12.4 Dose Assessment

Dose assessment is an important part of determining and projecting that the plant design and proposed methods of operation assure that occupational radiation exposure will be as low as reasonably achievable. Dose assessment depends upon estimates of occupancy, dose rates in various occupied areas, number of personnel involved in reactor operations and surveillance, routine maintenance, waste processing, refueling, inservice inspection, and special maintenance.

The goal is to reduce the exposure associated with each phase of plant operation and maintenance to the minimum level consistent with practical considerations for accomplishing each task. To achieve this goal, the ABWR design includes numerous significant design improvements to reduce occupational exposures from past experience. The design improvements include the elimination of recirculation piping and valves, improved water chemistry and low cobalt alloys at the cooling water boundary, reduced equipment maintenance and improved access, RHR discharge to the feedwater piping, overhaul handling and refueling devices, multiple main steamline plugs, automatic MSIV seat lapping system and reactor vessel stud tensioner. In assessing the collective occupational dose, each potentially significant dose-causing activity was evaluated. Values referred to as typical BWR operations are taken from References 12.4-1 through 12.4-4, which are a compendium of maintenance and work tasks .

12.4.1 Drywell Dose

The following provides the basis by which the drywell dose estimates for occupational exposure were made.

(1) The main steam isolation valves are located in the upper drywell area (4 valves) and in the Reactor Building outboard of the primary containment isolation wall (4 valves). These valves require periodic testing and maintenance to insure proper action and leaktightness. Typical values for BWRs for maintenance of these valves is 4,000 hours of drywell and 5,000 hours of Reactor Building work in effective radiation fields of 135 μGy/h and 36 μGy/h, respectively. The ABWR design incorporates three specific features to reduce occupational exposure in the MSIV maintenance area: (1) improved water chemistry with lower overall contamination rates; (2) improved maintenance procedures with some procedures automated; and (3) reduced radiation fields, primarily due to the absence of the recirculation piping. Each area is discussed below.

Beginning in the early 1980s, the BWR Owners' Group began an extensive study of the causes for failure of MSIVs to meet the technical leakage specification limits and extensive person-hours required to maintain these valves. As a result of these studies, the ABWR will use the latest technology for valve maintenance, including mechanical aids for valve disassembly and assembly, automated lapping devices, and slightly relaxed leakage specifications to delete unnecessary maintenance. As a result of these aids, it is estimated that overall maintenance hours will be reduced by 50-60%.

Early studies on dose rates during MSIV maintenance showed increases in dose rate directly proportional to recirculation line activity. The ABWR has deleted the recirculation lines entirely, thereby removing the singly most significant source of radiation in the drywell. The second most significant dose for MSIV operations will be the deposited and suspended activity in the feedwater lines. The deposited activity in the feedwater lines is expected to be lower than typical BWRs owing to an enhanced condensate polishing system, a 2% CUW System, and titanium or stainless steel condenser tubes. Additionally, the ABWR is designed to limit the use of cobalt bearing materials on moving components which have historically been identified as major sources of in-water contamination. Overall, the feedwater line radiation is expected to be a factor of three lower than current BWRs. Because of these factors, it is expected that the effective dose rate in the drywell will be 18 μSv/h and 13 μSv/h in the steam tunnel outboard of the primary containment.

(2) Drywell valve and pump maintenance other than the MSIVs consists primarily of maintaining the safety/relief valves (SRVs), which for the most part consist of minor maintenance or removal of valves to a maintenance facility. Overall typical values for a BWR for these tasks are 1,450 person-hours per year in an effective radiation field of 170 μGy/h. In the ABWR, the primary source of radiation exposure, the recirculation lines and pumps, have been removed. Overall, the reduction in drywell dose levels for these types of maintenance is expected to be a factor of two or 90 μGy/h. Overhead tracks and in-place removal equipment is provided in the ABWR for an estimated person-hour reduction to 1,150 person-hour per year broken down into 200 person-hours for 18 SRV maintenance at 60 μGy/h, 200 person-hours per year to pull and replace 3 RIPs with one heat exchanger at 200 μGy/h, and the remainder on miscellaneous valves at 45 μGy/h.

