,STA                                              0005555
      COMMON/FLEX/FLUX(10),MMN,MOUT,INDEX,QXN,AXN,ERR,NOBLND,MZERO      0005560
      COMMON/EQ/XZERO(800),XZH(800),XTEMP(800),XNEW(10,800),            0005565
     1      B(800),D(800)                                               0005570
      COMMON/MPC/MPCTAB,AMPC(800),WMPC(800)                             0005575
      COMMON/FLUXN/T(20),POWER(10),TOCAP(800),FISS(100),DIS(800),ILITE, 0005580
     1 IACT,IFP,ITOT,NON,INPT                                           0005585
      COMMON/OUT/NUCL(800),TITLE(20),Q(800),FG(800),CUTOFF(7),          0005590
     1 POW,BURNUP,FLUXB,MSTAR,ALPHAN(100),SPONF(100),ABUND(500),        0005595
     2 BASIS(10),TCONST,TUNIT                                           0005600
      COMMON/MATRIX/A(2500),LOC(2500),NON0(800),KD(800)                 0005605
      EQUIVALENCE (XZERO(1),KAP(1)),(XZERO(401),MMAX(1)),               0005610
     1           ( XZH(1),COEFF(1,1)),(XNEW(1,401),NPROD(1,1))          0005615
      EQUIVALENCE (A1,DLAM)                                             0005620
      DATA NUCAL/-20030,-10000,10,11,-10,-9/                            0005625
      DATA MSRS/922330,922350,902320,922380,942390,922330,922350,942410, 0005630
     1          922380,942390,942410,922350,942400,922380,942390,922330, 0005635
     2          922350,902320,922380,942390/                           0005640
C                                                                       0005645
C     PROGRAM TO COMPUTE A MATRIX (TRANSITION MATRIX) FROM NUCLEAR DATA  0005650
C                                                                       0005655
      READ 9011,             (TITLE(I),I=1,18),NLIBE                    0005660
C     IF(NLIBE.LT.0) PROGRAM WILL READ TAPE IN CASDAR FORMAT            0005665
      IGWC=0                                                            0005670
      IF(NLIBE.GT.0)  GO TO  10                                         0005675
      IGWC=1                                                            0005680
      NLIBE=-NLIBE                                                      0005685
      PRINT 9000                                                        0005690
 9000 FORMAT(1H0,'WILL READ TAPE GENERATED BY CASDAR')                  0005695
```

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1141.      10   N1=4-NLIBE
1142.      20   READ 9001,     THERM,RES,FAST,ERR,NMO,NDAY,NYR,MPCTAB,INPT,IR          0005700
1143.           PRINT 9005,      NMO,NDAY,NYR                                          0005705
1144.           PRINT 9006                                                             0005710
1145.           PRINT 9007                                                             0005715
1146.           PRINT 9008                                                             0005720
1147.           PRINT 9009                                                             0005725
1148.           PRINT 9010                                                             0005730
1149.           PRINT 9013                                                             0005735
1150.           PRINT 9014                                                             0005740
1151.     C                                                                            0005745
1152.     C     THERM = RATIO OF THERMAL FLUX TO TOTAL FLUX                            0005750
1153.     C     RES =  RATIO OF RESONANCE FLUX TO TOTAL FLUX                           0005755
1154.     C     FAST = RATIO OF FAST FLUX TO TOTAL FLUX                                0005760
1155.     C     ERR = TRUNCATION ERROR LIMIT                                           0005765
1156.     C                                                                            0005770
1157.     C     READ DATA FOR LIGHT ELEMENTS                                           0005775
1158.     C                                                                            0005780
1159.           K=5*(NLIBE-1)                                                          0005785
1160.           DO 30 K1=1,5                                                           0005790
1161.           K2=K+K1                                                                0005795
1162.      30   NSORS(K1)=MSRS(K2)                                                     0005800
1163.           PRINT 9018,    THERM,RES,FAST,(NSORS(K),K=1,5),NLIBE                   0005805
1164.           I=0                                                                    0005810
1165.           NUTAPE=0                                                               0005815
1166.      40   I=I+1                                                                  0005820
1167.      50   READ(8,9034,END=260)NUCL(I),DLAM,IU,FB1,FP,FP1,FT,FA,FSF,              0005825
1168.          1Q(I),FG(I),ABUND(I),WMPC(I),AMPC(I)                                  0005830
1169.           IF(IGWC.GT.0)  GO TO 70                                                0005835
1170.           DO 60 N=1,NLIBE                                                        0005840
1171.      60   READ(8,9035) SIGTH,FNG1,FNA,FNP,RITH,FINA,FINP,SIGMEV,FN2N1,FFNA,      0005845
1172.          1             FFNP,IT                                                 0005850
1173.           GO TO 90                                                               0005855
1174.      70   DO 80 N=1,NLIBE                                                        0005860
1175.      80   READ(8,9040) SIGTH,FNG1,FNA,FNP,RITH,FINA,FINP,SIGMEV,FN2N1,FFNA,      0005865
1176.          1             FFNP,IT                                                 0005870
1177.      90   IF(N1.EQ.0) GO TO 110                                                  0005875
1178.           DO 100 N=1,N1                                                          0005880
1179.      100  READ(8,9036)  SKIP                                                    0005885
1180.      110  IF(IT.EQ.0) GO TO 50                                                   0005890
1181.      120  M=0                                                                    0005895
1182.           CALL HALF(A1,IU)                                                       0005900
1183.           NUCLI=NUCL(I)                                                          0005905
1184.           IF(NUCLI.EQ.0)  GO TO 260                                              0005910
1185.           CALL NOAH(NUCLI,NAME)                                                  0005915
1186.           IF(MOD(I-1,50) .EQ. 0) PRINT 9012,     (TITLE (N),N=1,18)              0005920
1187.           IF(MOD(I-1,50) .EQ. 0) PRINT 9016                                      0005925
1188.           SIGTH=THERM*SIGTH                                                      0005930
1189.           RITH=RES*RITH                                                          0005935
1190.           SIGMEV=FAST*SIGMEV                                                     0005940
1191.           SIGNA=SIGTH*FNA+RITH*FINA+SIGMEV*FFNA                                  0005945
1192.           SIGNP=SIGTH*FNP+RITH*FINP+SIGMEV*FFNP                                  0005950
