GALE 3.0

Fall 2017 RAMP USERS GROUP MEETING – Washington D.C.

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U.S. Nuclear Regulatory Commission Headquarters

DAVID COLAMECO

Nuclear Engineer

Pacific Northwest National Laboratory

PNNL-SA-129728

GALE Development Team

- NRC
  - Contracting Officer's Representative – John Tomon
  - Technical Monitor – Zachary Gran
- PNNL (Software Developers)
  - Kenneth Geelhood
  - David Colameco
  - Brian Collins

Agenda

- GALE Overview
  - Purpose of Code
  - Code Requirements
  - GALE-3.0 Features
- Code Development
  - History of Code Development
  - Code Development Process
  - GALE-BWR Development Sequence
  - GALE-PWR Development Sequence
  - GALE Development Details
- GALE-3.0 (beta): Validation and Verification

Agenda (cont.)

- Basics of Reactor Cleanup
  - BWR Structures and Components
  - PWR Structures and Components
- Getting Started with GALE 3.0
  - Installation
  - Use
  - GALE 3.0 Example Code Demonstration
- GALE Modeling Parameters
  - GALE 86 to GALE 09 Detail
  - Fixed Parameters files
- 15 Minute Break

Agenda (cont.)

- Participants Setup and Run GALE
- GALE User's Group
  - Training
  - Member Presentations
  - Technical Support
- New GALE Website
  - Download GALE
  - Documentation
  - Training and Presentation Materials
  - Support
- Updates to ANS-18.1
- Q&A and Wrap Up

GALE-3.0

- GALE 3.0 currently posted as a Beta version
  - Validation and verification is complete
    - NUREG 0016 (Draft October 11) Revision 2 Appendix A
    - NUREG 0017 (Draft October 11) Revision 2 Appendix A
    - PNNL-26984, Revision 0, October 2017
  - PNNL and NRC staff are resolving comments on documentation
- Work performed by PNNL for US NRC

Purpose of Code

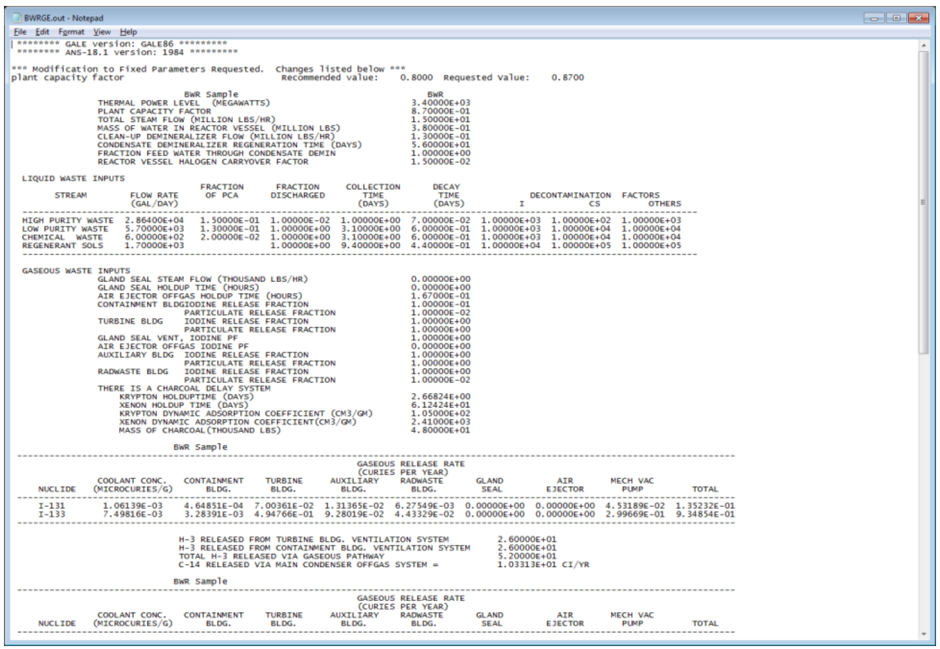
- GALE Code is a computerized mathematical model for calculating the releases of radioactive material in gaseous and liquid effluents (i.e., the gaseous and liquid source terms).
- The U.S. Nuclear Regulatory Commission uses the GALE Code to determine conformance with the requirements of Appendix I to 10 Code of Federal Regulations (CFR) Part 50.
- With the nuclear power generating facilities that have been proposed for operation in the United States using new reactor core designs, a comprehensive review of the GALE code was completed to verify applicability to both the current and proposed designs.
  - Upon review, it was determined that the code was applicable to both current and future designs
  - Updates to the code to comply with recent standards and operational data were required. Hard-coded parameters were updated to reflect recent plant operations data

Code Requirements

- Code runs on Microsoft Windows PCs
  - Graphical user interface uses standard Windows dialog boxes

Code Requirements (cont.)

- Code output is via text file
- Microsoft Excel worksheet has been included to visualize output and to facilitate use of output data in other calculations


BWRGE.out - Notepad

```
******** GALE version: GALE86 *********
******** ANS-18.1 version: 1984 *********

*** Modification to Fixed Parameters Requested.  Changes listed below ***
plant capacity factor                      Recommended value:    0.8000  Requested value:    0.8700

                     BWR Sample                                    BWR
            THERMAL POWER LEVEL  (MEGAWATTS)                    3.40000E+03
            PLANT CAPACITY FACTOR                               8.70000E-01
            TOTAL STEAM FLOW (MILLION LBS/HR)                   1.50000E+01
            MASS OF WATER IN REACTOR VESSEL (MILLION LBS)       3.80000E-01
            CLEAN-UP DEMINERALIZER FLOW (MILLION LBS/HR)        1.30000E-01
            CONDENSATE DEMINERALIZER REGENERATION TIME (DAYS)   5.60000E+01
            FRACTION FEED WATER THROUGH CONDENSATE DEMIN        1.00000E+00
            REACTOR VESSEL HALOGEN CARRYOVER FACTOR             1.50000E-02

  LIQUID WASTE INPUTS
                                  FRACTION     FRACTION     COLLECTION     DECAY
       STREAM          FLOW RATE   OF PCA     DISCHARGED       TIME         TIME              DECONTAMINATION  FACTORS
                       (GAL/DAY)                              (DAYS)       (DAYS)          I              CS           OTHERS
  ----------------------------------------------------------------------------------------------------------------------
  HIGH PURITY WASTE  2.86400E+04  1.50000E-01 1.00000E-02 1.00000E+00 7.00000E-02 1.00000E+03 1.00000E+02 1.00000E+03
  LOW PURITY WASTE   5.70000E+03  1.30000E-01 1.00000E+00 3.10000E+00 6.00000E-01 1.00000E+03 1.00000E+04 1.00000E+04
  CHEMICAL  WASTE    6.00000E+02  2.00000E-02 1.00000E+00 3.10000E+00 6.00000E-01 1.00000E+03 1.00000E+04 1.00000E+04
  REGENERANT SOLS    1.70000E+03              1.00000E+00 9.40000E+00 4.40000E-01 1.00000E+04 1.00000E+05 1.00000E+05
  ----------------------------------------------------------------------------------------------------------------------

  GASEOUS WASTE INPUTS
            GLAND SEAL STEAM FLOW (THOUSAND LBS/HR)             0.00000E+00
            GLAND SEAL HOLDUP TIME (HOURS)                      0.00000E+00
            AIR EJECTOR OFFGAS HOLDUP TIME (HOURS)              1.67000E-01
            CONTAINMENT BLDGIODINE RELEASE FRACTION             1.00000E-01
                        PARTICULATE RELEASE FRACTION            1.00000E-02
            TURBINE BLDG    IODINE RELEASE FRACTION             1.00000E+00
                        PARTICULATE RELEASE FRACTION            1.00000E+00
            GLAND SEAL VENT, IODINE PF                          1.00000E+00
            AIR EJECTOR OFFGAS IODINE PF                        0.00000E+00
            AUXILIARY BLDG  IODINE RELEASE FRACTION             1.00000E+00
                        PARTICULATE RELEASE FRACTION            1.00000E+00
            RADWASTE BLDG   IODINE RELEASE FRACTION             1.00000E+00
                        PARTICULATE RELEASE FRACTION            1.00000E-02
            THERE IS A CHARCOAL DELAY SYSTEM
               KRYPTON HOLDUPTIME (DAYS)                        2.66824E+00
               XENON HOLDUP TIME (DAYS)                         6.12424E+01
               KRYPTON DYNAMIC ADSORPTION COEFFICIENT (CM3/GM)  1.05000E+02
               XENON DYNAMIC ADSORPTION COEFFICIENT(CM3/GM)     2.41000E+03
               MASS OF CHARCOAL(THOUSAND LBS)                   4.80000E+01

                     BWR Sample
 ---------------------------------------------------------------------------------------------------------------------------
                                                         GASEOUS RELEASE RATE
                                                          (CURIES PER YEAR)
           COOLANT CONC.   CONTAINMENT   TURBINE    AUXILIARY   RADWASTE     GLAND        AIR       MECH VAC
  NUCLIDE (MICROCURIES/G)     BLDG.       BLDG.       BLDG.       BLDG.       SEAL       EJECTOR      PUMP        TOTAL
 ---------------------------------------------------------------------------------------------------------------------------
   I-131     1.06139E-03  4.64851E-04 7.00361E-02 1.31365E-02 6.27549E-03 0.00000E+00 0.00000E+00 4.53189E-02 1.35232E-01
   I-133     7.49816E-03  3.28391E-03 4.94766E-01 9.28019E-02 4.43329E-02 0.00000E+00 0.00000E+00 2.99669E-01 9.34854E-01
 ---------------------------------------------------------------------------------------------------------------------------

                      H-3 RELEASED FROM TURBINE BLDG. VENTILATION SYSTEM        2.60000E+01
                      H-3 RELEASED FROM CONTAINMENT BLDG. VENTILATION SYSTEM    2.60000E+01
                      TOTAL H-3 RELEASED VIA GASEOUS PATHWAY                    5.20000E+01
                      C-14 RELEASED VIA MAIN CONDENSER OFFGAS SYSTEM =          1.03313E+01 CI/YR

                     BWR Sample
 ---------------------------------------------------------------------------------------------------------------------------
                                                         GASEOUS RELEASE RATE
                                                          (CURIES PER YEAR)
           COOLANT CONC.   CONTAINMENT   TURBINE    AUXILIARY   RADWASTE     GLAND        AIR       MECH VAC
  NUCLIDE (MICROCURIES/G)     BLDG.       BLDG.       BLDG.       BLDG.       SEAL       EJECTOR      PUMP        TOTAL
 ---------------------------------------------------------------------------------------------------------------------------
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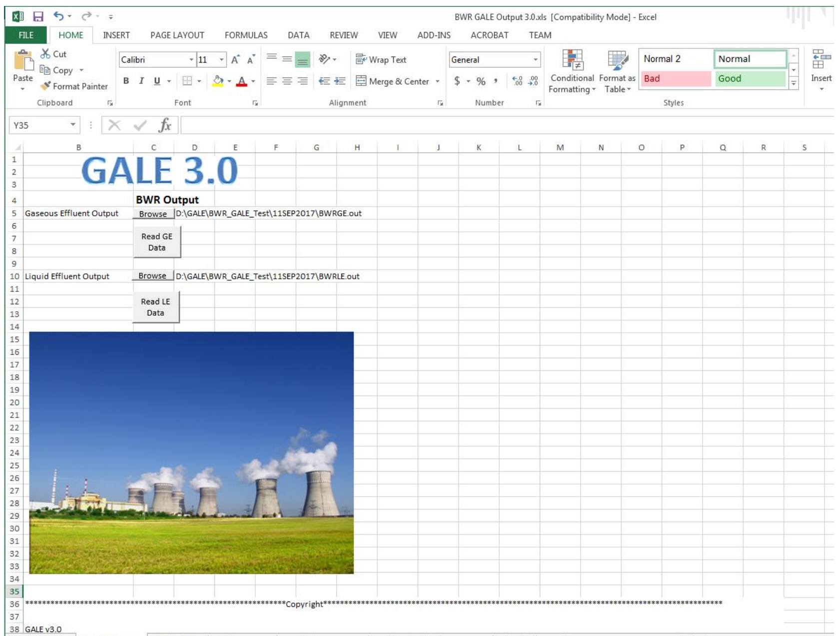


GALE-3.0 Features

- Specific Features
  - Ability to save input information and read previously set up input
  - Ability to read legacy input files from GALE
  - Built-in calculators to combine liquid waste from various sources
  - Built-in calculators to calculate liquid waste collection, processing, and discharge times
- Microsoft Excel worksheet has been included to:
  - Visualize output of gaseous isotopes by building and select components
  - Facilitate use of output data in other calculations
    - Liquid effluents read into Liquid tab

History of Code Development

- Code originally developed by NRC staff
  - GALE-86
  - Documented by NUREG-0016 (BWR) and NUREG-0017 (PWR)
- Code Development moved to PNNL in 2008
- Several internal versions were released with no NUREG-series documentation
  - GALE-08
    - Built in nuclide concentrations from ANS-18.1 were updated to those in latest (1999) standard
    - Recommended parameters from ANS-55.6 and Regulatory Guide 1.140 were updated to values from current versions
  - GALE-09
    - A review of recent reactor operational experience was performed and recommendations for updates to the GALE source codes and their user guidance were made.

History of Code Development (cont.)

- GALE-2.0 (beta version with draft NUREG series documentation)
  - Code results are identical to GALE-09
  - Graphical user interface was added to facilitate user interaction
  - Excel worksheet was included to help visualize results
  - Code benchmarking was performed to validate GALE-2.0 (beta) results to recent reactor experience
- GALE-3.0 (beta version)
  - NUREG-0016 Revision 2 and NUREG-0017 Revision 2 currently under review
  - PNNL GALE Code Verification document available, PNNL-26984
  - Technical change to add PWRGE I-132, I-134, and I-135 consistent with I-131 and I-133.
  - General modification requests completed to GUI, code, and excel files.
  - Verification of GALE 3.0 source changes to GALE 86 source of NUREG-0016 Revision 1 and NUREG-0017 Revision 1.

Code Development Process

- Series of Sequential versions of GALE-BWR and GALE-PWR were prepared in the update efforts to:
  - Provide means for NRC to evaluate the implications of each of the updates
  - Provide high level of traceability back to the previous version of the code.
- GALE 3.0 is being released to update GALE 86
  - GALE-BWR 3.0 as an update to GALE-BWR 86 NUREG-0016 Revision 1
    - Boiling Water Reactor Gaseous Effluent module BWRGE-86
    - Boiling Water Reactor Liquid Effluent module BWRLE-86
  - GALE-PWR 3.0 as an update to GALE-PWR 86 NUREG-0017 Revision 1
    - Pressurized Water Reactor Gaseous Effluent module PWRGE-86
    - Pressurized Water Reactor Liquid Effluent module PWRLE-86

GALE-BWR Development Sequence

Version Name	Model Names	ANSI/ANS-18.1 Version	Update Type
GALE-BWR 86 (GALE86)	BWRLE86 BWRGE86	1984	Starting Version for conducting updates (NUREG-0016, Revision 1)
GALE-BWR 08 (GALE08)	BWRLE86 BWRGE86	1999	Hard-coded parameters updated to conform to ANSI/ANS-18.1-1999 and ANSI/ANS-55.6.1993 (reaffirmed May 2007)
GALE-BWR 09 (GALE86)	BWRLE09 BWRGE09	1999	GALE-BWR 08 with hard-coded parameters updated based on recent plant operation (PNNL-18150 and PNNL-18957)
GALE-BWR 2.0 (GALE 2.0)	BWRLE09 BWRGE09	1999	GALE-BWR 09 updated with a graphical user interface (GUI) to facilitate easier input and operation and incorporation into the NRC's Radiation Protection Computer Code Analysis and Maintenance Program (RAMP).
GALE-BWR 3.0 (GALE 3.0)	BWRLE86 BWRGE86 BWRLE09 BWRGE09	1984 1999 2016	GALE-BWR 3.0 code is updated with additional GUI options for the user to select the source term (ANSI/ANS-18.1 version), GALE version (GALE86 or GALE09) and to allow the user to modify selected GALE fixed modeling parameters.

GALE-BWR 08 Development Detail

Change #	GALE-BWR 08 Changes in Detail
1	The concentrations of radionuclides in the reactor coolant from ANSI/ANS-18.1-1999 Table 5 were changed for the following radionuclides: Na-24, P-32, Cr-51, Mn-54, Mn-56, Fe-55, Fe-59, Co-58, Co-60, Ni-63, Cu-64, Zn-65.
2	The concentrations of radionuclides in the reactor steam from ANSI/ANS-18.1-1999 Table 5 were changed for the following radionuclides: I-131, I-132, I-133, I-134, I-135, Na-24, P-32, Cr-51, Mn-54, Mn-56, Fe-55, Fe-59, Co-58, Co-60, Ni-63, Cu-64 and Zn-65.
3	The values for NS and R_n from ANSI/ANS-18.1-1999 Table 8 have changed for Class 2 radionuclides.
4	The adjustment factor of 1.0E+01 was added from ANSI/ANS-18.1-1999 Table 10 for Zn-65.
5	The values used for Class 1 and Class 2 radionuclides in GALE-BWR 86 were not consistent with the values found in ANSI/ANS-18.1-1984 Table 5. The values for the Class 1 and Class 2 radionuclides were updated to be consistent with ANSI/ANS-18.1-1999 Table 5.
6	The values used for the variable Rn in GALE-BWR 86 for Class 2 and Class 6 radionuclides were updated to be consistent with ANSI/ANS-18.1-1999 Table 8.

GALE-BWR 09 Development Detail

Change #	GALE-BWR 09 Changes in Detail
1	Plant capacity factor was increased from 8.0E-01 to 9.0E-01 (80 to 90 percent).
2	Radioiodine release rates from various buildings during normal operations were increased by multiplying by 1.125E+00.
3	Radioiodine release rates from various buildings during extended shutdown were decreased by multiplying by 5.0E-01.
4	Carbon-14 release rate was decreased from 9.5E+00 Ci/yr to 1.07E+01 Ci/yr.
5	Unexpected release rate was decreased from 1.0E-01 Ci/yr to 1.4E-02 Ci/yr.

GALE-BWR 2.0 Development Detail

Change #	GALE-BWR 2.0 Changes in Detail
1	Primary purpose the addition of a Graphical User Interface. Updates to GALE-BWR 2.0 source code did not involve changes in the model formulations. The source code had exactly the same formulation as the previous versions with differences in the outputs reflecting only the standards and operation-derived changes in hard-coded parameter values.
2	For operation in an interactive modeling environment, input/output routines were added for implantation of GALE-BWR 2.0 into future codes. These updates also enable direct linkage of the GALE-BWR 2.0 code results to models such as NRCDose.
3	PNNL Developed a GALE software quality assurance plan (PNNL-24249).
4	PNNL developed a GALE code configuration management plan (PNNL-24250).
5	Determination made that GALE conforms to the Level 2 requirements of NUREG/BR-0167, Software Quality Assurance Program and Guidelines.

GALE-BWR 3.0 Development Detail

Change #	GALE-BWR 3.0 Changes in Detail
1	Increased functionality to allow user to select GALE version 86 or 09 and the ANSI/ANS-18.1 version 1984, 1999, 2016.
2	Increased functionality to allow user to modify GALE-BWR fixed modeling parameters used to calculate the gaseous and liquid effluent.
3	Default GALE-BWR module set to GALE-86 (User selectable 86 or 09)
4	Default GALE-BWR ANSI/ANS-18.1 to 1984 (User selectable 1984, 1999 or 2016).

GALE-PWR Development Sequence

Version Name	Model Names	ANSI/ANS-18.1 Version	Update Type
GALE-PWR 86 (GALE86)	PWRLE86 PWRGE86	1984	Starting Version for conducting updates (NUREG-0017, Revision 1)
GALE-PWR 08 (GALE08)	PWRLE86 PWRGE86	1999	Hard-coded parameters updated to conform to ANSI/ANS-18.1-1999 and ANSI/ANS-55.6.1993 (reaffirmed May 2007)
GALE-PWR 09 (GALE86)	PWRLE09 PWRGE09	1999	GALE-PWR 08 with hard-coded parameters updated based on recent plant operation (PNNL-18150 and PNNL-18957)
GALE-PWR 2.0 (GALE 2.0)	PWRLE09 PWRGE09	1999	GALE-PWR 09 updated with a graphical user interface (GUI) to facilitate easier input and operation and incorporation into the NRC's Radiation Protection Computer Code Analysis and Maintenance Program (RAMP).
GALE-PWR 3.0 (GALE 3.0)	PWRLE86 PWRGE86 PWRLE09 PWRGE09	1984 1999 2016	GALE-PWR 3.0 code is updated with additional GUI options for the user to select the source term (ANSI/ANS-18.1 version), GALE version (GALE86 or GALE09) and to allow the user to modify selected GALE fixed modeling parameters.

GALE-PWR 08 Development Detail

Change #	GALE-PWR 08 Changes in Detail
1	The concentrations of radionuclides in the reactor coolant from ANSI/ANS-18.1-1999 Tables 6 and 7 were changed for the following radionuclides: Kr-85m, Kr-87, Kr-88, Xe-133, Xe-135, Xe-138, I-131, I-132, I-133, I-134, I-135, Cs-134, and Cs-137.
2	The concentrations of radionuclides in the secondary coolant water from ANSI/ANS-18.1-1999 Table 6 were changed for the following radionuclides: I-131, I-132, I-133, I-134, I-135, Cs-134, Cs-137, and Y-93.
3	The concentrations of radionuclides in the secondary coolant steam from ANSI/ANS-18.1-1999 Table 6 were changed for the following radionuclides: Kr-85m, Kr-87, Kr-88, Xe-133, Xe-135, Xe-138, I-131, I-132, I-133, I-134, I-135, Cs-134, Cs-137, and Sr-90.
4	The concentrations of radionuclides in the secondary coolant steam from ANSI/ANS-18.1-1999 Table 6 were changed for the following radionuclides: Kr-87m, Kr-88, Xe-133, Xe-138, I-131, I-132, I-133, I-134, I-135, Cs-134, and Cs-137
5	Adjustment factors of 1.0E+01 were added from ANSI/ANS-18.1-1999 Table 11 for PWRs with U-tube steam generators for the following radionuclides: Zn-65 and Co-58.

GALE-PWR 09 Development Detail

Change #	GALE-PWR 09 Changes in Detail
1	Plant capacity factor was increased from 8.0E-01 to 9.0E-01 (80 to 90 percent).
2	Tritium release rate was decreased from 4.0E-01 Ci/yr/MWt to 2.7E-01 Ci/yr/MWt
3	Argon-41 release rate was decreased from 3.4E+01 Ci/yr to 6.0E+00 Ci/yr
4	Carbon-14 release rate was decreased from 7.3E+00 Ci/yr to 5.9E+00 Ci/yr.
5	Unexpected release rate was decreased from 1.6E-01 Ci/yr to 1.6E-04 Ci/yr.
6	Condensate demineralizer DF for “Other Radionuclides” was changed from 5.0E+01 to 1.0E+01

GALE-PWR 2.0 Development Detail

Change #	GALE-PWR 2.0 Changes in Detail
1	Primary purpose the addition of a Graphical User Interface. Updates to GALE-PWR 2.0 source code did not involve changes in the model formulations. The source code had exactly the same formulation as the previous versions with differences in the outputs reflecting only the standards and operation-derived changes in hard-coded parameter values.
2	For operation in an interactive modeling environment, input/output routines were added for implantation of GALE-PWR 2.0 into future codes. These updates also enable direct linkage of the GALE-PWR 2.0 code results to models such as NRCDose.
3	PNNL Developed a GALE software quality assurance plan (PNNL-24249).
4	PNNL developed a GALE code configuration management plan (PNNL-24250).
5	Determination made that GALE conforms to the Level 2 requirements of NUREG/BR-0167, Software Quality Assurance Program and Guidelines.

GALE-PWR 3.0 Development Detail

Change #	GALE-PWR 3.0 Changes in Detail
1	Technical change to add iodine isotopes I-132, I-134, and I-135 to the PWRGE code assuming the primary and secondary coolant activities given in the appropriate ANS-18.1 tables. The decay constants for these isotopes were taken from the Isotope Generation and Depletion Code (ORIGEN) database in the PWRLE code. The release relative to the primary coolant activities from various buildings was assumed to be the same for all iodine isotopes consistent with the previous treatment of I-131 and I-133.
2	Increased functionality to allow user to select GALE version 86 or 09 and the ANSI/ANS-18.1 version 1984, 1999, 2016.
3	Increased functionality to allow user to modify GALE-PWR fixed modeling parameters used to calculate the gaseous and liquid effluent.
4	Default GALE-PWR module set to GALE-86 (User selectable 86 or 09)
5	Default GALE-PWR ANSI/ANS-18.1 to 1984 (User selectable 1984, 1999 or 2016).

GALE-3.0 Validation

- No overall code validation was performed on GALE86 (NUREG-0017 Rev. 1 and NUREG-0016 Rev. 1). The only validation that was performed was on the individual models and parameters that are used within GALE.
- For GALE-3.0, two types of validation have been performed.
  - Individual model parameters.
    - This validation is shown in NUREG-0016, Revision 2, Appendix A for GALE-BWR 3.0 and in NUREG-0017, Revision 2, Appendix A for GALE-PWR 3.0.
    - In these appendices, discussions are provided for the basis of each parameter selection. In many cases, recent data is shown to support the parameter selection.
  - Overall code prediction.
    - This validation is shown in NUREG-0016, Revision 2, Section 4.0 for GALE-BWR 3.0 and in NUREG-0017, Revision 2, Section 4.0 for GALE-PWR 3.0.
    - In these sections, the GALE-3.0 predictions of selected radionuclides in the gaseous and liquid effluents were compared to the measured effluents from selected nuclear power plant in recent years.

GALE-3.0 Validation (cont.)

- The result of the validation that is shown in these technical basis documents is a measure of the applicability of the parameters in GALE-3.0 (beta) to current reactor operation as well as the applicability of the overall GALE-3.0 (beta) predictions to effluent release from operating reactors.

GALE-3.0 Verification

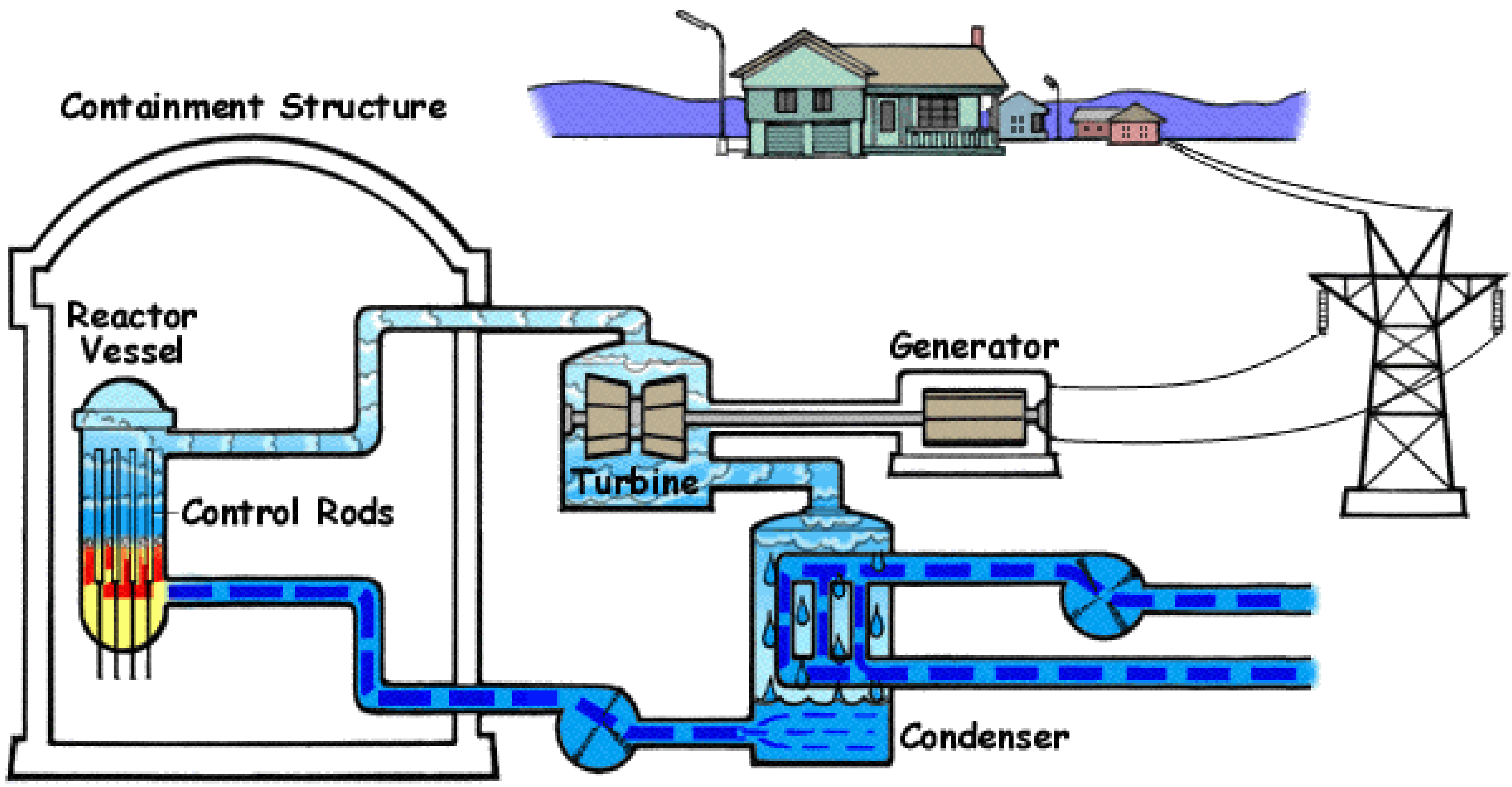
- Verification of GALE-3.0 was performed to ensure:
  - All updates since GALE-86 have been properly coded and result in expected changes to the output
  - The Graphical User Interface correctly takes values from the Windows interface to the appropriate GALE subroutines
- Verification was documented (PNNL-26984) and sent to NRC Office of Research

Basics of Reactor Cleanup Systems

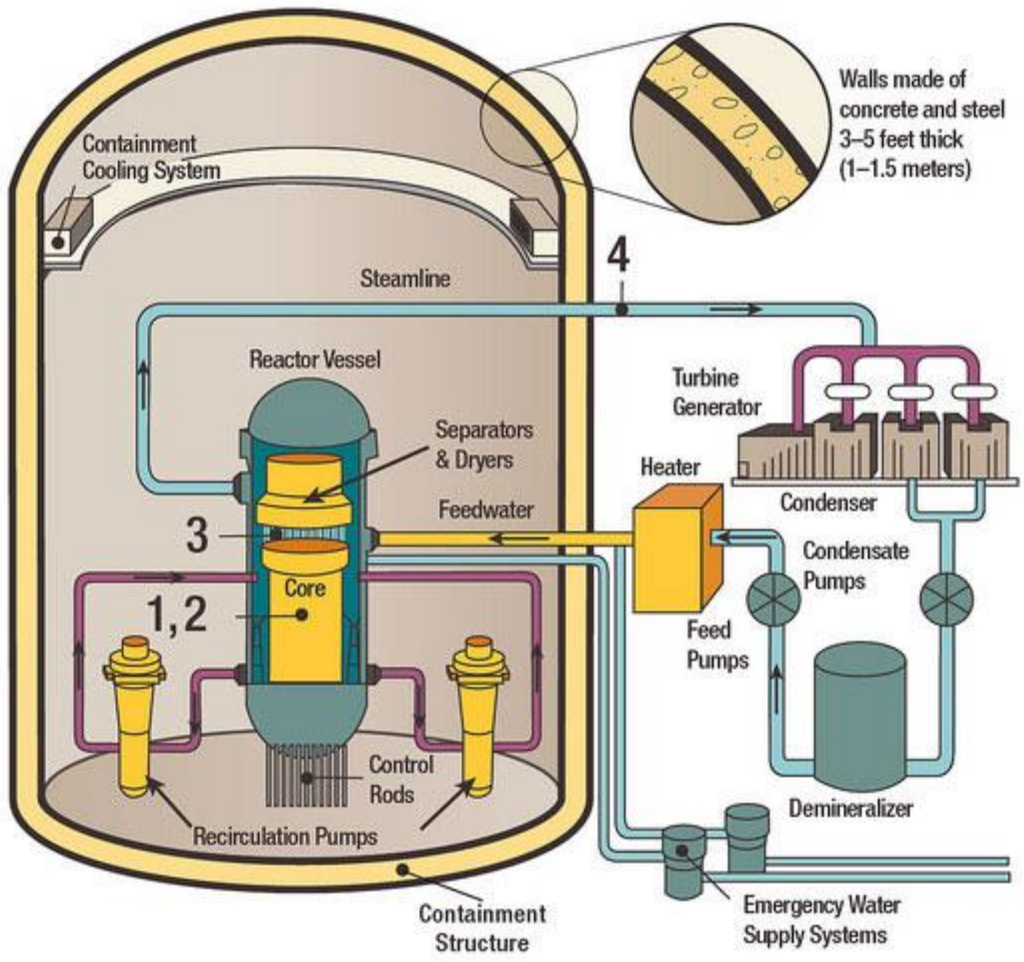
Introduction

- BWR
- PWR

Boiling Water Reactor



Boiling Water Reactor



Boiling Water Reactor: Liquid Waste Streams

- High Purity Waste
  - Liquid of low electrical conductivity
  - Equipment drains from
    - Drywell
    - Reactor building
    - Turbine building
    - Radwaste building
    - Auxiliary building
    - Fuel pool building
  - Ultrasonic resin cleaner overheads
  - Resin backwash
  - Transfer water
  - Filter backwash
  - Phase separator decant liquid
  - Radwaste evaporator condensate

Boiling Water Reactor: Liquid Waste Streams (cont.)

- Low Purity Waste
  - Liquid of moderate to high electrical conductivity
  - Floor drains from
    - Drywell
    - Reactor building
    - Turbine building
    - Radwaste building
    - Fuel pool building
  - Uncollected valve and pump seal leakoffs
  - Water resulting from dewatering of slurry wastes

Boiling Water Reactor: Liquid Waste Streams (cont.)

- Chemical Waste
  - Liquid of high conductivity and high total solids content
  - Laboratory drains
  - Non-detergent chemical decontamination wastes
- Regenerant Solutions Waste
  - Regenerant solution from ion exchange columns (condensate polishers)

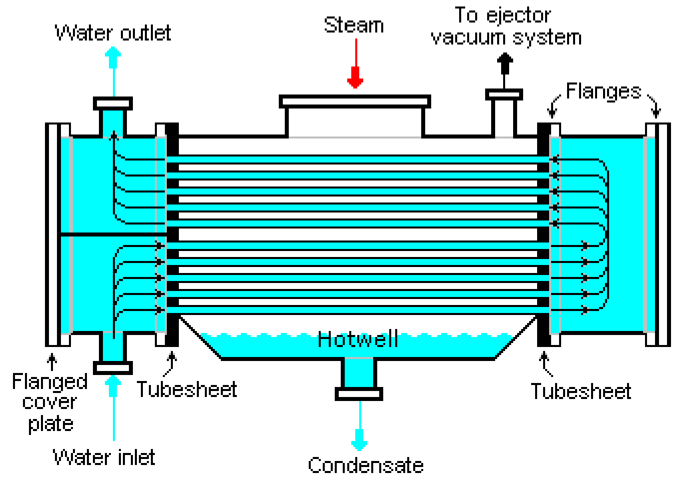
Boiling Water Reactor: Buildings

- Containment Building or Reactor Building
  - A building designed to sustain pressures of about 50 psi. Normally houses the reactor and the related cooling system that contains highly radioactive fluids. Building is of steel construction. Sometimes the building is surrounded by a concrete structure that is designed for much lower pressures (3 psi). The area between the steel and concrete building is called the annulus. In BWRs, the drywell is located in this building.
- Auxiliary Building
  - A building separate from the containment that houses much of the support equipment that may contain radioactive liquids and gases. Emergency equipment is also normally located in this building.
- Radwaste Building
  - A building that houses various systems provided to process liquid, solid and gaseous radioactive wastes generated by the plant.
- Turbine Building
  - A building that houses the turbine, generator, condenser, condensate and feedwater systems.

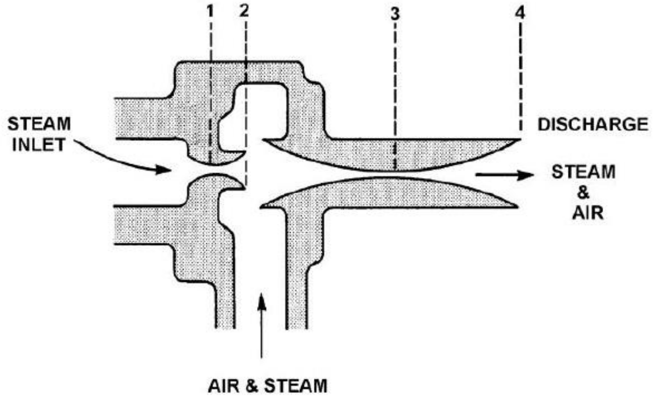
Boiling Water Reactor: Turbine Systems

Two special auxiliary systems that are potential sources of effluents are:

- Air Ejector
  - Passes steam through a series of nozzles and creates a vacuum that removes air from the condenser
- Turbine Gland Seal System
  - Gland seal steam is used to seal the main turbine by passing high pressure steam over a series of ridges and evacuating the steam when it reaches a low pressure.

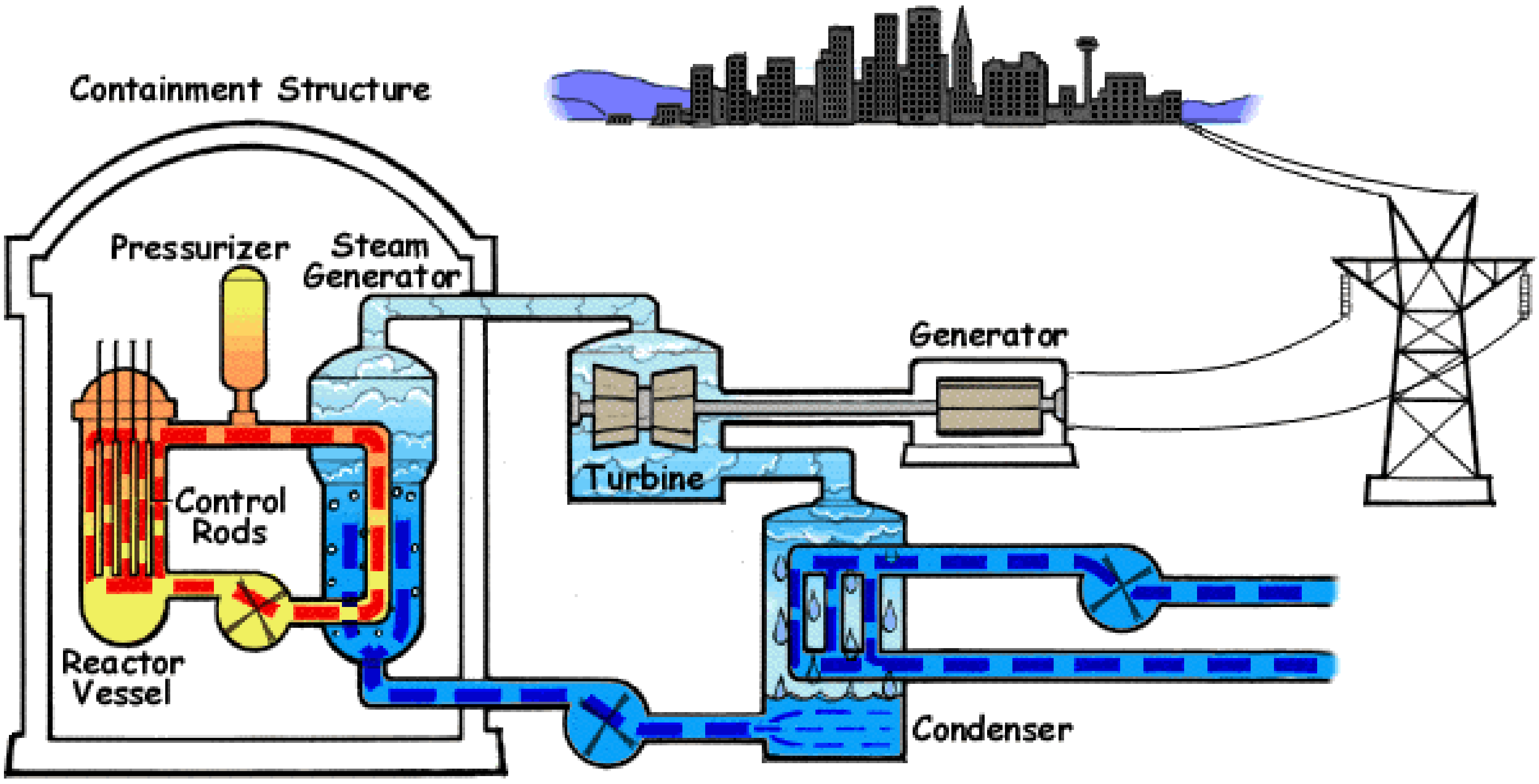


Condenser

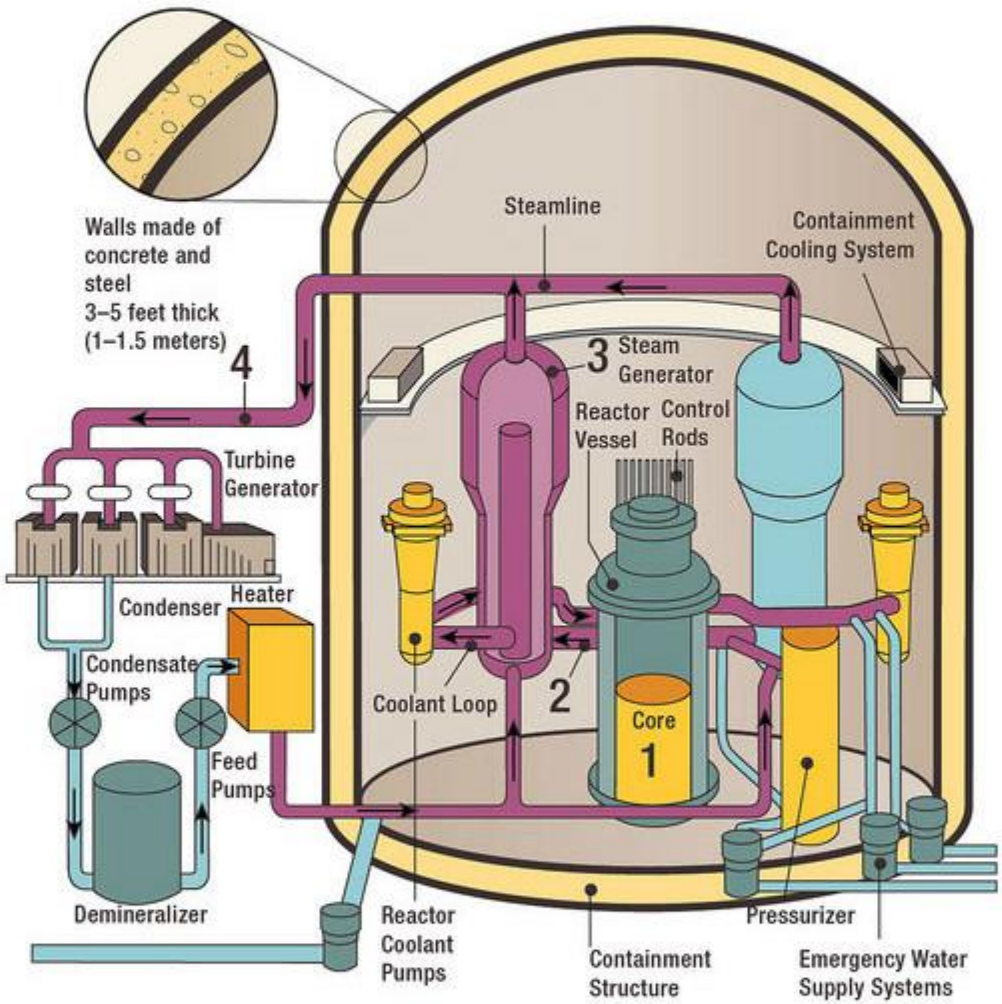


STEAM-JET AIR EJECTOR

Pressurized Water Reactor



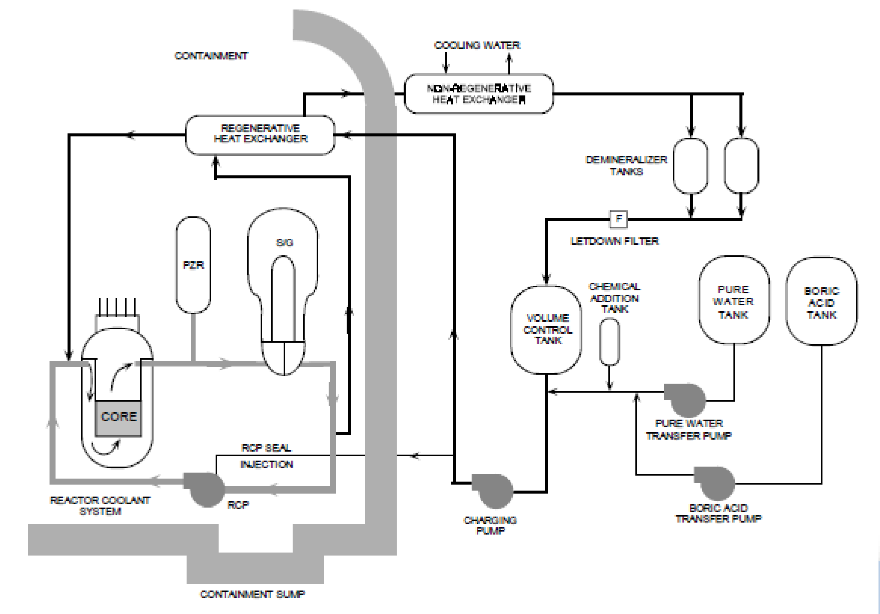
Pressurized Water Reactor



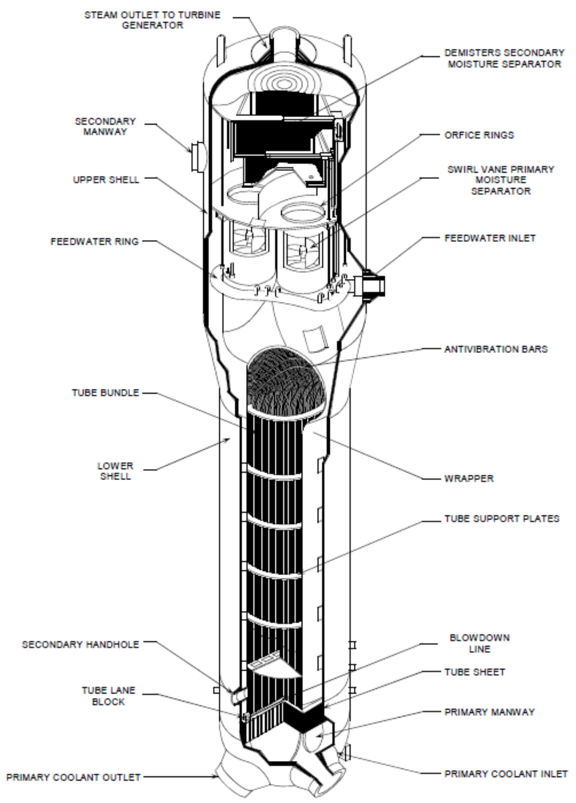
Pressurized Water Reactor: Letdown

- The chemical and volume control system (CVCS) is a major support system for the reactor coolant system. Some of the functions of the system are to:
  - Purify the reactor coolant system using filters and demineralizers
  - Add and remove boron as necessary
  - Maintain the level of the pressurizer at desired setpoint.

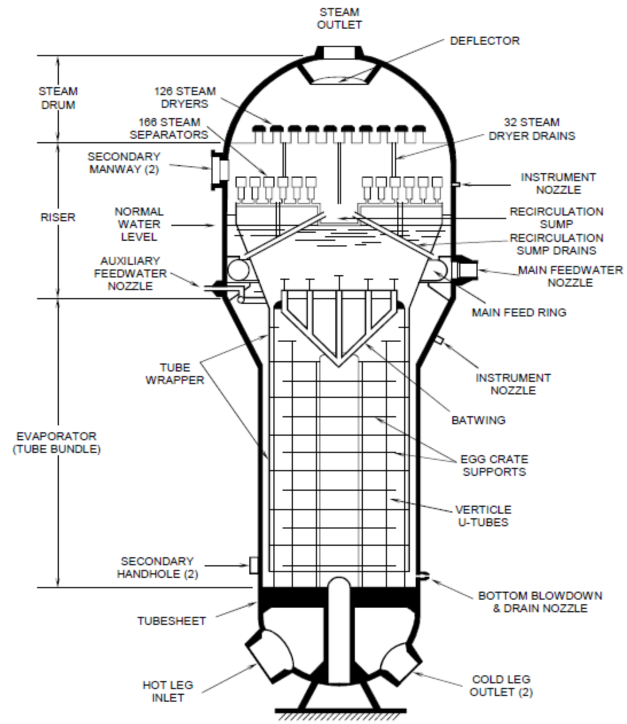
- A small amount of water (about 75 gpm) is continuously routed through the chemical and volume control system (called letdown). This provides a continuous cleanup of the reactor coolant system which maintains the purity of the coolant and helps to minimize the amount of radioactive material in the coolant.



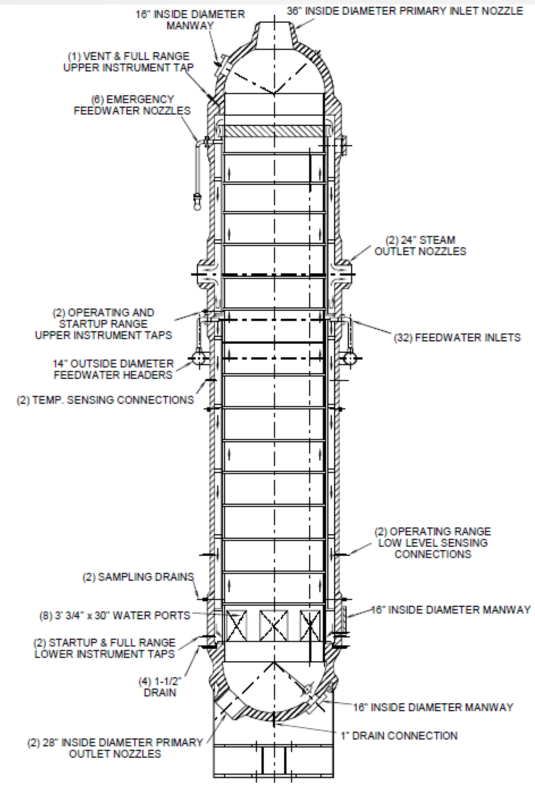
Pressurized Water Reactor: Steam Generator



Cutaway View of A Westinghouse Steam Generator



Cutaway View of a Combustion Engineering Steam Generator



Cutaway View of a Babcock & Wilcox Once Through Steam Generator

Pressurized Water Reactor: Steam Generator – U-Tube

- In the Westinghouse and Combustion Engineering designs, the steam/water mixture passes through multiple stages of moisture separation. One stage causes the mixture to spin, which slings the water to the outside. The water is then drained back to be used to make more steam. The drier steam is routed to the second stage of separation. In this stage, the mixture is forced to make rapid changes in direction. Because of the steam's ability to change direction and the water's inability to change, the steam exits the steam generator, and the water is drained back for reuse. The two stage process of moisture removal is so efficient at removing the water that for every 100 pounds of steam that exits the steam generator, the water content is less than 0.25 pounds. It is important to maintain the moisture content of the steam as low as possible to prevent damage to the turbine blading.

Pressurized Water Reactor: Steam Generator – Blowdown

- **Steam Generator blowdown** is water intentionally discharged from the steam generator to avoid concentration of impurities during continuing evaporation of steam.

Pressurized Water Reactor: Steam Generator – Once Through

- The Babcock & Wilcox design uses a once through steam generator. In this design, the flow of primary coolant is from the top of the steam generator to the bottom, instead of through U-shaped tubes as in the Westinghouse and Combustion Engineering designs. Because of the heat transfer achieved by this design, the steam that exits the once through steam generator contains no moisture. This is done by heating the steam above the boiling point, or superheating.

Pressurized Water Reactor: Liquid Waste Streams

- Shim Bleed – Controls reactivity by bleeding out borated water
- Equipment Drain Waste
  - Equipment drains from
    - Drywell
    - Reactor building
    - Turbine building
    - Radwaste building
    - Auxiliary building
    - Fuel pool building
- Clean Waste
  - Nomally tritiated, nonaerated, low-conductivity liquids consisting primarily of liquid waste collected from equipment leaks and drains and certain valve and pump seal leakoffs. These liquids originate from systems containing primary coolant and are normally reused as primary coolant makeup

Pressurized Water Reactor: Liquid Waste Streams (cont.)

- Dirty Waste
  - Normally nontritiated, aerated, high-conductivity, nonprimary-coolant quality liquids collected from building sumps and floor and sample station drains. These liquids are not readily amenable for reuse as primary coolant makeup water.
- Blowdown Waste
- Regenerant Waste
  - Regenerant solution from ion exchange columns (condensate polishers)

Pressurized Water Reactor: Buildings

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- Containment or Drywell Building
  - A building designed to sustain pressures of about 50 pounds per square inch. Normally houses the reactor and the related cooling system that contains highly radioactive fluids. Building is of steel construction. Sometimes the building is surrounded by a concrete structure that is designed for much lower pressures (3 pounds per square inch). The area between the steel and concrete building is called the annulus.
- Auxiliary or Reactor Support Building
  - A building separate from the containment that houses much of the support equipment that may contain radioactive liquids and gases. Emergency equipment is also normally located in this building.

Pressurized Water Reactor: Buildings (cont.)

- Turbine Building
  - A building that houses the turbine, generator, condenser, condensate and feedwater systems. Some PWRs in the United States have a structure without the traditional roof and wall structure.
- Fuel Handling Building
  - A building separate from the containment that is used to spent fuel assemblies in steel racks in a large 40 foot deep storage pool. Casks for shipping or onsite dry storage of spent fuel assemblies will be loaded (or unloaded in this pool). A new fuel storage area is provided for receipt of new assemblies and storage prior to going into the containment and subsequently into the reactor during a refueling.

Pressurized Water Reactor

- Gas stripping
  - Goes with letdown
- Blowdown tanks vent
  - Goes with steam generator
- Air ejector
  - Passes steam through a series of nozzles and creates a vacuum that removes air from the condenser

GALE 3.0 (beta) Getting Started

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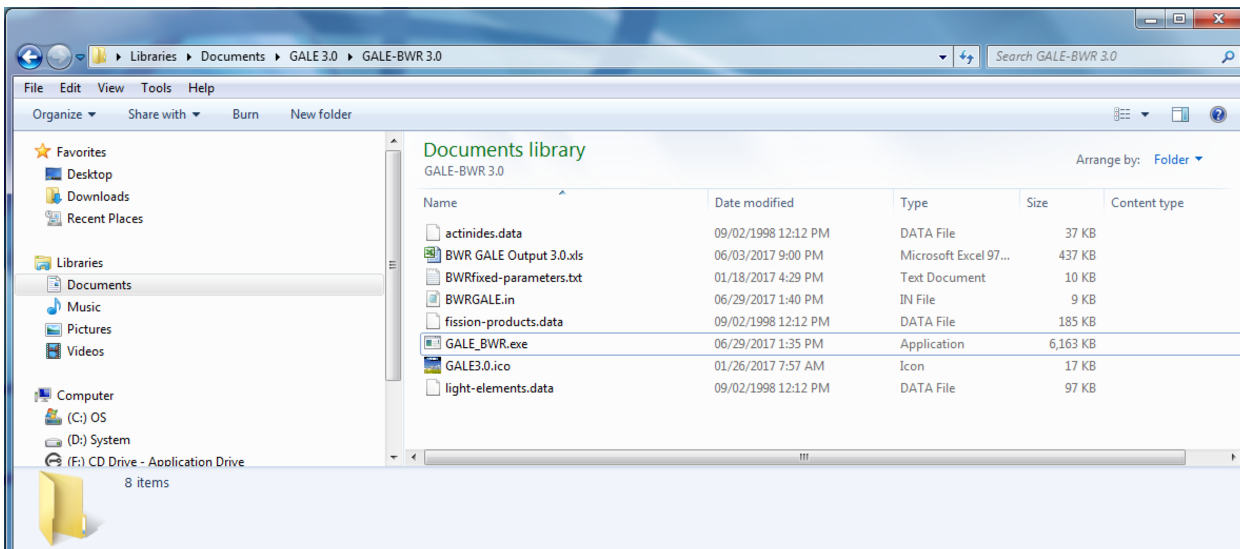
GALE 3.0 Code Package

- The GALE 3.0 Software Package Consists of:
  - **GALE_BWR.exe**: GALE 3.0 executable for boiling water reactors (BWRs)
  - **GALE_PWR.exe**: GALE 3.0 executable for pressurized water reactors (PWRs)
  - **actinides.data**: data file needed for liquid effluent runs
  - **fission-products.data**: data file needed for liquid effluent runs
  - **light-elements.data**: data file needed for liquid effluent runs
  - **BWRGALE.in**: sample input for gaseous and liquid effluents from BWRs
  - **PWRGALE.in**: sample input for gaseous and liquid effluents from PWRs
  - **BWR GALE Output 3.0.xls**: Excel file to read and display GALE output from BWRs
  - **PWR GALE Output 3.0.xls**: Excel file to read and display GALE output from PWRs

GALE-BWR 3.0 Installation

- Create a working directory and install the code package files
- The working directory should contain the 3 data files, and an existing input file if starting from a previous GALE 3.0 run. Otherwise the program will set up and save the input file. This working directory may also contain the spreadsheet for output visualization. The fixed-parameters file is optional.



GALE 3.0 Fixed Parameters File

- GALE-BWR 3.0 Fixed Parameters File

BWRfixed-parameters.txt - Notepad

File Edit Format View Help

