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Occupational Radiation Exposure at Commercial Nuclear Power Reactors and other Facilities 1997

Thirtieth Annual Report

U.S. Nuclear Regulatory Commission

Office of Nuclear Regulatory Research

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NUREG-0713	Occupational Radiation Exposure at Commercial Nuclear Power Reactors 1979, Vol. 1, U.S. Nuclear Regulatory Commission, March 1981.
NUREG-0713	Occupational Radiation Exposure at Commercial Nuclear Power Reactors 1980, Vol. 2, U.S. Nuclear Regulatory Commission, December 1981.
NUREG-0713	Occupational Radiation Exposure at Commercial Nuclear Power Reactors 1981, Vol. 3, U.S. Nuclear Regulatory Commission, November 1982.
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NUREG-0713	Occupational Radiation Exposure at Commercial Nuclear Power Reactors 1983, Vol. 5, U.S. Nuclear Regulatory Commission, March 1985.
NUREG-0713	Occupational Radiation Exposure At Commercial Nuclear Power Reactors and Other Facilities 1984, Vol. 6, U.S. Nuclear Regulatory Commission, October 1986.
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NUREG-0713	Occupational Radiation Exposure At Commercial Nuclear Power Reactors and Other Facilities 1987, Vol. 9, U.S. Nuclear Regulatory Commission, November 1990.
NUREG-0713	Occupational Radiation Exposure At Commercial Nuclear Power Reactors and Other Facilities 1988, Vol. 10, U.S. Nuclear Regulatory Commission, July 1991.
NUREG-0713	Occupational Radiation Exposure At Commercial Nuclear Power Reactors and Other Facilities 1989, Vol. 11, U.S. Nuclear Regulatory Commission, April 1992.
NUREG-0713	Occupational Radiation Exposure At Commercial Nuclear Power Reactors and Other Facilities 1990, Vol. 12, U.S. Nuclear Regulatory Commission, January 1993.
NUREG-0713	Occupational Radiation Exposure At Commercial Nuclear Power Reactors and Other Facilities 1991, Vol. 13, U.S. Nuclear Regulatory Commission, July 1993.
NUREG-0713	Occupational Radiation Exposure At Commercial Nuclear Power Reactors and Other Facilities 1992, Vol. 14, U.S. Nuclear Regulatory Commission, December 1993.
NUREG-0713	Occupational Radiation Exposure At Commercial Nuclear Power Reactors and Other Facilities 1993, Vol. 15, U.S. Nuclear Regulatory Commission, January 1995.
NUREG-0713	Occupational Radiation Exposure At Commercial Nuclear Power Reactors and Other Facilities 1994, Vol. 16, U.S. Nuclear Regulatory Commission, January 1996.
NUREG-0713	Occupational Radiation Exposure At Commercial Nuclear Power Reactors and Other Facilities 1995, Vol. 17, U.S. Nuclear Regulatory Commission, January 1997.
NUREG-0713	Occupational Radiation Exposure At Commercial Nuclear Power Reactors and Other Facilities 1996, Vol. 18, U.S. Nuclear Regulatory Commission, February 1998.

Previous reports in the NUREG-0714 series, which are now combined with NUREG-0713, are as follows:

WASH-1350-R1 through WASH-1350-R6	First through Sixth Annual Reports of the Operation of the U.S. AEC's Centralized Ionizing Radiation Exposure Records and Reporting System, U.S. Atomic Energy Commission.
NUREG-75/108	Seventh Annual Occupational Radiation Exposure Report for Certain NRC Licensees - 1974, U.S. Nuclear Regulatory Commission, October 1975.
NUREG-0119	Eighth Annual Occupational Radiation Exposure Report for 1975, U.S. Nuclear Regulatory Commission, October 1976.
NUREG-0322	Ninth Annual Occupational Radiation Exposure Report for 1976, U.S. Nuclear Regulatory Commission, October 1977.
NUREG-0463	Tenth Annual Occupational Radiation Exposure Report for 1977, U.S. Nuclear Regulatory Commission, October 1978.
NUREG-0593	Eleventh Annual Occupational Radiation Exposure Report for 1978, U.S. Nuclear Regulatory Commission, January 1981.
NUREG-0714	Twelfth Annual Occupational Radiation Exposure Report for 1979, Vol. 1, U.S. Nuclear Regulatory Commission, August 1982.
NUREG-0714	Occupational Radiation Exposure, Thirteenth and Fourteenth Annual Reports, 1980 and 1981, Vols. 2 and 3, U.S. Nuclear Regulatory Commission, October 1983.
NUREG-0714	Occupational Radiation Exposure, Fifteenth and Sixteenth Annual Reports, 1982 and 1983, Vols. 4 and 5, U.S. Nuclear Regulatory Commission, October 1985.

ABSTRACT

This report summarizes the occupational exposure data that are maintained in the U.S. Nuclear Regulatory Commission's (NRC) Radiation Exposure Information and Reporting System (REIRS). The bulk of the information contained in the report was compiled from the 1997 annual reports submitted by six of the seven categories[1] of NRC licensees subject to the reporting requirements of 10 CFR 20.2206. Since there are no geologic repositories for high level waste currently licensed, only six categories will be considered in this report.

Annual reports for 1997 were received from a total of **296** NRC licensees, of which **109** were operators of nuclear power reactors in commercial operation. Compilations of the reports submitted by the 296 licensees indicated that **142,730** individuals were monitored, **75,291** of whom received a measurable dose (Table 3.1). The collective dose incurred by these individuals was **19,841** person-rem which represents a **9% decrease** from the 1996 value. The number of workers receiving a measurable dose also decreased, resulting in the average measurable dose of **0.26** rem for 1997. The average measurable dose is defined to be the total collective dose (TEDE) divided by the number of workers receiving a measurable dose. These figures have been adjusted to account for transient reactor workers.

In 1997, the annual collective dose per reactor for light water reactor licensees (LWRs) was **157** person-rem. This represents a 9% decrease from the value reported for 1996. The annual collective dose per reactor for boiling water reactors (BWRs) was **205** person-rem and, for pressurized water reactors (PWRs), it was **132** person-rem.

Analyses of transient worker data indicate that **31,065** individuals completed work assignments at two or more licensees during the monitoring year. The dose distributions are adjusted each year to account for the duplicate reporting of transient workers by multiple licensees. In 1997, the average measurable dose calculated from reported data was **0.22** rem. The corrected dose distribution resulted in an average measurable dose of **0.26** rem.

[1] Commercial nuclear power reactors; industrial radiographers; fuel processors (including uranium enrichment), fabricators, and reprocessors; manufacturers and distributors of byproduct material; independent spent fuel storage installations; facilities for land disposal of low-level waste; and geologic repositories for high-level waste.

EDITOR'S NOTE

The NRC currently has a five-year contract with Science Applications International Corporation (SAIC) to assist the NRC Staff in the preparation of the NUREG-0713 series. Mr. Charles Hinson (NRR) assisted in the preparation of this NUREG, serving as the NRC Technical reviewer. SAIC will be suggesting changes in the presentation of certain data in these reports. Readers should be alert to these changes, and the NRC welcomes responses, especially where these changes can be improved upon.

Comments should be directed to:

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Foreword

NUREG-0713, Volume 19, summarizes the 1997 occupational radiation exposure data maintained in the U.S. Nuclear Regulatory Commission's Radiation Exposures Information Reporting System (REIRS). Certain classes of licensees are required to annually report individual exposures in accordance with 10 CFR 20.2206.

The occupational radiation exposure data contained in this volume of NUREG-0713 is a compilation of the annual reports received from 300 licensees required to submit annual reports. The annual collective dose decreased by 9% overall from 1996 to 1997. This decrease is partially a result of a decrease in the total number of workers who received a measurable dose. This decrease is shown in Table 3.1 of this NUREG.

John W. Craig, Director
Division of Regulatory Applications
Office of Nuclear Regulatory Research

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PREFACE

A number of NRC licensees have inquired as to how the occupational radiation exposure data that are compiled from the individual exposure reports required by § 20.2206 and the annual dose data reported by work function in accordance with Subsection 6.9.1.5 of the standard technical specifications for nuclear power plants are used by the NRC staff. This is a very appropriate inquiry that may be of importance to many affected licensees. In combination with other sources of information, the principal uses of the data are to provide facts regarding routine occupational exposures to radiation and radioactive material that occur in connection with certain NRC-licensed activities. These facts are used by the NRC staff as indicated below:

1. The data permit evaluation, from the viewpoint of trends, of the effectiveness of the overall NRC/licensee radiation protection and ALARA efforts by certain licensees. They also provide for the identification (and subsequent correction) of unfavorable trends.

2. The external dose data assist in the evaluation of the radiological risk associated with certain categories of NRC-licensed activities and are used for comparative analyses of radiation protection performance: US/foreign, BWRs/PWRs, civilian/military, facility/facility, nuclear industry/other industries, etc.

3. The data provide for the monitoring of transient workers who may affect dose distribution statistics through multiple counting.

4. The data help provide facts for evaluating the adequacy of the current risk limitation system (e.g., are individual lifetime dose limits, worker population collective dose limits, and requirements for optimization needed?).

5. The data permit comparisons of occupational radiation risks with potential public risks when action for additional protection of the public involves worker exposures.

6. The data are used in the establishment of priorities for the utilization of NRC health physics resources: research, standards development, and regulatory program development.

7. The data provide facts for answering Congressional and Administration inquiries and for responding to questions raised by the public.

8. The data provide information that may be used in the planning of epidemiological studies.

Occupational Radiation Exposure
at Commercial Nuclear Power Reactors and Other Facilities
Thirtieth Annual Report, 1997

1 INTRODUCTION

One of the basic purposes of the Atomic Energy Act and the implementing regulations in Title 10, Code of Federal Regulations, Chapter I, Part 20, is to protect the health and safety of the public, including the employees of the licensees conducting operations under those regulations. Among the regulations designed to ensure that the standards for protection against radiation set out in 10 CFR 20 are met is a requirement that licensees provide individuals likely to be exposed to radiation with devices to monitor their exposure. Each licensee is also required to maintain indefinitely records of the results of such monitoring. However, there was no initial provision that these records or any summary of them be transmitted to a central location where the data could be retrieved and analyzed.

On November 4, 1968, the U.S. Atomic Energy Commission (AEC) published an amendment to 10 CFR 20 requiring the reporting of certain occupational radiation exposure information to a central repository at AEC Headquarters. This information was required of the four categories[3] of AEC licensees that were considered to involve the greatest potential for significant occupational doses and of AEC facilities and contractors exempt from licensing. A procedure was established whereby the appropriate occupational exposure data were extracted from these reports and entered into the Commission’s Radiation Exposure Information Reporting System (REIRS), a computer system that was maintained at the Oak Ridge National Laboratory Computer Technology Center in Oak Ridge, Tennessee, until May 1990. At that time, the data were transferred to a database management system at Science Applications International Corporation (SAIC) at Oak Ridge, Tennessee. The computerization of these data ensures that they are kept indefinitely and facilitates their retrieval and analysis. The data maintained in REIRS have been summarized and published in a report every year since 1969. Annual reports for each of the years 1969 through 1973 presented the data reported by both AEC licensees and contractors and were published in six documents designated as WASH-1350-R1 through WASH-1350-R6.

In January 1975, with the separation of the AEC into the Energy Research and Development Administration (ERDA) and the U.S. Nuclear Regulatory Commission (NRC), each agency assumed responsibility for collecting and maintaining occupational radiation exposure information reported by the facilities under its jurisdiction. The annual reports published by the

[3] Commercial nuclear power reactors; industrial radiographers; fuel processors (including uranium enrichment as of 1997), fabricators, and reprocessors; manufacturers and distributors of specified quantities of byproduct material.

NRC on occupational exposure for calendar year 1974 and subsequent years do not contain information pertaining to ERDA facilities or contractors. Comparable information for facilities and contractors under ERDA, now the Department of Energy (DOE), is collected and published by DOE's Office of Health, a division of Environment, Safety and Health, in Germantown, Maryland.

In 1982 and 1983, paragraph 20.408(a) of Title 10 of the Code of Federal Regulations was amended to require three additional categories of NRC licensees to submit annual statistical exposure reports and individual termination exposure reports. The new categories are (1) geologic repositories for high-level radioactive waste, (2) independent spent fuel storage installations, and (3) facilities for the land disposal of low-level radioactive waste. Therefore, this document presents the exposure information that was reported by NRC licensees representing two of these new categories. (There are no geologic repositories for high-level waste currently licensed.)

This report and each of the predecessors summarizes information reported for both the current year and for previous years. More licensee-specific data for previous years, such as the annual reports submitted by each commercial power reactor pursuant to 10 CFR 20.407 and their technical specifications, may be found in those documents listed on the inside of the front cover of this report for the specific year desired. Additional operating data and statistics for each power reactor for the years 1973 through 1982 may be found in a series of reports, "Nuclear Power Plant Operating Experience" [Refs. 1-9]. These documents are available for viewing at all NRC public document rooms, or they may be purchased from the National Technical Information Service, as shown in the Reference section.

In May of 1991, the revised 10 CFR 20 "Standards for Protection Against Radiation; Final Rule" was published in the Federal Register. The revision redefined the radiation monitoring and reporting requirements of NRC licensees. Instead of summary annual reports (§ 20.407) and termination reports (§ 20.408), licensees are now required to submit an annual report of the dose received by each monitored worker (§ 20.2206). Licensees were required to implement the new requirements on or before January of 1994. This report is the fourth compilation of radiation exposure information collected under the revised 10 CFR 20. Certain sections of the report have been modified to account for the change in the reporting of exposure information. Readers are encouraged to comment on these changes. Recommendations for further analysis or for different presentation of information are welcome.

1.1 Radiation Exposure Information on the Internet

In May of 1995, the NRC began pursuing the dissemination of radiation exposure information via a World Wide Web site on the Internet. This allows interested parties with the appropriate equipment to access the data electronically rather than through the published NUREG-0713 document. A web site was created for radiation exposure and linked into the main NRC web page. The web site contains up-to-date information on radiation exposure, as well as information and guidance on reporting radiation exposure information to the NRC. Interested parties may read the documents on-line or down-load information to their systems for further analysis. Software, such as REMIT, is also available for downloading via the web site. There are also links to other web sites dealing with the topics of radiation and health physics. The NRC intends to continue pursuing the dissemination of radiation exposure information via the World Wide Web and will focus more resources on the electronic distribution of information rather than the published hard copy reports.

The main web URL address for the NRC is:

http://www.nrc.gov

The NRC radiation exposure information web URL address is:

http://www.saic.com/home/nrc_rad

Comments on this report or the NRC's web page should be directed to:

REIRS Project Manager
Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission
Washington, DC 20555

2 LIMITATIONS OF THE DATA

All of the figures compiled in this report relating to exposures and doses are based on the results and interpretations of the readings of various types of personnel monitoring devices employed by each licensee. This information, obtained from routine personnel monitoring programs, is sufficient to characterize the radiation environment in which individuals work and is used in evaluating the radiation protection program.

Monitoring requirements are specified in 10 CFR § 20.1502, which requires licensees to monitor individuals who receive or are likely to receive a dose in a year in excess of 10% of the applicable limits. For most adults, the annual limit for the whole body is 5 rem, so 0.5 rem per year is the level above which monitoring is required. Separate dose limits have been established for minors and pregnant workers. Monitoring is required for any individual entering a high or very high radiation area. Depending on the administrative policy of each licensee, persons such as visitors and clerical workers may also be provided with monitoring devices, although the probability of their being exposed to measurable levels of radiation is extremely small. Licensees must report the dose records of those individuals for whom monitoring is required. Many licensees elect to report the doses for every individual for whom they provided monitoring. This practice tends to increase the number of individuals that one could consider to be radiation workers. In an effort to account for this, the number of individuals reported as having “no measurable exposure” has been subtracted from the total number of individuals monitored in order to calculate an average dose per individual receiving a measurable dose, as well as the average dose per monitored individual (for example, see Table 3.1).

The Revised 10 CFR § 20 was published in the Federal Register on May 21, 1991. With the revision of Part 20, licensees report the monitoring results for each individual. This has eliminated the need for the staff to calculate collective dose from the statistical distributions and has improved the accuracy of the collective dose information presented in this report. Although licensees were required to implement the new reporting requirements as of January 1, 1994, certain licensees began reporting under these new requirements during 1993, and that data has been included in the analyses presented here.

