FINAL SAFETY ANALYSIS REPORT

CHAPTER 11

RADIOACTIVE WASTE MANAGEMENT

11.0 RADIOACTIVE WASTE MANAGEMENT

This chapter of the U.S. EPR Final Safety Analysis Report (FSAR) is incorporated by reference with supplements {and departures} as identified in the following sections.

11.1 SOURCE TERMS

{This section of the U.S. EPR FSAR is incorporated by reference with the following supplement.

In general, BBNPP will minimize radioactive contamination of the facility by using structure, system, and component (SSC) designs and operational procedures that limit leakage and/or control the spread of contamination. The design and operational procedures will provide for the early detection of leaks thus allowing prompt assessment to support a timely and appropriate response. In accordance with Regulatory Guide 4.21 (NRC, 2008), the minimization of facility contamination will be considered in the context of overall facility safety.

11.1.1 REFERENCE

NRC, 2008. Minimization of Contamination and Radioactive Waste Generation: Life-Cycle Planning, Regulatory Guide 4.21, U. S. Nuclear Regulatory Commission, June, 2008.}

11.2 LIQUID WASTE MANAGEMENT SYSTEM

{This section of the U.S. EPR FSAR is incorporated by reference with the following departures and supplements.}

11.2.1 DESIGN BASIS

{No departures or supplements.}

11.2.2 SYSTEM DESCRIPTION

{No departures or supplements.}

11.2.3 RADIOACTIVE EFFLUENT RELEASES

{This section of the U.S. EPR FSAR is incorporated by reference with the following departures and supplements.}

11.2.3.1 Discharge Requirements

{No departures or supplements.}

11.2.3.2 Estimated Annual Releases

{The U.S. EPR FSAR, Sections 11.2.3.2 and associated tables, are incorporated by reference with the following supplemental information.

BBNPP will depart from the U.S. EPR FSAR by utilizing several different input parameter values to the GALE code in the development of the liquid and gaseous effluent release source term for normal plant operations. In addition, an alternate method to the GALE code was used to estimate the release of C^{14} in gaseous releases. This model change departs from the guidance in NUREG-0800 (NRC, 2007a) which indicates that the GALE code should be used for normal effluent release estimates.

Alternate Inputs to GALE

The use of alternate inputs to the GALE code model does not constitute a deviation from the regulatory guidance provided in NUREG-0800, Chapter 11.0 (NRC, 2007a) and Regulatory Guide 1.206, Sections C.I.11 and C.III.1 (NRC, 2007b) that calls for the application of the GALE code in the calculation of normal effluent releases. The use of the alternate inputs is a departure from the U.S. EPR FSAR that described more conservative operating conditions than are expected for operations at BBNPP.

The GALE code design inputs are listed in Table 11.2-1 (The values for this table are listed in U.S. EPR FSAR Table 11.2-3). These inputs are identical to those used for the U.S. EPR design certification with the following exceptions:

Table 11.2-1; Item 12, shim bleed flow rate - increased to reflect total letdown flow and remove the FSAR assumption that 5% of processed flow is sent to the liquid radwaste system for processing and release. The shim bleed flow for BBNPP is assumed to be recycled.

Table 11.2-1; Items 16 and 24, shim bleed collection time - adjusted to reflect zero shim bleed flow into tank that would be used for collection and release.

Table 11.2-1; Item 18, shim bleed average fraction of waste to be discharged - set to 0, per discussion for Item 12 above (100% shim bleed recycle).

The input parameters used in the calculation of liquid and gaseous effluent releases to the environment for the U.S. EPR FSAR, conservatively assumed that 5% of the total shim bleed flow was directed to the liquid waste system for processing and discharged to the environment. Examples and tables contained in NUREG-0017 (NRC, 1985) implied that 0.1 (10%) was the lowest value allowed for Item 18 (fraction of waste to be discharged). By setting the fraction of waste discharged to 1.0, and reducing the total shim bleed flow rate (Item 12) to 5% of actual, a shim bleed flow discharged less than 10% could be represented in the GALE code.

In expected operation of the shim bleed system for BBNPP, all of the processed shim bleed liquid is recycled (i.e., none of the shim bleed is directed to the liquid waste system). Use of the GALE code demonstrated that a value of 0.0 could be entered for Item 18 (fraction of waste discharged). As such, this calculation changes the assumption that 5% of the processed shim bleed flow is directed to liquid waste system. This will require an operational restriction to ensure that shim bleed flow is recycled.

With the above noted changes in input parameters to GALE, the liquid and gaseous normal effluent source term for BBNPP was generated in a similar fashion to what was done for the U.S. EPR. The U.S. EPR FSAR followed the guidance provided in NUREG-0800 (NRC, 2007a) for the generation of normal effluent source terms. The results of the U.S. EPR design certification effort are presented in the U.S. EPR FSAR (AREVA, 2009). The generation of a site specific normal effluent source term for BBNPP using GALE does not constitute a deviation, with the exception of C^{14} in gaseous waste, from the NRC guidance documents (NRC, 2007b, NRC, 2007c and NRC, 1985). However, the implementation of the GALE code does deviate from the U.S. EPR FSAR Chapter 11 description of inputs to GALE. The primary impact of these input assumptions to the GALE code causes the annual release of Kr^{85} to drop from a very conservative estimate of 34,000 Ci (1.26E+06 GBq) to 2,800 Ci (1.04E+05 GBq) in gaseous effluents. Only three other gaseous effluent radionuclides showed a change in the release quantity from the U.S. EPR FSAR for this change in input assumptions. These include Xe^{131m} with a 22.9% decrease, Xe^{133} with a 16.3% decrease and Xe^{133m} with a 5.6% reduction. Table 11.2-3 compares the effects of these input parameter changes.

Based on the same GALE inputs discussed above, only minor difference in the expected liquid waste effluent is seen (see Table 11.2-2) for individual radionuclides, with no net overall change of the activity estimated to be released between the U.S. EPR FSAR estimate and the BBNPP application. The changes in liquid effluent for individual radionuclides ranged from plus 6.7% to minus 2.9%, with 6 radionuclides increasing in effluent activity slightly, while 1 radionuclide decreased slightly.

Carbon-14 Model Departures from GALE

As a separate change from the input parameters used to execute the GALE code, a departure from the NRC guidance in NUREG-0800 to use the GALE code for all effluent isotopes was taken from the U.S. EPR FSAR for BBNPP with respect to the estimated annual quantity of C^{14} assumed to be released in gaseous effluents. The GALE code has a fixed annual release value for C^{14} of 7.3 Ci (270 GBq) (NRC, 1985) regardless of the power level of the reactor, and with no determination of the chemical form of the carbon released in the waste gas to the environment. This fixed C^{14} production in GALE does not allow for changes to effluent production based on differences in plant design, such as power output. The main production in nuclear power plants of C^{14} is by activation of O^{17} content of water in the primary coolant circuit and activation of nitrogen impurities in the fuel. The quantity released is directly linked to energy provided by the reactor which can be correlated to rated thermal power of the plant. The U.S. EPR is significantly larger, approximately 4,500 MWt, than the size of the nuclear power plants, approximately 2089 MWt, used in the development of the GALE code. This fixed C^{14} release value is considered non-conservative for plants significantly larger than those included in the GALE release estimate.