```
$user
!3.1     Plant Capacity Factor (GE and LE)
! Value from Section 2.2.2 of NUREG-0016, Revision 1 (GALE86 Code)
PF_user=0.8  !Plant Capacity Factor (fraction)

!3.2     Radionuclide Concentrations in the Reactor Coolant and Main Steam (GE and LE)
! GE noble gas concentrations in reactor main steam (micro curies/g)
! Values from Table 5 of ANSI/ANS-18.1-1984 (GALE86 Code)
xb_user(1)=0.0000E+00 ! AR-41
xb_user(2)=5.9000E-04 ! KR-83M
xb_user(3)=1.0000E-03 ! KR-85M
xb_user(4)=4.0000E-06 ! KR-85
xb_user(5)=3.3000E-03 ! KR-87
xb_user(6)=3.3000E-03 ! KR-88
xb_user(7)=2.1000E-02 ! KR-89
xb_user(8)=3.3000E-06 ! XE-131M
xb_user(9)=4.9000E-05 ! XE-133M
xb_user(10)=1.4000E-03! XE-133
xb_user(11)=4.4000E-03! XE-135M
xb_user(12)=3.8000E-03! XE-135
xb_user(13)=2.6000E-02! XE-137
xb_user(14)=1.5000E-02! XE-138
! GE noble gas concentrations in reactor water (micro curies/g)
CBWR_user(1) =2.2000E-03 ! I-131
CBWR_user(2) =1.5000E-02 ! I-133
! LE Radionuclide concentrations in reactor water (micro curies/g)

!3.10 Tritium Releases (GE and LE)
! Values from Section 2.2.15 of NUREG-0016, Revision 1 (GALE86 Code)
H3PCA_user=0.01  !Tritium activity in primary coolant (microcuries/g)
H3rel_user=0.03  !Total tritium release (Ci/yr/MWth)
H3liq_user=0.5   !Fraction of tritium released through liquid pathway (remainder released through gaseous pathway)
H3tbb_user=0.5   !Fraction of gaseous tritium released from turbine bldg. (remainder released from containment building)

!3.11 Argon-41 Releases (GE)
! Values from Section 2.2.23 of NUREG-0016, Revision 1 (GALE86 Code)
XKARnorm_user=6.4  !Ar-41 dynamic adsorption coefficient for ambient temperature systems
XKARchill_user=16.0 !Ar-41 dynamic adsorption coefficient for chilled temperature systems

!3.12   Carbon-14 Releases (GE)
! Value from Section 2.2.22 of NUREG-0016, Revision 1 (GALE86 Code)
C14_user=9.5  !Ci/yr