Another impact of the Revised Part 20 is the change from whole body dose to total effective dose equivalent (TEDE). The TEDE includes both external and internal dose. The TEDE is determined by summing the deep dose equivalent (DDE) from external radiation exposure and the committed effective dose equivalent (CEDE) from internal exposures. For reports prior to 1994, only the whole body dose (equivalent to the DDE) was reported and analyzed. In subsequent reports, the TEDE is presented and analyzed in all graphs and tables unless otherwise noted. Readers should be aware of this change from external whole body dose to

the TEDE. For most licensed activities, the internal dose is not a significant contributor to the TEDE. However, workers at Fuel Fabrication facilities receive significant exposures from internal exposure. This change in reporting requirements can be seen in the 1994 through 1997 data for this licensee category. (See Section 3.3.5)

The average dose per individual, as well as the dose distributions shown for groups of licensees, also can be affected by the multiple reporting of individuals who were monitored by two or more licensees during the year. Licensees are only required to report the doses received by individuals at their licensed facility. A dose distribution for a single licensee does not consider that some of the individuals may have received doses at other facilities. When the data are summed to determine the total number of individuals monitored by a group of licensees, individuals may be counted more than once. This can also affect the distribution of doses because individuals may be counted multiple times in the lower dose ranges rather than one time in the higher range corresponding to the actual accumulated dose for the year (the sum of the individual's dose accrued at all facilities). This source of error has the greatest potential impact on the data reported by power reactor facilities since they employ many short-term workers. Further discussion of this point is provided in Section 5.

Another fact that should be kept in mind when examining the annual statistical data is that all of the personnel included in the report may not have been monitored throughout the entire year. Many licensees, such as radiography firms and nuclear power facilities, may monitor numerous individuals for periods much less than a year. The average doses calculated from these data, therefore, are less than the average dose that an individual would receive if involved in that activity for the full year.

Considerable attention should also be given when referencing the collective totals presented in this report. The differences between the totals presented for all licensees that reported versus only those licensees that are required to report should be noted. Likewise, one should distinguish between the doses attributed to the pressurized water reactors (PWRs), and boiling water reactors (BWRs). The totals may be inclusive or exclusive of those licensees that were in commercial operation for less than one full year. These parameters vary throughout the tables and appendices of this report in order to provide the most comprehensive analysis of all the data available. The apparent discrepancies among the various tables are a necessary side-effect of this endeavor.

Also, it should again be pointed out that this report contains information reported by NRC licensees only. Since the NRC licenses all commercial nuclear power reactors, fuel processors and fabricators, and independent spent fuel storage facilities, information shown for these categories reflects the U.S. experience. This is not the case, however, for the remaining categories of industrial radiography, manufacturing and distribution of specified quantities of

by-product material, and low-level waste disposal. Companies that conduct these types of activities in Agreement States[4] are licensed by the state and are not required to submit occupational exposure reports to the NRC. Approximately twice as many facilities are licensed to Agreement States than the number licensed by the NRC. This report also does not include non-occupational exposure such as exposure due to medical x-rays, fluoroscopy, and accelerators received as a patient. Information shown for these categories does not reflect the total U.S. experience.

All dose equivalent values in this report are given in units of rem in accordance with the general provisions for records, 10 CFR 20.2101(a). In order to convert rem into the SI unit of Sieverts (Sv), one should divide the value in rem by 100. Therefore 1 rem = 0.01 Sv. In order to convert rem into millisieverts (mSv), multiply the value in rem by 10. Therefore 1 rem = 10 mSv.

[4] States that have entered into an agreement with the NRC that allows each state to license organizations using radioactive materials for certain purposes. As of 12/31/97, there are 30 Agreement States.

3 ANNUAL PERSONNEL MONITORING REPORTS - 10 CFR 20.2206

3.1 Definition of Terms and Sources of Data

3.1.1 Statistical Summary Reports

On February 4, 1974, 10 CFR 20.407 was amended to require certain categories[4] of licensees to submit an annual statistical report indicating the distribution of the whole body doses incurred by workers whom they monitored for exposure to radiation. Since the regulations did not require these licensees to report the collective dose incurred by the workers shown on the statistical reports, the dose distributions were used as the basis for the staff's calculation of the collective dose (see Section 3.1.4).

The revised 10 CFR 20 was published in the Federal Register on May 21, 1991. Section 20.2206 of the revised rule requires licensees to report the radiation exposure monitoring results for each individual for the monitoring year. All licensees were required to implement the new reporting requirements on or before January 1, 1994.

Under the revised requirements, the individual's total effective dose equivalent (TEDE, as defined in § 20.1003) is reported, so that the dose distributions may be determined directly from the individual's exposure. The TEDE is summed per individual and tabulated into the appropriate dose range to generate the dose distribution for each licensee. The total collective dose is more accurate using this method, since the licensee reported the dose to each individual and the total collective dose was calculated from the sum of these doses and not statistically derived from the distribution (see Section 3.1.4). The TEDE includes the dose contribution from the committed effective dose equivalent (CEDE) for those workers who had intakes that required monitoring and reporting of internal dose. Reports submitted under formerly applicable 10 CFR 20.407 did not include the whole body contribution from internal dose.

3.1.2 Number of Monitored Workers

The number of monitored workers refers to the total number of workers that the NRC licensees, who are covered by 10 CFR 20.1502, reported as being monitored for exposure to external and internal radiation during the year. This number includes all workers for whom monitoring is required, and may include visitors, service representatives, contract workers, clerical workers, and any other workers for whom the licensee feels that monitoring devices should be provided.

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[4] Commercial nuclear power reactors; industrial radiographers; fuel processors (inclding uranium enrichment as of 1997), fabricators and reprocessors; and manufacturers and distributors of by-product material. Independent spent fuel storage installations; and facilities for land disposal of low-level radioactive waste were added to this list in 1983.

For licensees submitting under the revised 10 CFR 20.2206, the total number of workers was determined from the number of unique personal identification numbers submitted per licensee. Uniqueness is defined by the combination of identification number and identification type. [Ref. 18]

3.1.3 Number of Workers with Measurable Dose

Under the revised 10 CFR 20.2206, the number of workers with measurable dose includes any individual with a TEDE greater than zero rem. This does not include workers with a TEDE reported as zero, not detectable (ND), or not required to be reported (NR). [Ref. 18]

3.1.4 Collective Dose

The concept of collective dose is used in this report to denote the summation of the TEDE received by all monitored workers and has the units person-rem. The revised 10 CFR 20.2206 requires that the TEDE be reported, so the collective dose is calculated by summing the TEDE for all monitored workers. The phrase “collective dose” is used throughout this report to mean the collective TEDE, unless otherwise specified.

It should be noted that prior to the implementation of the revised dose reporting requirements of 10 CFR 20.2206 in 1994, the collective dose was, in some cases, calculated from the dose distributions by summing the products obtained from multiplying the number of workers reported in each of the dose ranges by the midpoint of the corresponding dose range. This assumes that the midpoint of the range is equal to the arithmetic mean of the individual doses in the range. Past experience has shown that the actual mean dose of workers reported in each dose range is less than the midpoint of the range, and therefore the resultant calculated collective doses shown in this report for these licensees may be about 10% higher than the sum of the actual individual doses. Care should be taken when comparing the actual collective dose calculated for 1997 with the collective dose for years prior to 1994 because of this change in methodology. In addition, prior to 1994, doses only included the external whole body dose. Although the contribution of internal dose to the TEDE is minimal for most licensees, it should be taken into consideration when comparing the 1997 collective dose with the collective dose for prior years. One noted exception is for fuel fabrication licensees where the CEDE in some cases contributes the majority of the TEDE (see Section 3.3.5.).

3.1.5 Average Individual Dose

The average individual dose is obtained by dividing the collective dose by the total number of workers reported as being monitored. This figure is usually less than the average measurable dose (see below) because it includes the number of those workers who received zero or less than measurable doses.

3.1.6 Average Measurable Dose

The average measurable dose is obtained by dividing the collective TEDE by the number of workers who received a measurable dose. This is the average most commonly used in this and other reports when examining trends and comparing doses received by workers in various segments of the nuclear industry because it deletes those workers receiving zero or minimal doses, many of whom were monitored for convenience or identification purposes.

3.1.7 Number of Licensees Reporting

The number of licensees refers to the NRC licenses issued to companies to use radioactive material for certain activities that would place them in one of the six categories that are required to report pursuant to 10 CFR 20.2206. The third column in Table 3.1 shows the number of licensees that have filed such reports during the last 10 years. Agreement State licensees do not submit such reports to the NRC and are not included in this report.

3.1.8 CR

One of the parameters that the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) recommends be calculated for occupational dose distributions to aid in the comparison of exposure data is a ratio “CR.” CR is defined to be the ratio of the annual collective dose incurred by workers whose annual doses exceed 1.5 rem to the total annual collective dose. One UNSCEAR report [Ref. 10] states that normal values of CR should be between 0.05 and 0.50. A CR of 0.50 means that 50% of the collective dose is due to individual doses that exceed 1.5 rem.

Prior to 1994, the value of CR was calculated from the statistical distributions that were submitted under 10 CFR 20.407. For this calculation, it was assumed that the doses were uniformly distributed between each dose range interval. The number of people in each dose range above 1.5 rem was multiplied by the midpoint of the dose range to estimate the collective dose attributed to each dose range. The collective dose of workers with doses exceeding 1.5 rem in the 1 to 2 rem range was calculated by assuming that half of the collective dose incurred by workers with doses between 1 and 2 rem was because of doses greater than 1.5 rem. This value was then added to the collective dose incurred by workers in the higher ranges. This was known to yield a conservative CR value, but was a useful indicator when consistently applied to the data from year to year.

TABLE 3.1
ANNUAL EXPOSURE DATA FOR CERTAIN CATEGORIES OF LICENSEES
1988 - 1997

License Category* and Program Code	Calendar Year	Number of Licensees Reporting	Number of Monitored Individuals	Number of Workers With Measurable TEDE	Collective TEDE (person-rem)	Average TEDE (rem)	Average Measurable TEDE per Worker (rem)	CR**
Industrial	1997	143	3,436	2,454	1,291	0.38	0.53	0.38
Radiography	1996	144	3,631	2,537	1,385	0.38	0.55	0.42
03310	1995	139	3,530	2,465	1,338	0.38	0.54	0.40
03320	1994	139	3,230	2,351	1,415	0.44	0.60	0.51
	1993	176	4,721	3,007	1,596	0.34	0.53	0.45
	1992	246	6,703	4,265	1,864	0.28	0.44	0.37
	1991	248	6,820	4,649	2,160	0.32	0.46	0.40
	1990	258	6,523	4,458	2,120	0.33	0.48	0.42
	1989	276	6,745	4,352	2,067	0.31	0.47	0.42
	1988	286	6,878	4,223	1,981	0.29	0.47	0.43
Manufacturing	1997	31	1,151	665	397	0.34	0.60	0.70
and	1996	36	2,628	1,239	556	0.21	0.45	0.53
Distribution	1995	36	2,666	1,222	595	0.22	0.49	0.58
	1994	44	2,941	1,251	580	0.20	0.46	0.59
02500	1993	58	4,913	2,254	680	0.14	0.30	0.47
03211	1992	67	5,210	2,250	784	0.15	0.35	0.54
03212	1991	59	4,930	1,952	722	0.15	0.37	0.59
03214	1990	58	4,203	2,279	693	0.16	0.30	0.55
	1989	48	4,554	2,345	770	0.17	0.33	0.53
	1988	16	2,177	868	343	0.16	0.40	0.62
Low-Level	1997	2	185	50	5	0.03	0.11	0.00
Waste	1996	2	165	67	8	0.05	0.12	0.00
Disposal	1995	2	212	56	8	0.04	0.15	0.00
	1994	2	202	83	22	0.11	0.27	0.15
03231	1993	2	432	76	21	0.05	0.27	0.22
	1992	2	467	82	37	0.08	0.45	0.34
	1991	2	905	147	39	0.04	0.27	0.24
	1990	2	784	115	26	0.03	0.23	0.17
	1989	2	925	119	35	0.04	0.29	0.17
	1988	2	864	171	27	0.03	0.16	0.06
Independent	1997	1	55	24	6	0.11	0.24	0.00
Spent Fuel	1996	1	97	53	54	0.56	1.02	0.73
Storage	1995	1	104	49	51	0.49	1.04	0.83
	1994	1	158	89	42	0.27	0.47	0.44
23100	1993	2	135	52	14	0.10	0.26	0.11
	1992	2	290	85	11	0.04	0.13	0.00
	1991	2	41	24	4	0.10	0.17	0.00
	1990	2	56	22	6	0.11	0.27	0.00
	1989	2	190	102	33	0.17	0.32	0.09
	1988	2	217	57	25	0.12	0.44	0.27
Fuel	1997	10	11,214	3,910	1,006	0.09	0.26	0.18
Cycle	1996	8	4,369	3,061	878	0.20	0.29	0.19
Licenses -	1995	8	4,106	2,959	1,217	0.30	0.41	0.38
Fabrication	1994	8	3,596	2,847	1,147	0.32	0.40	0.40
Processing and	1993	8	9,649	2,611	339	0.04	0.13	0.08
Uranium Enrich.	1992	11	8,439	5,061	545	0.06	0.11	0.03
	1991	11	11,702	3,929	378	0.03	0.10	0.01
21210	1990	11	14,505	3,871	422	0.03	0.11	0.01
21200	1989	8	11,583	2,992	243	0.02	0.08	0.00
	1988	10	11,994	3,869	455	0.04	0.12	0.01
Commercial	1997	109	126,689	68,188	17,136	0.14	0.25	0.04
Light Water	1996	109	127,420	68,182	18,874	0.15	0.28	0.04
Reactors***	1995	109	133,066	70,986	21,674	0.16	0.31	0.06
	1994	109	142,707	73,780	21,695	0.15	0.29	0.08
41111	1993	114	169,862	86,187	26,365	0.16	0.31	0.22
	1992	114	183,900	94,317	29,298	0.16	0.31	0.24
	1991	115	179,043	91,085	28,528	0.16	0.31	0.26
	1990	116	187,081	98,802	36,607	0.20	0.37	0.33
	1989	113	188,477	100,080	35,930	0.19	0.36	0.33
	1988	111	193,532	96,653	40,055	0.21	0.41	0.38
Grand Totals	1997	296	142,730	75,291	19,841	0.14	0.26	0.09
and Averages	1996	300	138,310	75,139	21,755	0.16	0.29	0.09
	1995	295	143,684	77,737	24,884	0.17	0.32	0.11
	1994	303	152,834	80,401	24,901	0.16	0.31	0.13
	1993	360	189,712	94,187	29,014	0.15	0.31	0.24
	1992	442	205,009	106,060	32,538	0.16	0.31	0.25
	1991	437	203,441	101,786	31,831	0.16	0.31	0.27
	1990	447	213,152	109,547	39,874	0.19	0.36	0.34
	1989	449	212,474	109,990	39,078	0.18	0.36	0.34
	1988	427	215,662	105,841	42,886	0.20	0.41	0.38

* These categories consist only of NRC licensees. Agreement State licensed organizations do not report occupational exposure data to the NRC.
** CR is the ratio of the annual collective dose delivered at annual doses exceeding 1.5 rem to the total annual collective dose. (Section 3.1.8)
*** Includes all LWRs in commercial operation, although some of them may not have been in operation for a full year. 1994 - 1997 data are only for reactors that completed a full year of operation during the year. Reactor data have been corrected to account for the multiple counting of transient reactor workers. (see Section 5)

The last column in Table 3.1 shows the values of CR for the different types of licensees. With the implementation of the revised 10 CFR 20 in 1994, licensees were required to submit dose records for each individual. This allowed the NRC to determine the CR value directly by summing the collective dose for individuals with a total TEDE greater than or equal to 1.5 rem and divide it by the collective TEDE for the licensee. This method yielded a large reduction in the CR for Reactors. The CR value for Reactors dropped 64% from 0.22 in 1993 to 0.08 in 1994 and to 0.04 in 1997. Using the previous methodology, the CR value would have been calculated to be 0.08 for 1997. One of the contributing factors for this difference is the administrative controls imposed at nuclear power facilities for individuals who exceed 1 rem. This causes the dose distribution to drop off sharply above 1 rem with fewer exposures exceeding 1.5 rem. Therefore, the actual CR is significantly less than the value that is calculated by assuming a uniform dose distribution.

The Manufacturing and Distribution licensees have experienced an increase in the CR value and exceed the 0.50 value recommended by UNSCEAR. Fuel Fabrication doses, including the CR value, have increased primarily because of the inclusion of internal exposure in the TEDE for 1994 through 1997. However, the overall average CR for all licensees remained well below 0.50, primarily because of the low CR values at power reactor licensees. The overall average CR remained at a value of 0.09 in 1997.

3.2 Annual TEDE Dose Distributions

Table 3.2 is a statistical compilation of the exposure reports submitted by six categories of licensees (see Section 3.3 for a description of each licensee category). The dose distributions are generated by summing the TEDE for each individual and counting the number of individuals in each dose range. In nearly every category a large number of workers receive doses that are less than measurable, and very few doses exceed 4 or 5 rem. About 90% of the reported workers continue to be monitored by nuclear power facilities where they receive approximately 90% of the total collective dose.

