



# GALE User's Group Meeting

KEN GEELHOOD

Pacific Northwest National Laboratory

Richland, WA

October 22, 2015

# Agenda - Thursday

- ▶ GALE Overview
  - Purpose of Code
  - Code Requirements
  - History of Code Development
- ▶ GALE-2.0: Features and Validation
- ▶ Basics of Reactor Cleanup
- ▶ Code Demonstration
- ▶ Participants Set Up and Run GALE
- ▶ Q&A with GALE developers

# Agenda - Friday

- ▶ GALE User's Group
  - Website
  - Training
  - Member Presentations
  - Technical Support
- ▶ Updates to ANS-18.1
- ▶ Activities Associated with GALE and SMRs
- ▶ Q&A and Wrap Up

# Purpose of Code

- ▶ GALE-2.0 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-2.0 PWR Code to determine conformance with the requirements of Appendix I to 10 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 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
- ▶ Updates have been made to make the output of GALE more flexible to link with other NRC codes such as GASPAR, LADTAP, and GENII

# Code Requirements

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

# 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

# History of Code Development (cont.)

- ▶ 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.
- ▶ Official GALE release with NUREG/CR documentation was made in 2015
- ▶ GALE-2.0
  - 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 results to recent reactor experience



- ▶ Graphical User Interface
  - Uses standard Windows Dialog Boxes
- ▶ 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 and to facilitate use of output data in other calculations