(3) Control rod drive maintenance is significantly reduced in the ABWR with the introduction of fine motion control rod drives (FMCRDs). Based upon European experience, two FMCRDs will be replaced and repaired per outage along with 20 motors. Estimated work will consist of 64 person-hours under vessel preparation, 40 person-hours FMCRD removal and reinstallation, 200 person-hours motor removal and installation, and 64 person-hours cleanup. Typical under vessel effective dose rates are 170 μGy/h but, because of the removal of the recirculation pumps and lines, dose rates have been reduced to 65 μGy/h.

(4) The LPRM/TIP system assumes the servicing of two sensors per year and is based upon a total of 200 person-hours per year at an effective dose rate of 500 μGy/h, which is typical for BWR operations.

(5) Inservice inspection consists of primarily NDE examination of vessel and piping systems and welds. Typical BWR values are 2400 person-hours per year at 120 μGy/h effective exposure rate. ABWR inservice inspection is estimated based upon the following:

Elimination of recirculation lines and pumps with the following savings:

(a) Elimination of 14 nozzle inspections at 2 per year, saving 360 person-hours.

(b) Elimination of shield penetration and shield plug removal saving 240 person-hours per year.

(c) Reduction on weld inspection on recirculation lines estimated at 240 person-hour per year.

(d) Reduction in drywell dose by 50% based upon the assumption that the contact dose rate on the feedwater line is less than half the contact dose rate on the typical BWR recirculation line. Hence, at equal distances from the line, the total general drywell dose rate which is dominated by the recirculation and feedwater lines will be less than half what is typically seen with recirculation lines.

Overall, it is estimated that by use of automated turtles for inspection, person-hours expended in ISI will be reduced by a factor of two.

The ABWR uses a forged ring pressure vessel in comparison to older plate welded vessels, reducing the total vessel weld length inspection by 30% and the total weld inspection in the drywell by 10%.

The ABWR design incorporates specific access panels and shield doors into required inspection areas permitting easy bypass of insulation areas, resulting in an estimated person-hour savings of 120 person-hours.

Overall person-hours reduction is 1,200 person-hours at approximately half the typical effective dose rate or 55 μGy/h.

(6) Other drywell work includes items such as minor valve maintenance, instrumentation work, and all other drywell work. These miscellaneous tasks in the drywell consume on the average 5,500 person-hours per year in a radiation field of 170 μGy/h. However, this average is a combination of some specific higher radiation tasks such as work on recirculation lines (involving snubbers, weld inspection, etc.) and many lower radiation tasks such as work on drywell coolers. Overall reduction in this effort due to ABWR design improvements are:

(a) Significant savings in total hours are estimated due to removal of the recirculation lines with miscellaneous recirculation line work such as line snubbers, fewer drywell cooling units, and less assembly/disassembly work on insulation due to the use of automated units. Overall, it is estimated that 2,000 person-hours savings can be made.

(b) Overall reduction in the drywell radiation due to removal of the recirculation system results in the reduction of the overall upper drywell dose rate to 18 µGy/h and the lower drywell dose rate to 56 µGy/h, since the components involved such as drywell coolers typically do not carry radioactive inventory. Of the remaining 3,500 person-hours, 2,000 is upper drywell work and 1,500 is lower drywell work.

12.4.2 Reactor Building Dose

The following provides the basis by which the Reactor Building dose estimates for occupational exposure were made.

(1) Vessel access and reassembly typically requires 4500 person-hours of work at an effective dose rate of 30 µGy/h. The ABWR work will involve the use of a stud tensioner for a 96-bolt top head. The projected time to remove 96 bolts with this equipment is between 600 to 1200 person-hours. Due to the larger ABWR vessel and expected reduced water contamination with the improved cleanup system, the estimated projected effective dose rate is 15 µGy/h.

(2) ABWR refueling is accomplished via an automated refueling machine. All operations for refueling are accomplished as described in Section 9.1.4.2.7.1. Time for refueling is reduced from a typical 4,400 person-hours down to 2,000 person-hours and from an effective dose rate of 25 µSv/h to less than 2 µSv/h.

(3) RHR/CUW maintenance work consists of inspections for two pumps per year in each system. In the RHR System this consumes 150 person-hours per year at an effective dose rate of 400 µGy/h. In the CUW System, this typically uses 1400 person-hours per year at an effective dose rate of 140 µGy/h. ABWR will use canned pumps for both systems with an estimated reduction in maintenance to 100 person-hours per pump. With improved water chemistry and overall reductions in reactor water concentrations due to the 2% cleanup system the effective dose rate is estimated at 20% of the typical value for these systems.