Under the regulatory limits of the revised 10 CFR 20.1201, annual TEDE in excess of 5 rem for occupationally exposed adults is, by definition, an exposure in excess of regulatory limits (see Section 6).

Table 3.3 gives a summary of the annual exposures reported to the Commission by certain categories of NRC licensees as required by 10 CFR 20.2206. Table 3.3 shows that ~ 95% of the exposures consistently remained <2 rem between 1968 and 1984. For the past 12 years the percentage of workers with <2 rem has been ≥98%. The number of workers receiving an annual exposure in excess of 5 rem had been <0.01% since 1985. 1997 is the first year recorded where no individual received a TEDE or whole body dose in excess of 5 rem.

TABLE 3.2
DISTRIBUTION OF ANNUAL COLLECTIVE TEDE BY LICENSE CATEGORY
1997

LICENSE CATEGORY (Number of sites reporting)	*Number of Individuals with TEDE in the Ranges (rem)														TOTAL NUMBER MONITORED	NUMBER WITH MEAS. DOSE	TOTAL COLLECTIVE DOSE (TEDE) (person-rem)
	No Meas.	Meas. <0.1	0.10-0.25	0.25-0.50	0.50-0.75	0.75-1.00	1.00-2.00	2.00-3.00	3.00-4.00	4.00-5.00	5.00-6.00	6.00-7.00	7-12	>12			
INDUSTRIAL RADIOGRAPHY																	
Single Location (27)	212	55	14	11	4										296	84	10
Multiple Location (116)	770	655	466	403	252	183	302	82	25	2					3,140	2,370	1,281
Total (143)	982	710	480	414	256	183	302	82	25	2					3,436	2,454	1,291
MANUFACTURING AND DISTRIBUTION																	
"A" - Broad (5)	110	124	48	50	22	18	43	42	35	4					496	386	364
Limited (26)	376	193	41	32	9	2	2								655	279	33
Total (31)	486	317	89	82	31	20	45	42	35	4					1,151	665	397
LOW-LEVEL WASTE DISPOSAL																	
Total (2)	135	31	12	6	1										185	50	5
INDEPENDENT SPENT FUEL STORAGE																	
Total (1)	31	7	9	4	2	2									55	24	6
FUEL CYCLE LICENSES**																	
Total (10)	7,304	2,159	646	430	248	161	223	43							11,214	3,910	1,006
COMMERCIAL POWER REACTORS**																	
Boiling Water (37)	29,284	16,261	7,546	5,422	2,533	1,110	930	40	3						63,129	33,845	7,597
Pressurized Water (72)	50,879	25,498	12,405	7,974	2,861	1,130	741	19	-						101,507	50,628	9,539
Total (109)	80,163	41,759	19,951	13,396	5,394	2,240	1,671	59	3						164,636	84,473	17,136
GRAND TOTALS	89,101	44,983	21,187	14,332	5,932	2,606	2,241	226	63	6					180,677	91,576	19,841

* Dose values exactly equal to the values separating ranges are reported in the next higher range.

** Includes fabrication, processing and uranium enrichment plants (see Section 3.3.5).

*** Includes all reactors in commercial operation for a full year during 1997.
These values have not been adjusted for the multiple counting of transient reactor workers (see Section 5).

TABLE 3.3

SUMMARY OF ANNUAL DOSE DISTRIBUTIONS FOR CERTAIN* NRC LICENSEES

1968-1996

Year	Total Number of Monitored Persons: Reported Number	Total Number of Monitored Persons: Corrected Number	Percent of Individuals With Doses < 2 cSv**	Percent of Individuals With Doses < 5 cSv**	Number of Individuals With Doses >12 cSv**
1968	36,836		97.2%	99.5%	3
1969	31,176		96.5%	99.5%	7
1970	36,164		96.1%	99.4%	0
1971	36,311		96.3%	99.3%	1
1972	44,690		95.7%	99.5%	8
1973	67,862		95.0%	99.5%	1
1974	85,097		96.4%	99.7%	1
1975	78,713		94.8%	99.5%	1
1976	92,773		95.0%	99.6%	3
1977	98,212	93,438	93.8%	99.6%	1
1978	105,893	100,818	94.6%	99.8%	3
1979	131,027	125,316	95.2%	99.8%	1
1980	159,177	150,675	94.6%	99.7%	0
1981	157,874	149,314	94.6%	99.8%	1
1982	162,456	154,117	94.9%	99.9%	0
1983	172,927	164,239	94.6%	99.9%	0
1984	181,627	168,899	95.1%	99.9%	0
1985	212,217	201,339	97.5%	>99.99% (15)	2
1986	225,582	213,017	98.0%	>99.99% (8)	0
1987	243,562	227,997	98.7%	>99.99% (4)	1
1988	231,234	215,662	98.6%	>99.99% (8)	0
1989	229,353	212,474	98.9%	>99.99% (7)	1
1990	234,045	214,781	98.9%	>99.99% (3)	0
1991	219,229	206,732	99.4%	>99.99% (2)	0
1992	222,728	205,009	99.4%	>99.99% (1)	0
1993	209,386	189,711	99.5%	>99.99% (2)	0
1994	179,803	152,834	99.5%	>99.99% (1)	0
1995	179,176	143,684	99.5%	>99.99% (1)	0
1996	173,536	137,968	99.5%	>99.99% (1)	0
1997	180,677	128,466	99.5%	100% (0)	0

* Licensees required to submit radiation exposure reports to the NRC under 10 CFR 20.2206.

** Data for 1977-1997 are based on the distribution of individual doses after adjusting for the multiple counting of transient reactor workers (see Section 5). The number of people exceeding 5 rem is shown in parentheses from 1985-1997.

3.3 Summary of Occupational Exposure Data by License Category

3.3.1 Industrial Radiography Licenses, Single and Multiple Locations

Industrial Radiography licenses are issued to allow the use of sealed radioactive materials, usually in exposure devices or “cameras,” that primarily emit gamma rays for nondestructive testing of pipeline weld joints, steel structures, boilers, aircraft and ship parts, and other high-stress alloy parts. Some firms are licensed to conduct such activities in one location, usually in a permanent facility that was designed and shielded for radiography, and others perform radiography at multiple, temporary sites in the field. The radioisotopes most commonly used are cobalt-60 and iridium-192. As shown in Table 3.1, annual reports were received for 143 radiography licensees in 1997. Table 3.4 summarizes the reported data for the two types of radiography licenses for 1997 and for the previous 2 years for comparison purposes.

The average measurable dose for workers performing radiography at a single location ranges from 20 to 30% of the average measurable dose of workers at multiple location facilities. This is because it is more difficult for workers to avoid exposure to radiation in the field, where conditions are not optimal and may change daily. To see the contribution that each radiography licensee made to the total collective dose, a summary of the information reported by each of these licensees in 1997 is presented in Appendix A.

TABLE 3.4
ANNUAL EXPOSURE INFORMATION FOR INDUSTRIAL RADIOGRAPHERS
1995 - 1997

Year	Type of License	Number of Licenses	Number of Monitored Workers	Workers with Measurable Dose	Collective Dose (person-rem)	Average Measurable Dose (rem)
	Single Location	27	296	84	10	0.12
1997	Multiple Locations	116	3,140	2,370	1,281	0.54
	Total	143	3,436	2,454	1,291	0.53
	Single Location	27	291	60	10	0.17
1996	Multiple Locations	117	3,340	2,477	1,375	0.56
	Total	144	3,631	2,537	1,385	0.55
	Single Location	27	285	61	6	0.10
1995	Multiple Locations	112	3,245	2,404	1,332	0.55
	Total	139	3,530	2,465	1,338	0.54

High exposures in radiography can be directly attributable to the type and location of the radiography field work. For example, locations such as oil drilling platforms and aerial tanks offer the radiographer little available shielding. In these situations, there may not be an opportunity to use distance as a means of minimizing exposure and achieving ALARA. Although these licensed activities usually result in average measurable doses that are higher than other licensees, they involve a relatively small number of exposed workers.

Figure 3.1 shows the number of workers with measurable dose per licensee, the total collective dose per licensee, and the average measurable dose per worker for both types of Industrial Radiography facilities from 1973 through 1997.

3.3.2 Manufacturing and Distribution Licenses, Type “A” Broad and Limited

Manufacturing and Distribution licenses are issued to allow the manufacture and distribution of radionuclides in various forms for a number of diverse purposes. The products are usually distributed to persons specifically licensed by the NRC or an Agreement State. Type “A” Broad licenses are issued to larger organizations that may use many different radionuclides in many different ways and that have a comprehensive radiation protection program. The Limited licenses are usually issued to smaller firms requiring a more restrictive license. Some firms are medical suppliers that process, package, or distribute such products as diagnostic test kits, radioactive surgical implants, and tagged radiochemicals for use in medical research, diagnosis, and therapy. Limited firms are suppliers of industrial radionuclides and are involved in the processing, encapsulation, packaging, and distribution of the radionuclides that they have purchased in bulk quantities from production reactors and cyclotrons. Major products include gamma radiography sources, cobalt irradiation sources, well-logging sources, sealed sources for gauges and smoke detectors, and radiochemicals for nonmedical research. However, only those NRC licensees that possess or use at any one time specified quantities of the nuclides listed in paragraph 20.2206(a)(7) are required to submit reports to the NRC.

Table 3.5 presents the annual data that were reported by the two types of licensees for 1997 and the previous 2 years. Looking at the information shown separately for the Type “A” Broad and Limited licensees, it can be seen that the values of all of the parameters remain higher for the Broad licensees. However, when attempting to examine trends in the data presented for this category of licensees, it should be noted that the types and quantities of radionuclides may fluctuate from year to year, and even during the year, so that some licensees may report dose data one year and not the next and may be included as a Broad licensee one year and a Limited licensee at other times. Because the number of reporting licensees is quite small, these fluctuations may have a significant impact on the values of the parameters.

FIGURE 3.1
Average Annual Values at Industrial Radiography Facilities 1973 - 1997

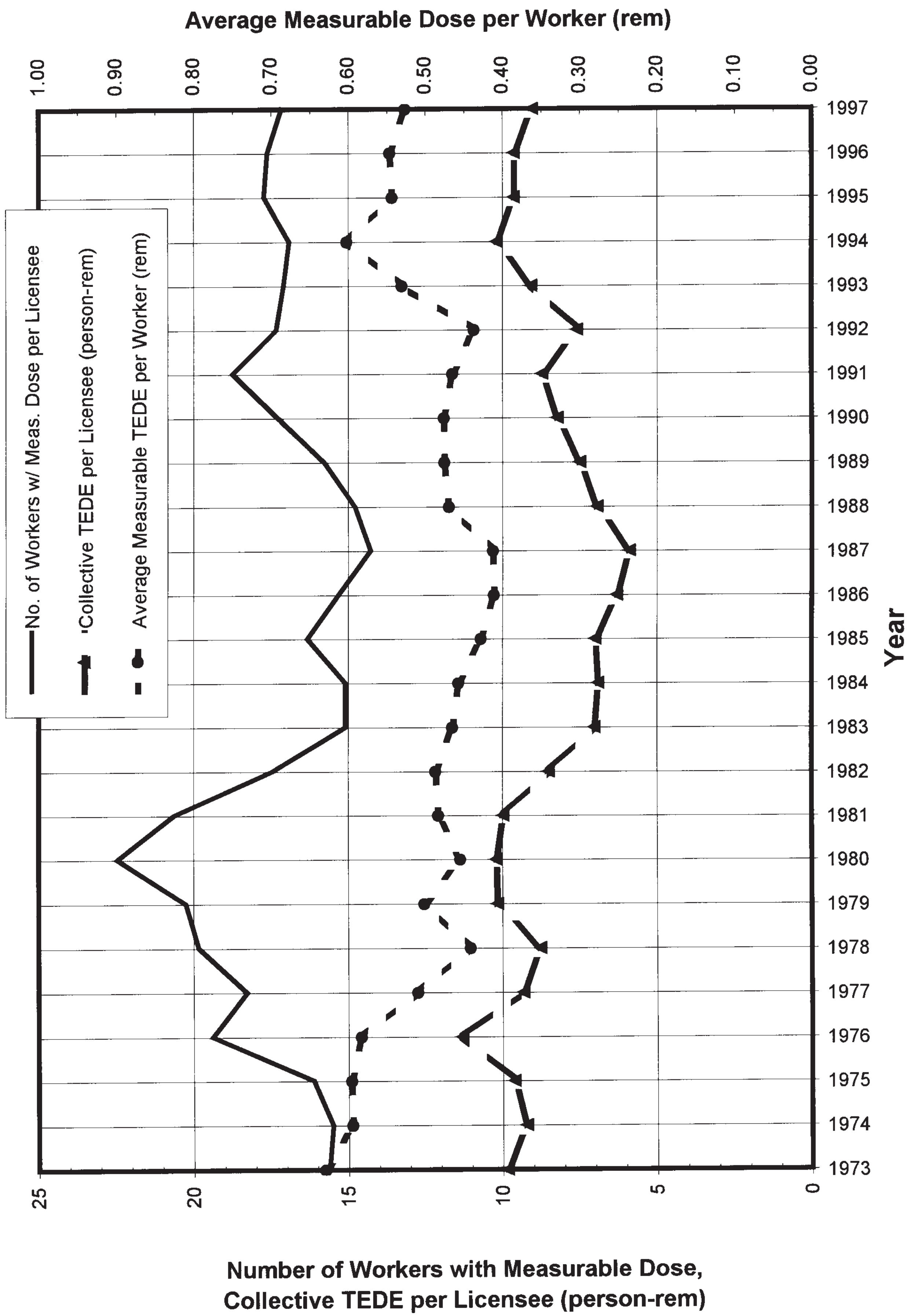


TABLE 3.5

ANNUAL EXPOSURE INFORMATION FOR MANUFACTURERS AND DISTRIBUTORS

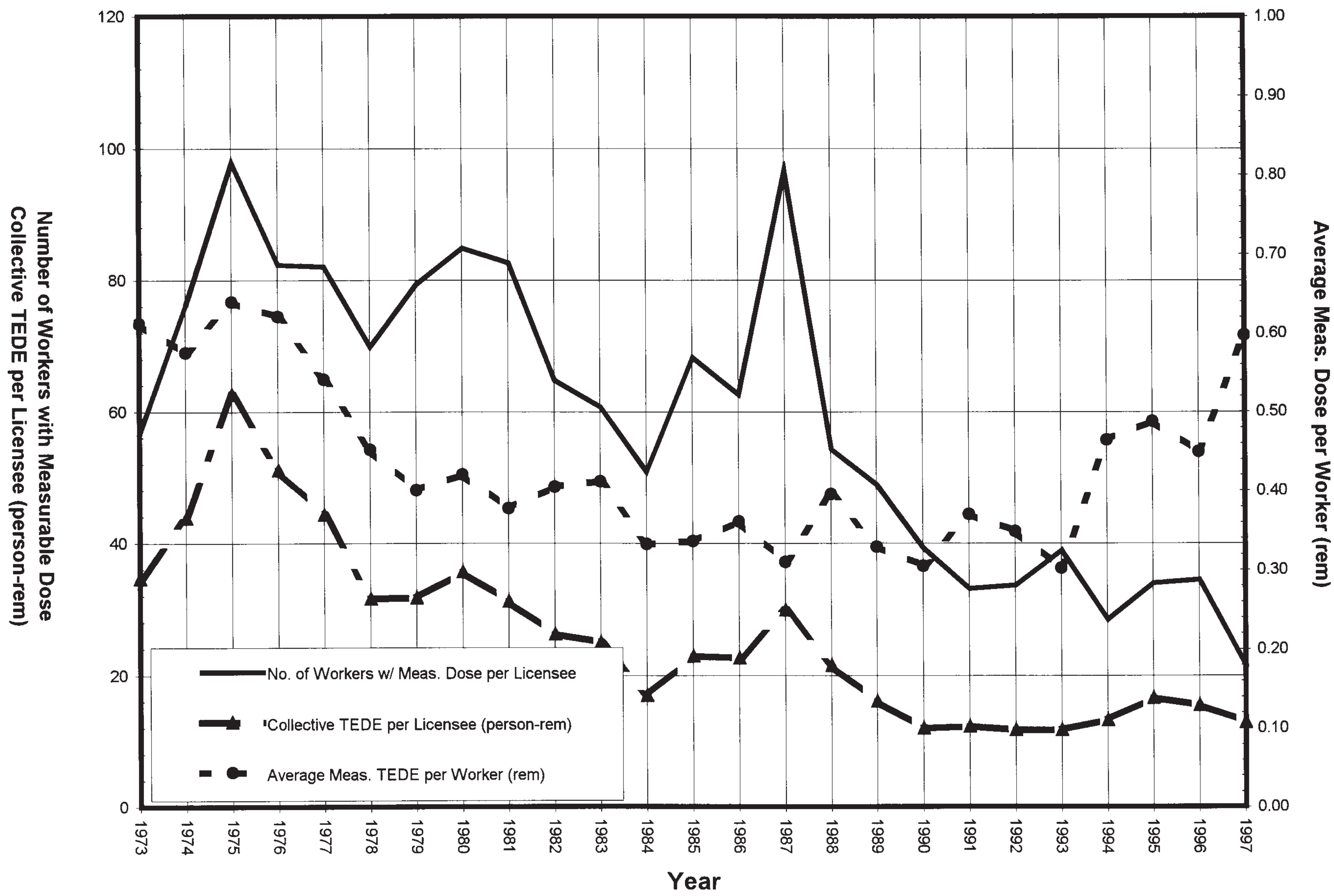
1995 - 1997

Year	Type of License	Number of Licenses	Number of Monitored Workers	Workers with Measurable Dose	Collective Dose (person-rem)	Average Measurable Dose (rem)
	M & D-"A"-Broad	5	496	386	364	0.94
1997	M & D-Limited	26	655	279	33	0.12
	Total	31	1,151	665	397	0.60
	M & D-"A"-Broad	7	2,018	987	522	0.53
1996	M & D-Limited	29	610	252	34	0.13
	Total	36	2,628	1,239	556	0.45
	M & D-"A"-Broad	7	2,016	909	557	0.61
1995	M & D-Limited	29	650	313	38	0.12
	Total	36	2,666	1,222	595	0.49

Figure 3.2 shows the number of workers with measurable dose per licensee, the total collective dose per licensee, and the average measurable dose per worker for both Type "A" Broad and Limited Manufacturing and Distribution facilities. The average measurable dose for Type "A" Broad licensees increased by 77% from 1996 to 1997 primarily due to the increase in average measurable dose at Mallinckrodt Medical, Inc.. In addition, three Type "A" Broad licensees that have reported significant dose in prior years, were transferred to Agreement State licensees in the Commonwealth of Massachusetts.