1193.           FNG=1.0-FNA-FNP                                                        0005955
1194.           IF(FNG.LT.1.0E-4)FNG=0.                                                0005960
1195.           FING=1.0-FINA-FINP                                                     0005965
1196.           IF(FING.LT.1.0E-4)FING=0.                                              0005970
1197.           FN2N=1.0-FFNA-FFNP                                                     0005975
1198.           IF(FN2N.LT.1.0E-4)FN2N=0.                                              0005980
1199.           SIGNG=SIGTH*FNG+RITH*FING                                              0005985
1200.           SIGN2N=SIGMEV*FN2N                                                     0005990
                                                                                       0005995
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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
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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.           1Q(I),FG(I),DUMMY,WMPC(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
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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
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1381.            IF(CAPKI.LT.ERR)  GO TO 410
1382.            M=M+1                                                          0006900
1383.            TOCAP(I)=TOCAP(I)+CAPKI                                        0006905
1384.            COEFF(M,I)=CAPKI                                               0006910
1385.            NPROD(M,I)=NUCLI+NUCAL(K+2)                                    0006915
1386.       410  CONTINUE                                                       0006920
1387.            TOCAP(I)=TOCAP(I)+FISS(IACT)                                   0006925
1388.       C    N-3N CROSS SECTION                                             0006930
1389.            A17=SIGN3N                                                     0006935
1390.            IF(A17.LT.ERR) GO TO 420                                       0006940
1391.            M=M+1                                                          0006945
1392.            COEFF(M  ,I)= A17                                              0006950
1393.            NPROD(M  ,I)= NUCLI-20                                         0006955
1394.            TOCAP(I)=TOCAP(I)+A17                                          0006960
1395.       420  IF(MOD(NUCLI,10).EQ.0) GO TO 440                             0006965
1396.            DO 430 K=1,M                                                   0006970
1397.       430  NPROD(K,I)=NPROD(K,I)-1                                       0006975
1398.       440  MMAX(I)=M                                                      0006980
1399.            IF(M.GT.7)  PRINT 9039, M                                      0006985
1400.            SPONF(IACT)=FSF*A1*6.023E23                                    0006990
1401.            ALPHAN(IACT)=FA*A1*6.023E13*Q(I)**3.65                         0006995
1402.            DIS(I)=A1                                                      0007000
1403.            I=I+1                                                          0007005
1404.            GO TO 270                                                      0007010
1405.       450  IL=0                                                           0007015
1406.            DO 460 K=1,5                                                   0007020
1407.       460  TYLD(K)=0.0                                                    0007025
1408.       C                                                                   0007030
1409.       C    READ DATA FOR FISSION PRODUCTS                                 0007035
1410.       C                                                                   0007040
1411.       470  READ(8,9034,END=690)NUCL(I),DLAM,IU,FB1,FP,FP1,FT,FA,FSF,     0007045
1412.           1Q(I),FG(I),DUMMY,WMPC(I),AMPC(I)                               0007050
1413.            DO 480 N=1,NLIBE                                               0007055
1414.       480  READ(8,9038) SIGNG,RING,FNG1,Y,IT                              0007060
1415.            IF(N1.EQ.0) GO TO 500                                          0007065
1416.            DO 490 N=1,N1                                                  0007070
1417.       490  READ(8,9036)  SKIP                                            0007075
1418.       500  IF(IT .EQ. 0) GO TO 470                                        0007080
1419.       510  M=0                                                            0007085
1420.            CALL HALF(A1,IU)                                               0007090
1421.       520  NUCLI=NUCL(I)                                                  0007095
1422.            IF(NUCLI.EQ.0) GO TO 690                                       0007100
1423.            CALL NOAH(NUCLI,NAME)                                          0007105
1424.            IF(MOD(IL,50).EQ. 0)   PRINT 9012,    (TITLE (N),N=1,18)       0007110
1425.            SIGNG=THERM*SIGNG+RES*RING                                     0007115
1426.            IF(NLIBE.EQ.3) GO TO 540                                       0007120
1427.       530  IF(MOD( IL        ,50).EQ.0)  PRINT 9019                       0007125
1428.            PRINT 9021,    NAME,              DLAM,FB1,FP,FP1,FT,SIGNG,    0007130
1429.           1     FNG1,Y,Q(I),FG(I)                                         0007135
1430.            GO TO 550                                                      0007140
1431.       540  IF(MOD(IL,50).EQ.0) PRINT 9020                                 0007145
1432.            PRINT 9022,    NAME ,              DLAM,FB1,FP,FP1,FT,SIGNG,FNG1,  0007150
1433.           1               Y(2),Y(4),Y(5),Q(I),FG(I)                       0007155
1434.       C                                                                   0007160
1435.       C    TEST RADIOACTIVITY                                             0007165
1436.       C                                                                   0007170
1437.       550  IF(A1.LT.ERR)  GO TO 600                                       0007175
1438.            ABETA=1.0                                                      0007180
1439.       C    POSITRON EMISSION                                              0007185
1440.            A3=FP                                                          0007190
                                                                                0007195
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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
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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
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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=MMAX(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=MMAX(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
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      JT=J                                                                  0008100