As a result, the BBNPP annual release of C^{14} is conservatively increased for analysis purposes to 18.9 Ci (0.7 TBq). In supporting this estimation for C^{14}, plant thermal power ratings for those units used in the GALE code estimate was ratioed in the increased higher thermal rating of the U.S. EPR. the GALE estimated C^{14} release value of 7.3 Ci/yr (270 GBq/yr) was based on measurements of 10 PWR reactor units with an averaged power level of approximately 2,089 MWt (Table 11.2-4). If the resulting C^{14} production rate of 0.00351 curie/yr per MWt is applied to the approximate power level of the U.S. EPR of 4,500 MWt, the estimated C^{14} release would increase to 15.8 Ci/yr (0.59 TBq). This is conservatively within the 18.9 Ci/yr (0.7 TBq/yr) noted above for use in effluent release analyses, and represents a conservative increase in the estimated release of C^{14} compared to the GALE model.

With respect to chemical form of C^{14} released in gaseous effluents, the U.S. EPR is expected to release C^{14} as 80% methane and only 20% carbon dioxide, consistent with reported chemical form measurements (Kunz, 1985) from U.S. PWRs which indicate values of CO_2 between 10% and 26% (Table 11.2-5) of the total gaseous C^{14} released and immediately available by photosynthesis for incorporation in vegetable food products assumed in the dose estimates for members of the public.

Conclusions

The use of the GALE code for the determination of the liquid and gaseous effluent releases, except for C^{14} in gaseous releases, from BBNPP was used consistent with NRC guidance for use of the GALE code in the license applications. Three of the GALE code input parameters did depart from those used in the U.S. EPR FSAR application execution of GALE which was reflected in the code output results that reduced the amount of noble gas released to the environment. The one exception from the use of GALE to produce an effluent gas release quantity was the replacement of the fixed quantity of C^{14} assumed in the GALE code with a larger total quantity which reflects the expectation that the larger size of the U.S. EPR than previous U.S. PWR designs would tend to generate higher quantities. This departure from the standard GALE assumption is conservative in that a larger total quantity released is estimated compared to that reported in the U.S. EPR FSAR. The allocation of 20% of the total C^{14} assigned to the gaseous release to be in the form of carbon dioxide is consistent with measurements of the chemical form of C^{14} emissions in PWR gaseous waste.

The resulting liquid and gaseous effluent release concentrations for BBNPP (Table 11.2-6 and Table 11.2-7) and associated doses to members of the public, comply with the regulatory limits of 10 CFR Part 20, Appendix B, Table 2 (CFR, 2008a) for radioactive concentrations in unrestricted areas, and the ALARA dose objectives of 10CFR Part 50, Appendix I (CFR, 2008b) as have been calculated for the BBNPP Environmental Report as reported in Environmental Report Sections 3.5 and 5.4.}

11.2.3.3 Release Points and Dilution Factors

{No departures or supplements.}

11.2.3.4 Estimated Doses

{No departures or supplements.}

11.2.3.5 Maximum Release Concentrations

{No departures or supplements.}

11.2.3.6 Radioactive Liquid Waste System Leak or Failure

{No departures or supplements.}

11.2.3.7 Postulated Radioactive releases due to Liquid-Containing Tank Failures

{No departures or supplements.}

11.2.3.8 Quality Assurance

{No departures or supplements.}

11.2.4 LIQUID WASTE MANAGEMENT SYSTEM COST-BENEFIT ANALYSIS

{This section of the U. S. EPR FSAR is incorporated by reference with the following supplement:}

The U.S. EPR FSAR includes the following COL Item in Section 11.2.4:

> A COL applicant that references the U.S. EPR design certification will confirm that the liquid waste management system cost-benefit analysis for the typical site is applicable to their site; if it is not, provide a site-specific cost-benefit analysis.

This COL Item is addressed as follows:

{In addition to meeting the numerical As Low As Reasonably Achievable (ALARA) design objective dose values for effluents released from a light water reactor as stipulated in 1OCFR50, Appendix I (CFR, 2007b), the regulation also requires that plant designs include all items of reasonably demonstrated cleanup technology that when added to the liquid waste processing system sequentially and in order of diminishing cost-benefit return, can, at a favorable cost-benefit ratio, effect reductions in dose to the population reasonably expected to be within 50 mi (80 km) of the reactor. Although not required by NRC Regulations, values of $2,000 per person-rem, and $2,000 per person-thyroid-rem are conservatively used as a favorable cost benefit threshold based on NUREG-1530 (NRC, 1995a). The source term for each equipment configuration option was generated using the same GALE code as described in Environmental Report Section 3.5.1 along with the same plant specific parameters modified only to accommodate the changes in waste stream decontamination factor afforded by the design options simulated.

For the U.S. EPR, the dose reduction effects for the sequential addition of the next logical liquid waste processing component (i.e., waste demineralizer) results in a reduction in the 50 mi (80 km) population total body exposure of 0.06 person-rem (0.0006 person-sievert). Environmental Report Section 5.4 describes the population dose calculation for both the base system case of processing liquid waste with an evaporator and centrifuge for Group I and II waste streams, and the augmented system configuration that adds a vendor suppied waste demineralizer for additional processing of the distillate produced by the evaporator and centrifuge. Table 11.2-8 illustrates the relative population dose associated with both base equipment configuration and that associated with the addition of the waste demineralizer subsystem. Table 11.2-9 compares the estimated total body dose reduction or savings achieved for the addition of the demineralizer subsystem along with a conservative estimated cost for the purchase, operation and maintenance (O&M) of the equipment. The cost basis for the equipment option is taken from Regulatory Guide 1.110 (NRC, 1976) and reported in 1975 non-escalated dollars which provides a conservatively low estimate of the equipment cost to today's dollars. A 40 year operating time frame is used although the U.S. EPR is designed for a 60 year operating life. The BBNPP plant license submittal is for 40 years. The site area population wthin 50 mi (80 km) is based on a projected population in 2070, over 50 years from the estimated start of plant operations. Using the population at the end of plant life is conservative in that it maximizes the collective dose from plant effluents. For the total body dose reduction, Table 11.2-9 illustrates that the favorable benefit in reduced dose associated with the addition of a waste demineralizer system had a dollar equivalent benefit value of $4,800. However, the estimated cost to purchase, operate and maintain this equipment over its operating life was approximately $534,200, thereby resulting in a total body effective benefit to cost ratio of less than 1.0 (not justified on an ALARA basis of dose savings to the public).

In consideration of the collective thyroid dose reduction, Table 11.2-10 illustrates that the favorable benefit in reduced dose associated with the addition of a waste demineralizersystem had a dollar equivalent benefit value of $3,200. However, the estimated cost to purchase, operate and maintain this equipment over its operating life is the same as shown for the total. In assessing if there are any demonstrated technologies that could be added to the plant design at a favorable cost-benefit ratio, a bounding assessment has also been performed which demonstrates that there is insufficient collective dose available to be saved that would warrant additional equipment cost. For the bounding total body collective dose estimate, if an equipment option could reduce the base case population dose to zero, the maximum potential savings in collective dose would be equivalent to $2,000 per person-rem (reference value for favorable benefit from NUREG-1530 (NRC, 1995a)) times the life time integrated total body population dose associated with base condition (i.e., 0.155 person-rem/yr x 40 yrs x $2,000 per person-rem = $12,400). For the thyroid collective dose, the savings would be equivalent to $2,000 per person-rem times the life time integrated thyroid population dose associated with base condition (Le., 0.128 person-rem/yr x 40 yrs x $2,000 per person-rem = $10,240). The assumption of achieving a zero dose does not take into account that tritium in effluents contributes to the dose and that current available treatment options are ineffective to remove it.