# Basics of Reactor Cleanup Systems

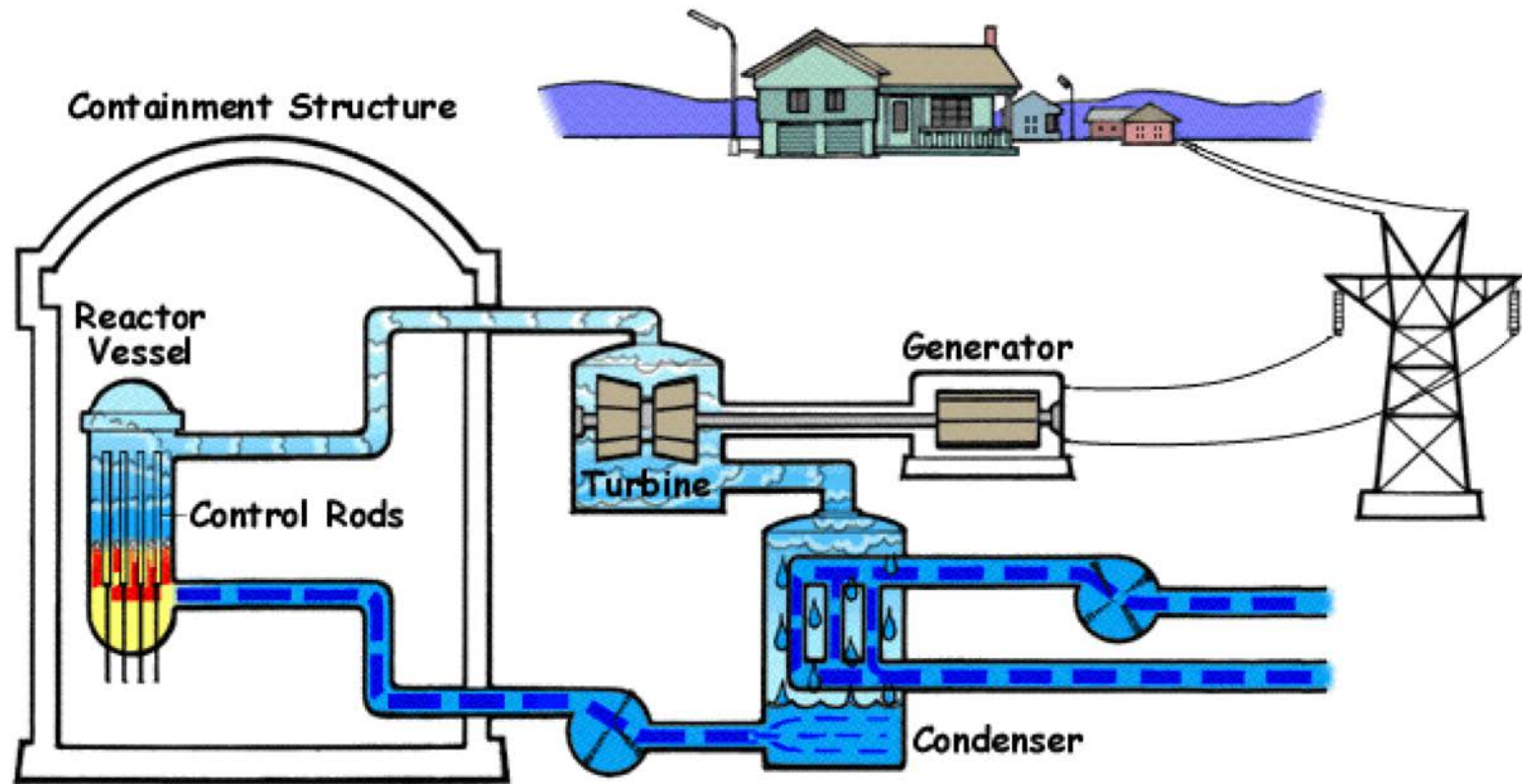
KEN GEELHOOD

Pacific Northwest National Laboratory  
Richland, WA

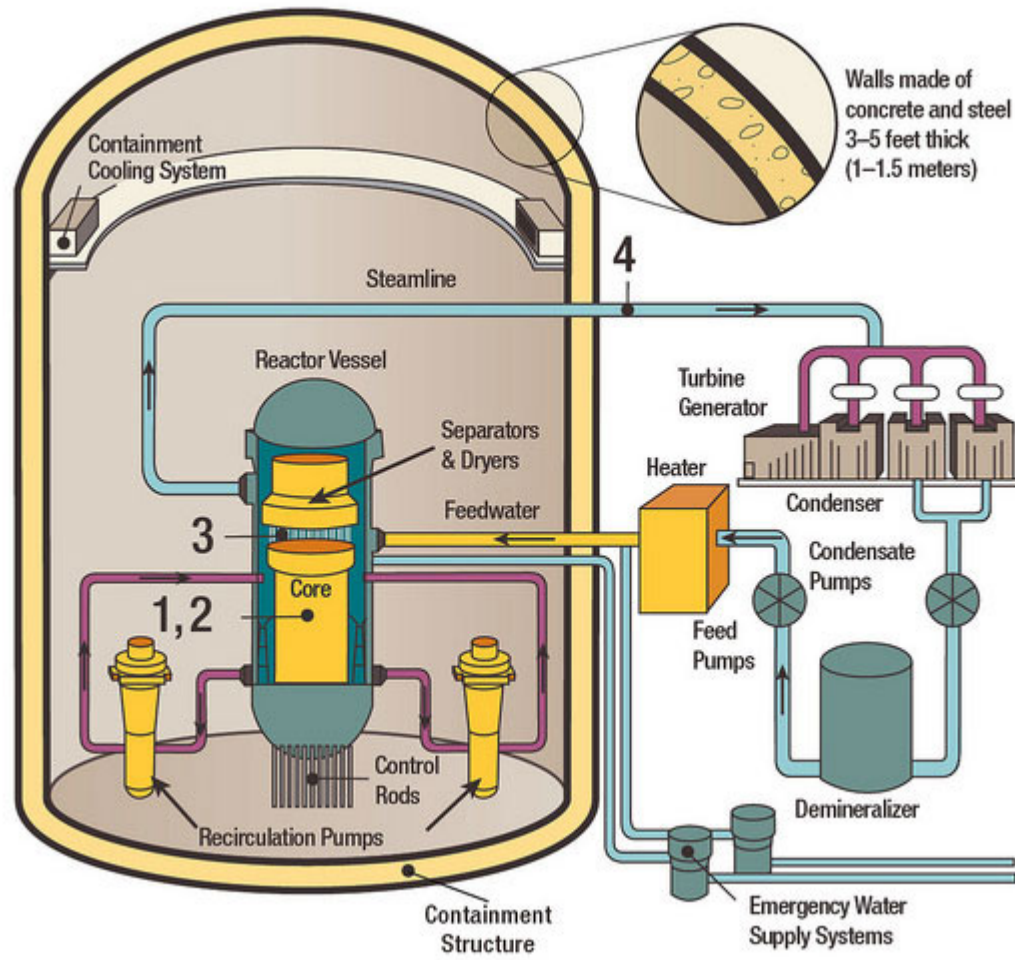
# Introduction

- ▶ 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

## ▶ 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

- 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.