      LOC(NON)=JT                                                           0008105
  850 CONTINUE                                                              0008110
  860 CONTINUE                                                              0008115
      IF(IACT.LT.1)  GO TO 880                                              0008120
      DO 870 K=1,5                                                          0008125
      IL=I-IM                                                               0008130
      IF(YIELD(K,IL).LT.ERR)  GO TO 870                                     0008135
      NON=NON+1                                                             0008140
      IF(NON.GT.2500)  PRINT 9041,     NON,NUCL(I)                          0008145
      NON0(I)=NON0(I)+1                                                     0008150
      KK=NSORS(K)                                                           0008155
      LOC(NON)=KK                                                           0008160
      KF=KK-ILITE                                                           0008165
      A(NON)=YIELD(K,IL)*FISS(KF)                                           0008170
  870 CONTINUE                                                              0008175
  880 CONTINUE                                                              0008180
      IF(IFP.LE.0) GO TO 900                                                0008185
      IF(NLIBE.NE.3) GO TO 890                                              0008190
      PRINT 9027,    TYLD(2),TYLD(4),TYLD(5)                                0008195
      GO TO 900                                                             0008200
  890 PRINT 9030,     (TYLD(I),I=1,5)                                       0008205
C                                                                           0008210
C     ALL MATRIX ELEMENTS ARE NOW COMPUTED                                  0008215
C     BEGIN TRANSIENT SOLUTION                                              0008220
C                                                                           0008225
C                                                                           0008230
C     TEMPORARILY WRITE OUT MATRIX ELEMENTS                                 0008235
C                                                                           0008240
  900 IF(IR .EQ. 0) RETURN                                                  0008245
      PRINT 9029                                                            0008250
      N=0                                                                   0008255
      DO 910 I=1,ITOT                                                       0008260
      NUM=NON0(I)                                                           0008265
      IF(NUM.LE.0)  GO TO 910                                               0008270
      N1=N+NUM                                                              0008275
      N=N+1                                                                 0008280
      PRINT 9028,    I,DIS (I),TOCAP(I),(A(K),LOC(K),K=N,N1)                0008285
      N=N1                                                                  0008290
  910 CONTINUE                                                              0008295
      RETURN                                                                0008300
  920 STOP                                                                  0008305
C                                                                           0008310
C     FORMATS     FORMATS     FORMATS     FORMATS                           0008315
C                                                                           0008320
 9001 FORMAT(4F10.5,6I2)                                                    0008325
 9002 FORMAT(I6,F5.3,I1,5F3.3,E5.2,F3.3,            13X,E5.2,F3.3,2E5.2    0008330
     1       ,F4.3,F3.3,F6.4)                                               0008335
 9003 FORMAT(I6,F5.3,I1,3X,4F3.3,2E5.2,F3.3,5E5.2,F4.3,F3.3)                0008340
 9004 FORMAT(I6,F5.3,I1,5F3.3,2E5.2,F3.3,4E5.2,F3.3,F4.3,F3.3,2E5.2)        0008345
 9005 FORMAT(1H1,43X,'NUCLEAR TRANSMUTATION DATA   REVISED ',I2,'/',I2,'    0008350
     1/',I2,/,'0NUCL = NUCLIDE = 10000 * ATOMIC NO + 10 * MASS NO + ISOM    0008355
     2ERIC STATE (0 OR 1)',10X,'DLAM = DECAY CONSTANT (1/SEC).',/,' FB,     0008360
     3FP, FA, FT = FRACTIONAL DECAY BY BETA, POSITRON (OR ELECTRON CAPTU    0008365
     4RE), ALPHA, INTERNAL TRANSITION.   FB = 1 - FP - FA - FT',/,' FB1,    0008370
     5 FP1, FNG1, FN2N1 = FRACTION OF BETA, POSITRON, N-GAMMA, N-2N TRAN    0008375
     6SITIONS TO EXCITED STATE OF PRODUCT NUCLIDE',/,' SIGTH, SIGNG, SIG    0008380
     7F, SIGNA, SIGNP = THERMAL CROSS SECTIONS (BARNS) FOR ABSORPTION, N    0008385
     8-GAMMA, FISSION, N-ALPHA, N-PROTON.')                                 0008390
 9006 FORMAT('   SIGNG = SIGTH * (1 - FNA -FNP).  SIGNA = SIGTH * FNA.      0008395
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     1SIGNP = SIGTH * FNP.  FNA, FNP = FRACTION THERMAL N-ALPHA, N-PROTO 0008400
     2N.',/,' RITH, RING, RIF, RINA, RINP = RESONANCE INTEGRAL FOR ABSOR 0008405
     3PTION, N-GAMMA, FISSION, N-ALPHA, N-PROTON.',/,'   RING = RITH * ( 0008410
     41 - FINA - FINP). RINA = RITH * FINA. RINP = RITH * FINP.  FINA, F 0008415
     5INP = FRACTION RESONANCE N-ALPHA, N-PROTON.',/,' SIGMEV, SIGFF, SI 0008420
     6GN2N, SIGNAF, SIGNPF = FAST CROSS SECTIONS (BARNS) FOR ABSORPTION, 0008425
     7FISSION, N-2N, N-ALPHA, N-PROTON.',/,'   SIGN2N = SIGMEV * (1 - FF 0008430
     8NA - FFNP).  SIGNAF = SIGMEV * FFNA.  SIGNPF = SIGMEV * FFNP.  FFN 0008435
     9A, FFNP = FRACTION FAST N-ALPHA, N-P.')                            0008440
9007 FORMAT(' Y23, Y25, Y02, Y28, Y49 = FISSION YIELD (PERCENT) FROM 23  0008445
     13-U, 235-U, 232-TH, 238-U, 239- PU.',/,' Q = HEAT PER DISINTEGRATI 0008450
     2ON.  FG = FRACTION OF HEAT IN GAMMAS OF ENERGY GREATER THAN 0.2 ME 0008455
     3V.',/,'0 EFFECTIVE CROSS SECTIONS FOR A VOLUME AVERAGED THERMAL (L 0008460
     4T 0.876 EV) FLUX ARE AS FOLLOWS.',/,'    N-GAMMA  -  SIGNG * THERM 0008465
     5 + RING * RES.',/,'    FISSION  -  SIGF * THERM + RIF * RES + SIGF 0008470
     6F * FAST.',10X,'THERM = 1/V CORRECTION FOR THERMAL SPECTRUM AND TE 0008475
     7MPERATURE.',/,'    N-2N     -  SIGN2N * FAST.',36X,'RES   = RATIO  0008480
     8OF RESONANCE FLUX PER LETHARGY UNIT TO THERMAL FLUX.')             0008485
9008 FORMAT('    N-ALPHA  -  SIGNA * THERM + RINA * RES + SIGNAF * FAST 0008490
     1.',7X,'FAST = 1.45 *  RATIO OF FAST (GT 1.0 MEV) TO THERMAL FLUX ' 0008495
     2/'    N-PROTON -  SIGNP * THERM + RINP * RES + SIGNPF * FAST.')    0008500
9009 FORMAT(1H0,59X,'REFERENCES',/,'    HALF LIVES, DECAY SCHEMES, AND   0008505
     1THERMAL POWER',/,' C M LEDERER, J M HOLLANDER, AND I PERLMAN ''TAB 0008510
     2LE OF ISOTOPES - SIXTH EDITION'' JOHN WILEY AND SONS, INC (1967)', 0008515
     3/,' B S DZHELEPOV AND L K PEKER ''DECAY SCHEMES OF RADIOACTIVE NUC 0008520
     4LEI'' PERGAMMON PRESS (1961)',/,' D T GOLDMAN AND JAMES R ROSSER ' 0008525
     5'CHART OF THE NUCLIDES'' NINTH EDITION · GENERAL ELECTRIC CO (JULY  0008530