!3.13 Source Term Adjustments for Anticipated Operational Occurrences (LE)
! Values from Section 2.2.20 of NUREG-0016, Revision 1 (GALE86 Code)
AOOfixed_user=0.1 !adjustment is made to liquid radwaste source terms to account for AOO (Ci/yr)
$end
```

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GALE-BWR 3.0 Use

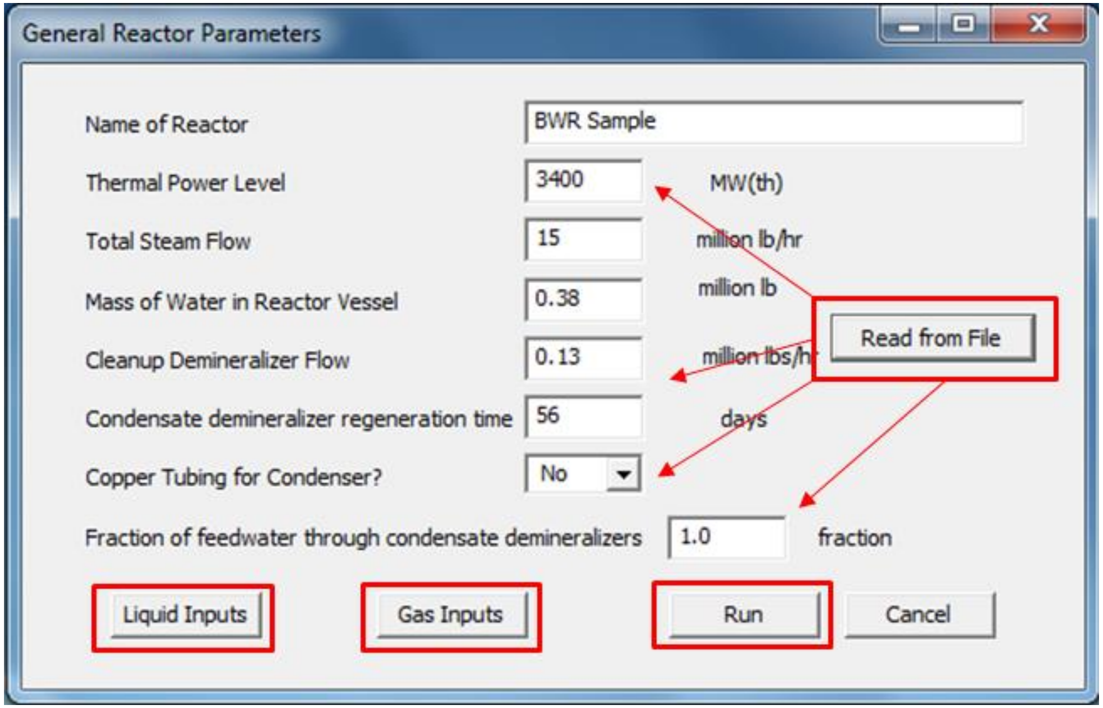
- GALE-BWR 3.0 Introductory Screen

GALE-BWR 3.0 Use

- GALE-BWR 3.0 Introductory Screen Selecting GALE and ANS 18.1 Version

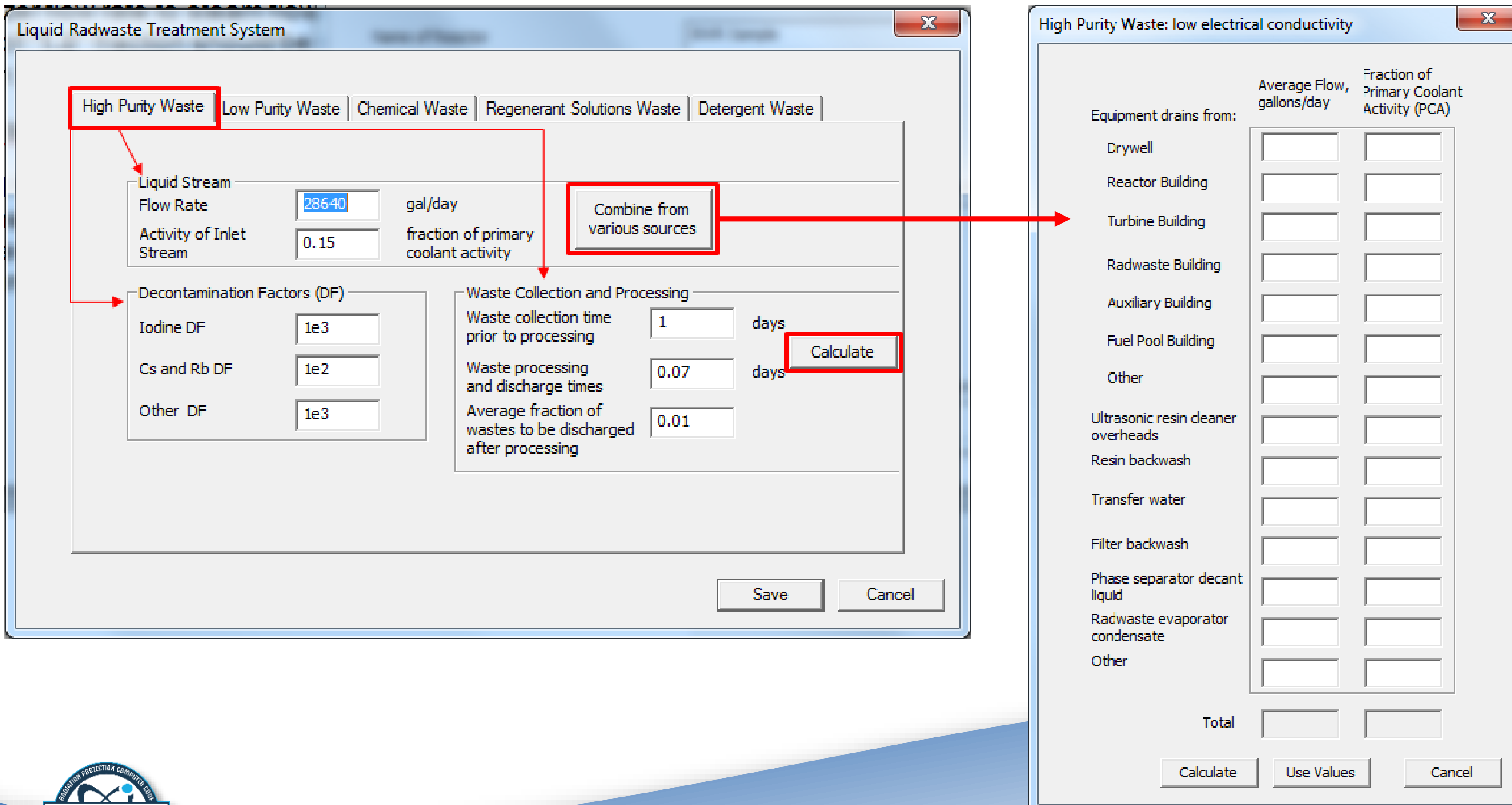
GALE-BWR 3.0 Use

- GALE-BWR 3.0 General Reactor Parameters Window



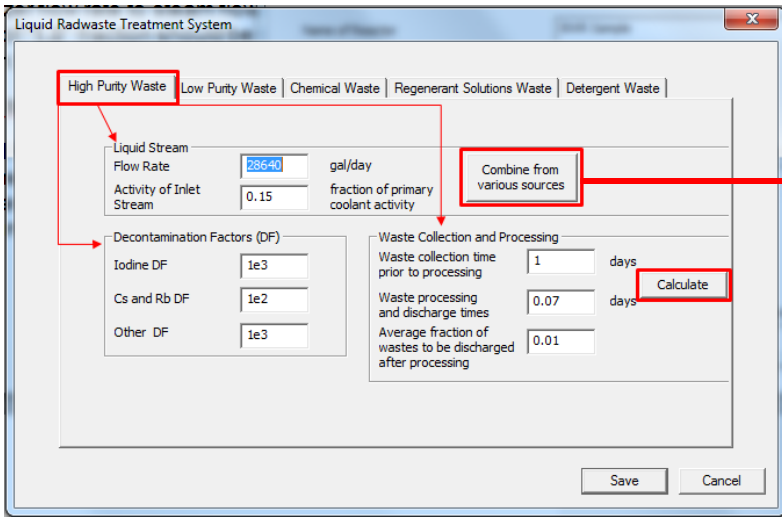
GALE-BWR 3.0 Use

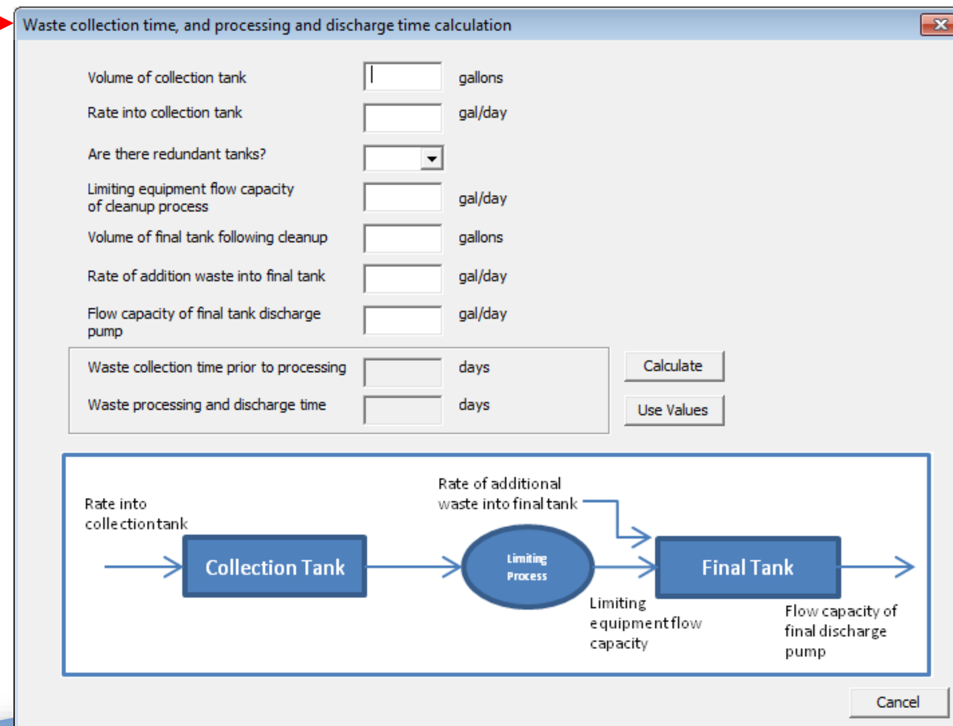
- GALE-BWR 3.0 High Purity Waste Window and Calculator



GALE-BWR 3.0 Use

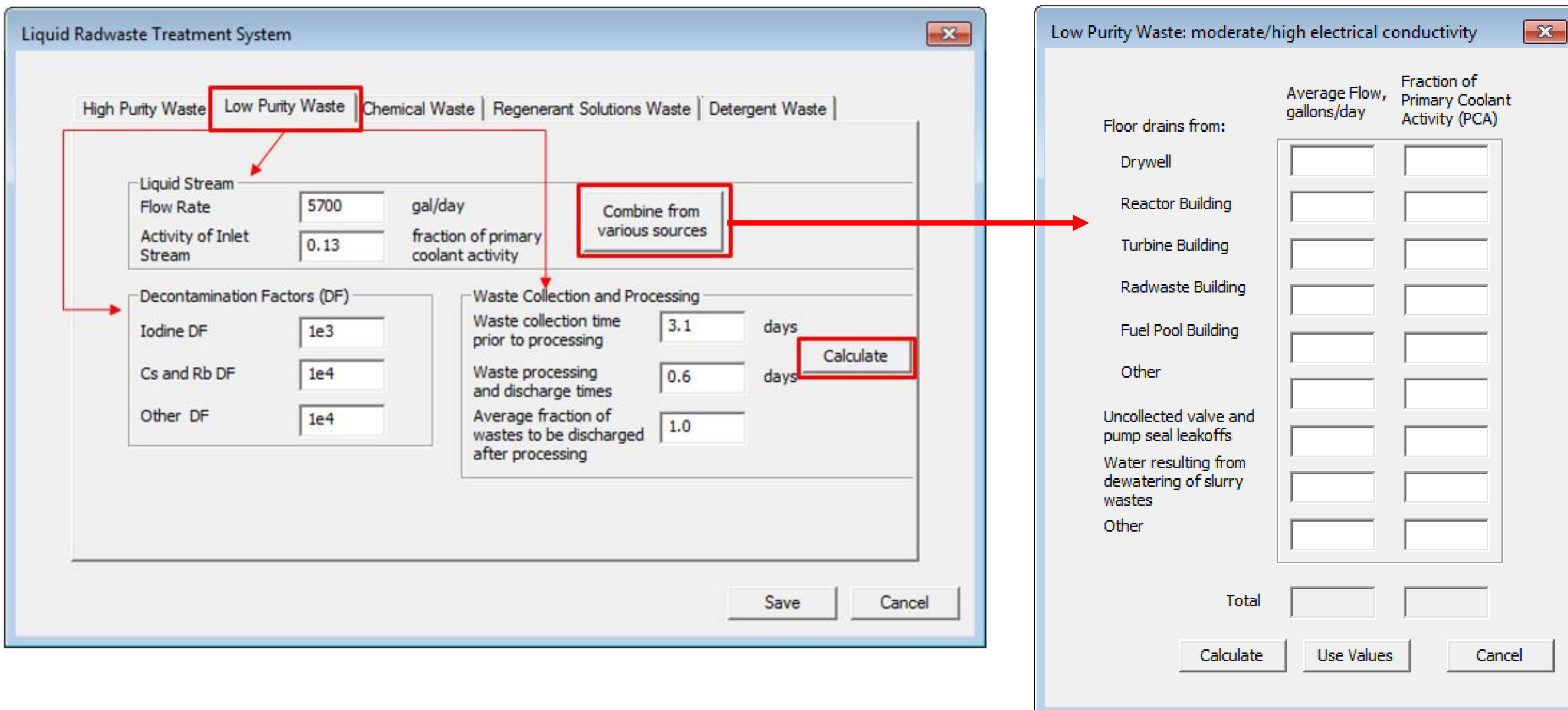
- GALE-BWR 3.0 High Purity Waste Window and Calculator (cont.)





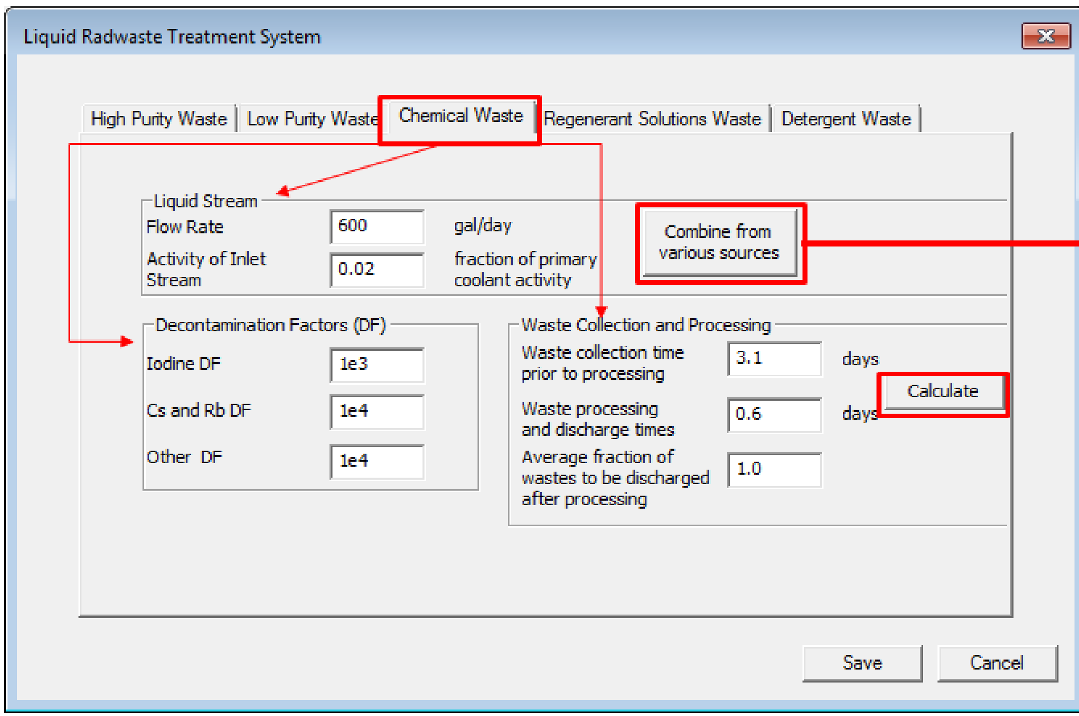
GALE-BWR 3.0 Use

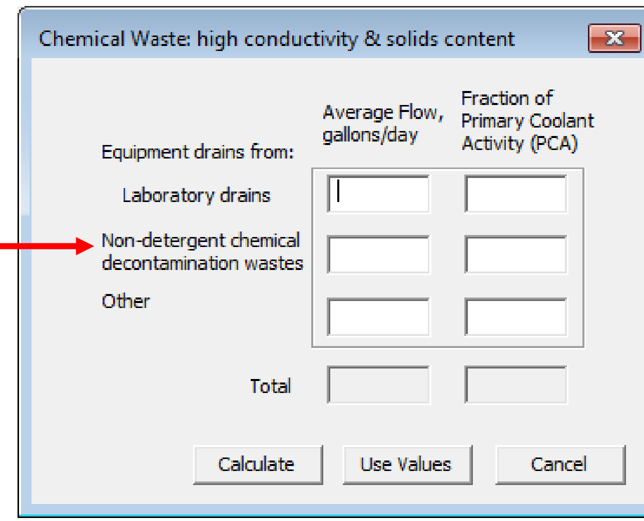
- GALE-BWR 3.0 Low Purity Waste Window and Calculator



GALE-BWR 3.0 Use

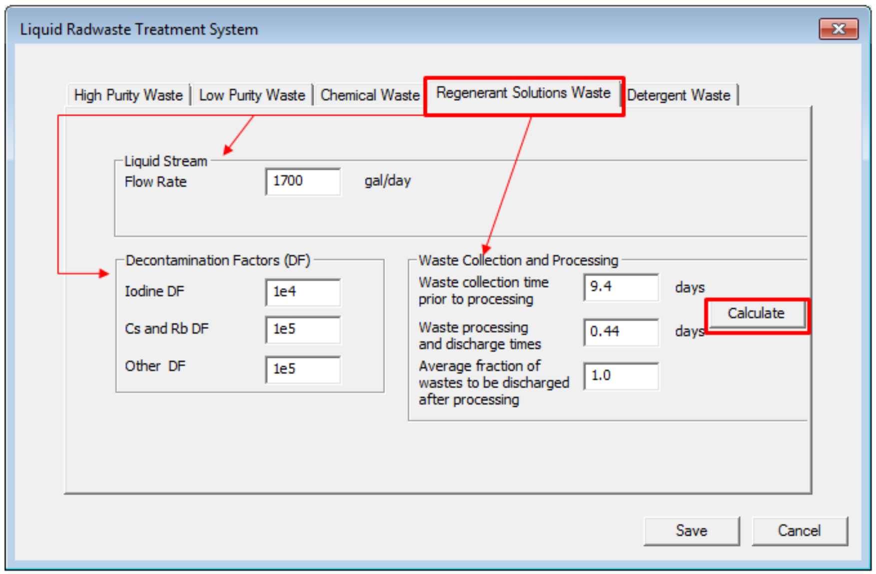
- GALE-BWR 3.0 Chemical Waste Window and Calculator

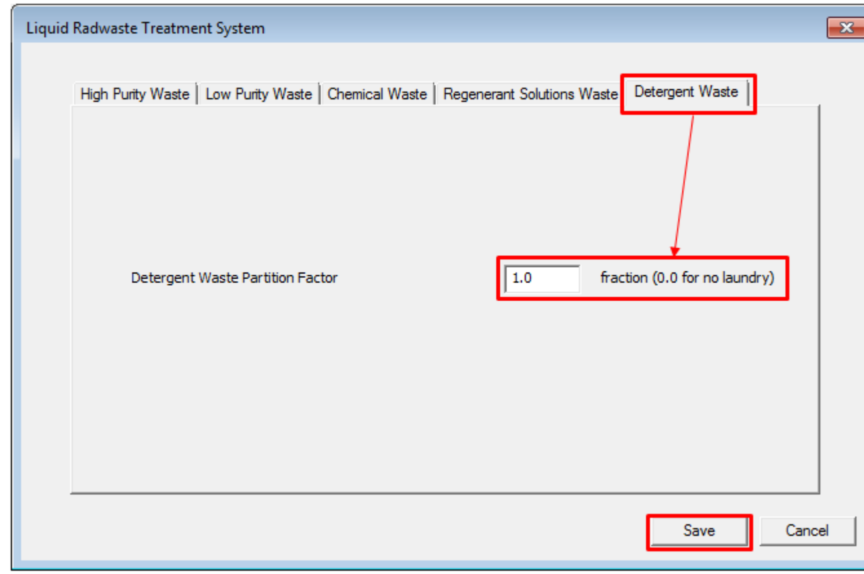




GALE-BWR 3.0 Use

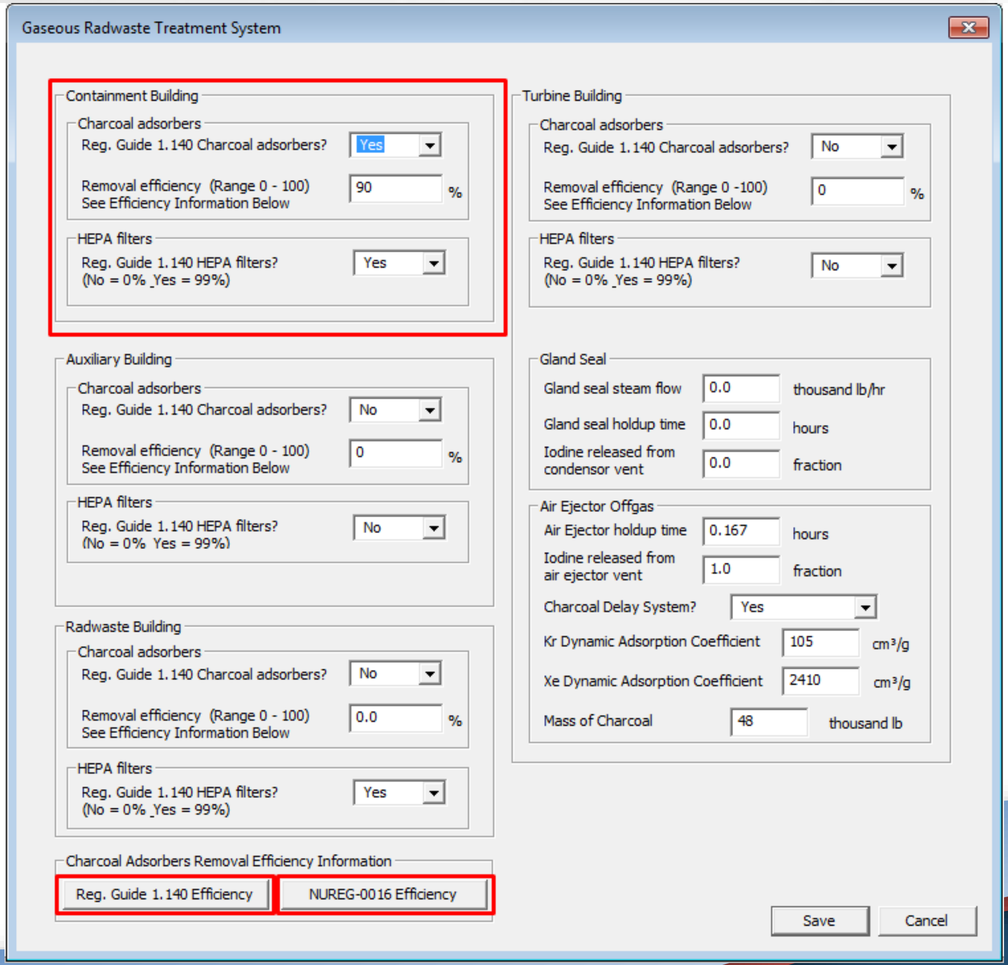
- GALE-BWR 3.0 Regenerant Solutions Waste and Detergent Waste Window





GALE-BWR 3.0 Use

- GALE-BWR 3.0 Gaseous Radwaste Treatment System Window



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GALE-BWR 3.0 Use

- GALE-BWR 3.0 Charcoal Adsorber Efficiency Windows

NUREG-0016, Revision 1 Charcoal Efficiency Information

Table 1-6 taken from NUREG-0016, Revision 1

Note: Recommended for use with GALE86

TABLE 1-6

ASSIGNED REMOVAL EFFICIENCIES FOR CHARCOAL ADSORBERS FOR RADIOIODINE REMOVAL

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

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

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

OK

Regulatory Guide 1.140, Revision 2 Charcoal Efficiency Information

Table 1 taken from Regulatory Guide 1.140, Revision 2

Note: Recommended for use with GALE09

Table 1: Laboratory Tests For Activated Carbon

Activated Carbon[a] Total Bed Depth[b]	Maximum Assigned Activated Carbon Decontamination Efficiencies		Methyl Iodide Penetration Acceptance Criterion for Representative Sample
2 inches	Elemental iodine Organic iodide	95% 95%	Penetration ≤5% when tested in accordance with ASTM D-3803-1989 (Ref. 4)
4 inches or greater	Elemental iodine Organic iodide	99% 99%	Penetration ≤1% when tested in accordance with ASTM D-3803-1989 (Ref. 4)

[a] The activated carbon, when new, should meet the specifications of Regulatory Position 4.9 of this guide.

[b] Multiple beds, e.g., two 2-inch beds in series, should be treated as a single bed of aggregate depth. It is advantageous when series beds are located in separate housings and individually in-place leak tested. This aids in mixing the challenge agent and contributes to the accuracy of the test results.

NOTES:

(1) Credited decontamination efficiencies (a portion of which includes bypass leakage) are based on 0.25 second residence time per 2-inch bed depth.

(2) Organic iodide and elemental iodine are the forms of iodine that are expected to be absorbed by activated carbon. Organic iodide is more difficult for activated carbon to adsorb than elemental iodine. Therefore, the laboratory test to determine the performance of the activated carbon adsorber is based on organic iodide. Methyl iodide is the organic form of iodine that is used in the laboratory test.

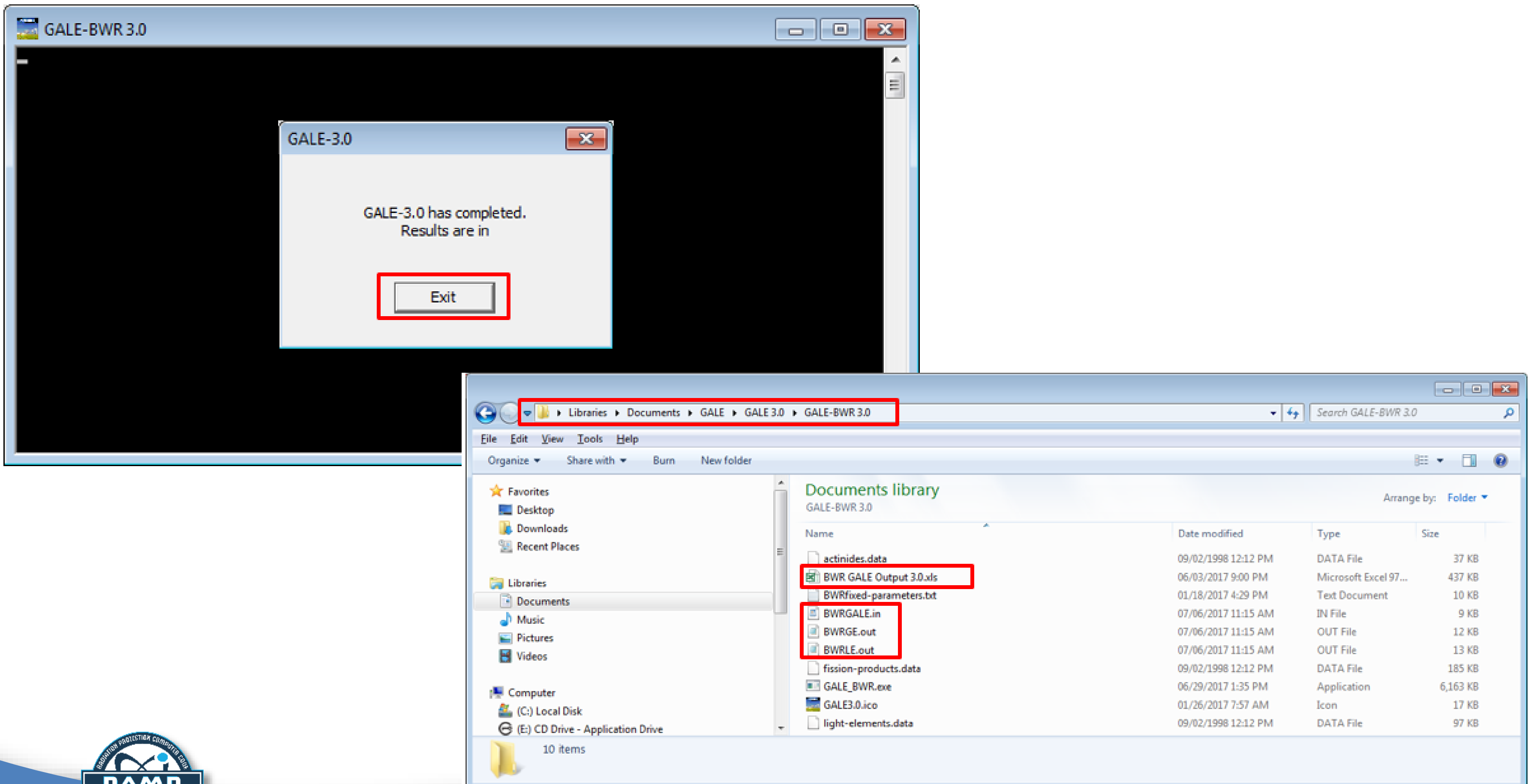
(3) This Table 1 provides acceptable decontamination efficiencies and methyl iodide test penetrations of used activated carbon samples for laboratory testing. Laboratory tests are conducted in accordance with ASTM D3803-1989 (Ref. 4). Tests are conducted at a temperature of 30°C and relative humidity of 95%, except a relative humidity of 70% is used when the air entering the carbon adsorber is maintained at less than or equal to 70% relative humidity.

(4) See Appendix A to ASME N509-1989 (Ref. 1) for the definition of a representative sample. Testing should be performed at the frequencies specified in Regulatory Position 7.2 of this guide. Testing should be performed in accordance with ASTM D3803-1989 (Ref. 4) at a temperature of 30°C and a relative humidity of 95% (or 70% with humidity control). Humidity control can be provided by heaters or an analysis that demonstrates that the air entering the carbon will be maintained less than or equal to 70% relative humidity.

OK

GALE-BWR 3.0 Use

- GALE-BWR 3.0 Execution and Outputs



GALE-BWR 3.0 Use

- GALE-BWRGE 3.0 Output

BWRGE.out - Notepad

File Edit Format View Help

```
******** GALE version: GALE86 ********
******** ANS-18.1 version: 1984 ********