Since the benefit value for both the total body and thyroid to reduce the dose to zero is significantly less than the direct and 40 year O&M cost of the waste demineralizer subsystem option or other options from Regulatory Guide 1.110 (NRC, 1976) not already incorporated in the plantdesign, the bounding assessment indicates that there are no likely equipment additions that could be justified on an ALARA basis for liquid waste processing. It should be noted that even though not warranted on a population dose savings basis, a vendor supplied waste demineralizer subsystem skid has been added to the plant design to provide plant operators greater flexibility to process waste liquids by different processes to best match waste stream characteristics, such as chemical form, with the waste process treatment method that best handles the waste from an economics standpoint.}

{This section of the U.S. EPR FSAR is incorporated by reference}

11.2.5 REFERENCES

{This section of the U.S. EPR FSAR is supplemented as follows.

AREVA, 2009. U.S. EPR Final Safety Analysis Report Revision 1, Docket No. 52-020, Areva NP, May 2009.

CFR, 2008a. Title 10, Code of Federal Regulations, Part 20, Appendix B, Table 2, Radionuclides, Annual Limits on Intake (ALIs) and Derived Air Concentrations (DACs) of Radionuclides for Occupational Exposure; Effluent Concentrations; Concentrations for Release to Sewage, 2008.

CFR, 2008b. Title 10, Code of Federal Regulations, Part 50.34a, Design Objectives for Equipment to Control Releases of Radioactive Material in Effluents - Nuclear Power Reactors, and Appendix I, Numerical Guides for Design Objectives and Limiting Conditions for Operation to Meet the Criterion "As Low as is Reasonably Achievable" for Radioactive Material in Light-Water-Cooled Nuclear Power Reactor Effluents, 2008.

Kunz, 1985. C. Kunz; "Carbon-14 Discharge at Three Light-Water Reactors", Health Physics, Volume 49, Issue 1, July 1985 (Pages 25-35).

NRC, 1976. Cost-Benefit Analysis for Radwaste Systems for Light Water-Cooled nuclear Power Reactors, regulatory Guide 1.110 (For Comment), Nuclear Regulatory Commission, March 1976.

NRC, 1985. NUREG-0017, Calculation of Releases of Radioactive Materials in Gaseous and Liquid Effluents from Pressurized Water Reactors (PWR-GALE Code)," Rev. 1, April 1985.

NRC, 1995. NUREG/CR-2907, Vol.13, "Radioactive Materials Released from Nuclear Power Plants, Annual Report 1992".U.S. NRC, Published August 1995.

NRC, 1995a. Reassessment of NRC's Dollar Per Person-Rem Conversion factor Policy, NUREG-1530, Nuclear Regulatory Commission, 1995.

NRC, 2007a. U.S. NRC NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants," Chapter 11.0 Radioactive Waste Management", Revision 4, 2007

NRC, 2007b. U.S.NRC Regulatory Guide 1.206, "Combined License Applications for Nuclear Power Plants (LWR Edition)," Sections C.I.11 and C.III.1, June 2007.

NRC, 2007c. Regulatory Guide 1.112, "Calculation of Releases of Radioactive Materials in Gaseous and Liquid Effluents from Light-Water-Cooled Nuclear Power Reactors," March 2007.}

Table 11.2-1—{Input Parameters for PWR GALE Computer Code}

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Item	GALE Input Parameter	value
1	Thermal Power Level (MWth) (4590 + 22MW measurement uncertainty)	4612 MWth
2	Mass of Coolant in Primary System (RCS dry nominal volume - not including the pressurizer) (13596 ft^3/0.02290 ft^3/lbm)	5.937E5 lbm
3	Primary System Letdown Rate (7.94E+04 lbm/h × 0.0229 ft^3/lbm × 7.48 gal/ ft^3 × 1 min/60 sec = 226.7 gpm)	226.7 gpm
4	Letdown Cation Demineralizer Flow Rate (No purification system cation demineralizer)	0 gpm
5	Number of steam generators	4
6	Total steam flow (Nominal 4 × 5.168E+06 = 20.67E+06 lbm/hr Increase by 1.05 to account for higher thermal power = 21.71E+06 lbm/hr)	2.171E+07 lbm/hr
7	Mass of liquid in each steam generator	1.6977E+05 lbm
8	SG Blowdown rate (Nominal 4 × 0.052E+06 lbm/hr = 208E+03 lbm/hr Adjust by 1.05 to account for higher thermal power 208×1.05 = 218.4E+03)	2.184E+05 lbm/hr
9	Blowdown Treatment Method (Full blowdown flow processed by Blowdown System and recycled to condensate system.)	0
10	Condensate Demineralizer Regeneration Time (days) (Regeneration not used)	0
11	Condensate Demineralizer Flow Fraction	0.33
12	Shim Bleed Flow Rate (gpd) (Shim bleed is letdown flow for boron control and the liquid is recycled. The nominal flow is: 500 lbm/hr × 0.0229 ft^3/lbm × 7.48 gal/ ft^3 × 24 hr/day = 2056 gpd Adjusting by 1.05 to account for higher thermal power yields 2158 gpd ~ 2160 gpd	2160 gpd
13	Shim Bleed DF for Iodine (With KPK Demineralizer)	1.0E+04
14	Shim Bleed DF for Cesium and Rubidium (With KPK Demineralizer)	1.0E+07
15	Shim Bleed DF for Other Nuclides (With KPK Demineralizer)	1.0E+07
16	Shim Bleed Collection Time (days) $\frac{18500\text{ gal}}{\left(\frac{1728\text{ gal}}{\text{day}}\right)} \times 0.8 = 8.56\text{ days}$ (The collection time is for one tank. The collection time for shim bleed must also address other waste streams into the same collection time. The 1728 gpd is from equipment drains)	8.56 days
17	Shim Bleed Processing and Discharge Times (days) $\frac{18500\text{ gal}}{\left(\frac{1.1\text{ kg}}{\text{sec}}\right) \times \left(\frac{1\text{E-3 m}^3}{1\text{ kg}}\right) \times \left(\frac{8.64\text{E4 sec}}{\text{d}}\right)} \times 0.8 = 0.589\text{ days}$ (Note: 18500 gallons ~ 70 m^3)	0.589 days
18	Shim Bleed Average Fraction of Waste to be Discharged (Shim Bleed liquid is recycled)	0.0

Table 11.2-1—{Input Parameters for PWR GALE Computer Code}

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Item	GALE Input Parameter	value
19	Equipment Drains Input (gpd) (The Standard TS limit unidentified RCS leakage rate to 1 gpm. It is assumed that 1 gpm is collected by floor drains. An addition 20% is applied for conservatism. The input is then 1 gal/m × 1440 m/d × 1.2 = 1728 gpd	1728 gal/day
20	Equipment Drains PCA	1.0
21	Equipment Drains DF for Iodine (With KPK Demineralizer)	1.0E+04
22	Equipment Drains DF for Cesium and Rubidium (With KPK Demineralizer)	1.0E+07
23	Equipment Drains DF for Other Nuclides (With KPK Demineralizer)	1.0E+07
24	Equipment Drains Collection Time (days) $\frac{70\ m^3}{\left(\frac{1728\ gal}{day}\right) \times \left(\frac{m^3}{264.17\ gal}\right)} \times 0.8 = 8.56\ days$ (Note: 18500 gallons ~ 70 m^3. The collection time for equipment drains must also address other waste streams into the same collection time. The 110 gpd is from shim bleed.)	8.56 days
25	Equipment Drains Processing and Discharge Times (days) $\frac{18500\ gal}{\left(\frac{1.1\ kg}{sec}\right) \times \left(\frac{1E\text{-}3\ m^3}{1\ kg}\right) \times \left(\frac{8.64E4\ sec}{d}\right)} \times 0.8 = 0.589\ days$ (Note: 18500 gallons ~ 70 m^3)	0.589 days
26	Equipment Drains Average Fraction of Waste to be Discharged (There is no recycling of liquid radioactive waste. The waste that is processed by the liquid radioactive waste processing system is discharged.)	1.0
27	Clean Waste Input (gpd) (Conservative - 66,000 gal/week / 7 day/week = 9428 gallons per day)	9428 gal/day
28	Clean Waste PCA (Ratio 3.7 Bq/cm^3 / 3.7(103) Bq/cm^3)	0.001
29	Clean Waste DF for Iodine (With KPK Demineralizer)	1.0E+02
30	Clean Waste DF for Cesium and Rubidium (With KPK Demineralizer)	1.0E+02
31	Clean Waste DF for Other Nuclides (With KPK Demineralizer)	1.0E+02
32	Clean Waste Collection Time (days) $\frac{70\ m^3}{\left(\frac{250\ m^3}{week}\right) \times \left(\frac{week}{7\ d}\right)} \times 0.8 = 1.6\ days$ (Note: 18500 gallons ~ 70 m^3)	1.6 days
33	Clean Waste Processing and Discharge Times (days) $\frac{70\ m^3}{\left(\frac{1.4\ kg}{sec}\right) \times \left(\frac{1E\text{-}3\ m^3}{1\ kg}\right) \times \left(\frac{8.64E4\ sec}{d}\right)} \times 0.8 = 0.463\ days$ (Note: 18500 gallons ~ 70 m^3)	0.463 days
34	Clean Waste Average Fraction of Waste to be Discharged (There is no recycling of liquid radioactive waste. The waste that is processed by the liquid radioactive waste processing system is discharged.)	1.0

