NUREG-0016

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

April 1976

UNITED STATES NUCLEAR REGULATORY COMMISSION

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CHAPTER 1. BWR-GALE CODE

1.1 INTRODUCTION

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 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 primary and secondary 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, and (3) plant-specific design features used to reduce the quantities of radioactive materials ultimately released to the environs.

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 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 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. Alternative treatment methods include holdup lines, long-term holdup systems using charcoal delay systems, and cryogenic distillation.

Another potential release point of radioactive material is the exhaust from the turbine gland sealing system. 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 iodine 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 gland seal as an 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 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.

In addition to the above release points, the BWR-GALE Code, the calculational model used for BWR source term calculations, considers releases from the turbine, containment, auxiliary, 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.

Chemical Waste Stream: Normally 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.

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: Processed 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: Processed 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 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.

Partition Factor (PF): The ratio of the quantity of a nuclide in the gas phase to the total quantity in both the liquid and gas phases 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 isotopes of fluorine, chlorine, bromine, and iodine. The radioactive isotopes of iodine are the key 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 key elements considered in dose calculations.

Radioactive Release Rate: The average quantity of radioactive material released to the environment from a nuclear power reactor during normal operation including anticipated operational occurrences.

Reactor Coolant (Primary Coolant): The fluid circulated through the reactor to remove heat. In a BWR, the fluid 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 proposed in the ANS 18.1 (Ref. 1) Working Group draft standard for BWRs. Provisions are made in the BWR-GALE Code, in accordance with the recommendations of the draft standard, for adjusting reactor coolant concentrations should the plant be designed to parameters that are outside the ranges considered in the standard. The radionuclide concentrations used are representative of measured values based on the available 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. 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 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.

Tramp Uranium: The uranium present on the cladding of a fuel rod.

1.3 GASEOUS SOURCE TERMS

The following sources are considered in calculating the release of radioactive materials (noble gases, radioactive particulates, 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.

The releases of radioactive materials in ventilation exhaust air from buildings not covered in 4. above are calculated to be negligible when compared to the gaseous source term from the sources listed above and are therefore not considered individually in the source term calculations.

Calculations show that approximately 9.5 Ci/yr of carbon-14 will be released from a BWR. All carbon-14 releases are assumed to be in the form of a vapor from the main condenser evacuation system vent.

Argon-41 is formed in the drywell by neutron activation of stable, naturally occurring argon-40 in the drywell air. The argon-41 is released to the environment when the drywell is vented or purged. Based on releases reported by licensees in semiannual reports, it is expected that, independent of power level, approximately 25 Ci/yr of argon-41 will be released to the environment.

The releases of radioactive materials in gaseous effluents are based on measurements made at operating BWRs. The radioiodine, 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.

The BWR-GALE Code also calculates tritium releases through the ventilation exhaust systems. The annual quantity of tritium available for release is calculated using a functional relationship derived from measured liquid and vapor tritium releases at operating BWRs and considering the integrated thermal power output during the calendar year in which the releases occurred. This relationship expresses total tritium as a function of power output. The tritium releases through the ventilation exhaust systems are assumed to be the total tritium available for release minus the tritium calculated to be released through the liquid pathway. Except for tritium, the radioactivity released in ventilation air is considered to be independent of the power level. Releases from the mechanical vacuum pump are also considered to be independent of the power level.

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 the ANS 18.1 Working Group (Ref. 1), which considers a noble gas release rate of 60,000 μCi/sec after a 30-minute decay.

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 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, Iodine, and Particulate Releases From Building Ventilation Systems Prior to Treatment

See Table 1-1.

1.5.1.4 Radioiodine Input Rate to Main Condenser Offgas System

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

1.5.1.5 Main Condenser Vacuum Pump Release

Xe-133 -- 2300 Ci/yr

Xe-135 -- 350 Ci/yr

I-131 -- 0.03 Ci/yr

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 are entered on Cards 31-35.

$$T = 0.262 \frac{MK}{10\ N}$$

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

NUCLIDE	CONTAINMENT BUILDING	AUXILIARY BUILDING	TURBINE* BUILDING	RADWASTE BUILDING
Kr-83m	**	**	**	**
Kr-85m	3	3	68	**
Kr-85	**	**	**	**
Kr-87	3	3	190	**
Kr-88	3	3	230	**
Kr-89	**	**	**	**
Xe-131m	**	**	**	**
Xe-133m	**	**	**	**
Xe-133	66	66	280	10
Xe-135m	46	46	650	**
Xe-135	34	34	630	45
Xe-137	**	**	**	**
Xe-138	7	7	1440	**
I-131	0.17	0.17	0.19	0.046
I-133	0.68	0.68	0.76	0.18
Co-60	0.01	0.01	0.002	0.09
Co-58	0.0006	0.0006	0.0006	0.0045
Cr-51	0.0003	0.0003	0.013	0.009
Mn-54	0.003	0.003	0.0006	0.036
Fe-59	0.0004	0.0004	0.0005	0.015
Zn-65	0.002	0.002	0.0002	0.001
Zr-95	0.0004	0.0004	0.0001	0.00005
Sr-89	0.00009	0.00009	0.006	0.0005
Sr-90	0.000005	0.000005	0.00002	0.0003
Sb-124	0.0002	0.0002	0.0003	0.00005
Cs-134	0.004	0.004	0.0003	0.0045
Cs-136	0.0003	0.0003	0.00005	0.00045
Cs-137	0.005	0.005	0.0006	0.009
Ba-140	0.0004	0.0004	0.011	0.0001
Ce-141	0.0001	0.0001	0.0006	0.0026

*For special design feature to control leakage from valves in lines 2-1/2 inches and larger, reduce the turbine building leakage rates by a factor of five.

**Less than 1 Ci/yr per reactor for noble gases.

where

K is the dynamic adsorption coefficient, in cm^3/g,

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

T is the holdup time, in hr, and

10 N is the number of condenser shells times 10, in ft^3/min per shell.

1.5.1.7 Cryogenic Distillation System

For a cryogenic distillation system, the BWR-GALE Code uses a partition factor (PF) of 0.0001 for Xe and I and a PF of 0.00025 for Kr to calculate Xe, I, and Kr losses 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 total of the noble gases and iodine 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	Halogens	Cs, Rb	Other Nuclides
Deep bed	10	2	10
Powdex	10	2	10

Note: For a system using filter/demineralizers (Powdex), a zero is entered for regeneration frequency on Card 6, as explained later in Section 1.5.2.6.

1.5.1.9 Detergent Wastes

The radionuclides listed in Table 2-32 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 0.025 Ci/yr per MWt. The quantity of tritium released through the liquid pathway is the calculated annual volumetric liquid release times 0.01 μCi/ml of tritium in liquid waste. The difference between the total release and liquid release is the amount considered to be released through the plant ventilation exhaust systems.

1.5.1.11 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 flow to the demineralizer is based on the radioactivity of the main steam.

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.

3. The radioactivity in the regenerant wastes is adjusted for radionuclide decay on the resins during demineralizer operation.

1.5.1.12 Adjustment to Liquid Radwaste Source Terms for Anticipated Operational Occurrences

1. The calculated source term is increased by 0.15 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.

Note: Adjust all power-dependent parameters to this power level.

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 lb/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 (in 10^6 lb).

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

Enter in spaces 73-80 the primary coolant flow rate (in 10^6 lb/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 a 7-day regeneration frequency. Multiply the frequency by the number of demineralizers and enter the calculated number of days in spaces 73-80. For filter/demineralizers (Powdex), enter zeros 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 Card 8: Dilution Flow (SAR/ER)

Enter in spaces 73-80 the annual average flow rate of water (10^3 gal/min) used to dilute liquid waste discharged to the environment.

1.5.2.9 Cards 9-20: Liquid Radwaste Treatment System Input Parameters

Four liquid radwaste inlet streams are considered in the BWR-GALE Code:

1. High-Purity Waste, Cards 9-11

2. Low-Purity Waste, Cards 12-14

3. Chemical Waste, Cards 15-17

4. Regenerant Solutions Waste, Cards 18-20

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 18 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 (9, 12, and 15) for the High-Purity, Low-Purity, and Chemical Waste Systems, respectively, are outlined below and described in more detail in Section 1.5.2.9.1.

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 Regenerate Solutions Waste System (i.e., Card 18), enter in spaces 73-80 the flow rate of the regenerant solutions waste inlet stream.

The second card (10, 13, 16, and 19) 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 iodine.

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 (11, 14, 17, and 20) 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 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 9-20 listed above.

1.5.2.9.1 Liquid Waste Flow Rates and Activities (Cards 9, 12, 15, and 18)

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 1-2. To the input flow rates 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 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 0.01PCA

Stream B 2,000 gal/day at 0.1PCA

Stream C 500 gal/day at 1.0PCA

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

TABLE 1-2
BWR LIQUID WASTES

SOURCE	EXPECTED DAILY AVERAGE INPUT FLOW RATE (in gal/day) PLANT WITH ULTRASONIC RESIN CLEANER	PLANT WITHOUT ULTRASONIC RESIN CLEANER	FRACTION OF THE PRIMARY COOLANT ACTIVITY (PCA)
Equipment Drains			
Drywell	3,400	3,400	1.00
Containment, auxiliary building, and fuel pool	3,720	3,720	0.01
Radwaste building	1,060	1,060	0.01
Turbine building	2,960	2,960	0.01
Ultrasonic resin cleaner	15,000	-	0.05
Resin rinse	2,500	5,000	0.002
Subtotal	28,640	16,140	-
Floor Drains			
Drywell	700	700	1.00
Containment, auxiliary building, and fuel pool	2,000	2,000	0.01
Radwaste building	1,000	1,000	0.01
Turbine building	2,000	2,000	0.01
Subtotal	5,700	5,700	-
Cleanup phase separator decant	640	640	0.002
Laundry drains	450	450	*
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
Total	37,730	26,930	

*Listed in BWR-GALE Code; see Table 2-32.

**Deep-bed condensate demineralizers.

***Calculated by BWR-GALE Code.

†Filter/demineralizer (Powdex) condensate demineralizers.

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

1.5.2.9.2 Decontamination Factors for Equipment Used in the Liquid Radwaste Treatment System (Cards 10, 13, 16, and 19)

The 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, including downtime. 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. Halogens

   b. Cs, Rb

   c. Other nuclides

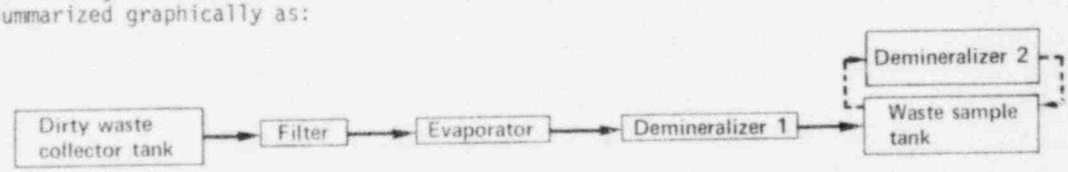
Note: A DF of 1 is assumed by the BWR-GALE Code for tritium. Noble gases and water activation products are not considered in the liquid code.

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 1-3 shows the decontamination factors to be used for BWR 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 graphically as:



Extracting from Table 1-3 gives the following values for the example:

	Filter	Evaporator	Demineralizer 1	Demineralizer 2	Product
Halogens	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 halogens and 10^4 for Cs, Rb, and other nuclides was applied for the radwaste evaporator.
- A DF of 10 was applied for halogens, Cs, Rb, and other nuclides and 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 1-3
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			
Mixed bed	10^2(10)	2(10)	10^2(10)
Cation bed	1(1)	10(10)	10^2(10)
Anion bed	10^2(10)	1(1)	1(1)
Powdex (any system)	10(10)	2(10)	10(10)
Evaporators	All Nuclides Except Iodine		Iodine
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 10 the following would be entered: in spaces 21-28, "10,000"; in spaces 34-41, "100,000"; and in spaces 47-54, "100,000."

1.5.2.9.3 Collection Time for Liquid Wastes (Cards 11, 14, 17, 20 -- Spaces 29-33)

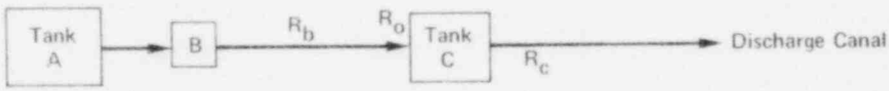
Collection time prior to processing is based on the input flow calculated above. Where redundant tanks are provided, assume the collection tank to be filled to 80% capacity. If only one tank is provided, assume the tank to be filled to 40% capacity. For example, if flow from a 1,000-gal/day floor drain 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 14.

1.5.2.9.4 Processing and Discharge Time (Cards 11, 14, 17, 20 -- Spaces 48-53)

Decay during processing and discharge of liquid wastes is shown graphically 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:

$$T_p = \frac{0.8A}{R_b}$$

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

$$T_d = \frac{0.8C}{R_c}$$

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

$$0.8C > T_p R_b + R_o$$

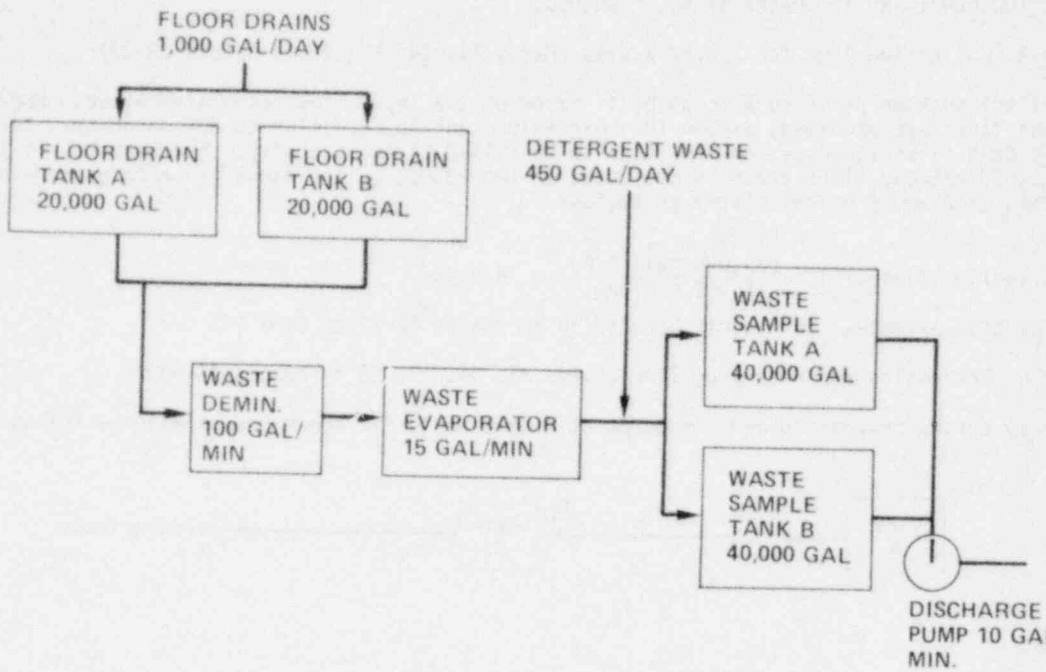
If so, then

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

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 11, 14, 17, and 20).

If, however, $0.8 \leq Tp(Rb + Ro)$, 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:

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

$$\text{Discharge Time } (T_d) = \frac{(0.8)(40{,}000 \text{ gal})}{(10 \text{ gal/min})(1440 \text{ min/day})} = 3 \text{ days}$$

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 2.2 days for processing and discharge. The input on spaces 48-53 to the Code is 2.2 days for processing and discharge time.

1.5.2.9.5 Fraction of Wastes Discharged (Cards 11, 14, 17, and 20 -- 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.

1.5.2.10 Card 21: Gland Seal Steam Flow

Enter in spaces 73-80 of Card 21 the steam flow (in 10^3 lb/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 a zero in spaces 73-80.

1.5.2.11 Card 22: Mass of Steam in Reactor Vessel (SAR/ER)

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

1.5.2.12 Card 23: Gland Seal Holdup Time (SAR/ER)

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

1.5.2.13 Card 24: 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 to be processed through the offgas treatment system, e.g., a 10-minute holdup time prior to cryogenic distillation.

1.5.2.14 Card 25: Containment Building Releases

1. If ventilation exhaust air is treated through charcoal adsorbers, enter YES in spaces 43-45. If no treatment is provided, leave spaces 43-45 blank.

2. If ventilation exhaust air is treated through HEPA filters, enter YES in spaces 52-54. If no treatment is provided, leave spaces 52-54 blank.

1.5.2.15 Card 26: Turbine Building Releases

1. If ventilation exhaust air is treated through charcoal adsorbers, enter YES in spaces 43-45. If no treatment is provided, leave spaces 43-45 blank.

2. If ventilation exhaust air is treated through HEPA filters, enter YES in spaces 52-54. If no treatment is provided, leave these spaces blank.

3. If "clean steam" or other acceptable special design features are provided on valves 2-1/2 inches and larger to reduce steam leakage, enter YES in spaces 68-70. If the above features are not provided, leave spaces 68-70 blank.

1.5.2.16 Card 27: Fraction of Iodine Released from Turbine Gland Seal Condenser Vent

1. Enter 1.0 in spaces 73-80 if the noncondensables are released from the turbine gland seal condenser without treatment or if clean steam is used.

2. Enter 0.1 in spaces 73-80 if, prior to release, the noncondensables are processed through charcoal adsorbers having a 90% efficiency.

1.5.2.17 Card 28: Fraction of Iodine Released from the Condenser Air Ejector Offgas Treatment System

1. Enter 1.0 in spaces 73-80 if the offgas is released without treatment.

2. Enter 0.1 in spaces 73-80 if, prior to release, the offgas is processed through a charcoal adsorber having a 90% efficiency.

3. Enter a zero in spaces 73-80 if the offgas is processed through a charcoal delay system.

4. Enter 1.0 in spaces 73-80 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 30).

1.5.2.18 Card 29: Auxiliary Building Releases

1. If ventilation exhaust air is treated through charcoal adsorbers, enter YES in spaces 43-45. If no treatment is provided, leave blank.

2. If ventilation effluent is treated through HEPA filters, enter YES in spaces 52-54. If no treatment is provided, leave blank.

1.5.2.19 Card 30: Radwaste Building Releases

1. If ventilation exhaust air is treated through charcoal adsorbers, enter YES in spaces 43-45. If no treatment is provided, leave blank.

2. If ventilation exhaust air is treated through HEPA filters, enter YES in spaces 52-54. If no treatment is provided, leave blank.

1.5.2.20 Card 31: Condenser Air Ejector Offgas Treatment System (SAR/ER)

1. Enter 1 in space 80 if 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 the cryogenic distillation.

3. Enter a zero in space 80 if the offgas is not treated either through a charcoal delay system or by cryogenic distillation.

Note: Cards 31, 32, 33, and 34 are left blank if a charcoal delay system is not used to treat the offgases from the condenser air ejector. The blank cards are included in the card deck.

1.5.2.21 Card 32: 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/g)

	OPERATING 77°F DEW POINT 45°F	OPERATING 77°F DEW POINT 0°F	OPERATING 0°F DEW POINT -20°F
Kr	18.5	25	105

1.5.2.22 Card 33: 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/g)

	OPERATING 77°F DEW POINT 45°F	OPERATING 77°F DEW POINT 0°F	OPERATING 0°F DEW POINT -20°F
Xe	330	440	2410

1.5.2.23 Card 34: Number of Main Condenser Shells (SAR/ER)

Enter in spaces 73-80 the number of shells in the main condenser.

1.5.2.24 Card 35: Mass of Charcoal in Charcoal Delay System (SAR/ER)

Enter in spaces 73-80 the mass of charcoal (in 10^3 lb) used in the charcoal delay system.

1.5.2.25 Card 36: Detergent Waste

1. If the plant does not have an onsite laundry, enter a zero 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 fraction of radionuclides remaining after treatment (1/DF) 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 source term is defined as the calculated average quantity of radioactive material released annually to the environment from a nuclear power reactor during normal operation, including anticipated operational occurrences. The parameters used in the calculations are the average values expected over the life of the plant. Normal operation includes anticipated operational occurrences that deviate from steady-state operation.

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 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

Plant capacity factor of 80%, 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 1961 through 1974.

The average plant capacity factors listed indicate that the 80% factor assumed is higher than the average factors experienced. However, it is expected that the maintenance and refueling problems that have contributed to the low capacity factors will be overcome.

2.2.3 RADIONUCLIDE CONCENTRATIONS IN THE REACTOR COOLANT

2.2.3.1 Parameter

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, adjust the concentrations in Table 2-2, using 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*

(in %)

FACILITY	INITIAL CRITICALITY	1968	1969	1970	1971	1972	1973	1974
Dresden 1	10/15/59	52	48	78	35	61	40	21
Big Rock Point	9/27/62	68	64	58	59	57	67	54
Humboldt Bay	2/16/63	82	68	76	61	59	70	61
Oyster Creek	5/3/69			74	78	77	64	66
Nine Mile Point 1	9/5/69				63	62	68	63
Dresden 2	1/7/70				39	47	74	51
Millstone 1	10/26/70				63	55	34	63
Monticello	12/10/70					74	68	57
Dresden 3	1/31/71					67	54	47
Quad Cities 1	10/18/71						70	51
Vermont Yankee	3/24/72						44	59
Quad Cities 2	4/26/72						74	68
Pilgrim 1	6/16/72						72	34
Average		67	60	72	57	62	61	53

*From "U.S. Nuclear Power Reactors," Atomic Energy Commission, WASH-1203-68 to 73, Table 1, "Selected Operating Statistics." Plant capacity factors listed are for the calendar year(s) following a period of at least six months since initial criticality. Operating BWRs not included in the table are Browns Ferry 1 and Peach Bottom 2, which achieved criticality during CY-1973. The LaCrosse Nuclear Power Station was not included since it is not considered to be representative of current power reactors.

TABLE 2-2
RADIONUCLIDE CONCENTRATIONS
IN BOILING WATER REACTOR COOLANT AND MAIN STEAM*
(in μCi/g)

ISOTOPE	REACTOR WATER	REACTOR STEAM
Noble Gases		
Kr-83m		1.1(-3)**
Kr-85m		1.9(-3)
Kr-85		6.0(-6)
Kr-87		6.6(-3)
Kr-88		6.6(-3)
Kr-89		4.1(-2)
Kr-90		9.0(-2)
Kr-91		1.1(-1)
Kr-92		1.1(-1)
Kr-93		2.9(-2)
Kr-94		7.2(-3)
Kr-95		6.6(-4)
Kr-97		4.4(-6)
Xe-131m		4.7(-6)
Xe-133m		9.0(-5)
Xe-133		2.6(-3)
Xe-135m		8.4(-3)
Xe-135		7.2(-3)
Xe-137		4.7(-2)
Xe-138		2.8(-2)
Xe-139		9.0(-2)
Xe-140		9.6(-2)
Xe-141		7.8(-2)
Xe-142		2.3(-2)
Xe-143		3.8(-3)
Xe-144		1.8(-4)
Halogens		
Br-83	3(-3)	6(-5)
Br-84	5(-3)	1(-4)
Br-85	3(-3)	6(-5)
I-131	5(-3)	1(-4)
I-132	3(-2)	6(-4)
I-133	2(-2)	4(-4)
I-134	5(-2)	1(-3)
I-135	2(-2)	4(-4)
Cesium and Rubidium		
Rb-89	5(-3)	5(-6)
Cs-134	3(-5)	3(-8)
Cs-136	2(-5)	2(-8)
Cs-137	7(-5)	7(-8)
Cs-138	1(-2)	1(-5)

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

**1.1(-3) = 1.1×10^{-3}.

TABLE 2-2 (Continued)

ISOTOPE	REACTOR WATER	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	9(-3)	9(-6)
P-32	2(-4)	2(-7)
Cr-51	5(-3)	5(-6)
Mn-54	6(-5)	6(-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	6(-6)	6(-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	7(-6)	7(-9)
Zr-97	5(-6)	5(-9)
Nb-95	7(-6)	7(-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 WATER	REACTOR STEAM
Te-132	1(-5)	1(-8)
Ba-139	1(-2)	1(-5)
Ba-140	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	7(-3)	7(-6)

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

PARAMETER	SYMBOL	UNITS	NOMINAL VALUE	RANGE	
				MAXIMUM	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	-	1.0	1.0	0.8

*3.8(5) = 3.8×10^5

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	**	0.02	0.001	***	1.0	0.001
R	Removal rate from the reactor water (hr^{-1})+	**	1.0	0.19	***	++	0.34

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

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

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

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

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

where the symbols are defined in this table and Table 2-3. 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 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.

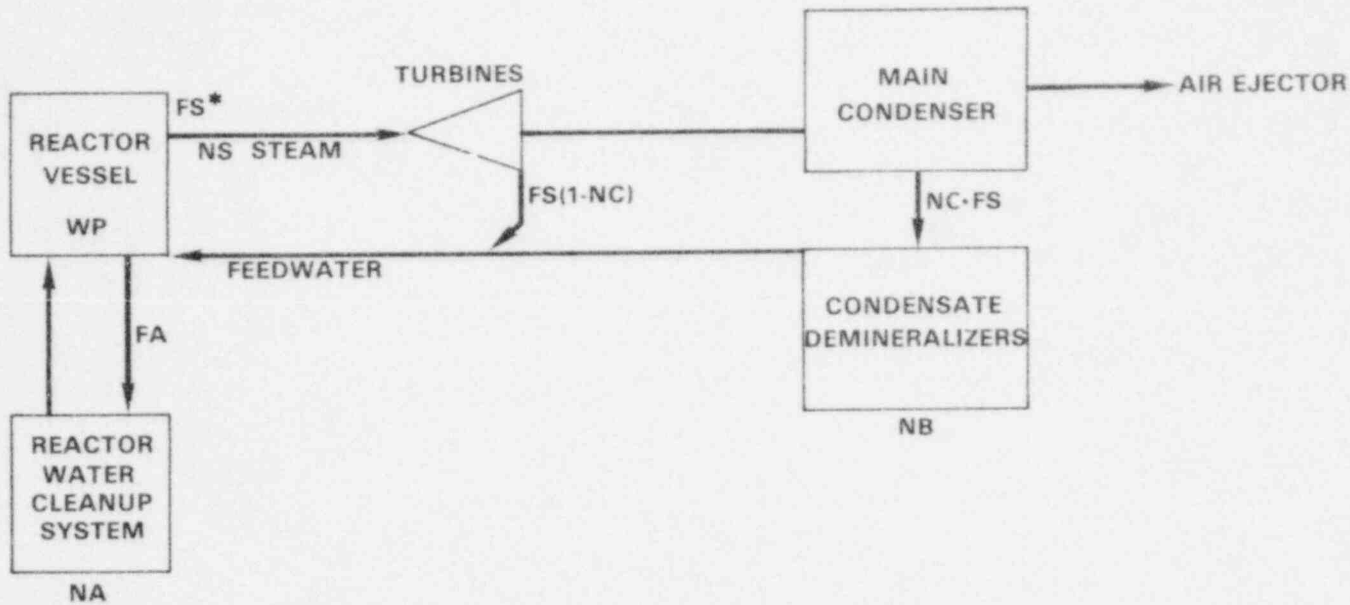
TABLE 2-5
ADJUSTMENT FACTORS FOR BOILING WATER REACTORS

NUCLIDES	REACTOR WATER	REACTOR STEAM
Noble gases*	1.0	1.0
Halogens**	$\frac{P}{WP}(110\ \frac{lb}{MWt})\frac{1.0 + \lambda}{R + \lambda}$	$\frac{P}{WP}(110\ \frac{lb}{MWt})\frac{1.0 + \lambda}{R + \lambda}$
Cs, Rb	$\frac{P}{WP}(110\ \frac{lb}{MWt})\frac{0.19 + \lambda}{R + \lambda}$	$\frac{P}{WP}(110\ \frac{lb}{MWt})\frac{0.19 + \lambda}{R + \lambda}$
Water activation products	1.0	1.0
Tritium***	1.0	1.0
Other nuclides	$\frac{P}{WP}(110\ \frac{lb}{MWt})\frac{0.34 + \lambda}{R + \lambda}$	$\frac{P}{WP}(110\ \frac{lb}{MWt})\frac{0.34 + \lambda}{R + \lambda}$

*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 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 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 proposed by the ANS 18.1 Working Group draft standard for boiling water reactor source terms (Ref. 1). 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 judged by the ANS Working Group to be representative of radionuclide concentrations in a BWR over its lifetime based on the currently available data and models (Refs. 2 and 3). 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 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/g;
- k is a conversion factor, 454 g/lb;
- 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 Barton Nuclear Station parameters compare with the range values in Table 2-3 as follows:

Parameter	Barton Station Value	Range Values
Thermal power level (MWt)	3758	3000-3800
Water weight in vessel (lb)	4.9×10^5	$3.4 \times 10^5 - 4.2 \times 10^5$
Cleanup demineralizer flow (lb/hr)	1.5×10^5	$1.1 \times 10^5 - 1.5 \times 10^5$
Steam flow rate (lb/hr)	15.4×10^6	$13.0 \times 10^6 - 17.0 \times 10^6$
Condensate demineralizer flow fraction	0.75	0.8 - 1.0

Since in this example two of the parameters (water weight in vessel and condensate demineralizer flow fraction) are 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:

$$A = \frac{P}{WP} (110) \frac{1.0 + \lambda}{R + \lambda} \qquad (2\text{-}1)$$

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:

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

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

Using the Barton Station parameters given above and the halogen parameters given in Table 2-4 and substituting in Equation (2-1) gives

$$R = \frac{1.5 \times 10^5 \times 0.9 + 0.75 \times 15.4 \times 10^6 \times 0.02 \times 0.9}{4.9 \times 10^5} = 0.7$$

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

$$A = \frac{3758}{4.9 \times 10^5} (110) \frac{1.0 + 3.6 \times 10^{-3}}{0.7 + 3.6 \times 10^{-3}} = 1.2$$

The adjusted I-131 concentration

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

= $1.2 \times 5 \times 10^{-3}$ μCi/g = 6.0×10^{-3} μCi/g

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:

$$A = \frac{P}{WP}(110)\frac{0.19 + \lambda}{R + \lambda} \qquad (2\text{-}3)$$

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 and the Barton Station parameters are used in the equation.

$$R = \frac{1.5 \times 10^5 \times 0.5 + 0.75 \times 15.4 \times 10^6 \times 0.001 \times 0.5}{4.9 \times 10^5} = 0.17$$

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

$$A = \left(\frac{3758}{4.9 \times 10^5}\right)(110)\left(\frac{0.19 + 2.6 \times 10^{-6}}{0.17 + 2.6 \times 10^{-6}}\right) = 0.97$$

The adjusted Cs-137 concentration

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

= $0.97 \times 7 \times 10^{-5}$ μCi/g = 6.8×10^{-5} μCi/g

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:

$$A = \frac{P}{WP}(110)\frac{0.34 + \lambda}{R + \lambda} \qquad (2\text{-}4)$$

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 and the Barton Station parameters are used in the equation:

$$R = \frac{1.5 \times 10^5 \times 0.9 + 0.75 \times 15.4 \times 10^6 \times 0.001 \times 0.9}{4.9 \times 10^5} = 0.3$$

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

$$A = \left(\frac{3758}{4.9 \times 10^5}\right)(110)\left(\frac{0.34 + 4.62 \times 10^{-2}}{0.3 + 4.62 \times 10^{-2}}\right) = 0.95$$

The adjusted concentration of Na-24

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

$= 0.95 \times 9 \times 10^{-3}\ \mu Ci/g = 8.6 \times 10^{-3}\ \mu Ci/g$

The noble gas concentrations in Table 2-2 are based on an offgas release rate of 60,000 μCi/sec measured at a 30-minute decay. A summary of noble gas release rates from a number of operating BWRs in 1971-72 is given in Table 2-6 and a similar summary for 1973-74 is given in Table 2-7. The data in these tables are limited to measurements from BWRs larger than 1000 MWt with more than one year of operating experience. The average of the noble gas release rates in Tables 2-6 and 2-7, based on the effective full power days of operation and normalized to 3400 MWt, is 60,000 μCi/sec.

A carryover factor of 0.02 is used to calculate the halogen concentrations in the main steam in Table 2-2. This carryover factor is derived from data taken at operating reactors (Refs. 2, 3, 4, and 5) which are listed in Table 2-8. The average of the data in Table 2-8 is 0.018 for halogen (iodine) carryover.

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 renewal 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, iodine, and radioactive particulate releases from ventilation systems for facilities with the BWR/6, Mark III containment design, prior to treatment, are shown in Table 2-9.

2.2.4.2 Bases

The iodine-131 releases from building ventilation effluents are based on measurements made at operating reactors. The measurements were made during normal operation and during plant shutdowns. The data are given in Tables 2-10 through 2-15. These data show that the release rates during plant shutdown differ from the release rates during plant operation. The ratio of releases during shutdowns to releases during normal operations, assuming a plant capacity factor of 80%, is used to calculate annual releases that consider both normal operation and shutdown releases.

Table 2-13 gives the iodine-131 release rates during normal operation and during plant shutdowns for the Oyster Creek turbine building as 0.024 μCi/sec and 0.081 μCi/sec, respectively. Using an 80% plan capacity factor, the ratio of releases due to normal operation and shutdowns to the releases during normal operation only can be expressed as

$$\frac{(0.024\ \mu Ci/sec)(0.8) + (0.081\ \mu Ci/sec)(0.2)}{(0.024\ \mu Ci/sec)(0.8)} = 1.8$$

Similarly, from Table 2-13 the ratio of releases due to normal operation and shutdowns to the releases during normal operation for Vermont Yankee is 1.7. Using the average of these ratios, the average annual turbine building releases during normal operation from Table 2-12 are normalized to obtain a total annual release as indicated below:

$$\frac{(1.8 + 1.7)}{2}(0.11\ Ci/yr) = 0.19\ Ci/yr \text{ total I-131 released}$$

TABLE 2-6
SUMMARY OF NOBLE GAS RELEASE RATES FOR
OPERATING BWRs (1971-1972)

REACTOR*	NOMINAL POWER (MWt)	HOLDUP TIME (min)	1971 RELEASES				1972 RELEASES			
			EFPD** (days)	NOBLE GAS (Ci/yr)	AVERAGE (μCi/sec)	AVERAGE AT 3400 MWt (μCi/sec)	EFPD** (days)	NOBLE GAS (Ci/yr)	AVERAGE (μCi/sec)	AVERAGE AT 3400 MWt (μCi/sec)
Oyster Creek	1930	90	260	516,000	23,000	69,000	280	866,000	36,000	120,000
Nine Mile Point	1850	60	210	253,000	14,000	36,000	230	517,000	27,000	73,000
Millstone 1	2011	50	230	276,000	14,000	30,000	200	721,000	42,000	88,000
Dresden 2, 3***	5052	60		---	---	---	420	431,000	35,000	35,000
Monticello	1670	60		---	---	---	270	565,000	25,000	76,000
Yearly Average						45,000				71,000

*Reactors smaller than 1000 MWt (Big Rock Point, Dresden 1, Humboldt Bay, Lacrosse) are not included. Quad Cities 1 and 2, Vermont Yankee, and Pilgrim 1 were undergoing startup when this table was compiled and are not included.