*** Modification to Fixed Parameters Requested.  Changes listed below ***
plant capacity factor              Recommended value:    0.8000  Requested value:    0.8700
```

BWR Sample	BWR
THERMAL POWER LEVEL (MEGAWATTS)	3.40000E+03
PLANT CAPACITY FACTOR	8.70000E-01
TOTAL STEAM FLOW (MILLION LBS/HR)	1.50000E+01
MASS OF WATER IN REACTOR VESSEL (MILLION LBS)	3.80000E-01
CLEAN-UP DEMINERALIZER FLOW (MILLION LBS/HR)	1.30000E-01
CONDENSATE DEMINERALIZER REGENERATION TIME (DAYS)	5.60000E+01
FRACTION FEED WATER THROUGH CONDENSATE DEMIN	1.00000E+00
REACTOR VESSEL HALOGEN CARRYOVER FACTOR	1.50000E-02

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	2.86400E+04	1.50000E-01	1.00000E-02	1.00000E+00	7.00000E-02	1.00000E+03	1.00000E+02	1.00000E+03
LOW PURITY WASTE	5.70000E+03	1.30000E-01	1.00000E+00	3.10000E+00	6.00000E-01	1.00000E+03	1.00000E+04	1.00000E+04
CHEMICAL WASTE	6.00000E+02	2.00000E-02	1.00000E+00	3.10000E+00	6.00000E-01	1.00000E+03	1.00000E+04	1.00000E+04
REGENERANT SOLS	1.70000E+03		1.00000E+00	9.40000E+00	4.40000E-01	1.00000E+04	1.00000E+05	1.00000E+05

GASEOUS WASTE INPUTS

GLAND SEAL STEAM FLOW (THOUSAND LBS/HR)	0.00000E+00
GLAND SEAL HOLDUP TIME (HOURS)	0.00000E+00
AIR EJECTOR OFFGAS HOLDUP TIME (HOURS)	1.67000E-01
CONTAINMENT BLDG IODINE RELEASE FRACTION	1.00000E-01
PARTICULATE RELEASE FRACTION	1.00000E-02
TURBINE BLDG IODINE RELEASE FRACTION	1.00000E+00
PARTICULATE RELEASE FRACTION	1.00000E+00
GLAND SEAL VENT, IODINE PF	1.00000E+00
AIR EJECTOR OFFGAS IODINE PF	0.00000E+00
AUXILIARY BLDG IODINE RELEASE FRACTION	1.00000E+00
PARTICULATE RELEASE FRACTION	1.00000E+00
RADWASTE BLDG IODINE RELEASE FRACTION	1.00000E+00
PARTICULATE RELEASE FRACTION	1.00000E-02
THERE IS A CHARCOAL DELAY SYSTEM	
KRYPTON HOLDUPTIME (DAYS)	2.66824E+00
XENON HOLDUP TIME (DAYS)	6.12424E+01
KRYPTON DYNAMIC ADSORPTION COEFFICIENT (CM3/GM)	1.05000E+02
XENON DYNAMIC ADSORPTION COEFFICIENT(CM3/GM)	2.41000E+03
MASS OF CHARCOAL (THOUSAND LBS)	4.80000E+01

BWR Sample

GASEOUS RELEASE RATE (CURIES PER YEAR)

NUCLIDE	COOLANT CONC. (MICROCURIES/G)	CONTAINMENT BLDG.	TURBINE BLDG.	AUXILIARY BLDG.	RADWASTE BLDG.	GLAND SEAL	AIR EJECTOR	MECH VAC PUMP	TOTAL
I-131	1.06139E-03	4.64851E-04	7.00361E-02	1.31365E-02	6.27549E-03	0.00000E+00	0.00000E+00	4.53189E-02	1.35232E-01
I-133	7.49816E-03	3.28391E-03	4.94766E-01	9.28019E-02	4.43329E-02	0.00000E+00	0.00000E+00	2.99669E-01	9.34854E-01

H-3 RELEASED FROM TURBINE BLDG. VENTILATION SYSTEM	2.60000E+01
H-3 RELEASED FROM CONTAINMENT BLDG. VENTILATION SYSTEM	2.60000E+01
TOTAL H-3 RELEASED VIA GASEOUS PATHWAY	5.20000E+01
C-14 RELEASED VIA MAIN CONDENSER OFFGAS SYSTEM =	1.03313E+01 CI/YR

BWR Sample

GASEOUS RELEASE RATE (CURIES PER YEAR)

NUCLIDE	COOLANT CONC. (MICROCURIES/G)	CONTAINMENT BLDG.	TURBINE BLDG.	AUXILIARY BLDG.	RADWASTE BLDG.	GLAND SEAL	AIR EJECTOR	MECH VAC PUMP	TOTAL
AR-41	0.00000E+00	1.50000E+01	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	2.30000E+01	0.00000E+00	3.83108E+01
KR-83M	5.90000E-04	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
KR-85M	1.00000E-03	1.00000E+00	2.50000E+01	3.00000E+00	0.00000E+00	0.00000E+00	2.00000E+00	0.00000E+00	3.11061E+01
KR-85	4.00000E-06	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	2.10000E+02	0.00000E+00	2.07502E+02
KR-87	3.30000E-03	0.00000E+00	6.10000E+01	2.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	6.30000E+01
KR-88	3.30000E-03	1.00000E+00	9.10000E+01	3.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	9.50000E+01
KR-89	2.10000E-02	0.00000E+00	5.80000E+02	2.00000E+00	2.90000E+01	0.00000E+00	0.00000E+00	0.00000E+00	6.11000E+02
XE-131M	3.30000E-06	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	5.00000E+00	0.00000E+00	4.68665E+00
XE-133M	4.90000E-05	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00
XE-133	1.40000E-03	2.70000E+01	1.50000E+02	8.30000E+01	2.20000E+02	0.00000E+00	2.30000E+01	1.30000E+03	1.80333E+03
XE-135M	4.40000E-03	1.50000E+01	4.00000E+02	4.50000E+01	5.30000E+02	0.00000E+00	0.00000E+00	0.00000E+00	9.90000E+02
XE-135	3.80000E-03	3.30000E+01	3.30000E+02	9.40000E+01	2.80000E+02	0.00000E+00	0.00000E+00	5.00000E+02	1.23700E+03
XE-137	2.60000E-02	4.50000E+01	1.00000E+03	1.35000E+02	8.30000E+01	0.00000E+00	0.00000E+00	0.00000E+00	1.26300E+03
XE-138	1.50000E-02	2.00000E+00	1.00000E+03	6.00000E+00	2.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	1.01000E+03
TOTAL NOBLE GASES									7.40000E+03

0.00000E+00 APPEARING IN THE TABLE INDICATES RELEASE IS LESS THAN 1.0 CI/YR FOR NOBLE GAS

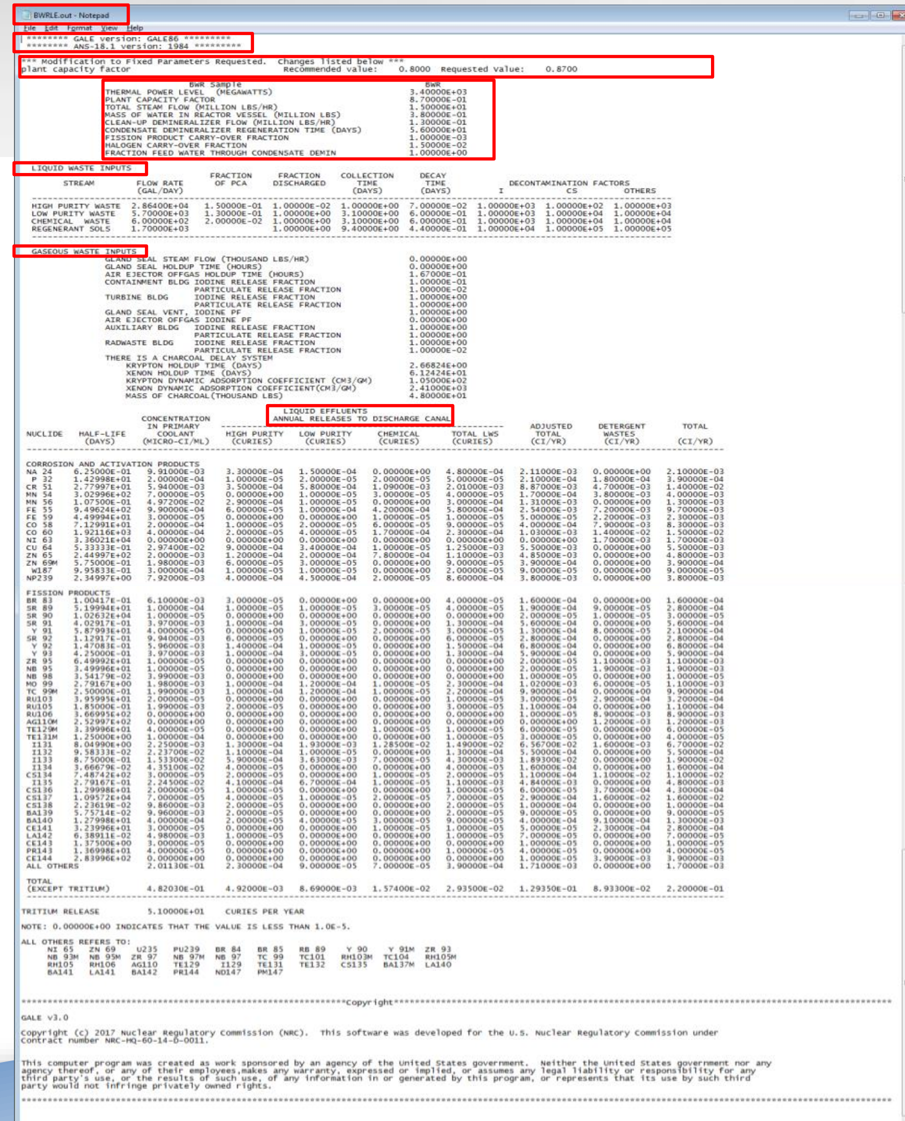
BWR Sample

AIRBORNE PARTICULATE RELEASE RATE (CURIES PER YEAR)

NUCLIDE	CONTAINMENT BLDG.	TURBINE BLDG.	AUXILIARY BLDG.	RADWASTE BLDG.	MECH VAC. PUMP	TOTAL
CR-51	2.00000E-06	9.00000E-04	9.00000E-04	7.00000E-06	1.00000E-06	1.80000E-03
MN-54	4.00000E-06	6.00000E-04	1.00000E-03	4.00000E-05	0.00000E+00	1.60000E-03
CO-58	1.00000E-06	1.00000E-03	2.00000E-04	2.00000E-06	0.00000E+00	1.20000E-03
FE-59	9.00000E-07	1.00000E-04	3.00000E-04	3.00000E-06	0.00000E+00	4.00000E-04
CO-60	1.00000E-05	1.00000E-03	4.00000E-03	7.00000E-05	5.60000E-07	5.10000E-03
ZN-65	1.00000E-05	6.00000E-03	4.00000E-03	3.00000E-06	3.40000E-07	1.00000E-02
SR-89	3.00000E-07	6.00000E-03	2.00000E-05	0.00000E+00	0.00000E+00	6.00000E-03
SR-90	3.00000E-08	2.00000E-05	7.00000E-06	0.00000E+00	0.00000E+00	2.70000E-05
NB-95	1.00000E-05	6.00000E-06	9.00000E-03	4.00000E-08	0.00000E+00	9.00000E-03
ZR-95	3.00000E-06	4.00000E-05	7.00000E-04	8.00000E-06	0.00000E+00	7.50000E-04
MO-99	6.00000E-05	2.00000E-03	6.00000E-02	3.00000E-08	0.00000E+00	6.20000E-02
RU-103	2.00000E-06	5.00000E-05	4.00000E-03	1.00000E-08	0.00000E+00	4.10000E-03
AG-110M	4.00000E-09	0.00000E+00	2.00000E-06	0.00000E+00	0.00000E+00	2.00000E-06
SB-124	2.00000E-07	1.00000E-04	3.00000E-05	7.00000E-07	0.00000E+00	1.30000E-04
CS-134	7.00000E-06	2.00000E-04	4.00000E-03	2.40000E-05	3.20000E-06	4.20000E-03
CS-136	1.00000E-06	1.00000E-04	4.00000E-04	0.00000E+00	1.90000E-06	5.00000E-04
CS-137	1.00000E-05	1.00000E-03	5.00000E-03	4.00000E-05	8.90000E-06	6.10000E-03
BA-140	2.00000E-05	1.00000E-02	2.00000E-02	4.00000E-08	1.10000E-05	3.00000E-02
CE-141	2.00000E-06	1.00000E-02	7.00000E-04	7.00000E-08	0.00000E+00	1.10000E-02

GALE-BWR 3.0 Use

- GALE-BWRLE 3.0 Output



BWRLE.out - Notepad

File Edit Format View Help

******** GALE version: GALE86 *********
******** ANS-18.1 version: 1984 *********

*** Modification to Fixed Parameters Requested. Changes listed below ***
plant capacity factor Recommended value: 0.8000 Requested value: 0.8700

BWR Sample	BWR
THERMAL POWER LEVEL (MEGAWATTS)	3.40000E+03
PLANT CAPACITY FACTOR	8.70000E-01
TOTAL STEAM FLOW (MILLION LBS/HR)	1.50000E+01
MASS OF WATER IN REACTOR VESSEL (MILLION LBS)	3.80000E-01
CLEAN-UP DEMINERALIZER FLOW (MILLION LBS/HR)	1.30000E-01
CONDENSATE DEMINERALIZER REGENERATION TIME (DAYS)	5.60000E+01
FISSION PRODUCT CARRY-OVER FRACTION	1.00000E-03
HALOGEN CARRY-OVER FRACTION	1.50000E-02
FRACTION FEED WATER THROUGH CONDENSATE DEMIN	1.00000E+00

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	2.86400E+04	1.50000E-01	1.00000E-02	1.00000E+00	7.00000E-02	1.00000E+03	1.00000E+02	1.00000E+03
LOW PURITY WASTE	5.70000E+03	1.30000E-01	1.00000E+00	3.10000E+00	6.00000E-01	1.00000E+03	1.00000E+04	1.00000E+04
CHEMICAL WASTE	6.00000E+02	2.00000E-02	1.00000E+00	3.10000E+00	6.00000E-01	1.00000E+03	1.00000E+04	1.00000E+04
REGENERANT SOLS	1.70000E+03		1.00000E+00	9.40000E+00	4.40000E-01	1.00000E+04	1.00000E+05	1.00000E+05

GASEOUS WASTE INPUTS

GLAND SEAL STEAM FLOW (THOUSAND LBS/HR)	0.00000E+00
GLAND SEAL HOLDUP TIME (HOURS)	0.00000E+00
AIR EJECTOR OFFGAS HOLDUP TIME (HOURS)	1.67000E-01
CONTAINMENT BLDG IODINE RELEASE FRACTION	1.00000E-01
PARTICULATE RELEASE FRACTION	1.00000E-02
TURBINE BLDG IODINE RELEASE FRACTION	1.00000E+00
PARTICULATE RELEASE FRACTION	1.00000E+00
GLAND SEAL VENT, IODINE PF	1.00000E+00
AIR EJECTOR OFFGAS IODINE PF	0.00000E+00
AUXILIARY BLDG IODINE RELEASE FRACTION	1.00000E+00
PARTICULATE RELEASE FRACTION	1.00000E+00
RADWASTE BLDG IODINE RELEASE FRACTION	1.00000E+00
PARTICULATE RELEASE FRACTION	1.00000E-02
THERE IS A CHARCOAL DELAY SYSTEM	
KRYPTON HOLDUP TIME (DAYS)	2.66824E+00
XENON HOLDUP TIME (DAYS)	6.12424E+01
KRYPTON DYNAMIC ADSORPTION COEFFICIENT (CM3/GM)	1.05000E+02
XENON DYNAMIC ADSORPTION COEFFICIENT(CM3/GM)	2.41000E+03
MASS OF CHARCOAL(THOUSAND LBS)	4.80000E+01

LIQUID EFFLUENTS
ANNUAL RELEASES TO DISCHARGE CANAL

NUCLIDE	HALF-LIFE (DAYS)	CONCENTRATION IN PRIMARY COOLANT (MICRO-CI/ML)	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	6.25000E-01	9.91000E-03	3.30000E-04	1.50000E-04	0.00000E+00	4.80000E-04	2.11000E-03	0.00000E+00	2.10000E-03
P 32	1.42998E+01	2.00000E-04	1.00000E-05	2.00000E-05	2.00000E-05	5.00000E-05	2.10000E-04	1.80000E-04	3.90000E-04
CR 51	2.77997E+01	5.94000E-03	3.50000E-04	5.80000E-04	1.09000E-03	2.01000E-03	8.87000E-03	4.70000E-03	1.40000E-02
MN 54	3.02996E+02	7.00000E-05	0.00000E+00	1.00000E-05	3.00000E-05	4.00000E-05	1.70000E-04	3.80000E-03	4.00000E-03
MN 56	1.07500E-01	4.97200E-02	2.90000E-04	1.00000E-05	0.00000E+00	3.00000E-04	1.31000E-03	0.00000E+00	1.30000E-03
FE 55	9.49624E+02	9.90000E-04	6.00000E-05	1.00000E-04	4.20000E-04	5.80000E-04	2.54000E-03	7.20000E-03	9.70000E-03
FE 59	4.49994E+01	3.00000E-05	0.00000E+00	0.00000E+00	1.00000E-05	1.00000E-05	5.00000E-05	2.20000E-03	2.30000E-03
CO 58	7.12991E+01	2.00000E-04	1.00000E-05	2.00000E-05	6.00000E-05	9.00000E-05	4.00000E-04	7.90000E-03	8.30000E-03
CO 60	1.92116E+03	4.00000E-04	2.00000E-05	4.00000E-05	1.70000E-04	2.30000E-04	1.03000E-03	1.40000E-02	1.50000E-02
NI 63	3.36021E+04	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	1.70000E-03	1.70000E-03
CU 64	5.33333E-01	2.97400E-02	9.00000E-04	3.40000E-04	1.00000E-05	1.25000E-03	5.50000E-03	0.00000E+00	5.50000E-03
ZN 65	2.44997E+02	2.00000E-03	1.20000E-04	2.00000E-04	7.80000E-04	1.10000E-03	4.85000E-03	0.00000E+00	4.80000E-03
ZN 69M	5.75000E-01	1.98000E-03	6.00000E-05	3.00000E-05	0.00000E+00	9.00000E-05	3.90000E-04	0.00000E+00	3.90000E-04
W187	9.95833E-01	3.00000E-04	1.00000E-05	1.00000E-05	0.00000E+00	2.00000E-05	9.00000E-05	0.00000E+00	9.00000E-05
NP239	2.34997E+00	7.92000E-03	4.00000E-04	4.50000E-04	2.00000E-05	8.60000E-04	3.80000E-03	0.00000E+00	3.80000E-03
FISSION PRODUCTS									
BR 83	1.00417E-01	6.10000E-03	3.00000E-05	0.00000E+00	0.00000E+00	4.00000E-05	1.60000E-04	0.00000E+00	1.60000E-04
SR 89	5.19994E+01	1.00000E-04	1.00000E-05	1.00000E-05	3.00000E-05	4.00000E-05	1.90000E-04	9.00000E-05	2.80000E-04
SR 90	1.02632E+04	1.00000E-05	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	2.00000E-05	1.00000E-05	3.00000E-05
SR 91	4.02917E-01	3.97000E-03	1.00000E-04	3.00000E-05	0.00000E+00	1.30000E-04	5.60000E-04	0.00000E+00	5.60000E-04
Y 91	5.87993E+01	4.00000E-05	0.00000E+00	1.00000E-05	2.00000E-05	3.00000E-05	1.30000E-04	8.00000E-05	2.10000E-04
SR 92	1.12917E-01	9.94000E-03	6.00000E-05	0.00000E+00	0.00000E+00	6.00000E-05	2.80000E-04	0.00000E+00	2.80000E-04
Y 92	1.47083E-01	5.96000E-03	1.40000E-04	1.00000E-05	0.00000E+00	1.50000E-04	6.80000E-04	0.00000E+00	6.80000E-04
Y 93	4.25000E-01	3.97000E-03	1.00000E-04	3.00000E-05	0.00000E+00	1.30000E-04	5.90000E-04	0.00000E+00	5.90000E-04
ZR 95	6.49992E+01	1.00000E-05	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	2.00000E-05	1.10000E-03	1.10000E-03
NB 95	3.49996E+01	1.00000E-05	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	2.00000E-05	1.90000E-03	1.90000E-03
NB 98	3.54179E-02	3.99000E-03	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	1.00000E-05	0.00000E+00	1.00000E-05
MO 99	2.79167E+00	1.98000E-03	1.00000E-04	1.20000E-04	1.00000E-05	2.30000E-04	1.02000E-03	6.00000E-05	1.10000E-03
TC 99M	2.50000E-01	1.99000E-03	1.00000E-04	1.20000E-04	1.00000E-05	2.20000E-04	9.90000E-04	0.00000E+00	9.90000E-04
RU103	3.95995E+01	2.00000E-05	0.00000E+00	0.00000E+00	0.00000E+00	1.00000E-05	3.00000E-05	2.90000E-04	3.20000E-04
RU105	1.85000E-01	1.99000E-03	2.00000E-05	0.00000E+00	0.00000E+00	3.00000E-05	1.10000E-04	0.00000E+00	1.10000E-04
RU106	3.66995E+02	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	1.00000E-05	8.90000E-03	8.90000E-03
AG110M	2.52997E+02	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	1.20000E-03	1.20000E-03
TE129M	3.39996E+01	4.00000E-05	0.00000E+00	0.00000E+00	1.00000E-05	1.00000E-05	6.00000E-05	0.00000E+00	6.00000E-05
TE131M	1.25000E+00	1.00000E-04	0.00000E+00	0.00000E+00	0.00000E+00	1.00000E-05	3.00000E-05	0.00000E+00	4.00000E-05
I131	8.04990E+00	2.25000E-03	1.30000E-04	1.93000E-03	1.28500E-02	1.49000E-02	6.56700E-02	1.60000E-03	6.70000E-02
I132	9.58333E-02	2.23700E-02	1.10000E-04	1.00000E-05	0.00000E+00	1.30000E-04	5.50000E-04	0.00000E+00	5.50000E-04
I133	8.75000E-01	1.53300E-02	5.90000E-04	3.63000E-03	7.00000E-05	4.30000E-03	1.89300E-02	0.00000E+00	1.90000E-02
I134	3.66679E-02	4.35100E-02	4.00000E-05	0.00000E+00	0.00000E+00	4.00000E-05	1.60000E-04	0.00000E+00	1.60000E-04
CS134	7.48742E+02	3.00000E-05	2.00000E-05	0.00000E+00	1.00000E-05	2.00000E-05	1.10000E-04	1.10000E-02	1.10000E-02
I135	2.79167E-01	2.24500E-02	4.10000E-04	6.70000E-04	1.00000E-05	1.10000E-03	4.84000E-03	0.00000E+00	4.80000E-03
CS136	1.29998E+01	2.00000E-05	1.00000E-05	0.00000E+00	0.00000E+00	1.00000E-05	6.00000E-05	3.70000E-04	4.30000E-04
CS137	1.09572E+04	7.00000E-05	4.00000E-05	1.00000E-05	2.00000E-05	7.00000E-05	2.90000E-04	1.60000E-02	1.60000E-02
CS138	2.23619E-02	9.86000E-03	2.00000E-05	0.00000E+00	0.00000E+00	2.00000E-05	1.00000E-04	0.00000E+00	1.00000E-04
BA139	5.75714E-02	9.96000E-03	2.00000E-05	0.00000E+00	0.00000E+00	2.00000E-05	9.00000E-05	0.00000E+00	9.00000E-05
BA140	1.27998E+01	4.00000E-04	2.00000E-05	4.00000E-05	3.00000E-05	9.00000E-05	4.00000E-04	9.10000E-04	1.30000E-03
CE141	3.23996E+01	3.00000E-05	0.00000E+00	0.00000E+00	1.00000E-05	1.00000E-05	5.00000E-05	2.30000E-04	2.80000E-04
LA142	6.38911E-02	4.98000E-03	1.00000E-05	0.00000E+00	0.00000E+00	1.00000E-05	7.00000E-05	0.00000E+00	7.00000E-05
CE143	1.37500E+00	3.00000E-05	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	1.00000E-05	0.00000E+00	1.00000E-05
PR143	1.36998E+01	4.00000E-05	0.00000E+00	0.00000E+00	0.00000E+00	1.00000E-05	4.00000E-05	0.00000E+00	4.00000E-05
CE144	2.83996E+02	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	1.00000E-05	3.90000E-03	3.90000E-03
ALL OTHERS		2.01130E-01	2.30000E-04	9.00000E-05	7.00000E-05	3.90000E-04	1.71000E-03	0.00000E+00	1.70000E-03
TOTAL (EXCEPT TRITIUM)		4.82030E-01	4.92000E-03	8.69000E-03	1.57400E-02	2.93500E-02	1.29350E-01	8.93300E-02	2.20000E-01

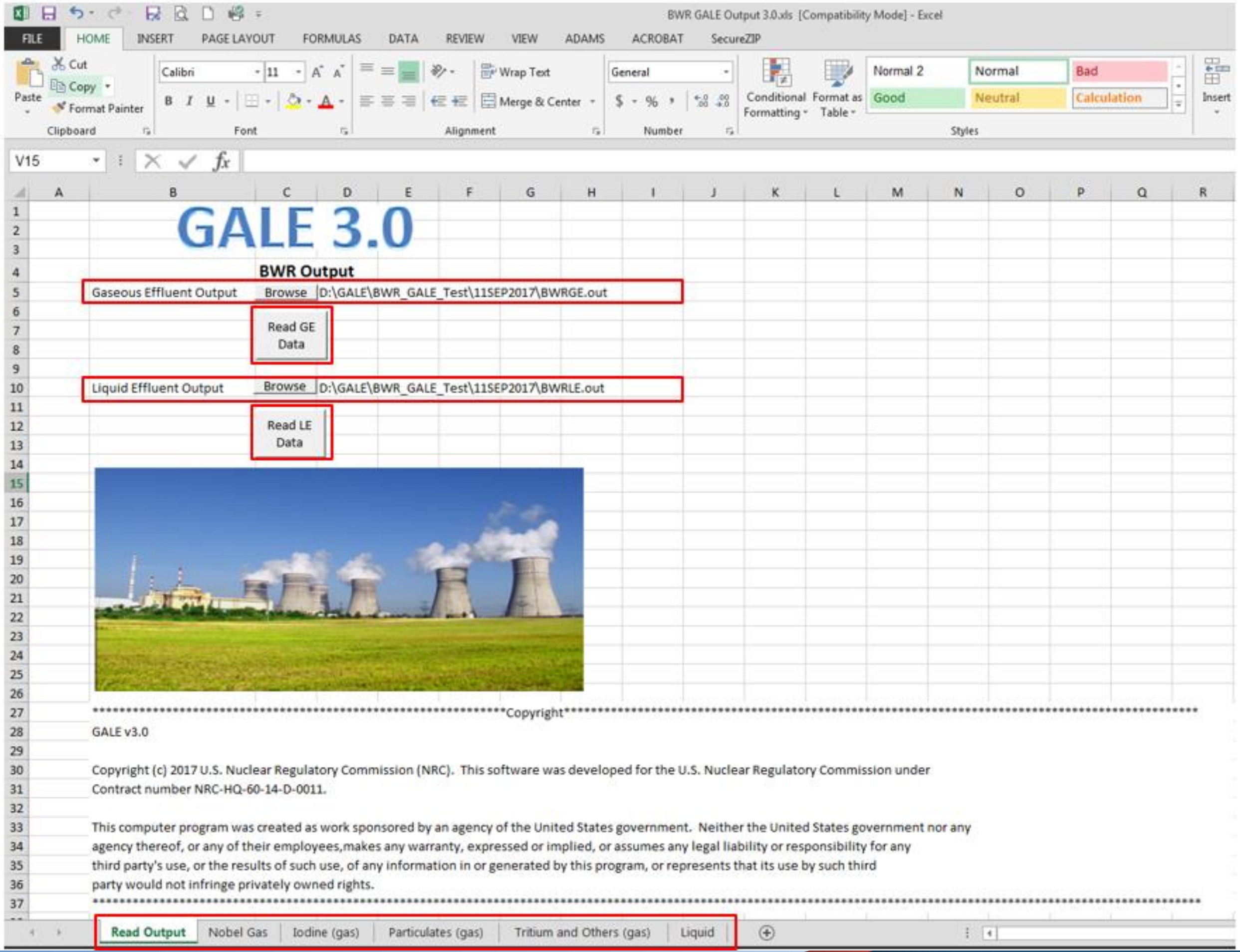
TRITIUM RELEASE 5.10000E+01 CURIES PER YEAR

NOTE: 0.00000E+00 INDICATES THAT THE VALUE IS LESS THAN 1.0E-5.

ALL OTHERS REFERS TO:
NI 65 ZN 69 U235 PU239 BR 84 BR 85 RB 89 Y 90 Y 91M ZR 93
NB 93M NB 95M ZR 97 NB 97M NB 97 TC 99 TC101 RH103M TC104 RH105M
RH105 RH106 AG110 TE129 I129 TE131 TE132 CS135 BA137M LA140
BA141 LA141 BA142 PR144 ND147 PM147

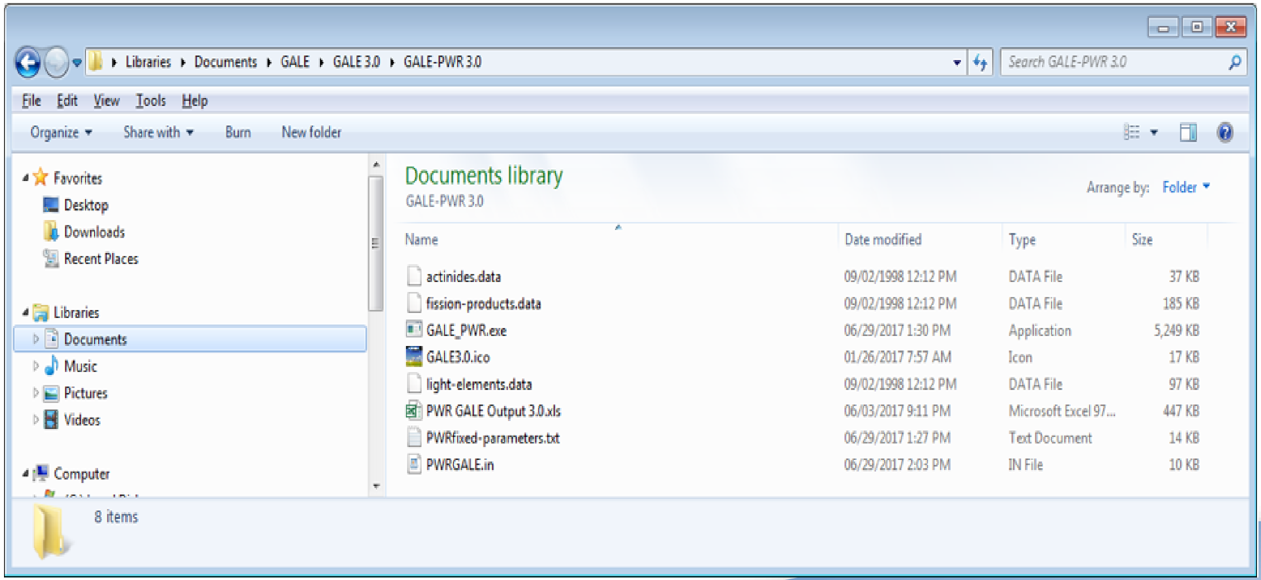
GALE-BWR 3.0 Use

- BWR GALE Output 3.0.xls



GALE-PWR 3.0 Installation

- Create a working directory and install the code package files
- The working directory should contain the 3 data files, and an existing input file if starting from a previous GALE 3.0 run. Otherwise the program will set up and save the input file. This working directory may also contain the spreadsheet for output visualization. The fixed-parameters file is optional.



GALE-PWR 3.0 Fixed Parameters

- GALE-PWR 3.0 Fixed Parameters File

PWRfixed-parameters.txt - Notepad

File Edit Format View Help

```
$user
!3.1    Plant Capacity Factor (GE and LE)
! Value from Section 2.2.2 of NUREG-0017, Revision 1 (GALE86 Code)
PF_user=0.8  !Plant Capacity Factor (fraction)

!3.2 Coolant and Main Steam Radionuclide Concentrations (GE and LE)
! GE noble gas and iodine concentrations in reactor coolant and main steam (micro curies/g)
! Values from Table 7 of ANSI/ANS-18.1-1984 (GALE86 Code)
! Once-Through Steam Generator
!  Reactor Coolant          Main Steam
   XP1o_user(1)=1.6E-01,    XP2o_user(1)=3.4E-08   ! KR-85M
   XP1o_user(2)=4.3E-01,    XP2o_user(2)=8.9E-08   ! KR-85
   XP1o_user(3)=1.5E-01,    XP2o_user(3)=3.0E-08   ! KR-87
   XP1o_user(4)=2.8E-01,    XP2o_user(4)=5.9E-08   ! KR-88
   XP1o_user(5)=7.3E-01,    XP2o_user(5)=1.5E-07   ! XE-131M
   XP1o_user(6)=7.0E-02,    XP2o_user(6)=1.5E-08   ! XE-133M
   XP1o_user(7)=2.6E+00,    XP2o_user(7)=5.4E-07   ! XE-133
   XP1o_user(8)=1.3E-01,    XP2o_user(8)=2.7E-08   ! XE-135M
   XP1o_user(9)=8.5E-01,    XP2o_user(9)=1.8E-07   ! XE-135
   XP1o_user(10)=3.4E-02,   XP2o_user(10)=7.1E-09   ! XE-137
   XP1o_user(11)=1.2E-01,   XP2o_user(11)=2.5E-08   ! XE-138
   XP1o_user(12)=4.5E-02,   XP2o_user(12)=5.2E-08   ! I-131
   XP1o_user(13)=2.1E-01,   XP2o_user(13)=2.4E-07   ! I-132
   XP1o_user(14)=1.4E-01,   XP2o_user(14)=1.6E-07   ! I-133
   XP1o_user(15)=3.4E-01,   XP2o_user(15)=3.8E-07   ! I-134
   XP1o_user(16)=2.6E-01,   XP2o_user(16)=3.0E-07   ! I-135

!3.13   Argon-41 Release (GE)
! Value from Section 2.2.26 of NUREG-0017, Revision 1 (GALE86 code)
Ar41_user=34.0  !Ci/yr

!3.14   Carbon-14 Release (GE)
! Value from Section 2.2.25 of NUREG-0017, Revision 1 (GALE86 code)
C14_user=7.3  !Ci/yr

!3.15   Decontamination Factors for Condensate Demineralizers (LE)
! Values from Section 2.2.18 of NUREG-0017, Revision 1 (GALE86 code)
DFCDI_user=10.0    !Anion DF for Condensate Demineralizers
DFCDO_user=10.0    !Other Nuclide DF for Condensate Demineralizers
DFCDCS_user=2.0    !Cesium DF for Condensate Demineralizers

!3.17   Releases of Radioactive Material in Liquid Waste from the Turbine Building Floor Drain System (LE)
! Value from Section 2.2.14 (Table 2-26) of NUREG-0017, Revision 1 (GALE86 code)
TBdrain_user = 7200.0    ! gal/day at main steam activity