## ▶ Auxiliary or Reactor 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. In BWRs, the drywell is 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

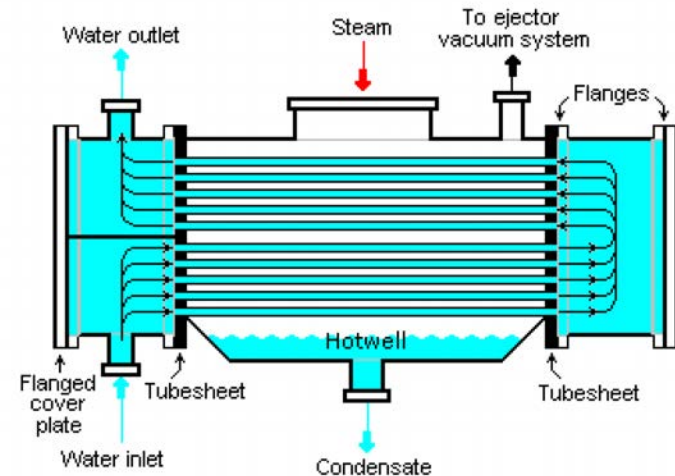
Two special auxiliary systems that are potential sources of effluents are:

▶ **Air Ejector**

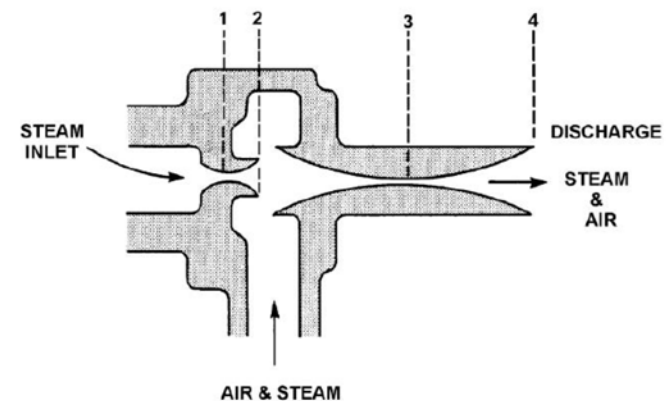
- Passes steam through a series of nozzles and creates a vacuum that removes air from the condenser

▶ **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.