**Effective full power days of operation.

***Dresden 2 and 3 are considered as two reactors.

TABLE 2-7
SUMMARY OF NOBLE GAS RELEASE RATES FOR
OPERATING BWRs (1973-1974)

REACTOR*	NOMINAL POWER (MWt)	HOLDUP TIME (min)	1973 RELEASES				1974 RELEASES			
			EFPD** (days)	NOBLE GAS (Ci/yr)	AVERAGE (μCi/sec)	AVERAGE AT 3400 MWt (μCi/sec)	EFPD** (days)	NOBLE GAS (Ci/yr)	AVERAGE (μCi/sec)	AVERAGE AT 3400 MWt (μCi/sec)
Oyster Creek	1930	90	230	812,000	35,000	120,000	240	280,000	14,000	47,000
Nine Mile Point 1	1850	60	250	872,000	40,000	110,000	240	617,000	30,000	75,000
Millstone 1	2011	50	120	69,500	7,000	21,000	230	912,000	46,000	99,000
Dresden 2, 3***	5054	60	440	875,000	46,000	43,000	340	628,000	21,000	20,000
Monticello	1670	60	250	732,000	34,000	95,000	220	1,490,000	78,000	220,000
Quad Cities 1, 2***	5022	60	510	903,000	41,000	42,000	430	1,049,000	28,000	26,000
Vermont Yankee	1593	60	160	187,000	20,000	63,000	+			
Pilgrim 1	1998	60	270	230,000	10,000	25,000	130	546,000	49,000	126,000
Yearly Average						61,000				73,000

*Reactors smaller than 1000 MWt (Big Rock Point, Dresden 1, Humboldt Bay, Lacrosse) are not included.
Reactors undergoing startup (Browns Ferry 1, Cooper 1, Duane Arnold, Peach Bottom 2) are not included.

**Effective full power days of operation.

***Dresden 2, 3 and Quad Cities 1, 2 are both considered as two reactors.

+Vermont Yankee Nuclear Power Station was not included for CY-1974 because of insufficient data regarding effect of augmented offgas treatment system.

TABLE 2-8
REACTOR VESSEL HALOGEN CARRYOVER FACTORS*
OBSERVED AT OPERATING BWRs

REACTOR	POWER LEVEL** (MWt)	METHOD***	PARTITION FACTOR	REFERENCE
Oyster Creek	(1930)	Condensate	0.018	3
	(1930)	No cleanup	0.018	3
	1830	Condensate	0.019	2
	1830	Condensate	0.021	2
	1830	No cleanup	0.023	2
	1820	Condensate	0.027	4
	(1930)	Condensate	0.023	4
	(1930)	Condensate	0.025	4
	(1930)	No cleanup	0.025	4
	(1930)	No cleanup	0.025	4
Dresden 2	1830	Condensate	0.022	5
	2210	Condensate	0.016	5
	2210	Condensate	0.017	5
	2400	Condensate	0.019	2
	2400	No cleanup	0.010	2
Dresden 3	2100	Condensate	0.022	2
	2100	No cleanup	0.020	2
Millstone	(2011)	Condensate	0.017	3
	2000	Condensate	0.005	2
Monticello	1670	Condensate	0.003	2
	1670	No cleanup	0.005	2
Nine Mile Point	(1850)	Condensate	0.02	3
	(1850)	No cleanup	0.02	3
Quad Cities 1	(2511)	Condensate	0.012	2
	(2511)	No cleanup	0.013	2
Average			0.018	

*Based on iodine-131.

**When test power level is not known, licensed power level is given in parentheses.

***Condensate method - The calculated partition factors are based on the ratio of the iodine-131 concentration in the condensate to that in the reactor water.

No-cleanup method - The calculated partition factors are based on the change in the concentrations of iodine-131 in the reactor water with the cleanup system isolated compared to the concentration with the cleanup system in service.

TABLE 2-9
GASEOUS RELEASES FROM VENTILATION SYSTEMS
(in Ci/yr per reactor)

NUCLIDE	CONTAINMENT BUILDING	AUXILIARY BUILDING	TURBINE* BUILDING	RADWASTE BUILDING
Kr-83m	**	**	**	**
Kr-85m	3	3	68	**
Kr-85	**	**	**	**
Kr-87	3	3	190	**
Kr-88	3	3	230	**
Kr-89	**	**	**	**
Xe-131m	**	**	**	**
Xe-133m	**	**	**	**
Xe-133	66	66	280	10
Xe-135m	46	46	650	**
Xe-135	34	34	630	45
Xe-137	**	**	**	**
Xe-138	7	7	1440	**
I-131	0.17	0.17	0.19	0.046
I-133	0.68	0.68	0.76	0.18
Co-60	0.01	0.01	0.002	0.09
Co-58	0.0006	0.0006	0.0006	0.0045
Cr-51	0.0003	0.0003	0.013	0.009
Mn-54	0.003	0.003	0.0006	0.036
Fe-59	0.0004	0.0004	0.0005	0.015
Zn-65	0.002	0.002	0.0002	0.001
Zr-95	0.0004	0.0004	0.0001	0.00005
Sr-89	0.00009	0.00009	0.006	0.0005
Sr-90	0.000005	0.000005	0.00002	0.0003
Sb-124	0.0002	0.0002	0.0003	0.00005
Cs-134	0.004	0.004	0.0003	0.0045
Cs-136	0.0003	0.0003	0.00005	0.00045
Cs-137	0.005	0.005	0.0006	0.009
Ba-140	0.0004	0.0004	0.011	0.0001
Ce-141	0.0001	0.0001	0.0006	0.0026

*Less than 1 Ci/yr per reactor.

**For special design features to control leakage from valves in lines 2-1/2 inches and larger, reduce the turbine building leakage rates by a factor of 5.

TABLE 2-10
ANNUAL IODINE-131 RELEASES FROM REACTOR BUILDING
VENTILATION SYSTEMS, NORMAL OPERATION

FACILITY	RELEASE (Ci/yr)*	REFERENCE
Vermont Yankee	0.12	6
Oyster Creek	0.072	2
Oyster Creek	0.04	7
Monticello	0.17	2
Dresden 2	0.096	2
Dresden 3	0.3	2
Millstone 1	0.03	8
Quad Cities 1	0.096	9
Nine Mile Point 1	0.096	10
Average	0.11	

*Annual release calculated from release rate (μCi/sec) based on 80% plant capacity factor.

TABLE 2-11
COMPARISON BETWEEN IODINE-131 RELEASES FROM REACTOR
BUILDING DURING NORMAL OPERATION AND RELEASES DURING PLANT OUTAGES

FACILITY	NORMAL OPERATION (μCi/sec)	OUTAGES (μCi/sec)	RATIO TOTAL RELEASES* TO NORMAL RELEASES	REFERENCE
Oyster Creek	0.0029	0.014**	2.6	2
Vermont Yankee	0.0038	0.041	3.7	6

*Ratio is based on normal releases occurring 80% of the year and releases during outages occurring 20% of the year.

**Oyster Creek releases include measurements made during drywell purge which was assumed to occur 48 hr/yr.

TABLE 2-12
ANNUAL IODINE-131 RELEASES FROM TURBINE BUILDING VENTILATION SYSTEMS DURING NORMAL OPERATION

FACILITY	RELEASE (Ci/yr)*	REFERENCE
Vermont Yankee	0.041	6
Oyster Creek	0.61	2
Oyster Creek	0.073	7
Oyster Creek	0.023	7
Millstone 1	0.012	8
Monticello	0.13	2
Dresden 2	0.007	2
Dresden 3	0.015	2
Quad Cities 1	0.012	9
Nine Mile Point 1	0.14	10
Average	0.11	

*Annual release calculated from release rate (μCi/sec) based on 80% plant capacity factor.

TABLE 2-13
COMPARISON BETWEEN IODINE-131 RELEASES FROM TURBINE BUILDING DURING NORMAL OPERATION AND RELEASES DURING PLANT OUTAGES

FACILITY	NORMAL OPERATION (μCi/sec)	OUTAGES (μCi/sec)	RATIO TOTAL RELEASES* TO NORMAL RELEASES	REFERENCE
Oyster Creek	0.024	0.081**	1.8	2
Vermont Yankee	0.0013	0.0035	1.7	6

*Ratio is based on normal releases occurring 80% of the year and releases during outages occurring 20% of the year.

**Oyster Creek releases include measurements made during drywell purge which was assumed to occur 48 hr/yr.

TABLE 2-14
ANNUAL IODINE-131 RELEASES FROM RADWASTE BUILDING VENTILATION SYSTEMS, NORMAL OPERATION

FACILITY	RELEASE (Ci/yr)*	REFERENCE
Vermont Yankee	0.057	6
Oyster Creek	0.024	2
Oyster Creek	0.008	7
Nine Mile Point 1	0.008	10
Average	0.024	

*Annual release calculated from release rate (μCi/sec) based on 80% plant capacity factor.

TABLE 2-15
COMPARISON BETWEEN IODINE-131 RELEASES FROM RADWASTE BUILDING DURING NORMAL OPERATION AND RELEASES DURING PLANT OUTAGES

FACILITY	NORMAL OPERATION (μCi/sec)	OUTAGES (μCi/sec)	RATIO TOTAL RELEASES* TO NORMAL RELEASES	REFERENCE
Oyster Creek	0.00086	0.0031**	1.9	2
Vermont Yankee	0.0018	0.0066	1.9	6

*Ratio is based on normal releases occurring 80% of the year and releases during outages occurring 20% of the year.

**Oyster Creek releases include measurements made during drywell purge which was assumed to occur 48 hr/yr.

The same procedure was used for the radwaste and reactor buildings to obtain total annual iodine-131 releases of 0.046 Ci/yr and 0.34 Ci/yr, respectively. The reactor building releases are based on reactors with a BWR Mark I containment design. Equipment such as the reactor coolant cleanup pumps, 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. Because of the potential for these systems to release radioactive materials from leakage during operation or testing, the Mark I reactor building releases have been assumed to be equally divided between the containment and auxiliary buildings for BWR/6, Mark III designs. The most significant leakage pathway in the turbine building is considered to be through valve stem packings. For this reason, the leakage rate is reduced by a factor of 5 if special design features are applied to reduce or collect leakage from valves in lines 2-1/2 inches in diameter and larger.

The noble gas release rates for building ventilation systems are the average of measurements made at Oyster Creek (Ref. 7) and Millstone Unit 1 (Ref. 8). These data are given in Tables 2-16 through 2-18. The noble gas release rates for the reactor building are equally divided between the containment and auxiliary buildings to reflect the BWR/6, Mark III design.

The radioactive particulate release rates for building ventilation systems are the average of measurements made at Vermont Yankee, Oyster Creek, Dresden 2 & 3, and Nine Mile Point (Refs. 11, 2, and 10). These data are given in Tables 2-21 through 2-27. The calculated annual release rates given above are based on an 80% plant capacity factor, i.e., 80% normal operation at 100% power and 20% plant downtime. To account for differences between release rates during shutdowns of long duration (greater than one week) and those for shorter shutdowns, the 20% downtime of 73 days was assumed to consist of 60 days of long-term shutdowns and 13 days of short-term shutdowns. The releases for normal operation were weighted to account for the operating and shutdown modes in a manner similar to that described previously for iodine releases. The particulate release rates in Tables 2-25 through 2-27 for the radwaste building were measured downstream of HEPA filters and were therefore normalized to upstream concentrations to obtain the radwaste building parameter above. A DF of 15, consistent with HEPA filter DF measurements at Nine Mile Point 1, was used in the normalization (Ref. 10). As described previously for noble gases and iodine, the particulate releases for the reactor building are equally divided between the containment and auxiliary buildings to reflect the BWR/6, Mark III containment design.

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 5 Ci/yr.

2.2.5.2 Bases

Table 2-28 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, 1973, and 1974 is approximately 5×10^{-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 5 Ci/yr.

2.2.6 TURBINE GLAND SEALING SYSTEM EXHAUST

2.2.6.1 Parameter

Use 0.1% of the main steam flow and assume 99% iodine removal due to radioiodine absorption by condensing steam in the turbine gland seal condenser. If 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 flow to be zero.

2.2.6.2 Bases

A design value of 0.1% of the main steam flow is used for the turbine gland seal steam flow (Ref. 12). A large fraction of the iodine is expected to be absorbed by the liquid phase during condensation of the gland seal steam. In the absence of radioiodine measurements, it is assumed that the gland seal condenser will remove approximately 99% of the iodine from the noncondensable stream due to iodine adsorption by the condensing water. It is further assumed that the iodine

TABLE 2-16
RELEASES OF NOBLE GASES FROM THE
REACTOR BUILDING VENTILATION SYSTEM
(μCi/sec)

NUCLIDE	MILLSTONE 07/21/72	MILLSTONE 07/24/72	OYSTER CREEK 04/18/72	AVERAGE
Kr-85m	0.44	0.07	NR	0.25
Kr-87	0.29	0.19	NR	0.24
Kr-88	0.56	0.20	0.02	0.25
Xe-133	0.67	0.36	15	5.3
Xe-135m	3.0	4.1	NR	3.6
Xe-135	3.1	2.9	2.1	2.7
Xe-138	0.87	NR	0.3	0.6

NR - Not reported.

TABLE 2-17
RELEASES OF NOBLE GASES FROM THE
TURBINE BUILDING VENTILATION SYSTEM
(μCi/sec)

NUCLIDE	MILLSTONE (Ref. 7)	OYSTER CREEK (Ref. 6)	AVERAGE
Kr-85m	2.7	NR	2.7
Kr-87	5.3	NR	5.3
Kr-88	8.2	10	9.1
Xe-133	7.4	12	10
Xe-135m	29	23	26
Xe-135	25	25	25
Xe-138	63	52	58

NR - Not reported.

TABLE 2-18
RELEASES OF NOBLE GASES FROM THE
RADWASTE BUILDING VENTILATION SYSTEM
(μCi/sec)

NUCLIDE	MILLSTONE (Ref. 7)	OYSTER CREEK (Ref. 6)	AVERAGE
Xe-133	0.25	0.56	0.4
Xe-135	2.0	1.5	1.8

TABLE 2-19
PARTICULATE RELEASE RATES FROM REACTOR BUILDING
VENTILATION SYSTEM, NORMAL OPERATION (Refs. 40, 2)
(10^{-6} μCi/sec)

NUCLIDE	VERMONT YANKEE	OYSTER CREEK	AVERAGE
Co-60	30	930	480
Co-58	4.6	56	30
Cr-51	5	5.4	5.2
Mn-54	21	370	196
Fe-59	5	47	26
Zn-65	35	11	23
Zr-95	2	NR	2
Sr-89	NA	6.8	6.8
Sr-90	NA	0.3	0.3
Sb-124	NR	11	11
Cs-134	18	18	18
Cs-136	13	NR	13
Cs-137	44	25	35
Ba-140	25	1.8	13
Ce-141	NR	4.3	4.3

NA - Not analyzed.
NR - Not reported.

TABLE 2-20
PARTICULATE RELEASE RATES FROM REACTOR BUILDING
VENTILATION SYSTEM, SHORT-TERM SHUTDOWN (2 DAYS/EVENT)(REFS. 11, 2)
(10^{-6} μCi/sec)

NUCLIDE	VERMONT YANKEE*	OYSTER CREEK	AVERAGE
Co-60	104	8100	4100
Co-58	71	37	54
Cr-51	31	37	34
Mn-54	131	23	77
Fe-59	31	37	34
Zn-65	57	19	38
Zr-95	31	NR	31
Sr-89	NA	NA	NA
Sr-90	NA	NA	NA
Sb-124	NR	37	37
Cs-134	51	12000	6030
Cs-136	33	NR	33
Cs-137	97	16000	8050
Ba-140	12	780	396
Ce-141	NR	37	37

NA - Not analyzed.
NR - Not reported.
*Initial drywell purge via SGTS not sampled.

TABLE 2-21
PARTICULATE RELEASE RATES FROM REACTOR BUILDING VENTILATION SYSTEM, REFUELING SHUTDOWN (REFS. 11, 2)
(10^{-6} μCi/sec)

NUCLIDE	VERMONT YANKEE	OYSTER CREEK	AVERAGE
Co-60	480	590	534
Co-58	77	34	56
Cr-51	120	43	81
Mn-54	55	240	150
Fe-59	21	6	14
Zn-65	1500	2.7	770
Zr-95	150	NR	152
Sr-89	NA	2	2
Sr-90	NA	0.36	0.36
Sb-124	NR	14	14
Cs-134	160	20	90
Cs-136	39	NR	39
Cs-137	380	34	210
Ba-140	27	2	14
Ce-141	NR	11	11

NA - Not analyzed.
NR - Not reported.

TABLE 2-22
PARTICULATE RELEASE RATES FROM TURBINE BUILDING VENTILATION SYSTEM, NORMAL OPERATION (REFS. 11, 2)
(10^{-6} μCi/sec)

NUCLIDE	VERMONT YANKEE	OYSTER CREEK	DRESDEN 2	DRESDEN 3	AVERAGE
Co-60	3.6	72	4.5	6.0	22
Co-58	2.7	6.7	NR	48	20
Cr-51	NR	840	NR	160	500
Mn-54	1.7	8.4	NR	5	5
Fe-59	NR	6.7	NR	NR	6.7
Zn-65	NR	3.3	NR	NR	3.3
Zr-95	NR	NR	NR	4.0	4.0
Sr-89	NA	610	48	36	230
Sr-90	NA	1.3	0.3	0.25	0.6
Sb-124	NR	6.7	NR	NR	6.7
Cs-134	2.9	15	NR	3.0	7
Cs-136	NR	NR	NR	NR	*
Cs-137	1.9	42	1.8	10	14
Ba-140	133	1400	115	65	430
Ce-141	NR	42	5.5	5	18

NA - Not analyzed.
NR - Not reported.
*Estimated to be less than 1×10^{-6} μCi/sec. A value of 1×10^{-6} μCi/sec was used to calculate annual release.

TABLE 2-23
PARTICULATE RELEASE RATES FROM TURBINE BUILDING
VENTILATION SYSTEM, SHORT-TERM SHUTDOWN (REFS. 11, 2)
(10^{-6} μCi/sec)

NUCLIDE	VERMONT YANKEE	OYSTER CREEK	AVERAGE
Co-60	5.5	46	26
Co-58	1.5	46	24
Cr-51	NR	46	46
Mn-54	3.5	15	9.2
Fe-59	NR	46	46
Zn-65	NR	23	23
Zr-95	NR	NR	*
Sr-89	NA	NA	NA
Sr-90	NA	NA	NA
Sb-124	NR	46	46
Cs-134	1.8	170	86
Cs-136	NR	NR	*
Cs-137	4.5	240	120
Ba-140	25	110	68
Ce-141	NR	46	46

NA - Not analyzed.
NR - Not reported.
*Estimated to be less than 10^{-6} μCi/sec. A value of 1×10^{-6} μCi/sec was used to calculate annual release.

TABLE 2-24
PARTICULATE RELEASE RATES FROM TURBINE BUILDING
VENTILATION SYSTEM, REFUELING SHUTDOWN (REFS. 11, 2)
(10^{-6} μCi/sec)

NUCLIDE	VERMONT YANKEE	OYSTER CREEK	AVERAGE
Co-60	3.5	490	250
Co-58	1	29	15
Cr-51	NR	72	72
Mn-54	1	180	90
Fe-59	NR	49	49
Zn-65	NR	11	11
Zr-95	NR	NR	*
Sr-89	NA	2.5	2.5
Sr-90	NA	0.25	0.25
Sb-124	NR	9.5	9.5
Cs-134	2.5	26	14
Cs-136	NR	NR	*
Cs-137	5	57	31
Ba-140	3.6	3.4	3.5
Ce-141	NR	20	20

NA - Not analyzed.
NR - Not reported.
*Estimated to be less than 10^{-6} μCi/sec. A value of 1×10^{-6} μCi/sec was used to calculate annual release.

TABLE 2-25
PARTICULATE RELEASE RATE* FROM RADWASTE BUILDING
VENTILATION SYSTEM, NORMAL OPERATION (REFS. 11, 2, 8)

(10^{-6} μCi/sec)

NUCLIDE	VERMONT YANKEE	OYSTER CREEK	NINE MILE POINT	AVERAGE
Co-60	0.7	55	83 **	46
Co-58	0.64	1.5	2.0	1.4
Cr-51	NR	5.3	NR **	5.3
Mn-54	0.43	14	8.7	7.7
Fe-59	NR	0.72	NR	0.72
Zn-65	1	0.63	NR	0.82
Zr-95	NR	NR	NR	***
Sr-89	NA	0.72	NR	0.72
Sr-90	NA	0.72	NR	0.72
Sb-124	NR	NR	NR	***
Cs-134	0.8	3	33	12
Cs-136	1	NR	NR	1
Cs-137	1.9	6.8	57	22
Ba-140	3.7	NR	NR	3.7
Ce-141	NR	0.72	NR	0.72

NR - Not reported.
NA - Not analyzed.

*Downstream of HEPA filters.

**Calculated based on known filter inlet activity concentration using DF of 15.

***Estimated to be less than 1×10^{-6} μCi/sec. A value of 1×10^{-6} was used to calculate annual release.

TABLE 2-26
PARTICULATE RELEASE RATE* FROM RADWASTE BUILDING
VENTILATION SYSTEM, SHORT-TERM SHUTDOWN (REFS. 11, 2)

(10^{-6} μCi/sec)

NUCLIDE	VERMONT YANKEE	OYSTER CREEK	AVERAGE
Co-60	1.1	68	35
Co-58	0.95	7.2	4.1
Cr-51	NR	7.2	7.2
Mn-54	0.64	19	9.8
Fe-59	NR	7.2	7.2
Zn-65	1	4.3	2.7
Zr-95	NR	NR	**
Sr-89	NA	NA	NA
Sr-90	NA	NA	NA
Sb-124	NR	NR	**
Cs-134	1.3	7.2	4.3
Cs-136	1.1	NR	1.1
Cs-137	8.6	7.2	8.0
Ba-140	0.92	NR	0.92
Ce-141	NR	7.2	7.2

NA - Not analyzed.
NR - Not reported.

*Downstream of HEPA filters.

**Estimated to be less than 10^{-6} μCi/sec. A value of 1×10^{-6} μCi/sec was used to calculate annual release.

TABLE 2-27
PARTICULATE RELEASE RATE* FROM RADWASTE BUILDING
VENTILATION SYSTEM, REFUELING SHUTDOWN (REFS. 11, 2)
(10^{-6} μCi/sec)

NUCLIDE	VERMONT YANKEE	OYSTER CREEK	AVERAGE
Co-60	0.8	1850	920
Co-58	0.6	114	57
Cr-51	NR	92	92
Mn-54	0.6	860	430
Fe-59	NR	250	250
Zn-65	1	29	15
Zr-95	NR	NR	**
Sr-89	NA	1.8	1.8
Sr-90	NA	0.08	0.08
Sb-124	NR	NR	**
Cs-134	1	15	8
Cs-136	1	NR	1
Cs-137	3.9	34	19
Ba-140	1.1	NR	1.1
Ce-141	NR	29	29

NR - Not reported.
NA - Not analyzed.

*Downstream of HEPA filters

**Estimated to be less than 10^{-6} μCi/sec. A value of 1×10^{-6} μCi/sec was used to calculate annual release.

TABLE 2-28

IODINE-131 RELEASES FROM THE MAIN CONDENSER AIR EJECTORS*

FACILITY	1972 IODINE RELEASE (Ci/yr)	1972 INTEGRATED THERMAL POWER (10^6 MWd)	1972 $\frac{Ci/yr}{10^6 MWd}$	1973 IODINE RELEASE (Ci/yr)	1973 INTEGRATED THERMAL POWER (10^6 MWd)	1973 $\frac{Ci/yr}{10^6 MWd}$	1974 IODINE RELEASE (Ci/yr)	1974 INTEGRATED THERMAL POWER (10^6 MWd)	1974 $\frac{Ci/yr}{10^6 MWd}$
Oyster Creek	6.3	0.542	12.0	6.7	0.453	14.0	3.3	0.46	7.2
Nine Mile Point 1	0.89	0.417	2.0	1.9	0.457	4.4	0.7	0.43	1.7
Millstone 1	1.2	0.404	3.0	0.15	0.248	0.6	0.29	0.47	0.6
Dresden 2, 3**	5.1	1.05	4.6	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	17.0
Pilgrim 1			***	0.46	0.523	0.9	1.4	0.25	5.8
Quad Cities 1, 2**			***	5.5	1.32	4.2	8.2	1.09	7.5
Average			4.5			5.4			6.2

Combined average for 1972, 1973, 1974 -- $5.4 \times 10^{-6} \frac{Ci/yr}{MWd}$

*Data from semiannual operating for 1972, 1973, 1974 for facilities listed.

**Two-unit plants with a single stack.

***Not included in 1972 average because plants had not achieved a full year of operation.

source term is negligible when clean steam (nonradioactive steam from an auxiliary steam supply system) is used for the gland seal. Because of noble gas removal in the main condenser, iodine removal by the condensate demineralizers, and partitioning in the boiler, steam produced from demineralized condensate is considered to be clean steam. Data in Tables 2-29 and 2-30 show the release of radioactive particulates from the turbine gland seal to be negligible.

TABLE 2-29
PARTICULATE RELEASE RATE FROM VERMONT YANKEE MECHANICAL VACUUM PUMP AND GLAND EXHAUST CONDENSER VENT, SHORT-TERM SHUTDOWN

(10^{-6} μCi/sec)

NUCLIDE	RELEASE RATE
Cs-134	1.2
Cs-136	1.1
Cs-137	4.9
Ba-140	2.9

TABLE 2-30
PARTICULATE RELEASE RATE FROM VERMONT YANKEE 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

2.2.7 MAIN CONDENSER MECHANICAL VACUUM PUMP

2.2.7.1 Parameter

Xe-133	2300 Ci/yr per reactor
Xe-135	350 Ci/yr per reactor
I-131	0.03 Ci/yr per reactor

2.2.7.2 Bases

The release values for Xe-133 and Xe-135 were derived from Dresden 1 operating data (Ref. 13). These data indicate that approximately 580 Ci of Xe-133 and 85 Ci of Xe-135 were released with the Dresden 1 mechanical vacuum pump effluent when establishing 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 release value for iodine-131 was derived from operating data taken at Vermont Yankee (Ref. 6). These data indicate that the release rate for iodine-131 due to mechanical vacuum pump operation during plant startup was approximately 0.09 μCi/sec. Information from reactor operators indicates that the mechanical vacuum pumps are operated periodically during plant shutdowns to maintain a slight condenser vacuum and prevent leakage from the condenser to the turbine building. A total of 24 hours of vacuum pump operation per shutdown was assumed for purposes of calculating iodine releases. The annual release estimates for noble gases and iodine-131 are based on four shutdowns per year. Data in Tables 2-29 and 2-30 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

10 ft^3/min air inleakage for each condenser shell of the main condenser.

2.2.8.2 Bases

Air inleakage to the main condenser is a function of the number of condenser shells and of the station housekeeping performed to reduce inleakage and maintain low inleakage levels. Operating data for inleakage vary widely. For example, Oyster Creek and Dresden 2 air inleakage measurements during early operation indicated that leakage rates were 4 to 250 ft^3/min. Yet, Dresden 1 inleakage during full-power operation has been measured to be approximately 3 ft^3/min.

A large amount of air inleakage data has been evaluated for TVA power plants, where inleakage measurements have been recorded for several years. Air inleakage measurements for six TVA plants, representing more than 40 years of cumulative experience, indicate leakage rates ranging from 4 to 12 ft^3/min per condenser shell.

An air leakage rate of 10 ft^3/min per condenser shell is assumed for nuclear power plants under normal operating conditions, including anticipated operational occurrences, averaged over the life of the plant.

2.2.9 HOLDUP TIMES FOR CHARCOAL DELAY SYSTEMS

2.2.9.1 Parameter

$T = 0.26\ MK/10\ N$

where

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

M is the mass of charcoal adsorber, in thousands of pounds;

T is the holdup time, in hours; and

10 N is the number of shells in main condenser times 10 ft^3/min inleakage per shell.

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

	OPERATING 77°F DEW POINT 45°F	OPERATING 77°F DEW POINT 0°F	OPERATING 0°F DEW POINT -20°F
Kr	18.5	25	105
Xe	330	440	2410

2.2.9.2 Bases

Charcoal delay systems are evaluated using the above equation and dynamic adsorption coefficients. $T = MK/10\ N$ is a standard equation for the calculation of delay times in charcoal adsorption systems (Ref. 14). The dynamic adsorption coefficients (K values) for Xe and Kr are dependent on operating temperature and moisture content (Refs. 15 and 16) 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. 17 and 18) and reports concerning charcoal adsorption systems (Refs. 14, 15, 16, 18, 19, 20, and 21).

The factors influencing the selection of [illegible] values are

1. Operational data from KRB* (K_{Kr} = [illegible]), K_{Xe} = 260-430) (Ref. 17) and from KWL** (K_{Kr} = 30, K_{Xe} = 50[illegible]

*Kernkraftwerk RWE - Bayernwerk GmbH.

**Kernkraftwerk Lingen GmbH.

2. The effect of temperature on the dynamic adsorption coefficients, indicated in Figure 2-2 (Ref. 15).

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. 15, 22, and 23). 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.

The coefficient 0.26 adjusts the units and was calculated as follows:

$$T(hr) = \frac{M(10^3\ lb)\ K(cm^3/g)(454\ g/lb)(3.53 \times 10^{-5}\ ft^3/cm^3)}{(10\ ft^3/min\text{-}shell)(N\ shells)(60\ min/hr)}$$

$$T = 0.26\ \frac{MK}{10\ N}$$

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. 24), which were derived from a proprietary report (Ref. 25) 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 DECONTAMINATION FACTOR FOR THE CHARCOAL ADSORBERS AND HEPA FILTERS

2.2.11.1 Parameter

Use a nominal DF of 10 for iodine removal by charcoal adsorbers subject to applicant's commitment to provide data to support charcoal bed depth for removal efficiency used. Use a DF of 100 for particulate removal by HEPA filtration.

2.2.11.2 Bases

Only very limited data are available concerning the removal of iodine at trace concentrations ($10^{-12}\ \mu Ci/cm^3$). The majority of the available data concerning iodine adsorption on activated carbon is addressed toward iodine concentrations that are orders of magnitude higher than the levels of concern in source term evaluations for normal operations.

The iodine removal efficiency of activated carbon varies greatly, even between carbon in the same lot (Ref. 23). This lack of consistency makes the comparison of reported data difficult. The difficulty is compounded by sampling and measurement problems encountered when working with the low iodine concentrations involved. Accordingly, useful information concerning the adsorption of trace quantities of iodine is limited (Ref. 26). In addition, when iodine is present in low concentrations, impurities in the carrier gas may be adsorbed by the charcoal causing competition between the iodine and impurities. Over long periods of time (i.e., several months), such impurities may saturate (poison) the adsorber (Ref. 27), thereby decreasing the apparent iodine adsorption coefficient (Ref. 26) and shortening the time before iodine breakthrough. Channeling through the charcoal bed via passages caused by poor initial bed packing or by settling during use will also decrease adsorber efficiency.

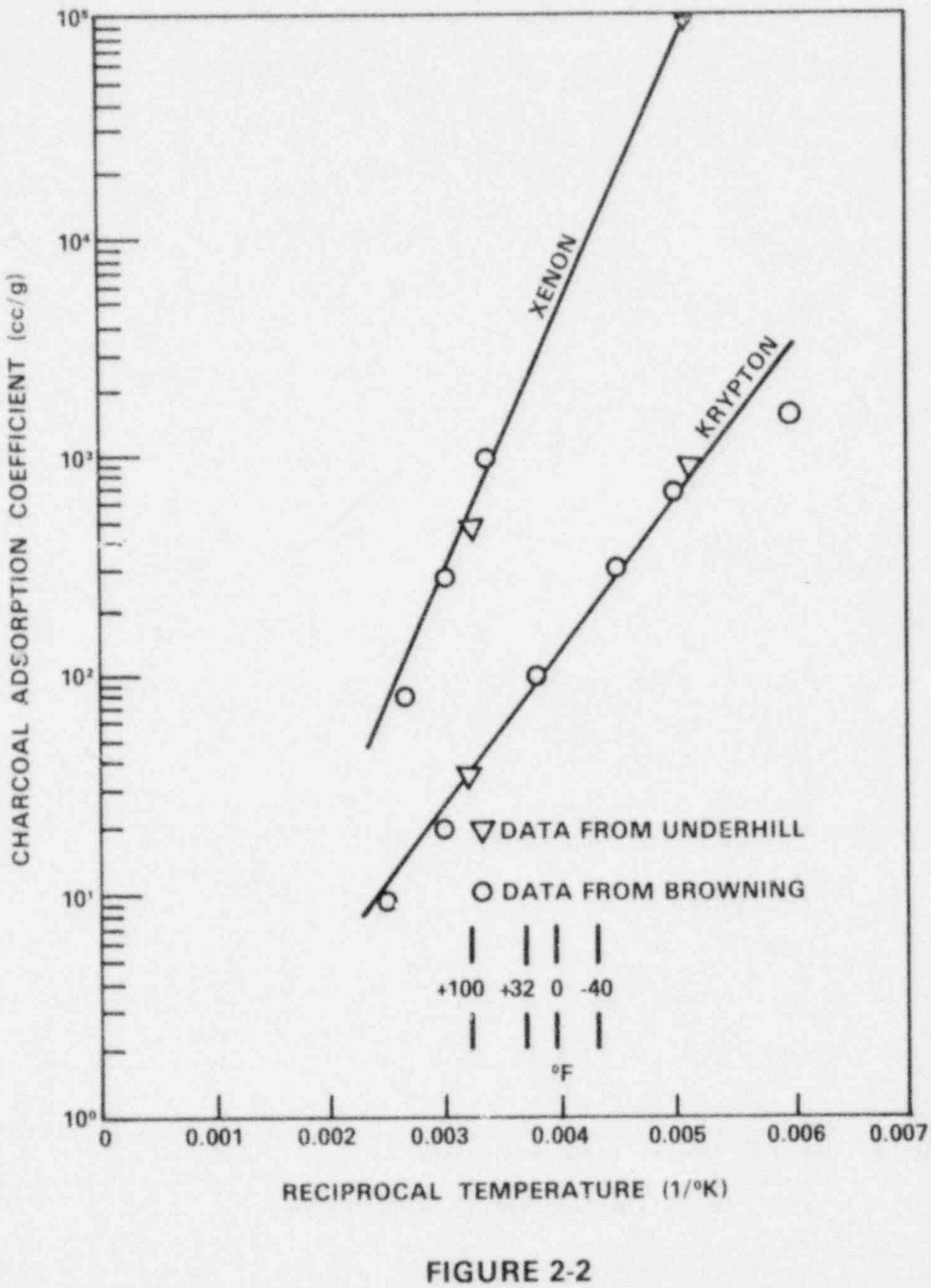


FIGURE 2-2

KRYPTON AND XENON K VALUES AS A FUNCTION OF RECIPROCAL TEMPERATURE

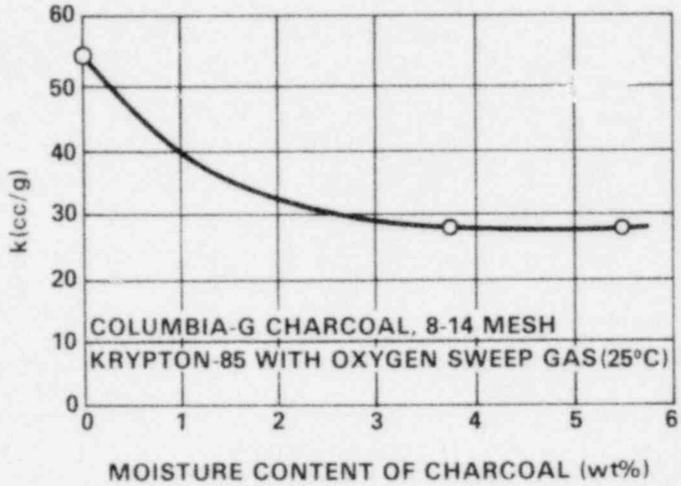


FIGURE 2-3

EFFECT OF MOISTURE CONTENT ON THE DYNAMIC ADSORPTION COEFFICIENT

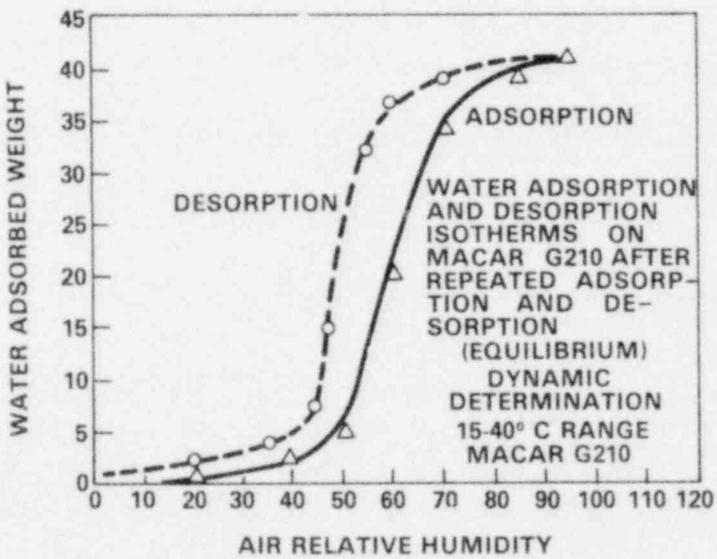


FIGURE 2-4

CHARCOAL MOISTURE AS A FUNCTION OF RELATIVE HUMIDITY

Data being developed for iodine removal at trace levels may be used by applicants to substantiate the iodine removal efficiencies. The DF of 100 for HEPA filters is consistent with expected particulate removal efficiencies under normal operating conditions.

