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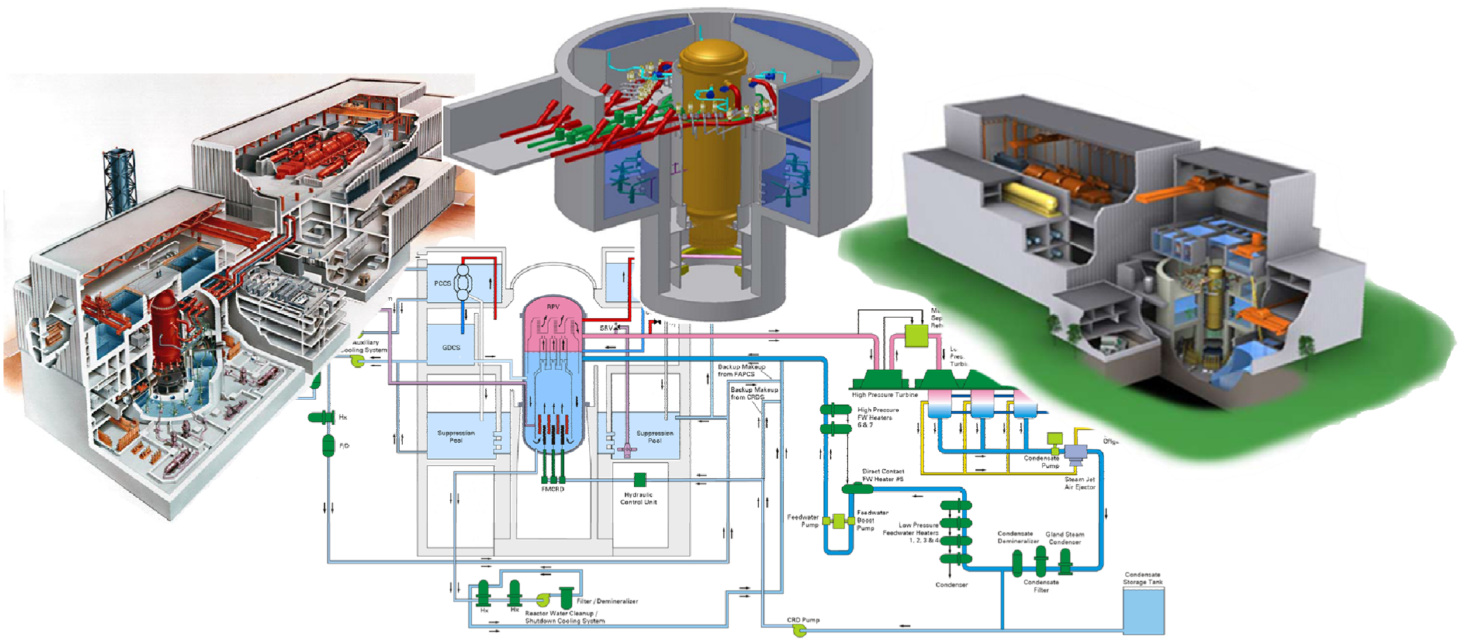
Reactor Technology Training Branch



Part II

Introduction to Reactor Technology - BWR

Chapter 12.0, ABWR Plant Overview

UNITED STATES

NUCLEAR REGULATORY COMMISSION

HUMAN RESOURCES TRAINING & DEVELOPMENT

Introduction to Reactor Technology

This manual is a text and reference document for the Introduction to Reactor Technology for the media briefing. It should be used by students as a study guide during attendance at this course. This manual was compiled by staff members from the Human Resources Training & Development in the Office of Human Resources.

The information in this manual was compiled for NRC personnel in support of internal training and qualification programs. No assumptions should be made as to its applicability for any other purpose. Information or statements contained in this manual should not be interpreted as setting official policy. The data provided are not necessarily specific to any particular nuclear power plant, but can be considered to be representative of the vendor design.