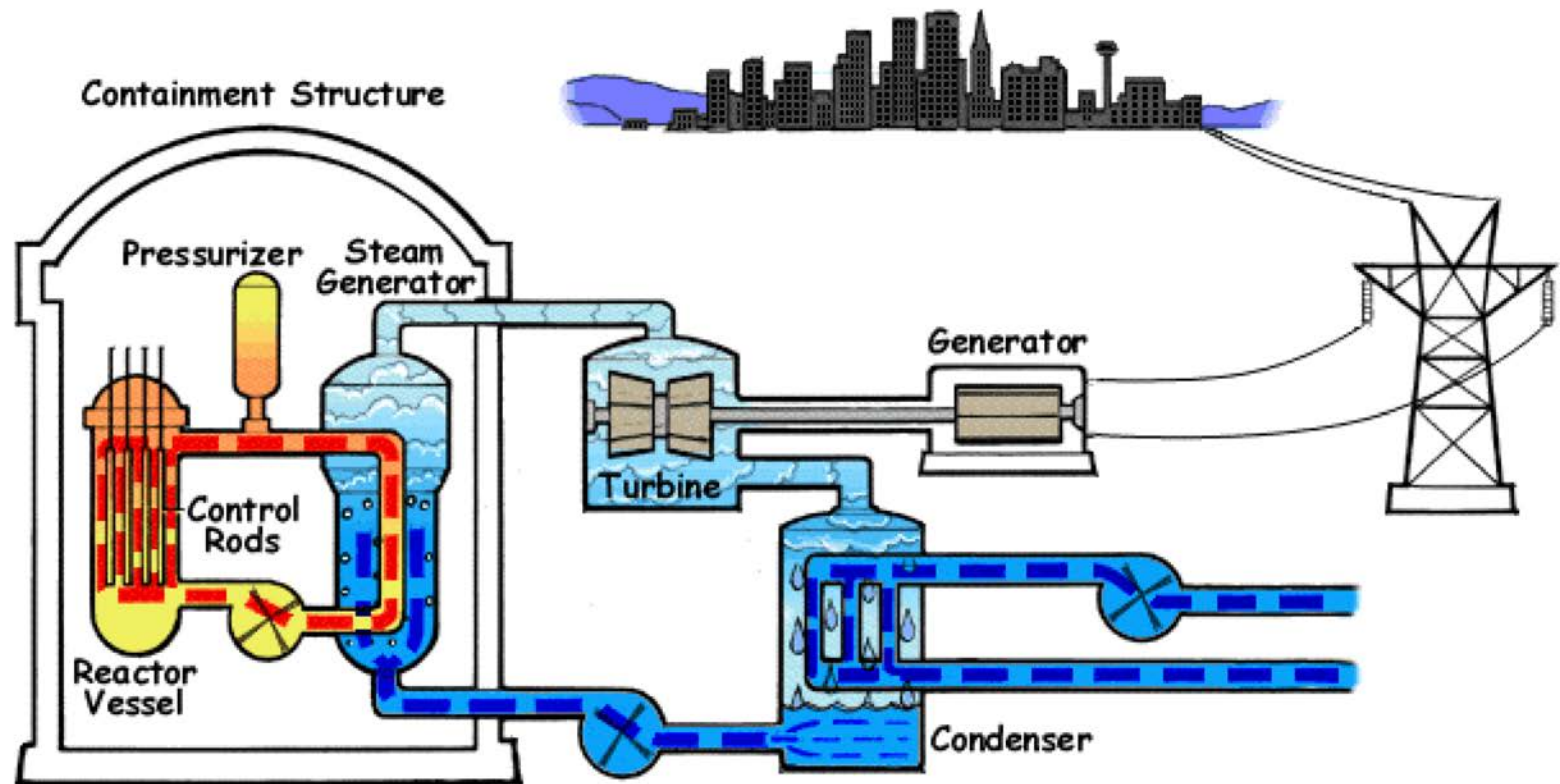


**Condenser**

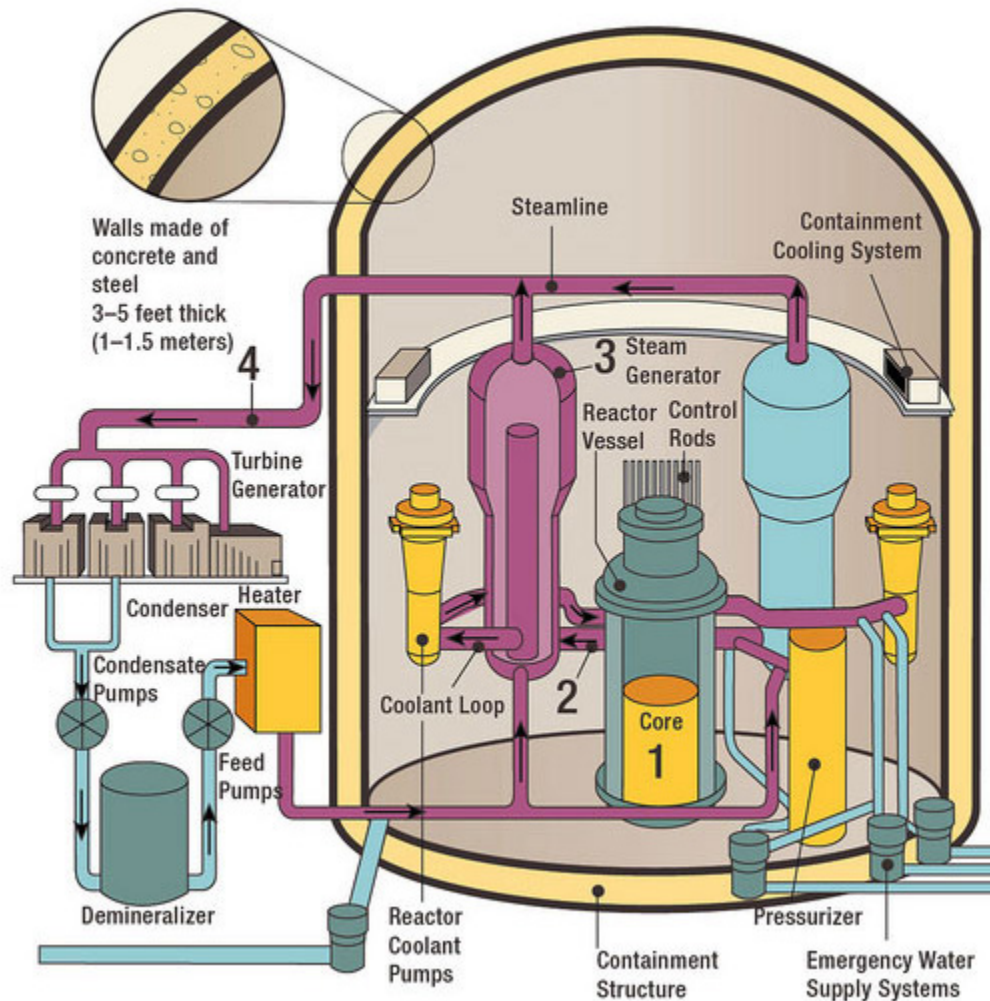


**STEAM-JET AIR EJECTOR**

# Pressurized Water Reactor

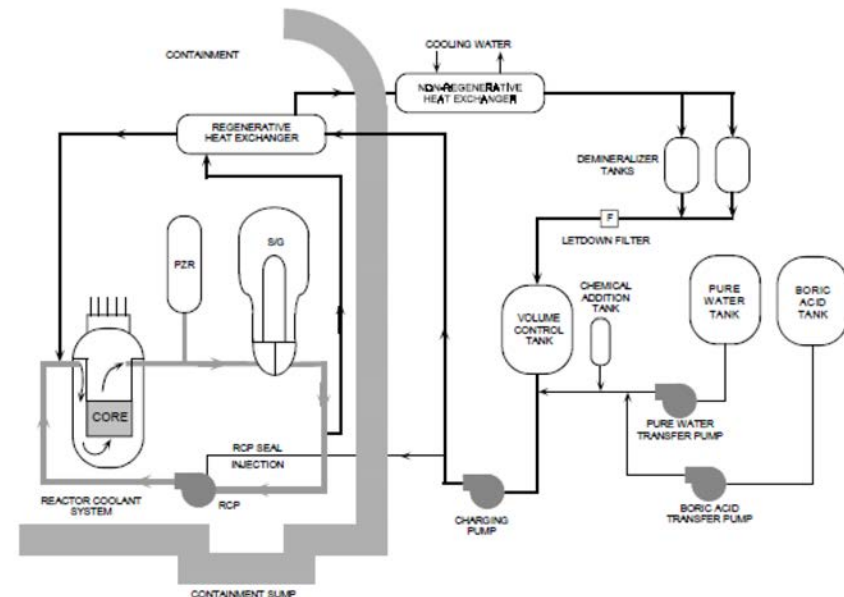