     61966)',/,' E D ARNOLD ''PROGRAM SPECTRA'' APPENDIX A OF ORNL-3576  0008535
     7(APRIL 1964)')                                                     0008540
9010 FORMAT('    CROSS SECTIONS AND FLUX SPECTRA',/,' B E PRINCE ''NEUT 0008545
     1RON REACTION RATES IN THE MSRE SPECTRUM'' ORNL-4119, PP 79-83 (JUL 0008550
     2Y 1967)',/,' B E PRINCE ''NEUTRON ENERGY SPECTRA IN MSRE AND MSBR' 0008555
     3' ORNL-4191, PP 50-58 (DEC 1967)',/,' M D GOLDBERG ET AL ''NEUTRON 0008560
     4 CROSS SECTIONS'' BNL-325, SECOND ED, SUPP NO 2 (MAY 1964 - AUG 19 0008565
     566) ALSO EARLIER EDITIONS',/,' H T KERR, UNPUBLISHED ERC COMPILATI 0008570
     6ON (FEB 1968)',/,' M K DRAKE ''A COMPILATION OF RESONANCE INTEGRAL 0008575
     7S'' NUCLEONICS, VOL 24, NO 8, PP 108-111 (AUG 1966)',/,' BNWL STAF 0008580
     8F ''INVESTIGATION OF N-2N CROSS SECTIONS'' BNWC-98, PP 44-98 (JUNE 0008585
     9 1965)')                                                           0008590
9011 FORMAT(18A4,I3)                                                     0008595
9012 FORMAT(1H1,20X,18A4)                                                0008600
9013 FORMAT(' H ALTER AND C E WEBER ''PRODUCTION OF H AND HE IN METALS   0008605
     1DURING REACTOR IRRADIATION'' J NUCL MATLS, VOL 16, PP 68-73 (1965) 0008610
     2',/,' L L BENNETT ''RECOMMENDED FISSION PRODUCT CHAINS FOR USE IN  0008615
     3REACTOR EVALUATION STUDIES'' ORNL-TM-1658 (SEPT 1966)')            0008620
9014 FORMAT('    FISSION PRODUCT YIELDS',/,' M E MEEK AND B F RIDER, '' 0008625
     1SUMMARY OF FISSION PRODUCT YIELDS FOR U-235, U-238, PU-239, AND PU 0008630
     2-241 AT THERMAL, FISSION SPECTRUM AND'/'     14 MEV NEUTRON ENERGI 0008635
     3ES'' APED-5398-A(REV.),(OCT. 1968)'/' S KATCOFF '' FISSION PRODUCT 0008640
     4YIELDS FROM NEUTRON INDUCED FISSION'' NUCLEONICS, VOL 18, NO 11,   0008645
     5(NOV 1960)'/' N D DUDEY '' REVIEW OF LOW-MASS ATOM PRODUCTION IN F 0008650
     6AST REACTORS'' ANL-7434,(APRIL 1968) ')                            0008655
9015 FORMAT(1H0,20X,'LIGHT ELEMENTS, MATERIALS OF CONSTRUCTION, AND ACT 0008660
     1IVATION PRODUCTS  ',/,'0 NUCL    DLAM    FB1   FP    FP1   FT    F 0008665
     2A    SIGTH   FNG1   FNA   FNP   RITH    FINA  FINP   SIGMEV  FN2N1 0008670
     3  FFNA  FFNP   Q    FG')                                           0008675
9016 FORMAT(1H0,20X,'LIGHT ELEMENTS, MATERIALS OF CONSTRUCTION, AND ACT 0008680
     1IVATION PRODUCTS  ',/,'0 NUCL    DLAM    FB1   FP    FP1   FT    F 0008685
     2A    SIGNG   FNG1   SIGN2N   FN2N1   SIGNA   SIGNP     Q    FG ABU 0008690
     3NDANCE')                                                           0008695
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 9017 FORMAT(1H ,A2,I3,A1,1PE9.2,0P5F6.3,1PE9.2,0P3F6.3,1PE9.2,0P2F6.3,  0008700
    11PE9.2,0P4F6.3,0PF5.2)                                              0008705
 9018 FORMAT(1H0,10X,'THERM= 'F10.5,5X,'RES= 'F10.5,5X,'FAST= 'F10.5,    0008710
    1//,1X,'NEUTRON SOURCE= '5(I10,5X),5X,'NLIBE= 'I3)                   0008715
 9019 FORMAT(1H0,36X,'FISSION PRODUCTS',/,'0 NUCL    DLAM    FB1   FP    0008720
    1 FP1   FT     SIGNG ',       ' FNG1    Y23      Y25       Y02      Y 0008725
    228      Y49      Q    FG')                                          0008730
 9020 FORMAT(1H0,36X,'FISSION PRODUCTS',/,'0 NUCL    DLAM    FB1   FP    0008735
    1 FP1   FT     SIGNG   FNG1    Y25     Y28     Y49     Q      FG')   0008740
 9021 FORMAT(1H ,A2,I3,A1,1PE9.2,0P4F6.3, 1PE9.2,0PF6.3,1P5E9.2,         0008745
    10P2F6.3)                                                            0008750
 9022 FORMAT(1H ,A2,I3,A1,1PE9.2,0P4F6.3,1PE9.2,0PF6.3,1P3E9.2,0P2F6.3)  0008755
 9023 FORMAT(1H0,32X, 'ACTINIDES AND THEIR DAUGHTERS',//                 0008760
    1'  NUCL     DLAM    FB1    FP     FP1    FT    FA  FSF E+6  SIGNG     R 0008765
    2ING    FNG1     SIGF     RIF     SIGFF    SIGN2N    SIGN3N   Q  FG') 0008770
 9024 FORMAT(1H0,32X, 'ACTINIDES AND THEIR DAUGHTERS',//                 0008775
    1'  NUCL     DLAM    FB1    FP     FP1    FT    FA    FSF E+6  SIGNG   F 0008780
    2NG21    SIGF    SIGN2N    SIGN3N    Q    FG')                      0008785
 9025 FORMAT(1H ,A2,I3,A1,1PE9.2,0P5F6.3,6PF6.1,1P2E9.2,0PF6.3,1P5E9.2,  0008790
    1       0PF6.3,F5.2)                                                 0008795
 9026 FORMAT(1H ,A2,I3,A1,1PE9.2,0P5F6.3,6PF9.1,1PE9.2,0PF6.3,1P3E9.2,   0008800
    1       0PF7.3,F5.2)                                                 0008805
 9027 FORMAT('0SUM OF YIELDS OF ALL FISSION PRODUCTS =',15X,1P3E9.2)     0008810
 9028 FORMAT(I5,2X,1PE10.3,3X,E10.3,5(2X,E10.3,3X,I5)/(30X,5(2X,E10.3,   0008815
    1     3X,I5)))                                                       0008820
 9029 FORMAT('1NON-ZERO MATRIX ELEMENTS AND THEIR LOCATIONS'/            0008825
    1'  I      DIS(I)       CAP(I)      A(I,J)       J    A(I,J)        0008830
    2J      A(I,J)       J      A(I,J)       J      A(I,J)       J  ')   0008835
 9030 FORMAT(64H0SUM OF YIELDS OF ALL FISSION PRODUCTS                   0008840
    1         ,1P5E9.2)                                                  0008845
 9031 FORMAT(5I10)                                                       0008850
 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
    1,F6.4)                                                              0008860
 9033 FORMAT(1H ,A2,I3,A1,1PE9.2,0P5F6.3,1PE9.2,0PF6.3,1PE9.2,0PF6.3,    0008865
    1       1P2E9.2,0P2F6.3,F7.3)                                        0008870
 9034 FORMAT(I7,F9.3,I1,5F5.3,1PE9.2,0P2F5.3,F7.3,2E6.0)                 0008875
 9035 FORMAT(7X,F9.2,3F5.3,F9.2,2F5.3,F9.2,3F5.3, 5X,I1)                 0008880
 9036 FORMAT(20A4)                                                       0008885
 9037 FORMAT(7X,2F9.2,F5.3,4F9.2,F4.3,F9.2,I1)                           0008890
 9038 FORMAT(7X,2F9.2,F5.3,5F9.2, 4X,I1)                                 0008895
 9039 FORMAT('0  WARNING, MOUT OF RANGE IN NUDATA, =' I5)                0008900
 9040 FORMAT(   7X,F9.2,3F8.6,F4.2,2F3.1,F9.2,3F5.3,5X,I1)               0008905
 9041 FORMAT('0 NON HAS EXCEEDED 2500, EQUAL TO '2I6)                    0008910
      END                                                                0008915
      SUBROUTINE COLECT(TMB,CWASTE,ILITE,ITOT)                           0008920
      COMMON/EQ/XZERO(800), XZH(800),XTEMP(800),XNEW(10,800),            0008925
     1      B(800),D(800)                                                0008930
      DIMENSION CWASTE(800)                                              0008935
      IF(TMB.LT.1) RETURN                                                0008940
      DO 10 I=1,ITOT                                                     0008945
      B(I)=CWASTE(I)                                                     0008950
10    XTEMP(I)=0.0                                                       0008955
      CALL DECAY(1,TMB,ITOT)                                             0008960
      CALL TERM(TMB,1,0,ITOT)                                            0008965
      CALL EQUIL(1,ITOT)                                                 0008970
      DO 20 I=1,ITOT                                                     0008975