For the contribution that each of these licensees made toward the total values of the number of workers monitored, number of workers, and collective dose, see Appendix A, which lists the values of these parameters for each licensee for 1997.

FIGURE 3.2
Average Annual Values at Manufacturing and Distribution Facilities 1973 - 1997



3.3.3 Low-Level Waste Disposal Licenses

Low-Level Waste Disposal licenses are issued to allow the receipt, possession, and disposal of low-level radioactive wastes at a land disposal facility. The licensee has the appropriate facilities to receive wastes from such places as hospitals and laboratories, store them for a short time, and dispose of them in a properly prepared burial ground. The licensees in this category are located in and licensed by Agreement States which have primary regulatory authority over its activity. However, these licensees also have an NRC license that covers certain special nuclear material they might receive. The annual dose reports submitted by these licensees include all doses received during the year regardless of whether they were the result of NRC or Agreement State licensed material.

The requirement for this category of NRC licensee to file annual reports became effective in January 1983. There was only one licensee in this category in 1982 and 1983 and two licensees in this category from 1984 to 1997. Table 3.1 summarizes the data reported for 1988 through 1997. Appendix A summarizes the exposure information reported by this licensee in 1997.

Figure 3.3 shows the number of workers with measurable dose per licensee, the total collective dose per licensee, and the average measurable dose per worker for Low-Level Waste Disposal facilities from 1982 through 1997. Because only two licensees have been involved in this activity over the past 10 years, the numbers have remained fairly stable from 1984 through 1997 with the exception of the average measurable TEDE, which peaked in 1992 and has decreased by 75% since then.

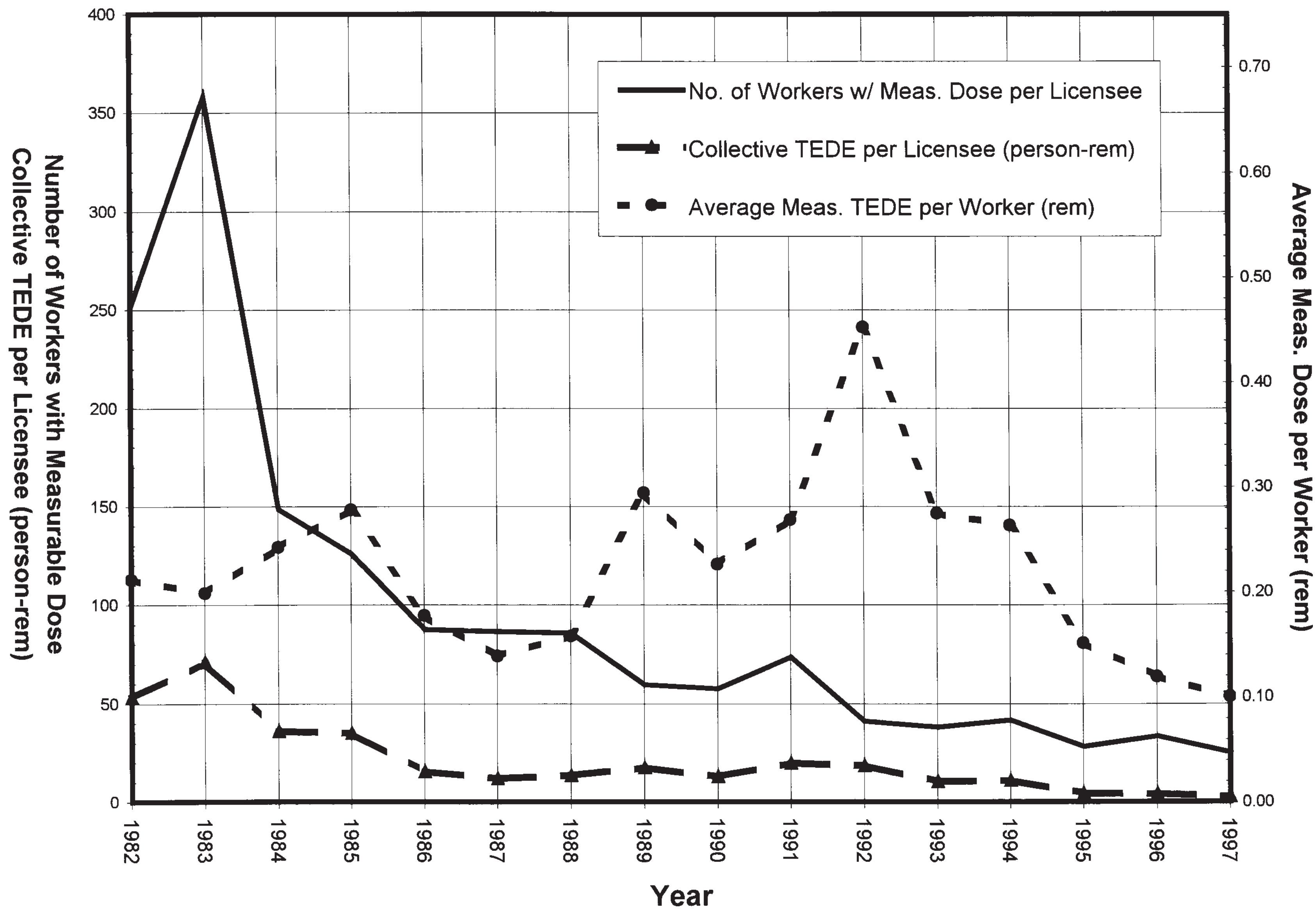
3.3.4 Independent Spent Fuel Storage Installation Licenses

Independent Spent Fuel Storage Installation (ISFSI) licenses are issued to allow the possession of power reactor spent fuel and other associated radioactive materials for the purpose of storage of such fuel in an ISFSI. Here, the spent fuel, which has undergone at least 1 year of decay since being used as a source of energy in a power reactor, is provided interim storage, protection, and safeguarding for a limited time pending its ultimate disposal.

Eighteen licenses have been issued for these activities. Eleven are at nuclear power plants, allowing on-site temporary storage of fuel. These licensees report the dose from fuel storage activities along with the dose from reactor operations at these sites. Out of the seven remaining licenses, only one is active and is located at a facility that is independent of a reactor site. Only this licensee is included in this analysis of ISFSI facilities for 1997. Appendix A summarizes the exposure information reported by this installation.

Figure 3.4 shows the number of workers with measurable dose per licensee, the total collective dose per licensee, and the average measurable dose per worker for Independent Spent Fuel Storage facilities. The large increase in the collective dose per licensee and number of

FIGURE 3.3
Average Annual Values at Low-Level Waste Disposal Facilities
1982 - 1997



workers per licensee in 1994 was mainly because only one licensee reported separately for 1994 through 1997, rather than the two licensees that reported in prior years. All parameters have decreased significantly from 1996 to 1997.

3.3.5 Fuel Cycle Licenses

Fuel cycle licenses are issued to allow the processing, enrichment, and fabrication of reactor fuels. In most uranium facilities where light water reactor fuels are fabricated enriched uranium hexafluoride is converted to solid uranium dioxide pellets and inserted into zirconium alloy tubes. The tubes are fabricated into fuel assemblies that are shipped to nuclear power plants. Some facilities also perform chemical operations to recover the uranium from scrap and other off-specification materials prior to disposal of these materials. For 1997, this category also includes the two uranium enrichment facilities at Portsmouth, Ohio, and Paducah, Kentucky. The regulatory oversight for these facilities was transferred from the U. S. Department of Energy to the NRC in 1997.

Figure 3.5 shows the number of workers with measurable dose per licensee, the total collective dose per licensee, and the average measurable dose per worker for Fuel Cycle licensees. In addition to the TEDE collective and average measurable dose, the Deep Dose Equivalent (DDE) collective dose and DDE average measurable dose are shown. Both doses are shown since the CEDE is a significant contribution to the TEDE for Fuel Fabrication facilities.

Appendix A lists each of the licensees reporting in 1997, with the number of workers monitored, the number of workers receiving measurable external doses, and the collective dose for each licensee. Table 3.6 shows that there were 10 licensed Fuel Cycle (Fabrication and Enrichment) facilities in 1997.

TABLE 3.6
ANNUAL EXPOSURE INFORMATION FOR FUEL CYCLE LICENSES
1995 - 1997

Year	Type of License	Number of Licenses	Number of Monitored Workers	Workers with Meas. TEDE	Collective TEDE (person-rem)	Average Meas. TEDE (rem)	Collective DDE (person-rem)	Average Meas. DDE (rem)	Collective CEDE (person-rem)	Average Meas. CEDE (rem)
1997	Fuel Cycle	10	11,214	3,910	1,006	0.26	197	0.08	800	0.30
1996	Fuel Cycle	8	4,369	3,061	878	0.29	161	0.08	711	0.32
1995	Fuel Cycle	8	4,106	2,959	1,217	0.41	131	0.10	990	0.33

FIGURE 3.4
Average Annual Values at Independent Spent Fuel Storage Facilities
1982 - 1997

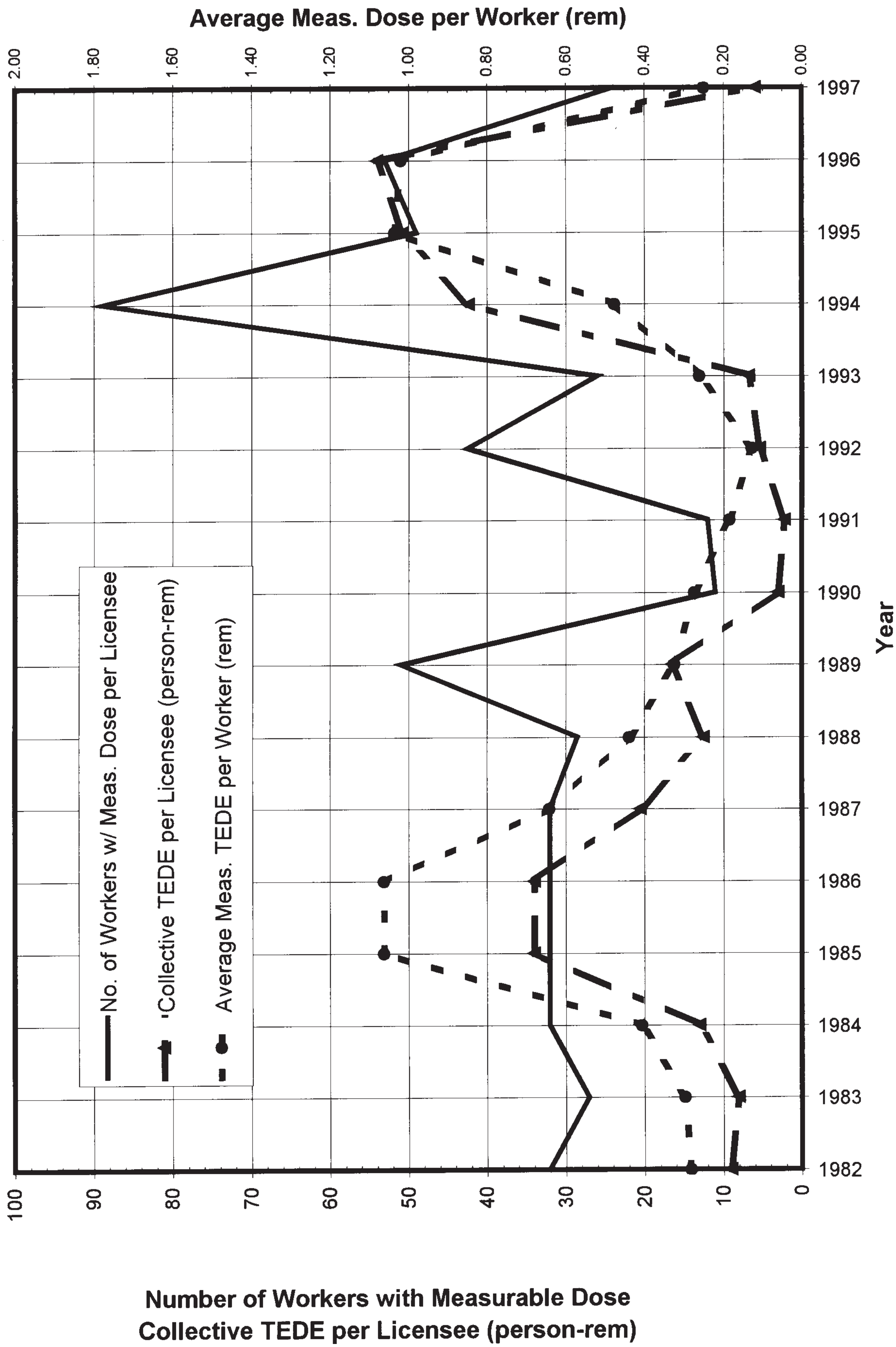
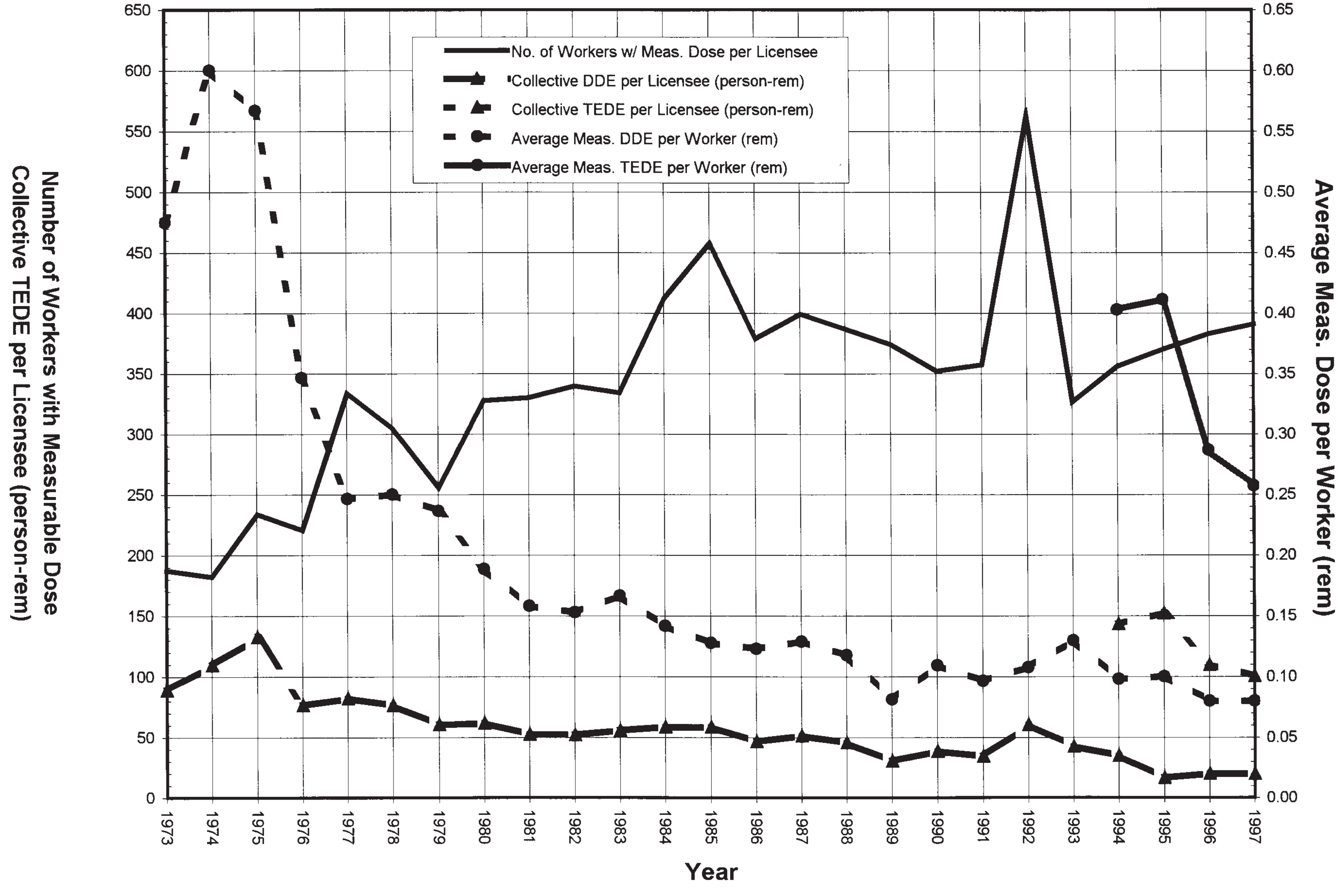


FIGURE 3.5
Average Annual Values at Fuel Cycle Licenses
1973 - 1997



3.3.6 Light-Water-Cooled Power Reactor (LWR) Licenses

LWR licenses are issued to utilities to allow them to use special nuclear material in a reactor that produces heat to generate electricity to be sold to consumers. There are two major types of commercial LWRs in the United States - pressurized water reactors (PWRs) and boiling water reactors (BWRs) - each of which uses water as the primary coolant.