!3.19   Source Term Adjustments for Anticipated Operational Occurrences (LE)
! Value from Section 2.2.23 of NUREG-0017, Revision 1 (GALE86 code)
AOIfixed_user = 0.16     !adjustment is made to liquid radwaste source terms to account for AOO (Ci/yr)
$end
```

GALE-PWR 3.0 Use

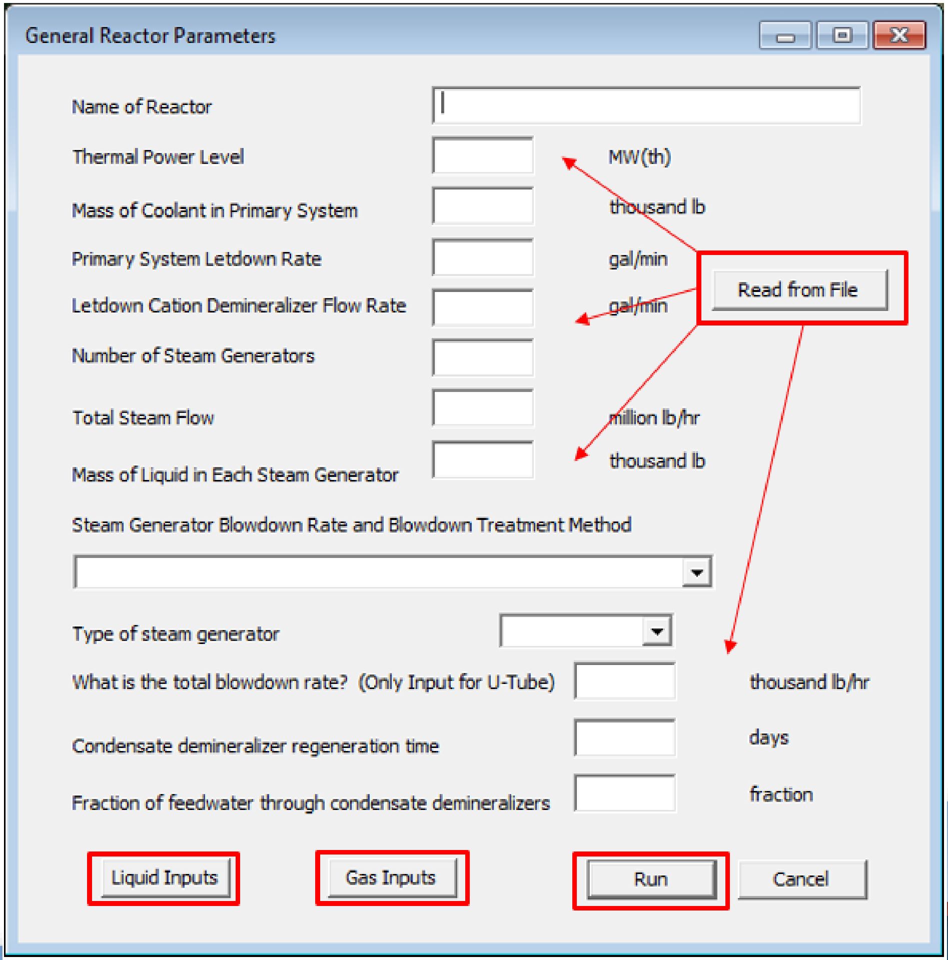
- GALE-PWR 3.0 Introductory Screen

GALE-PWR 3.0 Use

- GALE-PWR 3.0 Introductory Screen Selecting GALE and ANS 18.1 Version

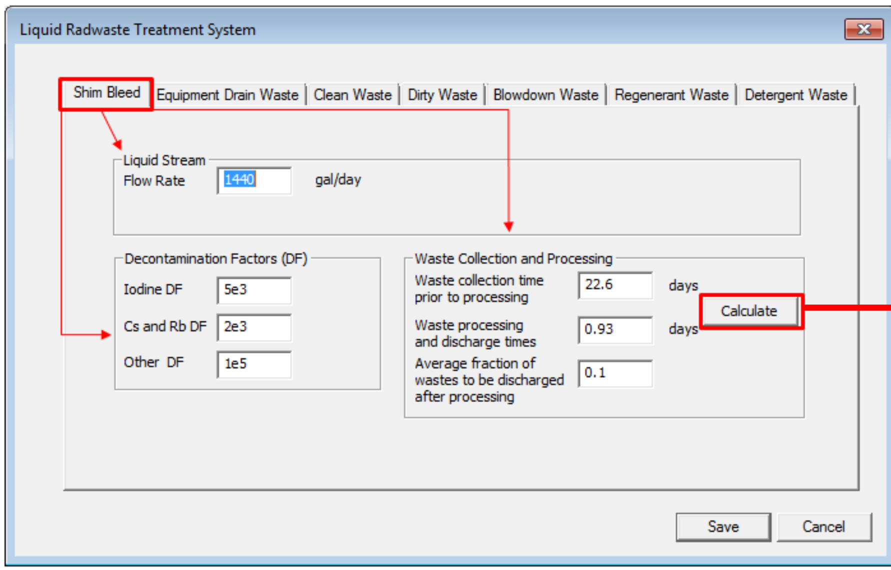
GALE-PWR 3.0 Use

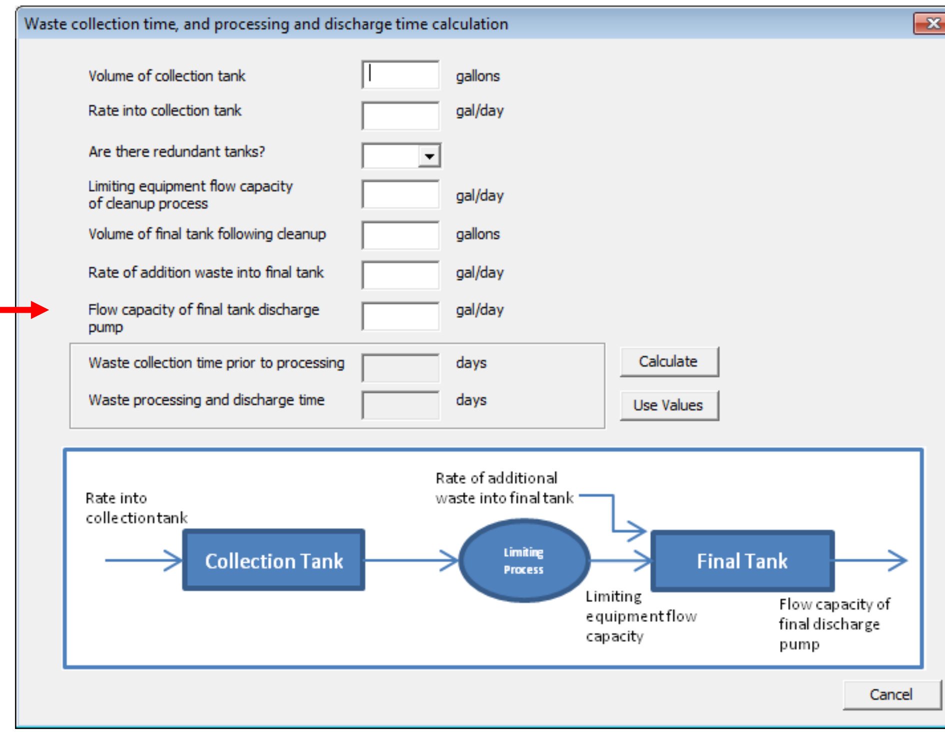
- GALE-PWR 3.0 General Reactor Parameters Window



GALE-PWR 3.0 Use

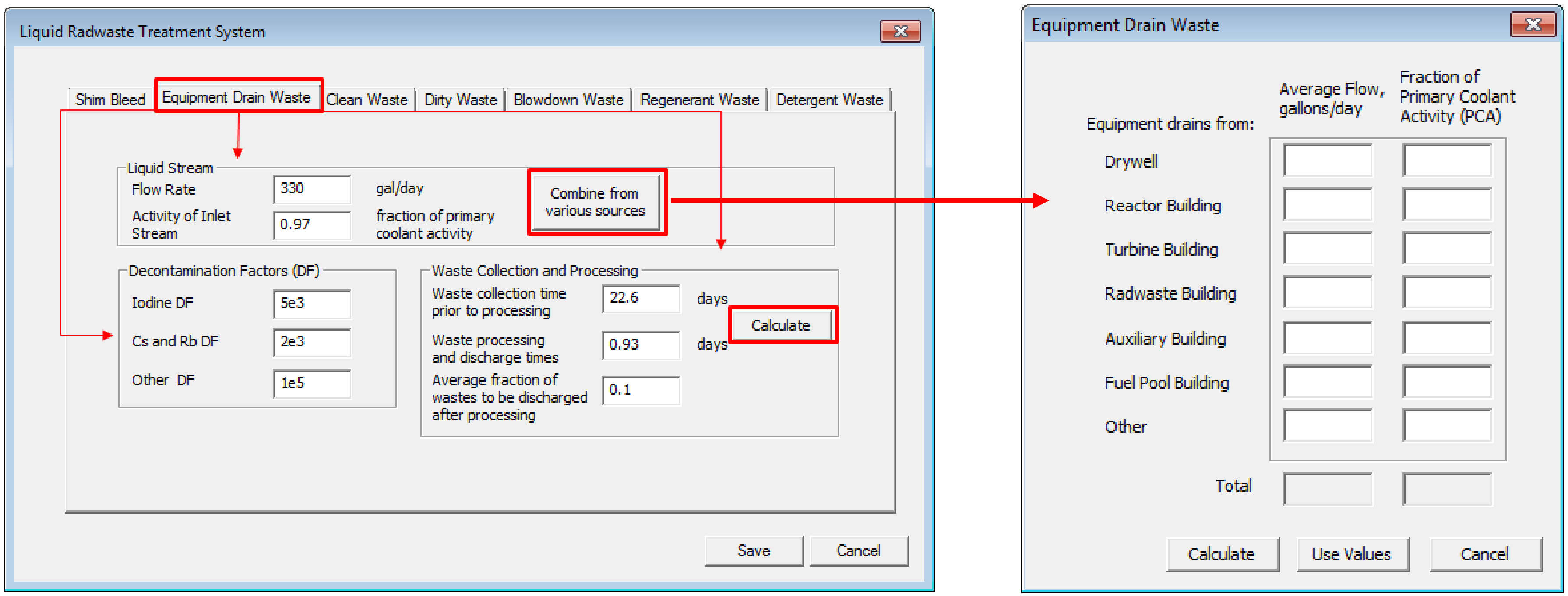
- GALE-PWR 3.0 Shim Bleed Window and Calculator





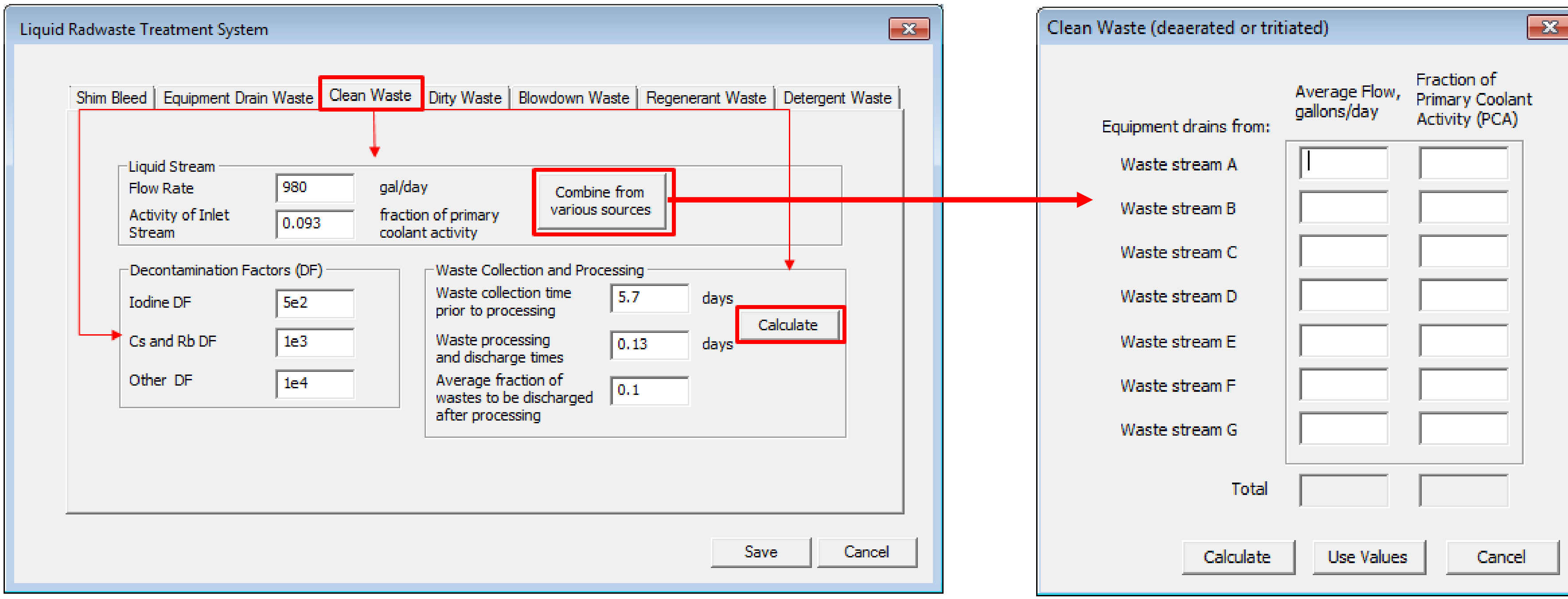
GALE-PWR 3.0 Use

- GALE-PWR 3.0 Equipment Drain Waste Window and Calculator



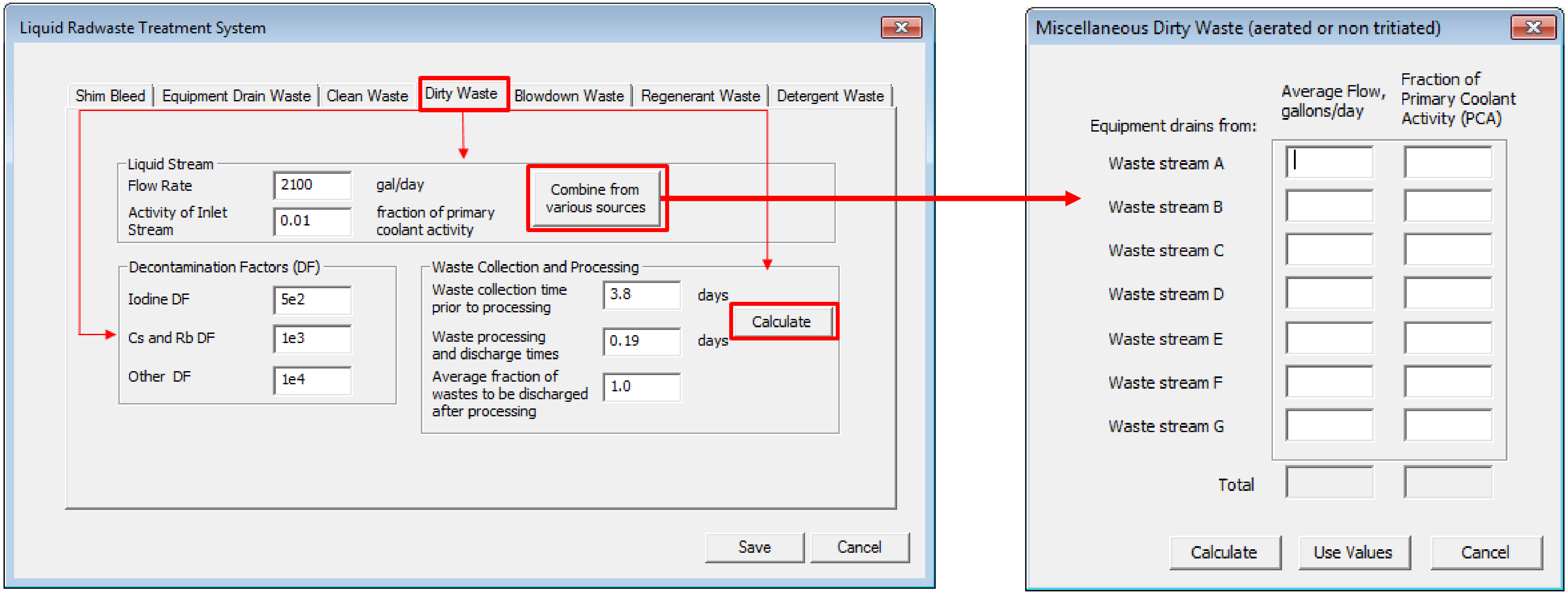
GALE-PWR 3.0 Use

- GALE-PWR 3.0 Clean Waste Window and Calculator



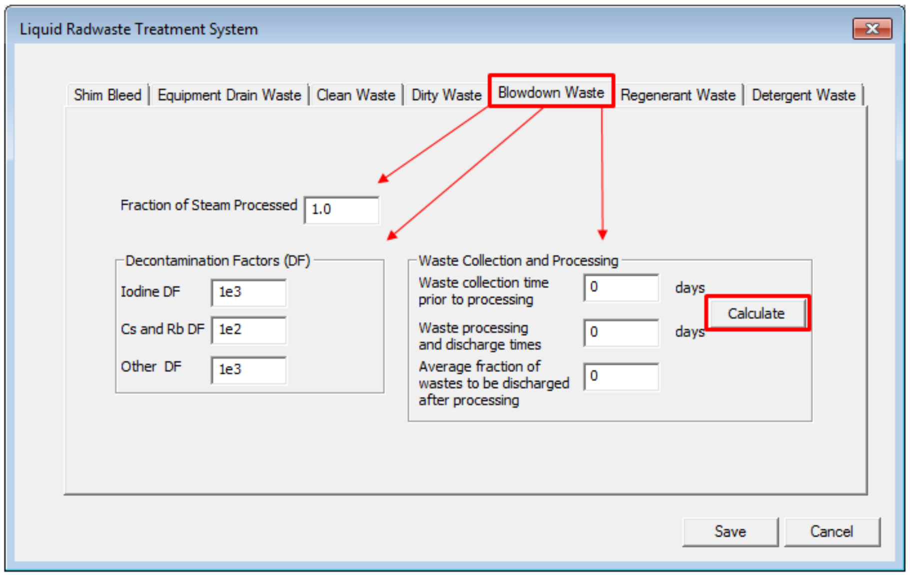
GALE-PWR 3.0 Use

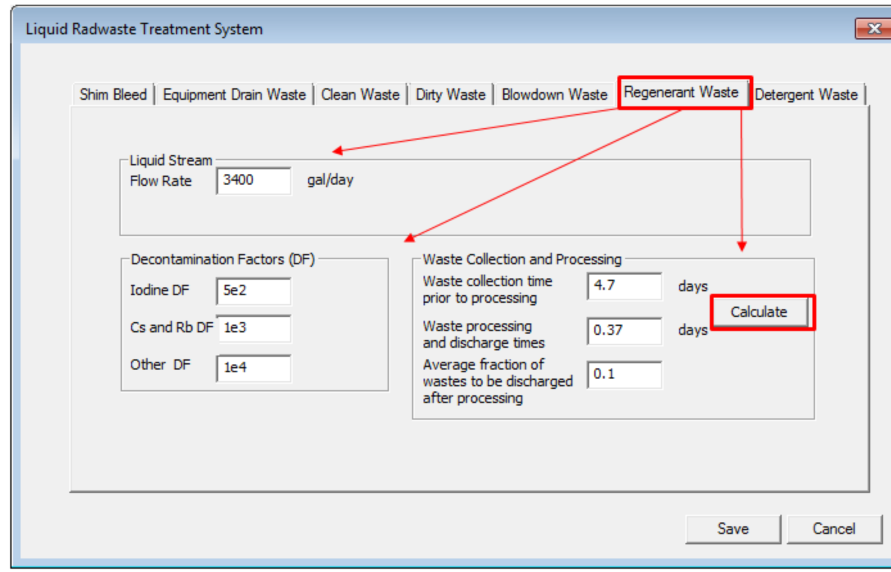
- GALE-PWR 3.0 Dirty Waste Window and Calculator



GALE-PWR 3.0 Use

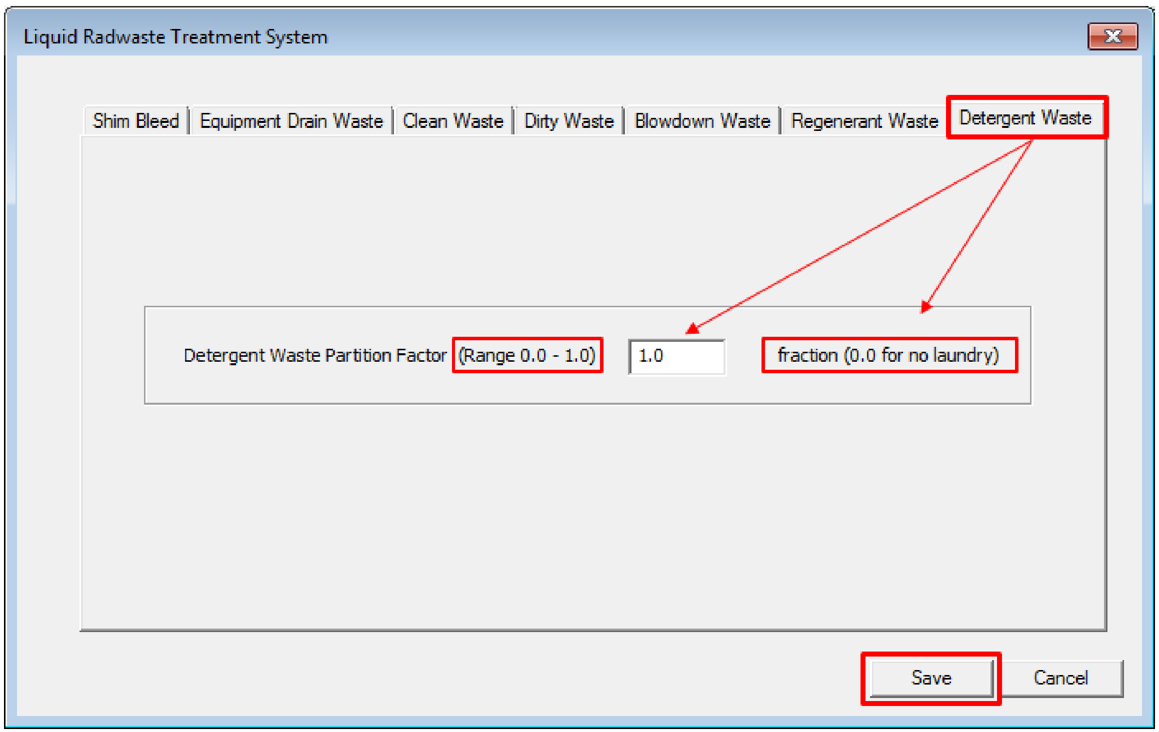
- GALE-PWR 3.0 Blowdown Waste and Regenerant Solutions Waste Window





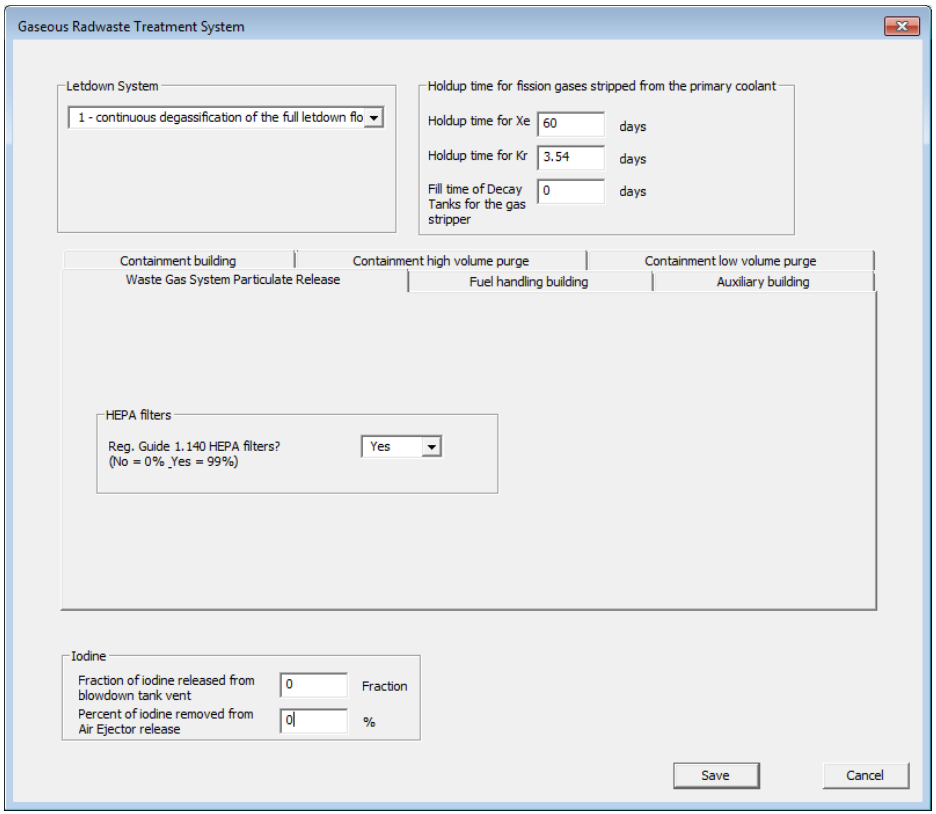
GALE-PWR 3.0 Use

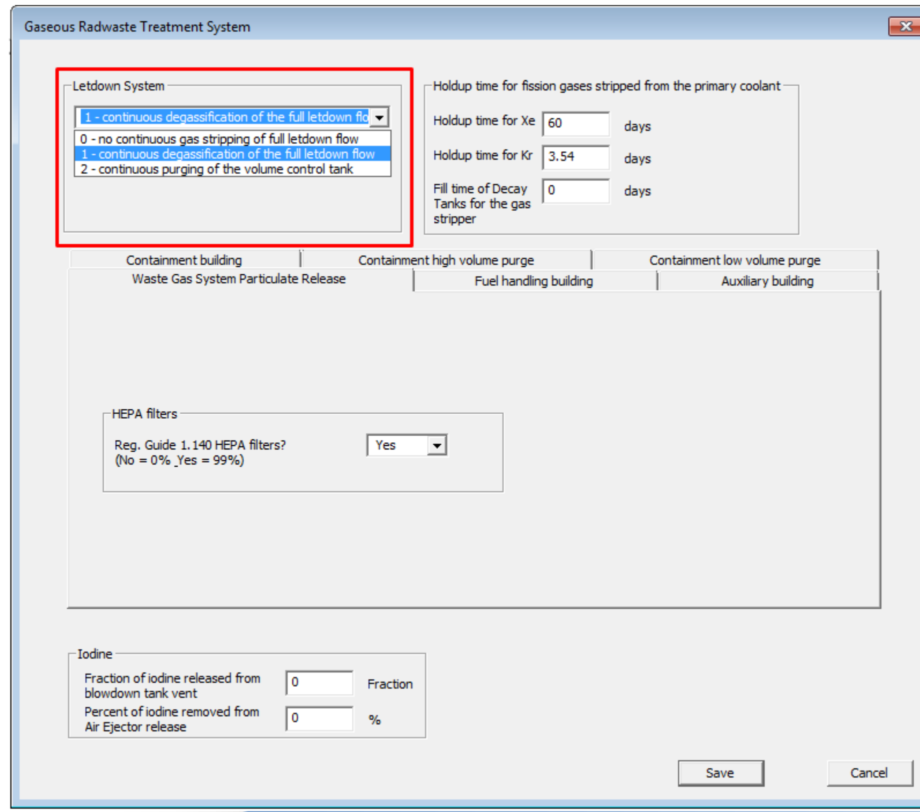
- GALE-PWR 3.0 Detergent Waste Window



GALE-PWR 3.0 Use

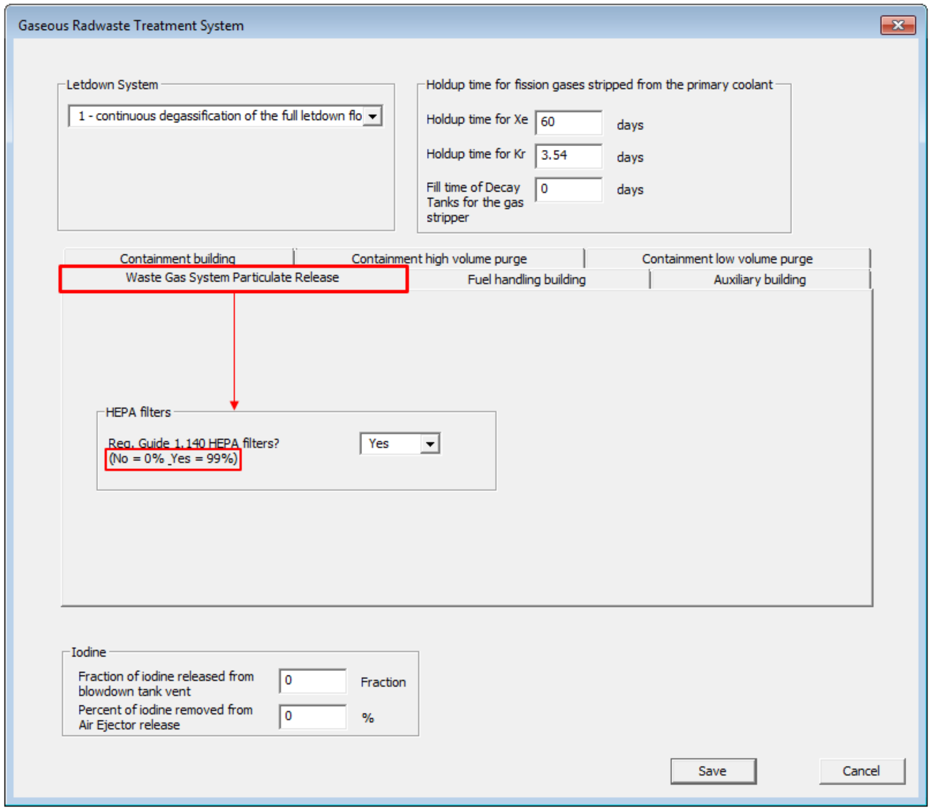
- GALE-PWR 3.0 Gaseous Radwaste Treatment System Window

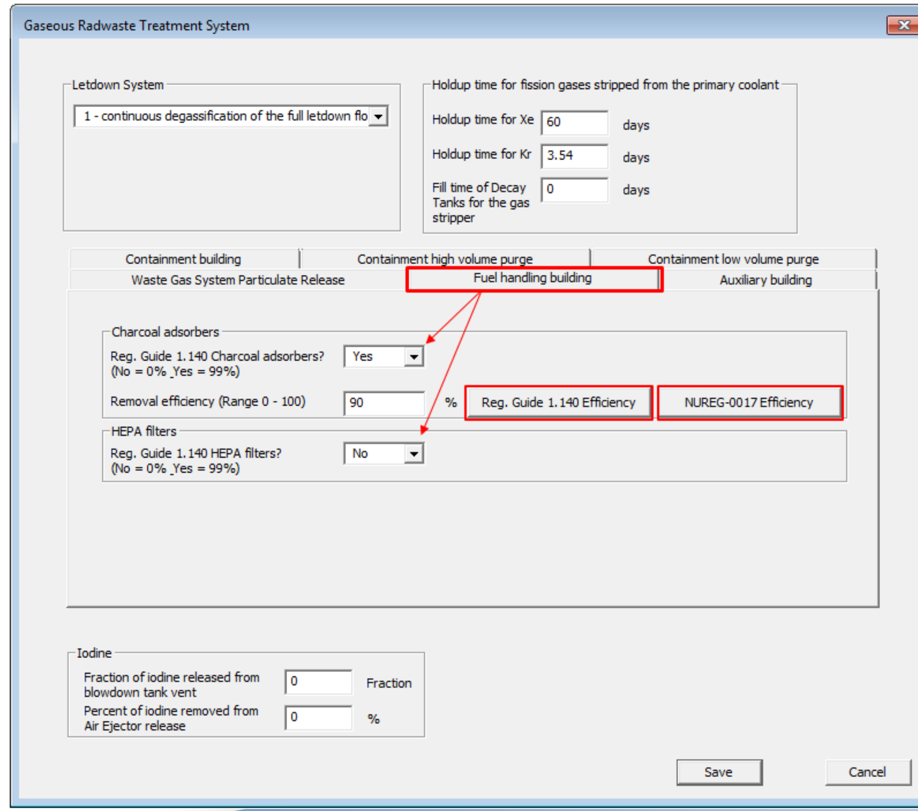




GALE-PWR 3.0 Use

- GALE-PWR 3.0 Gaseous Radwaste Treatment System Window (cont.)





GALE-PWR 3.0 Use

- GALE-PWR 3.0 Charcoal Adsorber Efficiency Windows

NUREG-0017, Revision 1 Charcoal Efficiency Information

Table 1-5 taken from NUREG-0017, Revision 1

Note: Recommended for use with GALE86

TABLE 1-5

ASSIGNED REMOVAL EFFICIENCIES FOR CHARCOAL ADSORBERS FOR RADIOIODINE REMOVAL

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

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

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

OK

Regulatory Guide 1.140, Revision 2 Charcoal Efficiency Information

Table 1 taken from Regulatory Guide 1.140, Revision 2

Note: Recommended for use with GALE09

Table 1: Laboratory Tests For Activated Carbon

Activated Carbon[a] Total Bed Depth[b]	Maximum Assigned Activated Carbon Decontamination Efficiencies		Methyl Iodide Penetration Acceptance Criterion for Representative Sample
2 inches	Elemental iodine Organic iodide	95% 95%	Penetration ≤5% when tested in accordance with ASTM D-3803-1989 (Ref. 4)
4 inches or greater	Elemental iodine Organic iodide	99% 99%	Penetration ≤1% when tested in accordance with ASTM D-3803-1989 (Ref. 4)

[a] The activated carbon, when new, should meet the specifications of Regulatory Position 4.9 of this guide.

[b] Multiple beds, e.g., two 2-inch beds in series, should be treated as a single bed of aggregate depth. It is advantageous when series beds are located in separate housings and individually in-place leak tested. This aids in mixing the challenge agent and contributes to the accuracy of the test results.

NOTES:

(1) Credited decontamination efficiencies (a portion of which includes bypass leakage) are based on 0.25 second residence time per 2-inch bed depth.

(2) Organic iodide and elemental iodine are the forms of iodine that are expected to be absorbed by activated carbon. Organic iodide is more difficult for activated carbon to adsorb than elemental iodine. Therefore, the laboratory test to determine the performance of the activated carbon adsorber is based on organic iodide. Methyl iodide is the organic form of iodine that is used in the laboratory test.

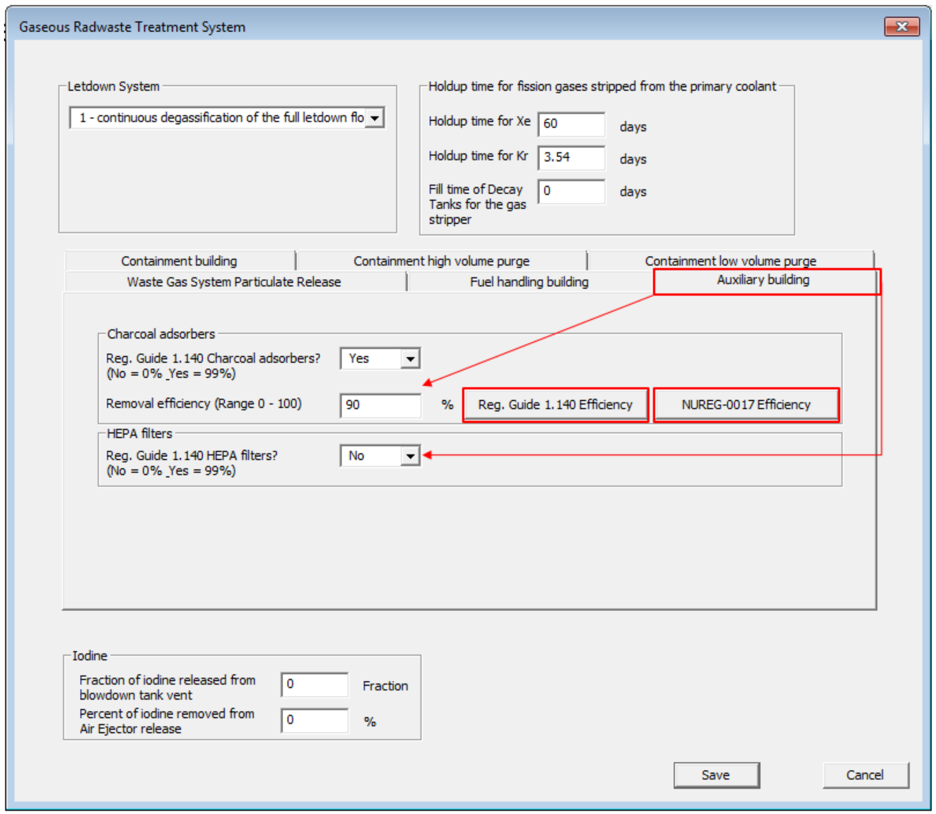
(3) This Table 1 provides acceptable decontamination efficiencies and methyl iodide test penetrations of used activated carbon samples for laboratory testing. Laboratory tests are conducted in accordance with ASTM D3803-1989 (Ref. 4). Tests are conducted at a temperature of 30°C and relative humidity of 95%, except a relative humidity of 70% is used when the air entering the carbon adsorber is maintained at less than or equal to 70% relative humidity.

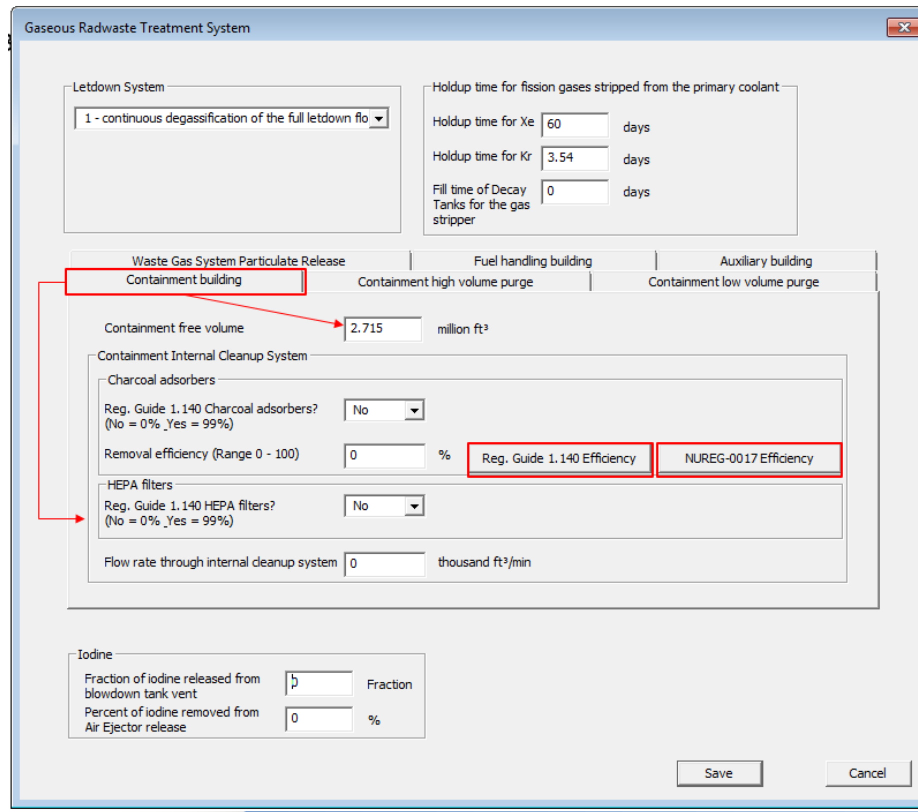
(4) See Appendix A to ASME N509-1989 (Ref. 1) for the definition of a representative sample. Testing should be performed at the frequencies specified in Regulatory Position 7.2 of this guide. Testing should be performed in accordance with ASTM D3803-1989 (Ref. 4) at a temperature of 30°C and a relative humidity of 95% (or 70% with humidity control). Humidity control can be provided by heaters or an analysis that demonstrates that the air entering the carbon will be maintained less than or equal to 70% relative humidity.

OK

GALE-PWR 3.0 Use

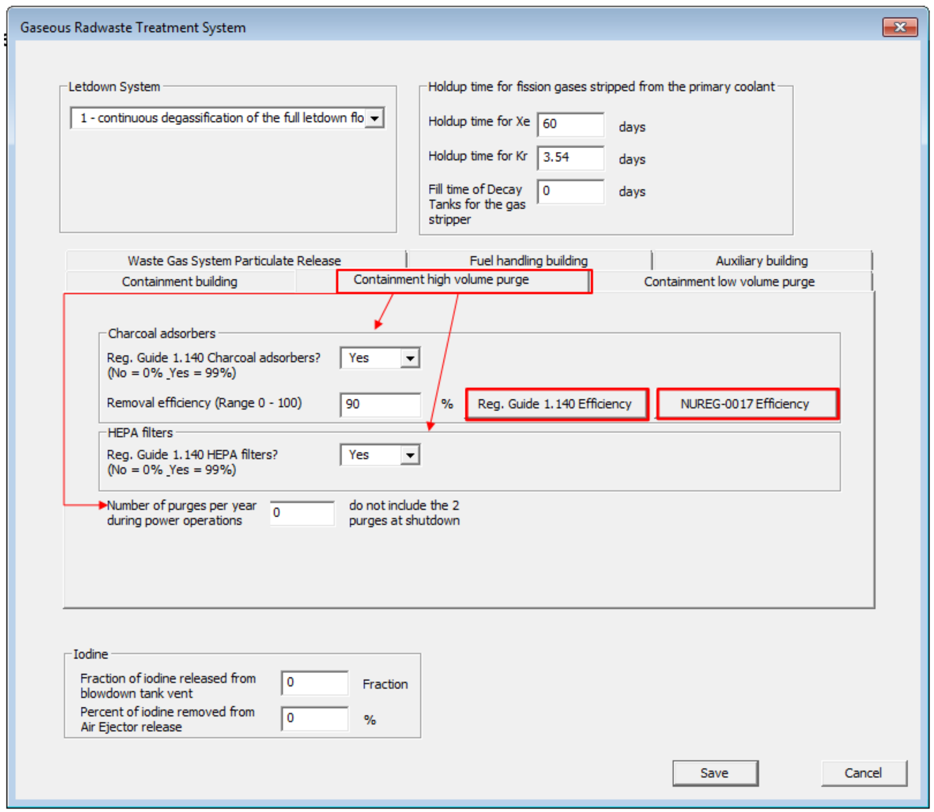
- GALE-PWR 3.0 Gaseous Radwaste Treatment System Window (cont.)

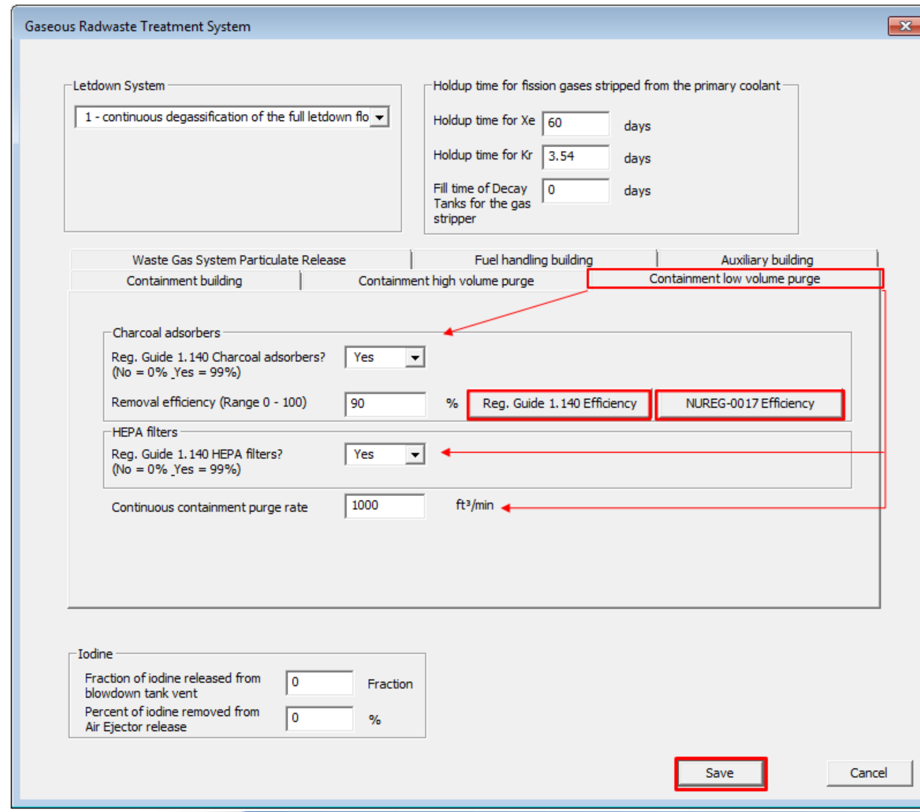




GALE-PWR 3.0 Use

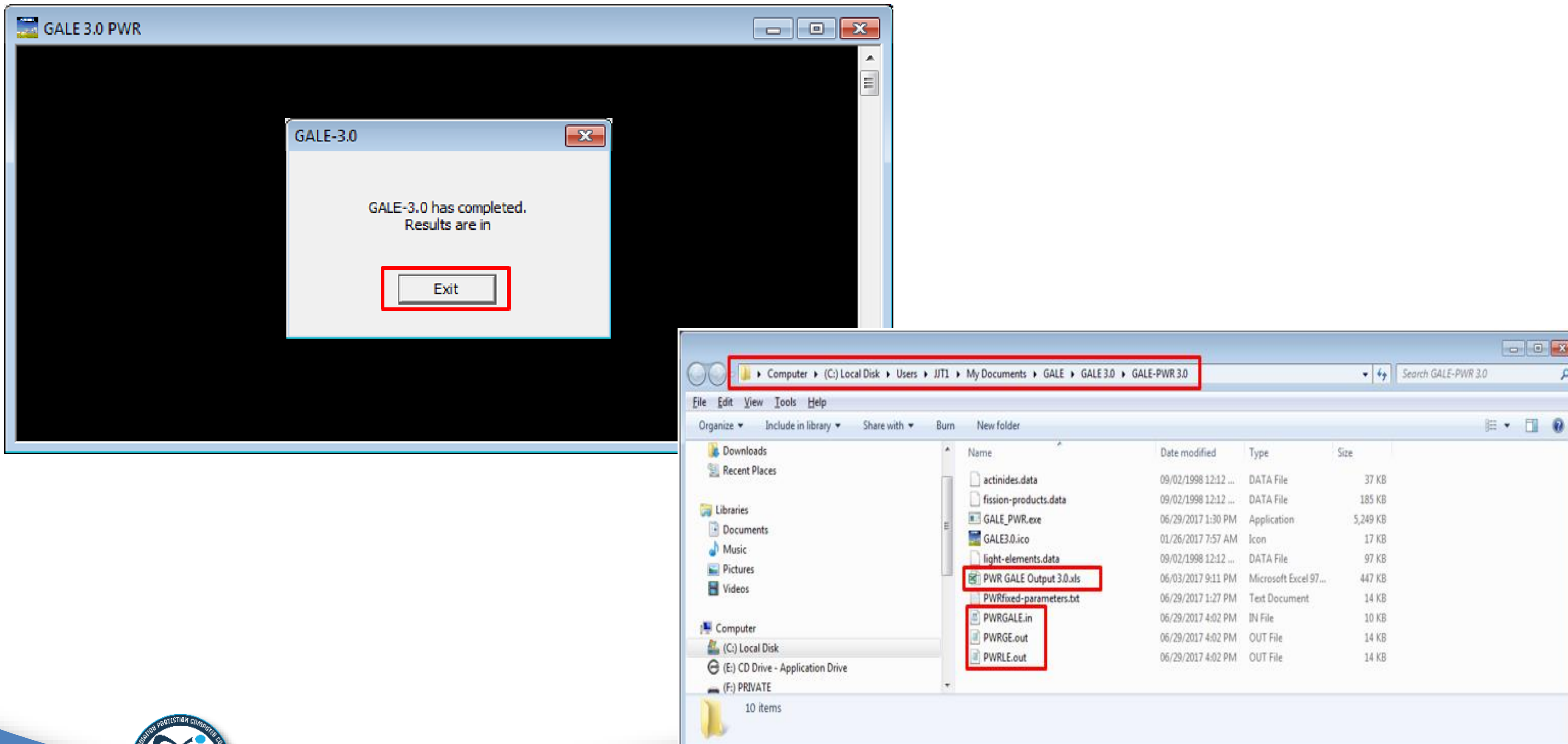
- GALE-PWR 3.0 Gaseous Radwaste Treatment System Window (cont.)





GALE-PWR 3.0 Use

- GALE-PWR 3.0 Code Execution and Outputs



GALE-PWR 3.0 Use

- GALE-PWRGE 3.0 Output