The DF assigned the charcoal adsorbers and HEPA filters considers in-place leak testing to be conducted before use and routinely thereafter, as recommended in ANSI Standard N510, "Testing of Nuclear Air Cleaning Systems" (Ref. 28).

2.2.12 LIQUID WASTE INPUTS

2.2.12.1 Parameter

The flow rates listed in Table 2-31 are used as inputs to the liquid radwaste treatment system. Flows that cannot be standardized are added to those listed in Table 2-31 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 52.3 Working Group draft standard for boiling water reactor liquid radwaste system (Ref. 29). Activity inputs are based on the reactor coolant concentrations proposed by ANS 18.1 Working Group draft standard (Ref. 1) boiling water reactor source terms 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 7 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. 30).

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, the effective bed life between regenerations will be approximately doubled based on preliminary operating data from Dresden and Pilgrim 1 (Refs. 31 and 32).

2.2.14 DETERGENT WASTE

2.2.14.1 Parameter

For plants with an onsite laundry, use 450 gal/day per reactor of detergent waste and the radionuclide distribution given in Table 2-32 for untreated detergent wastes. The quantities shown in Table 2-32 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 450 gal/day per reactor. The radionuclide distribution given in Table 2-32 is based on data from Ginna given in Table 2-33.

TABLE 2-31
BWR LIQUID WASTES

SOURCE	FLOW RATE (gal/day) PLANT WITH ULTRASONIC RESIN CLEANER	PLANT WITHOUT ULTRASONIC RESIN CLEANER	FRACTION OF PRIMARY COOLANT ACTIVITY (PCA)
Equipment Drains			
Drywell	3,400	3,400	1
Containment, auxiliary building, and fuel pool	3,720	3.720	0.01
Radwaste building	1,060	1,060	0.01
Turbine building	2,960	2,960	0.01
Ultrasonic resin cleaner*	15,000	-	0.05
Resin rinse	2,500	5,000	0.002
Subtotal	28,640	16,140	-
Floor Drains			
Drywell	700	700	1
Containment, auxiliary building, and fuel pool	2,000	2,000	0.01
Radwaste building	1,000	1,000	0.01
Turbine building	2,000	2,000	0.01
Subtotal	5,700	5,700	-
Other			
Cleanup phase separator decant	640	640	0.002
Laundry drains	450	450	**
Lab drains	500	500	0.02
Regenerants*	1,700	3,400	***
Condensate backwash†	-	8,100	2×10^{-6}
Chemical lab waste	100	100	0.02
Total	37,730	26,930	

* - Deep-bed condensate demineralizers.
** - Listed in BWR-GALE Code, see Table 2-32.
*** - Calculated by BWR-GALE Code.
† - Filter/demineralizer (Powdex) condensate demineralizer.

TABLE 2-32
CALCULATED ANNUAL RELEASE OF RADIOACTIVE MATERIALS IN UNTREATED DETERGENT WASTE FROM A BWR AND PWR

NUCLIDE	Ci/yr
Mn-54	0.001
Co-58	0.004
Co-60	0.009
Zr-95	0.0014
Nb-95	0.002
Ru-103	0.00014
Ru-106	0.0024
Ag-110m	0.00044
I-131	0.0006
Cs-134	0.013
Cs-137	0.024
Cs-144	0.005
Total	∿0.06

TABLE 2-33
GINNA NUCLEAR POWER STATION
RADIONUCLIDE DISTRIBUTION OF DETERGENT WASTE
FOR PERIOD OCTOBER 1972 - JULY 1973 (Ref. 33)

NUCLIDE	10/26/72 to 11/25/72	11/26/72 to 12/31/72	1/01/73 to 1/31/73	2/01/73 to 2/28/73	3/01/73 to 3/31/73	4/01/73 to 4/30/73	5/01/73 to 5/31/73	6/01/73 to 6/30/73	7/01/73 to 7/31/73	MONTHLY AVG.	MAX.	MIN.
Cs-137	2.93	0.87	0.31	1.02	1.59	12.8	0.55	0.48	1.58	2.46	12.8	0.31
Cs-134	2.04	0.48	0.19	0.53	0.82	7.0	0.26	0.21	0.60	1.35	7.0	0.19
Co-60	1.04	1.04	0.24	0.92	0.86	2.1	0.23	0.16	1.54	0.90	2.1	0.16
Co-58	0.82	0.74	0.10	0.17	1.32	0.43	0.08	0.02	0.03	0.4[illegible]	1.3	0.02
Mn-54	-	0.21	0.05	0.12	0.11	0.25	0.06	-	0.15	0[illegible]	0.25	0.05
Zr-95	0.59	0.25	0.07	0.09	0.10	0.17	-	-	-	0.14	0.59	0.07
Nb-95	0.49	0.39	0.09	0.16	0.17	0.35	0.06	-	0.11	0.20	0.49	0.06
I-131	-	-	-	-	-	-	-	-	0.06	0.06	0.06	-
Ce-144	1.05	0.76	0.17	0.55	0.43	1.50	0.26	0.08	0.41	0.53	1.50	0.08
Ce-141	-	-	0.01	-	-	-	-	-	-	0.001	0.01	-
Ru-106	1.91	-	0.30	-	-	-	-	-	-	0.25	1.9	0.30
Ru-103	-	-	0.02	0.019	0.09	-	-	-	-	0.014	0.09	0.23
Ag-110m	-	-	0.08	0.02	0.07	0.23	-	-	-	0.05	0.23	0.02
Cr-51	-	-	-	-	-	-	-	-	-	-	-	-
Mo-99	-	-	-	0.005	-	-	-	-	-	0.005	0.005	-
Total	10.9	4.7	1.6	3.4	5.6	24.8	1.5	0.9	4.5	6.4	24.8	0.94
Monthly Flow (gal)	24,380	6,770	1,800	10,680	10,290	8,620	5,220	3,400	5,200	8,420	24,380	1,800
Daily Flow (gal)	-	-	-	-	-	-	-	-	-	280	810	60

2.2.15 TRITIUM RELEASES

2.2.15.1 Parameter

The total tritium release through liquid and vapor pathways is 0.025 Ci/yr per MWt. The quantity of tritium released through the liquid pathway is based on the calculated volume of liquid released with a tritium concentration of 0.01 uCi/cm^3 up to a maximum of 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 vapor from the plant vent.

2.2.15.2 Bases

Table 2-34 lists the measured liquid and gaseous tritium releases from BWRs for 1972, 1973, and 1974. 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 0.025 Ci/MWt through the combined liquid and vapor pathways.

The tritium can be released either in liquid wastes or as a vapor with ventilation effluents, the relative amounts being dependent on liquid recycle practices. The tritium concentration assumed for the liquid releases is based on the tritium concentration given in Table 2-2 and is the value recommended by the ANS 18.1 Working Group for BWR source term calculations. This value is based on a review of tritium concentrations in BWR liquid streams (Ref. 1). This evaluation assumes steady-state conditions; i.e., the tritium inventory in the plant remains constant and the tritium entering the reactor water is released through the liquid and vapor pathways.

2.2.16 DECONTAMINATION FACTORS FOR DEMINERALIZERS

2.2.16.1 Parameter

The following are the expected decontamination factors (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.

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. 34). This reference contains operating and theoretical data that provide 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.

TABLE 2-34

TRITIUM RELEASE DATA FROM OPERATING BWRs*

REACTOR NAME	POWER (MWt)	STARTUP DATE	NUCLEAR THERMAL OUTPUT (10^6 MWdt)			TRITIUM RELEASED (Ci/yr)						RATIO OF TOTAL TRITIUM RELEASED (Ci/yr-MWt at 80% capacity)		
						GASEOUS			LIQUID					
			1972	1973	1974	1972	1973	1974	1972	1973	1974	1972	1973	1974
Dresden 1	700	1959	0.16	0.10	0.05	**	**	**	43	18.5	18.8	0.078	0.054	0.11
Oyster Creek	1930	1969	0.54	0.45	0.46	0.8	0.4	0.4	62	36.6	14.1	0.034	0.024	0.009
Nine Mile Point	1850	1969	0.42	0.46	0.44	18	26.8	**	28	46.5	18.7	0.032	0.047	0.012
Dresden 2, 3	2577	1970/71	1.04	1.18	0.91	31	10	11	26	26	22.6	0.016	0.009	0.011
Millstone 1	2011	1970	0.40	0.25	0.47	4.2	1.7	2.8	21	3.7	24.1	0.018	0.006	0.017
Monticello	1670	1970	0.46	0.41	0.37	12	**	**	***	***	***	0.008	-	-
Vermont Yankee	1593	1972	0.06	0.18	0.34	†	1.0	0.9	†	0.2	**	-	0.002	0.001
Quad Cities 1, 2	2511	1971/72	0.52	1.32	1.09	4.7	34††	29	4.7	24.5	34	0.005	~0.013	0.017
Pilgrim 1	1998	1972	0.11	0.53	0.25	**	14	8	4.2	0.4	10.5	0.011	0.008	0.022
Average												0.025	~0.020	0.025

*Data from semiannual reports of reactors listed.

**No reported data.

***No measurement made.

†Prior to first core refueling.

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

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 34 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 34, 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 IODINE	IODINE
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. 35). 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.

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. 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 2-35 through 2-37 give membrane DFs derived from operating data at Point Beach and Ginna (Refs. 36, 37, 38, and 39) and laboratory data on simulated radwaste liquids (Refs. 40 and 41). 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 2-35 and 2-37, the membrane DF for these isotopes is lower than the average membrane DF used in the evaluation for laundry waste.

2.2.19 GUIDELINES FOR CALCULATING LIQUID WASTE HOLDUP TIMES

The radioactive-decay holdup times applied to the input waste streams are calculated using the following parameters:

1. The collection time for an 80% volume change in the tank, based on the liquid waste flow rates from the source (above values).

2. The total time liquid remains in the system for processing, based on the flow rate through the limiting process step.

3. One-half the time required to empty the final liquid waste sample (test) tank to the environment. This value is based on the maximum rate of the discharge pumps and the nominal tank volume.

The calculated values in 1. and the total of 2. and 3. are used as inputs to the computer code.

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 0.15 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 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:

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.

2.2.20.2 Bases

Reactor operating data over a 2-1/2-year period January 1973 through June 1975, representing 102 reactor years of operation were evaluated to determine the frequency and extent of

TABLE 2-35
REVERSE OSMOSIS DECONTAMINATION FACTORS, GINNA STATION (REF. 36)

NUCLIDE	CONCENTRATE ACTIVITY ($\mu Ci/cm^3$)	PRODUCT ACTIVITY ($\mu Ci/cm^3$)	MEMBRANE DF
Ce-144	2.88×10^{-4}	$<2.2 \times 10^{-7}$	1200
Co-58	8.55×10^{-5}	$<3.4 \times 10^{-8}$	1600
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
Total isotopic - Weak β	1.93×10^{-3}	9.8×10^{-6}	190
Average*			200

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

TABLE 2-36
REVERSE OSMOSIS DECONTAMINATION FACTORS, POINT BEACH (REF. 39)

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
	Average			160

TABLE 2-37
EXPECTED REVERSE OSMOSIS DECONTAMINATION FACTORS
FOR SPECIFIC NUCLIDES (REF. 41)

NUCLIDE	CONCENTRATE 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

unplanned liquid releases. During the period evaluated, 27 unplanned liquid releases occurred, 12 due to personnel errors, 7 due to component failures, and the remainder due to miscellaneous causes such as procedural errors and design errors. Table 2-38 summarizes the findings of this evaluation. These findings indicate that approximately 0.15 Ci/yr per reactor is expected to occur as unplanned releases. The tanks most likely to be released are the low-level sample (test) tanks, and therefore the calculated liquid source term radionuclide distribution is applied to the releases.

TABLE 2-38
FREQUENCY AND EXTENT OF UNPLANNED LIQUID RADWASTE RELEASES FROM OPERATING PLANTS

UNPLANNED LIQUID RELEASES	FREQUENCY/VOLUME
Total number	27
Approximate activity (Ci)	14.0
Approximate volume (gal)	2.0×10^5
Fraction of cumulative occurrence per reactor year (releases/reactor year)	0.3
Activity per release (Ci/release)	0.5
Activity release per reactor year (Ci/reactor year)	0.14
Volume of release per reactor year (gal/reactor year)	2.0×10^3

Operating experience has shown the availability for evaporators in waste treatment systems 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.

2.2.22 CARBON-14 RELEASES

2.2.22.1 Parameter

The 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 0.08, 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. 42), 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

2.2.23.1 Parameter

The annual quantity of argon-41 released from a boiling water reactor is 25 Ci/yr. The argon-41 is released to the environment via the containment vent when the drywell is vented or purged.

2.2.23.2 Bases

Argon-41 is formed by neutron activation of stable naturally occurring argon-40 in the drywell air surrounding the reactor vessel. The argon-41 is released to the environment when the drywell is vented or purged. BWRs that have a common stack for the release from the main condenser offgas system and the containment purge do not report argon-41 releases because the argon-41 is a small fraction of the total release from the stack. Monticello reported that 50 curies of argon-41 were released in 1973 and that the isotope was not detected in effluents in 1974. Browns Ferry 1 reported 19.2 curies of argon-41 released in 1974. Based on these data, the argon-41 release is estimated to be 25 curies per year.

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 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 show (1) the form in which data should be entered on input data sheets and (2) a sample completed sheet.

IBM FORTRAN Coding Form

GX28-7327-6 U/M 050**
Printed in U.S.A.

PROGRAM	Input Data BWR-GALE Code
PROGRAMMER	
DATE	July 1975
PUNCHING INSTRUCTIONS	GRAPHIC / PUNCH
PAGE	1 OF 2
CARD ELECTRO NUMBER*	

C	Statement Number	Variable	FORTRAN Statement	Identification Sequence
CARD	1	NAME	NAME OF REACTOR [ ] TYPE=	BWR
CARD	2	POWTH	THERMAL POWER LEVEL (MEGAWATTS)	[ ]
CARD	3	GTO	TOTAL STEAM FLOW (MILLION LBS/HR)	[ ]
CARD	4	WLIQ	MASS OF WATER IN REACTOR VESSEL (MILLIONLBS)	[ ]
CARD	5	GDE	CLEAN-UPDEMINERALIZER FLOW (MILLION LBS/HR)	[ ]
CARD	6	REGENT	CONDENSATE DEMINERALIZER REGENERATION TIME (DAYS)	[ ]
CARD	7	FFCDM	FRACTION FEEDWATER THROUGH CONDENSATE DEMIN	[ ]
CARD	8	DILUT	RADWASTE DILUTION FLOW(THOUSAND GPM)	[ ]
CARD	9		HIGH PURITY WASTEINPUT [ ] GPD AT [ ]PCA	
CARD	10		DFI=[ ] DFCS=[ ] DFO =[ ]	
CARD	11		COLLECTION[ ]DAYS PROCESS [ ] DAYS FRACT DISCH [	]
CARD	12		LOW PURITY WASTE INPUT [ ] GPD AT [ ]PCA	
CARD	13		DFI=[ ] DFCS = [ ]DFO = [ ]	
CARD	14		COLLECTION[ ] DAYS PROCESS [ ]DAYS FRACT DISCH [	]
CARD	15		CHEMICALWASTE INPUT [ ] GPD AT[ ] PCA	
CARD	16		DFI=[ ] DFCS = [ ] DFO = [ ]	
CARD	17		COLLECTION[ ]DAYS PROCESS [ ] DAYS FRACT DISCH [	]
CARD	18		REGENERANT SOLTNS WASTE INPUT-GPD	[ ]
CARD	19		DFI=[ ] DFCS = [ ] DFO = [ ]	
CARD	20		COLLECTION[ ]DAYS PROCESS [ ] DAYS FRACT DISCH [	]
CARD	21	GGS	GLAND SEAL STEAM FLOW (THOUSAND LBS/HR)	[ ]
CARD	22	WSTE	MASS OF STEAM INREACTOR VESSEL (MILLION LBS)	[ ]
CARD	23	TIM3	GLAND SEAL HOLD UP TIME (HOURS)	[ ]
CARD	24	TIM4	AIR EJECTOR OFFGAS HOLDUP TIME (HOURS)	[ ]

*A standard card form, IBM electro 888157, is available for punching statements from this form.

**Number of forms per pad may vary slightly

IBM FORTRAN Coding Form

GX28-7327-6 U/M 050**
Printed in U.S.A.

PROGRAM	Input Data BWR-GALE Code	PAGE	2 OF 2
PROGRAMMER		DATE	July 1975

STATEMENT NUMBER		FORTRAN STATEMENT	IDENTIFICATION SEQUENCE
CARD 25		CONTAINMENT BLDG CHARCOAL? [ ] HEPA? [ ]	
CARD 26		TURBINEBLDG CHARCOAL? [ ] HEPA? [ ]SPEC FEATURES[ ]	
CARD 27	FIL3	GLAND SEAL VENT, IODINE PF	[ ]
CARD 28	FIL4	AIREJECTOR OFFGAS IODINE PF	[ ]
CARD 29		AUXILIARYBLDG CHARCOAL? [ ] HEPA? [ ]	
CARD 30		RADWASTE BLDG CHARCOAL? [ ] HEPA? [ ]	
CARD 31	KCHAR	CHARCOAL DELAY SYSTEM0=NO,1= YES,2-CRYOGENIC DISTILL	[]
CARD 32	KKR	KRYPTON DYNAMIC ADSORPTION COEFFICIENT (CM3/GM)	[ ]
CARD 33	KXE	XENON DYNAMIC ADSORPTION COEFFICIENT(CM3/GM)	[ ]
CARD 34	KNO	NUMBER OF MAIN CONDENSER SHELLS	[ ]
CARD 35	KMASS	MASS OF CHARCOAL (THOUSAND LBS)	[ ]
CARD 36	PFLAUN	DETERGENT WASTE DECON FACTOR	[ ]

**Number of forms per pad may vary slightly

3.3 SAMPLE PROBLEM - INPUT AND OUTPUT

The following pages show printouts of the input and output for a sample problem using the BWR-GALE Code.

```
CARD  1  NAME    NAME OF REACTOR   SAMPLE BWR CASE                              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.
CARD  8 DILUT    RADWASTE DILUTION FLOW (THOUSAND GPM)                           3.
CARD 9           HIGH PURITY WASTE  INPUT  28690.  GPD AT .15  PCA
CARD 10          DFI=  1.0E03DFCS=  1.0E02DFO =  1.0E03
CARD 11          COLLECTION  1.     DAYS PROCESS  .07   DAYS FRACT DISCH   0.01
CARD 12          LOW PURITY WASTE   INPUT  5700.   GPD AT.13
CARD 13          DFI=  1.0E03DFCS=  1.0E04DFO =  1.0E04
CARD 14          COLLECTION  3.1   DAYS PROCESS  .6    DAYS FRACT DISCH   1.
CARD 15          CHEMICAL  WASTE   INPUT     600.  GPD AT .02  PCA
CARD 16          DFI=  1.0E03DFCS=  1.0E04DFO =  1.0E04
CARD 17          COLLECTION  3.1   DAYS PROCESS  .6    DAYS FRACT DISCH   1.
CARD 18          REGENERATION SOLTNS INPUT  GPD                               1700.
CARD 19          DFI=  1.0E04DFCS=  1.0E05DFO =  1.0E05
CARD 20          COLLECTION  9.4   DAYS PROCESS  .44   DAYS FRACT DISCH   0.1
CARD 21  GGS     GLAND SEAL STEAM FLOW (THOUSAND LBS/HR)                         0.0
CARD 22  WSTE    MASS OF STEAM IN REACTOR VESSEL (MILLION LBS)                   .021
CARD 23  T1M3    GLAND SEAL HOLDUP TIME (HOURS)
CARD 24  TIM4    AIR EJECTOR OFFGAS HOLDUP TIME (HOURS)                          .167
CARD 25          CONTAINMENT BLDG CHARCOAL?YES HEPA?YES
CARD 26          TURBINE BLDG      CHARCOAL?    HEPA?    CLEAN STEAM?YES
CARD 27  FIL3    GLAND SEAL VENT, IODINE PF                                      1.0
CARD 28  FIL4    AIR EJECTOR OFFGAS IODINE PF
CARD 29          AUXILIARY BLDG   CHARCOAL?    HEPA?
CARD 30          RADWASTE BLDG    CHARCOAL?    HEPA?YES
CARD 31  KCHAR   CHARCOAL DELAY SYSTEM 0=NO,1=YES,2=CRYOGENIC DISTILL               1
CARD 32  KKR     KRYPTON DYNAMIC ADSORPTION COEFFICIENT (CM3/GM)                  105.
CARD 33  KXE     XENON DYNAMIC ADSORPTION COEFFICIENT (CM3/GM)                   2410.
CARD 34  KNO     NUMBER OF MAIN CONDENSER SHELLS                                 3.
CARD 35  KMASS   MASS OF CHARCOAL (THOUSAND LBS)                                 48.
CARD 36  PFLAUN  DETERGENT WASTE DECONTAMINATION FACTOR                           1.0
```

SAMPLE BWR CASE	BWR
THERMAL POWER LEVEL (MEGAWATTS)	3400,00000
PLANT CAPACITY FACTOR	0,80
TOTAL 'EAM FLOW (MILLION LBS/HR)	15,00000
MASS ' WATER IN REACTOR VESSEL (MILLION LBS)	0,38000
CL. .-UP DEMINERALIZER FLOW (MILLION LBS/HR)	0,13000
CONDENSATE DEMINERALIZER REGENERATION TIME (DAYS)	56,00000
FRACTION FEED WATER THROUGH CONDENSATE DEMIN	1,00000
RADWASTE DILUTION FLOW (THOUSAND GPM)	3,00000

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		0,100	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
MASS OF STEAM IN REACTOR VESSEL (MILLION LBS)		0,02100
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
	RELEASE FRACT,-SPECIAL DES, FEATURES	0,20000
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)		1,85500
XENON HOLDUP TIME (DAYS)		42,57663
KRYPTON DYNAMIC ADSORPTION COEFFICIENT (CM3/GM)		105,00000
XENON DYNAMIC ADSORPTION COEFFICIENT(CM3/GM)		2410,00000
NUMBER OF MAIN CONDENSER SHELLS		3,00000
MASS OF CHARCOAL (THOUSAND LBS)		48,00000

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
KR-83M	1.100E-03	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
KR-85M	1.900E-03	3.0E 00	1.4E 01	3.0E 00	0.0	0.0	8.0E 01	0.0	1.0E 02
KR-85	6.000E-06	0.0	0.0	0.0	0.0	0.0	2.9E 02	0.0	2.9E 02
KR-87	6.600E-03	3.0E 00	2.6E 01	3.0E 00	0.0	0.0	0.0	0.0	3.2E 01
KR-88	6.600E-03	3.0E 00	4.6E 01	3.0E 00	0.0	0.0	5.0E 00	0.0	5.7E 01
KR-89	4.100E-02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
XE-131M	4.700E-06	0.0	0.0	0.0	0.0	0.0	1.8E 01	0.0	1.8E 01
XE-133M	9.000E-05	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
XE-133	2.600E-03	6.6E 01	5.0E 01	6.6E 01	1.0E 01	0.0	4.6E 02	2.3E 03	3.0E 03
XE-135M	8.400E-04	4.6E 01	1.3E 02	4.6E 01	0.0	0.0	0.0	0.0	2.2E 02
XE-135	7.200E-03	3.4E 01	1.3E 02	3.4E 01	4.5E 01	0.0	0.0	3.5E 02	5.9E 02
XE-137	4.700E-02	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
XE-138	2.800E-02	7.0E 00	2.9E 02	7.0E 00	0.0	0.0	0.0	0.0	3.0E 02
TOTAL NOBLE GASES									4.6E 03
I-131	5.000E-03	1.7E-02	3.8E-02	1.7E-01	5.0E-02	0.0	0.0	3.0E-02	3.0E-01
I-133	2.000E-02	6.8E-02	1.5E-01	6.8E-01	1.8E-01	0.0	0.0	0.0	1.1E 00
TRITIUM GASEOUS RELEASE		43	CURIES/YR						

0.0 APPEARING IN THE TABLE INDICATES RELEASE IS LESS THAN 1.0 CI/YR FOR NOBLE GAS, 0.0001 CI/YR FOR I

SAMPLE BWR CASE

AIRBORNE PARTICULATE RELEASE RATE

(CURIES PER YEAR)

NUCLIDE	CONTAINMENT BLDG.	TURBINE BLDG.	AUXILIARY BLDG.	RADWASTE BLDG.	MECH VAC. PUMP	TOTAL
CR-51	3.0E-06	2.6E-03	3.0E-04	9.0E-05	0.0	3.0E-03
MN-54	3.0E-05	1.2E-04	3.0E-03	3.0E-04	0.0	3.4E-03
FE-59	4.0E-06	1.0E-04	4.0E-04	1.5E-04	0.0	6.5E-04
CO-58	6.0E-06	1.2E-04	6.0E-04	4.5E-05	0.0	7.7E-04
CO-60	1.0E-04	4.0E-04	1.0E-02	9.0E-04	0.0	1.1E-02
ZN-65	2.0E-05	4.0E-05	2.0E-03	1.5E-05	0.0	2.1E-03
SR-89	9.0E-07	1.2E-03	9.0E-05	4.5E-06	0.0	1.3E-03
SR-90	5.0E-08	4.0E-06	5.0E-06	3.0E-06	0.0	1.2E-05
ZR-95	4.0E-06	2.0E-05	4.0E-04	5.0E-07	0.0	4.2E-04
SB-124	2.0E-06	6.0E-05	2.0E-04	5.0E-07	0.0	2.6E-04
CS-134	4.0E-05	6.0E-05	4.0E-03	4.5E-05	3.0E-06	4.1E-03
CS-136	3.0E-06	1.0E-05	3.0E-04	4.5E-06	2.0E-06	3.2E-04
CS-137	5.5E-05	1.2E-04	5.5E-03	9.0E-05	1.0E-05	5.8E-03
BA-140	4.0E-06	2.2E-03	4.0E-04	1.0E-06	1.1E-05	2.6E-03
CE-141	1.0E-06	1.2E-04	1.0E-04	2.6E-05	0.0	2.5E-04

SAMPLE BWR CASE 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	9.00E-03	0.00030	0.00013	0.00000	0.00043	0.00310	0.0	0.00310
P 32	1.43E 01	2.00E-04	0.00001	0.00002	0.00000	0.00003	0.00024	0.0	0.00024
CR 51	2.78E 01	5.00E-03	0.00029	0.00049	0.00017	0.00095	0.00677	0.0	0.00680
MN 54	3.03E 02	6.00E-05	0.00000	0.00001	0.00000	0.00001	0.00010	0.00100	0.00110
MN 56	1.07E-01	5.00E-02	0.00029	0.00001	0.00000	0.00030	0.002[illegible]	0.0	0.00210
FE 55	9.50E 02	1.00E-03	0.00006	0.00010	0.00008	0.00024	0.[illegible]	0.0	0.00170
FE 59	4.50E 01	3.00E-05	0.00000	0.00000	0.00000	0.00001	0.[illegible]	0.0	0.00004
CO 58	7.13E 01	2.00E-04	0.00001	0.00002	0.00001	0.00004	0.00031	0.00400	0.00430
CO 60	1.92E 03	4.00E-04	0.00002	0.00004	0.00003	0.00010	0.00068	0.00870	0.00940
NI 65	1.07E-01	3.00E-04	0.00000	0.00000	0.00000	0.00000	0.00001	0.0	0.00001
CU 64	5.33E-01	3.00E-02	0.00091	0.00034	0.00001	0.00126	0.00900	0.0	0.00900
ZN 65	2.45E 02	2.00E-04	0.00001	0.00002	0.00001	0.00005	0.00033	0.0	0.00033
ZN 69M	5.75E-01	2.00E-03	0.00006	0.00003	0.00000	0.00009	0.00064	0.0	0.00064
ZN 69	3.96E-02	0.0	0.00007	0.00003	0.00000	0.00009	0.00068	0.0	0.00068
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	3.00E-04	0.00001	0.00001	0.00000	0.00002	0.00015	0.0	0.00015
NP239	2.35E 00	7.00E-03	0.00035	0.00039	0.00001	0.00075	0.00539	0.0	0.00540
FISSION PRODUCTS									
BR 83	1.00E-01	3.00E-03	0.00002	0.00000	0.00000	0.00002	0.00013	0.0	0.00013
SR 89	5.20E 01	1.00E-04	0.00001	0.00001	0.00000	0.00002	0.00015	0.0	0.00015
SR 91	4.03E-01	4.00E-03	0.00010	0.00003	0.00000	0.00013	0.00092	0.0	0.00092
Y 91M	3.47E-02	0.0	0.00006	0.00002	0.00000	0.00008	0.00058	0.0	0.00058
Y 91	5.88E 01	4.00E-05	0.00000	0.00001	0.00000	0.00001	0.00010	0.0	0.00009
SR 92	1.13E-01	1.00E-02	0.00006	0.00000	0.00000	0.00006	0.00046	0.0	0.00046
Y 92	1.47E-01	6.00E-03	0.00014	0.00001	0.00000	0.00015	0.00111	0.0	0.00110
Y 93	4.25E-01	4.00E-03	0.00010	0.00003	0.00000	0.00014	0.00097	0.0	0.00097
ZR 95	6.50E 01	7.00E-06	0.00000	0.00000	0.00000	0.00000	0.00001	0.0	0.00001
NB 95	3.50E 01	7.00E-06	0.00000	0.00000	0.00000	0.00000	0.00001	0.0	0.00001
NB 98	3.54E-02	4.00E-03	0.00000	0.00000	0.00000	0.00000	0.00002	0.0	0.00002
MO 99	2.79E 00	2.00E-03	0.00010	0.00012	0.00000	0.00023	0.00164	0.0	0.00160
TC 99M	2.50E-01	2.00E-02	0.00040	0.00016	0.00000	0.00056	0.00401	0.0	0.00400
RU103	3.96E 01	2.00E-05	0.00000	0.00000	0.00000	0.00000	0.00003	0.00014	0.00017
RH103M	3.96E-02	0.0	0.00000	0.00000	0.00000	0.00000	0.00003	0.0	0.00003
TC104	1.25E-02	8.00E-02	0.00000	0.00000	0.00000	0.00000	0.00001	0.0	0.00001
RU105	1.85E-01	2.00E-03	0.00002	0.00000	0.00000	0.00003	0.00018	0.0	0.00018
RH105M	5.21E-04	0.0	0.00002	0.00000	0.00000	0.00003	0.00018	0.0	0.00018
RH105	1.50E 00	0.0	0.00001	0.00001	0.00000	0.00002	0.00015	0.0	0.00015
RU106	3.67E 02	3.00E-06	0.00000	0.00000	0.00000	0.00000	0.00001	0.00240	0.00240
AG110M	2.53E 02	1.00E-06	0.00000	0.00000	0.00000	0.00000	0.00000	0.00044	0.00044
TE129M	3.40E 01	4.00E-05	0.00000	0.00000	0.00000	0.00001	0.00006	0.0	0.00006
TE129	4.79E-02	0.0	0.00000	0.00000	0.00000	0.00001	0.00004	0.0	0.00004
TE131M	1.25E 00	1.00E-04	0.00000	0.00000	0.00000	0.00001	0.00006	0.0	0.00006
I131	8.05E 00	5.00E-03	0.00028	0.00427	0.00683	0.01139	0.08138	0.00006	0.08100
I132	9.58E-02	3.00E-02	0.00015	0.00002	0.00000	0.00017	0.00120	0.0	0.00120
I133	8.75E-01	2.00E-02	0.00078	0.00474	0.00[illegible]08	0.00560	0.03998	0.0	0.04000
I134	3.67E-02	7.00E-02	0.00006	0.0000[illegible]	0.00000	0.00006	0.00042	0.0	0.00042
CS134	7.49E 02	3.00E-05	0.00002	0.00000	0.00000	0.00002	0.00016	0.01300	0.01300
I135	2.79E-01	2.00E-02	0.00037	0.00060	0.00001	0.00098	0.00699	0.0	0.00700
CS136	1.30E 01	2.00E-05	0.00001	0.00000	0.00000	0.00001	0.00010	0.0	0.00010

SAMPLE BWR CASE LIQUID EFFLUENTS (CONTINUED)

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	7.00E-05	0.00004	0.00001	0.00000	0.00005	0.00037	0.02400	0.02400
BA137M	1.77E-03	0.0	0.00004	0.00001	0.00000	0.00005	0.00035	0.0	0.00035
CS138	2.24E-02	1.00E-02	0.00002	0.00000	0.00000	0.00002	0.00016	0.0	0.00016
BA139	5.76E-02	1.00E-02	0.00002	0.00000	0.00000	0.00002	0.00015	0.0	0.00015
BA140	1.28E 01	4.00E-04	0.00002	0.00004	0.00001	0.00007	0.00047	0.0	0.00047
LA140	1.67E 00	0.0	0.00000	0.00002	0.00001	0.00003	0.00023	0.0	0.00023
LA141	1.62E-01	0.0	0.00001	0.00000	0.00000	0.00001	0.00006	0.0	0.00006
CE141	3.24E 01	3.00E-05	0.00000	0.00000	0.00000	0.00001	0.00005	0.0	0.00005
LA142	6.39E-02	5.00E-03	0.00001	0.00000	0.00000	0.00001	0.00011	0.0	0.00011
CE143	1.38E 00	3.00E-05	0.00000	0.00000	0.00000	0.00000	0.00002	0.0	0.00002
PR143	1.37E 01	4.00E-05	0.00000	0.00000	0.00000	0.00001	0.00005	0.0	0.00005
CE144	2.84E 02	3.00E-06	0.00000	0.00000	0.00000	0.00000	0.00000	0.00520	0.00520
ALL OTHERS		1.19E-01	0.00001	0.00000	0.00000	0.00001	0.00007	0.0	0.00007
TOTAL (EXCEPT TRITIUM)		5.31E-01	0.00534	0.01178	0.00730	0.02441	0.17441	0.06234	0.24000

TRITIUM RELEASE 42 CURIES PER YEAR

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 on magnetic tape 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 above 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 provides the program listing for the BWR-GALE Code.