Table 3.1 shows the number of licensees, total number of monitored workers, the number of workers with measurable dose, the total collective dose, and average dose per worker for all reports received from reactor facilities that were in commercial operation for the years 1988 through 1997. This table includes reactors that may not have been in commercial operation for a full year. Data for 1988 includes all reactors that reported, even though some of them were shut down. Data for 1989 through 1997 do not include reactors that have been shut down. These figures have been adjusted for the multiple counting of transient workers (see Section 5). The reported dose distribution of workers monitored at each plant site is presented in alphabetical order by site name in Appendix B.

More detailed presentations and analyses of the annual exposure information reported by nuclear power facilities can be found in Sections 4 and 5.

3.4 Summary of Intake Data by License Category

With the revision of 10 CFR 20 in 1994, licensees were required to report additional data to the NRC concerning intakes of radioactive material. Licensees were required to list for each intake the radionuclide that was taken into the body, the pulmonary clearance class, intake mode, and amount of the intake in microcuries. An NRC Form 5 report containing this information is required to be completed and submitted to the NRC under 10 CFR 20.2206.

Tables 3.7 and 3.8 summarize the intake data reported to the NRC during 1997. The data are categorized by licensee type and are listed in order of radionuclide and pulmonary clearance class. Table 3.7 lists the intakes where the mode of intake into the body was recorded as ingestion. In 1997, one record was reported as an ‘absorption’ of tritium and is included in Table 3.7. Table 3.8 lists the intakes where the mode of intake was inhalation from ambient airborne radioactive material in the workplace. The pulmonary clearance class is recorded as D, W, or Y corresponding to its clearance half-time in the order of **d**ays, **w**eeks, or **y**ears from the pulmonary region of the lung into the blood and gastrointestinal tract. The amount of material taken into the body is given in microcuries, a unit of measure of the quantity of radioactive material. For each category of licensee, the maximum number of intake records and the maximum intake is highlighted in the table in bold for ease of reference.

TABLE 3.7
INTAKE BY LICENSEE TYPE AND RADIONUCLIDE
MODE OF INTAKE - ***INGESTION***
1997

Licensee Type	Program Code	Radionuclide	Number of Intake Records*	Intake in microcuries	Intake in microcuries (sci. notation)
Power Reactors	41111	H-3 (Absorption)	1	1.120	1.12E+00
	41111	AM-241	2	0.000	1.15E-05
	41111	CE-144	1	0.019	1.90E-02
	41111	CM-242	1	0.000	4.33E-06
	41111	CM-244	2	0.000	9.97E-06
	41111	CO-58	14	90.254	9.03E+01
	41111	CO-60	**42**	**1,081.675**	**1.08E+03**
	41111	CR-51	9	1.395	1.40E+00
	41111	CS-134	2	0.050	5.00E-02
	41111	CS-137	1	0.070	7.00E-02
	41111	FE-55	4	0.479	4.79E-01
	41111	FE-59	4	1.027	1.03E+00
	41111	IN-113M	1	0.003	2.52E-03
	41111	MN-54	10	0.508	5.08E-01
	41111	NB-95	3	0.199	1.99E-01
	41111	PU-238	2	0.000	8.06E-06
	41111	PU-239	2	0.000	5.83E-06
	41111	PU-241	1	0.000	2.27E-04
	41111	SB-125	1	0.355	3.55E-01
	41111	SN-113	1	0.003	2.52E-03
	41111	SR-90	1	0.000	2.81E-05
	41111	UNKNOWN	5	16.500	1.65E+01
	41111	ZN-65	4	0.996	9.96E-01
	41111	ZR-95	3	0.173	1.73E-01

*An intake event may involve multiple nuclides, and individuals may incur multiple intakes during the year. The number of intake records given here indicates the number of separate intake reports that were submitted on NRC Form 5 reports under 10 CFR 20.2206.

TABLE 3.8
INTAKE BY LICENSEE TYPE AND RADIONUCLIDE
MODE OF INTAKE - ***INHALATION***
1997

Licensee Type	Program Code	Radionuclide	Pulmonary Clearance Class	Number of Intake Records*	Intake in microcuries	Intake in microcuries (sci. notation)
Nuclear Pharmacies	02500	I-131	D	21	7.968	7.97E+00
Manufacturing and Distribution	03211	CO-60	Y	**7**	**2.473**	**2.47E+00**
	03211	I-123	D	2	0.603	6.03E-01
	03211	I-131	D	7	2.137	2.14E+00
Uranium Enrichment	21200	TH-230	W	29	0.001	5.33E-04
	21200	U-234	D	**62**	**0.049**	**4.92E-02**
	21200	U-234	Y	4	0.000	3.95E-05
Fuel Fabrication	21210	CO-60	Y	545	0.456	4.56E-01
	21210	CS-137	D	5	0.000	3.01E-05
	21210	EU-152	W	16	0.000	5.89E-05
	21210	NP-237	W	1	0.000	1.04E-07
	21210	PA-234	W	1	0.000	2.19E-06
	21210	PU-238	W	5	0.000	3.92E-05
	21210	PU-239	W	84	2.581	2.58E+00
	21210	PU-239	Y	7	0.003	2.98E-03
	21210	SR-90	D	4	0.000	1.50E-04
	21210	SR-90	Y	29	0.000	1.40E-04
	21210	TC-99	D	1	0.000	8.61E-06
	21210	TH-228	W	1	0.000	1.00E-08
	21210	TH-228	Y	294	0.001	1.02E-03
	21210	TH-230	W	1	0.000	4.38E-07
	21210	TH-230	Y	294	0.000	4.74E-04
	21210	TH-232	W	1	0.000	2.00E-08
	21210	TH-232	Y	294	5.864	5.86E+00
	21210	TH-234	Y	1	0.000	8.64E-07
	21210	U-234	D	550	2.927	2.93E+00
	21210	U-234	W	325	0.083	8.26E-02
	21210	U-234	Y	**2,341**	**7.801**	**7.80E+00**
	21210	U-235	Y	1,086	0.121	1.21E-01
	21210	U-236	Y	243	0.004	4.03E-03
	21210	U-237	Y	4	0.000	1.42E-04
	21210	U-238	D	224	0.218	2.18E-01
	21210	U-238	Y	2,126	0.722	7.22E-01
Power Reactors	41111	AG-110M	Y	6	0.138	1.38E-01
	41111	AM-241	W	128	0.012	1.22E-02
	41111	C-14	O	2	0.015	1.50E-02
	41111	C0-60	Y	2	0.323	3.23E-01
	41111	CE-141	W	1	0.008	7.58E-03
	41111	CE-141	Y	1	0.086	8.60E-02
	41111	CE-144	W	2	0.010	1.00E-02
	41111	CE-144	Y	6	0.004	3.80E-03
	41111	CM-242	W	29	0.002	1.63E-03
	41111	CM-243	W	30	0.033	3.26E-02
	41111	CO-57	Y	1	0.001	9.09E-04
	41111	CO-58	Y	186	394.108	3.94E+02

TABLE 3.8
INTAKE BY LICENSEE TYPE AND RADIONUCLIDE
MODE OF INTAKE - ***INHALATION***
1997

Licensee Type	Program Code	Radionuclide	Pulmonary Clearance Class	Number of Intake Records*	Intake in microcuries	Intake in microcuries (sci. notation)
Power Reactors	41111	CO-60	Y	**234**	**1,276.151**	**1.28E+03**
	41111	CR-51	W	1	0.020	2.00E-02
	41111	CR-51	Y	4	1.635	1.64E+00
	41111	CS-134	D	14	0.321	3.21E-01
	41111	CS-136	D	2	0.038	3.80E-02
	41111	CS-137	D	81	14.309	1.43E+01
	41111	CS-137	Y	4	0.183	1.83E-01
	41111	FE-55	W	6	0.621	6.21E-01
	41111	FE-59	D	3	0.149	1.49E-01
	41111	FE-59	W	5	0.545	5.45E-01
	41111	H-3	V	6	21.510	2.15E+01
	41111	H-3	Y	1	17.280	1.73E+01
	41111	I-131	D	24	102.240	1.02E+02
	41111	I-133	D	1	0.170	1.70E-01
	41111	MIXTURE	W	144	6.336	6.34E+00
	41111	MN-54	W	48	186.318	1.86E+02
	41111	MN-54	Y	1	0.009	9.00E-03
	41111	MN-56	W	1	0.033	3.30E-02
	41111	NB-95	W	3	0.387	3.87E-01
	41111	NB-95	Y	7	0.423	4.23E-01
	41111	NI-63	W	6	0.206	2.06E-01
	41111	NP-237	W	10	0.001	7.20E-04
	41111	PU-238	Y	30	0.035	3.50E-02
	41111	PU-239	Y	18	0.000	3.15E-05
	41111	PU-240	Y	12	0.006	6.39E-03
	41111	PU-241	Y	111	2.167	2.17E+00
	41111	SB-125	W	1	0.010	9.75E-03
	41111	SN-113	W	1	0.003	2.67E-03
	41111	SR-89	D	1	0.000	1.14E-04
	41111	SR-90	D	1	0.000	1.10E-05
	41111	SR-90	Y	3	0.000	4.98E-04
	41111	UNKNOWN	W	1	1.600	1.60E+00
	41111	UNKNOWN	Y	1	2.700	2.70E+00
	41111	ZN-65	Y	6	0.199	1.99E-01
	41111	ZR-95	D	9	1.015	1.02E+00
	41111	ZR-95	W	3	0.386	3.86E-01
	41111	ZR-95	Y	7	0.155	1.55E-01
	41111	ZRNB-95	W	1	0.034	3.40E-02
	41111	ZRNB-95	Y	1	0.090	9.00E-02

*An intake event may involve multiple nuclides, and individuals may incur multiple intakes during the year. The number of intake records given here indicates the number of separate intake reports that were submitted on NRC Form 5 reports under 10 CFR 20.2206.

Table 3.9 lists the number of individuals with measurable CEDE, the collective CEDE and the average measurable CEDE in descending order of the number with measurable CEDE. Fuel fabrication facilities have the majority of internal dose (99%) and the highest average CEDE per individual. This is due to the worker's exposure to uranium during the processing and fabrication of the uranium fuel.

Table 3.10 shows the distribution of internal dose (CEDE) from 1994 to 1997 for licensees required to report under 10 CFR 20.2206. For the purposes of this table, the definition of a 'measurable CEDE' is any reported value greater than zero. As noted above, the vast majority of the internal doses are received by individuals working at fuel fabrication facilities. The table shows that the number with measurable CEDE remained at nearly 3,000 from 1994 to 1996, and then increased to 3,739 in 1997. However, the average measurable CEDE has decreased 31% in the past four years, from 0.316 rem in 1994 to 0.217 rem in 1997.

TABLE 3.9
COLLECTIVE AND AVERAGE CEDE BY LICENSEE
1997

Licensee Type	Licensee Name	License Number	Number with Meas. CEDE	Collective CEDE (person-rem)	Average Meas. CEDE (rem)
Nuclear Pharmacies 02500	NORTHERN VIRGINIA ISOTOPES, INC.	45-25221-01MD	13	0.088	0.007
	SYNCOR INTERNATIONAL CORPORATION	04-26507-01MD	9	0.188	0.021
		Total	**22**	**0.276**	**0.013**
Manufactuing and Distribution 03211	MALLINCKRODT MEDICAL INC.	24-04206-01	5	0.070	0.014
	ADVANCED MEDICAL SYS., INC.	34-19089-01	3	0.076	0.025
		Total	**8**	**0.146**	**0.018**
Uranium Enrichment 21200	USEC - PADUCAH	GDP-1	19	0.023	0.001
	USEC - PORTSMOUTH	GDP-2	17	0.291	0.017
		Total	**36**	**0.314**	**0.009**
Fuel Fabrication 21210	GE NUCLEAR ENERGY	SNM-1097	1,062	223.255	0.210
	SIEMENS POWER CORP. NUCLEAR DIVISION	SNM-1227	396	100.826	0.255
	NUCLEAR FUEL SERVICES, INC.	SNM-0124	375	30.736	0.082
	WESTINGHOUSE ELECTRIC COMPANY	SNM-1107	286	159.151	0.556
	BWX TECHNOLOGIES, INC.	SNM-0042	241	180.063	0.747
	COMBUSTION ENGINEERING INC.	SNM-0033	165	95.562	0.579
	FRAMATOME COGEMA FUELS	SNM-1168	114	10.567	0.093
		Total	**2,639**	**800.160**	**0.303**
Reactors 41111	SUSQUEHANNA	NPF-14	208	0.322	0.002
	THREE MILE ISLAND 1	DPR-50	148	0.899	0.006
	ST. LUCIE	DPR-67	101	0.994	0.010
	TURKEY POINT	DPR-31	98	0.248	0.003
	PILGRIM	DPR-35	59	1.311	0.022
	HUMBOLDT BAY	DPR-07	43	0.275	0.006
	WOLF CREEK	NPF-42	38	0.211	0.006
	RIVER BEND	NPF-47	32	0.546	0.017
	COOK	DPR-58	30	0.231	0.008
	VOGTLE	NPF-68	30	0.435	0.015
	WASHINGTON NUCLEAR	NPF-21	25	0.316	0.013
	NINE MILE POINT	DPR-63	20	0.411	0.021
	OYSTER CREEK	DPR-16	19	0.088	0.005
	OCONEE	DPR-38	13	0.254	0.020
	CALLAWAY	NPF-30	12	0.076	0.006
	INDIAN POINT 1,2	DPR-05	12	0.470	0.039
	COOPER	DPR-46	11	0.032	0.003
	SAN ONOFRE	DPR-13	11	0.074	0.007
	SEQUOYAH	DPR-77	11	0.664	0.060
	BRUNSWICK	DPR-62	10	0.067	0.007
	HARRIS	NPF-63	10	0.083	0.008
	MONTICELLO	DPR-22	10	0.227	0.023
	MAINE YANKEE	DPR-36	9	0.042	0.005
	ARKANSAS	DPR-51	6	0.192	0.032
	CATAWBA	NPF-35	6	0.094	0.016
	DRESDEN	DPR-19	6	0.288	0.048
	HATCH	DPR-57	6	0.112	0.019
	BROWNS FERRY	DPR-33	5	0.261	0.052
	LIMERICK	NPF-39	5	0.045	0.009
	VERMONT YANKEE	DPR-28	5	0.023	0.005
	PEACH BOTTOM	DPR-44	4	0.073	0.018
	CALVERT CLIFFS	DPR-53	3	0.290	0.097
	DIABLO CANYON	DPR-80	3	0.723	0.241
	POINT BEACH	DPR-24	3	0.039	0.013
	SUMMER	NPF-12	3	0.124	0.041
	YANKEE ROWE	DPR-03	3	0.063	0.021
	BIG ROCK POINT	DPR-06	2	0.023	0.012
	FARLEY	NPF-02	2	0.035	0.018
	INDIAN POINT 3	DPR-64	2	0.031	0.016
	NORTH ANNA	NPF-04	2	0.008	0.004
	SURRY	DPR-32	2	0.006	0.003
	BEAVER VALLEY	DPR-66	1	0.022	0.022
	CLINTON	NPF-62	1	0.023	0.023
	KEWAUNEE	DPR-43	1	0.017	0.017
	LASALLE	NPF-11	1	0.029	0.029
	PALISADES	DPR-20	1	0.010	0.010
	QUAD CITIES	DPR-29	1	0.186	0.186
		Total	**1,034**	**10.993**	**0.011**
Grand Totals			**3,739**	**811.889**	**0.217**

TABLE 3.10

INTERNAL DOSE (CEDE) DISTRIBUTION, 1994 - 1997

Year	Number of Individuals with CEDE in the Ranges (rem)										Total with Meas. CEDE	Collective CEDE (person-rem)	Average Meas. CEDE (rem)
	Meas. - 0.020	0.020 - 0.100	0.100 - 0.250	0.250- 0.500	0.500 - 0.750	0.750 - 1.000	1-2	2-3	3-4	4-5			
1994	1,382	526	286	352	196	138	293	69	2	-	3,244	1,024.851	0.316
1995	1,372	464	295	315	180	112	192	18	-	-	2,948	709.012	0.241
1996	1,345	557	303	317	190	121	185	22	2	-	3,042	722.160	0.237
1997	1,711	692	381	366	241	149	169	30	-	-	3,739	811.889	0.217

4 COMMERCIAL LIGHT WATER REACTORS - FURTHER ANALYSIS

4.1 Introduction

General trends in occupational radiation exposures at nuclear power reactors are best evaluated within the context of other pertinent information. In this chapter, some of the tables and appendices that summarize exposure data also show the type, capacity, and age of the reactor; the amount of electricity generated; the types of workers being exposed; and the sort of tasks being performed. Exposure data are then presented as a function of these data.

