12.4 DOSE ASSESSMENT

12.4.1 ANTICIPATED DOSE RATES

Peak external dose rates expected are those given as the maximum dose rates present in a designated access zone area shown in Figures 12.3-1 through 12.3-8. The access area zones have been designated by either anticipated radiation level of the equipment in the area or the desired radiation levels to be achieved through shielding. The peak external doses are not expected to occur during normal operation but could occur due to infrequent anticipated operational occurrences during which times the plant might be operating with maximum coolant activities corresponding to one percent defective fuel cladding. The annual average isotopic concentrations of fission products are expected to be much less than the design maximum, and therefore the actual dose rates in a given zone are expected to be significantly less (approximately one eighth of the design maximum) than the maximum calculated dose rate in that zone. Another source of radiation exposure within the plant comes from airborne radionuclides. Occupational exposure to the source is usually insignificant in comparison to direct radiation exposure. However under certain circumstances of coolant leakage in containment coupled with high coolant activity, doses from airborne activity could become a major fraction of the allowed limits. Proper purging however should maintain airborne exposures so low that their contribution to the total man-rem is insignificant in comparison with exposure to direct radiation.

Radiation exposures from direct radiation at locations outside the plant structures are insignificant since there are no potential sources of radiation outside the plant structures. Therefore the total exposure from the plant is given essentially by the occupational exposure to direct radiation within plant structures. Inside equipment compartments or adjacent to equipment carrying radioactive material, the anticipated dose rates will result from the function of the equipment. The highest doses in the plant occur in Zone V areas, such as in rooms containing equipment and piping handling highly radioactive fluids, or in the containment. Again it is emphasized that experience in the design of power plants shows that the measured radiation levels are usually less than those used as shielding design objectives for controlling the radiation doses. The annual doses received by the plant personnel will therefore be well below the limits of 10CFR20 since the plant shielding and access control are designed based on radiation levels from maximum coolant activities.
→ (DRN 99-2362)
The main control room and office areas in the Reactor Auxiliary Building will be Zone I areas and hence will have a maximum allowable dose rate of 0.25 mrem/hr as in Table 12.3.1. Therefore, annual doses in these areas, considering occupancy factor, will be well within the limits of IOCFR20, particularly since the expected dose rates in those areas will be well below 0.25 mrem/hr. PWR operating experience confirms the above assertions.
← (DRN 99-2362)

12.4.2 ESTIMATES OF PLANT PERSONNEL EXPOSURES (Direct)

12.4.2.1 General

The annual direct exposure that could be received by plant personnel during reactor operations and surveillance, routine and special maintenance, in-service inspection, radwaste handling and refueling has been estimated to verify that personnel exposures would be less than 10CFR20 limits.
→(DRN 02-110)
The expected doses to individuals at or beyond the site boundary are shown in Table 11.3-7.
←(DRN 02-110)

For the purposes of the estimate, reactor operations and surveillance, routine and special maintenance, in-service inspection, radwaste handling and refueling have been defined as follows:

a) Reactor Operations and Surveillance: Include main control room work, local operations such as valve alignment, starting and stopping pumps, operation of radwaste system (but not the actual handling of the solid wastes), periodic jobs such as sampling, radiation and contamination surveys, occasional lubrication, etc.

b) Routine and Special Maintenance: Routine maintenance includes periodic preventive maintenance operations such as oil changes, controls calibration, performance tests, and overhauls with possible preventive repairs. Special maintenance include unplanned repairs, or infrequent major jobs such as steam generator tube plugging, etc.

c) In-service Inspection: Primarily inspection for pressure boundary integrity. As such the testing includes removal of insulation, testing of the component installation of the insulation, and possibly the removal of the reactor vessel fuel and internals.

Exposures from routine operational inspections are not included in in-service inspection, nor are those associated with work on steam generation parts. The former are included in a) and the latter in b).