```
PWRGE.out - Notepad
File  Edit  Format  View  Help
 ********* GALE version: GALE86 **********
 ********* ANS-18.1 version: 1984 **********

*** Modification to Fixed Parameters Requested.  Changes listed below ***
plant capacity factor                        Recommended value:    0.8000  Requested Value:    0.8700
                   Sample PWR                                               PWR
           THERMAL POWER LEVEL (MEGAWATTS)                              3.40000E+03
           PLANT CAPACITY FACTOR                                        8.70000E-01
           MASS OF PRIMARY COOLANT (THOUSAND LBS)                       5.50000E+02
           PRIMARY SYSTEM LETDOWN RATE (GPM)                            7.50000E+01
           LETDOWN CATION DEMINERALIZER FLOW (GPM)                      7.50000E+00
           NUMBER OF STEAM GENERATORS                                   4.00000E+00
           TOTAL STEAM FLOW (MILLION LBS/HR)                            1.50000E+01
           MASS OF LIQUID IN EACH STEAM GENERATOR (THOUSAND LBS)        1.12500E+02
           BLOWDOWN RATE (THOUSAND LBS/HR)                              7.50000E+01
           CONDENSATE DEMINERALIZER REGENERATION TIME (DAYS)            8.40000E+00
           CONDENSATE DEMINERALIZER FLOW FRACTION                       6.50000E-01
  LIQUID WASTE INPUTS
                                      FRACTION     FRACTION     COLLECTION     DECAY
      STREAM          FLOW RATE        OF PCA     DISCHARGED       TIME         TIME          DECONTAMINATION  FACTORS
                      (GAL/DAY)                                   (DAYS)       (DAYS)           I            CS          OTHERS
  -----------------------------------------------------------------------------------------------------------------------------
  SHIM BLEED RATE     1.44000E+03  1.00000E+00  1.00000E-01  2.26000E+01  9.30000E-01  5.00000E+03  2.00000E+03  1.00000E+05
  EQUIPMENT DRAINS    3.30000E+02  9.70000E-01  1.00000E-01  2.26000E+01  9.30000E-01  5.00000E+03  2.00000E+03  1.00000E+05
  CLEAN WASTE INPUT   9.80000E+02  9.30000E-02  1.00000E-01  5.70000E+00  1.30000E-01  5.00000E+02  1.00000E+03  1.00000E+04
  DIRTY WASTES        2.10000E+03  1.00000E-02  1.00000E+00  3.80000E+00  1.90000E-01  5.00000E+02  1.00000E+03  1.00000E+04
  BLOWDOWN            2.15765E+05               0.00000E+00  0.00000E+00  0.00000E+00  1.00000E+03  1.00000E+02  1.00000E+03
  UNTREATED BLOWDOWN  0.00000E+00               1.00000E+00  0.00000E+00  0.00000E+00  1.00000E+00  1.00000E+00  1.00000E+00
  REGENERANT SOLS     3.40000E+03               1.00000E-01  4.70000E+00  3.70000E-01  5.00000E+02  1.00000E+03  1.00000E+04
  -----------------------------------------------------------------------------------------------------------------------------

  GASEOUS WASTE INPUTS
           THERE IS CONTINUOUS STRIPPING OF FULL LETDOWN FLOW
           FLOW RATE THROUGH GAS STRIPPER (GPM)                         7.52292E+01
           HOLDUP TIME FOR XENON (DAYS)                                 6.00000E+01
           HOLDUP TIME FOR KRYPTON (DAYS)                               3.54000E+00
           FILL TIME OF DECAY TANKS FOR THE GAS STRIPPER (DAYS)         0.00000E+00
           PRIMARY COOLANT LEAK TO AUXILIARY BLDG (LB/DAY)              1.60000E+02
           GAS WASTE SYSTEM    PARTICULATE RELEASE FRACTION             1.00000E-02
           FUEL HANDLG BLDG    IODINE RELEASE FRACTION                  1.00000E-01
                               PARTICULATE RELEASE FRACTION             1.00000E+00
           AUXILIARY BLDG      IODINE RELEASE FRACTION                  1.00000E-01
                               PARTICULATE RELEASE FRACTION             1.00000E+00
           CONTAINMENT VOLUME (MILLION FT3)                             2.71500E+00
           FREQUENCY OF PRIMARY COOLANT DEGASSING (TIMES/YR)            2.00000E+00
           PRIMARY TO SECONDARY LEAK RATE (LB/DAY)                      7.50000E+01
           THERE IS NOT A KIDNEY FILTER
           FRACTION IODINE BYPASSING CONDENSATE DEMINERALIZER           3.50000E-01
           IODINE PARTITION FACTOR (GAS/LIQUID) IN STEAM GENERATOR      1.00000E-02
           FREQUENCY OF CNTMT BLDG HIGH VOL PURGE(TIMES/YR)             2.00000E+00
           CNTMT-HIGH VOL PURGEIODINE RELEASE FRACTION                  1.00000E-01
                               PARTICULATE RELEASE FRACTION             1.00000E-02
           CNTMT LOW VOL PURGE RATE(CFM)                                1.00000E+03
           CNTMT LOW VOL PURGE IODINE RELEASE FRACTION                  1.00000E-01
                               PARTICULATE RELEASE FRACTION             1.00000E-02
           STEAM LEAK TO TURBINE BLDG (LBS/HR)                          1.70000E+03
           FRACTION IODINE RELEASED FROM BLOWDOWN TANK VENT             0.00000E+00
           PERCENT OF IODINE REMOVED FROM AIR EJECTOR RELEASE           0.00000E+00

           Sample PWR
                                                    GASEOUS RELEASE RATE - CURIES PER YEAR                     GASEOUS RELEASE RATE - CURIES PER YEAR
         PRIMARY      SECONDARY                              BUILDING VENTILATION                           -----------------------------------------
         COOLANT       COOLANT                -----------------------------------------------------------  BLOWDOWN     AIR EJECTOR      TOTAL
       (MICRO-CI/GM) (MICRO-CI/GM)            FUEL HANDLING    REACTOR      AUXILIARY      TURBINE        VENT OFFGAS    EXHAUST
  ---------------------------------------------------------------------------------------------------------------------------------------------------
   I-131   4.46316E-02  1.35572E-06           4.50000E-04   3.60000E-03   1.10000E-02   0.00000E+00   0.00000E+00   0.00000E+00   1.50000E-02
   I-132   2.09663E-01  2.77160E-06           2.10000E-03   5.30000E-03   5.00000E-02   1.20000E-04   0.00000E+00   0.00000E+00   5.80000E-02
   I-133   1.39188E-01  3.75488E-06           1.40000E-03   6.70000E-03   3.30000E-02   1.70000E-04   0.00000E+00   0.00000E+00   4.10000E-02
   I-134   3.39759E-01  2.26814E-06           3.50000E-03   7.70000E-03   8.00000E-02   0.00000E+00   0.00000E+00   0.00000E+00   9.10000E-02
   I-135   2.59109E-02  5.47555E-07           2.60000E-04   8.50000E-04   6.10000E-03   0.00000E+00   0.00000E+00   0.00000E+00   7.20000E-03
  ---------------------------------------------------------------------------------------------------------------------------------------------------
0.00000E+00 APPEARING IN THE TABLE INDICATES RELEASE IS LESS THAN 0.0001 CI/YR FOR I

                    TOTAL  H-3 RELEASED VIA GASEOUS PATHWAY  =  1.10000E+03 CI/YR

                          C-14 RELEASED VIA GASEOUS PATHWAY  =  7.30000E+00 CI/YR

                         AR-41 RELEASED VIA CONTAINMENT VENT =  3.40000E+01 CI/YR

           Sample PWR
                                          GASEOUS RELEASE RATE - CURIES PER YEAR                               GASEOUS RELEASE RATE - CURIES PER YEAR
         PRIMARY      SECONDARY          GAS STRIPPING                  BUILDING VENTILATION                -----------------------------------------
         COOLANT       COOLANT        --------------------------  ------------------------------------------  BLOWDOWN     AIR EJECTOR      TOTAL
       (MICRO-CI/GM) (MICRO-CI/GM)   SHUTDOWN      CONTINUOUS      REACTOR      AUXILIARY      TURBINE      VENT OFFGAS    EXHAUST
  ---------------------------------------------------------------------------------------------------------------------------------------------------
   KR-85M  1.12298E-01  2.38634E-08  0.00000E+00  0.00000E+00  3.30000E+01  3.00000E+00  0.00000E+00  0.00000E+00  1.00000E+00  3.70000E+01
   KR-85   5.71525E-03  1.18292E-09  3.00000E+00  7.30000E+02  1.40000E+01  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  7.50000E+02
   KR-87   1.33580E-01  2.67161E-08  0.00000E+00  0.00000E+00  1.20000E+01  3.00000E+00  0.00000E+00  0.00000E+00  1.00000E+00  1.60000E+01
   KR-88   2.20300E-01  4.64204E-08  0.00000E+00  0.00000E+00  4.30000E+01  5.00000E+00  0.00000E+00  0.00000E+00  2.00000E+00  5.00000E+01
   XE-131M 3.45671E-02  7.10283E-09  0.00000E+00  1.30000E+02  7.40000E+01  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  2.00000E+02
   XE-133M 1.18169E-02  2.53219E-09  0.00000E+00  0.00000E+00  1.80000E+01  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  1.80000E+01
   XE-133  2.24706E-01  4.66698E-08  0.00000E+00  1.10000E+01  4.30000E+02  5.00000E+00  0.00000E+00  0.00000E+00  2.00000E+00  4.50000E+02
   XE-135M 1.26796E-01  2.63345E-08  0.00000E+00  0.00000E+00  3.00000E+00  3.00000E+00  0.00000E+00  0.00000E+00  1.00000E+00  7.00000E+00
   XE-135  4.51009E-01  9.55077E-08  0.00000E+00  0.00000E+00  2.50000E+02  1.00000E+01  0.00000E+00  0.00000E+00  5.00000E+00  2.70000E+02
   XE-137  3.37855E-02  7.05520E-09  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00
   XE-138  1.17301E-01  2.44378E-08  0.00000E+00  0.00000E+00  2.00000E+00  3.00000E+00  0.00000E+00  0.00000E+00  1.00000E+00  6.00000E+00
   TOTAL NOBLE GASES                                                                                                                 1.80000E+03
  ---------------------------------------------------------------------------------------------------------------------------------------------------
0.00000E+00 APPEARING IN THE TABLE INDICATES RELEASE IS LESS THAN 1.0 CI/YR FOR NOBLE GAS

           Sample PWR
                                            AIRBORNE PARTICULATE RELEASE RATE-CURIES PER YEAR
                               WASTE GAS               BUILDING VENTILATION
  NUCLIDE                       SYSTEM      FUEL HANDLING    REACTOR      AUXILIARY                                              TOTAL
  ---------------------------------------------------------------------------------------------------------------------------------------------------
  CR-51                       1.40000E-07  1.80000E-04  9.20000E-05  3.20000E-04                                              5.90000E-04
  MN-54                       2.10000E-08  3.00000E-04  5.30000E-05  7.80000E-05                                              4.30000E-04
  CO-57                       0.00000E+00  0.00000E+00  8.20000E-06  0.00000E+00                                              8.20000E-06
  CO-58                       8.70000E-08  2.10000E-02  2.50000E-04  1.90000E-03                                              2.30000E-02
  CO-60                       1.40000E-07  8.20000E-03  2.60000E-05  5.10000E-04                                              8.70000E-03
  FE-59                       1.80000E-08  0.00000E+00  2.70000E-05  5.00000E-05                                              7.70000E-05
  SR-89                       4.40000E-07  2.10000E-03  1.30000E-04  7.50000E-04                                              3.00000E-03
  SR-90                       1.70000E-07  8.00000E-04  5.20000E-05  2.90000E-04                                              1.10000E-03
  ZR-95                       4.80000E-08  3.60000E-06  0.00000E+00  1.00000E-03                                              1.00000E-03
  NB-95                       3.70000E-08  2.40000E-03  1.80000E-05  3.00000E-05                                              2.40000E-03
  RU-103                      3.20000E-08  3.80000E-05  1.60000E-05  2.30000E-05                                              7.70000E-05
  RU-106                      2.70000E-08  6.90000E-05  0.00000E+00  6.00000E-06                                              7.50000E-05
  SB-125                      0.00000E+00  5.70000E-05  0.00000E+00  3.90000E-06                                              6.10000E-05
  CS-134                      3.30000E-07  1.70000E-03  2.50000E-05  5.40000E-04                                              2.30000E-03
  CS-136                      5.30000E-08  0.00000E+00  3.20000E-05  4.80000E-05                                              8.00000E-05
  CS-137                      7.70000E-07  2.70000E-03  5.50000E-05  7.20000E-04                                              3.50000E-03
  BA-140                      2.30000E-07  0.00000E+00  0.00000E+00  4.00000E-04                                              4.00000E-04
  CE-141                      2.20000E-08  4.40000E-07  1.30000E-05  2.60000E-05                                              3.90000E-05
  ---------------------------------------------------------------------------------------------------------------------------------------------------

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GALE v3.0

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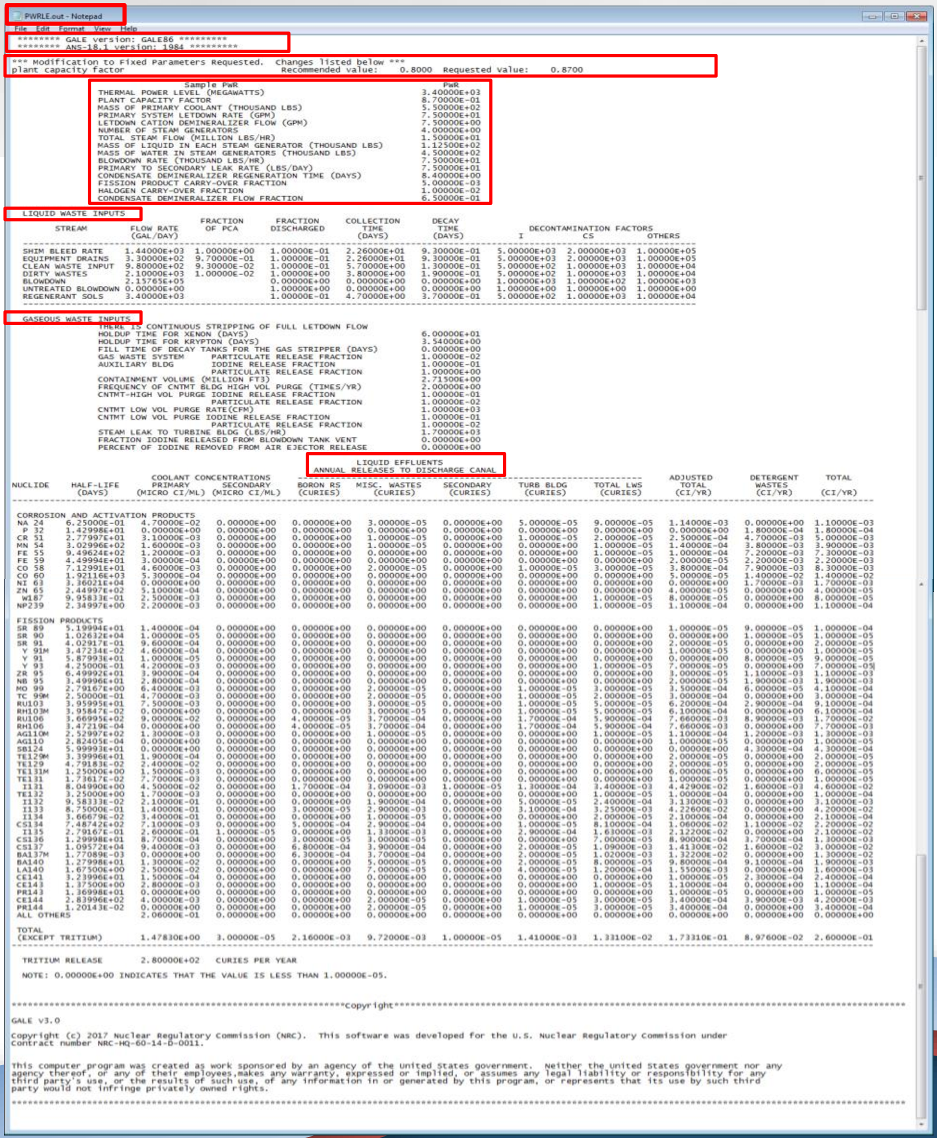
*******************************************************************************************************************************************
```

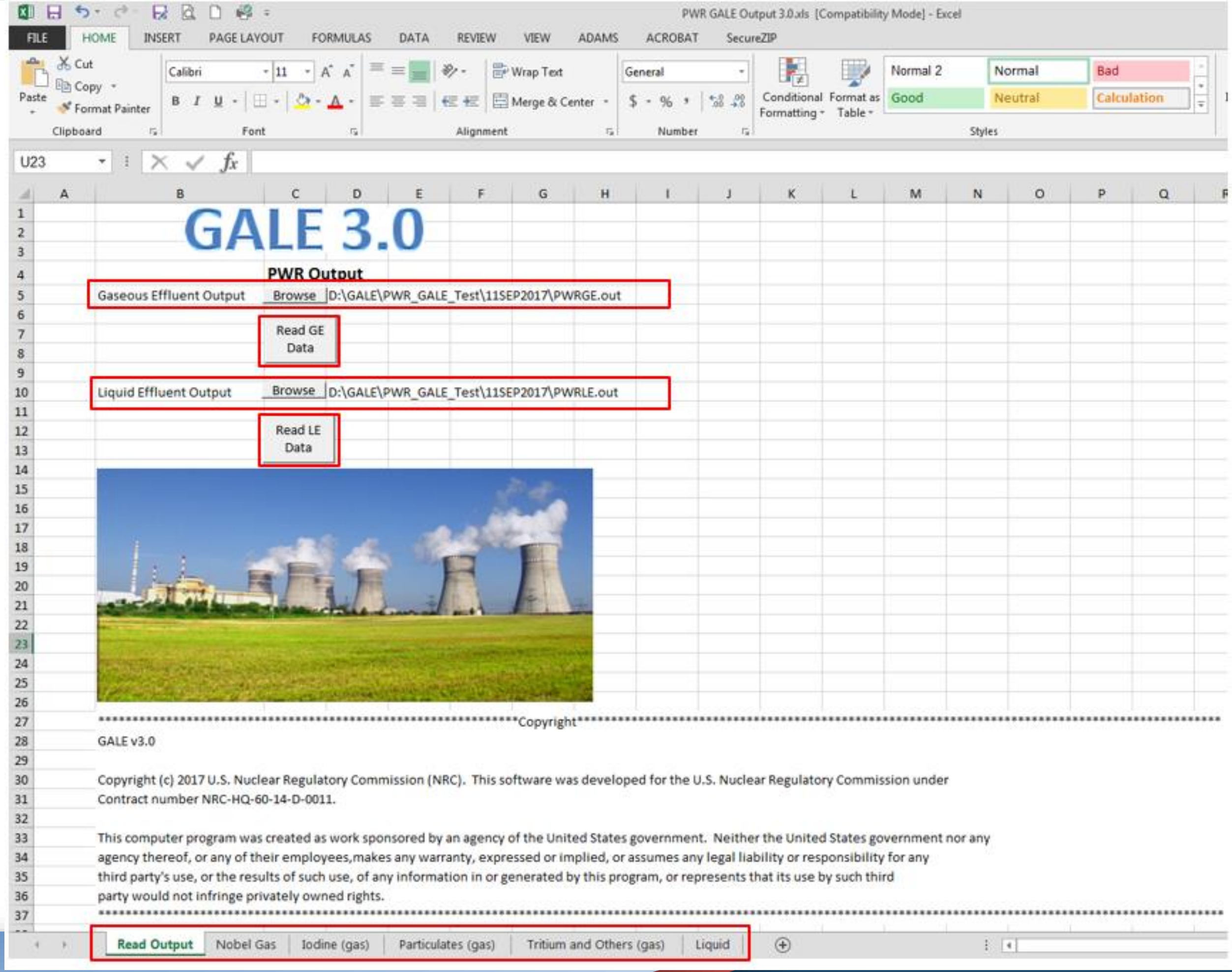
GALE-PWR 3.0 Use

- GALE-PWRLE 3.0 Output



GALE-PWR 3.0 Use

- PWR GALE Output 3.0.xls



GALE 3.0 (beta) Modeling Parameters

Modeling Parameters: Summary

- Summary of Differences GALE 86 to GALE 09
- Use of the fixed parameters files
  - BWRfixed-parameters.txt
  - PWRfixed-parameters.txt

GALE-BWR 86 to 09 Detail

Change #	GALE-BWR 86 to 09 Changes in Detail
1	Plant capacity factor was increased from 8.0E-01 to 9.0E-01 (80 to 90 percent).
2	Radioiodine release rates from various buildings during normal operations were increased by multiplying by 1.125E+00.
3	Radioiodine release rates from various buildings during extended shutdown were decreased by multiplying by 5.0E-01.
4	Carbon-14 release rate was decreased from 9.5E+00 Ci/yr to 1.07E+01 Ci/yr.
5	Unexpected release rate was decreased from 1.0E-01 Ci/yr to 1.4E-02 Ci/yr.

GALE-PWR 86 to 09 Detail

Change #	GALE-PWR 86 to 09 Changes in Detail
1	Plant capacity factor was increased from 8.0E-01 to 9.0E-01 (80 to 90 percent).
2	Tritium release rate was decreased from 4.0E-01 Ci/yr/MWt to 2.7E-01 Ci/yr/MWt
3	Argon-41 release rate was decreased from 3.4E+01 Ci/yr to 6.0E+00 Ci/yr
4	Carbon-14 release rate was decreased from 7.3E+00 Ci/yr to 5.9E+00 Ci/yr.
5	Unexpected release rate was decreased from 1.6E-01 Ci/yr to 1.6E-04 Ci/yr.
6	Condensate demineralizer DF for “Other Radionuclides” was changed from 5.0E+01 to 1.0E+01

Modeling Parameters: BWRfixed-parameters.txt

- Table 4-63 from NUREG-0016, Revision 2 (Draft)

Table 4-63 BWRfixed-parameters.txt file modifiable parameters

Code Line	Parameter	Location in GALE-BWR Code	Default Values[a]		
3.1	Plant Capacity Factor (fraction)	GE & LE	8.0E-01		
3.2	Radionuclide Concentration in Reactor Coolant and Main Steam (µCi/g)	GE	Noble gases in reactor main steam		See Table 4-51
		GE	Noble gases in reactor water		See Table 4-51
		LE	Halogens, Cs & Rb, and Other Nuclides in reactor water		See Table 4-51
3.3	Noble Gas, Radioiodine, and Particulate Releases from Building Ventilation Systems Prior to Treatment	GE	Noble Gas Releases (Ci/yr)		See Table 4-2
			Particulate Releases (µCi/yr)		See Table 4-2
			Radioiodine Releases (Ci/yr/µCi/g)	Reactor Building	See Table 4-5
				Turbine Building	See Table 4-4
				Radwaste Building	See Table 4-6
3.4	Radioiodine Input Rate to Main Condenser Offgas System (Ci/yr)	GE	6.0E+00		
3.5	Main Condenser Vacuum Pump Release	GE	Xe-133 (Ci/yr)		1.3E+03
			Xe-135 (Ci/yr)		5.0E+02
			I-131 normal operations (Ci/yr/µCi/g)		4.9E+02
			I-131 shutdown (Ci/yr/µCi/g)		1.1E+03

[a] The default values are from Section 4.1.1 (reference [3]) and Section 4.2.1 (reference [7]).

Modeling Parameters: BWRfixed-parameters.txt

- Table 4-63 from NUREG-0016, Revision 2 (Draft)

Table 4-63 BWRfixed-parameters.txt file modifiable parameters (cont.)

Code Line	Parameter	Location in GALE-BWR Code	Default Values[a]	
3.7	Cryogenic Distillation System	GE	PC for Xe and I	1.0E-04
			PC for Kr	2.5E-04
			Holdup time (d)	9.0E+01
3.9	Annual Releases in Untreated Detergent Waste (Ci/yr)	LE	See Table 4-30	
3.10	Tritium Releases	GE & LE	Tritium activity in primary coolant (µCi/g)	1.0E-02
			Total tritium release (Ci/yr/Mwt)	3.0E-02
			Maximum fraction of tritium released through liquid pathway	5.0E-01
			Fraction of gaseous tritium released from turbine building	5.0E-01
3.11	Argon-41 Release (Ci/yr)	GE	Dynamic adsorption coefficient for ambient temperature systems	6.4E+00
			Dynamic adsorption coefficient for chilled temperature systems	1.6E+01
3.12	Carbon-14 Releases (Ci/yr)	GE	9.5E+00	
3.13	Source Term Adjustments for AOOs (Ci/yr)	LE	1.0E-01	

[a] The default values are from Section 4.1.1 (reference [3]) and Section 4.2.1 (reference [7]).

Modeling Parameters: BWRfixed-parameters.txt

- Example File

BWRfixed-parameters1.txt - Notepad

File Edit Format View Help

```
$user
!3.1    Plant Capacity Factor (GE and LE)
! Value from Section 2.2.2 of NUREG-0016, Revision 1 (GALE86 Code)
PF_user=0.9  !Plant Capacity Factor (fraction)

!3.3    Noble Gas, Radioiodine, and Particulate Releases from Building Ventilation Systems Prior to Treatment (GE)
!Radioiodine release from Ventilation Systems Prior to Treatment (in Ci/yr/microcurie/g)
!(Assuming 90% capacity factor.  Will be adjusted based on actual capacity factor)
! Values from Section 2.2.4 (Tables 2-8 through 2-9) of NUREG-0016, Revision 1 (GALE86 Code)
!Reactor Building          Turbine Building          Radwaste Building
RN_user(1)=1.3800E+01, RNT_user(1)=4.3000E+03, RNR_user(1)=5.2000E+00   !I-131 during operation
RN_user(2)=1.3800E+01, RNT_user(2)=4.3000E+03, RNR_user(2)=5.2000E+00   !I-133 during operation
RNS_user(1)=2.6000E+00, RNTS_user(1)=2.1000E+02, RNRS_user(1)=7.0000E-01 !I-131 during shutdown
RNS_user(2)=2.6000E+00, RNTS_user(2)=2.1000E+02, RNRS_user(2)=7.0000E-01 !I-133 during shutdown