(4) FMCRD rebuilding estimates are taken from similar work done in Europe since no significant U.S. data exists to date. Two drives will be rebuilt at an effective dose rate of 45 µGy/h and 30–60 hours per drive.

(5) Instrumentation work typically requires 1,000 person-hours of work per year at an effective dose rate of 50 μGy/h the ABWR should take about the same effort in instrumentation; however, the increased emphasis and improved water chemistry systems, should reduce the effective dose rate to two-thirds the typical value or 30 μGy/h.

(6) All other work in the Reactor Building typically takes 7,400 person-hours per year at an effective dose rate of 28 μGy/h. This work includes all valve work, RIP rebuild work, minor maintenance, and CRD hydraulic line work. The major task in this area is the hydraulic control units which require 5,000 person-hours per year at an effective dose rate of 33 μGy/h. With the use of the FMCRD units, an additional savings of 2,000 person-hours is anticipated. In addition, the ABWR Reactor Building has been designed to provide for ease of maintenance with overhead lifts, coordinated hatch ways and ample space to maintain in place equipment. In addition, with the exception of one tank and the pressure vessel, all the equipment in the Reactor Building is removable with those pieces which can be expected to be moved being palatalized. Because of these factors, an overall reduction in work of 1,000 person-hours is estimated. Because of the improved water chemistry, the overall effective dose rate is anticipated at one-half the typical BWR dose rate.

12.4.3 Radwaste Building Dose

Radwaste Building work consists of water processing, pump and valve maintenance, shipment handling, radwaste management, and general cleanup activity. Radwaste building doses result from routine surveillance, testing, and maintenance of the solid and liquid waste treatment equipment. The liquid treatment system collects liquid wastes from equipment drains, floor drains, filter backwashes, and other sources within the facility. The solid treatment system processes resins, backwash slurries, and sludge from the phase separator. It also processes dry active waste from the plant. Some examples of radwaste activities include resin dewatering, movement of casks and liners, filter handling, resin movement, and installation and removal of mobile radwaste processing skids. Both waste treatment systems are based on current mobile radwaste processing technology and avoid complex permanently installed components. All radwaste tankage and support systems are permanently installed. More of the radwaste operations involve remote handling than in a typical BWR. This more flexible radwaste system and building design, simpler operation, and improved maintenance procedures result in a reduction in the number of total hours in the Radwaste Building radiation areas. The results of an industry assessment indicate that there was a substantial reduction in radiation dose (one plant experienced a factor of eight reduction in radiation dose) relative to the doses specified herein. Based on this experience, it is estimated that the Liquid Waste Management System (LWMS) design will result in a design reduction of the Radwaste Building annual radiation dose by a factor of approximately four (Reference 12.4-5). The average radiation dose rate to workers is provided in Table 12.4-1.

12.4.4 Turbine Building Dose

(1) Typical BWR valve maintenance in the Turbine Building uses 1,150 hours per year at an effective dose rate of 95 µGy/h. The valve maintenance requirements for the ABWR do not vary significantly over current plants; therefore, the total hours for this type of work is assumed to be approximately the same excepting minor adjustments for improved valves, maintenance jigs, and automated devices, which will lower the estimated maintenance time to 1,000 hours. In the ABWR, the estimated effective radiation field of 39 µGy/h for Turbine Building work is expected to be less than half the typical dose rate of 95 µGy/h due to the use of newer fuels which are more resistant pin-size leaks. The radiation fields in the turbine hall during maintenance are a combination of contamination from fission products from the fuel and corrosion products from the vessel and piping. Offgas measurements of the performance of the newer fuels, when operated under proper water chemistry standards (required for ABWR), have shown fission product release an order of magnitude less than older fuels. Likewise, the ABWR has placed stringent controls over material usage especially in the vessel and other high temperature components to minimize corrosion product releases.

(2) In a similar fashion, the turbine maintenance work typically requires 18,500 hours of work at an effective dose rate of 3 µGy/h. With additional operational improvements in automating turbine maintenance, overall work is estimated to be reduced to 15,500 hours. The effective dose rate for the turbine is not expected to be as sensitive to fuel performance as will the turbines but is estimated to reflect a decrease in dose to 2 µGy/h for turbine overhaul work.