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C      GALE CODE FOR CALCULATING GASEOUS EFFLUENTS FROM LWRS.  MODIFIED
C      JULY 1975 TO IMPLEMENT APPENDIX I TO 10 CFR PART 50.  REACTOR
C      WATER CONCENTRATIONS CALCULATED USING METHODS OF DRAFT STANDARD
C      ANS 237 'RADIOACTIVE MATERIALS IN PRINCIPAL FLUID STREAMS OF
C      LIGHT WATER COOLED NUCLEAR POWER PLANTS'  DRAFT DATED MAY 20, 1974
       REAL*8 NUCLID(20)/ ' KR=83M  KR=85M  KR=85   KR=87   KR=88   KR=89
      1   XE=131M XE=133M XE=133  XE=135M XE=135  XE=137  XE=138  I=131
      2 I=133                                                    '/
       REAL*8 BPART(15)/' CR=51   MN=54   FE=59   CO=58   CO=60   ZN=65
      1 SR=89   SR=90   ZR=95   SB=124  CS=134  CS=136  CS=137  BA=140  C
      2E=141 '/
       REAL*8 PPART(8)/' MN=54   FE=59   CO=58   CO=60   SR=89   SR=90
      1CS=134  CS=137 '/
       COMMON MSIG,NSIG
       DIMENSION ACONT(20),CHCP(20),CBSP(20),ASHIMC(20),ASHIMS(20)
       DIMENSION ASHIM(20),CONCL(20),CONCP(20),CONCS(20),DECON(20)
       DIMENSION DECOM(20),EX3(20),EX4(20),EXC(20),NAME(8)
       DIMENSION EJT(20),SGL(20),THL(20),CBL(20),RADBL(20),AXBL(20)
       DIMENSION VPR(20),BVOG(20),TOT(20),X0(20),X1(20),X2(20),X3(20)
       DIMENSION CBB(20),AXBB(20),TBB(20),RADBB(20)
       DIMENSION X4(20),X5(20),WORD(14),WARD(5),WORD(4)
       DIMENSION PCBB(15),PAXBB(15),PTBB(15),PRWBB(15),PVPR(15),PTOTB(15)
       DIMENSION PCBL(15),PTBL(15),PAXBL(15),PRWBL(15),PVPL(15)
       DIMENSION PCBP(8),PAXBP(8),PGWS(8),PTOTP(8),PGWL(8),PCBCP(8),
      1PCBSP(8),PRCONT(8)
       DIMENSION CTPRO(20)
C      XB CONTAINS COOLANT CONCENTRATIONS FOR BWR'S. THE FOLLOWING
C      ISOTOPES (WITH THEIR CONCENTRATIONS IN UCI/GM) ARE NOT
C      CONSIDERED SIGNIFICANT IN EFFLUENT CALCULATIONS;KR=90,.09;
C      KR=91,.11;KR=92,.11;KR=93,.029;KR=94,.0072;KR=95,6.6E=4;KR=97,
C      4.4E=6;XE=139,.09;XE=140,.096;XE=141,.078;XE=142,.023;XE=143,
C      .0038;XE=144,1.8E=4.
       DIMENSION XB(20)
C      XP1 CONTAINS PRIMARY COOLANT CONCENTRATIONS FOR PWR,S.  XP2
C      CONTAINS SECONDARY COOLANT CONCENTRATIONS FOR PWR,S
       DIMENSION XP1(20),XP2(13)
       DATA XB/1.1E=3,1.9E=3,6.0E=6,6.6E=3,6.6E=3,4.1E=2,4.7E=6,9.0E=5,
      1    2.6E=3,8.4E=4,7.2E=3,4.7E=2,2.8E=2,5.0E=3,2.0E=2,5*0./
       DATA XP1/.021,.11,.15,.06,.2,5E=3,.1.,22,1E.,.013,.35,9E=3,.044,
      1.27,.38,5*0./
       DATA XP2/5.8E=9,3.1E=8,4.2E=8,1.8E=8,5.5E=8,1.4E=9,3.1E=8,6.2E=8,
      15.0E=6,3.6E=9,9.7E=8,2.5E=9,1.2E=8/
       DATA DECON/1.035E=04,4.375E=05,2.040E=09,1.520E=04,6.680E=05,
      1           3.632E=03,6.800E=07,3.548E=06,1.520E=06,7.357E=04,
      2           2.090E=05,3.024E=03,6.800E=04,9.970E=07,9.170E=06,
      3           0.000E=00,0.000E=00,0.000E=00,0.000E=00,0.000E=00/
       DATA CBB/0.,3.,0,0.,3.,0,3.,3*0.,66.,46.,34.,0.,7.,.17,.66,5*0./
       DATA AXBB/0.,3.,0,0.,3.,0,3.,3*0.,66.,46.,34.,0.,7.,.17,.68,5*0./
       DATA TBB/0.,68.,0.,130.,230.,3*0.,250.,650.,630.,0.,1440.,.19,
      1.76,5*0./
       DATA RADBB/8*0.,10.,0.,45.,0.,0.,.05,.16,5*0./
       DATA VPR/8*0.,2300.,0.,350.,2*0.,.03,6*0./
       DATA PCBB/.3,3.,.4,.6,10.,2.,.09,.005,.4,.2,4.,.3,5.5,.4,.1/
       DATA PAXBB/.3,3.,.4,.6,10.,2.,.09,.005,.4,.2,4.,.3,5.5,.4,.1/
       DATA PTBB/13.,.6,.5,.6,2.,.2,6.,.02,.1,.3,.3,.05,.6,11.,.6/
       DATA PRWBB/9.,30.,15.,4.5,90.,1.5,.45,.3,.05,.05,4.5,.45,9.,.1,2.6
      1/
       DATA PVPR/10*0.,.003,.002,.01,.011,0./
       DATA PCBP/22.,7.5,75.,34.,1.7,.3,22.,38./
       DATA PAXBP/18.,6.,60.,27.,1.3,.24,18.,30./
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      DATA PGAS/4.5,1.5,15.,7.,.33,.06,4.5,7.5/
      DATA YES/'YES'/
      DATA NTRY,NTER/0,0/,PWR/' PWR'/,BWR/' BWR'/
      REAL KKR,KXE,KNO,KMASS
   50 FORMAT(20A4)
   51 FORMAT(16X,'PLANT CAPACITY FACTOR',T74,'0.80')
   52 FORMAT(32X,8A4,12X,A4)
   53 FORMAT(16X,13A4,A2,F10.5)
   54 FORMAT(16X,'PERCENT FUEL WITH CLADDING DEFECTS',T74,F6.5)
   55 FORMAT(15X,4A4,A2,8X,F8.0,7X,F5.3)
   56 FORMAT(20X,F8.0,2(5X,F8.0))
   57 FORMAT(27X,F6.2,14X,F6.2,18X,F6.2)
   58 FORMAT     (30X,'FRACTION  FRACTION  COLLECTION  DECAY'/6X,'STREAM
     1      FLOW RATE   OF PCA DISCHARGED     TIME       TIME',5X,' DECONTAM
     2INATION  FACTORS'/20X,'(GAL/DAY)',23X,'(DAYS)    (DAYS)',7X,
     3'I',8X,'CS',8X,'OTHERS')
   59 FORMAT(2X,4A4,A2,1PE9.2,1X,4(0PF8.3,2X),3(1PE9.2,1X))
   60 FORMAT(79X,I1)
   61 FORMAT(16X,'THERE IS A CRYOGENIC DISTILLATION COLUMN'/20X,'IODINE
     1AND XENON DECONTAMINATION FACTOR',T70,'10000.'/20X,'KRYPTON DECONT
     2AMINATION FACTOR',T71,'4000.'/20X,'KRYPTON AND  XENON HOLDUP TIME
     3(DAYS)',T73,'90.')
   62 FORMAT(16X,'THERE IS NO CHARCOAL DELAY SYSTEM')
   63 FORMAT(16X,'THERE IS A CHARCOAL DELAY SYSTEM'/20X,'KRYPTON HOLDUP
     1TIME (DAYS)',T72,F9.5/20X,'XENON HOLDUP TIME (DAYS)',T72,F9.5/
     220X,'KRYPTON DYNAMIC ADSORPTION COEFFICIENT (CM3/GM)',T72,F9.5/
     320X,'XENON DYNAMIC ADSORPTION COEFFICIENT(CM3/GM)',T71,F10.5/20X,
     4'NUMBER OF MAIN CONDENSER SHELLS',T72,F9.5/20X,'MASS OF CHARCOAL
     5(THOUSAND LBS)',T72,F9.5)
   64 FORMAT(36X,F8.4,35X,I1)
   65 FORMAT (16X,'FRACTION IODINE PASSING CONDENSATE DEMINERALIZER',
     1T71,F10.5)
   66 FORMAT(16X,'BLOWDOWN RATE (THOUSAND LBS/HR)',25X,F8.4)
   67 FORMAT(16X,'FLOW RATE THROUGH GAS STRIPPER (GPM)',20X,F8.4)
   68 FORMAT(70X,F10.5)
   69 FORMAT(2X,'BLOWDOWN',10X,1PE9.2,14X,0PF5.3,2X,2(F8.3,2X),
     13(1PE9.2,1X))
   70 FORMAT(2X,'UNTREATED BLOWDOWN',1PE9.2,11X,'   1.000      0.0
     10.0      1.00E 00  1.00E 00  1.00E 00')
   71 FORMAT(2X,'REGENERANT SOLS    ',1PE9.2,14X,0PF5.3,2X,2(F8.3,2X),
     13(1PE9.2,1X))
   72 FORMAT(16X,'PRIMARY COOLANT LEAK TO AUXILIARY BLDG (LB/DAY)',T72,
     1'160.')
   73 FORMAT(16X,'FREQUENCY OF PRIMARY COOLANT DEGASSING (TIMES/YR)',T74
     1,'2.'/16X,'PRIMARY TO SECONDARY LEAK RATE (LB/DAY)',T72,'100.')
   74 FORMAT(16X,'THERE IS A KIDNEY FILTER'/20X,'CONTAINMENT ATMOSPHERE
     1CLEANUP RATE (THOUSAND CFM)',T71,F10.5/20X,'PURGE TIME OF CONTAINM
     2ENT (HOURS)',T71,F10.5)
   75 FORMAT(16X,'THERE IS NOT A KIDNEY FILTER')
   76 FORMAT(16X,'THERE IS NOT A CONDENSATE DEMINERALIZER')
   77 FORMAT(16X,'FRACTION IODINE BYPASSING CONDENSATE DEMINERALIZER',
     17X,T72,F9.5)
  900 FORMAT(16X,'IODINE PARTITION FACTOR (GAS/LIQUID) IN STEAM GENERATO
     1R  ',F4.2)
  901 FORMAT(16X,'THERE IS A CRYOGENIC OFFGAS SYSTEM'/20X,'IODINE AND XE
     1NON DECONTAMINATION FACTOR',T70,'1000.'/20X,'KRYPTON DECONTAMINAT
     2ION FACTOR',T71,'4000.')
  902 FORMAT(16X,'THERE IS NOT A CRYOGENIC OFFGAS SYSTEM')
  903 FORMAT(16X,16A4)
  904 FORMAT (/,'  LIQUID WASTE INPUTS')
  905 FORMAT (/,'  GASEOUS WASTE INPUTS')
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906 FORMAT(1H1)
907 FORMAT('0',15X,'THERE IS NOT AN ON-SITE LAUNDRY')
908 FORMAT(16X,'THERE IS NOT CONTINUOUS STRIPPING OF FULL LETDOWN FLOW')
909 FORMAT(16X,'THERE IS CONTINUOUS STRIPPING OF FULL LETDOWN FLOW')
910 FORMAT(16X,'BLOWDOWN IS PROCESSED THROUGH CONDENSATE DEMIN')
911 FORMAT(16X,'BLOWDOWN IS NOT PROCESSED THROUGH COND. DEMIN.')
912 FORMAT(15X,4A4,A2,8X,F6.0)
913 FORMAT(16X,5A4,9X,F8.2,9X,A3,6X,A3)
914 FORMAT(16X,5A4,'RATE(CFM)',27X,F8.2/16X,5A4,'IODINE RELEASE FRACTI
   1ON',11X,F10.5/36X,'PARTICULATE RELEASE FRACTION',6X,F10.5)
920 FORMAT (1H0,4X,A8,22X,5(1PE7.1,5X),3X,1PE7.1)
925 FORMAT (16X,4A4,10X,A3,6X,A3)
926 FORMAT (16X,4A4,'IODINE RELEASE FRACTION',16X,F10.5/32X,'PARTICULA
   1TE RELEASE FRACTION',10X,F10.5)
927 FORMAT(16X,4A4,10X,A3,6X,A3,13X,A3)
928 FORMAT(16X,4A4,'IODINE RELEASE FRACTION',16X,F10.5/32X,'PARTICULAT
   1E RELEASE FRACTION',10X,F10.5/32X,'RELEASE FRACT.-SPECIAL OPS. FEA
   2TURES',1X,F10.5)
930 FORMAT(16X,'STEAM LEAK TO TURBINE BLDG (LBS/HR)',19X,F10.5)
931 FORMAT(16X,'AUXILIARY BLDG LEAK IODINE PARTITION FACTOR',11X,F10.5
   1)
932 FORMAT(16X,4A4,6X,A3)
933 FORMAT(16X,4A4,4X,'PARTICULATE RELEASE FRACTION',6X,F10.5)
934 FORMAT(16X,5A4,10X,A3,6X,A3)
935 FORMAT(16X,5A4,'IODINE RELEASE FRACTION',11X,F10.5/36X,'PARTICULAT
   1E RELEASE FRACTION',6X,F10.5)
936 FORMAT(16X,5A4,10X,A3,6X,A3,19X,F3.0)
937 FORMAT (16X,'FREQUENCY OF CNTMT BLDG HIGH VOL PURGE(TIMES/YR)',
   1T74,F6.0)
938 FORMAT (16X,'THERE IS NOT A CNTMT BLDG LOW VOLUME PURGE')
940 FORMAT(16X,'THERE IS CONTINUOUS LOW VOL PURGE OF VOL. CONTROL TK')
 80 READ(50,52)NAME,TYPE
    WRITE(51,906)
    WRITE(51,52)NAME,TYPE
    IF(TYPE.EQ.PWR) GO TO 1005
    READ(50,53)WORD,POWTH
    WRITE(51,53)WORD,POWTH
    DPFRA=0.80
    WRITE(51,51)
    READ(50,53)WORD,GTO
    WRITE(51,53)WORD,GTO
    READ(50,53)WORD,WLIQ
    WRITE(51,53)WORD,WLIQ
    READ(50,53)WORD,GOE
    WRITE(51,53)WORD,GOE
C
C     READ DATA FOR BWR LIQUID CODE
C
    READ(50,53)WORD,REGENT
    WRITE(51,53)WORD,REGENT
    READ(50,53)WORD,FFCON
    WRITE(51,53)WORD,FFCON
    READ(50,53)WORD,OILOT
    WRITE(51,53)WORD,OILOT
    WRITE(51,904)
    READ(50,55)WARD,CWFLR,CWA
    READ(50,56)DFICW,DFCSCW,DFCW
    READ(50,57)TC,TSTORC,CWFD
    WRITE(51,58)
    WRITE(51,59)WARD,CWFLR,CWA,CWFD,TC,TSTORC,DFICW,DFCSCW,DFCW
    READ(50,55)WARD,DWFLR,DWA
```

```
      READ(50,56)DFIDW,DFCSDW,DFDW
      READ(50,57)TD,TSTORD,DWFD
      WRITE(51,59)WARD,DWFLW,DWA,DWFD,TD,TSTORD,DFIDW,DFCSDW,DFDW
      READ(50,55)WARD,CMWFR,CMA
      READ(50,56)DFICM,DFCSCM,DFCM
      READ(50,57)TCM,TSTORM,CMFD
      WRITE(51,59)WARD,CMWFR,CMA,CMFD,TCM,TSTORM,DFICM,DFCSCM,DFCM
      READ(50,68)RGWFR
      READ(50,56)DFIRG,DFCSRG,DFRG
      READ(50,57)TRG,TSTORR,RGFD
      WRITE(51,71)RGWFR,RGFD,TRG,TSTORR,DFIRG,DFCSRG,DFRG
C
C     READ DATA FOR B&W GAS CODE
C
      WRITE(51,905)
      READ(50,53)WORD,GGS
      WRITE(51,53)WORD,GGS
      READ(50,53)WORD,WSTE
      WRITE(51,53)WORD,WSTE
      READ(50,53)WORD,TIM3
      WRITE(51,53)WORD,TIM3
      READ(50,53)WORD,TIM4
      WRITE(51,53)WORD,TIM4
      HEPA1=1.0
      FIL1=1.0
      HEPA2=1.0
      FIL2=1.0
      HEPA5=1.0
      FIL5=1.0
      HEPA6=1.0
      FIL6=1.0
      CSRF=1.0
      READ(50,925)WORD,CBCM,CBHEPA
      IF(CBCM.EQ.YES)FIL1=0.1
      IF(CBHEPA.EQ.YES)HEPA1=0.01
      WRITE(51,926)WORD,FIL1,HEPA1
      READ(50,927)WORD,TBCM,TBHEPA,TBCS
      IF(TBCM.EQ.YES)FIL2=0.1
      IF(TBHEPA.EQ.YES)HEPA2=0.01
      IF(TBCS.EQ.YES)CSRF=0.2
      WRITE(51,928) WORD,FIL2,HEPA2,CSRF
      READ(50,53)WORD,FIL3
      WRITE(51,53)WORD,FIL3
      READ(50,53)WORD,FIL4
      WRITE(51,53)WORD,FIL4
      READ (50,925)WORD,AXCM,AXHEPA
      IF(AXCM.EQ.YES)FIL5=0.1
      IF(AXHEPA.EQ.YES)HEPA5=0.01
      WRITE(51,926)WORD,FIL5,HEPA5
      READ(50,925)WORD,RWCM,RWHEPA
      IF(RWCM.EQ.YES)FIL6=0.1
      IF(RWHEPA.EQ.YES)HEPA6=0.01
      WRITE(51,926)WORD,FIL6,HEPA6
      READ(50,60)KCHAR
      READ(50,53)WORD,KKR
      READ(50,53)WORD,KXE
      READ(50,53)WORD,KIO
      READ(50,53)WORD,KMASS
      IF(KCHAR.EQ.0) GO TO 90
      IF(KCHAR.EQ.1) GO TO 91
      WRITE(51,61)
```

```
      CHTI1=90.
      CHTI2=90.
      GO TO 92
   90 WRITE(51,82)
      CHTI1=0.
      CHTI2=0.
      GO TO 92
   91 F=10.**KNO
      CHTI1=(0.53*KMASS*KKR)/(F*24.*2.)
      CHTI2=(0.53*KMASS*KXE)/(F*24.*2.)
      WRITE(51,83)CHTI1,CHTI2,KKR,KXE,KNO,KMASS
   92 CONTINUE
      CON=0.02
      P3=0.01
      READ(50,53)  NORD,PFLAUN
      IF(PFLAUN.LE.0.0)  WRITE(51,907)
C
C     CONVERSION OF UNITS
C
      GTU=GTU*1000000.
      GOE=GOE*1000000.
      GGS=GGS*1000.
      WLIW=WLIW*1000000.
      WSTE=WSTE*1000000.
      WRITE(51,906)
      WRITE(51,903)NAME
      WRITE(51,214)
  214 FORMAT(1H0,131H***************************************************
     1*******************************************************************
     2**************)
      WRITE(51,235)
  235 FORMAT(1H0,63X,'GASEOUS RELEASE RATE'/1H0,63X,'(CURIES PER YEAR)'/
     11H0,16X,'COOLANT CONC.',3X,'CONTAINMENT',3X,'TURBINE',4X,'AUXILIAR
     2Y',3X,'RADWASTE',5X,'GLAND',7X,'AIR',6X,'MECH VAC'/1H,4X,'NUCLIDE'
     3,3X,'(MICROCURIES/G)',6X,'BLDG.',7X,'BLDG.',7X,'BLDG.',6X,'BLDG.',
     46X,'SEAL',5X,'EJECTOR',7X,'PUMP',11X,'TOTAL')
      WRITE(51,214)
C     TRITCO IS THE BWR TRITIUM COOLANT CONCENTRATION IN UCI/GM
      TRITPR=.025*POWTH
      TRITCO=.01
      TLR=1.382*(CWFO*CWFLR+OWFO*OWFLR+CMFO*(CMWFR+1800.))
      TRITRL=TRITCO*TLR
      IF(TRITRL.GT.0.5*TRITPR)TRITRL=0.5*TRITPR
      TRITRG=TRITPR-TRITRL
      DIV=10.**(INT(ALOG10(TRITRG))-1)
      IDIV=DIV
      ITRITG=INT(TRITRG/DIV+0.5)*IDIV
      IOT=1
      IF(ABS(POWTH-3400).GT.400.1) GO TO 210
      IF(ABS(WLIW-3.8E5).GT.0.4001E5)GO TO 210
      IF(ABS(GOE-1.3E5).GT.0.2001E5)GO TO 210
      IF(ABS(GTU-1.5E7).GT.0.2001E7)GO TO 210
      IF(ABS(FFCOM-0.9).GT.0.1001)GO TO 210
      GO TO 211
  210 RMAL2=(GOE*0.9+FFCOM*GTU*0.018)/WLIW
      IOT=2
  211 CONTINUE
      DO5I=1,15
      DECOH(I)=DECOH(I)*3600.
      EX3(I)=DECOH(I)*TIM3
      IF(EX3(I).GT.75.)EX3(I)=75.
```

```
      EX4(I)=DECON(I)*TIMA
      IF(EX4(I).GT.75.)EX4(I)=75.
      IF(I.GT.13)GO TO 2000
      X1(I)=XB(I)
      CBL(I)=CBB(I)
      AXBL(I)=AXBB(I)
      TBL(I)=TBB(I)*CSRF
      RADBL(I)=RADBB(I)
      SGL(I)=GGS*X1(I)*EXP(-EX3(I))*3.977*DPFRA
      EXC(I)=DECON(I)*CHTI1*24.
      IF(I.GT.6)EXC(I)=DECON(I)*CHTI2*24.
      IF(EXC(I).GT.75.)EXC(I)=75.
      DFCR=0.0
      IF(KCHAR.EQ.2)  DFCR=0.00025
      IF(KCHAR.EQ.2.AND.I.GT.6)  DFCR=0.0001
      EJT(I)=GTO*X1(I)*EXP(-EX4(I))*(DFCR+EXP(-EXC(I)))*3.977*DPFRA
      GO TO 2001
 2000 CONTINUE
      IF(IOT.EQ.1)GO TO 2002
      XB(I)=XB(I)*(1)1.76*PCATH/WLIQ)*(1.018*DECON(I)/RHAL2 +DECON(I))
 2002 X1(I)=XB(I)*CON
      CBL(I)=CBB(I)*FIL1
      AXBL(I)=AXBB(I)*FIL5
      TBL(I)=TBB(I)*FIL2*CSRF
      RADBL(I)=RADBB(I)*FIL6
      SGL(I)=GGS*X1(I)*P3*FIL3*EXP(-EX3(I))*3.977*DPFRA
      EXC(I)=0.
      IF(KCHAR.EQ.2)EXC(I)=DECON(I)*CHTI1*24.
      IF(EXC(I).GT.75.)EXC(I)=75.
      IF(KCHAR.EQ.2)  DFCR=0.00010
      EJT(I)=5.0*EXP(-EX4(I))*(DFCR+EXP(-EXC(I)))*FIL4
      IF(I.EQ.15)  EJT(15)=EJT(15)*XB(15)/XB(14)
 2001 TEST=1.
      IF(I.GT.13)  TEST=0.0001
      IF(SGL(I).LE.TEST)      SGL(I)=0.0
      IF(EJT(I).LE.TEST)      EJT(I)=0.0
    5 CONTINUE
      MSIG=1
      NSIG=15
      CALL SIGF2(TBL)
      CALL SIGF2(SGL)
      CALL SIGF2(EJT)
      DO 2003 I=1,15
      TOT(I)=AXBL(I)+TBL(I)+SGL(I)+EJT(I)+CBL(I)+RADBL(I)+VPR(I)
 2003 CONTINUE
      CALL SIGF2(TOT)
      GASTOT=0.0
      DO 2004 I=1,13
      WRITE(51,230)NUCLID(I),XB(I),CBL(I),TBL(I),AXBL(I),RADBL(I),
     1     SGL(I),EJT(I),VPR(I),TOT(I)
      GASTOT=GASTOT+TOT(I)
 2004 CONTINUE
  230 FORMAT(1H0,4X,A8,5X,1PE9.3,8X,1PE7.1,1X,6(4X,1PE7.1,1X),7X,1PE7.1)
      DIV=10.**(INT(ALOG10(GASTOT))-1)
      GASTOT=AINT(GASTOT/DIV+0.5)*DIV
      WRITE(51,232)  GASTOT
  232 FORMAT(1H0,5X,'TOTAL NOBLE GASES', 99X,1PE7.1)
      DO 2006 I=14,15
      WRITE(51,230)NUCLID(I),XB(I),CBL(I),TBL(I),AXBL(I),RADBL(I),
     1     SGL(I),EJT(I),VPR(I),TOT(I)
 2006 CONTINUE
```

```
      WRITE(51,215)   ITRITG
  215 FORMAT(1H0,5X,'TRITIUM GASEOUS RELEASE',12X,I4,'   CURIES/YR')
      WRITE(51,214)
      WRITE(51,231)
  231 FORMAT(1H0,'0.0 APPEARING IN THE TABLE INDICATES RELEASE IS LESS
     1THAN 1.0 CI/YR FOR NOBLE GAS, 0.0001 CI/YR FOR I')
    6 CONTINUE
      WRITE (51,906)
      WRITE (51,903)NAME
      WRITE (51,214)
      WRITE (51,245)
  245 FORMAT (1H0,49X,'AIRBORNE PARTICULATE RELEASE RATE'/1H0,63X,'(CURI
     1ES PER YEAR)'/1H0,32X,'CONTAINMENT',3X,'TURBINE',6X,'AUXILIARY',4X
     2,'RADWASTE    MECH VAC.'/1H ,4X,'NUCLIDE',24X,'BLDG.',7X,'BLDG.',7X,
     3'BLDG.',8X,'BLDG.',6X,'PUMP',10X,'TOTAL')
      WRITE (51,214)
      DO 250 I=1,15
      PCBL(I)=PCBB(I)/1E3*HEPA1
      PTBL(I)=PTBB(I)/1E3*HEPA2*CSHF
      PVPL(I)=PVPR(I)/1E3
      PAXBL(I)=PAXBB(I)/1E3*HEPA5
      PRWBL(I)=PRWBB(I)/1E3*HEPA6
      PTOTB(I)=PCBL(I)+PTBL(I)+PAXBL(I)+PRWBL(I)+PVPL(I)
  250 CONTINUE
      MSIG=2
      NSIG=15
      CALL SIGF2(PTOTB)
      DO 253 I=1,15
      WRITE (51,920) NPART(I),PCBL(I),PTBL(I),PAXBL(I),PRWBL(I),PVPL(I),
     1PTOTB(I)
  253 CONTINUE
      WRITE (51,214)
      GO TO 80
C
C     THIS SECTION TREATS PWR RELEASES
C
 1003 READ(50,53)WORD,POWTH
      WRITE(51,53)WORD,POWTH
      OPFRA=0.80
      WRITE(51,51)
      READ(50,53)WORD,PRIVOL
      WRITE(51,53)WORD,PRIVOL
  600 PER=0.12
      WRITE(51,54)PER
      READ(50,53)WORD,DEMIFL
      WRITE(51,53)WORD,DEMIFL
      READ(50,53)WORD,CHFLR
      WRITE(51,53)WORD,CHFLR
      READ(50,53)WORD,GEN
      WRITE(51,53)WORD,GEN
      READ(50,53)WORD,TOSTFL
      WRITE(51,53)WORD,TOSTFL
      READ(50,53)WORD,WST
      WRITE(51,53)WORD,WST
      READ(50,53)WORD,WLI
      WRITE(51,53)WORD,WLI
      WLI=GEN*WLI
      READ(50,53)WORD,TMSC
      WRITE(51,53)WORD,TMSC
      READ(50,64)TBD,KFRRT
      WRITE(51,66)TBD
```