→ (DRN 99-2362)

d) Radwaste Handling: Includes actual handling operations of the plant wastes such as resin and concentrates handling, filter handling, and handling of low activity wastes such as rags, plastics, etc.

← (DRN 99-2362)

e) Refueling: Include exposures associated with all phases of refueling operations, but does not include exposures from surveillance or maintenance which for convenience may take place concurrently with refueling operations, but which are not part of refueling.

The assumptions in the estimate are as follows:

a) The power plant is staffed by the personnel shown in the organizational chart of Chapter 13.

b) The plant is operated in continuous shifts. Each shift should have as a minimum four members who hold an NRC license.

In addition two more auxiliary operators will be part of the shift. At all times at least two and often three of the above will be in the main control room. Two or three will be able to perform routine surveillance and inspection functions in other areas of the plant.

c) Maintenance personnel are normally available during the day shift only. On Shift Maintenance personnel cover all shifts normally performing preventive maintenance activities.

d) Shift Technical Advisors are on continuous shifts.

→(DRN 02-110)

From an operational basis, the Annual Radioactive Effluent Release Report provides an assessment of radiation doses to the public due to liquid and gaseous radioactive effluents.

←(DRN 02-110)

→(DRN 03-1135, R13)

The technical staff will spend most or all of their time in uncontrolled areas where the radiation levels are expected to be less than 0.03 mr/hr. For instance the Engineering Personnel will be involved essentially in office work except during refueling. Likewise the Radiation Protection Manager, the Chemistry Superintendent and their Associates and Technicians will spend a considerable part of their shift in office work. The Radiation Protection Technicians however, will be engaged in periodic plant surveys and Health Physics Technicians will be present during many maintenance operations. The technicians may spend approximately one third of their shifts in laboratory work and collecting certain samples.

←(DRN 03-1135, R13)

→(DRN 02-110, R12)

Actual annual exposure received during the plant operation years has been less than the estimated exposure listed in Table 12.4-1a. ALARA concepts and gained operation experiences with strong management support contributed to the exposure drop during the past years.

←(DRN 02-110, R12)

12.4.2.2 Reactor Operations and Surveillance

Exposures for reactor operations and surveillance are primarily incurred by operation personnel which patrol the plant during all shifts and operates it. The technical staff performs the majority of their work in offices and laboratories except for the surveys of the plant performed by Health Physics personnel and the collection of local samples by chemistry personnel.

The operations people, primarily the auxilary operators, patrol the plant every shift, check for leaks, inspect equipment, and during the day shift operate the blowdown, boric acid, and waste management systems. They also perform minor lubrication Jobs.

The exposures listed in Table 12.4-la are predicated on surveillance of the plant with inspection for checkup of every active equipment, and daily operation of the blowdown, boric acid, and waste management system panels.

The total exposures predicted agree reasonably well with the average exposures for reactor operation and surveillance deduced from Reference 1.

→(DRN 02-110, R12)

Actual annual exposure received during the plant operation years has been less than the estimated exposure listed in Table 12.4-1a. ALARA concepts and gained operation experiences with strong management support contributed to the exposure drop during the past years.

←(DRN 02-110, R12)

12.4.2.3 Maintenance

Two kinds of maintenance are performed in a power plant: routine maintenance and special maintenance. Exposures resulting from the former can be estimated by examining each individual maintenance item, identifying the personnel required, the time involved, and computing the resulting exposures. This maintenance includes the testing and check out of equipment, lubrication, etc, which are normally performed by the operators; tasting and calibration of controls, valve maintenance, overhaul, sump cleaning and so on, which are performed by maintenance personnel.

Special maintenance includes jobs of unanticipated occurrence and frequency. Estimates of the exposures from this type of maintenance are therefore, based entirely on past experience (References 1 and 2).

Table 12.4-lb lists a breakdown of the activities estimated for maintenance at the Waterford 3 Plant.