4.2 Definition of Terms and Sources of Data

4.2.1 Number of Reactors

The *number of reactors* shown in Tables 4.1, 4.2, and 4.3 is the number of BWRs, PWRs, and LWRs, respectively, that had been in commercial operation for at least 1 full year as of December 31 of each of the indicated years. This is the number of reactors on which the *average number of workers with measurable dose* and *average collective dose per reactor* is based. Excluded are those reactors that had been in commercial operation for less than 12 months during the first year and reactors that have been permanently defueled. This yields conservative values for many of the averages shown in the tables. The date that each reactor was declared to be in commercial operation was taken from Reference 14.

Three Mile Island (TMI) 2 had been included in the compilation of data for commercially operating reactors through 1988 even though the reactor was shut down following the 1979 accident and has been in the process of defueling and decommissioning since that time. TMI 2 has not been included in the data analysis since 1988. Data for this reactor, however, will be listed in Appendices B, C, D and E for reference purposes.

In 1997, Haddam Neck (a PWR) was removed from the count of operating reactors and Watts Bar Unit 1 (also a PWR) was added to the count, keeping the total count of operating reactors at 109. Three sites permanently ceased operation during 1997. These plants were kept in the count of operating reactors for 1997 even though they were not in commercial operation for the entire year. These plants are Maine Yankee (a PWR shut down 8/97), Big Rock Point (a BWR shut down 9/97) and Zion 1,2 (two PWRs shut down 12/97). Maine Yankee and Zion 2 produced no power during all of 1997 and Zion 1 generated only 12% of the unit's maximum dependable capacity. Big Rock Point is a relatively small plant, and only generated 45% of the unit's maximum dependable capacity prior to shut down. Therefore, the inclusion of these plants in the count of operating reactors for 1997 resulted in a decrease in the overall average electricity generated per reactor and an increase in the collective dose per megawatt-year for PWRs.

TABLE 4.1

SUMMARY OF INFORMATION REPORTED BY COMMERCIAL BOILING WATER REACTORS

1973 - 1997

Year	Number of Reactors Included*	Annual Collective Dose (person-rem)	No. of Workers With Measurable Dose**	Electricity Generated*** (MW-yrs)	Average Measurable Dose Per Worker (rem)**	Average Collective Dose Per Reactor (person-rem)	Average No. Personnel With Measurable Doses Per Reactor**	Average Collective Dose per MW-yr (person-rem /MW-yr)	Average Electricity Generated Per Reactor (MW-yr)	Average Maximum Dependable Capacity Net (MWe)	Percent of Maximum Dependable Capacity Achieved
1973	12	4,564	5,340	3,393.9	0.85	380	445	1.34	283	438	65%
1974	14	7,095	8,769	4,060.2	0.81	507	626	1.75	290	485	60%
1975	18	12,611	14,607	5,786.4	0.86	701	812	2.18	321	595	54%
1976	22	12,300	16,604	8,137.9	0.74	559	755	1.51	370	630	59%
1977	23	19,041	21,388	9,102.5	0.89	828	930	2.09	396	637	62%
1978	25	15,273	20,278	11,856.0	0.75	611	811	1.29	474	660	72%
1979	25	18,325	25,245	11,671.0	0.73	733	1,010	1.57	467	660	71%
1980	26	29,530	34,094	10,868.2	0.87	1,136	1,311	2.72	418	663	63%
1981	26	25,472	34,755	10,899.2	0.73	980	1,337	2.34	419	663	63%
1982	26	24,437	32,235	10,614.6	0.76	940	1,240	2.30	408	663	62%
1983	26	27,455	33,473	9,730.1	0.82	1,056	1,287	2.82	374	663	56%
1984	27	27,097	41,105	10,019.2	0.66	1,004	1,522	2.70	371	754	49%
1985	29	20,573	38,237	12,284.0	0.54	709	1,319	1.67	424	775	55%
1986	30	19,349	37,928	12,102.1	0.51	645	1,264	1.60	403	786	51%
1987	32	16,717	41,737	15,109.0	0.40	522	1,304	1.11	472	832	57%
1988	34	17,983	40,305	16,665.4	0.45	529	1,185	1.08	490	845	58%
1989	36	15,549	44,360	17,543.5	0.35	432	1,232	0.89	487	857	57%
1990	37	15,780	41,577	21,336.1	0.38	426	1,124	0.74	577	862	67%
1991	37	12,005	38,492	21,505.8	0.31	324	1,040	0.56	581	860	68%
1992	37	13,309	42,095	20,592.2	0.32	360	1,138	0.65	557	859	65%
1993	37	12,221	39,352	21,995.6	0.31	330	1,064	0.56	594	798	74%
1994	37	12,092	39,108	22,139.0	0.31	327	1,057	0.55	598	801	75%
1995	37	9,467	35,659	24,737.0	0.27	256	964	0.38	669	835	80%
1996	37	9,461	37,637	24,322.2	0.25	256	1,017	0.39	657	838	78%
1997	37	7,597	33,845	22,866.1	0.22	205	915	0.33	618	845	73%

* Includes only those reactors that had been in commercial operation for at least one full year as of December 31 of each of the indicated years.
** Figures are not adjusted for the multiple reporting of transient individuals. See Section 5.
*** Electricity Generated reflects the gross electricity generated for the years 1973 - 1996. Beginning in 1997, it reflects the net electricity generated.

10/22/98

TABLE 4.2

SUMMARY OF INFORMATION REPORTED BY COMMERCIAL PRESSURIZED WATER REACTORS

1973 - 1997

Year	Number of Reactors Included*	Annual Collective Dose (person-rem)	No. of Workers With Measurable Dose**	Electricity Generated*** (MW-yrs)	Average Measurable Dose Per Worker (rem)**	Average Collective Dose Per Reactor (person-rem)	Average No. Personnel With Measurable Doses Per Reactor**	Average Collective Dose per MW-yr (person-rem /MW-yr)	Average Electricity Generated Per Reactor (MW-yr)	Average Maximum Dependable Capacity Net (MWe)	Percent of Maximum Dependable Capacity Achieved
1973	12	9,398	9,440	3,770.2	1.00	783	787	2.49	314	544	58%
1974	19	6,555	9,370	6,530.7	0.70	345	493	1.00	344	591	58%
1975	26	8,268	10,884	11,982.5	0.76	318	419	0.69	461	647	71%
1976	30	13,807	17,588	13,325.0	0.79	460	586	1.04	444	701	63%
1977	34	13,467	20,878	17,345.8	0.65	396	614	0.78	510	688	74%
1978	39	16,528	25,700	19,840.5	0.64	424	659	0.83	509	706	72%
1979	42	21,657	38,828	18,255.0	0.56	516	924	1.19	435	746	58%
1980	42	24,267	46,237	18,289.3	0.52	578	1,101	1.33	435	746	58%
1981	44	28,673	47,351	20,553.7	0.61	652	1,076	1.40	467	752	62%
1982	48	27,754	52,146	22,140.6	0.53	578	1,086	1.25	461	777	59%
1983	49	29,017	52,173	23,195.5	0.56	592	1,065	1.25	473	785	60%
1984	51	28,138	56,994	26,478.4	0.49	552	1,118	1.06	519	809	64%
1985	53	22,469	54,633	29,470.7	0.41	424	1,031	0.76	556	820	68%
1986	60	23,032	62,995	33,593.0	0.37	384	1,050	0.69	560	878	64%
1987	64	23,684	62,597	37,007.3	0.38	370	978	0.64	578	900	64%
1988	68	22,786	62,921	42,929.7	0.36	335	925	0.53	631	885	71%
1989	71	20,381	63,894	44,679.5	0.32	287	900	0.46	629	897	70%
1990	73	20,812	67,081	46,955.6	0.31	285	919	0.44	643	907	71%
1991	74	16,510	60,269	51,942.6	0.27	223	814	0.32	702	913	77%
1992	73	15,985	61,048	53,419.8	0.26	219	836	0.30	732	923	79%
1993	71	14,142	56,588	50,480.6	0.25	199	797	0.28	711	945	75%
1994	72	9,603	44,766	54,618.3	0.21	133	622	0.18	759	932	81%
1995	72	12,207	51,867	55,825.1	0.24	170	720	0.22	775	933	83%
1996	72	9,413	46,812	55,337.8	0.20	131	650	0.17	769	935	82%
1997	72	9,539	50,628	48,985.3	0.19	132	703	0.19	680	943	72%

* Includes only those reactors that had been in commercial operation for at least one full year as of December 31 of each of the indicated years.
** Figures are not adjusted for the multiple reporting of transient individuals. See Section 5.
*** Electricity Generated reflects the gross electricity generated for the years 1973 - 1996. Beginning in 1997, it reflects the net electricity generated.

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TABLE 4.3

SUMMARY OF INFORMATION REPORTED BY COMMERCIAL LIGHT WATER REACTORS

1973 - 1997

Year	Number of Reactors Included*	Annual Collective Dose (person-rem)	No. of Workers With Measurable Dose**	Electricity Generated*** (MW-yrs)	Average Measurable Dose Per Worker (rem)**	Average Collective Dose Per Reactor (person-rem)	Average No. Personnel With Measurable Doses Per Reactor**	Average Collective Dose per MW-yr (person-rem /MW-yr)	Average Electricity Generated Per Reactor (MW-yr)	Average Maximum Dependable Capacity Net (MWe)	Percent of Maximum Dependable Capacity Achieved
1973	24	13,962	14,780	7,164.1	0.94	582	616	1.95	299	491	61%
1974	33	13,650	18,139	10,590.9	0.75	414	550	1.29	321	546	59%
1975	44	20,879	25,491	17,768.9	0.82	475	579	1.18	404	626	65%
1976	52	26,107	34,192	21,462.9	0.76	502	658	1.22	413	671	62%
1977	57	32,508	42,266	26,448.3	0.77	570	742	1.23	464	667	70%
1978	64	31,801	45,978	31,696.5	0.69	497	718	1.00	495	688	72%
1979	67	39,982	64,073	29,926.0	0.62	597	956	1.34	447	714	63%
1980	68	53,797	80,331	29,157.5	0.67	791	1,181	1.85	429	714	60%
1981	70	54,145	82,106	31,452.9	0.66	774	1,173	1.72	449	719	63%
1982	74	52,191	84,381	32,755.2	0.62	705	1,140	1.59	443	737	60%
1983	75	56,472	85,646	32,925.6	0.66	753	1,142	1.72	439	743	59%
1984	78	55,235	98,099	36,497.6	0.56	708	1,258	1.51	468	790	59%
1985	82	43,042	92,870	41,754.7	0.46	525	1,133	1.03	509	804	63%
1986	90	42,381	100,923	45,695.1	0.42	471	1,121	0.93	508	847	60%
1987	96	40,401	104,334	52,116.3	0.39	421	1,087	0.78	543	877	62%
1988	102	40,769	103,226	59,595.1	0.39	400	1,012	0.68	584	871	67%
1989	107	35,930	108,254	62,223.0	0.33	336	1,012	0.58	582	883	66%
1990	110	36,592	108,658	68,291.7	0.34	333	988	0.54	621	892	70%
1991	111	28,515	98,761	73,448.4	0.29	257	890	0.39	662	895	74%
1992	110	29,294	103,143	74,012.0	0.28	266	938	0.40	673	901	75%
1993	108	26,363	95,940	72,476.2	0.27	244	888	0.36	671	895	75%
1994	109	21,695	83,874	76,757.3	0.26	199	769	0.28	704	888	79%
1995	109	21,674	87,526	80,562.1	0.25	199	803	0.27	739	900	82%
1996	109	18,874	84,449	79,660.0	0.22	173	775	0.24	731	902	81%
1997	109	17,136	84,473	71,851.4	0.20	157	775	0.24	659	910	72%

* Includes only those reactors that had been in commercial operation for at least one full year as of December 31 of each of the indicated years.
** Figures are not adjusted for the multiple reporting of transient individuals. See Section 5.
*** Electricity Generated reflects the gross electricity generated for the years 1973 - 1996. Beginning in 1997, it reflects the net electricity generated.

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4.2.2 Electric Energy Generated

The electric energy generated in megawatt-years (MW-yr) each year by each facility is shown in Appendix C and graphically represented in Appendix E. This number was obtained by dividing the megawatt-hours of electricity annually produced by each facility by 8,760, the number of hours in the year, except for leap years when the number is 8,784 hours. For the years 1973 to 1996, the electricity generated is the gross electricity output of the reactor. In 1997, the number reflects the net electricity produced which is the gross electricity minus the amount the plant uses for operations. This change is the result of a change in the NRC power generation reporting requirements. The electricity generated (in megawatt-years) that is presented in Tables 4.1, 4.2, and 4.3 is the summation of electricity generated by the number of reactors included in each year. These sums are divided by the number of reactors included in each year to yield the average amount of electric energy generated per reactor, which is also shown in Tables 4.1, 4.2, and 4.3. The number of megawatt-hours of electricity produced each year was found in Reference 14.

As shown in Table 4.3, there was an 11% decrease in the electricity generated in 1997. Approximately 4% of this decrease is due to the change in reporting requirements from the gross electricity generated to the net electricity generated. The remaining 7% of the decrease is due to reductions in the power generated. Three BWR sites (Clinton, Lasalle 1 and 2, and Millstone Point 1) and four PWR sites (Crystal River, Maine Yankee, Millstone Point 2 and 3, and Zion 1 and 2) generated little or no power in 1997. Reasons for the outages at these sites included maintenance, refueling, and regulatory restrictions.

4.2.3 Collective Dose per Megawatt-Year

The number of megawatt-years of electricity generated was used in determining the ratio of the average value of the annual collective dose (TEDE) to the number of megawatt-years of electricity generated. The ratio was calculated by dividing the total collective dose in person-rem by the electric energy generated in megawatt-years and is a measure of the dose incurred by workers at power plants in relation to the electric energy produced. For the years 1973 to 1996, the electricity generated is the gross electricity output of the reactor. In 1997, the number reflects the net electricity produced. This ratio was also calculated for each reactor site and is presented in Tables 4.1, 4.2, and 4.3 and Appendix C.

4.2.4 Average Maximum Dependable Capacity

Average maximum dependable capacity, shown in Tables 4.1, 4.2, and 4.3, was found by dividing the sum of the net maximum dependable capacities of the reactors in megawatts (net MWe) by the number of reactors included each year. The net maximum dependable capacity is defined as the gross electrical output as measured at the output terminals of the turbine generator during the most restrictive seasonal conditions, less the normal station service loads.

This "capacity" of each plant was found in Reference 14, and it is shown for each site in Appendix C.

4.2.5 Percent of Maximum Dependable Capacity Achieved

The *percent of maximum dependable capacity achieved* is shown for all LWRs in Table 4.3. This parameter gives an indication of the overall power generation performance of LWRs as compared to the maximum capacity that could be obtained in a given year. It is calculated by dividing the average electricity generated per reactor by the average maximum dependable capacity for each year.