The Introduction to Reactor Technology – BWR briefing manual outlines the differences between the Boiling Water Reactors (BWR), Advanced Boiling Water Reactor (ABWR), and Economic Simplified Boiling Water Reactor (ESBWR). The course is broken down into discussions on design features, facility and plant layout, containment systems, nuclear steam supply systems, control and instrumentation, safety systems, balance of plant systems, normal, abnormal, and emergency operations.

The content of this course was based on the content provided in the following references:

- General Electric Systems Manual
- Introduction to ABWR Manual
- Introduction to ESBWR Course Manual
- Economic Simplified Boiling Water Reactor Plant General Description; June 2006, General Electric Company
- NUREG-1503, Final Safety Evaluation Report Related to the Certification of the Advanced Boiling Water Reactor Design and Appendices, U.S. Nuclear Regulatory Commission Office of Nuclear Reactor Regulation, July 1994
- ABWR, Advanced Boiling Water Reactor Plant General Description, “First of the Next Generation,” GE Nuclear Energy, June 2000
- Nuclear News, World List of Nuclear Power Plants, American Nuclear Society, March 2007
- J. Alan Beard & L.E. Fennern, General Electric presentation to DOE et.al, April 13th 2007, Germantown Md.

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12.0 Introduction to ABWR Design

The purpose of this course is to describe the significant features of the General Electric Advanced Boiling Water Reactor (ABWR). The ABWR is a Generation III reactor design in foreign operation. The ABWR design has been approved for construction within the United States. This chapter provides an overview of those features that are most dissimilar from those Boiling Water Reactors (BWRs) already in domestic operation. An emphasis is placed on containment design, reactivity and equipment controls, display systems and the prominence of automated plant operations.

12.1 Historical Perspective

Since Vallecitos (5 MWe), the first BWR nuclear plant built in 1957, the BWR design has subsequently undergone a series of evolutionary changes with one purpose in mind—simplification. The ABWR is an improved design, when compared to earlier BWR models, because several decades of operating experience on proven equipment has directly shaped the enhanced features of the plant.

The lessons of the Three Mile Island event required that Boiling Water Reactor (BWR) utilities revise equipment design, reactor protection and operating methods in ways unforeseen by the pioneers of commercial nuclear power. Because of the Three Mile Island event and the ensuing economic complications, US commercial nuclear power utilities suspended all new construction. During the subsequent period, nuclear technology designers were able to plan new reactor plant designs that eliminated or mitigated problems of the early generations of reactors. The Advanced Boiling Water Reactor (ABWR) was developed to reduce many of the burdens inherent to the earlier BWRs. Significant design changes not only simplify emergency response, operation, and maintenance, they also redefine much of the operators' responsibilities. The ABWR requires that operators supervise wide-scale automated plant operation. As compared to earlier generation BWRs, the ABWR automated response to a DBA-LOCA allows for a much longer time before operator action is required.

The ABWR designed and placed in production by GE Nuclear Energy (Figures 12.0-1 & 12.0-4) is the first advanced reactor design to accrue an operating history. The first ABWRs built and operated are the Tokyo Electric Power Corporation's Kashiwazaki Kariwa Units 6 and 7, which became operational in 1996 and 1997 respectively. Since then the Hamaoka-5 and Shika-2 plants, two other Japanese ABWRs began operation in 2005 and 2006 respectively Additional Japanese ABWRs are in construction or planning. The four operating Japanese ABWRs generate between 1304 and 1325 MWe. The ABWRs plants have a thermal efficiency of 35%, which is slightly higher than previous BWR designs. The present nominal electrical output for ABWRs is 1365 MWe.

Two ABWRs in Taipei (Lungmen 1 and 2) are expected to become operational after 2009. Both Lungmen ABWRs are expected to generate 1300 MWe. Domestic ABWRs may be

rated as high as 1371 MWe. US commercial nuclear companies have considered the ABWR and it is anticipated that the ABWR design will be used in new domestic construction. US ABWRs are currently certified for 1350 MWe net. The ABWR design considered by Finland is certified for 1460 MWe.