```
      IF(KFNRT,EQ,0) GO TO 601
      FNRTSC=0,9
      WRITE (51,910)
      GO TO 602
  601 WRITE (51,911)
      FNRTSC=1,0
  602 CONTINUE
      READ(50,53)WORD,REGENT
      WRITE(51,53)WORD,REGENT
C
C     READ DATA FOR PWR LIQUID CODE
C
      READ(50,53)WORD,FFCOM
      WRITE(51,53)WORD,FFCOM
      READ(50,53)WORD,DILUT
      WRITE(51,53)WORD,DILUT
      READ(50,912)WARD,SBLDR
      CWA=1,0
      READ(50,56)DFICW,DFCSCW,DFCW
      READ(50,57)TC,TSTORC,CWFD
      WRITE(51,904)
      WRITE(51,58)
      WRITE(51,59)WARD,SBLDR,CWA,CWFD,TC,TSTORC,DFICW,DFCSCW,DFCW
      READ(50,55)WARD,EDFLR,EDA
      READ(50,56)DFIED,DFCSED,DFED
      READ(50,57)TE,TS,EDFD
      WRITE(51,59)WARD,EDFLR,EDA,EDFD,TE,TS,DFIED,DFCSED,DFED
      READ(50,55)WARD,DWFLR,DWA
      READ(50,56)DFIDW,DFCSDW,DFDW
      READ(50,57)TD,TSTORD,DWFD
      WRITE(51,59)WARD,DWFLR,DWA,DWFD,TD,TSTORD,DFIDW,DFCSDW,DFDW
      READ(50,55)WARD,DWFL2,DW2
      READ(50,56)DFID2,DFCSD2,DFD2
      READ(50,57)T2,TSTOR2,DWF2
      WRITE(51,59)WARD,DWFL2,DW2,DWF2,T2,TSTOR2,DFID2,DFCSD2,DFD2
      READ(50,68)BDTFR
      READ(50,56)DFICM,DFCSCM,DFCM
      READ(50,57)TCM,TSTORR,CMFD
      READ(50,68)RGWFR
      READ(50,56)DFIRG,DFCSRG,DFRG
      READ(50,57)TRG,TSTORR,RGFD
      IF(TBD,EQ,0,0) GO TO 800
      BDFR=TBD*1,0E3*BDTFR/0,3476
      WRITE(51,69)BDFR,CMFD,TCM,TSTORR,DFICM,DFCSCM,DFCM
      BDFR=TBD*1,0E3*ABS(1,-BDTFR)/0,3476
      WRITE(51,70)BDFR
      IF(FFCOM,EQ,0,0)GO TO 801
  800 CONTINUE
      IF(REGENT,EQ,0,0) GO TO 802
      WRITE(51,71)RGWFR,RGFD,TRG,TSTORR,DFIRG,DFCSRG,DFRG
      GO TO 801
  802 RGWFR=0,0
      WRITE(51,71)RGWFR,RGFD,TRG,TSTORR,DFIRG,DFCSRG,DFRG
  801 CONTINUE
C
C     READ DATA FOR PWR GAS CODE
C
      WRITE(51,905)
      READ(50,60)KGTRNT
      IF(KGTRNT,EQ,0) GO TO 8801
      GTRN=(DEMIFL*SBLDR/1440,)/DEMIFL
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```
      IF(KGTRMT,EQ,2) GO TO 8803
      WRITE(51,909)
      GO TO 8802
 8803 GTRM=0,25*GTRM
      WRITE (51,940)
      GO TO 8802
 8801 GTRM=0,0
      WRITE (51,908)
 8802 BRR=GTRM*DEMIFL+(SHLDR+EDFLR)/1000,
      WRITE (51,67)BRR
      READ(50,53)WORD,TAU1
      WRITE(51,53)WORD,TAU1
      READ(50,53)WORD,TAU2
      WRITE(51,53)WORD,TAU2
      READ(50,53)WORD,TAU3
      WRITE(51,53)WORD,TAU3
      AUXLR=100,
      WRITE(51,72)
      PCLPF=0,0075
      WRITE (51,931)PCLPF
      GMHEPA=1,0
      FRIAB=1,0
      AXHEPA=1,0
      FPFP=1,0
      CSHEPA=1,0
      FPFPN=1,0
      CNHEPA=1,0
      READ(50,932)WORD,GMMT
      IF(GMMT,EQ,YES)GMHEPA=0,01
      WRITE(51,933)WORD,GMHEPA
      READ(50,934)WARD,AXCH,AXHT
      IF(AXCH,EQ,YES)FRIAB=0,1
      IF(AXHT,EQ,YES)AXHEPA=0,01
      WRITE(51,935)WARD,FRIAB,AXHEPA
      FAUX=PCLPF*FRIAB
      READ(50,53)WORD,CONVOL
      WRITE(51,53)WORD,CONVOL
      EM=2,0
      GENL=100,
      CLFNG=0,01
      CLFI=0,00001
      WRITE(51,73)
      READ(50,53)WORD,CFM
      PURTIM=16,
      IF(CFM,EQ,0,0)GO TO 803
      KIO=1
      WRITE(51,74)CFM,PURTIM
      GO TO 804
  803 KIO=0
      WRITE(51,75)
  804 CONTINUE
      IF(FFCDM,GT,0,0)GO TO 805
      WRITE(51,76)
      GO TO 806
  805 FIBCD=1,0-FFCDM
      WRITE(51,77)FIBCD
  806 CONTINUE
      IF(TBO,EQ,0,0) GO TO 809
      CON=0,01
      WRITE(51,900)CON
      GO TO 810
```

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  809 CON=1.0
      WRITE(51,900)CON
  810 CONTINUE
      READ (50,936)WARD,CSCH,CSHT,ENPU
      IF(CSCH.EQ.YES)FPFP=0.1
      IF(CSHT.EQ.YES)CSHEPA=0.01
      EN=4.0+ENPU
      WRITE (51,937)EN
      WRITE(51,935)WARD,FPFP,CSHEPA
      FPF=FPFP
      READ (50,913)WARD,PNOV1,CNCH,CNHT
      IF(CNCH.EQ.YES)FPFPN=0.1
      IF(CNHT.EQ.YES)CNHEPA=0.01
      IF (PNOV1.LT.1.0) GO TO 8811
      WRITE(51,914)WARD,PNOV1,WARD,FPFPN,CNHEPA
      GO TO 8812
 8811 WRITE (51,938)
 8812 CONTINUE
      FPFN=FPFPN
      TBLK=1700.
      WRITE(51,930)TBLK
      READ(50,53)WORD,FVN
      WRITE(51,53)WORD,FVN
      READ(50,53)WORD,FEJP
      WRITE(51,53)WORD,FEJP
      FEJ=FEJP*0.15
      KCRYO=0.0
      IF(KCRYO.EQ.0.0) GO TO 811
      WRITE(51,901)
      GO TO 812
  811 WRITE(51,902)
  812 CONTINUE
      READ(50,53)  WORD,PFLAUN
      IF(PFLAUN.LE.0.0)  WRITE(51,907)
C
C     CONVERSION OF UNITS
C
      TOSTFL=TOSTFL*1000000.
      WST=WST*1000.
      WLI=WLI*1000.
      CONVOL=CONVOL*1000000.
      CFM=CFM*1000.
      THD=THD*1E3
      PRIVOL=PRIVOL*1E3
      DEM1FL=DEM1FL*500.53
      SBLDR=SBLDR*.3476
      EDFLR=EDFLR*.3476
      DWFLR=DWFLR*.3476
      DWFL2=DWFL2*.3476
      CBFLR=CBFLR*500.53
      H3PRPW=0.4*POWTH
C     H3CUPW IS THE PWR TRITIUM PRIMARY COOLANT CONCENTRATION IN UCI/GM
      H3CUPW=1.0
      TPLRPW=SBLDR*CWA*CWFD+EDFLR*EDA*EDFD+DWFLR*DWA*DWFD+DWFL2*D-2*DWF2
      H3RLPW=TPLRPW*H3CUPW*3.977
      IF(H3RLPW.GT.0.5*H3PRPW)H3RLPW=0.5*H3PRPW
      H3RLG=H3PRPW-H3RLPW
      DIV=10.**(INT(ALOG10(H3RLG))-1)
      IDIV=DIV
      IH3RLG=INT(H3RLG/DIV+0.5)*IDIV
      IF(TAU3.EQ.0.)TAU3=.01
```

```
      SRB#SRB*500,53
      PE#365,/TAU3
      T1#3,1557E7/EN*ALPHA
      T3#3,1557E+07/PE
      T4#TAU1*86400,
      T5#TAU2*86400,
      DO 845 I#1,15
  845 DECOM(I)#DECOM(I)*3600,
      DO 850 I#1,15
  850 CONCP(I)#XP1(I)
      IF(ABS(POWTH=3400),GT,400,1)GO TO 855
      IF(ABS(PRIVOL=5,5E5),GT,,5001E5) GO TO 855
      IF(ABS(DEMIFL=3,7E4),GT,,5001E4) GO TO 855
      IF(ABS(SBLDR=625,),GT,375,1) GO TO 855
      IF(ABS(CHFLR=3750,),GT,3750,1) GO TO 855
      IF(KGTHAT,GT,0)  GO TO 855
      GO TO 861
  855 AFPTEG#1,0
      RNG2#(SBLDR+DEMIFL* GTH )/PRIVOL
      RHAL2#(DEMIFL*0,9+0,1*SBLDR)/PRIVOL
      RK2G#161,76*POWTH/PRIVOL
      DO 860 I#1,15
      IF(I,GT,13) GO TO 858
      CONCP(I)#CONCP(I)*RK2G*(,00091+DECOM(I))/(RNG2+DECOM(I))
      GO TO 860
  858 CONCP(I)#CONCP(I)*RK2G*(,00068+DECOM(I))/(RHAL2+DECOM(I))
  860 CONTINUE
  861 CONTINUE
      IF(THO,EQ,0,0)GO TO 880
      IF(FFCOM,LE,0,01)GO TO 870
      PWTYPE#1,0
      DO 865 I#1,13
  865 CONCS(I)#XP2(I)
      CONCS(14)#6,8E=6
      CONCS(15)#6,4E=6
      RSTAR#,3617
      IF(AFPTEG,EQ,1,0) GO TO 890
      IF(ABS(XLI=4,5E5),GT,,5001E5) GO TO 890
      IF(ABS(TOSTFL=1,5E7),GT,,2001E7) GO TO 890
      IF(ABS(THO=7,5E4),GT,2,5001E4) GO TO 890
      IF(ABS(FFCOM=,65),GT,,1001) GO TO 890
      GO TO 896
  870 PWTYPE#2,0
      DO 875 I#1,13
  875 CONCS(I)#XP2(I)
      CONCS(14)#1,1E=4
      CONCS(15)#6,5E=5
      RSTAR#,02
      IF(AFPTEG,EQ,1,0) GO TO 890
      IF(ABS(XLI=4,5E5),GT,,5001E5) GO TO 890
      IF(ABS(TOSTFL=1,5E7),GT,,2001E7) GO TO 890
      IF(ABS(THO=9E3),GT,1,001E3) GO TO 890
      IF(ABS(FFCOM=,005),GT,,005001) GO TO 890
      GO TO 896
  880 PWTYPE#3,0
      DO 885 I#1,13
  885 CONCS(I)#XP2(I)
      CONCS(14)#1,3E=7
      CONCS(15)#1,8E=7
      IF(AFPTEG,EQ,1,0)GO TO 890
      IF(ABS(TOSTFL=1,5E7),GT,,2001E7) GO TO 890
```

```
      IF(ABS(FFCOM-.65).GT..1001) GO TO 890
      GO TO 896
  890 RHAL3=(TBD*PHRISC+.9*CON*TOSTFL*FFCOM)/ALI
      DO 895 I=1,15
      IF(I.GT.13)GO TO 892
      CONCS(I)=CONCS(I)*1.5E7/TOSTFL*(CONCP(I)/XP1(I))
      GO TO 895
  892 KATH=3.7
      IF(PATYPE.EQ.3.0)GO TO 893
      CONCS(I)=CONCS(I)*(4.5E5/ALI )*(RSTAN+DECOM(I))/(RHAL3+DECOM(I))*
     1(CONCP(I)/XP1(I))
      GO TO 895
  893 CONCS(I)=CONCS(I)*(8.77E6/(ALI*RHAL3))*(CONCP(I)/XP1(I))
  895 CONTINUE
  896 PNOV=PNOV1/CONVOL*60.
C
C     THIS PART OF PROGRAM IS FOR NOBLE GASES
      CRYO=0.0
      DO7I=1,15
      X2(I)=(DECON(I)+PNOV/3600.)*T1
      IF (X2(I).GT.75.) X2(I)=75.
      X3(I) = DECON(I) * T3
      IF(X3(I).GT.75.) X3(I) = 75.
C
      X4(I) = DECON(I) * T4
      IF(X4(I).GT.75.) X4(I) = 75.
C
      X5(I) = DECON(I) * T5
      XDK=X5(I)
      IF(X5(I).GT.75.) X5(I) = 75.
      XCRYO=DECON(I)*600.
      IF(XCRYO.GT.75.)  XCRYO=75.
C
      IF(I.GT.13)GO TO 1030
C
      IF(I.GT.6) XDK=X4(I)
      IF(KCRYO.EQ.1)  CRYO=2.5E-4
      IF(I.GT.6.AND.KCRYO.EQ.1)  CRYO=1.0E-4
      CTPRO(I)=(CONCP(I)*PRIVOL*CLFAG)/(DECOM(I)+PNOV)*1.892E-5
      ACONT(I)=CTPRO(I)*(1.-EXP(-X2(I)))
      ASHIM(I)=(CONCP(I)*SRB)/DECOM(I)*4.54E-4*(1.-EXP(-X3(I)))
      AXBL(I)=CONCP(I)*AJXLR*.1657*OPFRA
      CBCP(I)=  EN * PNOV * (CTPRO(I)*T1/3600.+CTPRO(I)*(EXP(-X2(I))-1.)
     1/(DECOM(I)+PNOV))
      CBSP(I)=EN*ACONT(I)
      CBL(I)=CBCP(I)+CBSP(I)
      ASHIMC(I)=PE*ASHIM(I)*(EXP(-XDK)+CRYO*EXP(-XCRYO))*OPFRA
      ASHIMS(I)=EM*CONCP(I)*PRIVOL*4.54E-4*(EXP(-XDK)+CRYO*EXP(-XCRYO))
      EJT(I)=CONCS(I)*TOSTFL*3.977*OPFRA
      TBL(I)=CONCS(I)*TBLK*3.977*OPFRA
      BVOG(I)=0.0
      TEST=1.0
      IF(CBL(I).LT.TEST)CBL(I)=0.0
      IF(ASHIMS(I).LT.TEST)ASHIMS(I)=0.0
      IF(ASHIMC(I).LT.TEST)ASHIMC(I)=0.0
      IF(EJT(I).LT.TEST)EJT(I)=0.0
      IF(TBL(I).LT.TEST)TBL(I)=0.0
      IF(AXBL(I).LT.TEST)AXBL(I)=0.0
      GO TO 1031
C
C     THIS PART OF PROGRAM IS FOR IODINE
```

```
C
 1030 CTPRO(I)=(CONCP(I)*PRIVOL*CLFI)/(DECOM(I)*PNOV)*1.892E-5
      ACONT(I)=CTPRO(I)*(1.-EXP(-X2(I)))
      AXBL(I)=CONCP(I)*AUXLR*.1657*OPFRA*FAUX
      ASHIMC(I)=0.0
      ASHIMS(I)=0.0
      CBCP(I)=  EN * PNOV * ((CTPRO(I)*T1/3600.+CTPRO(I)*(EXP(-X2(I))-1.)
     1/(DECOM(I)*PNOV))*FPFR
      CBSP(I)=EN*ACONT(I)*FPF
      CBL(I)=CBCP(I)+CBSP(I)
      FVI=0.05
      EJT(I)=CONCP(I)*GENL*FVI*FEJ*.1657*OPFRA
      TBL(I)=CONCS(I)*CON*THLK*3.977*OPFRA
      BVOG(I)=CONCS(I)*THO*FVN*3.977*OPFRA
      IF(KID.EQ.0) GO TO 4002
      DLAK=((CFM*57./CONVOL)+DECOM(I))
      EXX2=DLAK*PORTIM
      IF(EXX2.GT.75.)EXX2=75.
      EXPF=EXP(-EXX2)
      EXPC=1.-EXPF
      ELSS=FPF*CONCP(I)*PRIVOL*CLFI*1.892E-5/DLAK*EXPC
      CBL(I)=CBSP(I)*EXPF+ELSS*EN+CBCP(I)*(1.-PORTIM/(8760.*OPFRA/EN))
 4002 TEST=0.0001
      IF(CBL(I).LT.TEST)CBL(I)=0.0
      IF(EJT(I).LT.TEST)EJT(I)=0.0
      IF(BVOG(I).LT.TEST)BVOG(I)=0.0
      IF(TBL(I).LT.TEST)TBL(I)=0.0
      IF(AXBL(I).LT.TEST)AXBL(I)=0.0
C
 1031 CONTINUE
C
    7 CONTINUE
      MSIG=1
      NSIG=15
      CALL SIGF2(CBL)
      CALL SIGF2(ASHIMS)
      CALL SIGF2(ASHIMC)
      CALL SIGF2(EJT)
      CALL SIGF2(BVOG)
      CALL SIGF2(TBL)
      CALL SIGF2(AXBL)
      DO 1035 I=1,15
      TOT(I)=CBL(I)+EJT(I)+TBL(I)+AXBL(I)+BVOG(I)+ASHIMC(I)+ASHIMS(I)
 1035 CONTINUE
      CALL SIGF2(TOT)
      WRITE(51,906)
      WRITE(51,903)NAME
      WRITE(51,1051)
 1051 FORMAT(1H0,67X,'GASEOUS RELEASE RATE - CURIES PER   AR')
      WRITE(51,1052)
 1052 FORMAT(1H0,11X,'PRIMARY',4X,'SECONDARY',7X,'GAS STRIPPING',11X,
     1'BUILDING VENTILATION'/12X,'COOLANT',5X,'COOLANT',5X,21('-').
     24X,30('-'),5X,'BLOWDOWN   AIR EJECTOR   TOTAL'/10X,'(MICROCI/GM)(M
     3ICROCI/GM  SHUTDOWN   CONTINUOUS   REACTOR   AUXILIARY   TURBINE
     4   VENT OFFGAS   EXHAUST')
      WRITE(51,1053)
 1053 FORMAT(1H0,'--------------------------------------------------------
     1------------------------------------------------------------------
     2-----------')
 1054 FORMAT('0 ',A8,2(2X,1PE10.3),8(3X,1PE8.1,1X))
      GASTOT=0.0
```

```
      DO 490 I=1,13
      WRITE(51,1054)NUCLID(I),CONCP(I),CONCS(I),ASHIMS(I),ASHIMC(I),
     1CBL(I),AXBL(I),TBL(I),BVUG(I),EJT(I),TOT(I)
      GASTOT=GASTOT+TOT(I)
  490 CONTINUE
      DIV=10,**(INT(ALOG10(GASTOT))-1)
      GASTOT=AINT(GASTOT/DIV+0,5)*DIV
      WRITE(51,1055) GASTOT
 1055 FORMAT(1H0,'  TOTAL NOBLE GASES',101X,1PE8,1)
      DO 492 I=14,15
      WRITE(51,1054)NUCLID(I),CONCP(I),CONCS(I),ASHIMS(I),ASHIMC(I),
     1CBL(I),AXBL(I),TBL(I),BVUG(I),EJT(I),TOT(I)
  492 CONTINUE
      WRITE(51,215)IM3RLG
      WRITE(51,1053)
      WRITE(51,231)
      WRITE (51,906)
      WRITE (51,903)NAME
      WRITE(51,1060)
      WRITE(51,1061)
      WRITE(51,1053)
 1060 FORMAT(1H0,54X,'AIRBORNE PARTICULATE RELEASE RATE-CURIES PER YEAR'
     1)
 1061 FORMAT(1H0,36X,'WASTE GAS',16X,'BUILDING VENTILATION'/2X,'NUCLIDE'
     1,28X,'SYSTEM',14X,'REACTOR      AUXILIARY',15X,'TOTAL')
      GM=8760,*UPFRA/EN
      DO 1070 I=1,8
      PRCONT(I)=PCBP(I)/(1E3*8760,*UPFRA)
      IF(PNOV,GT,0,0) GO TO 1067
      PCBCP(I)=0,0
      PCBSP(I)=EN*PRCONT(I)*GM*CSHEPA
      GO TO 1068
 1067 PCBCP(I)=(EN*(GM*PRCONT(I)-PRCONT(I)/PNOV*(1,-EXP(-PNOV*GM))))
     1*CNHEPA
      PCBSP(I)=(EN*(PRCONT(I)/PNOV*(1,-EXP(-PNOV*GM))))*CSHEPA
 1068 PCBL(I)=PCBCP(I)+PCBSP(I)
      PAXBL(I)=PAXBP(I)/1E3*AXHEPA
      PGWL(I)=PGWS(I)/1E3*GWHEPA
      IF (KID,EQ,0) GO TO 1070
      POLAK=CFM*41,6/CONVOL
      PEXX2=POLAK*PURTIM
      IF(PEXX2,GT,75,) PEXX2=75,
      PEXPF=EXP(-PEXX2)
      PEXPC=1,-PEXPF
      PELSS=PRCONT(I)/POLAK*PEXPC*CSHEPA
      PCBL(I)=PCBSP(I)*PEXPF+PELSS*EN+PCBCP(I)*(1,-PURTIM/(8760,*UPFRA/E
     1N))
 1070 CONTINUE
      MSIG=2
      NSIG=8
      CALL SIGF2(PCBL)
      DO 1075 I=1,8
      PTOTP(I)=PCBL(I)+PAXBL(I)+PGWL(I)
 1075 CONTINUE
      CALL SIGF2(PTOTP)
      DO 1076 I=1,8
      WRITE(51,1062)PPART(I),PGWL(I),PCBL(I),PAXBL(I),PTOTP(I)
 1076 CONTINUE
 1062 FORMAT(1H0,A8,28X,1PE8,1,11X,1PE8,1,4X,1PE8,1,16X,1PE8,1)
      WRITE(51,1053)
      GO TO 80
```

```
      END
      SUBROUTINE SIGF2(RLPT)
      COMMON MSIG,NSIG
      DIMENSION RLPT(NSIG)
      IF (MSIG.EQ.2) GO TO 30
      DO 20 I=1,NSIG
      IF (RLPT(I).EQ.0.0) GO TO 20
      IF (I.GT.13) GO TO 10
C     THIS PART OF SUBROUTINE IS FOR NOBLE GASES
      DIV=10.**(INT(ALOG10(RLPT(I)))-1)
      IF (RLPT(I).LT.10.) DIV=1.00
      RLPT(I)=AINT(RLPT(I)/DIV+0.5)*DIV
      GO TO 20
C     THIS PART OF SUBROUTINE IS FOR IODINE
   10 CONTINUE
      ISUB=2
      IF(RLPT(I).GT.1.0)ISUB=1
      DIV=10.**(INT(ALOG10(RLPT(I)))-ISUB)
      RLPT(I)=AINT(RLPT(I)/DIV+0.5)*DIV
   20 CONTINUE
   30 CONTINUE
C     THIS PART OF SUBROUTINE IS FOR PARTICULATES
      DO 50 I=1,NSIG
      IF (RLPT(I).EQ.0.) GO TO 50
      DIV=10.**(INT(ALOG10(RLPT(I)))-2)
      RLPT(I)=AINT(RLPT(I)/DIV+0.5)*DIV
   50 CONTINUE
      RETURN
      END
```

```
C      GALE CODE FOR CALCULATING LIQUID  EFFLUENTS FROM LWRS.  MODIFIED
C     JULY 1975 TO IMPLEMENT APPENDIX I TO 10 CFR PART 50.  REACTOR
C     WATER CONCENTRATIONS CALCULATED USING METHODS OF DRAFT STANDARD
C     ANS 237 'RADIOACTIVE MATERIALS IN PRINCIPAL FLUID STREAMS OF
C     LIGHT WATER COOLED NUCLEAR POWER PLANTS'  DRAFT DATED MAY 20, 1974
C     MODIFIED EDITION OF ORIGEN PROGRAM TO COMPUTE EFFLUENTS FROM BWR
C     AND PWR RADWASTE SYSTEMS
C
      LOGICAL DISCHG,POWRIT
      INTEGER*2 LOC,NONO,KD
      REAL*4 LETDWN,NOGEN
      REAL*4 LETDWA
      REAL KKR,KXE,KNU,KMASS
      INTEGER*2 NAME(3)
      COMMON/MATRIX/A(2500),LOC(2500),NONO(800),KD(800)
      COMMON/FLEX/FLUX(10),MMN,MOUT,INDEX,NXN,AXN,ERR,NOBLND,MZERO
      COMMON/PROCSS/  NPROS,PRATE(8),NUPROS(8),NZPROS(8,20),PR(800)
      COMMON/EQ/XZERO(800), XZM(800),XTEMP(800),XNEW(10,800),
     1       B(800),D(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),W(800),FG(800),CUTOFF(7),
     1 POW,BURNUP,FLUXB,MSTAR,ALPHAN(100),SPONF(100),ABUND(800),
     2 BASIS(10),TCONST,TUNIT
      COMMON/CONC/PCONC(800),DWCONC(800),CWCONC(800),CMCONC(800),
     1      SCON(800),RINV(800)
      COMMON/COOL/REACTR,POWI,TYPE,PCVOL,LETDWN,NOGAS,SCVOL,STMVOL,NOGEN
     1              ,NPURGE,NVLSPG,SHLUR,GASDLA,STLKR,BLWDWN,EJCTR,WLKRAT,
     2              GASLKR,CONDLR,DFWBDM,DFCBDM,NZWBDM,NZCBDM,NE,PF,
     3              STMFR,FPEF,MEF,FFCOM,DFMBCS,CMFLR,DFI,DFCS,DF,
     4              EDFLR,DFIED,DFCSED,DFED,DWFLR,DFIDW,DFCSDW,DFDW,DILUT
     5             ,SBA,EDA,DWA,CWFLR,CMPFR,CWA,CMA,DFCM,DFICM,DFCSCM,
     6              DFCW,DFICW,DFCSCW,MHOLD,MHOLDE,MHOLDW,MHOLCM,MHOLDC
     7             ,HDTFR,DFIHD,DFCSHD,DFHD,MHOLDB,REGENT,
     8               SHFD,DFMD,DFY,EDFD,DFMDED,DFYED,DWFD,DFMDDW,DFYDW,
     9               DFMDBD,DFYHD,CWFD,DFMDCW,DFYCW,CMFD,DFMDCM,DFYCM
     A   ,TS,TE,TD,TB,TC,TCM,TSTORC,TSTORD,TSTORB,TMSC,DWFL2,DW2,DWF2,
     B  T2,TSTOR2,DFID2,DFCSD2,DFMDD2,DFYD2,DFD2,PFLAUN
      COMMON/APCOOL/RGWFR,DFIRG,DFCSRG,DFRG,TRG,TSTORR,RGFD
      COMMON/BDTES/REPRT
      COMMON /CONB/BCONC(800)
      COMMON/CONP/PWCONC(800),SCUTV(800),SCUTP(800),SCOT(800)
      DIMENSION WORD13(4), WORD15(4),WORD18(5),WORD23(6),WORD28(7),
     1           WORD33(9),WORD10(3),WORD8(2),WORD40(10)
      DIMENSION REACTR(7),NZWBDM(26),NZCBDM(26)
      DIMENSION FACT(10),XCOMP(20),INUCL(20)
      DATA YES/'YES'/
C     BCONC CONTAINS PRIMARY COOLANT CONCENTRATIONS FOR BWR'S. THE
C     FOLLOWINFISOTOPES(WITH THEIR CONCENTRATIONS IN UCI/GM) ARE
C     ALSO PRESENT IN THE PRIMARY COOLANT BUT ARE NOT CONSIDERED
C     SIGNIFICANT IN EFFLUENT CALCULATIONS;N-13,.05;N-16,60;N-17,.009;
C     O-19,.7;F-18,.004.
C     PWCONC CONTAINS PRIMARY COOLANT CONCENTRATIONS FOR PWR'S.  SCUTV,
C     SCUTP, AND SCOT CONTAIN SECONDARY COOLANT CONCENTRATIONS FOR
C     PLANTS WITH U-TUBE STEAM GENERATORS AND VOLATILE SECONDARY CHEM-
C     ISTRY; FOR PLANTS WITH U-TUBE STEAM GENERATORS AND PHOSPHATE
C     SECONDARY CHEMISTRY; AND FOR PLANTS WITH ONCE-THROUGH STEAM
C     GENERATORS, RESPECTIVELY.
      DATA NTRY,NTER/0,0/,PWR/' PWR'/,BWR/' BWR'/
C
```

```
C     READ NUCLEAR DATA AND CONSTRUCT TRANSITION MATRIX
C
 10   CALL NUDATA(NLINE)
C
      DO 20 I=2,ITOT
      NONO(I)=NONO(I)+NONO(I-1)
 20   KD(I)=KD(I)+NONO(I-1)
 30   DISCHG=.FALSE.
      POWRIT=.FALSE.
      KT=0
      INDEX=0
      FLXB=0.0
      PWRH=0.0
      BURN=0.0
      BOTFR=1.0
      QXN=0.001
      AXN=-ALOG(QXN)
      NE=ITOT
      TCONST=86400.
      FDA=0.0
      TMSC=0.0
      TE=0.0
      TS=0.0
      T2=0.0
      TSTOR2=0.0
      DWFL2=0.0
      DW2=0.0
      DWF2=0.0
      DO 40 J=1,800
      PCONC(J)=0.0
      DWCONC(J)=0.0
      SCUN(J)=0.0
      RINV(J)=0.0
      CWCONC(J)=0.0
      CMCONC(J)=0.0
      XZH(J)=0.0
   40 CONTINUE
C
C     READ DESCRIPTION OF REACTOR AND RADWASTE TREATMENT PLANT
C
      DIMENSION WORD56(14)
      PRINT 9026
      READ 9010,REACTR,TYPE
      PRINT 9010,REACTR,TYPE
      READ 9011,WORD56,POWI
      PRINT 9011,WORD56,POWI
      PF=0.80
      PRINT 9027
      IF(TYPE.EQ.BWR) GO TO 50
C     READ DATA FOR PWR LIQUID CODE
      READ 9022,WORD56,PCVOL
      PRINT 9022,WORD56,PCVOL
  600 FAIL=0.12
      PRINT 9028,FAIL
      READ 9012,WORD56,LETDWN
      PRINT 9012,WORD56,LETDWN
      READ 9012,WORD56,CBFLR
      PRINT 9012,WORD56,CBFLR
      READ 9011,WORD56,NOGEN
      PRINT 9011,WORD56,NOGEN
      READ 9022,WORD56,STMFR
```

```
      PRINT 9022,WORD56,STMFR
      READ 9022,WORD56,WST
      PRINT 9022,WORD56,WST
      READ 9022,WORD56,WLI
      PRINT 9022,WORD56,WLI
      SCVOL=NOGEN*WLI
      PRINT 9029,SCVOL
      READ 9011,WORD56,TMSC
      PRINT 9011,WORD56,TMSC
      READ 9055,BLWDWN,KFNRT
      PRINT 9051,BLWDWN
      RFNRT=KFNRT
      IF(RFNRT.GT.1.0) RFNRT=1.0
      PRINT  9041
      READ 9012,WORD56,REGENT
      PRINT 9012,WORD56,REGENT
      IF(BLWDWN.EQ.0.0) GO TO 41
      FPEF=0.001
      HEF=0.01
      PRINT 9030,FPEF,HEF
      GO TO 44
   41 FPEF=1.0
      HEF=1.0
      PRINT 9030,FPEF,HEF
   44 CONTINUE
      READ 9020,WORD56,FFCDM
      PRINT 9020,WORD56,FFCDM
      IF(FFCDM.LT.0.001)GO TO 4444
      DFCH=10.0
      DFCHCS=2.0
      GO TO 4445
 4444 DFCH=1.0
      DFCHCS=1.0
 4445 CONTINUE
      READ 9011,WORD56,DILUT
      PRINT 9011,WORD56,DILUT
      READ 9056,WORD18,SBLDR
      CWA=1.0
      READ 9014,DFICW,DFCSCW,DFCW
      READ 9015,TC,TSTORC,CWFD
      PRINT 9045
      PRINT 9016
      PRINT 9017,WORD18,SBLDR,CWA,CWFD,TC,TSTORC,DFICW,DFCSCW,DFCW
      READ 9013,WORD18,EDFLR,WORD8,EDA
      READ 9014,DFIED,DFCSED,DFED
      READ 9015,TE,TS,EDFD
      PRINT 9017,WORD18,EDFLR,EDA,EDFD,TE,TS,DFIED,DFCSED,DFED
      READ 9013,WORD18,DWFLR,WORD8,DWA
      READ 9014,DFIDW,DFCSDW,DFDW
      READ 9015,TD,TSTORD,DWFD
      PRINT 9017,WORD18,DWFLR,DWA,DWFD,TD,TSTORD,DFIDW,DFCSDW,DFDW
      READ 9013,WORD18,DWFL2,WORD8,DW2
      READ 9014,DFID2,DFCSD2,DFD2
      READ 9015,T2,TSTOR2,DWF2
      PRINT 9017,WORD18,DWFL2,DW2,DWF2,T2,TSTOR2,DFID2,DFCSD2,DFD2
      READ 9037,HDTFR
      READ 9014,DFICM,DFCSCM,DFCM
      READ 9015,TCM,TSTORH,CHFD
      READ 9037,RGWFR
      READ 9014,DFIRG,DFCSRG,DFRG
      READ 9015,TRG,TSTORR,RGFD
```

```
      IF(BLWDWN,EQ,0,0) GO TO 45
      BDFR=BLWDWN*1E3*BDTFR/0,3476
      PRINT 9034,BDFR,CMFD,TCM,TSTORM,DFICM,DFCSCM,DFCM
      BDFR=BLWDWN*1,0E3*ABS(1,-BDTFR)/0,3476
      PRINT 9035,BDFR
      IF(FFCDM,EQ,0,0) GO TO 46
   45 CONTINUE
      IF(REGENT,EQ,0,0) GO TO 47
      PRINT 9038,RGWFR,RGFD,TRG,TSTORM,DFIRG,DFCSRG,DFRG
      GO TO 46
   47 RGWFR=0,0
      PRINT 9038,RGWFR,RGFD,TRG,TSTORM,DFIRG,DFCSRG,DFRG
   46 CONTINUE
      IF([illegible],EQ,0) GO TO 4446
      FNRTSD=1,0-1,0/(DFCM*DFCM)
      FNRTSI=1,0-1,0/(DFICM*DFCM)
      FNRTSC=1,0-1,0/(DFCSCM*DFCMCS)
      GO TO 4447
 4446 FNRTSD=1,0
      FNRTSI=1,0
      FNRTSC=1,0
 4447 CONTINUE
C
C     READ DATA FOR PWR GAS CODE
C
      PRINT 9046
      READ 9021,KGTRMT
      IF (KGTRMT,EQ,0) PRINT 9053
      IF (KGTRMT,EQ,1) PRINT 9052
      IF (KGTRMT,EQ,2) PRINT 9075
      READ 9012,WORD56,TAU1
      PRINT 9012,WORD56,TAU1
      READ 9012,WORD56,TAU2
      PRINT 9012,WORD56,TAU2
      READ 9012,WORD56,TAU3
      PRINT 9012,WORD56,TAU3
      GWHEPA=1,0
      FRIAR=1,0
      AXHEPA=1,0
      FPFP=1,0
      CSHEPA=1,0
      FPFPN=1,0
      CNHEPA=1,0
      READ 9065,WORD15,GWHT
      IF(GWHT,EQ,YES)GWHEPA=0,01
      PRINT 9066,WORD15,GWHEPA
      READ 9067,WORD18,AXCH,AXHT
      IF(AXCH,EQ,YES)FRIAR=0,1
      IF(AXHT,EQ,YES)AXHEPA=0,01
      PRINT 9068,WORD18,FRIAR,AXHEPA
      READ 9022,WORD56,CONVOL
      PRINT 9022,WORD56,CONVOL
      READ 9022,WORD56,CFM
      PRINT 9022,WORD56,CFM
      READ 9071,WORD18,CSCH,CSHT,EXPO
      IF(CSCH,EQ,YES)FPFP=0,1
      IF(CSHT,EQ,YES)CSHEPA=0,01
      EN=4,0+EXPO
      PRINT 9072,EN
      PRINT 9068,WORD18,FPFP,CSHEPA
      READ 9069,WORD18,PNOV1,CNCH,CNHT
```

```
      IF(CNCM.EQ.YES)FPFRN=0.1
      IF(CNHT.EQ.YES)CNHEPA=0.01
      IF (PNOV1.LT.1.0) GO TO 4448
      PRINT 9070,WORD18,PNOV1,WORD18,FPFRN,CNHEPA
      GO TO 4449
 4448 PRINT 9073
 4449 CONTINUE
      TALK=1700.
      PRINT 9064,TALK
      READ 9020,WORD56,FVN
      PRINT 9020,WORD56,FVN
      READ 9020,WORD56,FEJ
      PRINT 9020,WORD56,FEJ
      KCRYO=0.0
      IF(KCRYO.EQ.0.0) GO TO 48
      PRINT 9039
      GO TO 49
   48 PRINT 9040
   49 CONTINUE
      READ 9020,WORD56,PFLAUN
      IF(PFLAUN.LE.0.0)  PRINT 9048
      PRINT 9026
C
C     CONVERSION OF UNITS
C
      EDFLR=EDFLR*48.8
      DWFLR=DWFLR*48.8
      DWFL2=DWFL2*48.8
      GO TO 240
C
C     READ DATA FOR BWR LIQUID CODE
C
   50 READ 9022,WORD56,STMFR
      PRINT 9022,WORD56,STMFR
      READ 9022,WORD56,PCVOL
      PRINT 9022,WORD56,PCVOL
      FPEF=0.001
      HEF=0.020
      PRINT 9030,FPEF,HEF
      READ 9022,WORD56,LETDWN
      PRINT 9022,WORD56,LETDWN
      READ 9022,WORD56,REGENT
      PRINT 9022,WORD56,REGENT
      READ 9022,WORD56,FFCOM
      PRINT 9022,WORD56,FFCOM
      READ 9022,WORD56,DILUT
      PRINT 9022,WORD56,DILUT
      PRINT 9045
      READ 9013,WORD18,CWFLR,WORD8,CWA
      READ 9014,DFICW,DFCSCW,DFCW
      READ 9015,TC,TSTORC,CWFD
      PRINT 9016
      PRINT 9017,WORD18,CWFLR,CWA,CWFD,TC,TSTORC,DFICW,DFCSCW,DFCW
      READ 9013,WORD18,DWFLR,WORD8,DWA
      READ 9014,DFIDW,DFCSDW,DFDW
      READ 9015,TD,TSTORD,DWFD
      PRINT 9017,WORD18,DWFLR,DWA,DWFD,TD,TSTORD,DFIDW,DFCSDW,DFDW
      READ 9013,WORD18,CMWFR,WORD8,CMA
      READ 9014,DFICM,DFCSCM,DFCM
      READ 9015,TCM,TSTORH,CMFD
      PRINT 9017,WORD18,CMWFR,CMA,CMFD,TCM,TSTORH,DFICM,DFCSCM,DFCM
```

```
      READ 9037,RGWFR
      READ 9014,DFIRG,DFCSRG,DFRG
      READ 9015,TRG,TSTORR,RGFD
      PRINT 9038,RGWFR,RGFD,TRG,TSTORR,DFIRG,DFCSRG,DFRG
C
C     READ DATA FOR BWR GAS CODE
C
      PRINT 9046
      READ 9022,WORD56,GGS
      PRINT 9022,WORD56,GGS
      READ 9022,WORD56,WSTE
      PRINT 9022,WORD56,WSTE
      READ 9011,WORD56,TIM3
      PRINT 9011,WORD56,TIM3
      READ 9011,WORD56,TIM4
      PRINT 9011,WORD56,TIM4
      HEPA1=1,0
      FIL1=1,0
      HEPA2=1,0
      FIL2=1,0
      HEPA5=1,0
      FIL5=1,0
      HEPA6=1,0
      FIL6=1,0
      CSRF=1,0
      READ 9060,WORD15,CRCH,CRHEPA
      IF(CRCH,EQ,YES)FIL1=0,1
      IF(CRHEPA,EQ,YES)HEPA1=0,01
      PRINT 9061,WORD15,FIL1,HEPA1
      READ 9062,WORD15,TBCH,TBHEPA,TBCS
      IF(TBCH,EQ,YES)FIL2=0,1
      IF(TBHEPA,EQ,YES)HEPA2=0,01
      IF(TBCS,EQ,YES)CSRF=0,2
      PRINT 9063,WORD15,FIL2,HEPA2,CSRF
      READ 9022,WORD56,FIL3
      PRINT 9022,WORD56,FIL3
      READ 9022,WORD56,FIL4
      PRINT 9022,WORD56,FIL4
      READ 9060,WORD15,AXCH,AXHEPA
      IF(AXCH,EQ,YES)FIL5=0,1
      IF(AXHEPA,EQ,YES)HEPA5=0,01
      PRINT 9061,WORD15,FIL5,HEPA5
      READ 9060,WORD15,RWCH,RWHEPA
      IF(RWCH,EQ,YES)FIL6=0,1
      IF(RWHEPA,EQ,YES)HEPA6=0,01
      PRINT 9061,WORD15,FIL6,HEPA6
      READ 9021,KCHAR
      READ 9012,WORD56,KKR
      READ 9011,WORD56,KXE
      READ 9012,WORD56,KNO
      READ 9022,WORD56,KMASS
      IF(KCHAR,EQ,0) GO TO 54
      IF(KCHAR,EQ,1) GO TO 55
      PRINT 9023
      GO TO 56
   54 PRINT 9024
      GO TO 56
   55 F=10,*KNO
      CHTI1=(0,53*KKR*KMASS)/(F*24,*2,)
      CHTI2=(0,53*KXE*KMASS)/(F*24,*2,)
      PRINT 9025,KKR,KXE,KNO,KMASS,CHTI1,CHTI2
```

```
   56 CONTINUE
      READ 9020,WORD56,PFLAUN
      IF(PFLAUN.LE.0.0)  PRINT 9048
      PRINT 9026
   57 DO 58 I=1,ITOT
      B(I)=0.0
   58 CONTINUE
C
      DFIED=1.
      DFCSED=1.
      DFED=1.
      DFID2=1.
      DFCSD2=1.
      DFD2=1.
  240 CONTINUE
C
C     CALCULATE PRIMARY COOLANT CONCENTRATIONS FOR PWRS
C
      IF(TYPE.EQ.BWR)GO TO 251
      AFPTES=0.0
      DO 242 I=1,ITOT
  242 PCONC(I)=PWCONC(I)
      POWA=POW1
      PCVOA=PCVOL*1E3
      LETDWA=LETDWN*500.53
      SBLDA=SBLDR*.3476
      CBFLA=CBFLR*500.53
C     CHECK TO SEE IF PRIMARY PLANT PARAMETERS ARE WITHIN SPECIFIED
C     RANGES
      IF(ABS(POWA-3400).GT.400.1)GO TO 243
      IF(ABS(PCVOA-5.5E5).GT.0.5001E5)GO TO 243
      IF(ABS(LETDWA-3.7E4).GT.0.5001E4)GO TO 243
      IF(ABS(SBLDA-625.).GT.375.1)GO TO 243
      IF(ABS(CBFLA-3750.).GT.3750.1)GO TO 243
      GO TO 247
C     CALCULATE PWR PRIMARY COOLANT ADJUSTMENT FACTORS
  243 AFPTES=1.0
      RHAL2=(LETDWA*0.9+0.1*SBLDA)/PCVOA
      RCSRH2=(LETDWA*0.5+0.5*(SBLDA+CBFLA*0.9))/PCVOA
      RCFP2=(LETDWA*0.9+0.1*(SBLDA+CBFLA*0.9))/PCVOA
      RK2=161.76*POWA/PCVOA
      DO 246 J=1,ITOT
      IF(PCONC(J).EQ.0.0) GO TO 246
      NZ=NUCL(J)/10000
      DL=DIS(J)*3600.
      IF(NZ.EQ.53.OR.NZ.EQ.35)GO TO 244
      IF(NZ.EQ.37.OR.NZ.EQ.55)GO TO 245
      PCONC(J)=PCONC(J)*RK2*(0.0612+DL)/(RCFP2+DL)
      GO TO 246
  244 PCONC(J)=PCONC(J)*RK2*(0.0606+DL)/(RHAL2+DL)
      GO TO 246
  245 PCONC(J)=PCONC(J)*RK2*(0.0371+DL)/(RCSRH2+DL)
  246 CONTINUE
  247 SBLDR=SBLDR*48.8
      PCVOL=PCVOL*1000.*0.7/62.4
C     CALCULATE PWR SECONDARY COOLANT CONCENTRATIONS
      SCVOA=SCVOL*1E3
      BLWDWA=BLWDWN*1E3
      STMFA=STMFR*1E6
      FFCDA=FFCDM
C     CHECK TO SEE IF SECONDARY PLANT PARAMETERS ARE WITHIN SPECIFIED
```