Table 11.2-1—{Input Parameters for PWR GALE Computer Code}

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Item	GALE Input Parameter	value
35	Dirty Waste Input (gpd) (Group III waste is normally not radioactive and it is being neglected to maximize concentrations)	0 gal/day
36	Dirty Waste PCA (N/A since input is 0 gallons.per day)	0.1
37	Dirty Waste DF for Iodine (N/A since input is 0 gallons.per day)	1.0E+02
38	Dirty Waste DF for Cesium and Rubidium (N/A since input is 0 gallons.per day)	1.0E+03
39	Dirty Waste DF for Other Nuclides (N/A since input is 0 gallons.per day)	1.0E+03
40	Dirty Waste Collection Time (days) (N/A since input is 0 gallons.per day)	0
41	Dirty Waste Processing and Discharge Times (days) (N/A since input is 0 gallons.per day)	0
42	Dirty Waste Average Fraction of Waste to be Discharged (There is no recycling of liquid radioactive waste. The waste that is processed by the liquid radioactive waste processing system is discharged.)	1.0
43	Blowdown Fraction Processed	1.0
44	Blowdown DF for Iodine (1 in the cation bed x 100 in the mixed bed = 100 overall)	1.0E+02
45	Blowdown DF for Cesium and Rubidium (10 in the cation bed x 10 in the mixed bed = 100 overall)	1.0E+02
46	Blowdown DF for Other Nuclides (10 in the cation bed x 100 in the mixed bed = 100 overall)	1.0E+03
47	Blowdown Collection Time (days)	0 days
48	Blowdown Processing and Discharge Times (days)	0 days
49	Blowdown Average Fraction of Waste to be Discharged	0.0
50	Regenerant Flow Rate (gpd) (Regeneration not used)	0.0
51	Regenerant DF for Iodine	1.0
52	Regenerant DF for Cesium and Rubidium	1.0
53	Regenerant DF for Other Nuclides	1.0
54	Regenerant Collection Time (days)	0.0
55	Regenerant Processing and Discharge Times (days)	0.0
56	Regenerant Average Fraction of Waste to be Discharged	0.0
57	Is There Continuous Stripping of Full Letdown Flow? (The degasification is normally operated prior to refueling, prior to maintenance of the reactor coolant circuit or if required to decrease the concentration of gaseous reactivity. Value of 'Y' for card 30 is ratio of total amount of noble gases routed to gaseous radwaste from the purification system to total routed from the primary coolant system. Options are 0, 0.25, 1. This is a recycled loop during normal operations, and very little of the flow ends up in delay beds, the value of 0 best represents system.)	No
58	Holdup Time for Xenon (days)	27.7 days
59	Holdup Time for Krypton (days)	1.67 days
60	Fill Time of Decay Tanks for the Gas Stripper (Days)	0 days - Discharged directly to the stack
61	Waste Gas System Particulate Releases HEPA Efficiency (%)	99 %
62	Fuel Handling Building Releases: Charcoal Efficiency (%) (HEPA and Charcoal efficiencies for non-ESF systems taken to be the same as KLA)	90 %
63	Fuel Handling Building Releases: HEPA Efficiency (%) (HEPA and Charcoal efficiencies for non-ESF systems taken to be the same as KLA)	99 %
64	Auxiliary Building Releases: Charcoal Efficiency (%) (HEPA and Charcoal efficiencies for non-ESF systems taken to be the same as KLA)	90 %
65	Auxiliary Building Releases: HEPA Efficiency (%) (HEPA and Charcoal efficiencies for non-ESF systems taken to be the same as KLA)	99 %

Table 11.2-1—{Input Parameters for PWR GALE Computer Code}
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Item	GALE Input Parameter	value
66	Containment Free Volume (ft^3).	2.8E+06
67	Containment Internal Cleanup System: Charcoal Efficiency (%) (HEPA and Charcoal efficiencies for non-ESF systems taken to be the same as KLA)	90 %
68	Containment Internal Cleanup System: HEPA Efficiency (%) (HEPA and Charcoal efficiencies for non-ESF systems taken to be the same as KLA)	99 %
69	Containment Internal Cleanup System: Flow Rate (103 cfm) (1.95 m^3/s)/(4.72 x 10-4) = 4130 cfm	4.1 E+03 cfm
70	Containment High Volume Purge: Charcoal Efficiency (%) (HEPA and Charcoal efficiencies for non-ESF systems taken to be the same as KLA)	90 %
71	Containment High Volume Purge: HEPA Efficiency (%) (HEPA and Charcoal efficiencies for non-ESF systems taken to be the same as KLA)	99 %
72	Containment High Volume Purge: Purges per Year	0
73	Containment Low Volume Purge: Charcoal Efficiency (%)	90 %
74	Containment Low Volume Purge: HEPA Efficiency (%)	99 %
75	Containment Low Volume Purge: Flow Rate (cfm) (1.4 m^3/s)/(4.72 x 10-4) = 2970 cfm	2970 cfm
76	Percent of Iodine Released from Blowdown Tank Vent	0.0 %
77	Percent of Iodine Removed from Air Ejector Release (No condenser air ejectors, mechanical vacuum pumps vent to stack without treatment)	0.0 %
78	Detergent Waste PF (No onsite laundry)	0.0
79	SG blowdown flash tank gases vented via main condenser air ejector?	No.
80	Condenser air ejector offgas released without treatment? (No condenser air ejectors, mechanical vacuum pumps vent to stack without treatment)	Yes.
81	Condenser air ejector offgas processed via charcoal adsorbers prior to release? (No condenser air ejectors, mechanical vacuum pumps vent to stack without treatment)	No.
	Post Gale Calculation Values	
82	Average flow rate of water used to dilute liquid waste discharged to the environment.	100 cfs
83	Number of Main Condenser Water Boxes	3
84	Main Condenser Water Box liquid volume (each) (nominal operating conditions) (m^3)	180
85	Main Condenser Water Box temperature (nominal operating conditions) (°C)	20.8
86	Main Condenser Water Box pressure (nominal operating conditions) (millibars)	24.7