ABWR plants are designed for a service life in excess of 60 years.

12.2 Regulatory Oversight

The ABWR was the first plant to use the new standard plant licensing process in the U.S. (10CFR52). General Electric provided a complete design scope for any plant features that could affect safe operation in accordance with 10CFR52.47(b)(1). The NRC staff review of the ABWR design as required by 10CFR52.47(a)(1)(i) was completed in accordance with the standard review plan (NUREG 800) and safety standards established in 10CFR48. The Nuclear Regulatory Commission (NRC) approved the ABWR design in 1997. The Final Safety Evaluation Report related to the certification of the ABWR design was promulgated by NUREG 1503 (1994).

12.3 ABWR Innovations

ABWR innovations include first-of-kind features to the General Electric BWR product line and include features only incorporated at a few domestic BWRs.

Important innovations of the ABWR include:

- internal recirculation pumps (Figure 12.0-3)
- elimination of large Reactor Pressure Vessel (RPV) penetrations below the Top of Active Fuel (TAF)
- Fine-Motion Control Rod Drives (FMCRDs)
- microprocessor-based digital control and logic systems
- digital safety systems
- simplified, digital Main Control Room (MCR) displays and controls
- reduced dose rates
- 110% Steam bypass capability

The use of internal recirculation pumps eliminates large RPV pipe penetrations below the top-of-active fuel (TAF) reducing ECCS requirements. Concurrently, the postulated containment high pressure subsequent to a DBA LOCA is reduced. The primary containment includes a two segmented Drywell and a Suppression Pool (Figure 12.0-4). The structure itself is made of reinforced concrete with a steel liner.

FMCRDs (Figure 12.0-3) use a motor to position the control rods in 0.75” increments. The control rods are still scrammed using hydraulic force. Scram water is discharged directly

back into the Reactor Pressure Vessel (RPV), there are no scram discharge volumes. One HCU is used to scram two separate control rods.

ABWR controls and instrumentation were enhanced through incorporation of digital technologies with automated self-diagnostic features, multiplexing and fiber optic technology.

The ABWR uses 10 internal recirculation pumps (Figure 12.0-3), using a proven feature inherent to other vendors' design. By using pumps attached directly to the vessel itself, the jet pumps and the external recirculation systems, with all their pumps, valves, piping, and snubbers, have been eliminated altogether.

The ABWR operator-machine interface (Figure 12.0-6) was simplified by using large, flat-panel displays, touch-screen CRTs and function-oriented keyboards. Many operating processes and procedures are automated. The operator is free to diagnose potential problems, establish operational priorities and more closely observe components for proper operation. Monitoring devices and logic processors are physically and electrically separated to provide reliability.

12.4 Safety Improvements

GE proposes that the Calculated Core Damage Frequency (CDF) for an ABWR has been reduced by an order of magnitude (factor of 10) as compared to current domestic BWRs. An extensive reactor accident should not lead to a release to the public because of the following:

- The use of internal reactor recirculation pumps mitigates LOCA severity. The elimination of Jet Pumps provides for full core reflood vice 2/3 coverage.
- The use of a concrete reinforced containment structure and a lowered peak accident pressure (45 psig) reduces the probability of containment leakage
- The use of three divisions of high pressure injection and three divisions of low pressure injection, all separated physically and electrically, increase the reliability of reflooding the RPV volume subsequent to a LOCA.
- The larger volume of water and steam above the TAF reduces the immediate demand on ECCS systems subsequent to a LOCA.
- The addition of a non-safety related 20 MWe Combustion Turbine Generator (CTG) as another on-site power source.

The ABWR utilizes design changes to significantly reduce the probability and mitigate the consequences of a DBA LOCA and ATWS. The necessary operator response is simplified by automatic protective actions.