# Pressurized Water Reactor



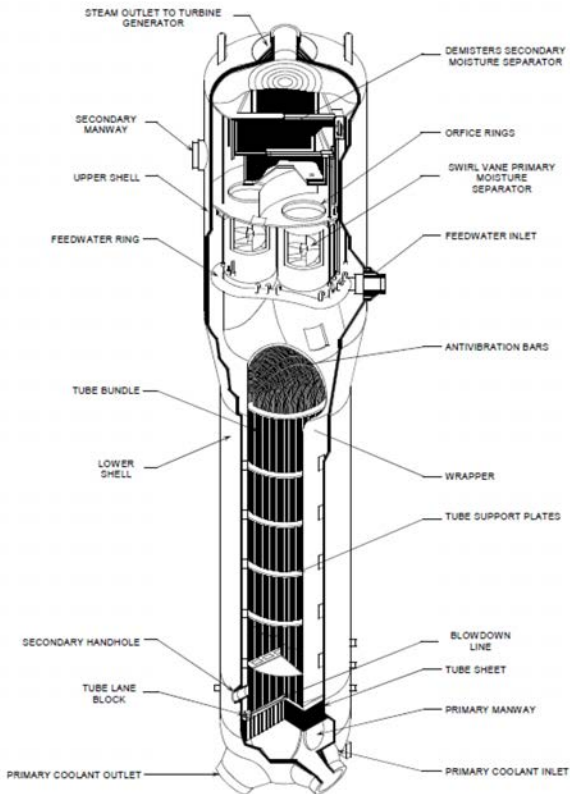
# Pressurized Water Reactor: Letdown

- ▶ 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 the 