20    CWASTE(I)=XNEW(1,I)/TMB                                            0008980
      RETURN                                                             0008985
      END                                                                0008990
      SUBROUTINE STORAG(TMB,CWASTE,ILITE,ITOT)                           0008995
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      COMMON/EQ/XZERO(800), XZH(800),XTEMP(800),XNEW(10,800),                0009000
     1       B(800),D(800)                                                  0009005
      DIMENSION CWASTE(ITOT)                                                0009010
      IF(TMB.LT.1)  RETURN                                                  0009015
      DELT=TMB                                                              0009020
      DO 10 I=1,ITOT                                                        0009025
      B(I)=0.0                                                              0009030
   10 XTEMP(I)=CWASTE(I)                                                    0009035
      CALL DECAY(1,DELT,ITOT)                                               0009040
      CALL TERM(TMB,1,ILITE,ITOT)                                           0009045
      CALL EQUIL(1,ITOT)                                                    0009050
      DO 20 I=1,ITOT                                                        0009055
   20 CWASTE(I)=XNEW(1,I)                                                   0009060
      RETURN                                                                0009065
      END                                                                   0009070
C     PROGRAM BLOCK DATA                                                    0009075
      BLOCK DATA                                                            0009080
      INTEGER*2 ELE(99),STA(2)                                              0009085
      COMMON/LABEL/  ELE,STA                                                0009090
      DATA ELE/' H','HE','LI','BE',' B',' C',' N',' O',' F','NE','NA','M 0009095
     1G','AL','SI',' P',' S','CL','AR',' K','CA','SC','TI',' V','CR','MN 0009100
     2','FE','CO','NI','CU','ZN','GA','GE','AS','SE','BR','KR','RB','SR' 0009105
     3,' Y','ZR','NB','MO','TC','RU','RH','PD','AG','CD','IN','SN','SB', 0009110
     4'TE',' I','XE','CS','BA','LA','CE','PR','ND','PM','SM','EU','GD',' 0009115
     5TB','DY','HO','ER','TM','YB','LU','HF','TA',' W','RE','OS','IR','P 0009120
     6T','AU','HG','TL','PB','BI','PO','AT','RN','FR','RA','AC','TH','PA 0009125
     7',' U','NP','PU','AM','CM','BK','CF','ES'/                          0009130
      DATA STA/'  ','M '/                                                   0009135
      END                                                                   0009140
      SUBROUTINE  HALF(A,I)                                                 0009145
C     SUBROUTINE HALF CONVERTS HALF-LIFE TO DECAY CONSTANT (1/SEC)          0009150
      DIMENSION C(9)                                                        0009155
      DATA C/6.9315E-01,1.1552E-02,1.9254E-04,8.0226E-06,2.1965E-08,0.0,    0009160
     1       2.1965E-11,2.1965E-14,2.1965E-17/                              0009165
      IF(A.GT.0.0)  GO TO 10                                                0009170
      IF(I.EQ.6)  GO TO 20                                                  0009175
      A=9.99                                                                0009180
      RETURN                                                                0009185
   10 A=C(I)/A                                                              0009190
      RETURN                                                                0009195
   20 A=0.0                                                                 0009200
      RETURN                                                                0009205
      END                                                                   0009210
      SUBROUTINE NOAH(NUCLI,NAME)                                           0009215
C     SUBROUTINE NOAH CONVERTS SIX DIGIT IDENTIFIER TO ALPHAMERIC SYMBOL    0009220
      INTEGER*2 NAME(3)                                                     0009225
      INTEGER*2 ELE(99),STA(2)                                              0009230
      COMMON/LABEL/  ELE,STA                                                0009235
      IS=MOD(NUCLI,10)+1                                                    0009240
      NZ  =NUCLI/10000                                                      0009245
      MW=NUCLI/10-NZ  *1000                                                 0009250
      NAME(1)=ELE(NZ)                                                       0009255
      NAME(2)=MW                                                            0009260
      NAME(3)=STA(IS)                                                       0009265
      RETURN                                                                0009270
      END                                                                   0009275
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      C      GALE CODE FOR CALCULATING GASEOUS EFFLUENTS FROM LWRS.  MODIFIED  0000000
      C     AUG. 1978 TO IMPLEMENT APPENDIX I TO 10 CFR PART 50.  REACTOR      0000005
      C     WATER CONCENTRATIONS CALCULATED USING METHODS OF DRAFT STANDARD     0000010
      C     ANS 237 'RADIOACTIVE MATERIALS IN PRINCIPAL FLUID STREAMS OF       0000015
      C     LIGHT WATER COOLED NUCLEAR POWER PLANTS'  DRAFT DATED MAY 20, 1974 0000020
            COMMON MSIG,NSIG                                                   0000025
            DIMENSION NAME(8)                                                  0000030
            DIMENSION DECON(14),DECOH(14)                                      0000035
            DIMENSION EX3(14),EX4(14),EXC(14),EJT(14)                          0000040
            DIMENSION PCBB(19),PAXBB(19),PTBB(19),PRWBB(19)                    0000045
            DIMENSION CBB(14),AXBB(14),TBB(14),RADBB(14)                       0000050
            DIMENSION PCBL(19),PTBL(19),PAXBL(19),PRWBL(19),PTOTB(19)          0000055
            DIMENSION WURD(4),WORD(14)                                         0000060
            DIMENSION PVPL(19),VPR(14),PVPR(19)                                0000065
            DIMENSION XB(14),X1(14)                                            0000070
            DIMENSION CBL(14),AXBL(14),TBL(14),RADBL(14),SGL(14)               0000075
            DIMENSION TOT(14)                                                  0000080
            DIMENSION EJTI(2),EXCI(2)                                          0000085
            DIMENSION TOTI(2),VPRI(2)                                          0000090
            DIMENSION RNR(2),RNRS(2),RBWRR(2),RBWRRS(2),RADBLI(2)              0000095
            DIMENSION RNT(2),RNTS(2),RBWRT(2),RBWRTS(2),TBLI(2)                0000100
            DIMENSION DECONI(2),DECOHI(2)                                      0000105
            DIMENSION EX3I(2),EX4I(2),CBWR1(2)                                 0000110
            DIMENSION RBWR(2),RN(2),CBWR(2),RBWRS(2),RNS(2)                    0000115