The elimination of recirculation piping and valves, improved material selection and equipment geometry mitigate the formation and deposition of crud in low flow areas known

as traps. The reduction in localized crud accumulation reduces personnel exposure. Japanese ABWR operating history has shown a 50% reduction in outage man-rem for drywell exposures.

GE predicts that the reduced safety demands, standardized design and modular construction methods are likely to reduce initial plant construction time (first cement to first critical) to less than 4 years; subsequent plants may be constructed in less than 3 years.

No.	FACILITY
1	REACTOR CONTAINMENT
2	REACTOR BUILDING
3	CONTROL BUILDING
4	MAIN STEAM / FEEDWATER TUNNEL
5	TURBINE BUILDING
6	SERVICE BUILDING
7	RADWASTE BUILDING
8	HOUSE BOILER
9	CONDENSATE STORAGE TANK
10	UNIT AUXILIARY TRANSFORMERS
11	NORMAL SWITCHGEAR
12	DIESEL OIL STORAGE TANK (3)
13	STACK
14	EQUIPMENT ENTRY LOCK
15	FIRE PROTECTION WATER STORAGE TANK (2)
16	FIRE PROTECTION PUMPHOUSE
17	BUNKER FUEL TANK
18	COMBUSTION TURBINE GENERATOR
19	RADWASTE TUNNELS RB, CB, TB
20	DG OIL TRANSFER TUNNEL (3)