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C     RANGES
      IF(BLWDWN.EQ.0.0) GO TO 263
      IF(FFCDM.LE.0.01) GO TO 261
C     PWTYPE=2.0 IS A PLANT WITH U-TUBE STEAM GENERATORS AND VOLATILE
C     SECONDARY CHEMISTRY
      PWTYPE=2.0
      DO 260 I=1,ITOT
  260 SCON(I)=SCUTV(I)
      IF(AFPTES.EQ.1.0) GO TO 266
      IF(ABS(SCVDA-4.5E5).GT.0.5001E5)GO TO 266
      IF(ABS(STMFA-1.5E7).GT.0.2001E7)GO TO 266
      IF(ABS(BLWDWA-7.5E4).GT.2.5001E4)GO TO 266
      IF(ABS(FFCDA-0.65).GT.0.10001)GO TO 266
      IF(FNRTSC.LT.0.8999)GO TO 2278
      GO TO 278
C     PWTYPE=3.0 IS A PLANT WITH U-TUBE STEAM GENERATORS AND PHOSPHATE
C     SECONDARY CHEMISTRY
  261 PWTYPE=3.0
      DO 262 I=1,ITOT
  262 SCON(I)=SCUTP(I)
      IF(AFPTES.EQ.1.0)  GO TO 266
      IF(ABS(SCVDA-4.5E5).GT.0.5001E5)GO TO 266
      IF(ABS(STMFA-1.5E7).GT.0.2001E7)GO TO 266
      IF(ABS(BLWDWA-9E3).GT.1.001E3)GO TO 266
      IF(ABS(FFCDA-.005).GT.0.005001)GO TO 266
      IF(FNRTSC.LT.0.8999)GO TO 2278
      GO TO 278
C     PWTYPE=1.0 IS A PLANT WITH ONCE-THROUGH STEAM GENERATORS
  263 PWTYPE=1.0
      DO 264 I=1,ITOT
  264 SCON(I)=SCOT(I)
      IF(AFPTES.EQ.1.0) GO TO 266
      IF(ABS(STMFA-1.5E7).GT.0.2001E7)GO TO 266
      IF(ABS(FFCDA-0.65).GT.0.10001)GO TO 266
      GO TO 278
C     CALCULATE PWR SECONDARY COOLANT ADJUSTMENT FACTORS
  266 RHAL3=(BLWDWA*FNRTSI+0.9*HEF*STMFA*FFCDA)/SCVDA
      RCSRB3=(BLWDWA*FNRTSC+0.5*FPEF*STMFA*FFCDA)/SCVDA
      RCFP3=(BLWDWA*FNRTSO+0.9*FPEF*STMFA*FFCDA)/SCVDA
      IF(PWTYPE.EQ.1.0)GO TO 274
      RK3=4.5E5/SCVDA
      IF(PWTYPE.EQ.2.0)GO TO 270
      DO 269 I=1,ITOT
      IF(SCON(I).EQ.0.0)GO TO 269
      NZ=NUCL(I)/10000
      DL=DIS(I)*3600.
      IF(NZ.EQ.53.OR.NZ.EQ.35) GO TO 267
      IF(NZ.EQ.37.OR.NZ.EQ.55) GO TO 268
      SCON(I)=SCON(I)*RK3*(.02+DL)/(RCFP3+DL)*(PCONC(I)/PWCONC(I))
      GO TO 269
  267 SCON(I)=SCON(I)*RK3*(.02+DL)/(RHAL3+DL)*(PCONC(I)/PWCONC(I))
      GO TO 269
  268 SCON(I)=SCON(I)*RK3*(.02+DL)/(RCSRB3+DL)*(PCONC(I)/PWCONC(I))
  269 CONTINUE
      GO TO 278
  270 CONTINUE
      DO 273 I=1,ITOT
      IF(SCON(I).EQ.0.0)GO TO 273
      NZ=NUCL(I)/10000
      DL=DIS(I)*3600.
      IF(NZ.EQ.53.OR.NZ.EQ.35)GO TO 271
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      IF(NZ.EQ.37.OR.NZ.EQ.55)GO TO 272
      SCON(I)=SCON(I)*RK3*(0.1862+DLD/(RCFP3+DLD*(PCONC(I)/PHCONC(I))
      GO TO 273
  271 SCON(I)=SCON(I)* RK3*(0.3617+DL)/ (RHAL3+DL)*(PCONC(I)/PHCONC(I))
      GO TO 273
  272 SCON(I)=SCON(I)*RK3*(0.1775+DLD/(RCSRB3+DLD*(PCONC(I)/PHCONC(I))
  273 CONTINUE
      GO TO 278
  274 RK3=1E5/SCVDA
      DO 277 I=1,ITOT
      IF(SCON(I).EQ.0.0)GO TO 277
      NZ=NUCL(I)/10000
      DL=DIS(I)*3600.
      IF(NZ.EQ.53.OR.NZ.EQ.35)GO TO 275
      IF(NZ.EQ.55.OR.NZ.EQ.37)GO TO 276
      SCON(I)=SCON(I)*RK3*87.75/RCFP3*(PCONC(I)/PHCONC(I))
      GO TO 277
  275 SCON(I)=SCON(I)*RK3*87.75/RHAL3*(PCONC(I)/PHCONC(I))
      GO TO 277
  276 SCON(I)=SCON(I)*RK3*48.75/RCSRB3*(PCONC(I)/PHCONC(I))
  277 CONTINUE
      GO TO 278
 2278 RCSRB3=(BLWDWA*FNRTSC+0.5*FPEF*STMFA*FFCDA)/SCVDA
      RK3=4.5E5/SCVDA
      DO 2279 I=1,ITOT
      IF(SCON(I).EQ.0.0)GO TO 2279
      NZ=NUCL(I)/10000
      IF (NZ.NE.37.AND.NZ.NE.55) GO TO 2279
      DL=DIS(I)*3600.
      RSC=.02
      IF(PWTYPE.EQ.2.0) RSC=.1775
      SCON(I)=SCON(I)*RK3*(RSC+DL)/(RCSRB3+DLD*(PCONC(I)/PHCONC(I))
 2279 CONTINUE
  278 BLWDWN=BLWDWN*1E3/500.53
      SCVOL=SCVOL*1000./62.4
      STMFR=STMFR*2000.
      DO 279 I=1,ITOT
      IF (PCONC(I).EQ.0.0)GO TO 279
      PCONC(I)=PCONC(I)/(DIS(I)*1.6283E13)
      SCON(I)=SCON(I)/(DIS(I)*1.6283E13)
  279 CONTINUE
C
C     COMPUTE REMOVAL CONSTANT FOR CONDENSATE DEMINERALIZER IN PWR
      IF(REGENT.GE.0.0) GO TO 300
      CALL EFFTAB
      GO TO 30
  300 CIXRC=(0.9*BLWDWN*RFNRT/DFCM+0.9*STMFR*FPEF*FFCDM)/(SCVOL*7.48*60.
     1)
      CIXRCS=(0.5*BLWDWN*RFNRT/DFCSCM+0.5*STMFR*FPEF*FFCDM)/(SCVOL*7.48*
     1 60.)
      CIXRIB=(0.9*BLWDWN*RFNRT/DFICM+0.9*STMFR*HEF*FFCDM)/(SCVOL*7.48*60
     1.)
      DO 305 I=1,ITOT
      NZ=NUCL(I)/10000
      PR(I)=CIXRC
      IF(NZ.EQ.37.OR.NZ.EQ.55)PR(I)=CIXRCS
      IF(NZ.EQ.53.OR.NZ.EQ.35)PR(I)=CIXRIB
      XZHJ=SCON(      I)*PR(I)*SCVOL*0.02832
      B(I)=XZHJ
      XZH(I)=XZHJ*86400.
      XZERO(I)=0.
```

```
  305 CONTINUE
C      CALCULATE RADIOISOTOPE INVENTORIES ON BWR CONDENSATE RESINS
       T(I)=REGENT
       CALL SOLVE
       DO 330 I=1,ITOT
  330  RINV(I)=XTEMP(I)
       CALL EFFTAB
       GO TO 30
C
C
  251 CONTINUE
C      CALCULATE BWR PRIMARY COOLANT CONCENTRATIONS
       DO 2251 I=1,ITOT
 2251 PCONC(I)=BCONC(I)
       POWA=POW1
       PCVOA=PCVOL*1E6
       LETDNA=LETDWN*1E6
       STMFA=STMFR*1E6
       FFCDA=FFCDM
C      CHECK TO SEE IF PLANT PARAMETERS ARE WITHIN SPECIFIED RANGES
       IF(ABS(POWA-3400),GT,400,1)GO TO 252
       IF(ABS(PCVOA-3,8E5),GT,0,4001E5)GO TO 252
       IF(ABS(LETDNA-1,3E5),GT,0,2001E5)GO TO 252
       IF(ABS(STMFA-1,5E7),GT,0,2001E7)GO TO 252
       IF(ABS(FFCDA-0,9),GT,0,1001)GO TO 252
       GO TO 256
C      CALCULATE BWR ADJUSTMENT FACTORS
  252 RHAL2=(LETDNA*0,9+FFCDA*STMFA*0,018)/PCVOA
       RCSRH2=(LETDNA*0,5+FFCDA*STMFA*5E-4)/PCVOA
       RCFP2=(LETDNA*0,9+FFCDA*STMFA*9E-4)/PCVOA
       RK2=111,76*POWA/PCVOA
       DO 255 J=1,ITOT
       IF(PCONC(J),EQ,0,0) GO TO 255
       NZ=NUCL(J)/10000
       DL=DIS(J)*3600
       IF (NZ,EQ,53,OR,NZ,EQ,35)GO TO 253
       IF (NZ,EQ,37,OR,NZ,EQ,55)GO TO 254
       PCONC(J)=PCONC(J)*RK2*(0,3434+DL)/(RCFP2+DL)
       GO TO 255
  253 PCONC(J)=PCONC(J)*RK2*(0,1908+DL)/(RCSRH2+DL)
       GO TO 255
  254 PCONC(J)=PCONC(J)*RK2*(0,1908+DL)/(RCSRH2+DL)
  255 CONTINUE
  256 PCVOL=PCVOL*1000000,/62,4
       LETDWN=LETDWN*2000,
       STMFR=STMFR*2851,
       DO 2255 J=1,ITOT
       IF (PCONC(J),GT,0,0)PCONC(J)=PCONC(J)/(DIS(J)*1,6283E13)
 2255 CONTINUE
       IF(REGENT,GT,0,0) GO TO 257
       CALL EFFTAB
       GO TO 30
C
C      COMPUTE REMOVAL CONSTANT FOR CONDENSATE DEMINERALIZER IN BWR
  257 CCBDM=0,9*STMFR*FPEF/(PCVOL*7,48*60,)*FFCDM
       CSBDM=0,5*STMFR*FPEF/(PCVOL*7,48*60,)*FFCDM
       DO 258 I=1,ITOT
       NZ=NUCL(I)/10000
       PR(I)=CCBDM
       IF(NZ,EQ,53,OR,NZ,EQ,35)PR(I)=CCBDM*HEF/FPEF
       IF(NZ,EQ,37,OR,NZ,EQ,55)PR(I)=CSBDM
```