Table 11.2-2—{GALE Liquid Release Rates (Ci/yr)}

Nuclide	U.S. EPR FSAR Ci/yr	BBNPP Ci/yr	Activity change BB - FSAR (Ci/yr)	% change from U.S. EPR FSAR
Na 24	6.1E-03	6.2E-03	1.0E-04	1.6%
Cr 51	1.0E-03	1.0E-03	0.0E+00	0.0%
Mn 54	5.4E-04	5.4E-04	0.0E+00	0.0%
Fe 55	4.1E-04	4.1E-04	0.0E+00	0.0%
Fe 59	1.0E-04	1.0E-04	0.0E+00	0.0%
Co 58	1.5E-03	1.6E-03	1.0E-04	6.7%
Co 60	1.8E-04	1.8E-04	0.0E+00	0.0%
Zn 65	1.7E-04	1.7E-04	0.0E+00	0.0%
W 187	4.6E-04	4.7E-04	1.0E-05	2.2%
Np 239	5.8E-04	5.8E-04	0.0E+00	0.0%
Sr 89	5.0E-05	5.0E-05	0.0E+00	0.0%
Sr 91	8.0E-05	8.0E-05	0.0E+00	0.0%
Y 91m	5.0E-05	5.0E-05	0.0E+00	0.0%
Y 93	3.6E-04	3.6E-04	0.0E+00	0.0%
Zr 95	1.3E-04	1.3E-04	0.0E+00	0.0%
Nb 95	1.0E-04	1.0E-04	0.0E+00	0.0%
Mo 99	1.8E-03	1.8E-03	0.0E+00	0.0%
Tc 99m	1.7E-03	1.7E-03	0.0E+00	0.0%
Ru 103	2.5E-03	2.5E-03	0.0E+00	0.0%
Ru 103m	2.5E-03	2.5E-03	0.0E+00	0.0%
Ru 106	3.1E-02	3.1E-02	0.0E+00	0.0%
Rh 106	3.1E-02	3.1E-02	0.0E+00	0.0%
Ag 110m	4.4E-04	4.4E-04	0.0E+00	0.0%
Ag 110	6.0E-05	6.0E-05	0.0E+00	0.0%
Te 129m	6.0E-05	6.0E-05	0.0E+00	0.0%
Te 129	4.0E-05	4.0E-05	0.0E+00	0.0%
Te 131m	3.1E-04	3.2E-04	1.0E-05	3.2%
Te 131	6.0E-05	6.0E-05	0.0E+00	0.0%
I 131	3.4E-02	3.4E-02	0.0E+00	0.0%
Te 132	4.8E-04	4.8E-04	0.0E+00	0.0%
I 132	1.2E-03	1.2E-03	0.0E+00	0.0%
I 133	3.5E-02	3.4E-02	-1.0E-03	-2.9%
I 135	1.5E-02	1.5E-02	0.0E+00	0.0%
Cs 134	2.6E-03	2.6E-03	0.0E+00	0.0%
Cs 136	3.1E-04	3.1E-04	0.0E+00	0.0%
Cs 137	3.5E-03	3.5E-03	0.0E+00	0.0%
Ba 137m	3.3E-03	3.3E-03	0.0E+00	0.0%
Ba 140	4.2E-03	4.2E-03	0.0E+00	0.0%
La 140	7.6E-03	7.7E-03	1.0E-04	1.3%
Ce 141	5.0E-05	5.0E-05	0.0E+00	0.0%
Ce 143	6.1E-04	6.2E-04	1.0E-05	1.6%
Ce 144	1.3E-03	1.3E-03	0.0E+00	0.0%
Pr 143	5.0E-05	5.0E-05	0.0E+00	0.0%
Pr 144	1.3E-03	1.3E-03	0.0E+00	0.0%
other	2.0E-05	2.0E-05	0.0E+00	0.0%
H 3	1.7E+03	1.7E+03	0.0E+00	0.0%
Total (except H-3)	1.9E-01	1.9E-01	0.0E+00	0.0%

Table 11.2-3—{GALE Gaseous Release Rates (Ci/yr)}

Nuclide	U.S. EPR FSAR Ci/yr	BBNPP Ci/yr	Activity change BB - FSAR (Ci/yr)	% change from U.S. EPR FSAR
H 3	180	180	0	0.00%
C 14	7.3	7.3	0	0.00%
Ar 41	34	34	0	0.00%
Iodines				
I 131	8.8E-03	8.8E-03	0	0.00%
I 133	3.2E-02	3.2E-02	0	0.00%
Noble Gases				
Kr 85m	1.5E+02	1.5E+02	0	0.00%
Kr 85	3.4E+04	2.8E+03	-31200	-91.76%
Kr 87	5.3E+01	5.3E+01	0	0.00%
Kr 88	1.8E+02	1.8E+02	0	0.00%
Xe 131m	3.5E+03	2.7E+03	-800	-22.86%
Xe 133m	1.8E+02	1.7E+02	-10	-5.56%
Xe 133	8.6E+03	7.2E+03	-1400	-16.28%
Xe 135m	1.4E+01	1.4E+01	0	0.00%
Xe 135	1.2E+03	1.2E+03	0	0.00%
Xe 138	1.2E+01	1.2E+01	0	0.00%
Airborne Particulate				
Cr 51	9.7E-05	9.7E-05	0	0.00%
Mn 54	5.7E-05	5.7E-05	0	0.00%
Co 57	8.2E-06	8.2E-06	0	0.00%
Co 58	4.8E-04	4.8E-04	0	0.00%
Co 60	1.1E-04	1.1E-04	0	0.00%
Fe 59	2.8E-05	2.8E-05	0	0.00%
Sr 89	1.6E-04	1.6E-04	0	0.00%
Sr 90	6.3E-05	6.3E-05	0	0.00%
Zr 95	1.0E-05	1.0E-05	0	0.00%
Nb 95	4.2E-05	4.2E-05	0	0.00%
Ru 103	1.7E-05	1.7E-05	0	0.00%
Ru 106	7.8E-07	7.8E-07	0	0.00%
Sb 125	6.1E-07	6.1E-07	0	0.00%
Cs 134	4.8E-05	4.8E-05	0	0.00%
Cs 136	3.3E-05	3.3E-05	0	0.00%
Cs 137	9.0E-05	9.0E-05	0	0.00%
Ba 140	4.2E-06	4.2E-06	0	0.00%
Ce 141	1.3E-05	1.3E-05	0	0.00%

Table 11.2-4—{Carbon - 14 Release Data from PWRs from GALE}

Plant	Annual Average Ci/yr - Unit	MWt Licensed[1]
Connecticut Yankee	46	1820
Yankee Rowe	0.58	600
Turkey Point 1	3.7	2200
Turkey Point 2	3.7	2200
Fort Calhoun	1.9	1500
Zion 1	3.3	3250
Zion 2	3.3	3250
Prarie Island 1	3.6	1650
Prarie Island 2	3.6	1650
Rancho Seco	3.6	2770
Average	7.3	2089
Ci/yr per MWt	0.00351	

Notes:
1. Licensed MW thermal rated data taken from NUREG/CR-2907 (NRC, 1995).