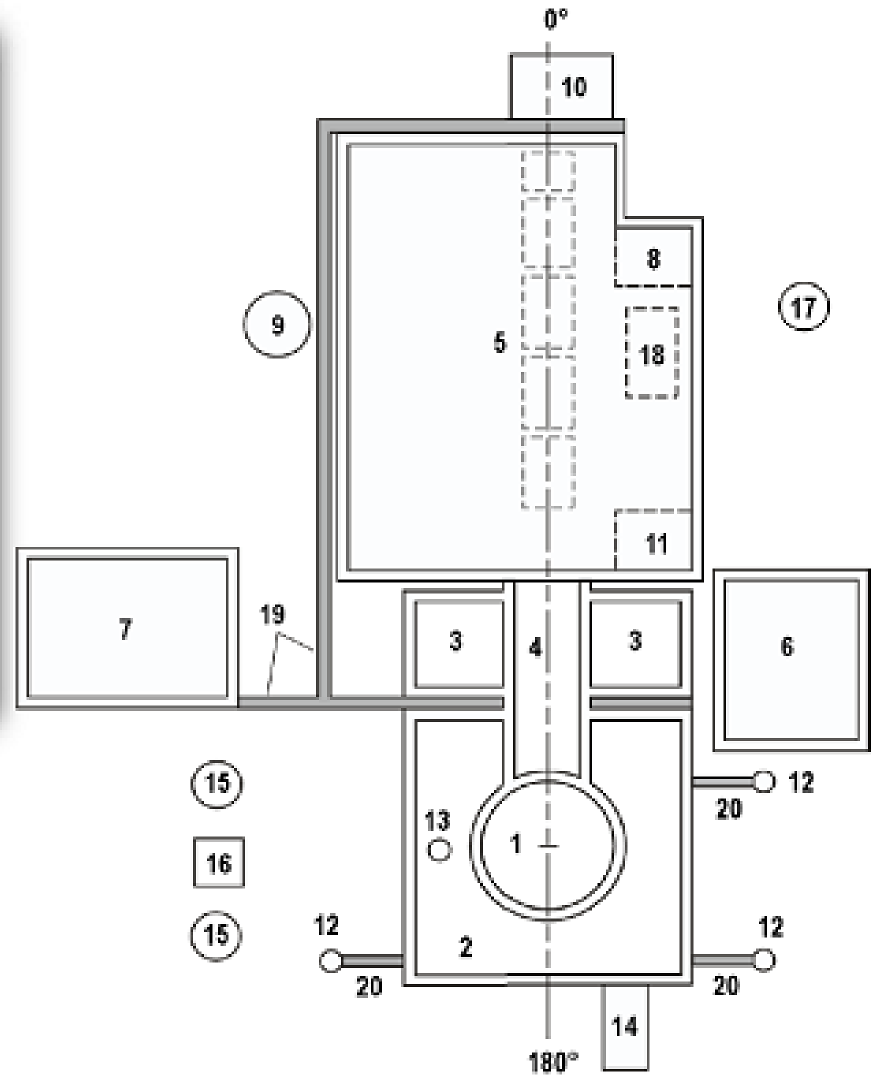


Figure 12.0-1, ABWR Plant Site Layout