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.

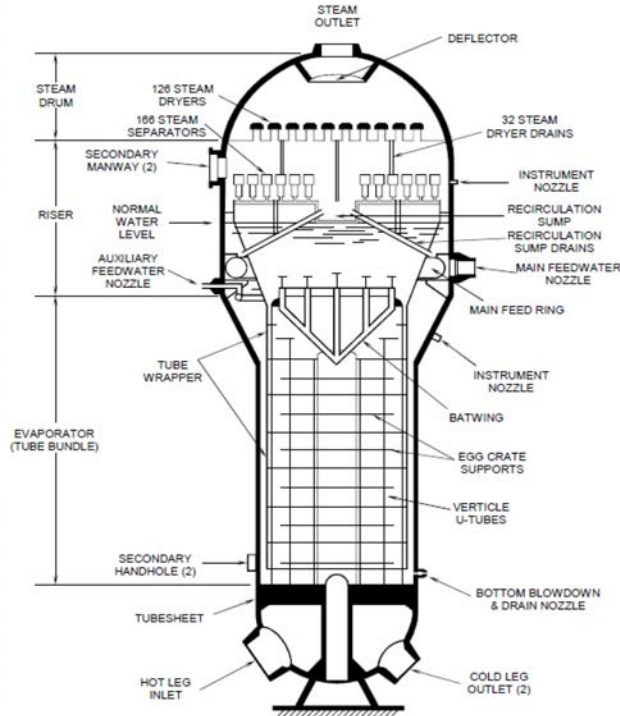




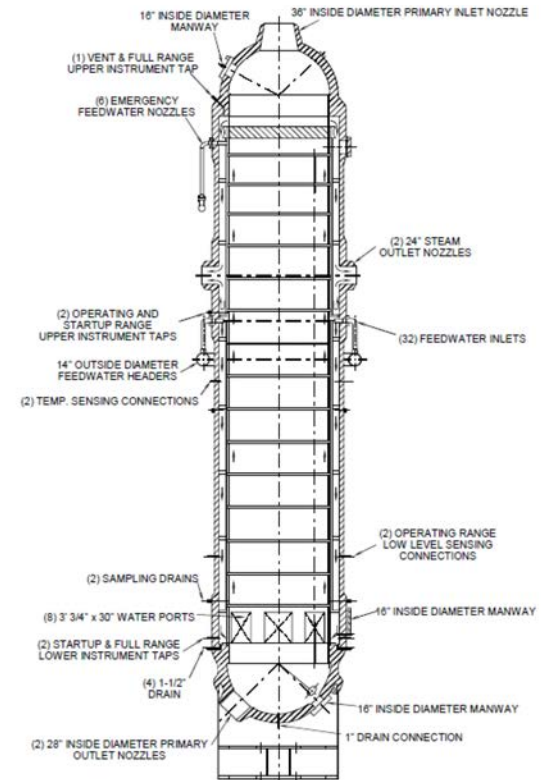
# Pressurized Water Reactor: Steam Generator