Table 11.2-5—{Carbon-14 Gaseous Release Chemical Form Reported at Two U.S. PWRs}

Chemical Form	R. E. Ginna (490 MWe)	Indian Pt. Unit 3 (1000 MWe)
$^{14}CO_2$	10%	26%
$^{14}CH_4$, $^{14}C_2H_6$, etc.	90%	74%

Table 11.2-6—{GALE Liquid Release for U.S. EPR at Bell Bend (Ci/yr)}

Nuclide	Shim Bleed	Misc. Wastes	Turbine Building	Total	Total as Adjusted[1]
Na-24	0.00E+00	1.04E-03	1.00E-05	1.05E-03	6.16E-03
Cr-51	0.00E+00	1.80E-04	0.00E+00	1.80E-04	1.04E-03
Mn-54	0.00E+00	9.00E-05	0.00E+00	9.00E-05	5.40E-04
Fe-55	0.00E+00	7.00E-05	0.00E+00	7.00E-05	4.10E-04
Fe-59	0.00E+00	2.00E-05	0.00E+00	2.00E-05	1.00E-04
Co-58	0.00E+00	2.60E-04	0.00E+00	2.70E-04	1.56E-03
Co-60	0.00E+00	3.00E-05	0.00E+00	3.00E-05	1.80E-04
Zn-65	0.00E+00	3.00E-05	0.00E+00	3.00E-05	1.70E-04
Sr-89	0.00E+00	1.00E-05	0.00E+00	1.00E-05	5.00E-05
Sr-91	0.00E+00	1.00E-05	0.00E+00	1.00E-05	8.00E-05
Y-91m	0.00E+00	1.00E-05	0.00E+00	1.00E-05	5.00E-05
Y-93	0.00E+00	6.00E-05	0.00E+00	6.00E-05	3.60E-04
Zr-95	0.00E+00	2.00E-05	0.00E+00	2.00E-05	1.30E-04
Nb-95	0.00E+00	2.00E-05	0.00E+00	2.00E-05	1.00E-04
Mo-99	0.00E+00	3.00E-04	0.00E+00	3.00E-04	1.76E-03
Tc-99m	0.00E+00	2.90E-04	0.00E+00	2.90E-04	1.71E-03
Ru-103	0.00E+00	4.30E-04	0.00E+00	4.30E-04	2.52E-03
Rh-103m	0.00E+00	4.30E-04	0.00E+00	4.30E-04	2.52E-03
Ru-106	1.00E-05	5.18E-03	3.00E-05	5.22E-03	3.07E-02
Rh-106	1.00E-05	5.18E-03	3.00E-05	5.22E-03	3.07E-02
Ag-110m	0.00E+00	7.00E-05	0.00E+00	8.00E-05	4.40E-04
Ag-110	0.00E+00	1.00E-05	0.00E+00	1.00E-05	6.00E-05
Te-129m	0.00E+00	1.00E-05	0.00E+00	1.00E-05	6.00E-05
Te-129	0.00E+00	1.00E-05	0.00E+00	1.00E-05	4.00E-05
Te-131m	0.00E+00	5.00E-05	0.00E+00	5.00E-05	3.20E-04
Te-131	0.00E+00	1.00E-05	0.00E+00	1.00E-05	6.00E-05
Te-132	0.00E+00	8.00E-05	0.00E+00	8.00E-05	4.80E-04
I-131	3.34E-03	2.43E-03	2.00E-05	5.80E-03	3.41E-02
I-132	1.00E-05	1.60E-04	2.00E-05	2.00E-04	1.16E-03
I-133	1.75E-03	4.05E-03	7.00E-05	5.87E-03	3.45E-02
I-135	5.00E-04	1.94E-03	1.00E-04	2.53E-03	1.49E-02
Cs-134	0.00E+00	4.50E-04	0.00E+00	4.50E-04	2.64E-03
Cs-136	0.00E+00	5.00E-05	0.00E+00	5.00E-05	3.10E-04
Cs-137	0.00E+00	5.90E-04	0.00E+00	6.00E-04	3.50E-03
Ba-137m	0.00E+00	5.50E-04	0.00E+00	5.60E-04	3.27E-03
Ba-140	0.00E+00	7.20E-04	0.00E+00	7.20E-04	4.23E-03
La-140	0.00E+00	1.30E-03	1.00E-05	1.31E-03	7.67E-03
Ce-141	0.00E+00	1.00E-05	0.00E+00	1.00E-05	5.00E-05
Ce-143	0.00E+00	1.00E-04	0.00E+00	1.00E-04	6.20E-04
Pr-143	0.00E+00	1.00E-05	0.00E+00	1.00E-05	5.00E-05
Ce-144	0.00E+00	2.20E-04	0.00E+00	2.30E-04	1.33E-03
Pr-144	0.00E+00	2.20E-04	0.00E+00	2.30E-04	1.33E-03
W-187	0.00E+00	8.00E-05	0.00E+00	8.00E-05	4.70E-04
Np-239	0.00E+00	1.00E-04	0.00E+00	1.00E-04	5.80E-04
Others	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.00E-05
Total (except H-3)	5.63E-03	2.69E-02	3.30E-04	3.28E-02	1.93E-01
H-3					1.66E+03

Notes:
1. Total liquid releases adjusted by 0.16 Ci/year for AOOs per NUREG-0017.
2. 0.00E+00 indicates that the value is less than 1.0E-05.

Table 11.2-7—{GALE Gaseous Release for U.S. EPR at Bell Bend (Ci/yr)}

Nuclide	Gas Stripping (continuous)	Reactor	Auxiliary	Turbine	Air Ejector Exhaust	Total
Kr-85m	2.00E+00	1.40E+02	4.00E+00	0.00E+00	2.00E+00	1.50E+02
Kr-85	1.70E+03	9.10E+02	8.00E+00	0.00E+00	4.00E+00	2.80E+03
Kr-87	0.00E+00	4.70E+01	4.00E+00	0.00E+00	2.00E+00	5.30E+01
Kr-88	0.00E+00	1.70E+02	7.00E+00	0.00E+00	4.00E+00	1.80E+02
Xe-131m	7.00E+02	1.90E+03	1.80E+01	0.00E+00	8.00E+00	2.70E+03
Xe-133m	0.00E+00	1.70E+02	2.00E+00	0.00E+00	0.00E+00	1.70E+02
Xe-133	3.50E+02	6.70E+03	6.60E+01	0.00E+00	3.10E+01	7.20E+03
Xe-135m	0.00E+00	9.00E+00	3.00E+00	0.00E+00	2.00E+00	1.40E+01
Xe-135	0.00E+00	1.20E+03	2.30E+01	0.00E+00	1.10E+01	1.20E+03
Xe-137	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Xe-138	0.00E+00	8.00E+00	3.00E+00	0.00E+00	1.00E+00	1.20E+01
Nuclide	**Fuel Building**	**Reactor**	**Auxiliary**	**Turbine**	**Air Ejector Exhaust**	**Total**
I-131	2.70E-04	1.90E-03	6.60E-03	0.00E+00	0.00E+00	8.80E-03
I-133	1.00E-03	5.80E-03	2.50E-02	0.00E+00	0.00E+00	3.20E-02
Nuclide	**Waste Gas System**	**Reactor**	**Auxiliary**	**Fuel Handling**	**Total**	
Cr-51	1.40E-07	9.20E-05	3.20E-06	1.80E-06	9.70E-05	
Mn-54	2.10E-08	5.30E-05	7.80E-07	3.00E-06	5.70E-05	
Co-57	0.00E+00	8.20E-06	0.00E+00	0.00E+00	8.20E-06	
Co-58	8.70E-08	2.50E-04	1.90E-05	2.10E-04	4.80E-04	
Co-60	1.40E-07	2.60E-05	5.10E-06	8.20E-05	1.10E-04	
Fe-59	1.80E-08	2.70E-05	5.00E-07	0.00E+00	2.80E-05	
Sr-89	4.40E-07	1.30E-04	7.50E-06	2.10E-05	1.60E-04	
Sr-90	1.70E-07	5.20E-05	2.90E-06	8.00E-06	6.30E-05	
Zr-95	4.80E-08	0.00E+00	1.00E-05	3.60E-08	1.00E-05	
Nb-95	3.70E-08	1.80E-05	3.00E-07	2.40E-05	4.20E-05	
Ru-103	3.20E-08	1.60E-05	2.30E-07	3.80E-07	1.70E-05	
Ru-106	2.70E-08	0.00E+00	6.00E-08	6.90E-07	7.80E-07	
Sb-125	0.00E+00	0.00E+00	3.90E-08	5.70E-07	6.10E-07	
Cs-134	3.30E-07	2.50E-05	5.40E-06	1.70E-05	4.80E-05	
Cs-136	5.30E-08	3.20E-05	4.80E-07	0.00E+00	3.30E-05	
Cs-137	7.70E-07	5.50E-05	7.20E-06	2.70E-05	9.00E-05	
Ba-140	2.30E-07	0.00E+00	4.00E-06	0.00E+00	4.20E-06	
Ce-141	2.20E-08	1.30E-05	2.60E-07	4.40E-09	1.30E-05	
H-3	N/A	N/A	N/A	N/A	1.8E+02	
C-14	N/A	N/A	N/A	N/A	1.89E+01[2]	
Ar-41	N/A	N/A	N/A	N/A	3.4E+01	