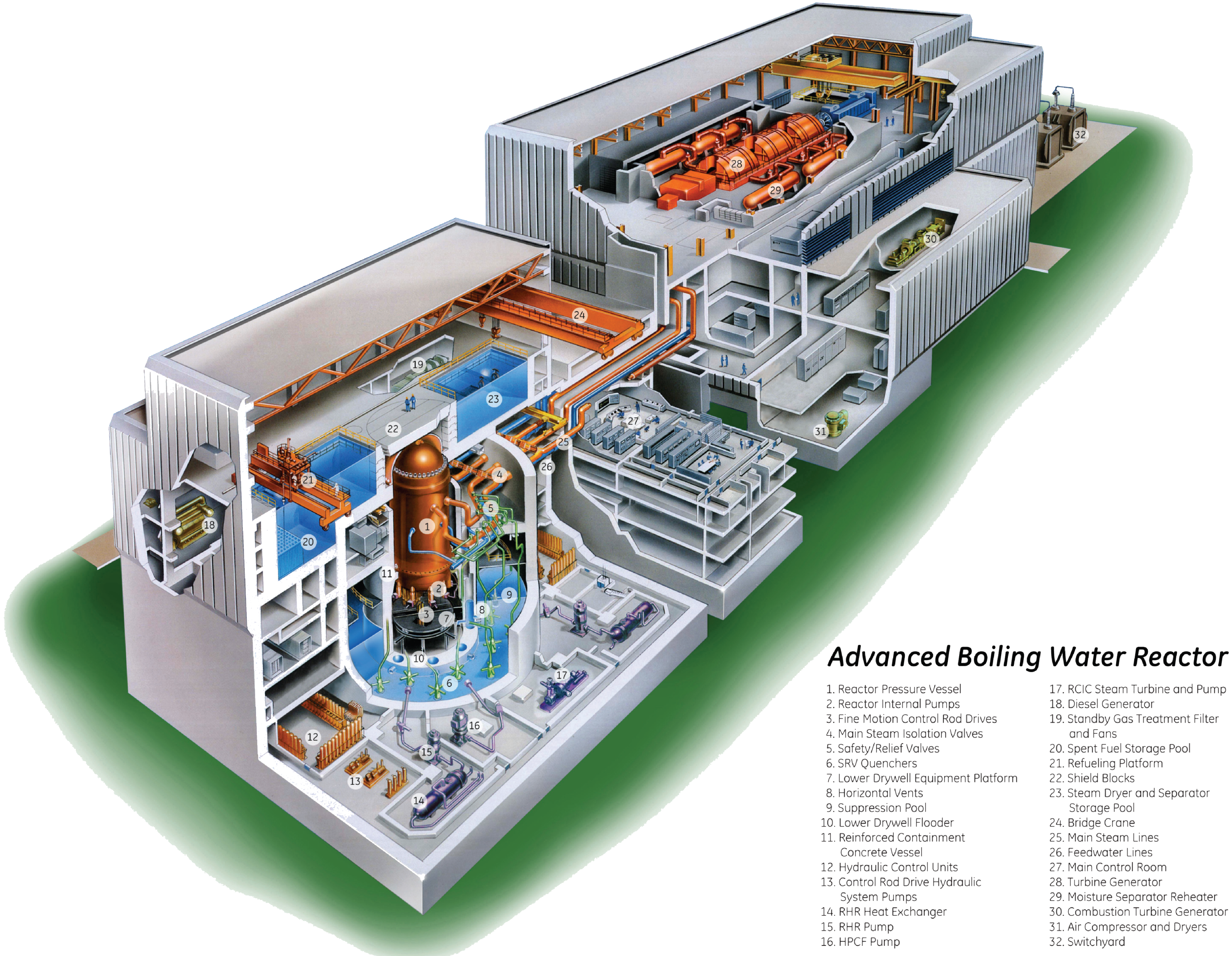
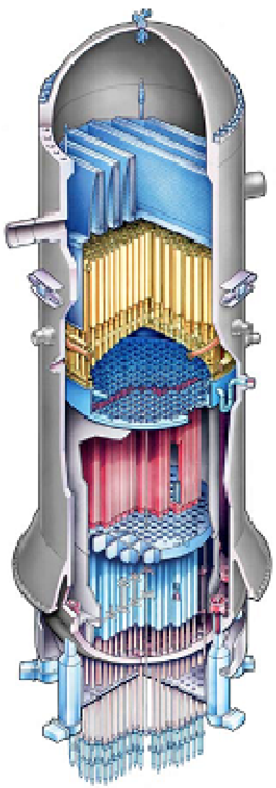