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
  - Deaerated or tritiated
- ▶ Dirty Waste
  - Aerated or non tritiated
- ▶ Blowdown Waste
- ▶ Regenerant Waste
  - Regenerant solution from ion exchange columns (condensate polishers)

## ► 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 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.

## ▶ 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
  - Discussed under BWR section





# GALE 2.0 Sample Problems

KEN GEELHOOD

Pacific Northwest National Laboratory  
Richland, WA

# 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                                | $5 \times 10^3$ |
| Cs and Rb Decontamination Factor                             | $2 \times 10^3$ |
| Other Decontamination Factor                                 | $1 \times 10^5$ |
| 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 – Equipment Drain Waste

| Parameter                                                    | Value                |
|--------------------------------------------------------------|----------------------|
| Flow rate                                                    | 330 gal/day          |
| Activity of Inlet Stream                                     | 0.97 fraction of PCA |
| Iodine Decontamination Factor                                | $5 \times 10^3$      |
| Cs and Rb Decontamination Factor                             | $2 \times 10^3$      |
| Other Decontamination Factor                                 | $1 \times 10^5$      |
| 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                                | $5 \times 10^2$       |
| Cs and Rb Decontamination Factor                             | $1 \times 10^3$       |
| Other Decontamination Factor                                 | $1 \times 10^4$       |
| 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                                | $5 \times 10^2$       |
| Cs and Rb Decontamination Factor                             | $1 \times 10^3$       |
| Other Decontamination Factor                                 | $1 \times 10^4$       |
| 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                                | $5 \times 10^2$ |
| Cs and Rb Decontamination Factor                             | $1 \times 10^3$ |
| Other Decontamination Factor                                 | $1 \times 10^4$ |
| 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                                | $5 \times 10^2$ |
| Cs and Rb Decontamination Factor                             | $1 \times 10^3$ |
| Other Decontamination Factor                                 | $1 \times 10^4$ |
| 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<br>•HEPA?                                                                              | Yes                                                                 |
| Fuel Handling building<br>•Charcoal adsorbers?<br>•HEPA?                                                             | Yes 90% efficient<br>Yes                                            |
| Auxiliary Building<br>•Charcoal adsorbers?<br>•HEPA?                                                                 | Yes 90% efficient<br>No                                             |
| Containment Building<br>•Charcoal adsorbers?<br>•HEPA?<br>•Free volume<br>•Flow rate through internal cleanup system | No<br>No<br>2.715 million ft <sup>3</sup><br>0 ft <sup>3</sup> /min |

# PWR Sample Problem Information: Gaseous Waste – Containment Purges

| Parameter                                                                                                                                             | Value                                                 |
|-------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------|
| Containment large volume purge <ul style="list-style-type: none"><li>•Charcoal adsorbers?</li><li>•HEPA?</li><li>•Number of purges per year</li></ul> | Yes 90% efficient<br>Yes<br>2 at shutdown             |
| Containment low volume purge <ul style="list-style-type: none"><li>•Charcoal adsorbers?</li><li>•HEPA?</li><li>•Continuous purge rate</li></ul>       | Yes 90% efficient<br>Yes<br>1000 ft <sup>3</sup> /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                                | $1 \times 10^3$      |
| Cs and Rb Decontamination Factor                             | $1 \times 10^2$      |
| Other Decontamination Factor                                 | $1 \times 10^3$      |
| 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                                | $1 \times 10^3$      |
| Cs and Rb Decontamination Factor                             | $1 \times 10^4$      |
| Other Decontamination Factor                                 | $1 \times 10^4$      |
| 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                                | $1 \times 10^3$      |
| Cs and Rb Decontamination Factor                             | $1 \times 10^4$      |
| Other Decontamination Factor                                 | $1 \times 10^4$      |
| 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                                | $1 \times 10^4$ |
| Cs and Rb Decontamination Factor                             | $1 \times 10^5$ |
| Other Decontamination Factor                                 | $1 \times 10^5$ |
| 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<br>•Charcoal adsorbers?<br>•HEPA? | Yes 90% efficient<br>Yes |
| Auxiliary building<br>•Charcoal adsorbers?<br>•HEPA?   | No<br>No                 |
| Radwaste Building<br>•Charcoal adsorbers?<br>•HEPA?    | No<br>Yes                |
| Turbine Building<br>•Charcoal adsorbers?<br>•HEPA?     | No<br>No                 |