Notes:

1. 0.0E+00 appearing in table indicate release is less than 1.0 Ci/yr for Noble Gases, less than 0.0001 Ci/yr for Iodine.
2. The GALE code produces a fixed value of 7.3 curies of Carbon-14 regardless of plant size or process cleanup design capabilities. A departure from GALE is applied for the estimation of Carbon-14 releases to 18.9 curies/year to account for the larger power level of the U.S. EPR from those plants used in the development of the GALE code.

Table 11.2-8—{Obtainable Dose Benefits for Liquid Waste System Augment}

Cases	Population Total Body Dose - Person-Rem (Person-Sievert)[1]	Population Thyroid Dose Person-Rem (Person-Sievert)[1]
Base Case Evaporator/Centrifuge only, no Waste Demineralizer	1.55E-01 (1.55E-03)	1.28E-01 (1.28E-03)
Additional Waste Demineralizer	9.3E-02 (9.3E-04)	8.8E-02 (8.8E-04)
Obtainable dose benefit	6.2E-02 (6.2E-04)	4.0E-02 (4.0E-04)

Note:
(1) Population dose estimates described in Environmental Report Section 5.4.

Table 11.2-9—{Liquid Waste System Augment Total-Body Dose Cost-Benefit Analysis}

Parameter	Value
Annual Total-body collective dose benefit to the population within 50 miles of the BBNPP site.	0.06 person-rem (0.0006 person-sievert)
Nominal total collective dose over 40 years of operation (0.06 person-rem x 40 yr =2.4 person-rem)	2.4 person-rem (0.024 person-sievert)
Value for estimating impact based on NUREG1530	$2,000 per person-rem ($200,000 per person-sievert)
Obtainable benefit from addition of radwaste processing and control option (2.46 person-rem x $2,000/person-rem =$4,800)	$4,800
Cost Options for radwaste processing and control technology upgrade from Regulatory Guide 1.110	400 gpm demineralizer for clean waste processing [(a)]
Direct cost for option using methodology in Regulatory Guide 1.110, Table A-1 based on 1975 Dollars	$146,200
Total O&M Annual Cost (From Regulatory Guide 1.110, Table A-2 based on 1975 dollars)	$9,700
Total cost over 40 years of operation (direct cost + O&M x 40 years)	$534,200
Benefit/Cost Ratio (Values greater than 1 should be included in plant system design) $4,800/ $534,200 =0.009	0.009

Note:
[(a)] The clean waste reflects the nomenclature in GALE and the sizing is based on the EPR GALE input (Table 11.2-1).

Table 11.2-10—{Liquid Waste System Augment Thyroid Dose Cost-Benefit Analysis}

Parameter	Value
Annual Thyroid collective dose benefit to the population within 50 miles of the BBNPP site.	0.04 person-rem (0.0004 person-sievert)
Nominal total collective dose over 40 years of operation (0.04 person-rem x 40 yr =1.6 person-rem)	1.6 person-rem (0.016 person-sievert)
Value for estimating impact based on NUREG1530 (Note: 10 CFR Part 50, Appendix Ihas $1,000 per person-rem)	$2,000 per person-rem ($200,000 per person-sievert)
Obtainable benefit from addition of radwaste processing and control options	$3,200
Cost Options for radwaste processing and control technology upgrade from Regulatory Guide 1.110	400 gpm demineralizer for clean waste processing [a]
Direct cost for option using methodology in Regulatory Guide 1.110, Table A-1 based on 1975 Dollars	$146,200
Total O&M Annual Cost (From Regulatory Guide 1.110, Table A-2 based on 1975 dollars)	$9,700
Total cost over 40 years of operation (direct cost + O&M x 40 years)	$534,200
Benefit/Cost Ratio (Values greater than 1 should be included in plant system design) $3,200/ $534,200 =0.006	0.006

Note:
[a] The clean waste reflects the nomenclature in GALE and the sizing is based on the EPR GALE input (Table 11.2-1).

11.3 GASEOUS WASTE MANAGEMENT SYSTEMS

{This section of the U.S. EPR FSAR is incorporated by reference with the following supplements}.

11.3.1 DESIGN BASIS

{No departures or supplements.}

11.3.2 SYSTEM DESCRIPTION

{No departures or supplements.}

11.3.3 RADIOACTIVE EFFLUENT RELEASES

{No departures or supplements.}

11.3.4 GASEOUS WASTE MANAGEMENT SYSTEM COST-BENEFIT ANALYSIS

The U.S. EPR FSAR includes the following COL Item in Section 11.3.4:

> A COL applicant that references the U.S. EPR design certification will confirm that the gaseous waste management system cost-benefit analysis for the typical site is applicable to their site; if it is not, provide a site-specific cost-benefit analysis.

This COL Item is addressed as follows:

{As with the liquid waste processing systems, the ALARA design objective dose values for effluents released from a light water reactor are stipulated in 10 CFR 50, Appendix I (CFR, 2009). The regulation also requires that plant designs include all items of reasonably demonstrated cleanup technology that when added to the gaseous waste processing system sequentially and in order of diminishing costbenefit return, can, at a favorable cost-benefit ratio, effect reductions in dose to the population reasonably expected to be within 50 mi (80 km) of the reactor. Although not required by NRC Regulations, values of $2,000 per person-rem, and $2,000 per person-thyroid-rem are conservatively used as a favorable cost benefit threshold based on NRC NUREG-1530 (NRC, 1995). The source term for each equipment configuration option was generated using the same GALE code as described in Section 3.5.1 along with the same plant specific parameters modified only to accommodate the changes in waste stream decontamination factor afforded by the design options simulated.

For the U.S. EPR, the dose reduction effects for the sequential addition of the next logical gaseous waste processing component (Le., addition of an additional charcoal delay bed to the waste gas holdup subsystem)) results in a reduction in the 50 mi (80 km) population total body exposure of 0.05 person-rem (0.0005 person-sievert). Environmental Report Section 5.4 describes the population dose calculation for both the base case and the augmented charcoal delay bed holdup system for processing gaseous waste. Table 11.3-1 illustrates the relative population dose associated with both the base equipment configuration and that associated with the augmented holdup system. Table 11.3-2 compares the estimated total body and thyroid dose reduction or savings achieved for the addition of the extra delay bed along with a conservative estimated cost for the purchase. Operating and maintenance cost associated with this passive subsystem is negligible. The cost basis for the equipment option is taken from Regulatory Guide 1.110 (NRC, 1976) and reported in 1975 non-escalated dollars which provides a conservatively low estimate of the equipment cost to today's dollars. The site area population within 50 mi (80 km) is based a projected population in 2070, over 50 years from the estimated start of plant operations. Using the population at the end of plant life is conservative in that it maximizes the collective dose from plant effluents.