Figure 12.0-2, ABWR Plant Cutaway



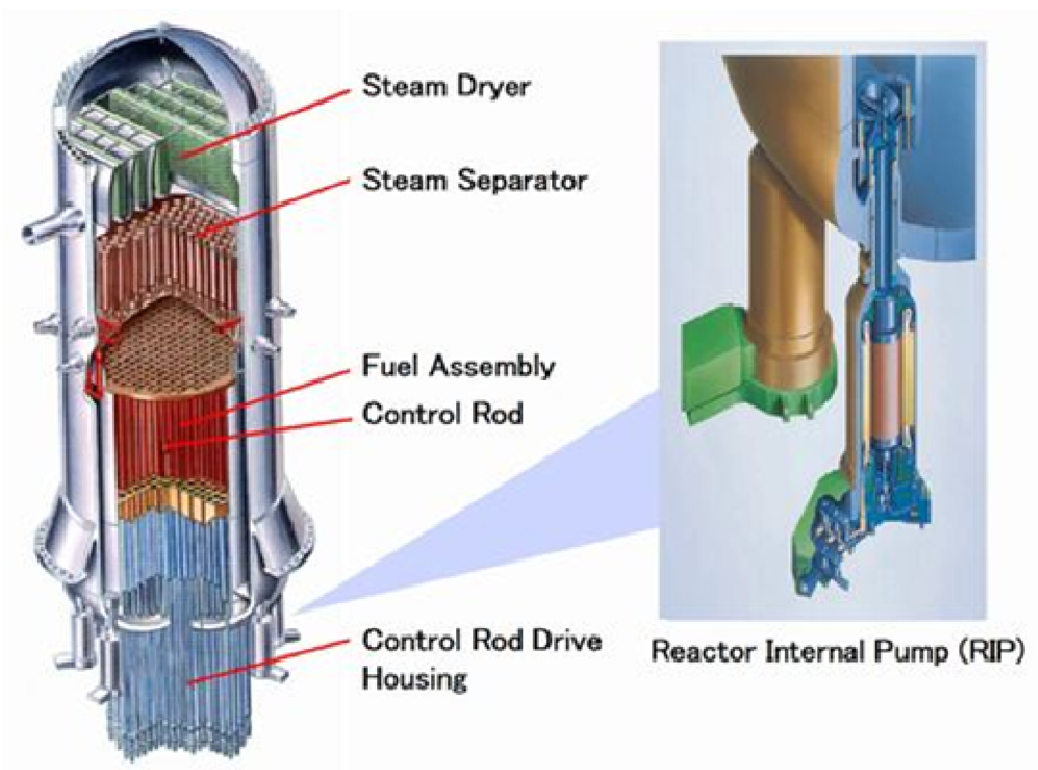


Figure 12.0-3, ABWR RPV Arrangement

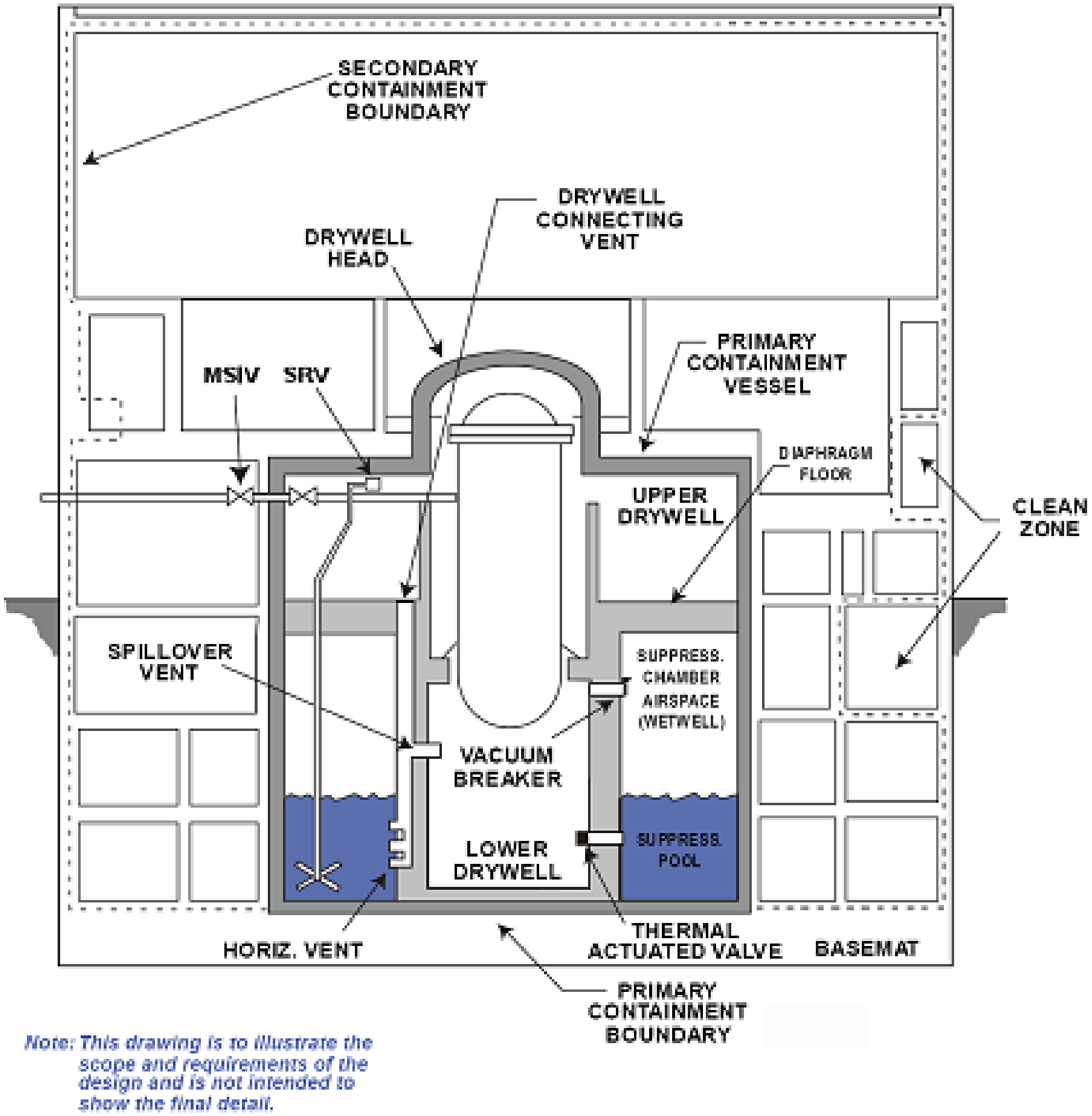