!3.5    Main Condenser Vacuum Pump Release (GE)
! Values from Section 2.2.7 and Table 2-26 of NUREG-0016, Revision 1 (GALE86 Code)
VPR_user(10)=1300.0  !Ci/yr Xe-133
VPR_user(12)=500.0   !Ci/yr Xe-133
RNMVP_user(1)=550.0  !Ci/yr/microCurie/g I-131(normal operations assuming 90% capacity.  Will be adjusted for actual capacity factor)
RNMVP_user(2)=550.0  !Ci/yr/microCurie/g I-133(normal operations assuming 90% capacity.  Will be adjusted for actual capacity factor)
RNMVPS_user(1)=550.0 !Ci/yr/microCurie/g I-131(shutdown assuming 90% capacity.  Will be adjusted for actual capacity factor)
RNMVPS_user(2)=550.0 !Ci/yr/microCurie/g I-133(shutdown assuming 90% capacity.  Will be adjusted for actual capacity factor)

!3.13 Source Term Adjustments for Anticipated Operational Occurrences (LE)
! Values from Section 2.2.20 of NUREG-0016, Revision 1 (GALE86 Code)
AOIfixed_user=0.014 !adjustment is made to liquid radwaste source terms to account for AOO (Ci/yr)

$end
```

Modified Parameters

Modeling Parameters: PWRfixed-parameters.txt

- Table 4-62 from NUREG-0017, Revision 2 (Draft)

Table 4-62 PWRfixed-parameters.txt file modifiable parameters

<table>
<tr><th>Code Line</th><th>Parameter</th><th>Location in GALE-PWR Code</th><th colspan="3">Default Values[a]</th></tr>
<tr><td>3.1</td><td>Plant Capacity Factor (fraction)</td><td>GE & LE</td><td colspan="3">8.0E-01</td></tr>
<tr><td rowspan="3">3.2</td><td rowspan="3">Coolant and Main Steam Radionuclide Concentration (µCi/g)</td><td>GE</td><td colspan="2">Once-Through Steam Generator (noble gases & halogens)</td><td>See Table 4-43</td></tr>
<tr><td>GE</td><td colspan="2">U-tube Steam Generator (noble gases & halogens)</td><td>See Table 4-42</td></tr>
<tr><td>LE</td><td colspan="2">Primary and Secondary Coolant</td><td>See Table 4-42</td></tr>
<tr><td rowspan="8">3.3</td><td rowspan="8">Radioiodine release from Ventilation Systems Prior to Treatment (Ci/yr/µCi/g)</td><td rowspan="8">GE</td><td rowspan="2">Containment</td><td>Normal Operation</td><td>8.0E-06</td></tr>
<tr><td>Shutdown</td><td>3.2E-01</td></tr>
<tr><td rowspan="2">Auxiliary Building</td><td>Normal Operation</td><td>6.8E-01</td></tr>
<tr><td>Shutdown</td><td>2.5E+00</td></tr>
<tr><td rowspan="2">Fuel Handling Building</td><td>Normal Operation</td><td>3.8E-02</td></tr>
<tr><td>Shutdown</td><td>9.3E-02</td></tr>
<tr><td rowspan="2">Turbine Building</td><td>Normal Operation</td><td>3.8E+03</td></tr>
<tr><td>Shutdown</td><td>4.2E+02</td></tr>
<tr><td colspan="6">[a] The default values are from Section 4.1.1 (reference [3]) and Section 4.2.1 (reference [7]).</td></tr>
</table>

Modeling Parameters: PWRfixed-parameters.txt

- Table 4-62 from NUREG-0017, Revision 2 (Draft)

Table 4-62 PWRfixed-parameters.txt file modifiable parameters (cont.)

Code Line	Parameter	Location in GALE-PWR Code	Default Values[a]	
3.4	Particulate release from Ventilation Systems Prior to Treatment (Ci/yr for each radionuclide)	GE	Containment	See Table 4-8
			Auxiliary Building	See Table 4-8
			Fuel Pool Area	See Table 4-8
			Waste Gas System	See Table 4-8
3.5	Noble Gas Releases from Building Ventilation Systems	GE	Primary coolant leakage to auxiliary building (lb/d)	1.6E+02
			Steam leakage to turbine building (lb/d)	1.7E+03
			Primary Coolant noble gas inventory leakage to containment building (fraction/d)	3.0E-02
3.6	Containment Building Purge Frequency	GE & LE	2.0E+00	
3.7	Primary System Volumes Degassed per Year	GE	2.0E+00	
3.8	Steam Generator Partition Coefficient	LE	Nonvolatile PC for U-tube Steam Generator	5.0E-03
			Radioiodine PC for U-tube Steam Generator	1.0E-02
			Nonvolatile PC for Once-through Steam Generator	1.0E+00
			Radioiodine PC for Once-through Steam Generator	1.0E+00
3.9	Radioiodine Releases from the Air Ejector Exhaust Prior to Treatment (Ci/yr/pCi/g)	GE	1.7E+03	
3.10	Containment Internal Cleanup System	GE	System operation time (h)	1.6E+01
			System mixing efficiency (fraction)	7.0E-01
			System particulate DF	1.0E+02
3.11	Annual Releases in Untreated Detergent Waste (Ci/yr)	LE	See Table 4-21	

[a] The default values are from Section 4.1.1 (reference [3]) and Section 4.2.1 (reference [7]).

Modeling Parameters: PWRfixed-parameters.txt

- Table 4-62 from NUREG-0017, Revision 2 (Draft)

Table 4-62 PWRfixed-parameters.txt file modifiable parameters (cont.)

Code Line	Parameter	Location in GALE-PWR Code	Default Values[a]	
3.12	Tritium Releases	GE & LE	Tritium activity in primary coolant (μCi/yr)	1.0E+00
			Total tritium release (Ci/yr/Mwt)	4.0E-01
			Maximum fraction of tritium released through liquid pathway	9.0E-01
3.13	Argon-41 Release (Ci/yr)	GE	3.4E+01	
3.14	Carbon-14 Release (Ci/yr)	GE	7.3E+00	
3.15	DFs for Condensate Demineralizers	LE	Anion DF for Condensate Demineralizers	1.0E+01
			Other Nuclide DF for Condensate Demineralizers	1.0E+01
			Cs DF for Condensate Demineralizers	2.0E+00
3.17	Releases of Radioactive Material in Liquid Waste from the Turbine Building Floor Drain System (gal/d)	LE	7.2E+03	
3.19	Source Term Adjustments for AOOs (Ci/yr)	LE	1.6E-01	

[a] The default values are from Section 4.1.1 (reference [3]) and Section 4.2.1 (reference [7]).

Modeling Parameters: PWRfixed-parameters.txt

- Example File

PWRfixed-parameters1.txt - Notepad

File Edit Format View Help

```
$user
!3.1     Plant Capacity Factor (GE and LE)
! Value from Section 2.2.2 of NUREG-0017, Revision 1 (GALE86 Code)
PF_user=0.9   !Plant Capacity Factor (fraction)

!3.2 Coolant and Main Steam Radionuclide Concentrations (GE and LE)
! GE noble gas and iodine concentrations in reactor coolant and main steam (micro curies/g)
! Values from Table 6 of ANSI/ANS-18.1-1984( GALE86 Code)
! U-Tube Steam Generator
!   Reactor Coolant          Main Steam
    XP1u_user(6)=8.0E-02,     XP2u_user(6)=1.5E-08    ! XE-133M

! 3.4 Particulate release from Ventilation Systems Prior to Treatment (GE)
!(in micro-Ci/yr)
! Values from Section 2.2.5 (Table 2-17) of NUREG-0017, Revision 1 (GALE86 Code)
!Containment Building    Auxiliary Building      Fuel Pool Area         Waste Gas System
PCBP_user(8)=6.2E-03,  PAXBP_user(8)=2.9E-04,  PFHBP_user(8)=8.0E-04,  PGWS_user(8)=1.7E-05   ! SR-90

!3.9     Radioiodine Releases from the Air Ejector Exhaust Prior to Treatment (GE)
! Values from Section 2.2.8 (Table 2-22) of NUREG-0017, Revision 1 (GALE86 Code)
EJTfixed_user = 2300.0   !Ci/yr/pCi/g

!3.13    Argon-41 Release (GE)
! Value from Section 2.2.26 of NUREG-0017, Revision 1 (GALE86 Code)
Ar41_user=16.0   !Ci/yr

!3.14    Carbon-14 Release (GE)
! Value from Section 2.2.25 of NUREG-0017, Revision 1 (GALE86 Code)
C14_user=5.9   !Ci/yr

!3.19    Source Term Adjustments for Anticipated Operational Occurrences (LE)
! Values from Section 2.2.23 of NUREG-0017, Revision 1 (GALE86 Code)
AOIfixed_user = 0.00016      !adjustment is made to liquid radwaste source terms to account for AOO (Ci/yr)