For both the total body and thyroid dose reduction, Table 11.3-2 illustrates that the favorable benefit in reduced dose associated with the additional dlarcoal delay bed had a dollar equivalent benefit value of $4,000. However, the estimated cost to purchase this equipment was approximately $67,500, thereby resulting in a total body effective beneftt to cost ratio of less than 1.0 (not justified on an ALARA basis of dose savings to the public).

The total gas release from the plant is made up of several sources, of which the charcoal delay bed subsystem provides treatment for the process gas from primary side reactor system components only. As a consequence, assuming that the process gas stream release has a zero value does not result in a zero dose to the population. Ventilation system exhaust from the reactor building and other controlled area buildings, along with any secondary side process gas releases if primary to secondary leaks occur also contribute to the total release. Because these sources are distributed throughout the plant, no single system can be added that effectively reduces all sources of gas releases. However, beyond the waste gas processing that is accomplished by the charcoal delay beds, the existing controlled area ventilation systems already provide for HEPA filtration, and as needed charcoal filtration, to the major sources of gas released to the environment. As a result, no other treatment options not in use are available that could treat a significant fraction of the total release at a favorable cost to that shown for the charcoal delay bed.}

11.3.5 REFERENCES

{CFR, 2009. Title 10, Code of Federal Regulations, Part 50.34a, Design Objectives for Equipment to Control Releases of Radioactive Material in Effluents - Nuclear Power Reactors, and Appendix I, Numerical Guides for Design Objectives and Limiting Conditions for Operation to Meet the Criterion "As Low as is Reasonably Achievable" for Radioactive Material in Light-Water-Cooled Nuclear Power Reactor Effluents, 2009.

NRC, 1976. Cost-Benefit Analysis for Radwaste Systems for Light Water-Cooled Nuclear Power Reactors, Regulatory Guide 1.110 (For Comment), Nuclear Regulatory Commission, March 1976.

NRC, 1995. Reassessment of NRC's Dollar Per Person-Rem Conversion Factor Policy, NUREG-1530, Nuclear Regulatory Commission, 1995.}

Table 11.3-1—{Obtainable Dose Benefits for Gaseous Waste System Augment}

Cases	Population Total Body Dose [(a)] - Person-Rem (Person-Sievert)	Population Thyroid Dose [(a)] Person-Rem (Person-Sievert)
Baseline Configuration	6.55E+00 (6.55E-02)	6.88E+00 (6.88E-02)
Extra Carbon	6.50E-00 (6.55E-02)	8.8E+00 (6.88E-02)
Obtainable dose benefit by augment	5.0E-02(5.0E-04)	5.0E-02 (5.0E-04)

Note:
[(a)] Population dose estimates described in Environmental Report Section 5.4.

Table 11.3-2—{Gaseous Waste System Augment Total Body / Thyroid Dose Cost-Benefit Analysis}

Parameter	Value [(a)]
Annual whole-body / Thyroid collective dose benefit to the population within 50 miles of the BBNPP site.	0.05 person-rem (0.0005 person-sievert)
Nominal total collective dose over 40 years of operation (0.05 person-rem x 40 yr =2.0 person-rem)	2.0 person-rem (0.02 person-sievert)
Value for estimating impact based on NUREG1530 (Note: 10 CFR Part 50, Appendix Ihas $1,000 per person-rem)	$2,000 per person-rem ($200,000 per person-sievert)
Obtainable benefit from addition of radwaste processing and control option (2.0 person-rem x $2,000/person-rem =$4,000)	$4,000
Cost Options for radwaste processing and control technology upgrade from Regulatory Guide 1.110	3-ton charcoal absorber
Direct cost for option using methodology in Regulatory Guide 1.110, Table A-1 based on 1975 Dollars	$67,500
Total O&M Annual Cost (From Regulatory Guide 1.110, Table A-2 based on 1975 dollars)	$9,700
Total cost over 40 years of operation (direct cost + O&M x 40 years)	Negligible
Benefit/Cost Ratio (Values greater than 1 should be included in plant system design) $4,000/ $67,500 =0.06	0.06

Note:
[(a)] Since the dose reduction benefit for both the total body and the thyroid give the same collective dose savings, the cost benefit results are directly applicable to both the total body adn thyroid evaluations.

11.4 SOLID WASTE MANAGEMENT SYSTEMS

This section of the U.S. EPR FSAR is incorporated by reference with the following supplements.

11.4.1 DESIGN BASIS

No departures or supplements.

11.4.2 SYSTEM DESCRIPTION

No departures or supplements.

11.4.3 RADIOACTIVE EFFLUENT RELEASES

The U.S. EPR FSAR includes the following COL Item in Section 11.4.3:

> A COL applicant that references the U.S. EPR will fully describe, at the functional level, elements of the Process Control Program (PCP). This program description will identify the administrative and operational controls for waste processing process parameters and surveillance requirements which demonstrate that the final waste products meet the requirements of applicable federal, state, and disposal site waste form requirements for burial at a 10 CFR Part 61 licensed low level waste (LLW) disposal site and will be in accordance with the guidance provided in RG 1.21, NUREG-0800, BTP 11-3, ANSI/ANS-55.1-1992 and Generic Letters 80-09, 81-38, and 81-39.

This COL Item is addressed as follows:

{BBNPP} will adopt NEI 07-10A, "Generic FSAR Template Guidance for Process Control Program (PCP)," (NEI, 2009a). The milestone for development and implementation of the PCP is addressed in Table 13.4-1.

11.4.4 SOLID WASTE MANAGEMENT SYSTEM COST-BENEFIT ANALYSIS

No departures or supplements.

11.4.5 FAILURE TOLERANCE

No departures or supplements.

11.4.6 REFERENCES

No departures or supplements.

11.5 PROCESS AND EFFLUENT RADIOLOGICAL MONITORING AND SAMPLING SYSTEMS

This section of the U.S. EPR FSAR is incorporated by reference with the following supplements.

11.5.1 DESIGN BASIS

No departures or supplements.

11.5.2 SYSTEM DESCRIPTION

The U.S. EPR FSAR includes the following COL Item in Section 11.5.2:

> A COL applicant that references the U.S. EPR will fully describe, at the functional level, elements of the process and effluent monitoring and sampling programs required by 10 CFR Part 50, Appendix I and 10 CFR 52.79(a)(16). This program description, Offsite Dose Calculation Manual (ODCM), will specify how a licensee controls, monitors, and performs radiological evaluations of releases. The program will also document and report radiological effluents discharged to the environment.

This COL Item is addressed as follows:

{BBNPP} will adopt NEI 07-09A, "Generic FSAR Template Guidance for Offsite Dose Calculation Manual (ODCM) Program Description," (NEI, 2009b). The milestone for development and implementation of the ODCM is addressed in Table 13.4-1.

11.5.3 EFFLUENT MONITORING AND SAMPLING

No departures or supplements.

11.5.4 PROCESS MONITORING AND SAMPLING

No departures or supplements.

11.5.5 REFERENCES

{**CFR, 2008a.** Domestic Licensing of Production and Utilization Facilities, Title 10, Code of Federal Regulations, Part 50, U.S. Nuclear Regulatory Commission, 2008.

CFR, 2008b. Contents of Applications; Technical Information in Final Safety Analysis Report, Title 10, Code of Federal Regulations, Part 52.79, U.S. Nuclear Regulatory Commission, 2008.

NEI, 2009a. NEI 07-10A, Generic FSAR Template Guidance for Process Control Program (PCP) , Revision 0, Nuclear Energy Institute, March 2009.

NEI, 2009b. NEI 07-09A, Generic FSAR Template Guidance for Offsite Dose Calculation Manual (ODCM)Program Description, Revision 0, Nuclear Energy Institute, March 2009.}