From 1973 to 1978 this indicator exhibited an increasing trend as a number of new reactors began producing power at higher efficiencies. Following the accident at Three Mile Island, reactor operations personnel concentrated on improving safety systems and complying with the new regulations for these systems. During this time period, from 1979 to 1987, the percent of maximum dependable capacity remained around 61%. Following the completion of most of these mandated repairs, reactors have increased the percent of maximum dependable capacity from 62% in 1987 to 81% in 1996, a gain of nearly 20% in 10 years. For 1997, the number dropped down to 72% due to the change from measuring the gross electricity generated to the net electricity generated, and a decrease in the electricity generated due to outages for maintenance, refueling, and regulatory restrictions (see Section 4.2.2).

4.3 Annual TEDE Distributions

Table 4.4 summarizes the distribution of the annual TEDE doses received by workers at all commercial LWRs during each of the years 1977 through 1997. This distribution is the sum of the annual dose distributions reported by each licensed LWR each year. As previously noted, the distribution reported by each LWR site for 1997 is shown in Appendix B. Table 4.4 shows the reported dose distributions corrected for the number of transient workers that were reported by more than one site (see Section 5). The total collective dose decreased by 9% to a value of 17,136 person-rem in 1997. The value of CR decreased to a value of 0.04. The large decrease in the value of CR from 1993 to 1994 is primarily because of the change in methodology by which the CR value is determined. CR is defined to be the ratio of the annual collective dose. CR is one of the parameters that the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) recommends be calculated for occupational dose distributions to aid in the comparison of exposure data. Once UNSCEAR report [Ref. 10] states that normal values of CR should be between 0.05 and 0.50. A CR of 0.50 means that 50% of the collective dose is due to individual doses that exceed 1.5 rem. For the years 1994 to 1997, the CR value was determined directly from the individual radiation exposure records submitted under 10 CFR 20.2206 (Form 5) rather than calculating the value indirectly from the statistical dose distribution summary as in prior years. This is the thirteenth consecutive year that the value of CR has been <0.50.

TABLE 4.4

SUMMARY DISTRIBUTION OF ANNUAL WHOLE BODY DOSES AT COMMERCIAL LIGHT WATER REACTORS*

1977 - 1997

Year	Number of Individuals with Whole Body Doses in the Ranges (rem)																Total Number Monitored	Number with Measurable Exposure	Collective Dose** (person-rem)	CR***
	No Meas'ble Exposure	Meas'ble <0.10	0.10-0.25	0.25-0.5	0.50-0.75	0.75-1.0	1.0-2.0	2.0-3.0	3.0-4.0	4.0-5.0	5.0-6.0	6.0-7.0	7.0-8.0	8.0-9.0	9.0-10.0	10.0-12.0	>12				
1977	23,562	12,395	6,030	4,518	2,890	2,220	5,649	2,856	1,288	661	186	89	47	23	6			62,420	38,858	32,508	0.65
1978	28,372	15,101	6,342	4,998	3,088	2,247	5,995	3,034	1,197	514	109	37	9	0	1	0	2	71,046	42,674	31,801	0.61
1979	43,330	22,508	8,985	7,469	4,797	3,259	7,572	3,404	1,400	545	117	42	17	3	1			103,449	60,119	39,982	0.57
1980	50,873	26,903	10,676	8,904	5,570	4,134	10,671	4,607	1,816	831	235	119	29	7	1			125,376	74,503	53,795	0.59
1981	39,265	26,836	11,226	9,330	6,042	4,497	11,170	4,811	1,999	533	103	93	9	3	1	0	1	115,919	76,654	54,144	0.57
1982	41,713	29,225	11,713	9,903	6,229	4,420	10,220	4,716	2,066	596	97	31	5	0	1	1		120,936	79,223	52,190	0.58
1983	47,048	29,107	11,195	9,344	5,851	4,276	11,345	5,332	2,269	716	121	38	8	2				126,652	79,604	56,472	0.60
1984	54,670	36,296	13,427	10,275	6,336	4,804	11,283	5,206	2,122	487	52	22						144,980	90,310	55,235	0.57
1985	59,634	36,831	13,008	11,041	6,627	4,547	10,040	3,575	1,001	157	1							146,462	86,828	43,042	0.48
1986	67,701	41,467	14,570	11,842	7,016	4,693	10,241	3,062	868	146								161,606	93,905	42,381	0.45
1987	85,181	41,222	15,834	12,839	7,586	5,332	10,611	2,192	477	69								181,343	96,162	40,401	0.38
1988	87,254	40,225	15,913	13,153	7,903	5,461	10,310	2,442	511	26		1						183,199	95,945	40,769	0.39
1989	83,947	45,282	17,267	13,777	7,945	5,137	8,634	1,614	370	34								184,007	100,060	35,930	0.33
1990	83,873	42,607	17,529	14,192	8,226	5,260	8,594	1,794	335	21								182,431	98,558	36,592	0.33
1991	87,250	42,587	16,764	13,184	7,187	4,194	5,975	938	219	17								178,315	91,065	28,527	0.27
1992	87,717	41,934	17,822	14,777	8,134	4,520	6,076	808	85	4								181,877	94,160	29,294	0.24
1993	83,069	37,331	17,235	13,733	7,562	4,289	5,322	638	76	5								169,260	86,191	26,363	0.22
1994	68,927	31,100	15,750	12,386	6,362	3,655	4,092	415	20									142,707	73,780	21,695	0.08
1995	62,080	29,681	15,152	12,083	6,146	3,306	3,905	590	121	2								133,066	70,986	21,674	0.06
1996	59,238	30,432	14,626	11,248	5,389	2,823	3,186	409	69									127,420	68,182	18,874	0.05
1997	58,501	31,832	14,875	10,910	5,246	2,407	2,575	299	44									126,689	68,188	17,136	0.04

*Summary of reports submitted in accordance with 10 CFR 20.407 or 20.2206 (since 1994) by only those plants that had been in commercial operation for at least 1 full year as of December 31 of each of the indicated years. Figures shown have been adjusted for the multiple reporting of transient individuals (see Section 5).

** The collective dose, when not reported by the licensee, was calculated by the NRC staff using methods described in Section 3.1.4.

***CR is the ratio of annual collective dose delivered at individual doses exceeding 1.5 rem to the total annual collective dose. For 1994 - 1997, CR was determined directly from individual dose records submitted under 10 CFR 20.2206.

4.4 Average Annual TEDE Doses

Some of the data presented in Tables 4.1, 4.2, and 4.3 are graphically displayed in Figure 4.1, where it can be seen that the average collective dose and average number of workers per BWR have been higher than those for PWRs since 1974 and that the values of both parameters, in general, continued to rise at both types of facilities until 1983. Between 1983 and 1997, the average collective dose per reactor dropped by 79%. In 1997, the collective dose per reactor for PWRs increased by 1% to 132 person-rem. The collective dose per reactor for BWRs decreased by 20% to 205 person-rem in 1997. The overall collective dose per reactor for LWRs decreased by 9% to 157 person-rem in 1997. The number of workers with measurable dose per reactor decreased to 915 for BWRs but increased to 703 for PWRs in 1997. However, the overall decreasing trend in average reactor collective doses since 1983 indicates that licensees are continuing to successfully implement ALARA dose reduction features at their facilities.

Figures 4.2 and 4.3 are plots of most of the other information that is given in Tables 4.1, 4.2, and 4.3. The value for the total collective dose for all LWRs decreased by 9% from a value of 18,874 person-rem in 1996 to 17,136 person-rem in 1997. Together with the slight increase in the number of workers with measurable dose, this resulted in the average measurable dose per worker decreasing to 0.20 rem in 1997. Figure 4.2 shows that in 1997 the net electricity generated was 71,851 megawatt-years.

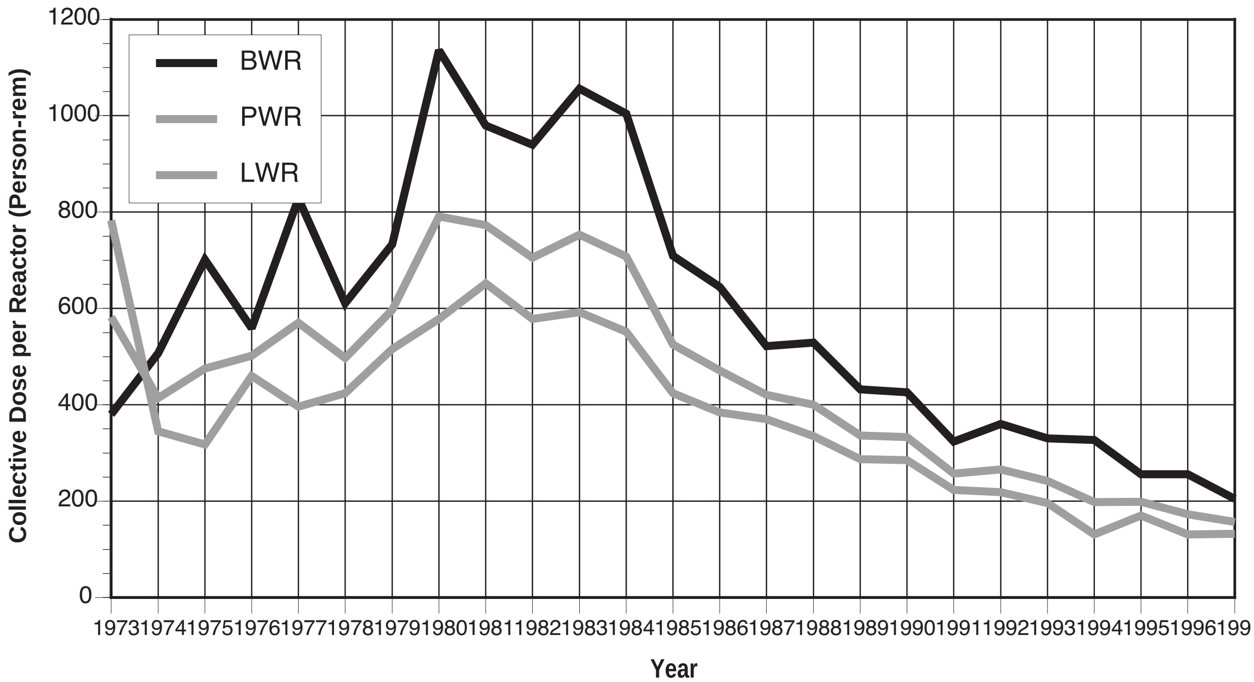
The fluctuations in the parameters for the years following the accident at the TMI plant in 1979 may reflect some of the impact that this incident had on the nuclear power industry. The decrease seen in dose trends since 1983 may be attributable to several factors. Utilities have completed most of the tasks initiated as a result of the lessons learned from the Three Mile Island accident, and they are increasing efforts to avoid and reduce exposure. The importance of exposure control and the concept of keeping exposures to ALARA levels is continually being stressed, and most utilities have established programs to collect and share information relative to tasks, techniques, and exposures.

To further assist in the identification of any trends that might exist, Figure 4.4 displays the average and median[5] values of the collective dose per reactor for BWRs and for PWRs for the years 1973 through 1997. The ranges of the values reported each year are shown by the vertical lines with a small bar at each end marking the two extreme values. The rectangles indicate the range of values of the collective dose exhibited by those plants ranked in the twenty-fifth through the seventy-fifth percentiles. Since the median values usually are not as greatly affected by the extreme values of the collective doses, they do not normally fluctuate as much from year to year as do the average values. The median collective dose for PWRs

[5] The value at which 50% of the reactors reported greater collective doses and the other 50% reported smaller collective doses.

Figure 4.1
Average Collective Dose and Number of Workers per Reactor 1973 – 1997

Average Annual Collective Dose



Average Annual Number of Workers with Measurable Dose

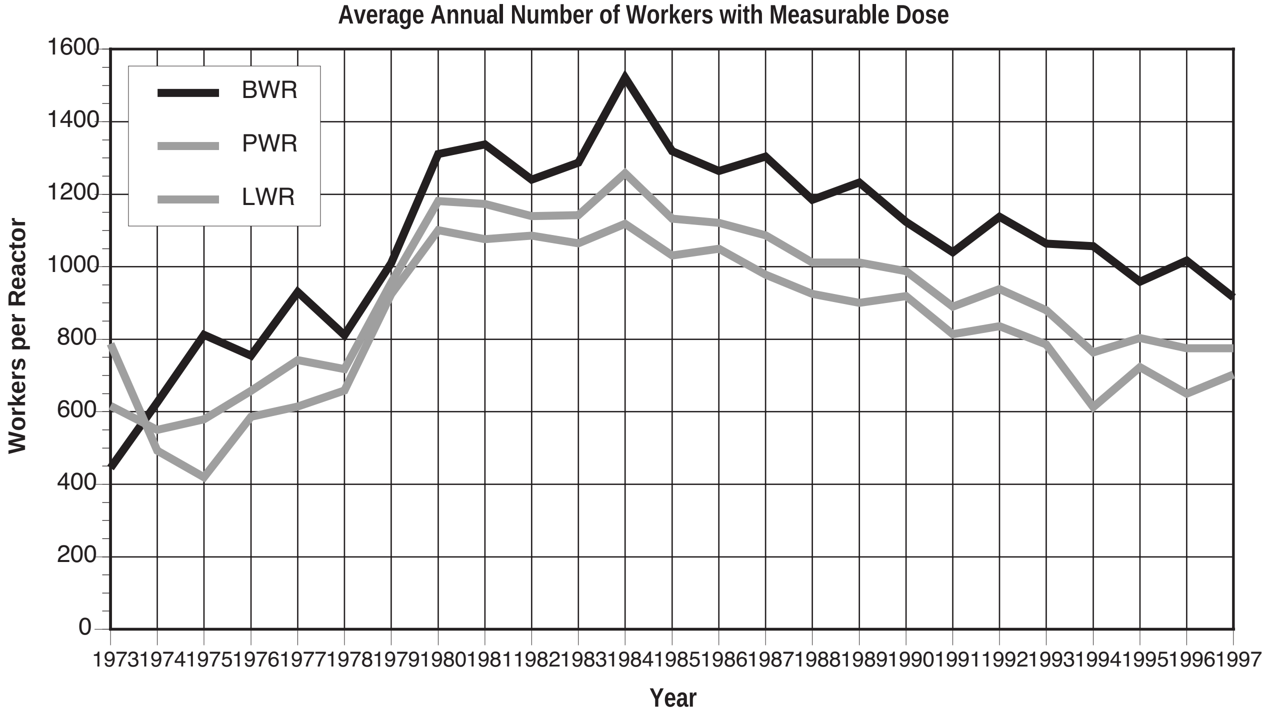
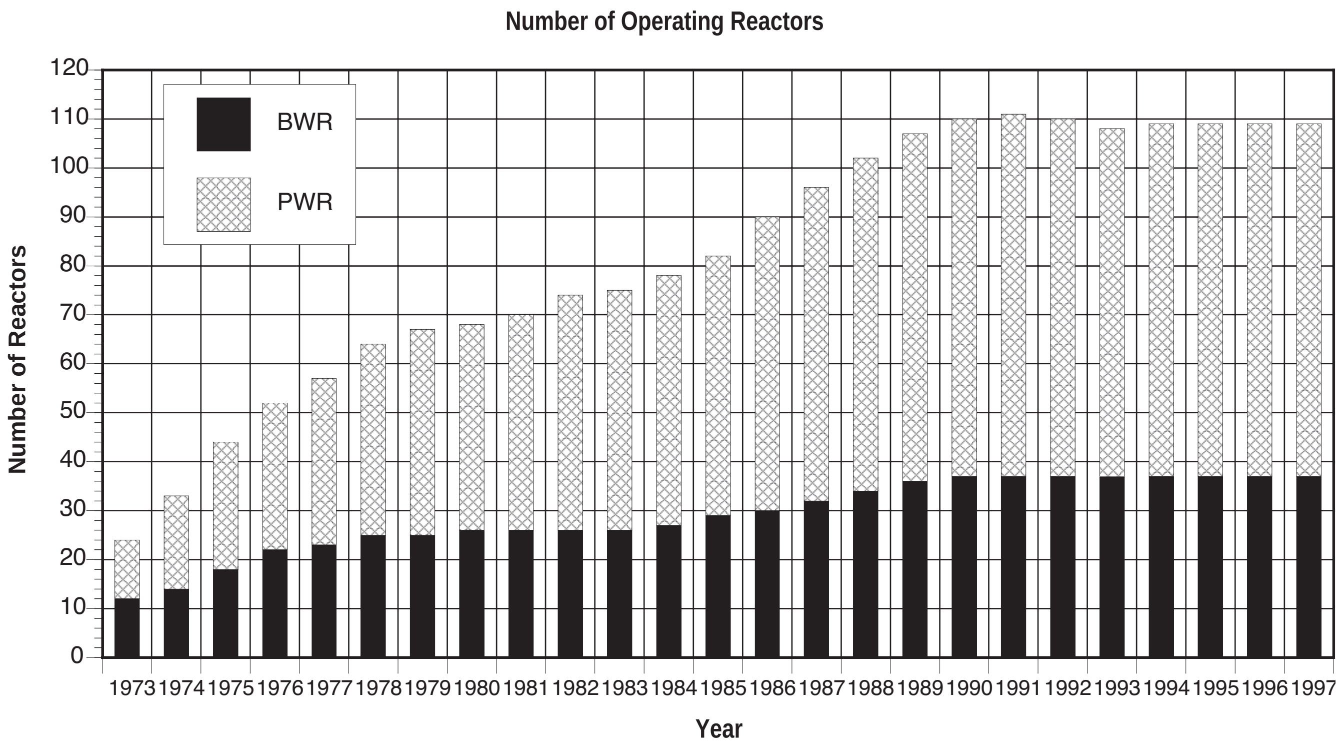
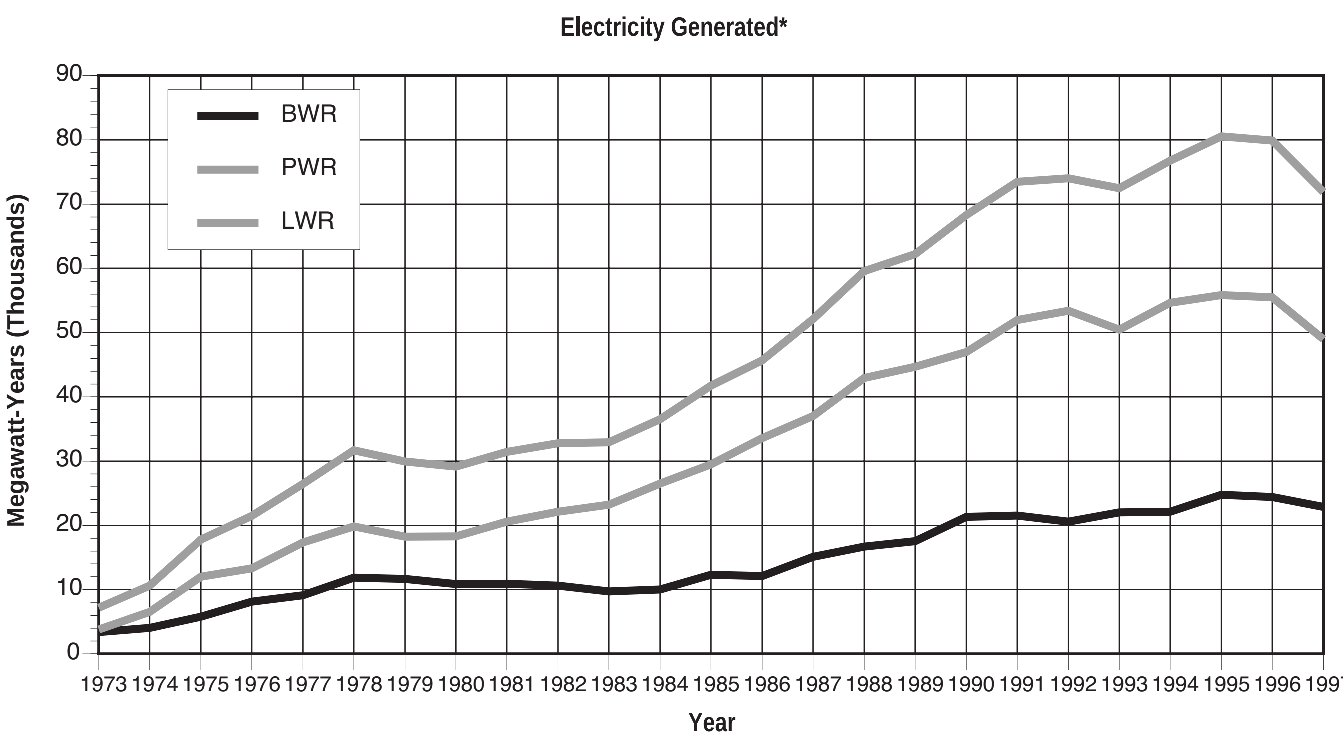