```
      XZHJ=PCONC(I)*PH(I)*PCVOL*0.02832
      B(I)=XZHJ
      XZH(I)=XZHJ*86400.
  258 CONTINUE
      XZERO(I)=0.
C     CALCULATE INVENTORIES ON BWR CONDENSATE RESINS
 290  T(1)=REGENT
      CALL SOLVE
      DO 295 I=1,ITOT
  295 RINV(I)=XTEMP(I)
      CALL EFFTAB
      GO TO 30
C
C     FORMATS                    FORMATS                    FORMATS
C
 9000 FORMAT(20A4)
 9001 FORMAT(10E8.2)
 9002 FORMAT(8E10.3)
 9003 FORMAT(5(I6,F9.2),I5)
 9004 FORMAT(16I5)
 9005 FORMAT('0MMN OR MOUT EXCEEDS DIMENSIONS')
 9006 FORMAT('0MOUT SHOULD NOT EXCEED MMN BY MORE THAN 10'/)
 9007 FORMAT(8(E8.2,I2))
 9008 FORMAT(20I4)
 9009 FORMAT(10A4,F7.0,A3,F10.3)
 9010 FORMAT(32X,7A4,16X,A4)
 9011 FORMAT(16X,13A4,A3,F9.4)
 9012 FORMAT(16X,14A4,F8.4)
 9013 FORMAT(15X,4A4,A2,8X,F8.0,1X,A4,A2,F5.3)
 9014 FORMAT(20X,F8.0,2(5X,F8.0))
 9015 FORMAT(27X,F6.2,14X,F6.2,18X,F6.2)
 9016 FORMAT('0',30X,'FRACTION  FRACTION  COLLECTION  DECAY'/8X,'STREAM
     1     FLOW RATE   OF PCA  DISCHARGED   TIME       TIME',10X,'DECONTA
     2MINATION FACTORS'/20X,'(GAL/DAY)'23X,'(DAYS)     (DAYS)',7X,
     3'I',8X,'CS',6X,'OTHERS')
 9017 FORMAT(2X,4A4,A2,1PE9.2,1X,4(0PF8.3,2X),3(1PE9.2,1X))
 9020 FORMAT(16X,14A4,F8.4)
 9021 FORMAT(79X,I1)
 9022 FORMAT(16X,14A4,F8.4)
 9023 FORMAT(16X,'THERE IS A CRYOGENIC DISTILLATION COLUMN'/20X,'IODINE
     1AND XENON DECONTAMINATION FACTOR',T71,'10000.'/20X,'KRYPTON DECONT
     2AMINATION FACTOR',T72,'4000.'/20X,'KRYPTON AND XENON HOLDUP TIME (
     3DAYS)',T74,'90.')
 9024 FORMAT(16X,'THERE IS NO CHARCOAL DELAY SYSTEM')
 9025 FORMAT(16X,'THERE IS A CHARCOAL DELAY SYSTEM'/20X,'KRYPTON DYNAMIC
     1 ADSORPTION COEFFICIENT (CM3/GM)',T72,F9.4/20X,'XENON DYNAMIC ADSO
     2RPTION COEFFICIENT (CM3/GM)',T72,F9.4/20X,'NUMBER OF MAIN CONDENSE
     3R SHELLS',T72,F9.4/20X,'MASS OF CHARCOAL (SHORT TONS)',T72,F9.4/
     420X,'KRYPTON HOLDUP TIME (DAYS)',T72,F9.4/20X,'XENON HOLDUP TIME (
     5DAYS)',T72,F9.4)
 9026 FORMAT(1H1)
 9027 FORMAT(16X,'PLANT CAPACITY FACTOR',T75,'0.80')
 9028 FORMAT(16X,'PERCENT FUEL WITH CLADDING DEFECTS',T75,F6.4)
 9029 FORMAT(16X,'MASS OF WATER IN STEAM GENERATORS (THOUSAND LBS)',T73,
     1F8.4)
 9030 FORMAT(16X,'FISSION PRODUCT CARRY-OVER FRACTION',T75,F6.4/16X,
     1'HALOGEN CARRY-OVER FRACTION',T75,F6.4)
 9032 FORMAT(2X,7A4,F7.0,3A4,A1,F5.3,3A4,A3,I2,2A4)
 9034 FORMAT(2X,'BLOWDOWN',10X,1PE9.2,14X,0PF5.3,2X,2(F8.3,2X),
     13(1PE9.2,1X))
 9035 FORMAT(2X,'UNTREATED BLOWDOWN',1PE9.2,11X,'   1.000       0.0
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   10.0      1.00E 00  1.00E 00  1.00E 00')
9036 FORMAT(16X,'THERE IS NOT A CONDENSATE DEMINERALIZER')
9037 FORMAT(72X,F8.2)
9038 FORMAT(2X,'REGENERANT SOLS    ',1PE9.2,14X,0PF5.3,2X,2(F8.3,2X),
    13(1PE9.2,1X))
9039 FORMAT(16X,'THERE IS A CRYOGENIC OFFGAS SYSTEM')
9040 FORMAT(16X,'THERE IS NO CRYOGENIC OFFGAS SYSTEM')
9041 FORMAT(16X,'PRIMARY TO SECONDARY LEAK RATE (LBS/DAY)',T73,'100.')
9045 FORMAT   (/,'0 LIQUID WASTE INPUTS')
9046 FORMAT   (/,'0 GASEOUS WASTE INPUTS')
9048 FORMAT('0',15X,'THERE IS NOT AN ON-SITE LAUNDRY')
9051 FORMAT(16X,'BLOWDOWN RATE (THOUSAND LBS/HR)',25X,F9.4)
9052 FORMAT(16X,'THERE IS CONTINUOUS STRIPPING OF FULL LETDOWN FLOW')
9053 FORMAT (16X,'THERE IS NOT CONTINOUS STRIPPING OF FUL  LETDWN FLOW'
    1)
9054 FORMAT(16X,'FLOW RATE THROUGH GAS STRIPPER (GPM)',20X,F8.4)
9055 FORMAT(36X,F8.4,35X,I1)
9056 FORMAT(15X,4A4,A2,8X,F8.0)
9060 FORMAT (16X,4A4,10X,A3,6X,A3)
9061 FORMAT (16X,4A4,'IODINE RELEASE FRACTION',16X,F10.5/32X,'PARTICULA
    1TE RELEASE FRACTION',10X,F10.5)
9062 FORMAT(16X,4A4,10X,A3,6X,A3,13X,A3)
9063 FORMAT(16X,4A4,'IODINE RELEASE FRACTION',16X,F10.5/32X,'PARTICULAT
    1E RELEASE FRACTION',10X,F10.5/32X,'RELEASE FRACT.-SPECIAL DES. FEA
    2TURES',1X,F10.5)
9064 FORMAT(16X,'STEAM LEAK TO TURBINE BLDG (LBS/HR)',19X,F10.5)
9065 FORMAT(16X,4A4,6X,A3)
9066 FORMAT(16X,4A4,4X,'PARTICULATE RELEASE FRACTION',6X,F10.5)
9067 FORMAT(16X,5A4,10X,A3,6X,A3)
9068 FORMAT(16X,5A4,'IODINE RELEASE FRACTION',11X,F10.5/36X,'PARTICULAT
    1E RELEASE FRACTION',6X,F10.5)
9069 FORMAT(16X,5A4,9X,F8.2,9X,A3,6X,A3)
9070 FORMAT(16X,5A4,'RATE(CFM)',27X,F8.2/16X,5A4,'IODINE RELEASE FRACTI
    1ON',11X,F10.5/36X,'PARTICULATE RELEASE FRACTION',6X,F10.5)
9071 FORMAT(16X,5A4,10X,A3,6X,A3,19X,F3.0)
9072 FORMAT (16X,'FREQUENCY OF CNTMT BLDG HIGH VOL PURGE (TIMES/YR)',
    1T74,F6.0)
9073 FORMAT (16X,'THERE IS NOT A CNTMT BLDG LOW VOL PURGE')
9075 FORMAT(16X,'THERE IS CONTINUOUS LOW VOL PURGE OF VOL. CONTROL TK')
     END
     SUBROUTINE EFFTAB
     INTEGER*2 NAME(3)
     DIMENSION NZMBDM(26),NZCBDM(26),REACTR(7)
     DIMENSION TURBDR(800),DWCON2(800),EDCONC(800)
     DIMENSION  LAUNDRY(12),WLAUND(12)
     COMMON/ER/XZERO(800), XZM(800),XTEMP(800),XNEW(10,800),
    1        H(800),D(800)
     COMMON/FLUXN/Y(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,FLUXR,MSTAR,ALPHAN(100),SPONF(100),ABUND(500),
    2 BASIS(10),TCONST,TUNIT
     COMMON/COOL/REACTR,POWT,TYPE,PCVOL,LETDWN,NOGAS,SCVOL,STMVOL,NOGEN
    1               ,NPURGE,NVCSPG,SHLDR,GASDLA,STLKR,BLWDWN,EJCTR,WLKRAT,
    2               GASLKR,CONDLR,DFMBDM,DFCBDM,NZMBDM,NZCBDM,NF,PF,
    3               STMFR,FPFF,MFF,FFCOM,DFMBCS,CHFLR,DFI,DFCS,DF,
    4               EDFLR,DFIED,DFCSED,DFED,DWFLR,DFIDW,DFCSDW,DFDW,DILUT
    5              ,SHA,EDA,DWA,CWFLR,CMWFR,CWA,CHA,DFCM,DFICM,DFCSCM,
    6               DFCW,DFICW,DFCSCW,WHOLD,WHOLDE,WHOLDW,WHOLCM,WHOLDC
    7              ,BDTFR,DFIBD,DFCSBD,DFBD,WHOLDR,REGENT,
    8                SBFD,DFMD,DFY,EDFD,DFMDED,DFYED,DWFD,DFMDDW,DFYDW,
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     9             DFMDWD,DFYWD,CWFD,DFMDCW,DFYCW,CMFD,DFMDCM,DFYCM
     A   ,TS,TE,TD,TR,TC,TCM,TSTORC,TSTORD,TSTORB,TMSC,DWFL2,DW2,DWF2,
     B  T2,TSTOR2,DFID2,DFCSD2,DFMDD2,DFYD2,DFD2,PFLAUN
      COMMON/APCOOL/RGWFR,DFIRG,DFCSRG,DFRG,TRG,TSTORR,RGFD
      COMMON/BOTES/RENRT
      COMMON/FLEX/FLUX(10),MMN,MOUT,INDEX,GXN,AXN,ERR,NOBLND,MZERO
      COMMON/CONC/PCONC(800),DWCONC(800),CWCONC(800),CMCONC(800),
     1     SCON(800),RINV(800)
      COMMON/MPC/MPCTAB,AMPC(800),WMPC(800)
      EQUIVALENCE  (XZERO(1),TURROR(1)),(XZM(1),DWCON2(1))
      DATA PWR/' PWR'/,BWR/' BWR'/
      DATA LAUNDRY/250540,270580,270600,400950,410950,441030,441060,
     1            471101,531310,551340,551370,581440/
      DATA WLAUND/0.001,0.004,0.0087,0.0014,0.002,0.00014,0.0024,
     1            0.00044,0.000062,0.013,0.024,0.0052/
      DO 10 I=1,ITOT
 10   D(I)=-DIS(I)
      IF(TYPE.EQ.BWR)  GO TO 15
      H3PRPW=0.4*POW1
C     H3COPW IS THE PWR TRITIUM PRIMARY COOLANT CONCENTRATION IN
C     UCI/GM
      H3COPW=1.0
      C1=SHLDR*CWA
      C2=EDFLW*CWA
      C1=C1/(C1+C2)
      C2=1.-C1
      GO TO 20
C     TRITCO IS THE  BWR TRITIUM PRIMARY COOLANT CONCENTRATION IN
C     UCI/GM.
   15 TRITPR=.025*POW1
      TRITCO=.01
 20   DO 30 J=1,ITOT
      CWCONC(J)=0.0
      EDCONC(J)=0.0
      DWCONC(J)=0.0
      DWCON2(J)=0.0
      CMCONC(J)=0.0
      NZ=NUCL(J)/10000
      IF(NZ.EQ.36.OR.NZ.EQ.54) GO TO 30
      CWCONC(J)=PCONC(J)*CWA
      EDCONC(J)=PCONC(J)*EDA
      DWCONC(J)=PCONC(J)*DWA
      DWCON2(J)=PCONC(J)*DW2
      IF(TYPE.EQ.BWR) CMCONC(J)=PCONC(J)*CMA
      IF(TYPE.EQ.BWR) GO TO 30
      CMCONC(J)=SCON(J)
      DFCVCS=10.
      IF(NZ.EQ.1)DFCVCS=1.0
      IF(NZ.EQ.37.OR.NZ.EQ.55) DFCVCS=2.
      CWCONC(J)=CWCONC(J)/DFCVCS
 30   CONTINUE
C
C     CALCULATE RADIOACTIVITY AFTER COLLECTION AT A CONSTANT RATE
C
      CALL COLLECT(TC*86400.,CWCONC,ILITE,ITOT)
      CALL COLLECT(TE*86400.,EDCONC,ILITE,ITOT)
      CALL COLLECT(TD*86400.,DWCONC,ILITE,ITOT)
      CALL COLLECT(T2*86400.,DWCON2,ILITE,ITOT)
      CALL COLLECT(TCM*86400.,CMCONC,ILITE,ITOT)
 40   IF(REGENT.LE.0.0) GO TO 50
      CALL STORAG(TRG*86400.,RINV,ILITE,ITOT)
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 50   DO 100 I=1,ITOT
      NZ=NUCL(I)/10000
      TURBDR(I)=1991.*5.*SCON(I)
      IF(NZ.EQ.1) GO TO 100
      IF(NZ.EQ.35.OR.NZ.EQ.53) GO TO 60
      IF(NZ.EQ.37.OR.NZ.EQ.55) GO TO 70
C
C     CHEMICAL TREATMENT FOR OTHER CATIONS
C
      CWCONC(I)=CWCONC(I)/DFCW
      EDCONC(I)=EDCONC(I)/DFED
      DWCONC(I)=DWCONC(I)/DFDW
      DWCON2(I)=DWCON2(I)/DFD2
      CMCONC(I)=CMCONC(I)*(1.0-BDTFR*(1.0-CMFD/DFCM))
C     TO TREAT PWR TURBINE BUILDING FLOOR DRAINS THROUGH DIRTY WASTE
C     SYSTEM, DELETE C FOR COMMENT ON CARDS BELOW, UNTIL NEXT MESSAGE
      RINV  (I)=RINV  (I)/DFRG
      TURBDR(I)=1991.*5.*SCON(I)*FPEF
C     TURBDR(I)=1991.*5.*SCON(I)*FPEF/DFDW
      GO TO 100
C
C     CHEMICAL TREATMENT FOR ANIONS
C
 60   CWCONC(I)=CWCONC(I)/DFICW
      EDCONC(I)=EDCONC(I)/DFIED
      DWCONC(I)=DWCONC(I)/DFIDW
      DWCON2(I)=DWCON2(I)/DFID2
      CMCONC(I)=CMCONC(I)*(1.0-BDTFR*(1.0-CMFD/DFICM))
      RINV  (I)=RINV  (I)/DFIRG
      TURBDR(I)=1991.*5.*SCON(I)*HEF
C     TURBDR(I)=1991.*5.*SCON(I)*HEF/DFIDW
      GO TO 100
C
C     CHEMICAL TREATMENT FOR RB AND CS
C
 70   CWCONC(I)=CWCONC(I)/DFCSCW
      EDCONC(I)=EDCONC(I)/DFCSED
      DWCONC(I)=DWCONC(I)/DFCSDW
      DWCON2(I)=DWCON2(I)/DFCSD2
      CMCONC(I)=CMCONC(I)*(1.0-BDTFR*(1.0-CMFD/DFCSCM))
      RINV  (I)=RINV  (I)/DFCSRG
      TURBDR(I)=1991.*5.*SCON(I)*FPEF
C     TURBDR(I)=1991.*5.*SCON(I)*FPEF/DFCSDW
 100  CONTINUE
C
C     COMPUTE RADIOACTIVE DECAY DURING PROCESSING AND SAMPLING
C
      CALL STORAG(TSTORC*86400.,CWCONC,ILITE,ITOT)
      CALL STORAG(TS    *86400.,EDCONC,ILITE,ITOT)
      CALL STORAG(TSTORD*86400.,DWCONC,ILITE,ITOT)
      CALL STORAG(TSTOR2*86400.,DWCON2,ILITE,ITOT)
      CALL STORAG(TSTORM*86400.,CMCONC,ILITE,ITOT)
      CALL STORAG(TSTORR*86400.,RINV,ILITE,ITOT)
      CALL STORAG(21600.,TURBDR,ILITE,ITOT)
      DO   130 I=1,ITOT
      NZ=NUCL(I)/10000
      ABLOW=0.0
      IF(REGENT.LT.0.001) GO TO 110
      ABLOW=RINV(I)*365.5*RGFD/REGENT
 110  IF(TYPE.EQ.BWR) GO TO 120
      ABLOW=ABLOW+BLOWDN*1991.*CMCONC(I)*(1.0-RFNRT)
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      GO TO 130
120   ABLOW=ABLOW+CMFR*1.382*CMCONC(I)
130   CMCONC(I)=ABLOW
      IF(TYPE.EQ.BWR) GO TO 133
      CWFR=BBLDR*CWFD*0.02832
      EDFLR=EDFLR*EDFD*0.02832
      DWFR=DWFLR*DWFD*0.02832
      DWFR2=DWFL2*DWF2*0.02832
      TPLRPW=CWFR*CWA+EDFLR*EDA+DWFR*DWA+DWFR2*DW2
      H3RLPW=TPLRPW*H3COPW
      IF(H3RLPW.GT.0.5*H3PRPW) H3RLPW=0.5*H3PRPW
      RH3RLP=H3RLPW/10.
      INTRIM=RH3RLP
      IH3RLP=INTRIM*10
      GO TO 136
  133 CWFR=CWFLR*1.382*CWFD
      DWFR=DWFLR*DWFD*1.382
      TLR=(CWFR+DWFR)+1.382*(CMFD*CMFR+RGFD*RGWFR)
      TRITRL=TRITCD*TLR
      IF(TRITRL.GT.0.5*TRITPR)TRITRL=0.5*TRITPR
      RTRITR=TRITRL+0.5
      ITRITR=RTRITR
  136 TOTAL=0.0
      DO 140 I=1,ITOT
      NZ=NUCL(I)/10000
      IF(NZ.EQ.36.OR.NZ.EQ.54)  GO TO 140
      DISI=DIS(I)*1.6283E13
      CWCONC(I)=DISI*(CWCONC(I)*CWFR+EDCONC(I)*EDFLR)
      DWCONC(I)=(DWCONC(I)*DWFR+DWCON2(I)*DWFR2)*DISI
      CMCONC(I)=CMCONC(I)*DISI
      TURBDR(I)=TURBDR(I)*DISI
      IF(NUCL(I).EQ.10030) GO TO 140
      TOTAL =TOTAL +CWCONC(I)+DWCONC(I)+CMCONC(I)+TURBDR(I)
  140 CONTINUE
      ADI=0.15
      ADR=(ADI+TOTAL)/TOTAL
150   SCNORM=0.0
      SAPRIM=0.0
      SSEC=0.0
      SCWAST=0.0
      SDWAST=0.0
      SABLOW=0.0
      STB=0.0
      STOTAL =0.0
      SCANAL=0.0
      SPER=0.0
      PAPRIM=0.0
      PSEC=0.0
      PCWAST=0.0
      PDWAST=0.0
      PABLOW=0.0
      PTB=0.0
      PTOTAL =0.0
      PCANAL=0.0
      PPER=0.0
      PNORM=0.0
      TLAUND=0.0
      CTOTAL=0.0
      PRINT 9001,    REACTR
      IF(TYPE.EQ.PWR) PRINT 9002
      IF(TYPE.EQ.BWR) PRINT 9006
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      PRINT 9010
      KOUNTR=1
      I1=ILITE+IACT+1
      L=1
      DO 180 I=1,ITOT
      IF(I.EQ.I1)  PRINT 9011
      NZ=NUCL(I)/10000
      IF(NZ.EQ.36.OR.NZ.EQ.54)  GO TO 180
      IF(NZ.EQ.1)  GO TO 180
      DISI=DIS(I)*1.6283E+13
      APRIM=PCONC(I)*DISI
      ASEC=0.0
      IF(TYPE.EQ.PWR) ASEC=SCON(I)*DISI
      CWASTE=CWCONC(I)
      DWASTE=DWCONC(I)
      ABLOW=CMCONC(I)
      TB=TURBDR(I)
      TOTAL=CWASTE+DWASTE+ABLOW+TB
      TOTALN=TOTAL*ADR
      NUCLI=NUCL(I)
      XLAUND=0.0
      TOTALG=TOTALN
      IF(NUCLI.NE.LAUNDRY(L))  GO TO 155
      XLAUND=WLAUND(L)*PFLAUN
      TOTALG=TOTALN+WLAUND(L)*PFLAUN
      L=L+1
  155 CONTINUE
      IF (TOTALG.LT.1E-5) GO TO 156
      ISUB=2
      IF (TOTALG.GT.1.)ISUB=1
      DIV=10.**(INT(ALOG10(TOTALG))-ISUB)
      TOTALG=AINT(TOTALG/DIV+0.5)*DIV
  156 CONTINUE
      IF(NUCL(I).EQ.10030)  TOTALN=TOTAL
      CANAL= TOTAL/DILUT*35.315
      PERCEN=CANAL/WMPC(I)*100.
      IF(NZ.EQ.1) GO TO 160
      SAPRIM=SAPRIM+APRIM
      SSEC=SSEC+ASEC
      SABLOW=SABLOW+ABLOW
      SCWAST=SCWAST+CWASTE
      SDWAST=SDWAST+DWASTE
      STB=STB+TB
      STOTAL=STOTAL+TOTAL
      SCANAL=SCANAL+CANAL
      SPER=SPER+PERCEN
      SCNORM=SCNORM+TOTALN
      TLAUND=TLAUND+XLAUND
      CTOTAL=CTOTAL+TOTALG
  160 IF(TOTALG.LT.1.E-5)  GO TO180
      IF(MOD(KOUNTR,50).NE.0) GO TO 170
      PRINT 9000,    REACTR
      IF(TYPE.EQ.PWR) PRINT 9002
      IF(TYPE.EQ.BWR) PRINT 9006
  170 CALL NOAH(NUCL(I),NAME)
      THALF=8.0225E-6/DIS(I)
      IF(TYPE.EQ.PWR) PRINT 9003,     NAME,THALF,APRIM,ASEC,CWASTE,DWASTE
     1,                ABLOW,TB,TOTAL,TOTALN,XLAUND,TOTALG
      IF(TYPE.EQ.BWR) PRINT 9007,     NAME,THALF,APRIM,CWASTE,DWASTE,
     1                ABLOW,TOTAL,TOTALN,XLAUND,TOTALG
      KOUNTR=KOUNTR+1
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      IF(NZ.EQ.1) GO TO 180
      PAPRIM=PAPRIM+APRIM
      PSEC=PSEC+ASEC
      PCWAST=PCWAST+CWASTE
      PDWAST=PDWAST+DWASTE
      PABLOW=PABLOW+ABLOW
      PTB=PTB+TB
      PTOTAL=PTOTAL+TOTAL
      PCANAL=PCANAL+CANAL
      PPER=PPER+PERCEN
      PNORM=PNORM+TOTALN
180   CONTINUE
      PAPRIM=SAPRIM-PAPRIM
      PSEC=SSEC-PSEC
      PCWAST=SCWAST-PCWAST
      PDWAST=SDWAST-PDWAST
      PABLOW=SABLOW-PABLOW
      PTB=STB-PTB
      PTOTAL=STOTAL-PTOTAL
      PCANAL=SCANAL-PCANAL
      PPER=SPER-PPER
      PNORM=SCNORM-PNORM
      ISUBC=2
      IF (CTOTAL.GT.1.)ISUBC=1
      DIV=10.**(INT(ALOG10(CTOTAL))-ISUBC)
      CTOTAL=AINT(CTOTAL/DIV+0.5)*DIV
      IF (PNORM.LT.1E-5) GO TO 184
        DIV=10.**(INT(ALOG10(PNORM))-2)
      PNORMT=AINT(PNORM/DIV+0.5)*DIV
      GO TO 186
 184  PNORMT=PNORM
 186  CONTINUE
      IF(TYPE.EQ.BWR) GO TO 190
      PRINT 9004,    PAPRIM, PSEC,PCWAST,PDWAST,PABLOW,PTB,PTOTAL,PNORM,
     1               PNORMT
      PRINT 9005,    SAPRIM,SSEC,SCWAST,SDWAST,SABLOW,STB,STOTAL,SCNORM,
     1               TLAUND,CTOTAL
      PRINT 9012,    IH3HLF
      RETURN
190   PRINT 9008,    PAPRIM,PCWAST,PDWAST,PABLOW,PTOTAL,PNORM,PNORMT
      PRINT 9009,     SAPRIM,SCWAST,SDWAST,SABLOW,STOTAL,SCNORM,TLAUND,
     1                CTOTAL
 195  PRINT 9012,    ITRITH
      RETURN
9000  FORMAT(1H1,20X,7A4,' LIQUID EFFLUENTS (CONTINUED)')
9001  FORMAT(1H1,20X,7A4,' LIQUID EFFLUENTS')
9002  FORMAT(1H0,55X,'ANNUAL RELEASES TO DISCHARGE CANAL'/20X,'COOLANT C
     1ONCENTRATIONS',57('-'),'  ADJUSTED    DETERGENT     TOTAL '/' NUCLI
     2E HALF-LIFE     PRIMARY     SECONDARY     BORON RS MISC. WASTES SECON
     3DARY  TURB BLDG  TOTAL LWS     TOTAL       WASTES          '/10X,
     4'(DAYS)   '2('(MICRO CI/ML)'),1X,4('(CURIES)   '),'(CURIES) ',
     5'   (CI/YR)      (CI/YR)      (CI/YR)')
9003  FORMAT(1X,A2,I3,A1,2X,1PE9.2,2(2X,E9.2,2X),5(1X,0PF9.5,1X),2(1X,0P
     1  F9.5,1X),0PF10.5)
9004  FORMAT(1X,'ALL OTHERS',9X,1PE9.2,4X,E9.2,2X,5(1X,0PF9.5,1X),
     1         1X,0PF9.5,4X,'0.0',5X,0PF10.5)
9005  FORMAT(' TOTAL'/,' (EXCEPT TRITIUM)    ',1PE9.2,4X,E9.2,2X,
     1         5(1X,0PF9.5,1X),2(1X,0PF9.5,1X),0PF10.5)
9006  FORMAT(1H0,17X,'CONCENTRATION      ANNUAL RELEASES TO DISCHARGE CAN
     1AL'/18X,' IN PRIMARY  ',43('-'),'  ADJUSTED   DETERGENT    TOTAL
     2 '/' NUCLIDE HALF-LIFE   COOLANT     HIGH PURITY LOW PURITY  CHEMICA
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3L  TOTAL L*B    TOTAL       WASTES           '/10X,'(DAYS)  (MICRO C
4I/ML)',3('  (CURIES) '), ' (CURIES)    (CI/YR)     (CI/YR)     (CI/Y
5R)')
9007 FORMAT(1X,A2,I3,A1,2X,1PE9.2,  2X,E9.2,2X ,4(1X,0PF9.5,1X),2(1X,0P
1F9.5,1X),1X,0PF9.5)
9008 FORMAT(1X,'ALL OTHERS',9X,1PE9.2,2X,4(1X,0PF9.5,1X),1X,0PF9.5,4X,
1        '0.0',6X,0PF9.5)
9009 FORMAT(' TOTAL'/,' (EXCEPT TRITIUM)    ',1PE9.2,2X,4(1X,0PF9.5,1X),
1        2(1X,0PF9.5,1X),1X,0PF9.5)
9010 FORMAT(' CORROSION AND ACTIVATION PRODUCTS')
9011 FORMAT('0FISSION PRODUCTS')
9012 FORMAT (1H0,1X,'TRITIUM RELEASE',12X,I3,'   CURIES PER YEAR')
     END
     BLOCK DATA
     COMMON /CONB/BCONC(800)
     COMMON/CONP/PWCONC(800),SCUTV(800),SCUTP(800),SCOT(800)
     DATA BCONC/36*0,9E-3,13*0,2E-4,53*0,5E-3,4*0,6E-5,0,0,5E-2,3*0,
    11E-3,3*0,3E-5,0,0,2E-4,2*0,4E-4,7*0,1E-6,0,0,5E-4,2*0,3E-2,4*0,
    22E-4,3*0,2E-3,98*0,3E-4,64*0,7E-3,63*0,3E-3,4*0,5E-3,2*0,3E-3,
    319*0,5E-3,1E-4,3*0,6E-6,5*0,4E-3,0,0,4E-5,3*0,1E-2,6E-3,4*0,4E-3,
    411*0,7E-6,0,0,7E-6,6*0,5E-6,5*0,4E-3,2*0,2E-3,2E-2,8*0,9E-2,7*0,
    52E-5,3*0,8E-2,6*0,2E-3,4*0,3E-6,21*0,1E-6,104*0,4E-5,13*0,1E-4,
    60,0,5E-3,5*0,1E-5,3E-2,4*0,2E-2,5*0,7E-2,2*0,3E-5,2*0,2E-2,8*0,
    72E-5,3*0,7E-5,4*0,1E-2,4*0,1E-2,3*0,4E-4,4*0,1E-2,0,0,3E-5,3*0,
    86E-3,5E-3,7*0,3E-5,4E-5,2*0,3E-6,10*0,3E-6,81*0/
     DATA PWCONC/104*0,1.9E-3,4*0,3.1E-4,5*0,1.6E-3,3*0,1E-3,0,0,.016,
    12*0,2E-3,185*0,1.2E-3,63*0,4.8E-3,4*0,2.6E-3,2*0,3E-4,6*0,8.5E-5,
    28*0,.2,4*0,3.5E-4,3*0,1E-5,0,0,1.2E-6,3*0,6.5E-4,3.6E-4,6.4E-5,9*
    3,3.4E-5,11*0,6E-5,0.,5E-5,15*0,.084,.048,16*0,4.5E-5,4.5E-5,14*0,
    41E-5,0,0,1E-5,103*0,2.9E-5,8*0,2.8E-4,8.5E-4,10*0,1.4E-3,1.6E-3,
    58*0,2.1E-3,3*0,2.5E-3,1.1E-3,.27,5*0,.027,.1,4*0,.38,5*0,.047,2*0,
    6,025,2*0,.19,8*0,.013,3*0,.018,.016,12*0,2.2E-4,1.5E-4,5*0,7E-5,
    712*0,4E-5,5E-5,2*0,3.3E-5,3.3E-5,91*0/
     DATA SCUTV/104*0,9E-8,4*0,2E-8,5*0,8E-8,3*0,6E-8,0,0,8E-7,2*0,
    19E-8,185*0,6E-8,63*0,6.9E-8,4*0,1.5E-8,2*0,2E-10,6*0,4.4E-9,8*0,
    27.4E-7,4*0,2E-8,3*0,4E-10,0,0,8E-11,3*0,2E-8,1E-8,3E-9,9*0,1E-9,
    311*0,4E-9,0,0,4E-9,15*0,4E-6,3E-6,16*0,2E-9,2E-9,14*0,4E-10,0,0,
    44E-10,103*0,1E-09,8*0,1E-8,3E-8,10*0,6E-8,6E-8,8*0,4.6E-8,3*0,
    51E-7,2E-8,6.8E-6,5*0,1E-6,1.9E-6,4*0,8.9E-6,5*0,3.8E-7,2*0,1.3E-6,
    62*0,3.8E-6,8*0,6.7E-7,3*0,9.4E-7,9E-7,12*0,1E-8,7E-9,5*0,4E-9,
    712*0,1E-09,2E-9,2*0,2E-9,2E-9,91*0/
     DATA SCUTP/104*0,8E-7,4*0,2E-7,5*0,7E-7,3*0,5E-7,0,0,7E-6,2*0,
    19E-7,185*0,3E-7,63*0,1.5E-7,4*0,2E-8,2*0,2E-10,6*0,4E-8,8*0,8E-7,
    24*0,2E-7,3*0,5E-9,0,0,2E-9,3*0,6E-8,3E-8,3E-8,9*0,4E-9,11*0,3E-8,
    30,0,3E-8,15*0,3.0E-5,3.0E-5,16*0,2E-8,2E-8,14*0,5E-9,0,0,5E-9,
    4103*0,9E-9,8*0,9E-8,2E-7,10*0,6E-7,6E-7,8*0,2.5E-7,3*0,5E-7,5E-7,
    51.1E-4,5*0,8E-6,1.1E-5,4*0,6.5E-5,5*0,5.7E-7,2*0,1.2E-5,2*0,
    61.4E-5,8*0,5E-6,3*0,8E-6,8E-6,12*0,9E-8,8E-8,5*0,3E-8,12*0,9E-9,
    72E-8,2*0,2E-8,2E-8,91*0/
     DATA SCUT/104*0,9E-10,4*0,2E-10,5*0,8E-10,3*0,5E-10,0,0,8E-9,2*0,
    19E-10,185*0,6E-10,63*0,2.3E-9,4*0,1.2E-9,2*0,1.4E-10,6*0,7E-11,8*0
    2,2.E-7,4*0,2E-10,3*0,5E-12,0,0,6E-13,3*0,3E-10,2E-10,3E-11,9*0,
    32E-11,11*0,3E-11,0,0,2E-11,15*0,4E-7,2E-7,16*0,2E-11,2E-11,14*0,
    45E-12,0,0,5E-12,103*0,1E-11,8*0,1E-10,4E-10,10*0,7E-10,8E-10,8*0,
    51E-9,3*0,5E-10,5E-10,1.3E-7,5*0,1E-8,4.7E-8,4*0,1.8E-7,5*0,2.2E-8,
    62*0,2.0E-8,2*0,9.0E-8,8*0,1.0E-8,3*0,1.5E-8,8E-9,12*0,1E-10,7E-11,
    75*0,3E-11,12*0,2E-11,2E-11,2*0,2E-11,2E-11,91*0/
     END
     SUBROUTINE SOLVE
     COMMON/EQ/XZERO(800), XZH(800),XTEMP(800),XNEW(10,800),
    1      B(800),D(800)
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      COMMON/FLEX/FLUX(10),MMN,MOUT,INDEX,GXN,AXN,ERR,NOBLND,MZERO
      COMMON/PROCSS/  MPROS,PRATE(8),NUPROS(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     CIMO(J) IS THE VECTOR CONTAINING THE LAST TERM ADDED TO EACH
C     ELEMENT OF CSUM(J)
C     CIMN(J) IS THE VECTOR CONTAINING 1/TON TIMES THE NEW TERM TO BE
C     ADDED TO  CSUM(J)
C     CIMN(J) IS GENERATED FROM CIMO(J) BY A RECURSION RELATION:
C          CIMN(J)= SUM OVER L OF (AP(J,L)*CIMO(L))
C     AP(I,J) IS THE REDUCED TRANSITION MATRIX FOR THE LONG-LIVED
C     NUCLIDES
C
      LOGICAL*1 LONG
      INTEGER*2 LOC,NONO,KD
      INTEGER*2 LOCP(2500)
      INTEGER*2 NONP(800)
      INTEGER*2 NQ,NQU,NQUEUE
      REAL*8 BATE,BATM
      REAL*8 CIMN(800),CSUM(800),CIMNI
      DIMENSION AP(2500),CIMB(800),CIMO(800)
      DIMENSION QUB(50)
      COMMON/SERIES/ XP(800),XPAR(800),LONG(800)
      COMMON/FLEX/FLUX(10),MMN,MOUT,INDEX,GXN,AXN,ERR,NOBLND,MZERO
      COMMON/EQ/XZERO(800),XZM(800),XTEMP(800),XNEW(10,800),
     1       B(800),D(800)
      COMMON/MATRIX/A(2500),LOC(2500),NONO(800),KD(800)
      COMMON/DEBUGG/AP
      COMMON/TERMD/DD(100),DXP(100),QUEUE(50),NQU(50),NQUEUE(50),NQ(800)
      NUL=0
      NN=0
C     FIRST CONSTRUCT REDUCED TRANSITION MATRIX FOR LONG-LIVED ISOTOPES
      DO 220 L=1,ITOT
      IF(.NOT.LONG(L)) GO TO 210
      NUM=NONO(L)
      IF(M.GT.MMN.OR.M.EQ.MZERO)  NUM=KD(L)
      CIMB(L)=B(L)
      IF(NUM.LE.NUL) GO TO 210
      NS=NN+1
      N=NUL
      NL=NUM-NUL
      DO 200 N1=1,NL
      N=N+1
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      J=LOC(N)
      DJ=-D(J)
C
C     THIS IS A TEST TO SEE IF ONE OF THE ASSYMPTOTIC SOLUTIONS APPLIES
C
      IF(.NOT.LONG(J)) GO TO 10
      NN=NN+1
      AP(NN)=A(N)
      LOCP(NN)=J
      GO TO 200
C
C     GOING BACK UP THE CHAIN TO FIND A PARENT WHICH IS NOT IN
C     EQUILIBRIUM
C
 10   NSAVE=0
      QUE=A(N)/DJ
      DRH=1.0
      CIMH(L)=CIMH(L)+QUE*H(J)
      NQ(L)=0
      NQ(J)=L
 20   NOX=NONO(J)
      IF(M.GT.MMN.OR.M.EQ.MZERO)  NOX=NO(J)
      NOF=0
      IF(J.GT.1)  NOF=NONO(J-1)
      NX=NOX-NOF
      IF(NX.LT.1)  GO TO 190
      K=NOF
      DO 180 KK=1,NX
      K=K +1
      J1=LOC(K)
      DJ=-D(J1)
      KP=J
 30   IF(J1.EQ.NQ(KP))  GO TO 180
      KP=NQ(KP)
      IF(KP.NE.0)  GO TO 30
      AKDJQ=QUE*A(K)/DJ
      IF(.NOT.LONG(J1)) GO TO 160
      TRM=1.0-XP(J1)
      IF(TRM.LT.1.0E-6) GO TO 120
      NQ(J1)=J
      I=1
      KP=J1
 40   DD(I)=-D(KP)
      DXP(I)=XP(KP)
      KP=NQ(KP)
      IF(KP.EQ.0) GO TO 50
      I=I+1
      IF(I.LE.100) GO TO 40
C     IF QUEUE OF SHORT-LIVED NUCLIDES EXCEEDS 100 ISOTOPES, TERMINATE
C     CHAIN AND WRITE MESSAGE
      PRINT 9000,    M,L,J1,J,AKDJG
 9000 FORMAT('1TOO LONG A QUEUE HAS BEEN FORMED IN TERM',4I5,E12.5)
      GO TO 190
 50   BATM=0.00
      IM=I-1
      DO 110 I=2,IM
      DL=DD(I)
      XPL=DXP(I)
      BATE=0.00
      I1=I-1
C     D R VONDY FORM OF BATEMAN EQUATIONS -- ORNL-TM-361
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      DO 100 KB=1,I1
      XPJ=DXP(KB)
      IF(XPL+XPJ.LT.ERR) GO TO 100
      DK=DD(KB)
      PROD=(DL/DK-1.0)
      DKR=PROD
      IF( ABS(PROD).GT.1.E-4) GO TO 60
C     USE THIS FORM FOR TWO NEARLY EQUAL HALF-LIVES
      PROD=T*DK*XPJ*(1.0-0.5*(DL-DJ)*T)
      GO TO 70
   60 PROD=(XPJ-XPL)/PROD
      PRO1=XPJ/DKR
   70 PI=1.0
      S1=2./(DK*T)
      DO 90 JK=1,I1
      IF(JK.EQ.KB) GO TO 90
      S=1.0-DK/DD(JK)
      IF( ABS(S).GT.1.E-4) GO TO 80
      IF(ABS(DKR).GT.1.0E-4)  PROD=PRO1
      S=S1
   80 PI=PI*S
      IF(ABS(PI).GT.1.E25)  GO TO 100
   90 CONTINUE
      BATE=BATE+PROD/PI
  100 CONTINUE
C     IF SUMMATION IS NEGATIVE, SET EQUAL TO ZERO AND PRINT MESSAGE
      IF(BATE.LT.0.D0)  PRINT 9001,      L,IM,BATE,BATM
 9001 FORMAT('1BATE IS NEGATIVE IN TERM, THERE ARE MORE THAN TWO SHORT-L
     1IVED NUCLIDES IN A CHAIN WITH NEARLY EQUAL DIAGONAL ELEMENTS'/
     2' L,IM,BATE,BATM = ',2I5,1P2E12.5)
      IF(BATE.LT.0.D0)  BATE=0.D0
      BATM=BATM+BATE
  110 CONTINUE
      DRA=AKDJQ*DJ*(TRM-BATM)/TRM
      GO TO 130
  120 DRA=AKDJQ*AMAX1(DRB,0.0)*DJ
  130 IF(NS.GT.NN) GO TO 150
      DO 140 LJ=NS,NN
      IF(LOCP(LJ).NE.J1)  GO TO 140
      AP(LJ)=AP(LJ)+DRA
      GO TO 180
  140 CONTINUE
  150 NN=NN+1
      AP(NN)=DRA
      LOCP(NN)=J1
      GO TO 180
  160 IF(AKDJQ.LE.1.0E-06)  GO TO 180
      IF(NSAVE.GE.50) GO TO 180
  170 NSAVE=NSAVE+1
      NQUEUE(NSAVE)=J1
      QUEUE(NSAVE)=AKDJQ
      NQU(NSAVE)=J
      QUB(NSAVE)=DRB-1./(DJ*T)
  180 CONTINUE
  190 IF(NSAVE.LE.0) GO TO 200
      J=NQUEUE(NSAVE)
      QUE=QUEUE(NSAVE)
      NQ(J)=NQU(NSAVE)
      DRB=QUB(NSAVE)
      CIMB(L)=CIMB(L)+QUE*B(J)*AMAX1(DRB,0.0)
      NSAVE=NSAVE-1
```

```
      GO TO 20
  200 CONTINUE
  210 NUL=NONO(L)
      NONP(L)=NN
  220 CONTINUE
C     FIND NORM OF MATRIX AND ESTIMATE ERROR AS DESCRIBED IN LAPIDUS
C     AND LUUS, OPTIMAL CONTROL OF ENGINEERING PROCESSES BLAISDELL 1967
C     FIND THE MINIMUM OF THE MAXIMUM ROW SUM AND THE MAXIMUM COLUMN SUM
      ASUM =0.0
      ASUMJ=0.0
      NUL=1
      DO 250 I=1,ITOT
      IF(.NOT.LONG(I)) GO TO 250
      DI=-D(I)*T
      AJ=DI
      NUM=NONP(I)
      IF(NUL.GT.NUM) GO TO 240
      DO 230 N=NUL,NUM
  230 AJ=AJ+AP(N)
  240 AI=DI+DI
      IF(AI.GT.ASUM )  ASUM =AI
      IF(AJ.GT.ASUMJ)  ASUMJ=AJ
  250 NUL=NONP(I)+1
      IF(ASUMJ.LT.ASUM)  ASUM=ASUMJ
C     USE ASUM TO DECIDE HOW MANY TERMS ARE REQUIRED AND ESTIMATE ERROR
      NLARGE=3.5*ASUM +5.
      XLARGE=NLARGE
      ERR1=EXP(ASUM )*(ASUM *2.71828/XLARGE)**NLARGE/SQRT(6.2832*XLARGE)
      IF(ERR1.GT.1.E-3)  PRINT 9002,     ERR1,ASUM ,NLARGE
 9002 FORMAT('0MAXIMUM ERROR GT 0.001, ='F10.6,', TRACE = 'F10.4,
     1  ' NLARGE = 'I6)
C     NEXT GENERATE MATRIX EXPONENTIAL SOLUTION
      DO 260 I=1,ITOT
      CSUM(I)=XTEMP(I)
      CIMN(I)=XTEMP(I)
  260 CONTINUE
      ERR3=0.001*ERR
      DO 310 NT=1,NLARGE
      DO 270 I=1,ITOT
      CIMO(I)=CIMN(I)
  270 CONTINUE
      TON=T/NT
      NUL=1
      DO 300 I=1,ITOT
      IF(.NOT.LONG(I)) GO TO 300
      NUM=NONP(I)
      CIMNI=0.0
      IF(NT.EQ.1) CIMNI=CIMB(I)
      IF(NUL.GT.NUM) GO TO 290
      DO 280 N=NUL,NUM
      J=LOCP(N)
  280 CIMNI=CIMNI+AP(N)*CIMO(J)
  290 CIMNI=CIMNI+D(I)*CIMO(I)
      CIMNI=TON*CIMNI
      IF(DABS(CIMNI).LT.ERR3)  CIMNI=0.00
      CIMN(I)=CIMNI
      CSUM(I)=CSUM(I)+CIMNI
  300 NUL=NONP(I)+1
  310 CONTINUE
      DO 320 I=1,ITOT
      IF(CSUM(I).LT.ERR)  CSUM(I)=0.0
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      IF(LONG(I)) XNEW(M,I)=CSUM(I)
  320 CONTINUE
      RETURN
      END
      SUBROUTINE DECAY(M,T,ITOT)
C     DECAY TREATS SHORT-LIVED ISOTOPES AT BEGINNING OF CHAINS USING
C     BATEMAN EQUATIONS
      LOGICAL*1 LONG
      REAL*8 BATE
      INTEGER*2 LOC,NONO,KD
      INTEGER*2 NQ,NQU,NQUEUE
      COMMON/DEBUGG/AP(2500)
      COMMON/SERIES/ XP(800),XPAR(800),LONG(800)
      COMMON/FLEX/FLUX(10),MMN,MOUT,INDEX,QXN,AXN,ERR,NOBLND,MZERO
      COMMON/EQ/XZERO(800),XZM(800),XTEMP(800),XNEW(10,800),
     1      B(800),D(800)
      COMMON/MATRIX/A(2500),LOC(2500),NONO(800),KD(800)
      COMMON/TERMD/DD(100),DXP(100),QUEUE(50),NQU(50),NQUEUE(50),NQ(800)
      DO 10 I=1,ITOT
      XPAR(I)=0.0
      LONG(I)=.FALSE.
      XPI=0.0
      DT=D(I)*T
      IF(DT.LT.-50.)  GO TO 10
      IF(ABS(DT).LE.AXN)  LONG(I)=.TRUE.
      XPI=EXP(DT)
   10 XP(I)=XPI
      NUL=1
      DO 160 L=1,ITOT
      XTEM=0.0
      DL=-D(L)
      NUM=NONO(L)
      IF(M.GT.MMN.OR.M.EQ.MZERO)  NUM=KD(L)
      IF(NUM.LT.NUL) GO TO 150
      DO 140 N=NUL,NUM
      J=LOC(N)
      DJ=-D(J)
      IF(LONG(J)) GO TO 140
C     USE THIS FORM FOR TWO NEARLY EQUAL HALF-LIVES
      IF(ABS(DL/DJ-1.0).LE.1.0E-5)  XTEM=XTEM+XTEMP(J)*A(N)*XP(J)*T
      IF(ABS(DL/DJ-1.0).GT.1.0E-5)
     1              XTEM=XTEM+XTEMP(J)*A(N)*(XP(J)-XP(L))/(DL-DJ)
      QUE=A(N)/DJ
      NQ(L)=0
      NQ(J)=L
      NSAVE=0
   20 NUX=NONO(J)
      IF(M.GT.MMN.OR.M.EQ.MZERO)  NUX=KD(J)
      NUF=1
      IF(J.GT.1)  NUF=NONO(J-1)+1
      IF(NUF.GT.NUX)  GO TO 130
      DO 120 K=NUF,NUX
      J1=LOC(K)
      IF(LONG(J1)) GO TO 120
      KP=J
   30 IF(J1.EQ.NQ(KP))  GO TO 120
      KP=NQ(KP)
      IF(KP.NE.0)  GO TO 30
      DJ=-D(J1)
      AKDJQ=A(K)/DJ*QUE
      IF(AKDJQ.LE.1.0E-06)  GO TO 120
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      NQ(J1)=J
      I=1
      KP=J1
40    DD(I)=D(KP)
      DXP(I)=XP(KP)
      KP=NQ(KP)
      IF(KP.EQ.0) GO TO 50
      I=I+1
      IF(I.LE.100) GO TO 40
      PRINT 9000,    M,L,J1,J,AKDJQ
9000  FORMAT('1',4I5,E12.5)
      GO TO 130
50    RATE=0.D0
      I1=I-1
      XPL=XP(L)
C     D R VONDY FORM OF BATEMAN EQUATIONS -- ORNL-TM-361
      DO 100 KB=1,I1
      XPJ=DXP(KB)
      IF(XPL*XPJ.LT.ERR) GO TO 100
      DK=DD(KB)
      PROD=(DL/DK-1.0)
      DKR=PROD
      IF( ABS(PROD).GT.1.E-4) GO TO 60
      PROD=T*DK*XPJ*(1.0-0.5*(DL-DJ)*T)
      GO TO 70
60    PROD=(XPJ*XPL)/PROD
      PRO1=XPJ/DKR
70    PI=1.0
      S1=2./(DK*T)
      DO 90 JK=1,I1
      IF(JK.EQ.KB) GO TO 90
      S=1.0-DK/DD(JK)
      IF( ABS(S).GT.1.E-4) GO TO 80
C     USE THIS FORM FOR TWO NEARLY EQUAL HALF-LIVES
      IF(ABS(DKR).GT.1.0E-4)  PROD=PRO1
      S=S1
80    PI=PI*S
      IF(ABS(PI).GT.1.E25)  GO TO 100
90    CONTINUE
      RATE=RATE+PROD/PI
100   CONTINUE
      IF(RATE.LT.0.D0)  PRINT 9001,     L,I,RATE,XTEM,XTEMP(J1),AKDJQ
9001  FORMAT(' L,I,RATE,XTEM,XTEMP(J1),AKDJQ = ',2I5,1P4E12.5)
      IF(RATE.LT.0.D0)  RATE=0.D0
      XTEM=XTEM+XTEMP(J1)*AKDJQ*RATE
      IF(NSAVE.GE.50) GO TO 120
110   NSAVE=NSAVE+1
      NQUEUE(NSAVE)=J1
      QUEUE(NSAVE)=AKDJQ
      NQU(NSAVE)=J
120   CONTINUE
130   IF(NSAVE.LE.0) GO TO 140
      J=NQUEUE(NSAVE)
      QUE=QUEUE(NSAVE)
      NQ(J)=NQU(NSAVE)
      NSAVE=NSAVE-1
      GO TO 20
140   CONTINUE
      IF(LONG(L)) XPAR(L)=XTEM/XP(L)
150   NUL=NONQ(L)+1
      IF(.NOT.LONG(L)) XNEW(M,L)=XTEM+XTEMP(L)*XP(L)
```

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

```
      END
      SUBROUTINE NUDATA(NLIBE)
C     NUDATA VERSION TO HANDLE THREE TYPES OF NUCLEAR DATA LIBRARIES
C     HAS POINTER, NLIBE, = 1 FOR HTGR
C                         = 2 FOR LIGHT WATER REACTOR
C                         = 3 FOR LMFBR
C                         = 4 FOR MSBR
      INTEGER*2 LOC,NONO,KD
      INTEGER*2 ELE(99),STA(2)
      INTEGER*2 KAP(800),MMAX(800)
      INTEGER*2 NAME(3)
      DIMENSION COEFF(7,800),NPROD(7,800),CAPT(6),
     1 NUCAL(6),NSORB(5),              YIELD(5,500),TYLD(5)
      DIMENSION Y(5)
      DIMENSION SKIP(20)
      DIMENSION MSRS(20)
      COMMON/LABEL/ELE,STA
      COMMON/FLEX/FLUX(10),MMN,MOUT,INDEX,GXN,AXN,ERR,NOBLND,MZERO
      COMMON/EQ/XZERO(800),XZM(800),XTEMP(800),XNEW(10,800),
     1       B(800),D(800)
      COMMON/MPC/MPCTAB,AMPC(800),WMPC(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,FLUXM,MSTAR,ALPHAN(100),SPONF(100),ABUND(500),
     2 BASIS(10),TCONST,TUNIT
      COMMON/MATRIX/A(2500),LOC(2500),NONO(800),KD(800)
      EQUIVALENCE (XZERO(1),KAP(1)),(XZERO(401),MMAX(1)),
     1            ( XZM(1),COEFF(1,1)),(XNEW(1,401),NPROD(1,1))
      EQUIVALENCE (A1,DLAM)
      DATA NUCAL/-20030,-10000,10,11,-10,-9/
      DATA MSRS/922330,922350,902320,922380,942390,922330,922350,942410,
     1          922380,942390,942410,922350,942400,922380,942390,922330,
     2          922350,902320,922380,942390/
C
C     PROGRAM TO COMPUTE A MATRIX (TRANSITION MATRIX) FROM NUCLEAR DATA
C
      READ 9011,             (TITLE(I),I=1,18),NLIBE
C     IF(NLIBE.LT.0) PROGRAM WILL READ TAPE IN CASDAR FORMAT
      IGMC=0
      IF(NLIBE.GT.0)  GO TO  10
      IGMC=1
      NLIBE=-NLIBE
      PRINT 9000
 9000 FORMAT(1H0,'WILL READ TAPE GENERATED BY CASDAR')
 10   NI=A-NLIBE
 20   READ 9001,     THERM,RES,FAST,ERR,NMO,NDAY,NYR,MPCTAB,INPT,IW
      PRINT 9005,      NMO,NDAY,NYR
      PRINT 9006
      PRINT 9007
      PRINT 9008
      PRINT 9009
      PRINT 9010
      PRINT 9013
      PRINT 9014
C
C     THERM = RATIO OF THERMAL FLUX TO TOTAL FLUX
C     RES =  RATIO OF RESONANCE FLUX TO TOTAL FLUX
C     FAST = RATIO OF FAST FLUX TO TOTAL FLUX
C     ERR = TRUNCATION ERROR LIMIT
C
```

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