            DIMENSION AUXMK1(2),AUXBLN(2),CBLN(2),AUXM1S(2),CBLS(2),AUXBLS(2)  0000120
            DIMENSION CBLI(2),AUXLI(2),SGLI(2)                                 0000125
            DIMENSION WARD(5)                                                  0000130
            DIMENSION RNMVP(2),RNMVPS(2)                                       0000135
            DIMENSION RMVP(2),RMVPS(2)                                         0000140
            REAL KKR,KXE,KNO,KMASS,KAR                                         0000145
            REAL*8 NUCLID(14)/'  AR-41 ',' KR-83M ',' KR-85M ',' KR-85 ',' K   0000150
           1R-87 ',' KR-88 ',' KR-89 ',' XE-131M',' XE-133M',' XE-133 ',' XE   0000155
           2-135M',' XE-135 ',' XE-137 ',' XE-138 '/                           0000160
            REAL*8 BPART(19)/'  CR-51 ',' MN-54 ',' CO-58 ',' FE-59 ',' CO     0000165
           1-60 ',' ZN-65 ',' SR-89 ',' SR-90 ',' NB-95 ',' ZR-95 ',' MO      0000170
           2-99 ',' RU-103 ',' AG-110M',' SB-124 ',' CS-134 ',' CS-136 ',' CS- 0000175
           3137 ',' BA-140 ',' CE-141 '/                                       0000180
            REAL*8 HAL(2)/'  I-131 ',' I-133 '/                                0000185
            DATA PCBB/.2,.4,.1,.09,1.,1.,.03,.003,1.,.3,6.,.2,.0004,.02,.7,.1, 0000190
           11.,2.,.2/                                                          0000195
            DATA PAXBB/.9,1.,.2,.3,4.,4.,.02,.007,9.,.7,60.,4.,.002,.03,4.,.4, 0000200
           15,20.,.7/                                                          0000205
            DATA PTBB/.9,.6,1.,.1,1.,6.,6.,.02,.006,.04,2.,.05,0.,.1,.2,.1,1., 0000210
           110.,10./                                                           0000215
            DATA PRWBB/.7,4.,.2,.3,7.,.3,0.,0.,.004,.8,.003,.001,0.,.07,2.4,0. 0000220
           1,4.,.004,.007/                                                     0000225
            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
            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
           1/                                                                  0000240
            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
           200.0,1000.0/                                                       0000250
            DATA RADBB/6*0.0,29.0,2*0.0,220.0,530.0,280.0,83.0,2.0/            0000255
            DATA PVPR/.001,3*0.,.00056,.00034,8*0.,.0032,.0019,.0089,.011,1*0. 0000260
           1/                                                                  0000265
            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
           15E-5,2.1E-3,7.0E-3,6.0E-3,3.9E-2,2.3E-2/                           0000275
            DATA DECON/1.052E-04,1.035E-04,4.375E-05,2.040E-09,1.520E-04,6.880 0000280
           1E-05,3.632E-03,6.800E-07,3.548E-06,1.520E-06,7.357E-04,2.090E-05,3 0000285
           2.024E-03,6.800E-04/                                                0000290
            DATA VPR/9*0.0,1300.0,0.0,500.0,2*0.0/                             0000295
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      C                                                                         0000300
      C  DECONI DEFINES THE DECAY CONSTANT FOR IODINES                          0000305
      C                                                                         0000310
           DATA DECONI/9.970E-07,9.170E-06/                                     0000315
      C                                                                         0000320
      C  CBWR DEFINES THE REACTOR WATER CONCENTRATIONS FOR IODINES              0000325
      C                                                                         0000330
           DATA CBWR/3.7E-3,5.0E-2/                                             0000335
      C                                                                         0000340
      C  RN DEFINES THE NORMALIZED ANNUAL RELEASES DURING POWER OPERATIONS FOR  0000345
      C  THE REACTOR BLDG.                                                      0000350
      C                                                                         0000355
      C                                                                         0000360
           DATA RN/12.3,12.3/                                                   0000365
      C                                                                         0000370
      C   RNS DEFINES THE NORMALIZED ANNUAL RELEASES DURING SHUTDOWNS FOR THE  0000375
      C   REACTOR BLDG.                                                        0000380
      C                                                                         0000385
           DATA RNS/5.2,5.2/                                                    0000390
      C                                                                         0000395
      C  RNT DEFINES THE NORMALIZED ANNUAL RELEASES DURING POWER OPERATION FOR 0000400
      C   THE TURBINE BLDG.                                                    0000405
      C                                                                         0000410
           DATA RNT/3.8E3,3.8E3/                                                0000415
      C                                                                         0000420
      C   RNTS DEFINES THE NORMALIZED ANNUAL RELEASES DURING SHUTDOWNS FOR     0000425
      C   THE TURBINE BLDG.                                                    0000430
      C                                                                         0000435
           DATA RNTS/4.1E2,4.1E2/                                               0000440
      C                                                                         0000445
      C  RNR DEFINES THE NORMALIZED RELEASES FROM THE RADWASTE BLDG. DURING     0000450
      C   POWER OPERATIONS                                                     0000455
      C                                                                         0000460
           DATA RNR/4.6,4.6/                                                    0000465
      C                                                                         0000470
      C    RNRS DEFINES THE NORMALIZED RELEASES FROM THE RADWASTE BLDG.         0000475
      C    DURING SHUTDOWNS                                                    0000480
      C                                                                         0000485
           DATA RNRS/1.4,1.4/                                                   0000490
      C                                                                         0000495
      C    RNMVP DEFINES NORMALIZED RELEASES FROM THE MECHANICAL VACUUM PUMP    0000500
            DATA RNMVP/4.9E2,4.9E2/                                             0000505
            DATA RNMVPS/1.1E3,1.1E3/                                            0000510
         49 FORMAT(16X,'REACTOR VESSEL HALOGEN CARRYOVER FACTOR',15X,F10.5)     0000515
         51 FORMAT(16X,'PLANT CAPACITY FACTOR',T74,'0.80')                      0000520
         52 FORMAT(32X,8A4,12X,A4)                                              0000525
         53 FORMAT(16X,13A4,A2,F10.5)                                           0000530