$end
```

Modified Parameters

15 Minute Break

GALE 3.0 (beta) Sample Problems

Pacific Northwest NATIONAL LABORATORY
Proudly Operated by Battelle Since 1965

Sample Problems: Summary

- PWR Sample Problem
- BWR Sample Problem

PWR Sample Problem Information: Basic Plant Information

Parameter	Value
Thermal power level	3400 MW(th)
Mass of coolant in primary system	550 thousand lbs
Primary system letdown rate	75 gal/min
Letdown cation demineralizer flow rate	7.5 gal/min
Number of steam generators	4
Total steam flow	15 million lbs/hr
Mass of liquid in each steam generator	112.5 thousand lbs
Steam generator blowdown treatment method	Recycled after treatment
Type of steam generator	U-Tube
Blowdown rate	75 thousand lbs/hr
Condensate demineralizer regeneration time	8.4 days
Fraction of feedwater through condensate demineralizers	0.65

PWR Sample Problem Information: Liquid Waste – Shim Bleed

Parameter	Value
Flow rate	1440 gal/day
Iodine Decontamination Factor	$5x10^3$
Cs and Rb Decontamination Factor	$2x10^3$
Other Decontamination Factor	$1x10^5$
Waste collection time prior to processing	22.6 days
Waste processing and discharge times	0.93 days
Average fraction of wastes to be discharged after processing	0.1

PWR Sample Problem Information: Liquid Waste – Equipment Drain Waste

Parameter	Value
Flow rate	330 gal/day
Activity of Inlet Stream	0.97 fraction of PCA
Iodine Decontamination Factor	5×10^3
Cs and Rb Decontamination Factor	2×10^3
Other Decontamination Factor	1×10^5
Waste collection time prior to processing	22.6 days
Waste processing and discharge times	0.93 days
Average fraction of wastes to be discharged after processing	0.1

PWR Sample Problem Information: Liquid Waste – Clean Waste

Parameter	Value
Flow rate	980 gal/day
Activity of Inlet Stream	0.093 fraction of PCA
Iodine Decontamination Factor	5×10^{2}
Cs and Rb Decontamination Factor	1×10^{3}
Other Decontamination Factor	1×10^{4}
Waste collection time prior to processing	5.7 days
Waste processing and discharge times	0.13 days
Average fraction of wastes to be discharged after processing	0.1

PWR Sample Problem Information: Liquid Waste – Dirty Waste

Parameter	Value
Flow rate	2100 gal/day
Activity of Inlet Stream	0.001 fraction of PCA
Iodine Decontamination Factor	$5x10^2$
Cs and Rb Decontamination Factor	$1x10^3$
Other Decontamination Factor	$1x10^4$
Waste collection time prior to processing	3.8 days
Waste processing and discharge times	0.19 days
Average fraction of wastes to be discharged after processing	1.0

PWR Sample Problem Information: Liquid Waste – Blowdown Waste

Parameter	Value
Fraction of Steam Processed	1
Iodine Decontamination Factor	$5x10^2$
Cs and Rb Decontamination Factor	$1x10^3$
Other Decontamination Factor	$1x10^4$
Waste collection time prior to processing	0 days
Waste processing and discharge times	0 days
Average fraction of wastes to be discharged after processing	0

PWR Sample Problem Information: Liquid Waste – Regenerant Waste

Parameter	Value
Flow rate	3400 gal/day
Iodine Decontamination Factor	$5x10^2$
Cs and Rb Decontamination Factor	$1x10^3$
Other Decontamination Factor	$1x10^4$
Waste collection time prior to processing	4.7 days
Waste processing and discharge times	0.37 days
Average fraction of wastes to be discharged after processing	0.1

PWR Sample Problem Information: Liquid Waste – Laundry

Parameter	Value
Detergent Waste Partition Factor	1

PWR Sample Problem Information: Gaseous Waste – Building Vents

Parameter	Value
Waste Gas particulate release •HEPA?	 Yes
Fuel Handling building •Charcoal adsorbers? •HEPA?	 Yes 90% efficient Yes
Auxiliary Building •Charcoal adsorbers? •HEPA?	 Yes 90% efficient No
Containment Building •Charcoal adsorbers? •HEPA? •Free volume •Flow rate through internal cleanup system	 No No 2.715 million ft^3 0 ft^3/min

PWR Sample Problem Information: Gaseous Waste – Containment Purges

Parameter	Value
Containment large volume purge •Charcoal adsorbers? •HEPA? •Number of purges per year	 Yes 90% efficient Yes 2 at shutdown
Containment low volume purge •Charcoal adsorbers? •HEPA? •Continuous purge rate	 Yes 90% efficient Yes 1000 ft^3/min

PWR Sample Problem Information: Gaseous Waste – Misc.

Parameter	Value
Letdown System	Continuous degasification of full letdown flow
Holdup time for Xe stripped from primary coolant	60 days
Holdup time for Kr stripped from primary coolant	3.54 days
Fill time of decay tanks for gas stripper	0 days
Fraction of iodine released from blowdown tank vent	0.0
Fraction of iodine released from air ejector release	0.0

BWR Sample Problem Information: Basic Plant Information

Parameter	Value
Thermal power level	3400 MW(th)
Total steam flow	15 million lbs/hr
Mass of water in reactor vessel	0.38 million lbs
Cleanup demineralizer flow	0.13 million lbs/hr
Condensate demineralizer regeneration time	56 days
Copper tubing for condenser	No
Fraction of feedwater through condensate demineralizers	1.0

BWR Sample Problem Information: Liquid Waste – High Purity Waste

Parameter	Value
Flow rate	28640 gal/day
Activity of Inlet Stream	0.15 fraction of PCA
Iodine Decontamination Factor	$1x10^3$
Cs and Rb Decontamination Factor	$1x10^2$
Other Decontamination Factor	$1x10^3$
Waste collection time prior to processing	1 days
Waste processing and discharge times	0.07 days
Average fraction of wastes to be discharged after processing	0.01

BWR Sample Problem Information: Liquid Waste – Low Purity Waste

Parameter	Value
Flow rate	5700 gal/day
Activity of Inlet Stream	0.13 fraction of PCA
Iodine Decontamination Factor	$1x10^3$
Cs and Rb Decontamination Factor	$1x10^4$
Other Decontamination Factor	$1x10^4$
Waste collection time prior to processing	3.1 days
Waste processing and discharge times	0.6 days
Average fraction of wastes to be discharged after processing	1.0

BWR Sample Problem Information: Liquid Waste – Chemical Waste

Parameter	Value
Flow rate	600 gal/day
Activity of Inlet Stream	0.02 fraction of PCA
Iodine Decontamination Factor	$1x10^3$
Cs and Rb Decontamination Factor	$1x10^4$
Other Decontamination Factor	$1x10^4$
Waste collection time prior to processing	3.1 days
Waste processing and discharge times	0.6 days
Average fraction of wastes to be discharged after processing	1.0

BWR Sample Problem Information: Liquid Waste – Regenerant Waste

Parameter	Value
Flow rate	1700 gal/day
Iodine Decontamination Factor	$1x10^4$
Cs and Rb Decontamination Factor	$1x10^5$
Other Decontamination Factor	$1x10^5$
Waste collection time prior to processing	9.4 days
Waste processing and discharge times	0.44 days
Average fraction of wastes to be discharged after processing	1.0

BWR Sample Problem Information: Liquid Waste – Laundry

Parameter	Value
Detergent Waste Partition Factor	1

BWR Sample Problem Information: Gaseous Waste – Building Vents

Parameter	Value
Containment Building •Charcoal adsorbers? •HEPA?	 Yes 90% efficient Yes
Auxiliary building •Charcoal adsorbers? •HEPA?	 No No
Radwaste Building •Charcoal adsorbers? •HEPA?	 No Yes
Turbine Building •Charcoal adsorbers? •HEPA?	 No No

BWR Sample Problem Information: Gaseous Waste – Turbine Systems

Parameter	Value
Gland Seal •Gland seal steam flow •Gland seal holdup time •Fraction iodine release from condenser vent	 0.0 lbs/hr 0 hrs 0
Air Ejector Offgas •Air Ejector holdup time •Fraction iodine released from air ejector vent •Charcoal delays system? •Kr dynamic adsorption coefficient •Xe dynamic adsorption coefficient •Mass of charcoal	 0.167 hrs 1.0 Yes 105 cm^3/g 2410 cm^3/g 48 thousand lbs

Users Group

Users Group

- GALE Website Demonstration
- GALE Training
  - GALE training will be available at annual RAMP users group meeting to RAMP members
  - Onsite training is available under contract
- Member Presentations
  - As membership grows, members are encouraged to give presentations of activities with GALE at RAMP users group meeting
- Technical Support
  - Limited technical support is available to RAMP members by e-mailing
    - kenneth.geelhood@pnnl.gov
    - david.colameco@pnnl.gov

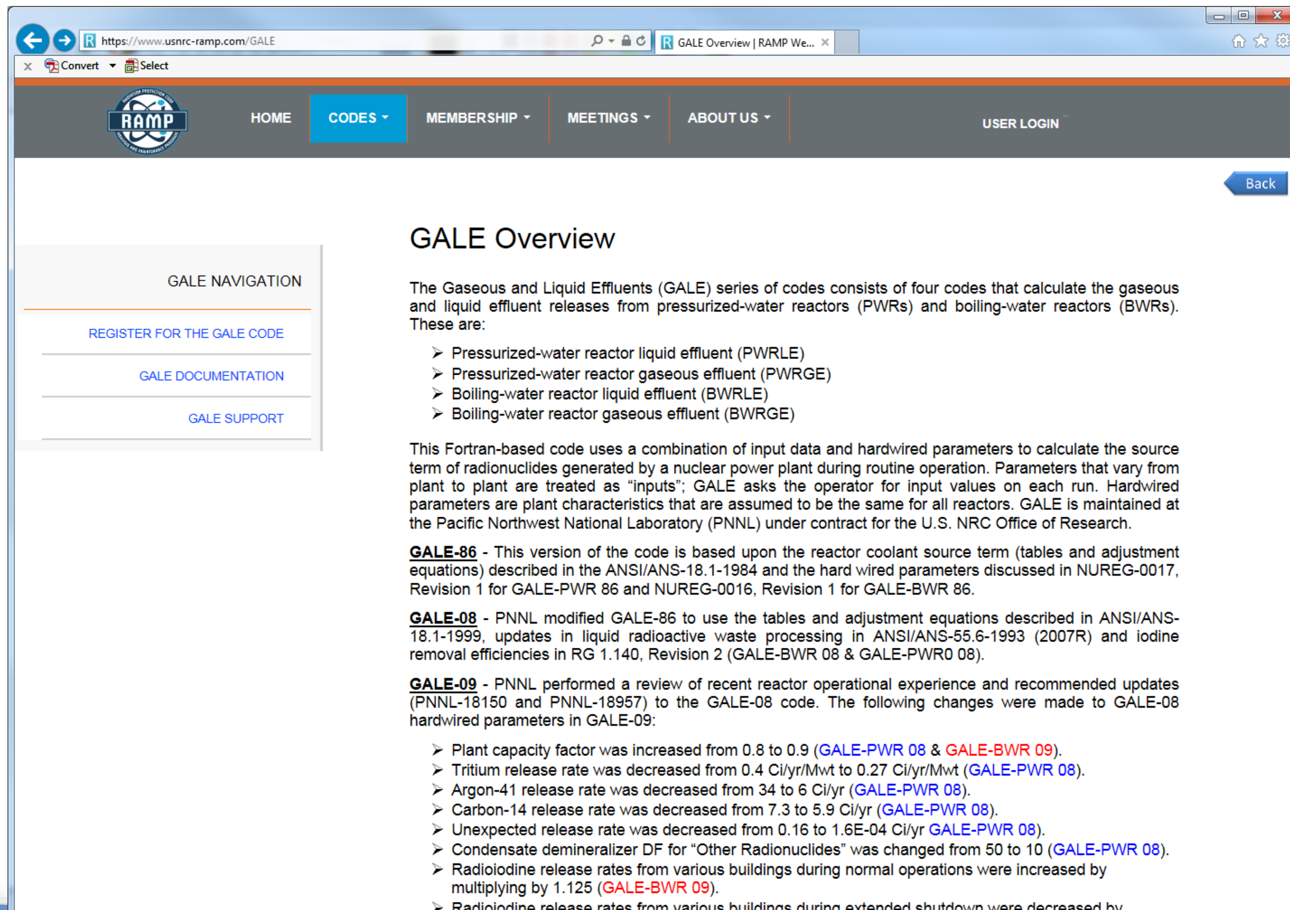
New GALE Website

GALE Website

- Main Welcome Page
  - Download the GALE Code
  - GALE Documentation
    - Technical Documents
    - User's Guide
    - Code Change Logs
    - SQAP - V&V Testing
  - GALE Training and Presentation Materials
  - GALE Support
    - Forum
    - FAQ

GALE Website Main Welcome Page

- GALE Website https://www.usnrc-ramp.com/GALE



GALE Overview

The Gaseous and Liquid Effluents (GALE) series of codes consists of four codes that calculate the gaseous and liquid effluent releases from pressurized-water reactors (PWRs) and boiling-water reactors (BWRs). These are:

- Pressurized-water reactor liquid effluent (PWRLE)
- Pressurized-water reactor gaseous effluent (PWRGE)
- Boiling-water reactor liquid effluent (BWRLE)
- Boiling-water reactor gaseous effluent (BWRGE)

This Fortran-based code uses a combination of input data and hardwired parameters to calculate the source term of radionuclides generated by a nuclear power plant during routine operation. Parameters that vary from plant to plant are treated as "inputs"; GALE asks the operator for input values on each run. Hardwired parameters are plant characteristics that are assumed to be the same for all reactors. GALE is maintained at the Pacific Northwest National Laboratory (PNNL) under contract for the U.S. NRC Office of Research.

GALE-86 - This version of the code is based upon the reactor coolant source term (tables and adjustment equations) described in the ANSI/ANS-18.1-1984 and the hard wired parameters discussed in NUREG-0017, Revision 1 for GALE-PWR 86 and NUREG-0016, Revision 1 for GALE-BWR 86.

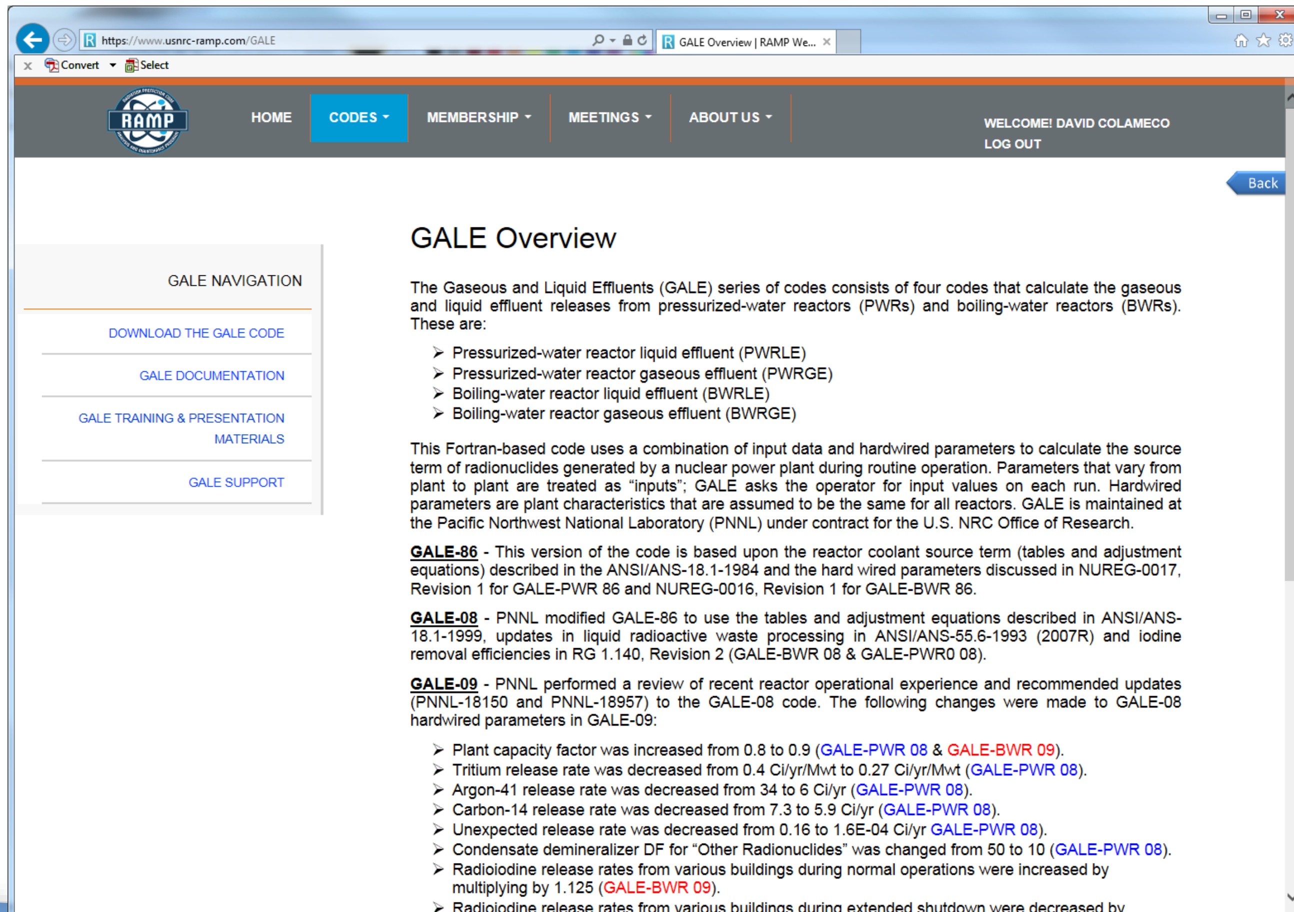
GALE-08 - PNNL modified GALE-86 to use the tables and adjustment equations described in ANSI/ANS-18.1-1999, updates in liquid radioactive waste processing in ANSI/ANS-55.6-1993 (2007R) and iodine removal efficiencies in RG 1.140, Revision 2 (GALE-BWR 08 & GALE-PWR0 08).

GALE-09 - PNNL performed a review of recent reactor operational experience and recommended updates (PNNL-18150 and PNNL-18957) to the GALE-08 code. The following changes were made to GALE-08 hardwired parameters in GALE-09:

- Plant capacity factor was increased from 0.8 to 0.9 (GALE-PWR 08 & GALE-BWR 09).
- Tritium release rate was decreased from 0.4 Ci/yr/Mwt to 0.27 Ci/yr/Mwt (GALE-PWR 08).
- Argon-41 release rate was decreased from 34 to 6 Ci/yr (GALE-PWR 08).
- Carbon-14 release rate was decreased from 7.3 to 5.9 Ci/yr (GALE-PWR 08).
- Unexpected release rate was decreased from 0.16 to 1.6E-04 Ci/yr GALE-PWR 08).
- Condensate demineralizer DF for "Other Radionuclides" was changed from 50 to 10 (GALE-PWR 08).
- Radioiodine release rates from various buildings during normal operations were increased by multiplying by 1.125 (GALE-BWR 09).
- Radioiodine release rates from various buildings during extended shutdown were decreased by

GALE Website Main Welcome Page

- GALE Website https://www.usnrc-ramp.com/GALE



GALE Overview

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- Pressurized-water reactor liquid effluent (PWRLE)
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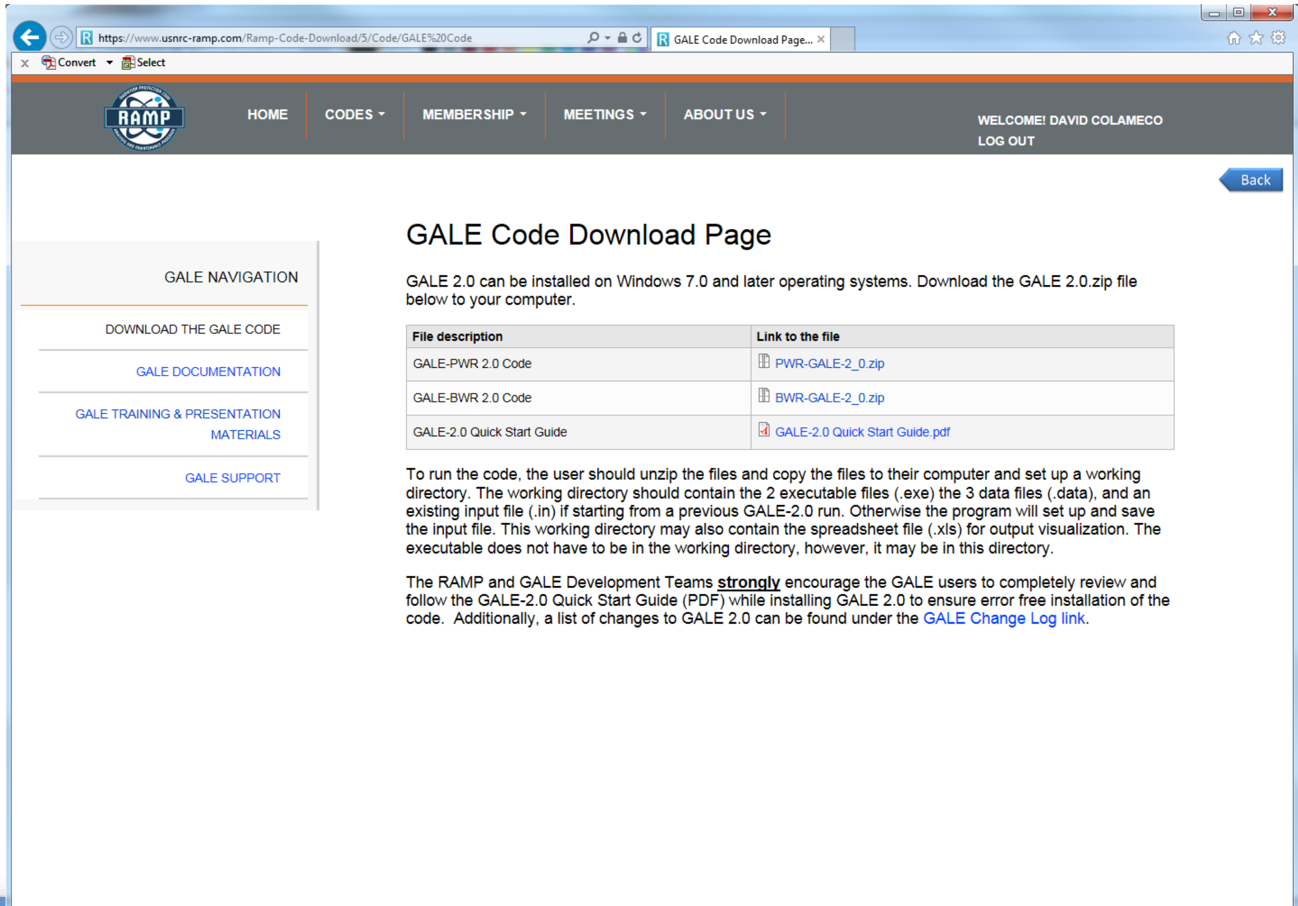
- Argon-41 release rate was decreased from 34 to 6 Ci/yr (GALE-PWR 08).
- Carbon-14 release rate was decreased from 7.3 to 5.9 Ci/yr (GALE-PWR 08).
- Unexpected release rate was decreased from 0.16 to 1.6E-04 Ci/yr GALE-PWR 08).
- Condensate demineralizer DF for "Other Radionuclides" was changed from 50 to 10 (GALE-PWR 08).
- Radioiodine release rates from various buildings during normal operations were increased by multiplying by 1.125 (GALE-BWR 09).
- Radioiodine release rates from various buildings during extended shutdown were decreased by

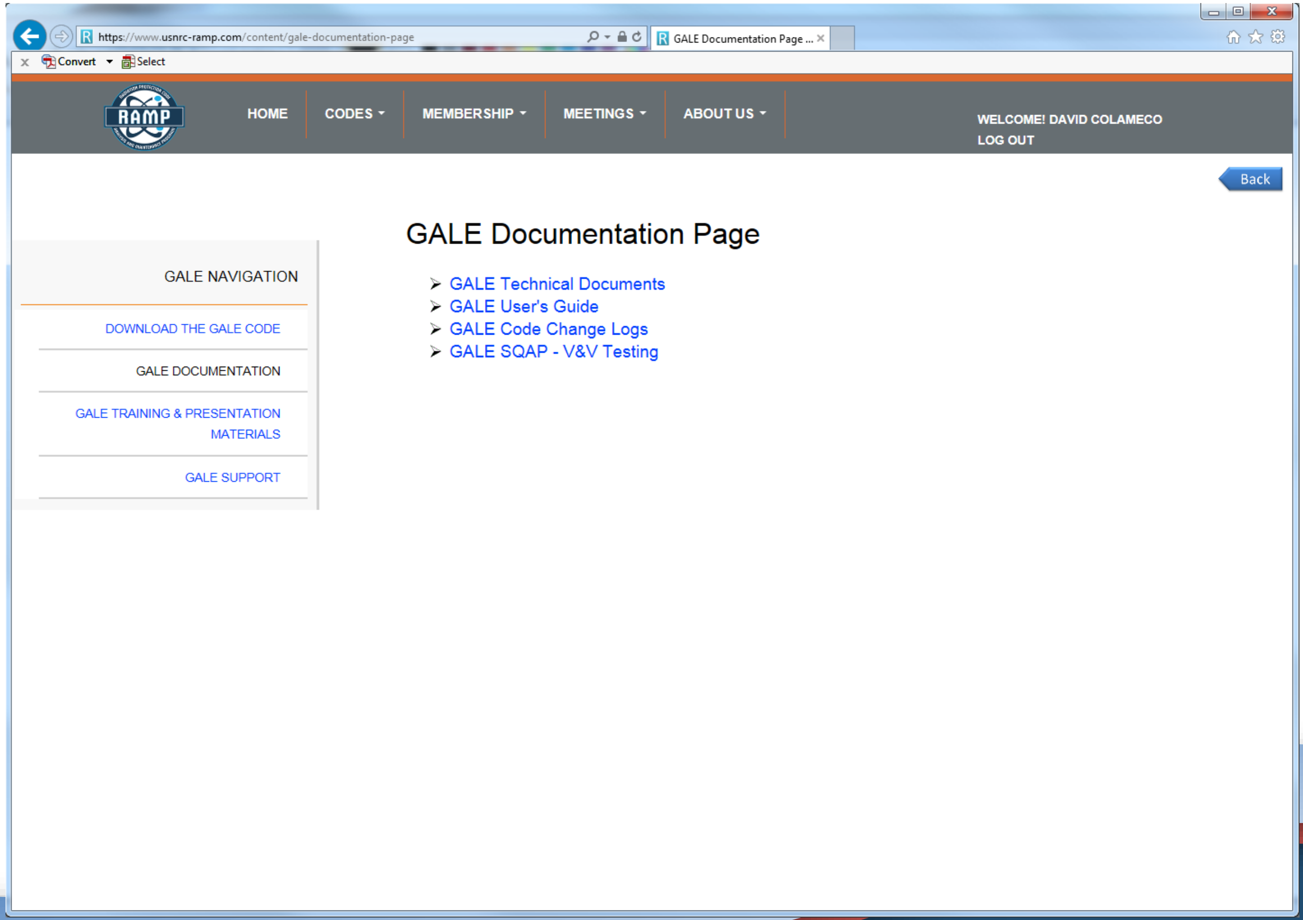
GALE Website Download Code

- GALE Website https://www.usnrc-ramp.com/Ramp-Code-Download/5/Code/GALE%20Code



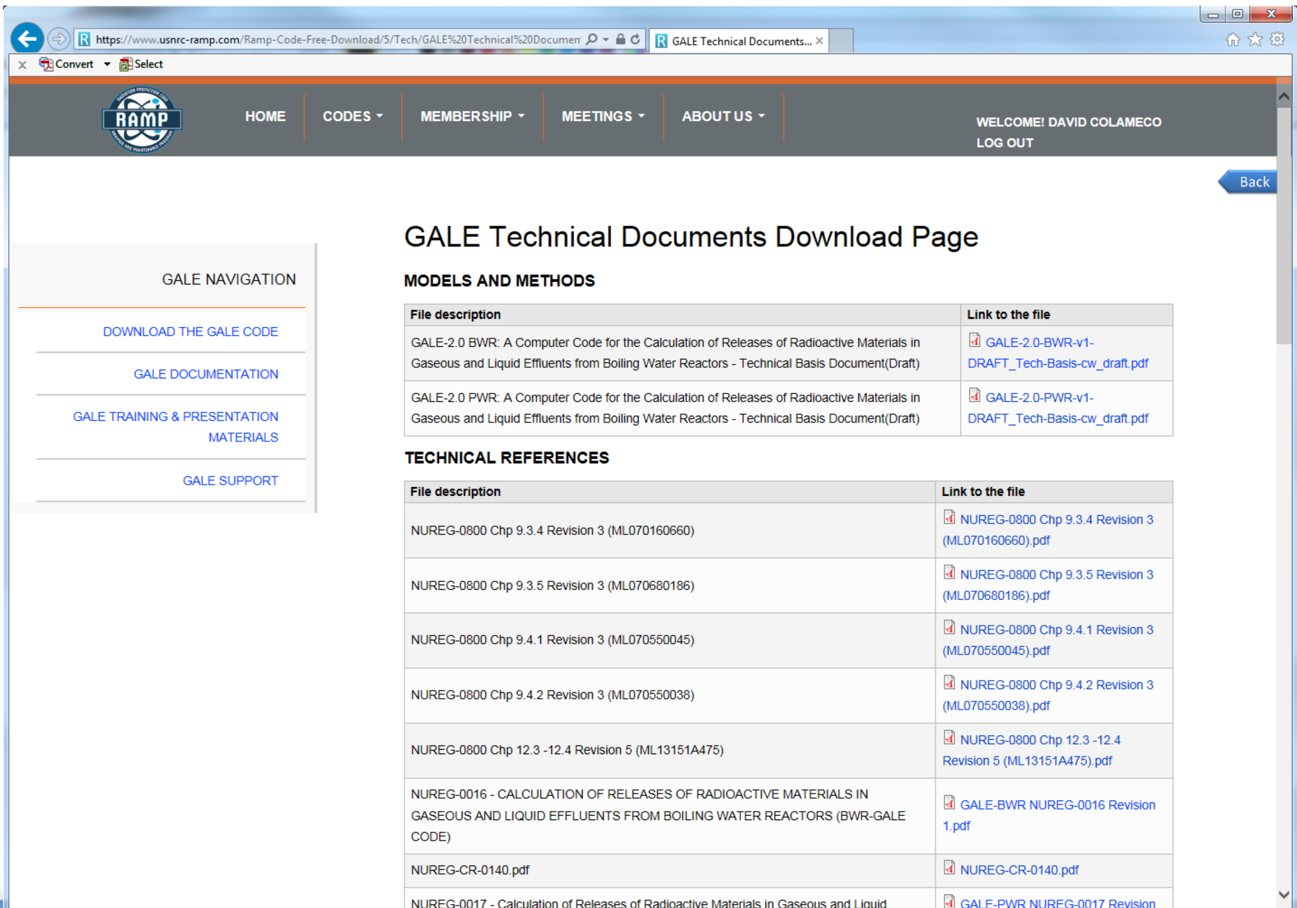
GALE Website Documentation Page

- GALE Website https://www.usnrc-ramp.com/content/gale-documentation-page



GALE Website Documentation Page

- GALE Website https://www.usnrc-ramp.com/Ramp-Code-Free-Download/5/Tech/GALE%20Technical%20Documents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MODELS AND METHODS

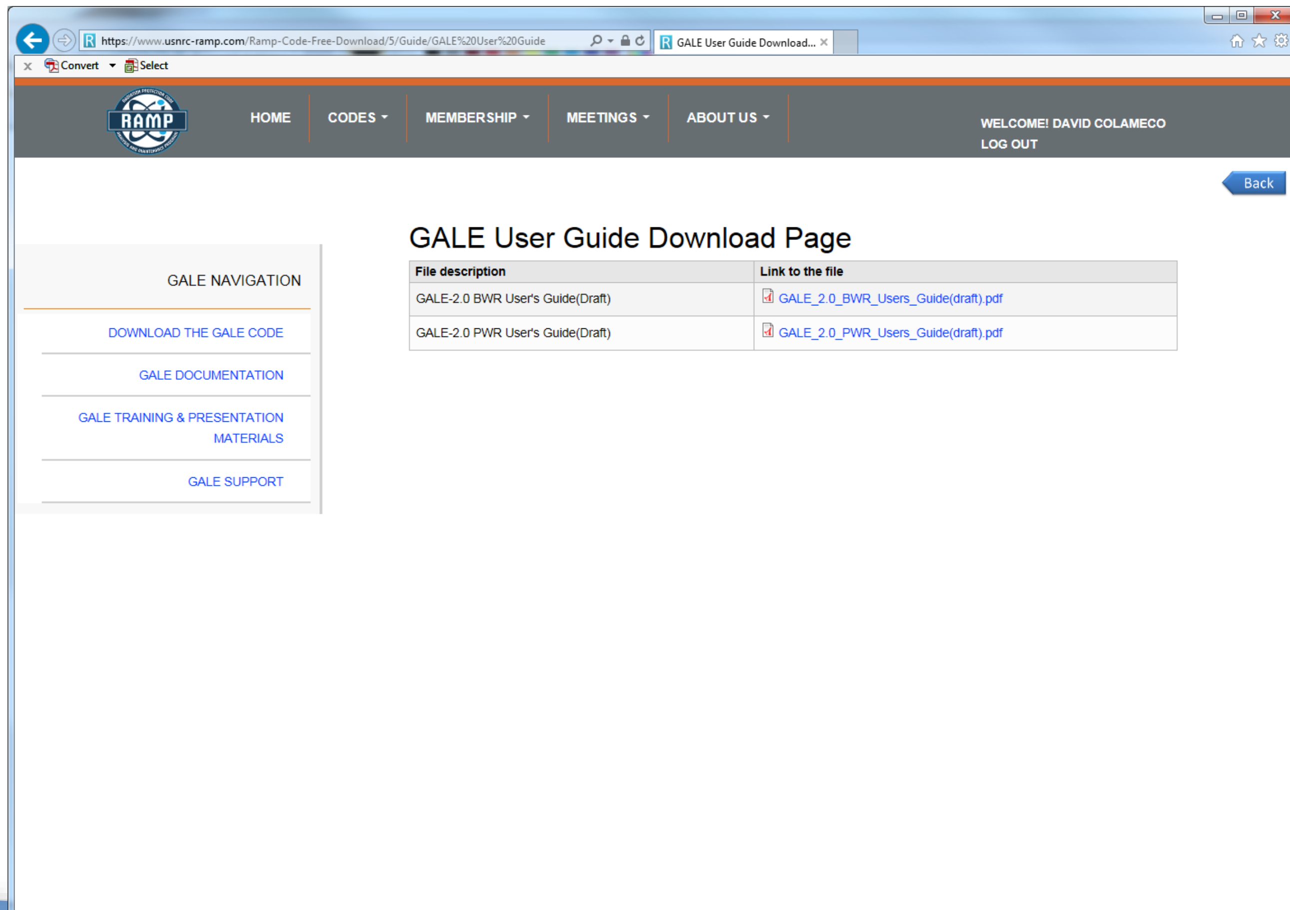
File description	Link to the file
GALE-2.0 BWR: A Computer Code for the Calculation of Releases of Radioactive Materials in Gaseous and Liquid Effluents from Boiling Water Reactors - Technical Basis Document(Draft)	GALE-2.0-BWR-v1-DRAFT_Tech-Basis-cw_draft.pdf
GALE-2.0 PWR: A Computer Code for the Calculation of Releases of Radioactive Materials in Gaseous and Liquid Effluents from Boiling Water Reactors - Technical Basis Document(Draft)	GALE-2.0-PWR-v1-DRAFT_Tech-Basis-cw_draft.pdf

TECHNICAL REFERENCES

File description	Link to the file
NUREG-0800 Chp 9.3.4 Revision 3 (ML070160660)	NUREG-0800 Chp 9.3.4 Revision 3 (ML070160660).pdf
NUREG-0800 Chp 9.3.5 Revision 3 (ML070680186)	NUREG-0800 Chp 9.3.5 Revision 3 (ML070680186).pdf
NUREG-0800 Chp 9.4.1 Revision 3 (ML070550045)	NUREG-0800 Chp 9.4.1 Revision 3 (ML070550045).pdf
NUREG-0800 Chp 9.4.2 Revision 3 (ML070550038)	NUREG-0800 Chp 9.4.2 Revision 3 (ML070550038).pdf
NUREG-0800 Chp 12.3 -12.4 Revision 5 (ML13151A475)	NUREG-0800 Chp 12.3 -12.4 Revision 5 (ML13151A475).pdf
NUREG-0016 - CALCULATION OF RELEASES OF RADIOACTIVE MATERIALS IN GASEOUS AND LIQUID EFFLUENTS FROM BOILING WATER REACTORS (BWR-GALE CODE)	GALE-BWR NUREG-0016 Revision 1.pdf
NUREG-CR-0140.pdf	NUREG-CR-0140.pdf
NUREG-0017 - Calculation of Releases of Radioactive Materials in Gaseous and Liquid	GALE-PWR NUREG-0017 Revision

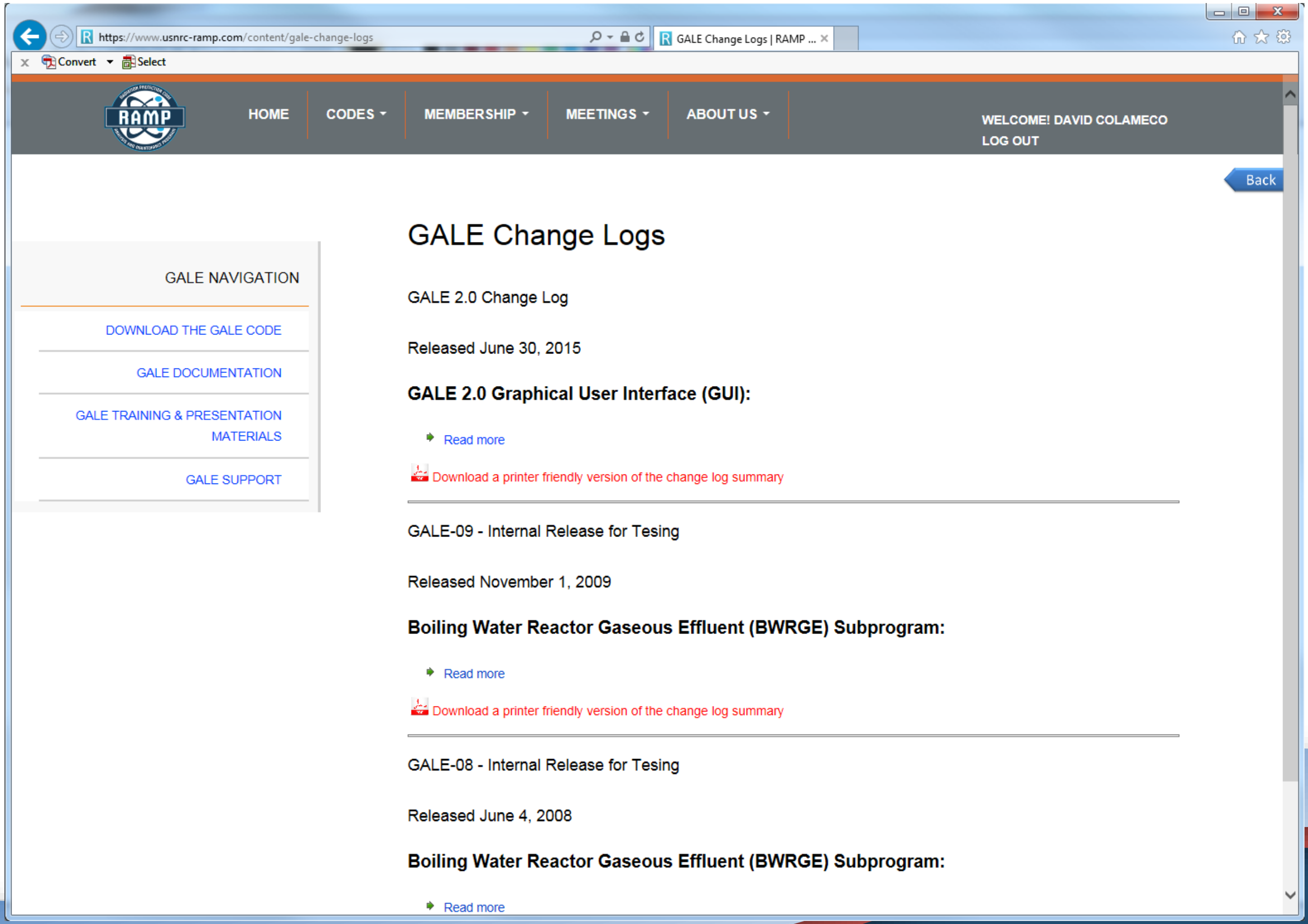
GALE Website User Guide Page

- GALE Website https://www.usnrc-ramp.com/Ramp-Code-Free-Download/5/Guide/GALE%20User%20Guide



GALE Website Change Logs Page

- GALE Website https://www.usnrc-ramp.com/content/gale-change-logs



GALE Website SQAP – V&V Page

- GALE Website https://www.usnrc-ramp.com/content/gale-sqap-vv-testing

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GALE SQAP -V&V Testing

SOFTWARE QUALITY ASSURANCE PLAN (SQAP) & CONFIGURATION MANAGEMENT & MAINTENANCE PLAN (CMMP)

The table below provided a list of the GALE SQAP and GALE CMMP which describe the software quality assurance (SQA) activities and configuration management and maintenance plan that will be followed during the course of software development and deployment of releases to the GALE code.

File description	Link to file
Software Quality Assurance Plan for the Support of the Gaseous and liquid Effluent (GALE) Computer Code Project (PNNL-242249)	GALE SQAP PNNL-24249 Rev 0.pdf
Configuration Management & Maintenance Plan Support for the Gaseous and Liquid Effluent (GALE) Computer Code Project (PNNL-24250)	GALE CMMP PNNL-24250 Rev 0.pdf
NUREG-BR-0167 (ML012750471).pdf	NUREG-BR-0167 (ML012750471).pdf

GALE Validation & Verification (V&V) Testing

The following GALE test reports document the verification testing performed by the GALE Development Team (GDT) to demonstrate the consistency of the GALE output files.

File description	Link to file
GALE-2.o Verification Report (Draft)	GALE-2.0 Verification Report (Draft).pdf

GALE Code Benchmarking and “In-Kind” Reports

The table below provides a list of technical benchmarking studies which compare the output calculations

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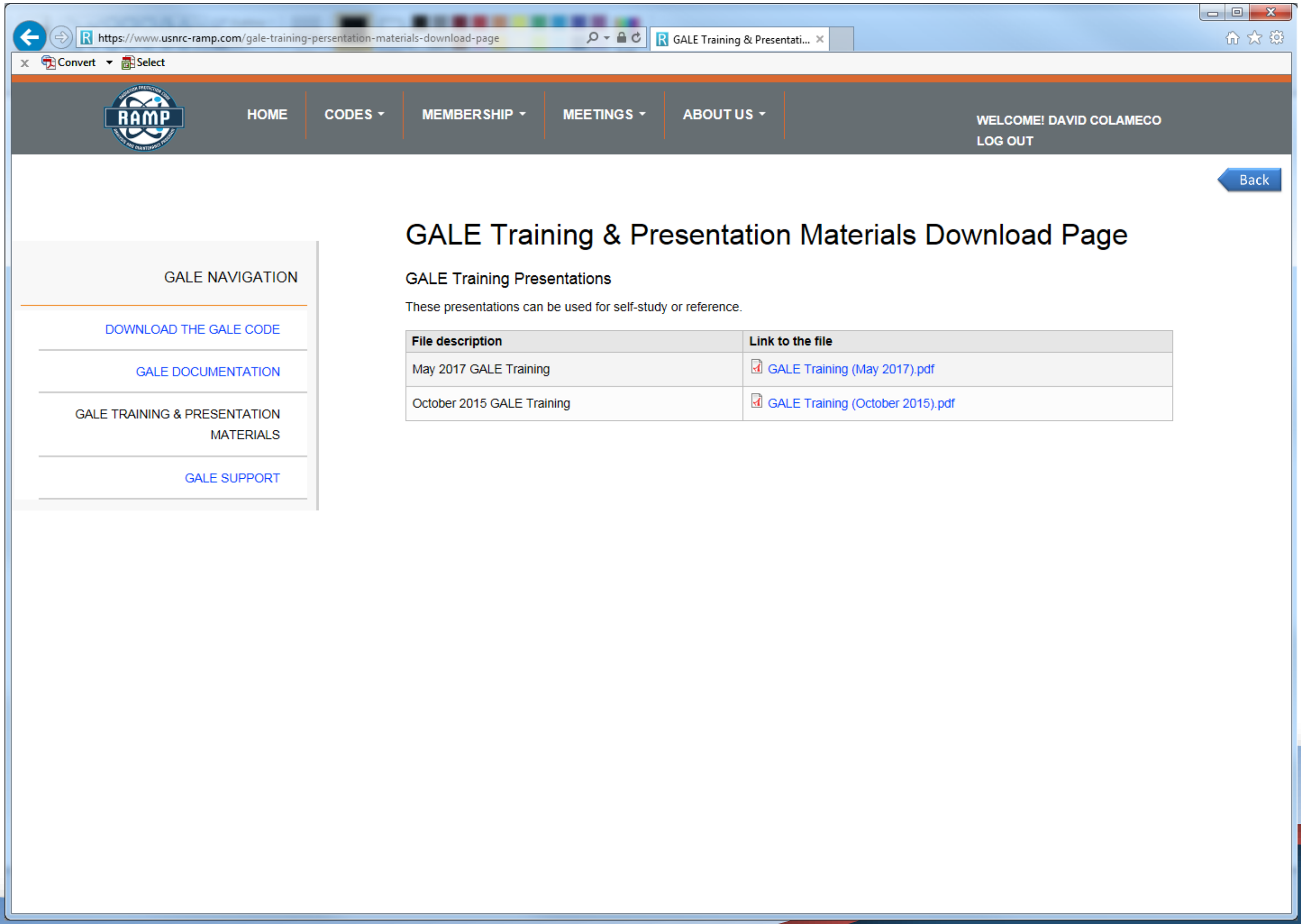
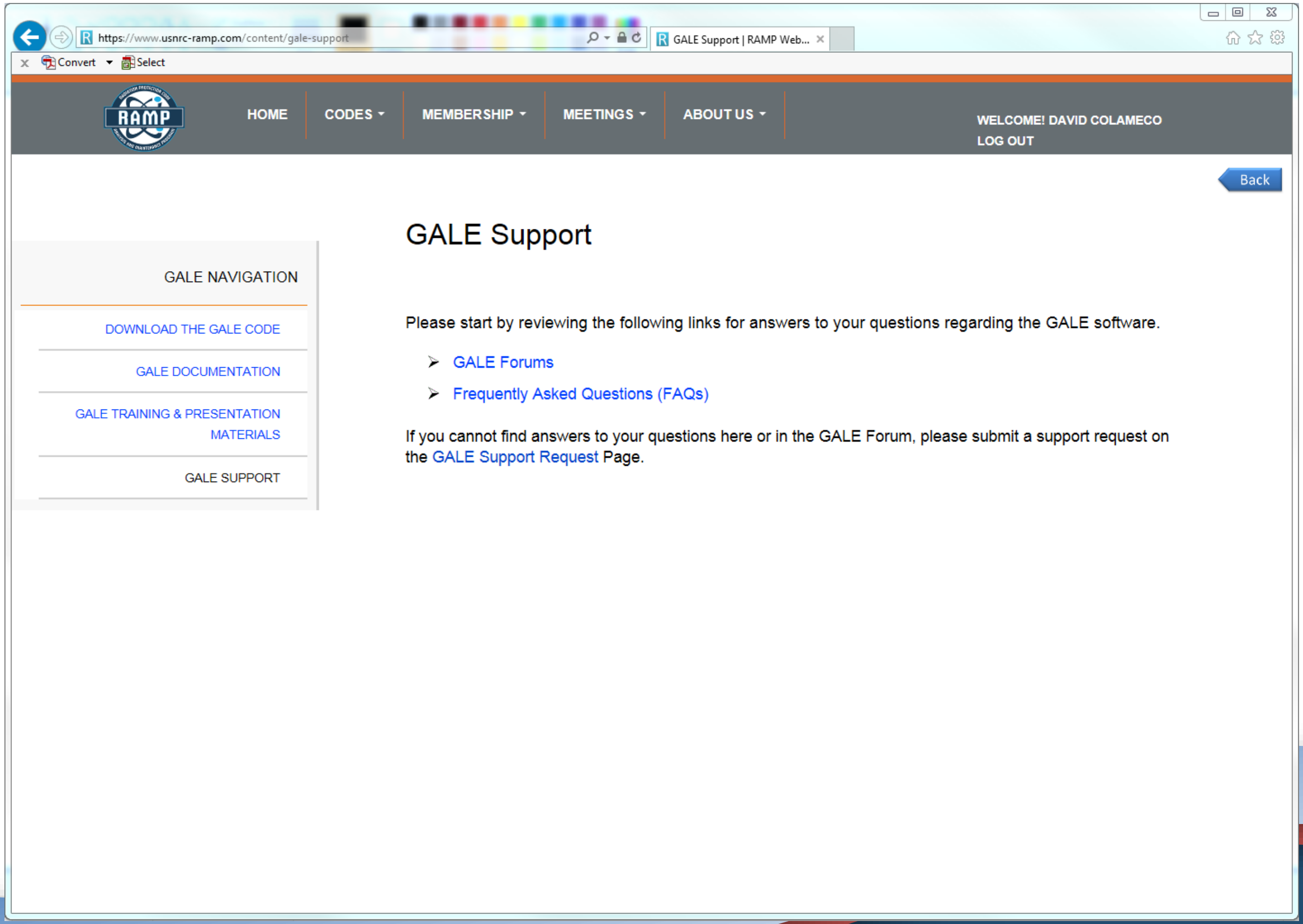
- GALE Website https://www.usnrc-ramp.com/gale-training-persentation-materials-download-page



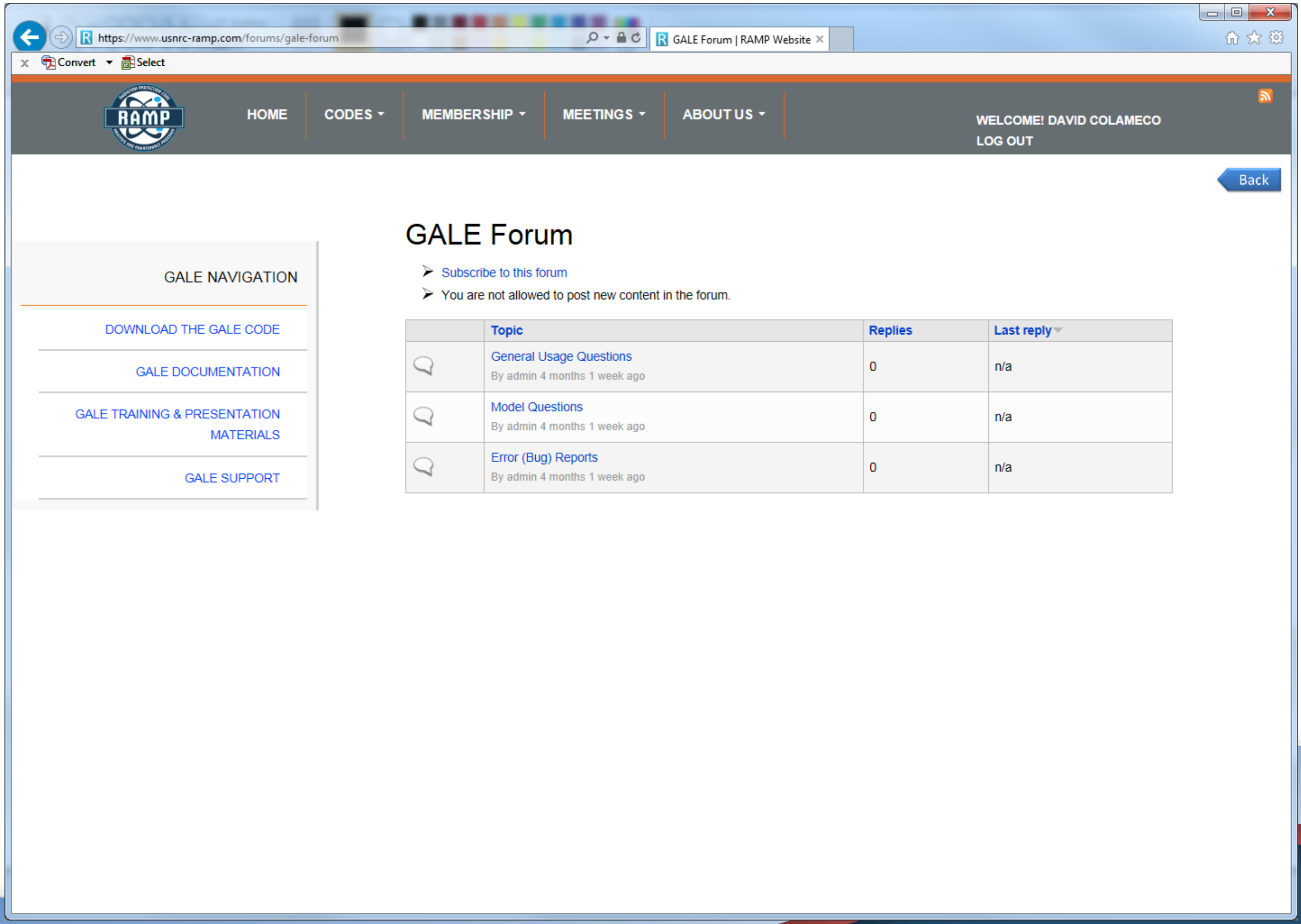
GALE Website Support Page

- GALE Website https://www.usnrc-ramp.com/gale-training-persentation-materials-download-page



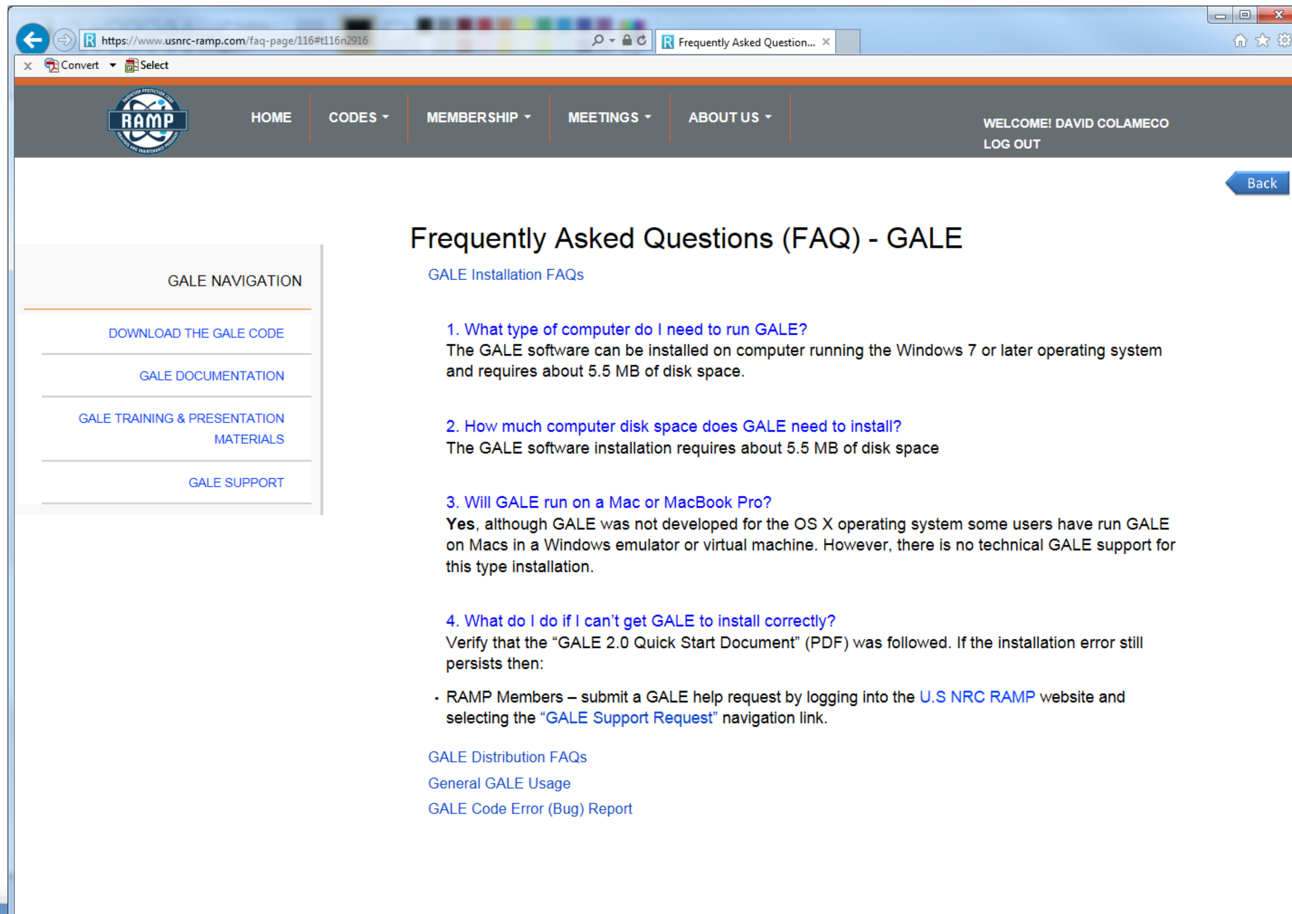
GALE Website Forum Page

- GALE Website https://www.usnrc-ramp.com/gale-forum



GALE Website FAQ Page

- GALE Website https://www.usnrc-ramp.com/faq-page/116#t116n2916



ANS-18.1 Updates

ANS-18.1 Summary

- Scope and History of ANS-18.1
- Use of ANS-18.1 in GALE
- Restart of ANS-18.1 Working Group in 2015
  - Near term plans
  - Long term plans

Scope and History of ANS-18.1

- Scope
  - Provides primary and secondary coolant concentrations of various radionuclides
  - Provides methodology to scale nuclide concentrations based on reactor parameters
- History
  - ANS-18.1 (1984) – used in GALE86
  - ANS-18.1 (1999) – used in GALE08 and GALE09
  - ANS-18.1 (1984, 1999, 2016) used in GALE 3.0 as chosen by user
  - Standard considered delinquent after 10 years with no update or reaffirmation

Use of ANS-18.1 in GALE

- Nuclide concentrations for ANS-18.1 reference reactor included in GALE for
  - BWR water and steam
  - PWR primary and secondary coolant for U-tube steam generators
  - PWR primary and secondary coolant for once-through steam generators
- Adjustment methodology included in GALE to adjust concentrations for given reactor parameters

ANS-18.1 Working Group

- First meeting held June 10, 2015 in San Antonio
  - Ken Geelhood Chair
  - Working group members from NRC, GNF, EPRI, and NuScale
  - Current and future uses for standard were established
  - EPRI presented results from recent project to collect effluent release data
- Path-forward for new standard releases were established
  - Standard back in active status
  - ANS-18.1-2016 is latest version

Q&A and Wrap Up