```
      IF(FP1 .LT. ERR) GO TO 150
      M=M+1
      COEFF(M,I)=FP1*COEFF(M-1,I)
      NPROD(M,I)=NPROD(M-1,I)+1
      COEFF(M-1,I)=COEFF(M-1,I)-COEFF(M,I)
C
C     TEST ISOMERIC TRANSITION
C
 150  IF(FT .LT.ERR) GO TO 160
      M=M+1
      COEFF(M,I)=FT*A1
      NPROD(M,I)=NUCLI
      ABETA=ABETA-FT
C
C     TEST ALPHA EMISSION
C
 160  IF(FA .LT. ERR) GO TO 170
      M=M+1
      COEFF(M,I)=FA*A1
      NPROD(M,I)=NUCLI-20040
      M=M+1
      COEFF(M,I)=COEFF(M-1,I)
      NPROD(M,I)=20040
      ABETA=ABETA-FA
C
C     TEST NEGATRON EMISSION
C
 170  IF(ABETA.LT.1.E-4) GO TO 180
      M=M+1
      COEFF(M,I)=ABETA*A1
      NPROD(M,I)=NUCLI+10000
C
C     TEST NEGATRON EMISSION TO EXCITED STATE OF PRODUCT NUCLIDE
C
      IF(FB1 .LT. ERR)GO TO 180
      M=M+1
      COEFF(M,I)=FB1*COEFF(M-1,I)
      NPROD(M,I)=NPROD(M-1,I)+1
      COEFF(M-1,I)=COEFF(M-1,I)-COEFF(M,I)
C
C     COMPUTE NEUTRON CAPTURE CROSS SECTIONS IN THREE REGIONS
C
 180  KAP(I)=M
      DO 190 KI=1,6
 190  CAPT(KI) =0.0
      CAPT(1)=SIGNA
      CAPT(2)=SIGNP
      CAPT(4)=SIGNG*FNG1
      CAPT(3)=SIGNG-CAPT(4)
      CAPT(6)=SIGN2N*FN2N1
      CAPT(5)=SIGN2N-CAPT(6)
 200  TOCAP(I)=0.0
C     TOTAL NEUTRON CROSS SECTION FOR NUCLIDE(I)
      DO 220 K=1,6
      CAPKI=CAPT(K)
      IF(CAPKI.LT.ERR)  GO TO 220
      M=M+1
      NPROD(M,I)=NUCLI+NUCAL(K)
      COEFF(M,I)=CAPKI
      TOCAP(I)=TOCAP(I)+CAPKI
      IF(K.NE.1) GO TO 210
```

```
      M=M+1
      COEFF(M,I)=COEFF(M-1,I)
      NPROD(M,I)=20040
  210 IF(K.NE.2) GO TO 220
      M=M+1
      COEFF(M,I)=COEFF(M-1,I)
      NPROD(M,I)=10010
  220 CONTINUE
  230 IF(MOD(NUCLI,  10).EQ.0) GO TO 250
      DO 240 K=1,M
  240 NPROD(K,I)=NPROD(K,I)-1
  250 MMAX(I) =M
      IF(M.GT.7)  PRINT 9039, M
      DIS(I)=A1
      GO TO 40
  260 ILITE = I-1
      IACT=0
C
C     READ DATA ON ACTINIDES
C
  270 READ(8,9034,END=450)NUCL(I),DLAM,IU,FB1,FP,FP1,FT,FA,FSF,
     1Q(I),FG(I),DUMMY,AMPC(I),AMPC(I)
      DO 280 N=1,NLIBE
      READ(8,9037) SIGNG,RING,FNG1,SIGF,RIF,SIGFF,SIGN2N,FN2N1,SIGN3N,IT
  280 CONTINUE
      IF(N1.EQ.0) GO TO 300
      DO 290 N=1,N1
  290 READ(8,9036)  SKIP
  300 IF(IT .EQ. 0) GO TO 270
  310 M=0
      NUCLI=NUCL(I)
      IF(NUCLI.EQ.0)  GO TO 450
      DO 320 K=1,5
      IF(NUCLI.EQ.NSURS(K))  NSURS(K)=I
  320 CONTINUE
      CALL HALF(A1,IU)
      CALL NOAM(NUCLI,NAME)
      SIGNG=THERM*SIGNG+RES*RING
      SIGF =THERM*SIGF +RES*RIF +FAST*SIGFF
      SIGN2N=SIGN2N*FAST
      SIGN3N=SIGN3N*FAST
      IF(MOD(IACT,50).EQ.0)  PRINT 9012,     (TITLE (N),N=1,18)
  330 IF(MOD(IACT,50).EQ.0) PRINT 9024
      PRINT 9026,     NAME,                DLAM,FB1,FP,FP1,FT,FA,FSF,SIGNG,
     1                FNG1,SIGF,SIGN2N,SIGN3N,Q(I),FG(I)
  340 IACT=IACT+1
C
C     TEST RADIOACTIVITY
C
      IF(A1.LT.ERR)  GO TO 380
      ABETA=1.0
C     TEST POSITRON EMISSION
      IF(FP .LT. ERR) GO TO 350
      ABETA=ABETA-FP
      M=M+1
      COEFF(M,I)=FP*A1
      NPROD(M,I)=NUCLI-10000
C     POSITRON EMISSION TO EXCITED STATE
      IF(FP1 .LT. ERR)GO TO 350
      M=M+1
      COEFF(M,I)=FP1*COEFF(M-1,I)
```

```
      NPROD(M,I)=NPROD(M-1,I)+1
      COEFF(M-1,I)=COEFF(M-1,I)-COEFF(M,I)
C     ISOMERIC TRANSITION
  350 IF(FT .LT.ERR)GO TO 360
      M=M+1
      COEFF(M,I)=FT*A1
      NPROD(M,I)=NUCLI
      ABETA=ABETA-FT
C     ALPHA EMISSION
  360 IF(FA .LT.ERR)GO TO 370
      M=M+1
      COEFF(M,I)=FA*A1
      NPROD(M,I)=NUCLI-20040
      M=M+1
      COEFF(M,I)=COEFF(M-1,I)
      NPROD(M,I)=20040
      ABETA=ABETA-FA
C     BETA DECAY
  370 IF(ABETA.LT.1.E-4) GO TO 380
      M=M+1
      COEFF(M,I)=ABETA*A1
      NPROD(M,I)=NUCLI+10000
      IF(FB1 .LT. ERR)GO TO 380
      M=M+1
      COEFF(M,I)=COEFF(M-1,I)*FB1
      COEFF(M-1,I)=COEFF(M-1,I)-COEFF(M,I)
      NPROD(M,I)=NPROD(M-1,I)+1
C
C     NEUTRON CAPTURE CROSS SECTIONS
C
  380 KAP(I)=M
      DO 390 K=1,6
  390 CAPT(K  )=0.0
      CAPT(2)=SIGNG*FNG1
      CAPT(1)=SIGNG-CAPT(2)
      CAPT(4)=SIGN2N*FN2N1
      CAPT(3)=SIGN2N-CAPT(4)
  400 FISS(IACT)=SIGF
      TOCAP(I)=0.0
      DO 410 K=1,4
      CAPKI=CAPT(K)
      IF(CAPKI.LT.ERR)  GO TO 410
      M=M+1
      TOCAP(I)=TOCAP(I)+CAPKI
      COEFF(M,I)=CAPKI
      NPROD(M,I)=NUCLI+NUCAL(K+2)
  410 CONTINUE
      TOCAP(I)=TOCAP(I)+FISS(IACT)
C     N-3N CROSS SECTION
      A17=SIGN3N
      IF(A17.LT.ERR) GO TO 420
      M=M+1
      COEFF(M  ,I)= A17
      NPROD(M  ,I)= NUCLI-20
      TOCAP(I)=TOCAP(I)+A17
  420 IF(MOD(NUCLI,10).EQ.0) GO TO 440
      DO 430 K=1,M
  430 NPROD(K,I)=NPROD(K,I)-1
  440 MMAX(I)=M
      IF(M.GT.7)  PRINT 9039, M
      SPONF(IACT)=FSF*A1*6.023E23
```

```
      ALPHAN(IACT)=FA*A1*6.023E13*Q(I)**3.65
      DIS(I)=A1
      I=I+1
      GO TO 270
  450 IL=0
      DO 460 K=1,5
  460 TYLD(K)=0.0
C
C     READ DATA FOR FISSION PRODUCTS
C
  470 READ(8,9034,END=690)NUCL(I),DLAM,IU,FB1,FP,FP1,FT,FA,FSF,
     1Q(I),FG(I),DUMMY,AMPC(I),AMPC(I)
      DO 480 N=1,NLIBE
  480 READ(8,9038) SIGNG,RING,FNG1,Y,IT
      IF(N1.EQ.0) GO TO 500
      DO 490 N=1,N1
  490 READ(8,9036)  SKIP
  500 IF(IT .EQ. 0) GO TO 470
  510 M=0
      CALL HALF(A1,IU)
  520 NUCLI=NUCL(I)
      IF(NUCLI.EQ.0) GO TO 690
      CALL NOAH(NUCLI,NAME)
      IF(MOD(IL,50).EQ. 0)   PRINT 9012,     (TITLE (N),N=1,18)
      SIGNG=THERM*SIGNG+RES*RING
      IF(NLIBE.EQ.3) GO TO 540
  530 IF(MOD( IL         ,50).EQ.0)   PRINT 9019
      PRINT 9021,     NAME,                 DLAM,FB1,FP,FP1,FT,SIGNG,
     1     FNG1,Y,Q(I).FG(I)
      GO TO 550
  540 IF(MOD(IL,50).EQ.0) PRINT 9020
      PRINT 9022,     NAME  ,               DLAM,FB1,FP,FP1,FT,SIGNG,FNG1,
     1                Y(2),Y(4),Y(5),Q(I),FG(I)
C
C     TEST RADIOACTIVITY
C
  550 IF(A1.LT.ERR)   GO TO 600
      ABETA=1.0
C     POSITRON EMISSION
      A3=FP
      IF(A3.LT.ERR)  GO TO 570
      ABETA=ABETA-A3
      AP1=A3*FP1
      AP=A3-AP1
      IF(AP.LT.ERR)   GO TO 560
      M=M+1
      COEFF(M,I)=AP*A1
      NPROD(M,I)=NUCLI-10000
  560 IF(AP1.LT.ERR)   GO TO 570
      M=M+1
      COEFF(M,I)=AP1*A1
      NPROD(M,I)=NUCLI-9999
C     ISOMERIC TRANSITION
  570 IF(FT .LT. ERR) GO TO 580
      M=M+1
      COEFF(M,I)=FT*A1
      NPROD(M,I)=NUCLI
      ABETA=ABETA-FT
C     NEGATRON EMISSION
  580 IF(ABETA.LT.1.0E-4) GO TO 600
      A2=FB1
```

```
      AB1=ABETA*A2
      AB=ABETA-AB1
      IF(AB.LT.1.E-4) GO TO 590
      M=M+1
      COEFF(M,I)=AB*A1
      NPROD(M,I)=NUCLI+10000
  590 IF(AB1.LT.1.E-6) GO TO 600
      M=M+1
      COEFF(M,I)=AB1*A1
      NPROD(M,I)=NUCLI+10001
C
C     NEUTRON CAPTURE CROSS SECTIONS FOR FISSION PRODUCTS USING THREE
C     REGION APPROXIMATION
C
  600 KAP(I)=M
      DO 610 K=1,6
  610 CAPT(K)=0.0
      CAPT(2)=SIGNG*FAG1
      CAPT(1)=SIGNG-CAPT(2)
      TOCAP(I)=0.0
      DO 620 K=1,2
      CAPKI=CAPT(K)
      IF(CAPKI.LT.ERR)  GO TO 620
      M=M+1
      TOCAP(I)=TOCAP(I)+CAPKI
      COEFF(M,I)=CAPKI
      NPROD(M,I)=NUCLI+NUCAL(K+2)
  620 CONTINUE
  630 IF(MOD(NUCLI,10).EQ.0) GO TO 650
      DO 640 K=1,M
  640 NPROD(K,I)=NPROD(K,I)-1
  650 IL=IL+1
      DO 660 J=1,5
      YJ=Y(J)*0.010
      TYLD(J)=TYLD(J)+YJ
  660 YIELD(J,IL)=YJ
      IF(NLIBE.EQ.1.OR.NLIBE.EQ.4)  GO TO 680
  670 IF(NLIBE.EQ.3)  YIELD(1,IL)=YJ
      YIELD(3,IL)=YJ
  680 MMAX(I)=M
      IF(M.GT.7)  PRINT 9039, M
      DIS(I)=A1
      I=I+1
      GO TO 470
  690 IFP=IL
C
C     ALL DATA ON NUCLIDES HAS BEEN READ. BEGIN TO COMPUTE MATRIX COEFF
C
      ITOT=I-1
C
C     FIND PRODUCT NUCLIDES FOR REACTIONS OF LIGHT ELEMENTS
C
      NON=0
      DO 700 K=1,ITOT
  700 NONO(K)=0
      IF(ILITE.LT.1)  GO TO 760
      DO 750 I=1,ILITE
      NUCLI=NUCL(I)
      DO 720  J=1,ILITE
      KMAX=KAP(J)
      IF(KMAX.LT.1)  GO TO 720
```

```
      DO 710 M=1,KMAX
      IF(NUCLI.NE.NPROD(M,J)) GO TO 710
      NONO(I)=NONO(I)+1
      NON=NON+1
      IF(NON.GT.2500)  PRINT 9041,      NON,NUCL(I)
      A(NON)=COEFF(M,J)
      JT=J
      LOC(NON)=JT
  710 CONTINUE
  720 CONTINUE
      KD(I)=NONO(I)
      DO 740  J=1,ILITE
      K1=KAP(J)+1
      KMAX=MMAX(J)
      IF(KMAX.LT.K1)  GO TO 740
      DO 730 M=K1,KMAX
      IF(NUCLI.NE.NPROD(M,J)) GO TO 730
      NONO(I)=NONO(I)+1
      NON=NON+1
      IF(NON.GT.2500)  PRINT 9041,      NON,NUCL(I)
      A(NON)=COEFF(M,J)
      JT=J
      LOC(NON)=JT
  730 CONTINUE
  740 CONTINUE
  750 CONTINUE
C
C     NON ZERO MATRIX ELEMENTS FOR THE ACTINIDES
C
  760 IF(IACT.LT.1)  GO TO 820
      I0=ILITE+1
      I1=ILITE+IACT
      DO 810 I=I0,I1
      NUCLI=NUCL(I)
      DO 780 J=I0,I1
      MAX=KAP(J)
      IF(MAX.LT.1)  GO TO 780
      DO 770 M=1,MAX
      IF(NUCLI.NE.NPROD(M,J))  GO TO 770
      NONO(I)=NONO(I)+1
      NON=NON+1
      IF(NON.GT.2500)  PRINT 9041,      NON,NUCL(I)
      A(NON)=COEFF(M,J)
      JT=J
      LOC(NON)=JT
  770 CONTINUE
  780 CONTINUE
      KD(I)=NONO(I)
      DO 800 J=I0,I1
      M1=KAP(J)+1
      M2=MMAX(J)
      IF(M2.LT.M1)  GO TO 800
      DO 790 M=M1,M2
      IF(NUCLI.NE.NPROD(M,J)) GO TO 790
      NONO(I)=NONO(I)+1
      NON=NON+1
      IF(NON.GT.2500)  PRINT 9041,      NON,NUCL(I)
      A(NON)=COEFF(M,J)
      JT=J
      LOC(NON)=JT
  790 CONTINUE
```

```
 800  CONTINUE
 810  CONTINUE
C
C     MATRIX ELEMENTS FOR FISSION PRODUCTS
C
 820  IF(IFP.LT.1)  GO TO 900
      IM=ILITE+IACT
      I0=IM+1
      IF(ITOT.LT.I0)  GO TO 900
      DO 880 I=I0,ITOT
      NUCLI=NUCL(I)
      I2=MAX0(I0,I-10)
      I3=MIN0(ITOT,I+10)
      DO 840 J=I2,I3
      KMAX=KAP(J)
      IF(KMAX.LT.1)  GO TO 840
      DO 830 M=1,KMAX
      IF(NUCLI.NE.NPROD(M,J)) GO TO 830
      NONO(I)=NONO(I)+1
      NON=NON+1
      IF(NON.GT.2500)  PRINT 9041,      NON,NUCL(I)
      A(NON)=COEFF(M,J)
      JT=J
      LOC(NON)=JT
 830  CONTINUE
 840  CONTINUE
      MD(I)=NONO(I)
      DO 860 J=I2,I3
      K1=KAP(J)+1
      KMAX=MMAX(J)
      IF(KMAX.LT.K1)  GO TO 860
      DO 850 M=K1,KMAX
      IF(NUCLI.NE.NPROD(M,J)) GO TO 850
      NONO(I)=NONO(I)+1
      NON=NON+1
      IF(NON.GT.2500)  PRINT 9041,      NON,NUCL(I)
      A(NON)=COEFF(M,J)
      JT=J
      LOC(NON)=JT
 850  CONTINUE
 860  CONTINUE
      IF(IACT.LT.1)  GO TO 880
      DO 870 K=1,5
      IL=I-IM
      IF(YIELD(K,IL).LT.ERR)  GO TO 870
      NON=NON+1
      IF(NON.GT.2500)  PRINT 9041,      NON,NUCL(I)
      NONO(I)=NONO(I)+1
      KK=NSORS(K)
      LOC(NON)=KK
      KF=KK-ILITE
      A(NON)=YIELD(K,IL)*FISS(KF)
 870  CONTINUE
 880  CONTINUE
      IF(IFP.LE.0) GO TO 900
      IF(NLIBE.NE.3) GO TO 890
      PRINT 9027,     TYLD(2),TYLD(4),TYLD(5)
      GO TO 900
 890  PRINT 9030,     (TYLD(I),I=1,5)
C
C     ALL MATRIX ELEMENTS ARE NOW COMPUTED
```

```
C     BEGIN TRANSIENT SOLUTION
C
C
C     TEMPORARILY WRITE OUT MATRIX ELEMENTS
C
 900  IF(IR .EQ. 0) RETURN
      PRINT 9029
      N=0
      DO 910 I=1,ITOT
      NUM=NONO(I)
      IF(NUM.LE.0)  GO TO 910
      N1=N+NUM
      N=N+1
      PRINT 9028,    I,DIS (I),TOCAP(I),(A(K),LOC(K),K=N,N1)
      N=N1
 910  CONTINUE
      RETURN
 920  STOP
C
C     FORMATS     FORMATS     FORMATS     FORMATS
C
 9001 FORMAT(4F10.5,6I2)
 9002 FORMAT(I6,F5.3,I1,5F3.3,F5.2,F3.3,                   13X,E5.2,F3.3,2E5.2
     1       ,F4.3,F3.3,F6.4)
 9003 FORMAT(I6,F5.3,I1,3X,4F3.3,2E5.2,F3.3,5E5.2,F4.3,F3.3)
 9004 FORMAT(I6,F5.3,I1,5F3.3,2F5.2,F3.3,4E5.2,F3.3,F4.3,F3.3,2E5.2)
 9005 FORMAT(1H1,43X,'NUCLEAR TRANSMUTATION DATA   REVISED ',I2,'/',I2,'
     1/',I2,/,'0NUCL = NUCLIDE = 10000 * ATOMIC NO + 10 * MASS NO + ISOM
     2ERIC STATE (0 OR 1)',10X,'DLAM = DECAY CONSTANT (1/SEC),',/,' FB,
     3FP, FA, FT = FRACTIONAL DECAY BY BETA, POSITRON (OR ELECTRON CAPTU
     4RE), ALPHA, INTERNAL TRANSITION,   FB = 1 - FP - FA - FT',/,' FB1,
     5 FP1, FNG1, FN2N1 = FRACTION OF BETA, POSITRON, N-GAMMA, N-2N TRAN
     6SITIONS TO EXCITED STATE OF PRODUCT NUCLIDE',/,' SIGTH, SIGNG, SIG
     7F, SIGNA, SIGNP = THERMAL CROSS SECTIONS (BARNS) FOR ABSORPTION, N
     8-GAMMA, FISSION, N-ALPHA, N-PROTON,')
 9006 FORMAT('   SIGNG = SIGTH * (1 - FNA -FNP),  SIGNA = SIGTH * FNA,
     1SIGNP = SIGTH * FNP,  FNA, FNP = FRACTION THERMAL N-ALPHA, N-PROTO
     2N,',/,' RITH, RING, RIF, RINA, RINP = RESONANCE INTEGRAL FOR ABSOR
     3PTION, N-GAMMA, FISSION, N-ALPHA, N-PROTON,',/,'   RING = RITH * (
     41 - FINA - FINP), RINA = RITH * FINA, RINP = RITH * FINP,  FINA, F
     5INP = FRACTION RESONANCE N-ALPHA, N-PROTON,',/,' SIGMEV, SIGFF, SI
     6GN2N, SIGNAF, SIGNPF = FAST CROSS SECTIONS (BARNS) FOR ABSORPTION,
     7FISSION, N-2N, N-ALPHA, N-PROTON,',/,'   SIGN2N = SIGMEV * (1 - FF
     8NA - FFNP),  SIGNAF = SIGMEV * FFNA,  SIGNPF = SIGMEV * FFNP,  FFN
     9A, FFNP = FRACTION FAST N-ALPHA, N-P,')
 9007 FORMAT(' Y23, Y25, Y02, Y28, Y49 = FISSION YIELD (PERCENT) FROM 23
     13-U, 235-U, 232-TH, 238-U, 239- PU,',/,' Q = HEAT PER DISINTEGRATI
     2ON,  FG = FRACTION OF HEAT IN GAMMAS OF ENERGY GREATER THAN 0.2 ME
     3V,',/,'0 EFFECTIVE CROSS SECTIONS FOR A VOLUME AVERAGED THERMAL (L
     4T 0.876 EV) FLUX ARE AS FOLLOWS.',/,'    N-GAMMA  =  SIGNG * THERM
     5 + RING * RES,',/,'    FISSION  =  SIGF * THERM + RIF * RES + SIGF
     6F * FAST,',10X,'THERM = 1/V CORRECTION FOR THERMAL SPECTRUM AND TE
     7MPERATURE,',/,'    N-2N     =  SIGN2N * FAST,',36X,'RES   = RATIO
     8OF RESONANCE FLUX PER LETHARGY UNIT TO THERMAL FLUX,')
 9008 FORMAT('    N-ALPHA  =  SIGNA * THERM + RINA * RES + SIGNAF * FAST
     1,',7X,'FAST = 1.45 *  RATIO OF FAST (GT 1.0 MEV) TO THERMAL FLUX '
     2/'    N-PROTON  =  SIGNP * THERM + RINP * RES + SIGNPF * FAST,')
 9009 FORMAT(1H0,59X,'REFERENCES',/,'    HALF LIVES, DECAY SCHEMES, AND
     1THERMAL POWER',/,' C M LEDERER, J M HOLLANDER, AND I PERLMAN ''TAB
     2LE OF ISOTOPES - SIXTH EDITION'' JOHN WILEY AND SONS, INC (1967)',
     3/,' B S DZHELEPOV AND L K PEKER ''DECAY SCHEMES OF RADIOACTIVE NUC
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     4LEI'' PERGAMMON PRESS (1961)','/',' D T GOLDMAN AND JAMES R ROSSER '
     5'CHART OF THE NUCLIDES'' NINTH EDITION  GENERAL ELECTRIC CO (JULY
     61966)','/',' E D ARNOLD ''PROGRAM SPECTRA'' APPENDIX A OF ORNL-3576
     7(APRIL 1964)')
9010 FORMAT('    CROSS SECTIONS AND FLUX SPECTRA','/',' R E PRINCE ''NEUT
     1RON REACTION RATES IN THE MSRF SPECTRUM'' ORNL-4119, PP 79-83 (JUL
     2Y 1967)','/',' R E PRINCE ''NEUTRON ENERGY SPECTRA IN MSRE AND MSBR'
     3' ORNL-4191, PP 50-58 (DEC 1967)','/',' M D GOLDBERG ET AL ''NEUTRON
     4 CROSS SECTIONS'' BNL-325, SECOND ED, SUPP NO 2 (MAY 1964 - AUG 19
     566) ALSO EARLIER EDITIONS','/',' H T KERR, UNPUBLISHED FRC COMPILATI
     6ON (FEB 1968)','/',' M K DRAKE ''A COMPILATION OF RESONANCE INTEGRAL
     7S'' NUCLEONICS, VOL 24, NO 8, PP 108-111 (AUG 1966)','/',' BNL STAF
     8F ''INVESTIGATION OF N-2N CROSS SECTIONS'' BNPC-98, PP 44-98 (JUNE
     9 1965)')
9011 FORMAT(18A4,I3)
9012 FORMAT(1H1,20X,18A4)
9013 FORMAT(' H ALTER AND C E WEBER ''PRODUCTION OF H AND HE IN METALS
     1DURING REACTOR IRRADIATION'' J NUCL MATLS, VOL 16, PP 68-73 (1965)
     2','/',' L L BENNETT ''RECOMMENDED FISSION PRODUCT CHAINS FOR USE IN
     3REACTOR EVALUATION STUDIES'' ORNL-TM-1658 (SEPT 1966)')
9014 FORMAT('    FISSION PRODUCT YIELDS','/',' M E MEEK AND B F RIDER, ''
     1SUMMARY OF FISSION PRODUCT YIELDS FOR U-235, U-238, PU-239, AND PU
     2-241 AT THERMAL, FISSION SPECTRUM AND'/'      14 MEV NEUTRON ENERGI
     3ES'' APED-5398-A(REV.),(OCT. 1968)'/' S KATCOFF '' FISSION PRODUCT
     4YIELDS FROM NEUTRON INDUCED FISSION'' NUCLEONICS, VOL 18, NO 11,
     5(NOV 1960)'/' N D DUDEY '' REVIEW OF LOW-MASS ATOM PRODUCTION IN F
     6AST REACTORS'' ANL-7434,(APRIL 1968) ')
9015 FORMAT(1H0,20X,'LIGHT ELEMENTS, MATERIALS OF CONSTRUCTION, AND ACT
     1IVATION PRODUCTS  ','/','0 NUCL     DLAM     FB1    FP     FP1    FT     F
     2A    SIGTH    FNG1    FNA    FNP    RITH    FINA  FINP   SIGMEV  FN2N
     3 FFNA  FFNP    Q    FG')
9016 FORMAT(1H0,20X,'LIGHT ELEMENTS, MATERIALS OF CONSTRUCTION, AND ACT
     1IVATION PRODUCTS  ','/','0 NUCL     DLAM     FB1    FP     FP1    FT     F
     2A    SIGNG    FNG1   SIGN2N    FN2N1    SIGNA    SIGNP     Q     FG AB
     3UNDANCE')
9017 FORMAT(1H ,A2,I3,A1,1PE9.2,0P5F6.3,1PE9.2,0P3F6.3,1PE9.2,0P2F6.3,
     11PE9.2,0P4F6.3,0PF5.2)
9018 FORMAT(1H0,10X,'THERM= 'F10.5,5X,'RES= 'F10.5,5X,'FAST= 'F10.5,
     1//,1X,'NEUTRON SOURCE= '5(I10,5X),5X,'NLIBE= 'I3)
9019 FORMAT(1H0,36X,'FISSION PRODUCTS','/','0 NUCL     DLAM     FB1    FP
     1 FP1    FT      SIGNG ',       ' FNG1     Y23       Y25      Y02       Y
     228      Y49      Q     FG')
9020 FORMAT(1H0,36X,'FISSION PRODUCTS','/','0 NUCL     DLAM     FB1    FP
     1 FP1    FT      SIGNG   FNG1     Y25      Y28      Y49     Q      FG')
9021 FORMAT(1H ,A2,I3,A1,1PE9.2,0P4F6.3, 1PE9.2,0PF6.3,1P5E9.2,
     10P2F6.3)
9022 FORMAT(1H ,A2,I3,A1,1PE9.2,0P4F6.3,1PE9.2,0PF6.3,1P3E9.2,0P2F6.3)
9023 FORMAT(1H0,32X, 'ACTINIDES AND THEIR DAUGHTERS',//
     1'  NUCL     DLAM     FB1    FP     FP1    FT    FA  FSF E+6  SIGNG     R
     2ING    FNG1     SIGF     RIF      SIGFF     SIGN2N     SIGN3N    Q  FG')
9024 FORMAT(1H0,32X, 'ACTINIDES AND THEIR DAUGHTERS',//
     1'  NUCL     DLAM     FB1    FP     FP1    FT    FA     FSF E+6  SIGNG    F
     2NG21     SIGF     SIGN2N     SIGN3N     Q     FG')
9025 FORMAT(1H ,A2,I3,A1,1PE9.2,0P5F6.3,6PF6.1,1P2E9.2,0PF6.3,1P5E9.2,
     1         0PF6.3,F5.2)
9026 FORMAT(1H ,A2,I3,A1,1PE9.2,0P5F6.3,6PF9.1,1PE9.2,0PF6.3,1P3E9.2,
     1         0PF7.3,F5.2)
9027 FORMAT('0SUM OF YIELDS OF ALL FISSION PRODUCTS =',15X,1P3E9.2)
9028 FORMAT(I5,2X,1PE10.3,3X,E10.3,5(2X,E10.3,3X,I5)/(30X,5(2X,E10.3,
     1      3X,I5)))
9029 FORMAT('1NON-ZERO MATRIX ELEMENTS AND THEIR LOCATIONS'/
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1'  I        DIS(I)        CAP(I)       A(I,J)        J     A(I,J)
2J       A(I,J)        J       A(I,J)        J       A(I,J)        J  ')
9030 FORMAT(64H0SUM OF YIELDS OF ALL FISSION PRODUCTS
    1        ,1P5E9,2)
9031 FORMAT(5I10)
9032 FORMAT(I6,F5.3,I1,5F3.3,E5.2,3F3.3,E5.2,2F3.3,E5.2,3F3.3,F4.3,F3.3
    1,F6.4)
9033 FORMAT(1H ,A2,I3,A1,1PE9.2,0P5F6.3,1PE9.2,0PF6.3,1PE9.2,0PF6.3,
    1        1P2E9.2,0P2F6.3,F7.3)
9034 FORMAT(I7,F9.3,I1,5F5.3,1PE9.2,0P2F5.3,F7.3,2E6.0)
9035 FORMAT(7X,F9.2,3F5.3,F9.2,2F5.3,F9.2,3F5.3, 5X,I1)
9036 FORMAT(20A4)
9037 FORMAT(7X,2F9.2,F5.3,4F9.2,F4.3,F9.2,I1)
9038 FORMAT(7X,2F9.2,F5.3,5F9.2, 4X,I1)
9039 FORMAT('0  WARNING, NOUT OF RANGE IN NUDATA, =' I5)
9040 FORMAT(   7X,F9.2,3F8.6,F4.2,2F3.1,F9.2,3F5.3,5X,I1)
9041 FORMAT('0 NON HAS EXCEEDED 2500, EQUAL TO '2I6)
     END
     SUBROUTINE COLLECT(TMB,CWASTE,ILITE,ITOT)
     COMMON/EQ/XZERO(800), XZH(800),XTEMP(800),XNEW(10,800),
    1       B(800),D(800)
     DIMENSION CWASTE(800)
     IF(TMB.LT.1) RETURN
     DO 10 I=1,ITOT
     B(I)=CWASTE(I)
10   XTEMP(I)=0.0
     CALL DECAY(1,TMB,ITOT)
     CALL TERM(TMB,1,0,ITOT)
     CALL EQUIL(1,ITOT)
     DO 20 I=1,ITOT
20   CWASTE(I)=XNEW(1,I)/TMB
     RETURN
     END
     SUBROUTINE STORAG(TMB,CWASTE,ILITE,ITOT)
     COMMON/EQ/XZERO(800), XZH(800),XTEMP(800),XNEW(10,800),
    1       B(800),D(800)
     DIMENSION CWASTE(ITOT)
     IF(TMB.LT.1)  RETURN
     DELT=TMB
     DO 10 I=1,ITOT
     B(I)=0.0
10   XTEMP(I)=CWASTE(I)
     CALL DECAY(1,DELT,ITOT)
     CALL TERM(TMB,1,ILITE,ITOT)
     CALL EQUIL(1,ITOT)
     DO 20 I=1,ITOT
20   CWASTE(I)=XNEW(1,I)
     RETURN
     END
C    PROGRAM BLOCK DATA
     BLOCK DATA
     INTEGER*2 ELE(99),STA(2)
     COMMON/LABEL/  ELE,STA
     DATA ELE/' H','HE','LI','BE',' B',' C',' N',' O',' F','NE','NA','M
    1G','AL','SI',' P',' S','CL','AR',' K','CA','SC','TI',' V','CR','MN
    2','FE','CO','NI','CU','ZN','GA','GE','AS','SE','BR','KR','RB','SR'
    3,' Y','ZR','NB','MO','TC','RU','RH','PD','AG','CD','IN','SN','SB',
    4'TE',' I','XE','CS','BA','LA','CE','PR','ND','PM','SM','EU','GD','
    5TB','DY','HO','ER','TM','YB','LU','HF','TA',' W','RE','OS','IR','P
    6T','AU','HG','TL','PB','BI','PO','AT','RN','FR','RA','AC','TH','PA
    7',' U','NP','PU','AM','CM','BK','CF','ES'/
```

```
      DATA STA/'  ','M '/                                               00022610
      END                                                               00022620
      SUBROUTINE  HALF(A,I)                                             00022630
C     SUBROUTINE HALF CONVERTS HALF-LIFE TO DECAY CONSTANT (1/SEC)      00022640
      DIMENSION C(9)                                                    00022650
      DATA C/6.9315E-01,1.1552E-02,1.9254E-04,8.0226E-06,2.1965E-08,0.0,00022660
     1       2.1965E-11,2.1965E-14,2.1965E-17/                          00022670
      IF(A.GT.0.0)  GO TO 10                                            00022680
      IF(I.EQ.6)  GO TO 20                                              00022690
      A=9.99                                                            00022700
      RETURN                                                            00022710
   10 A=C(I)/A                                                          00022720
      RETURN                                                            00022730
   20 A=0.0                                                             00022740
      RETURN                                                            00022750
      END                                                               00022760
      SUBROUTINE NOAH(NUCLI,NAME)                                       00022770
C     SUBROUTINE NOAH CONVERTS SIX DIGIT IDENTIFIER TO ALPHAMERIC SYMBOL00022780
      INTEGER*2 NAME(3)                                                 00022790
      INTEGER*2 ELE(99),STA(2)                                          00022800
      COMMON/LABEL/  ELE,STA                                            00022810
      IS=MOD(NUCLI,10)+1                                                00022820
      NZ  =NUCLI/10000                                                  00022830
      M=NUCLI/10-NZ  *1000                                              00022840
      NAME(1)=ELE(NZ)                                                   00022850
      NAME(2)=M                                                         00022860
      NAME(3)=STA(IS)                                                   00022870
      RETURN                                                            00022880
      END                                                               00022890
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CHAPTER 4. DATA NEEDED FOR 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 lb/hr).

2. Demineralizer type (deep bed or powdered resin) and size (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 lb/hr).

2. Demineralizer type (deep bed or powdered resin).

3. Number and size (in ft^3) 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 holdup time (in hr) for offgases from the main condenser air ejector prior to processing by the offgas treatment system.

2. 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 expected air inleakage per condenser shell, the number of condenser shells, and the iodine source term from the condenser.

3. 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.

4. 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.

5. The steam flow (in lb/hr) to the turbine gland seal and the source of the steam (primary or auxiliary).

6. 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.

7. 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); radioactive particulate size distribution; 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.

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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13. Hope Creek Preliminary Safety Analysis Report (PSAR), Amendment 4, p. 9.4-3, March 1971.

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15. L. R. Michaels and N. R. Horton, "Improved BWR Offgas Systems," 12th Air Cleaning Conference, San Jose, Calif., August 1972.

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