         55 FORMAT(15X,4A4,A2,8X,F8.0,7X,F5.3)                                  0000535
         56 FORMAT(20X,F8.0,2(5X,F8.0))                                         0000540
         57 FORMAT(27X,F6.2,14X,F6.2,18X,F6.2)                                  0000545
         58 FORMAT    (30X,'FRACTION  FRACTION  COLLECTION  DECAY'/8X,'STREAM   0000550
           1     FLOW RATE   OF PCA DISCHARGED    TIME     TIME',5X,' DECONTAM 0000555
           2INATION  FACTORS'/20X,'(GAL/DAY)',23X,'(DAYS)   (DAYS)',7X,        0000560
           3'I',8X,'CS',8X,'OTHERS')                                            0000565
         59 FORMAT(2X,4A4,A2,1PE9.2,1X,4(0PF8.3,2X),3(1PE9.2,1X))               0000570
         60 FORMAT(79X,I1)                                                      0000575
         61 FORMAT(16X,'THERE IS A CRYOGENIC DISTILLATION COLUMN'/20X,'IODINE   0000580
           1AND XENON DECONTAMINATION FACTOR',T70,'10000.'/20X,'KRYPTON DECONT  0000585
           2AMINATION FACTOR',T71,'4000.'/20X,'KRYPTON AND  XENON HOLDUP TIME   0000590
           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)                                                                  0000330
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.      C                                                                    0000970
196.      C     READ DATA FOR BWR LIQUID CODE                                  0000975
197.      C                                                                    0000980
198.            WRITE(6,904)                                                   0000985
199.            READ(1,55)WARD,CWFLR,CWA                                       0000990
200.            READ(1,56)DFICW,DFCSCW,DFCW                                    0000995
201.            READ(1,57)TC,TSTORC,CWFD                                       0001000
202.            WRITE(6,58)                                                    0001005
203.            WRITE(6,59)WARD,CWFLR,CWA,CWFD,TC,TSTORC,DFICW,DFCSCW,DFCW     0001010
204.            READ(1,55)WARD,DWFLR,DWA                                       0001015
205.            READ(1,56)DFIDW,DFCSDW,DFDW                                    0001020
206.            READ(1,57)TD,TSTORD,DWFD                                       0001025
207.            WRITE(6,59)WARD,DWFLR,DWA,DWFD,TD,TSTORD,DFIDW,DFCSDW,DFDW     0001030
208.            READ(1,55)WARD,CMWFR,CMA                                       0001035
209.            READ(1,56)DFICM,DFCSCM,DFCM                                    0001040
210.            READ(1,57)TCM,TSTORB,CMFD                                      0001045
211.            WRITE(6,59)WARD,CMWFR,CMA,CMFD,TCM,TSTORB,DFICM,DFCSCM,DFCM    0001050
212.            READ(1,68)RGWFR                                                0001055
213.            READ(1,56)DFIRG,DFCSRG,DFRG                                    0001060
214.            READ(1,57)TRG,TSTORR,RGFD                                      0001065
215.            WRITE(6,71)RGWFR,RGFD,TRG,TSTORR,DFIRG,DFCSRG,DFRG             0001070
216.      C                                                                    0001075
217.      C     READ DATA FOR BWR GAS CODE                                     0001080
218.      C                                                                    0001085
219.            WRITE(6,905)                                                   0001090
220.            READ(1,53)WORD,GGS                                             0001095
221.            WRITE(6,53)WORD,GGS                                            0001100
222.            READ(1,53)WORD,TIM3                                            0001105
223.            WRITE(6,53)WORD,TIM3                                           0001110
224.            READ(1,53)WORD,TIM4                                            0001115
225.            WRITE(6,53)WORD,TIM4                                           0001120
226.            HEPA1=1.0                                                      0001125
227.            FIL1=1.0                                                       0001130
228.            HEPA2=1.0                                                      0001135
229.            FIL2=1.0                                                       0001140
230.            HEPA5=1.0                                                      0001145
231.            FIL5=1.0                                                       0001150
232.            HEPA6=1.0                                                      0001155
233.            FIL6=1.0                                                       0001160
234.            FILGS = 1.0                                                    0001165
235.            FILEJ = 1.0                                                    0001170
236.            READ(1,925)WURD,CBCH,CBHEPA                                    0001175
237.            IF(CBCH.GT.0.0)FIL1 = (1.0 - CBCH/100.)                        0001180
238.            IF(CBHEPA.GT.0.0)HEPA1 = (1.0 - CBHEPA/100.)                   0001185
239.            WRITE(6,926)WURD,FIL1,HEPA1                                    0001190
240.            READ(1,927)WURD,TBCH,TBHEPA                                    0001195
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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     CONVERSION OF UNITS                                              0001425
287.      C                                                                      0001430
288.            GTO=GTO*1000000.                                                 0001435
289.            GDE=GDE*1000000.                                                 0001440
290.            GGS=GGS*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))/( 0001580
318.           1RHAL2 + DECOHI(I)))                                             0001585
319.      C                                                                     0001590
320.      C  CALCULATION OF IODINE RELEASES FROM RX. BLDG. DURING NORMAL OPERATIONS0001595
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.            RNVPS(I) = RNMVPS(I) * CBWR(I) * PC                             0001795
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      899 RMVPS(2) = RNMVP(I) * CBWR(I) * PC                                    0001800
          VPRI(I) = RMVP(I) + RMVPS(I)                                          0001805
          TEST = 0.0001                                                         0001810
          IF(SGLI(I).LE.TEST) SGLI(I) = 0.0                                     0001815
          IF(EJTI(I).LE.TEST) EJTI(I) = 0.0                                     0001820
       88 CONTINUE                                                              0001825
          MSIG = 1                                                              0001830
          NSIG = 2                                                              0001835
          CALL SIGF2(SGLI)                                                      0001840
          CALL SIGF2(EJTI)                                                      0001845
          DO 89 I = 1,2                                                         0001850