Figure 12.0-4, ABWR Containment Arrangement

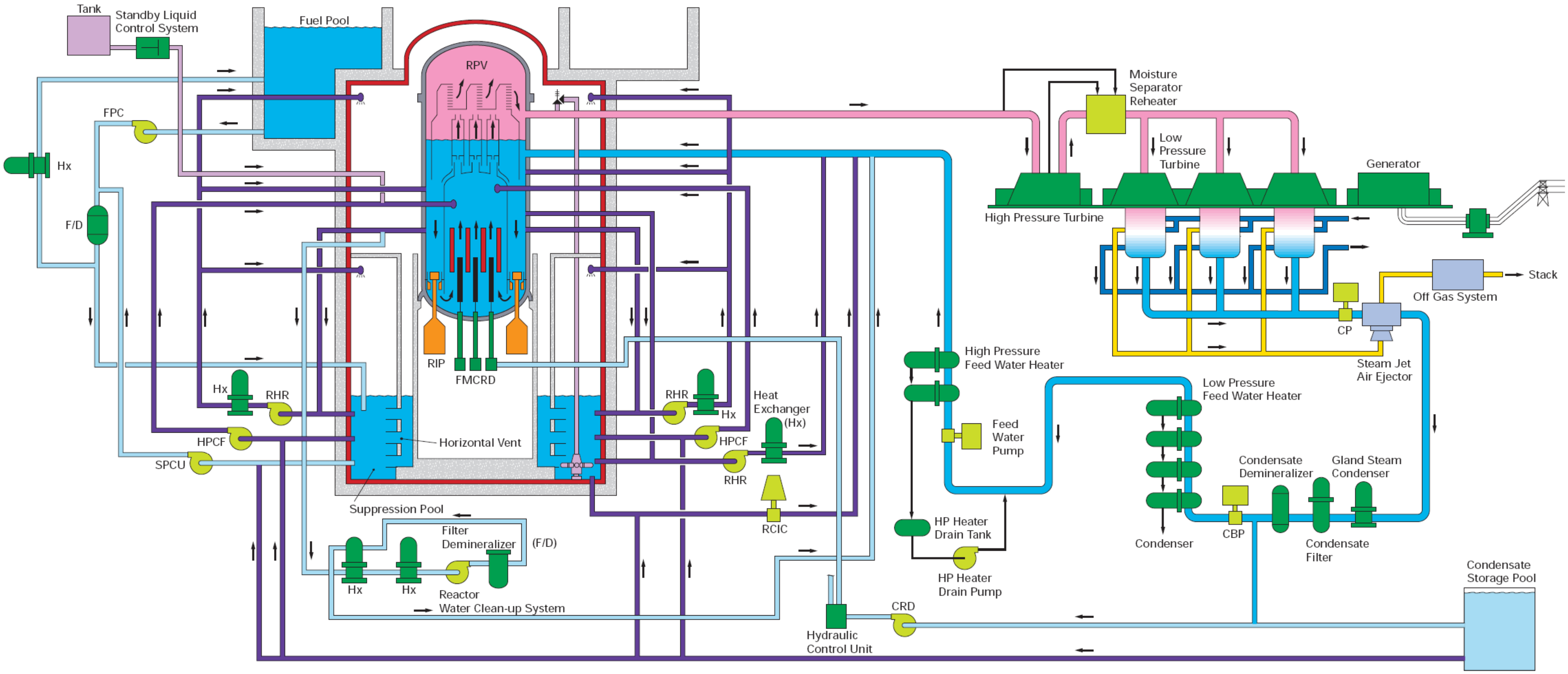


Figure 12.0-5, ABWR Major Flowpaths

Figure 12.0-6, Main Control Room Arrangement