The exposures associated with each activity have been derived considering the time and number of personnel required to perform routine maintenance of pumps, compressors, and selected instrumentation.

The maintenance involves oil changing, greasing, disassembly, including "cutting and rewelding, removal to hot machine or instrumentation shop, reassembly, etc. For general valve maintenance and instrumentation and control work, exposures have been derived from Reference 2. The distribution of these exposures is allocated to the individual disciplines in the table on the basis of the efforts normally required by the disciplines to perform an individual valve maintenance.

Exposures resulting from special maintenance have also been derived from Reference 2. Guidance from that document and operating utilities reports have been used to distribute the exposures for special maintenance among the worker's categories.

It has been assumed that major repair work would be handled by outside contractors. From Reference 2, the average amount of exposure in manrem for major equipment failure type work has been derived to be approximately 30 man-rems.

→(DRN 02-110)

Actual annual exposure received during the plant operation years has been less than the estimated exposure listed in Table 12.4-1a. ALARA concepts and gained operation experiences with strong management support contributed to the exposure drop during the past years.

←(DRN 02-110)

12.4.2.4 In-service Inspection

→ (DRN 99-0823)

It is expected that exposures from in-service inspection activities will be borne primarily by outside contractors, site non-desctructive examination, and operation personnel with some exposure received by Waterford 3 supervisory personnel.

Exposures due to inservice inspection activities have averaged approximately 8.2 man-rem per outage. This average is based on the exposure received during outages contained in the first inservice inspection interval. Therefore, in Table 12.4-1, the total exposure for inservice inspection is estimated also as 5.5 man-rem per year.

← (DRN 99-0823)

12.4.2.5 Waste Processing

Exposures resulting from waste handling evolutions are primarily confined to operating personnel and Radwaste personnel who operate the solid waste handling and solidification area, perform the spent resin transfers, perform the periodic filter replacements, and package the low activity radioactive wastes. Some additional exposure will also be received by Health Physics and Chemistry personnel who support the sampling and radiological monitoring activities affiliated with waste processing activities.

→ (DRN 99-2362)

A large fraction of the exposure will result from filter handling. The exposures for this operation have been estimated by assuming a frequency of filter change based on plant experience for that type of filter and a sequence of operation. The sequence of operation involves the installation of the filter transfer shield container, unbolting and swinging the filter head, withdrawal of the filter, removal of the shield container and transport to the filter packaging area. insertion of new filter and repetition of the opening phases in reverse.

←(DRN 99-2362)

→(DRN 02-110)

Actual annual exposure received during the plant operation years has been less than the estimated exposure listed in Table 12.4-1a. ALARA concepts and gained operation experiences with strong management support contributed to the exposure drop during the past years.

←(DRN 02-110)

12.4.2.6 Refueling Operations

Exposures during refueling have been estimated on the basis of known tasks and estimated time required for the performance of these tasks. The forecasted exposures are tabulated by personnel categories in Table 12.4 – 1 a&b. These exposures do not include exposures resulting from maintenance (either special or routine) or in-service inspection activities which are likely to be conducted during the refueling outage. Of the total exposure, approximately nine man-rem are associated with the actual fuel handling operations. 18 man-rem are associated with health physics surveys and building decontamination with the remaining 35 man-rem being due to head removal and reinstallation.

It must be emphasized that exposures during refueling are difficult to evaluate on the basis of predicted) dose rates, since the number of persons involved will vary. Experience (3) indicates that approximately 29 manrem occur at PWR plants per removal and reinstallation of the head. These exposures appear to be primarily due to activation products accumulation in the control rod drive mechanism. The predicted exposures are then in good agreement with those experienced in the past. The exposures accrued during the actual fuel handling may vary between six and 33 man-rem/yr. This range appears to be caused by random difficulties encountered in the removal and replacement of fuel assemblies. The nine man-rem of this estimate considers such difficulties only to the extent of employing two full weeks for the fuel shuffling operation. Since these difficulties are encountered commonly, the personnel dose could be higher.