          TOTI(I) = AUXLI(I)+TBLI(I)+SGLI(I)+EJTI(I)+CBLI(I)+RADBLI(I)+VPRI(    0001855
         1I)                                                                    0001860
       89 CONTINUE                                                              0001865
          WRITE(6,906)                                                          0001870
          WRITE(6,903) NAME                                                     0001875
          WRITE(6,214)                                                          0001880
          WRITE(6,235)                                                          0001885
          WRITE(6,214)                                                          0001890
          DO 79 I = 1,2                                                         0001895
          WRITE(6,230) HAL(I),CBWR(I),CBLI(I),TBLI(I),AUXLI(I),RADBLI(I),SGL    0001900
         1I(I),EJTI(I),VPRI(I),TOTI(I)                                          0001905
          CBWR(I) = CBWR1(I)                                                    0001910
       79 CONTINUE                                                              0001915
          WRITE(6,214)                                                          0001920
C                                                                               0001925
C CALCULATION OF TRITIUM RELEASES                                               0001930
C                                                                               0001935
          TRITRP = 0.03 * POWTH                                                 0001940
          GASH3 = TRITRP * 0.5                                                  0001945
          TBH3 = GASH3 * 0.5                                                    0001950
          CBH3 = GASH3 - TBH3                                                   0001955
          TH3 = TBH3 + CBH3                                                     0001960
          DIV = 10.**(INT(ALOG10(TBH3))-1)                                      0001965
          TBH = INT(TBH3/DIV+0.5)*DIV                                           0001970
          DIV = 10.**(INT(ALOG10(CBH3))-1)                                      0001975
          CBH = INT(CBH3/DIV+0.5)*DIV                                           0001980
          DIV = 10.**(INT(ALOG10(TH3))-1)                                       0001985
          TH = INT(TH3/DIV+1.0)*DIV                                             0001990
          WRITE(6,960) TBH                                                      0001995
          WRITE(6,962) CBH                                                      0002000
          WRITE(6,964) TH                                                       0002005
          WRITE(6,963)                                                          0002010
C                                                                               0002015
C   CALCULATION OF NOBLE GAS RELEASES                                           0002020
C                                                                               0002025
          WRITE(6,906)                                                          0002030
          WRITE(6,903) NAME                                                     0002035
          WRITE(6,214)                                                          0002040
          WRITE(6,235)                                                          0002045
          WRITE(6,214)                                                          0002050
          DO 5 I = 1,14                                                         0002055
          DECOH(I)=DECON(I)*3600.                                               0002060
          EX3(I)=DECOH(I)*TIM3                                                  0002065
          IF(EX3(I).GT.75.)EX3(I)=75.                                           0002070
          EX4(I)=DECOH(I)*TIM4                                                  0002075
          IF(EX4(I).GT.75.)EX4(I)=75.                                           0002080
          X1(I)=XB(I)                                                           0002085
          CBL(I)=CBB(I)                                                         0002090
          AXBL(I)=AXBB(I)                                                       0002095
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421.            TBL(I)=TBB(I)                                                          0002100
422.            RADBL(I)=RADBB(I)                                                      0002105
423.            SGL(I)=GGS*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)=GTO*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)=AXBL(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),AXBL(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=AINT(GASTOT/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 ft^3).

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 ft^3) 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

Demineralizer Service	Regeneration Frequency
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 $CaCo_3$ ion exchange capacity per ft^3 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 ft^3. 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 - 10^3
Cs, Rb - 10^4
Others - 10^4

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

I - 10^2
Cs, Rb - 2_2
Others - 10^2

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 - 10^3
Cs, Rb - $2_4 \times 10^4$
Others - 10^4

Card 10

Spaces 29-32 "Collection Time." Using the value from Table A-1 of 25,000 gal/ft^3, the regeneration frequency would be:

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

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 souce 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.

NRC FORM 335 (7-77) U.S. NUCLEAR REGULATORY COMMISSION

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7. AUTHOR(S): Frank P. Cardile and others

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16. ABSTRACT *(200 words or less)*

In April of 1976, the NRC published NUREG-0016. That document presented methods for calculation of releases from BWRs based on operating data available at that time. In promulgating Appendix I to 10 CFR Part 50, the Commission indicated its desire to use the best available data for improving the calculational models. Therefore, at this time, we are updating NUREG-0016 by issuing Revision 1 which incorporates more recent operating data now available and also incorporates the results of a number of in-plant measurement programs at operating BWRs.

NUREG-0016, Revision 1, is similar to NUREG-0016 in that it provides instructions for using the BWR-GALE Code. It describes the parameters incorporated in the Code, the input data required, and a step-by-step procedure for completing the input data cards. It provides parameters for an assessment of reactor and radwaste system performance for normal operation including anticipated operational occurrences, and the bases for selecting the parameters. It also contains a Fortran IV listing of the BWR-GALE Code, a form for entering the input data, and a sample calculation.

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