# BWR Sample Problem Information: Gaseous Waste – Turbine Systems

| Parameter                                                                                                                                                                                                                                                                                              | Value                                                                                               |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------|
| Gland Seal <ul style="list-style-type: none"><li>•Gland seal steam flow</li><li>•Gland seal holdup time</li><li>•Fraction iodine release from condenser vent</li></ul>                                                                                                                                 | 0.0 lbs/hr<br>0 hrs<br>0                                                                            |
| Air Ejecector Offgas <ul style="list-style-type: none"><li>•Air Ejector holdup time</li><li>•Fraction iodine released from air ejector vent</li><li>•Charcoal delays system?</li><li>•Kr dynamic adsorption coefficient</li><li>•Xe dynamic adsorption coefficient</li><li>•Mass of charcoal</li></ul> | 0.167 hrs<br>1.0<br><br>Yes<br>105 cm <sup>3</sup> /g<br>2410 cm <sup>3</sup> /g<br>48 thousand lbs |

- ▶ 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 [GALE@pnnl.gov](mailto:GALE@pnnl.gov)



# ANS-18.1 Updates

KEN GEELHOOD

Pacific Northwest National Laboratory  
Richland, WA

# Summary

- ▶ Scope and History of ANS-18.1
- ▶ Use of ANS-18.1 in GALE
- ▶ Restart of ANS-18.1 Working Group
  - 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
- Standard considered delinquent after 10 years with no update or reaffirmation

# Used 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

# Restart of 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 futures uses for standard were established
  - EPRI presented results from recent project to collect effluent release data
- ▶ Path-forward for new standard releases were established
  - Near term: Release a new version of the standard changing only nuclide concentrations based on recent EPRI data
    - Standard will go back to active status
  - Long term: work on the development of a new standard that would provide nominal concentrations plus uncertainty bands. Also, investigate updates to scaling methodology recommended in the standard.
- ▶ Next meeting November 11, 2015 in Washington DC
  - Plan is for working group to propose a new standard for near term





# Development of GALE version for Small Modular Reactors

KEN GEELHOOD

Pacific Northwest National Laboratory  
Richland, WA

# Summary

- ▶ SMR Designs
- ▶ Previous study and recommendations
- ▶ Current status of NuScale

- ▶ Each SMR consists of a fully integrated reactor vessel, pressurizer, steam generator, and containment vessel, and is accompanied by a companion turbine
  
- ▶ NuScale
  - 50 MWe (gross).
- ▶ B&W mPower
  - 530 MWth, 155-180 MWe
- ▶ Westinghouse
  - 225 MWe
- ▶ Holtec HI-SMUR SMR-160
  - 160 MWe

# Previous Study and Recommendations

- ▶ In 2012 a study was performed on the applicability of GALE to SMRs (PNNL-21386)
- ▶ mPower reactor was selected as the baseline as this design was the most mature at that time
- ▶ It was determined that the scaling factors in ANS-18.1 should be applicable to SMRs
- ▶ PNNL recommended that the following changes be made to the PWR GALE codes to make them applicable to the mPower® design and other iPWR designs:
  - changes already made and documented in GALE-08 and GALE-09 (now in GALE 2.0)
  - addition of new nuclides to GALE output (if desired)
  - hardwired parameters in GALE that should be changed
  - changes to GALE input and output format (if more precision is desired)
  - tritium production and release from plants without soluble boron
  - carbon-14 production and release

# Current Status of NuScale

- ▶ PNNL has been in contact with NuScale staff
  - The current decision is that they cannot use the existing GALE code for the license submittal, because their plant is just outside of its applicable range.
  - Plant specific tritium calculations significantly different than NUREG-0017 says they should be based on the power level.
  - Staff thinks some things will be the same
  - NuScale is developing alternate methodology to GALE for the submittal, but wants to use GALE's methodology as much as possible and only deviate where there are differences.
- ▶ NuScale is interested in helping the NRC develop a GALE-iPWR