→(DRN 02-110)

Actual annual exposure received during the plant operation years has been less than the estimated exposure listed in Table 12.4-1a. ALARA concepts and gained operation experiences with strong management support contributed to the exposure drop during the past years.

←(DRN 02-110)

12.4.2.7 Comparison With Exposure Experience at Other PWR Plants

Table 12.4-2 presents data on total number of personnel and total annual dose in operating PWRs. These data are taken from References 1 and 3 and is further supported by data given in Reference 2. Data from this table is reduced to a weighted average expressing the average man-rem for operating power plants in Table 12.4-3, which also shows the good agreement between this average and the exposure estimated for Waterford 3.

Table 12.4-4 derived from Reference 1, lists the distribution of man-rem doses for various functions of operating light water reactors (including BWRs) and compares it with that estimated for Waterford 3.

SECTION 12.4: REFERENCES

1. NUREG-0322. Ninth Annual Occupational Radiation Exposure Report. 1976 . USNRC Office of Management. Information and Program Control. Oct. 1977

2. National Enviromental Studies Project. Compilation and Analyses of Data on Occupational Radiation Exposure Experienced at Operating Nuclear Power Plants SAI Services. Sept. 1974

3. Murphy, T D et al. NUREG-75/032. Occupational Radiation Exposure at Light Water Cooled Power Reactors 1969-1974 . USNRC Radiological Assessment Branch. June, 1975

TABLE 12.4-1a Revision 11 (05/01)

ESTIMATE OF PERSONNEL EXPOSURE (MAN-REM)

Activity	Total Man-Rem/Yr.	Operation & Maintenance Supv./ Control & Maint Op/ Maintenance Op.	Maintenance			Tech Staff			Others		
			Mech.	Elect	I & C	Nucl. Eng./Asso. Nuc. Eng.	Health Phys/ Engr. Tech/ Tech	Chem Eng/ Asso. Eng/ Engr. Tech/ Tech	QA	NSSS	Contr.
Reactor Operations & Surveillance	17.5	13.0				0.115	2.25	2.25			
Maintenance → (DRN 99-0823)	291	35.0	120	3.0	7.0	-	25.0	-	1	20	80
In-service Insp. ← (DRN 99-0823)	5.5	2.0								1.5	2.0
Waste Processing	5.5	2.3					1.15	1.1			1.0
Refueling → (DRN 99-0823)	51	7.0	17.8	0.2	1.9	1.8	1.67	1.0		2.5	1.2
Total ← (DRN 99-0823)	370.5	59.3	138	3.0	9	2.0	46	4	1	24	84.2

TABLE 12.4-1b (Sheet 1 of 2) Revision 11-A (02/02)

ESTIMATE OF PERSONNEL EXPOSURE DURING MAINTENANCE (MAN-REM)