(3) Work on the turbine hall condensate system typically requires 2,000 hours per year at an effective dose rate of 75 µGy/h. The condensate system in the ABWR uses hollow-fiber filled filters which require half the maintenance of a typical system. In addition, with the plant incorporating Fe control in the Feedwater System and a significant reduction in cobalt bearing materials, the overall effective dose rate is estimated at half the above value.

(4) Other work in the Turbine Building typically takes 13,140 hours per year at an effective dose rate of 1 µGy/h. Only minor changes can be assumed with the ABWR with some remote operations and slight reductions in operating exposures. For the ABWR, it is estimated that a 10% reduction can be realized with improving technology with no significant change in dose rate.

12.4.5 Work at Power

Work at power typically requires 5,000 hours per year at an effective dose rate of 66 µSv/h for the BWR. This category covers literally all aspects of plant maintenance performed during normal operations from health physics coverage to surveillance, to minor equipment adjustment, and minor equipment repair. Overall, the ABWR has been designed to use more automatic and remote equipment. It is expected that items of routine monitoring will be performed by camera or additional instrumentation. Most equipment in the ABWR is palatalized, which permits quick and easy replacement and removal for decontamination and repair. Therefore, a reduction in actual hours needed at power is estimated at 1,000 hours less than the typical value. In the area of effective dose rate, the ABWR is expected to have significantly lower general radiation levels over current plants, owing to more stringent water chemistry controls, a full flow condensate flow system, a 2% cleanup water program, titanium or stainless steel condenser tubes, Fe feedwater control, and low cobalt usage. In addition, the ABWR has in the basic design, compartmentalized all major pieces of equipment so that any piece of equipment can be maintained or removed for maintenance without affecting normal plant operations. This design concept thereby reduces radiation exposure to personnel maintaining or testing one piece of equipment from both shine and airborne contamination from other equipment. Finally, the ABWR has incorporated in the basic design the use of hydrogen water chemistry (HWC) and the additional shielding necessary to protect from the factor of six increase in N-16 shine produced through the steamlines into the Turbine Building. For normally occupied areas, sufficient shielding is provided to protect from N-16 shine. In areas which may be occupied temporarily for specific maintenance or surveillance tasks and where additional shielding is not appropriate (for the surveillance function) or deemed reasonable, the HWC injection can be stopped causing the N-16 shine to decrease to within normal operating BWR limits within 90 seconds and thus permitting those actions needed. Overall, it is estimated that the effective dose rate for work at power will be slightly over two thirds the typical rate or 40 µSv/h.

12.4.6 References

12.4-1 CDCC-2009-100118, “Occupational Radiation Exposure Experience for ABWRs in Japan”, Revision 3, December 2009.

12.4-2 Not Used.

12.4-3 Not Used..

12.4-4 CDCC-2009-100119, “Evaluation of Expected Annual Radiation Exposure at an ABWR”, Revision 3, December 2009.

12.4-5 “Performance Evaluation of Advanced LLW Liquid Processing Technology, Boiling Water Reactor Liquid Processing,” EPRI Technical Report 1003063, November 2001.

Table 12.4-1 Projected Annual Radiation Exposure

Operation Task	Tier 2 Section	hours per year	μSv/h	person-mSv/yr
Drywell				
MSIV	12.4.1(1)	~4,200	15	63
SRV, RIP, etc	12.4.1(2)	1,150	75	86
FMCRD	12.4.1(3)	370	65	24
LPRM/TIP	12.4.1(4)	200	500	100
ISI	12.4.1(5)	1,200	55	66
Other	12.4.1(6)	3,500	35	123
Total		10,620		462
Reactor Building				
Vessel	12.4.2(1)	1,200	15	18
Refueling	12.4.2(2)	2,000	2	4
RHR/CUW	12.4.2(3)	400	54	22
FMCRD	12.4.2(4)	120	45	5
Instrument	12.4.2(5)	1,000	30	30
Other	12.4.2(6)	4,400	15	66
Total		9,120		145
Radwaste Building	12.4.3	1,000	25	25
Turbine Building				
Valve Maintenance	12.4.4(1)	1,000	39	39
Turbine Overhaul	12.4.4(2)	15,500	2	31
Condensate	12.4.4(3)	1,000	35	35
Other	12.4.4(4)	11,800	1	12
Total		29,300		117
Work at Power	12.4.5	4,000	40	160
Totals		54,040		909