	Maintenance				Tech Staff			Others		
Activity	Operation & Maintenance Supv./ Control & Maint Op/ Maintenance Op.	Mech. Eng.	Elect	I & C	Nucl. Eng./Asso. Nuc. Eng.	Health Phys/ Engr. Tech/ Tech	Chem Eng/ Asso. Eng/ Engr. Tech/ Tech	QA	NSSS	Outside Contractor
ROUTINE MAINT.										
a) Waste Gas Compressors	.085	0.56	0.26	-	-	0.16	-	-	-	-
b) All Valve Work	2.4	8.2	0.4	0.4	-	1.7	-	-	-	-
c) Inst. & Controls	-	-	-	5.8	-	3.6	-	-	-	-
d) Charging Pumps	.09	2.16	0.22	0.27	-	0.48	-	.04	-	-
e) BA Condensate Tanks & Pumps	.02	0.37	0.04	-	-	0.16	-	-	-	-
f) Hold-Up Pumps	.03	0.55	0.06	-	-	0.24	-	-	-	-
g) BA Make-up Tanks & Pumps	.02	1.27	0.55	-	-	0.175	-	-	-	-
h) Sump Pumps & Sumps	0.12	6.44	0.48	-	-	3.92	-	-	-	-
i) Waste Condensate Tanks, Laundry Tanks & Pumps	0.04	1.48	0.16	-	-	0.64	-	-	-	-
j) Waste Tanks & Pumps	0.06	1.44	0.08	0.12	-	0.32	-	-	-	-
k) Shutdown HX Room	0.06	-	-	0.03	-	0.015	-	-	-	-
l) Safety Inj. Pumps	0.27	8.0	0.48	0.81	-	1.92	-	0.32	-	-
m) BA & Waste Concentratr.	0.10	0.20	0.05	0.10	-	0.10	-	-	-	-
n) Process Monitors →(DRN 00-1046)	0.18	1.8	-	-	-	0.18	-	-	-	-
o) Hot Tool Room ←(DRN 00-1046)	0.10	0.20	0.05	0.10	-	0.10	-	-	-	-
p) Concentrate Tank	-	0.45	0.07	-	-	0.07	-	-	-	-
q) Containment Work	1.0	-	1.0	-	-	1.0	-	-	-	-

TABLE 12.4-1b (Sheet 2 of 2)

ESTIMATE OF PERSONNEL EXPOSURE DURING MAINTENANCE (MAN-REM)

		Maintenance			Tech Staff				Others	
Activity	Operation & Maintenance Supv./ Control & Maint Op/ Maintenance Op.	Mech. Eng.	Elect	I & C	Nucl. Eng./Asso. Nuc. Eng.	Health Phys/ Engr. Tech/ Tech	Chem Eng/ Asso. Eng/ Engr. Tech/ Tech	QA	NSSS	Outside Contractor
SPECIAL MAINT.										
a) Major Equipment Failure	-	-	-	-	-	-	-	-	-	30
b) S.G. Repair	11	45	-	-	-	3	-	0.2	10	45
c) Main Coolant Loops	5	11	-	-	-	2	-	0.2	1	-
d) R.C. Pump	5	7	-	-	-	2.5	-	0.2	2	-
e) Fuel Pool Decon. Weld	2	4	-	-	-	1	-	-	-	-
f) Maint. of Loose Parts Mon. Syst.	1	-	-	-	-	-	-	-	-	1
g) Chem & Vol. Control Syst.	1	2	-	-	-	.5	-	-	1	-
h) Pressurizer	3.5	9	-	-	-	1.0	-	-	-	-
i) Clean Up Containment	2	9	-	-	-	1.0	-	-	-	-
j) Constr. Work on Plant	-	-	-	-	-	-	-	-	-	5
k) Work Inside Reactor Vessel	-	-	-	-	-	-	-	-	5	-
GRAND TOTAL	35.6	1.20	2.3	7.6	-	25.3	-	.96	20	81
TOTALS ROUNDOFF	35	1.20	3.0	7.0	-	25.0	-	1.0	20	80

TABLE 12.4-2 (Sheet 1 of 2)

DATA FROM OPERATING PWR PLANTS [a]

Year	Plant	Designed Power Level (MWe)	Total No. of Personnel	Total Annual Dose (Man-Rem)
1970	Connecticut Yankee	575	734	689
	San Onofre - Unit 1	450	251	155
1971	Connecticut Yankee	575	289	342
	Ginna	490	340	430
	San Onofre - Unit	450	121	50
1972	Connecticut Yankee	575	355	325
	Ginna	490	677	1,032
	Point Beach - Unit 1	497	NA	580
	Robinson	707	245	215
	San Onofre - Unit 1	450	326	256
1973	Connecticut Yankee	575	841	673
	Ginna	490	421	244
	Palisades	821	901	1,109
	Point Beach - Units 1 & 2 (2nd Unit 4/73)	497, 497	729	570
	Robinson	707	831	695
	San Onofre - Unit 1	450	878	329
1974	Connecticut Yankee	575	550	201
	Fort Calhoun	457	327	71
	Ginna	490	884	1,225
	Haddam Neck	575	550	201
	Maine Yankee	790	610	420
	Oconee - Unit 1	886	844	517
	Palisades	821	774	627
	Point Beach - Units 1 & 2	497, 497	400	295
	Robinson	707	853	672
	San Onofre	450	219	71
	Surry - Units 1 & 2 (Unit 2 5/73)	823, 823	1,715	884
	Turkey Point - Units 3 & 4 (Units 4 9/73)	745, 745	794	454

a. These are taken from data for operating PWR plants given in Reference 1 and 3. In compiling this table, generally data from the first year of plant operation has not been considered. Only data from those PWR plants that are designed to operate at power levels greater than or equal to 450 MWe were chose.

NA: Not available

TABLE 12.4-2 (Sheet 2 of 2)

Year	Plant	Designed Power Level (MWe)	Total No. of Personnel	Total Annual Dose (Man-Rem)
1975	Arkansas One Unit 1	850	147	21
	Calvert Cliffs 1	1,065	783	77
	Fort Calhoun	457	469	294
	Haddam Neck	575	685	538
	Kewaunee	560	104	28
	Maine Yankee	790	440	319
	Oconee Unit 1	886	829	497
	Palisades	821	495	306
	Point Beach 1 & 2	497, 497	339	459
	Robinson	707	849	1,142
	San Onofre	450	424	292
	Surry 1 & 2	823, 823	1,948	1,649
	Turkey Point 3 & 4	745, 745	1,176	876
1976	Arkansas One Unit 1	850	476	289
	Calvert Cliffs	1,065	507	74
	D C Cook	1,090	395	116
	Fort Calhoun	457	516	313
	Haddam Neck	575	758	636
	Kewaunee	560	381	270
	Maine Yankee	790	244	85
	Oconee 12	886	1,215	1,026
	Palisades	821	742	696
	Point Beach 1 & 2	447	313	459
	Prairie Island 1 & 2	NA	818	447
	Robinson	707	597	715
	San Onofre	450	1,330	880
	Surry 1 & 2	823, 823	2,753	3,165
	Three Mile Island	819	819	286
	Turkey Point 3 & 4	745, 745	1,647	1,184
	Zion 1 & 2	1,015, 1,015	774	571

TABLE 12.4-3

YEARLY AVERAGES AND GRAND AVERAGE FOR NUMBER OF PERSONNEL

AND MAN-REM DOSES FOR OPERATING PWR PLANTS [a]

Year	No. of Units	Total No.of Personnel	Total Man-Rem Dose	Average No. of Personnel	Average Man-Rem Dose
1970	2	985	844	493	422
1971	3	750	822	250	274
1972	5	1,603[b]	2,408	401	482
1973	7	4,601	3,620	657	517
1974	15	8,529	5,538	568	369
1975	16	9,483	7,794	593	487
1976	23	15,416	12,031	670	523
1970 - 1976	71	41,367[c]	33,057	583	466

(a) This table is based on the data given in Table 12.4-2.

(b) The entry corresponds to four plants only, since no information on personnel is available for Point Beach, Units 1.

(c) The entry corresponds to a total of 70 plants only.

TABLE 12.4-4

DISTRIBUTION MAN-REM DOSES
FOR VARIOUS FUNCTIONS

	Operating Light Water Reactors* (Includes BWRs)	Waterford 3
	Percentage of Total Man-Rem	Percentage of Total Man-Rem
Reactor Operation & Surveillance	10.4	4.2
Maintenance (Routine & Special)	71.2	70.5
In-Service Inspection	5.7	11.8
Waste Processing	4.8	1.3
Refueling	7.9	12.2

* Reference 1 Table 5 1976 data