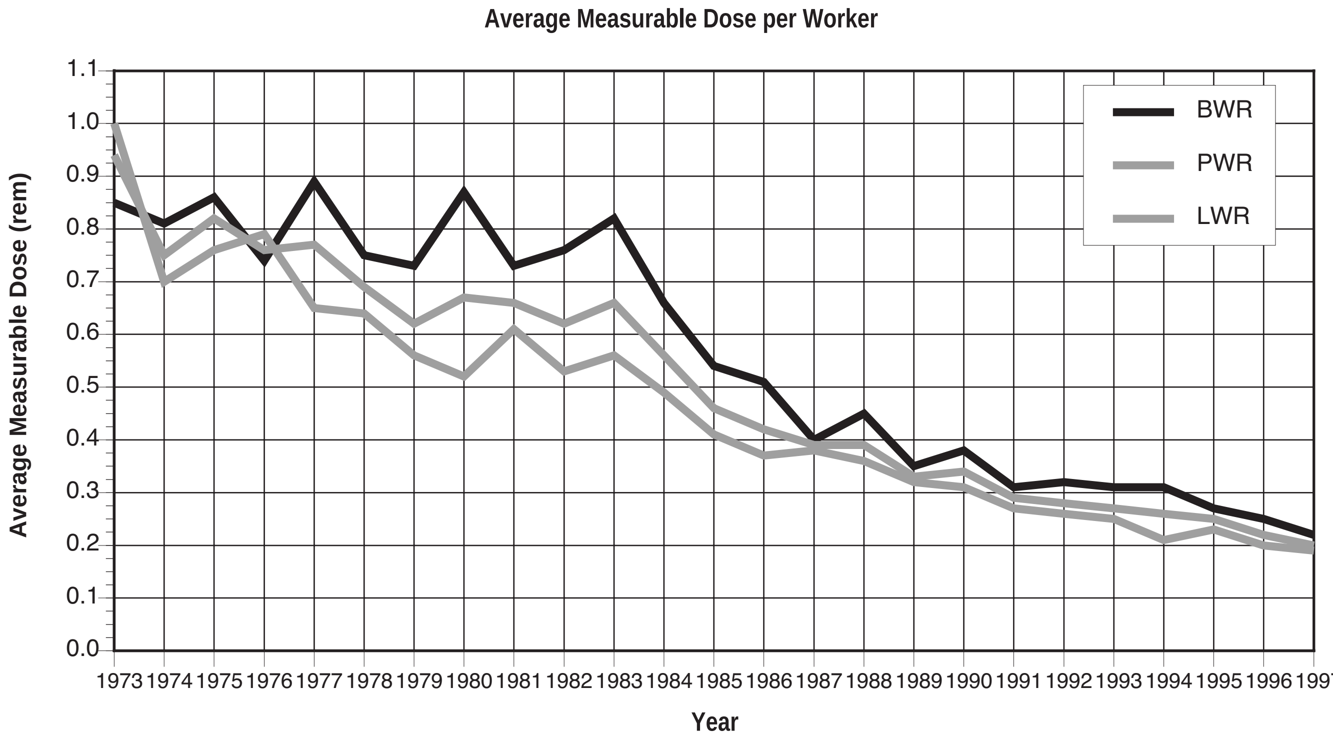
Figure 4.2
Number of Operating Reactors and Gross Electricity Generated 1973 – 1997

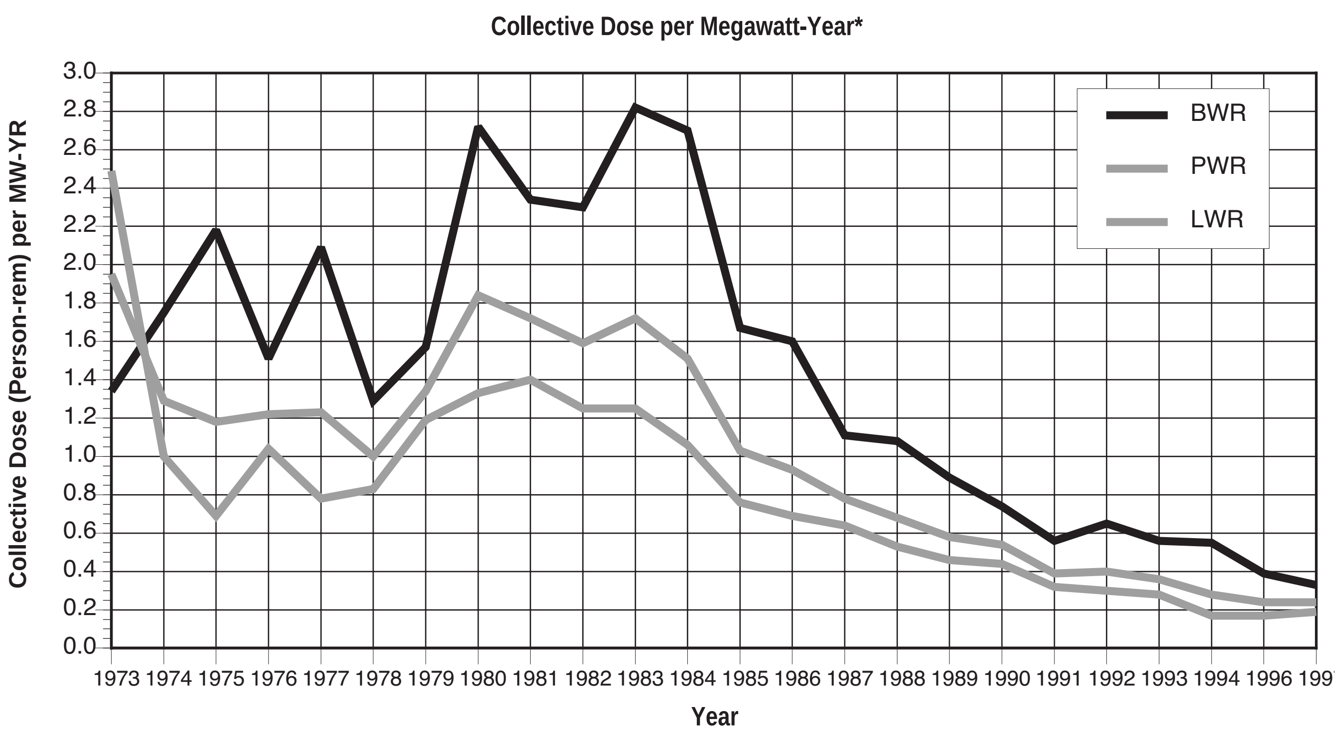




*Gross electricity 1973-1996, Net electricity for 1997.

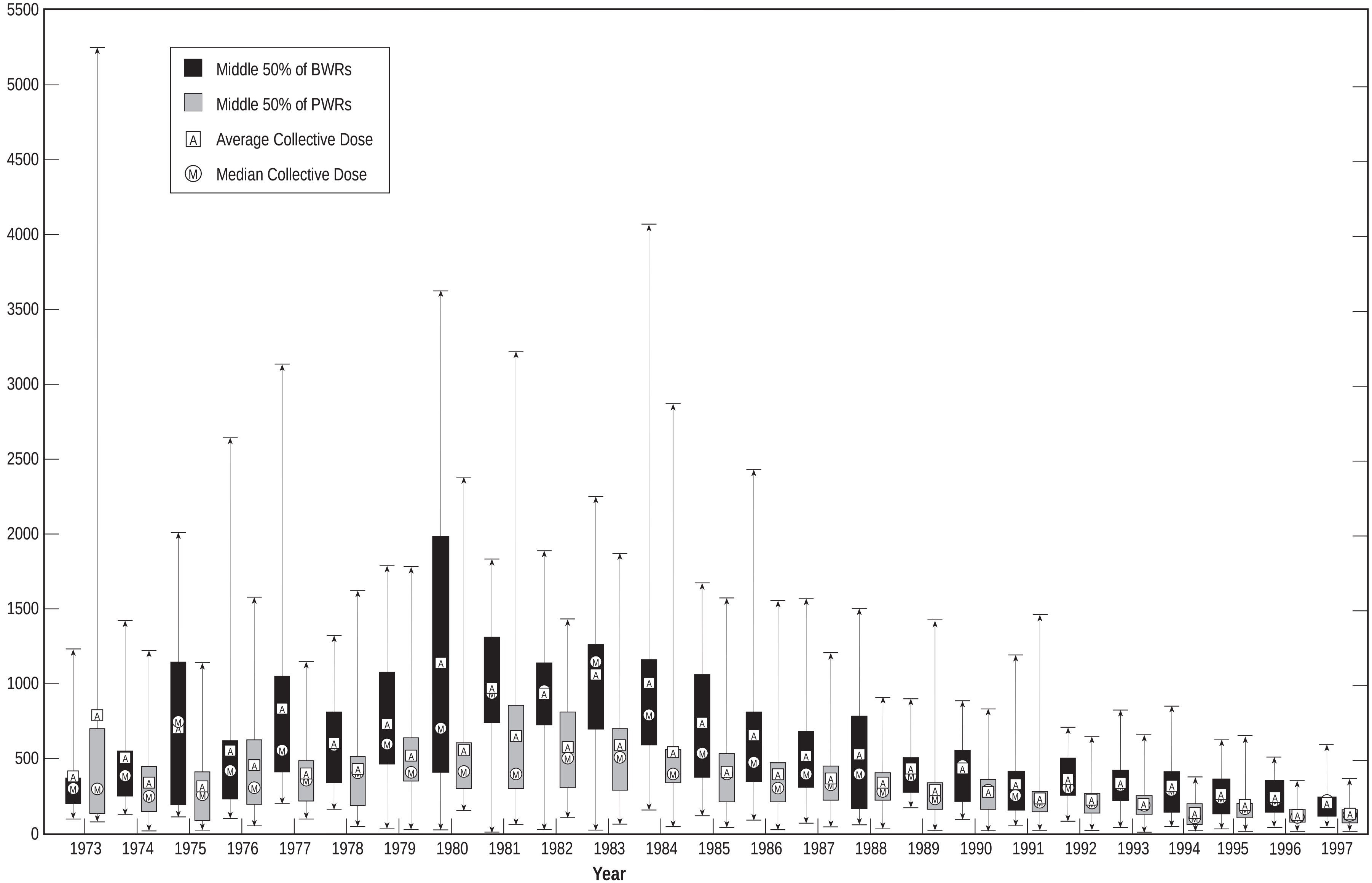
Figure 4.3
Average Measurable Dose per Worker and Collective Dose per Megawatt-Year 1973 – 1997





*Gross electricity 1973-1996, Net electricity for 1997.

Figure 4.4
Average, Median, and Extreme Values of the Collective Dose Per Reactor 1973 – 1997



experienced a slight increase from 120 person-rem in 1996 to 121 person-rem in 1997. At BWRs, the median fluctuates more from year to year, and in 1997 the median collective dose decreased to 206 person-rem. Figure 4.4 also shows that, in 1997, 50% of the PWRs reported collective doses between 74 and 163 person-rem while 50% of the BWRs reported collective doses between 117 and 245 person-rem. Nearly every year, the median collective dose is less than the average, which indicates that the collective dose for most plants is less than the average collective dose per reactor (the value that is widely quoted).

4.5 Plant Rankings by Collective Dose per Reactor

Because the number of reactors from which data have been collected is statistically rather small, the information reported by a few reactors where unusual conditions or problems may have occurred could have a large impact on some of the statistics presented in this report. In an effort to identify those plants, Tables 4.5 and 4.6 list the BWRs and PWRs in ascending order of collective dose per reactor for each of the 5 years from 1993 through 1997. The total collective dose per site is listed in the tables even though the dose per reactor was used for the ranking. Two other parameters, average measurable dose per worker and collective dose per megawatt-year, are also given for each plant. Also shown is a parameter CR, which is defined as the ratio of the annual collective dose delivered at individual doses exceeding 1.5 rem to the total annual collective dose. The value of CR has continued to decline for most plants, and in 1997, the CR for all the U.S. LWRs fell to 0.04 which is the first time that the CR has been below the 0.05 to 0.50 range recommended by the UNSCEAR [Ref. 10]. Note that for 1994 through 1997, the CR value was determined directly from the individual radiation exposure records submitted under 10 CFR 20.2206 (Form 5) rather than calculating the value from the statistical dose distribution summary (see Section 3.1.8).

Tables 4.7a and b list the sites that had been in commercial operation for at least 5 years as of December 31, 1997, and show the values of several parameters for each of the sites. They also give averages for the two types of reactors. Based on the 185 reactor-years of operation accumulated by the 37 BWRs listed, the average annual collective dose per reactor was found to be 275 person-rem, the average measurable dose per worker was 0.27 rem, and the average collective dose per megawatt-year was 0.4.

Based on the 345 reactor-years of operation at the 69 PWRs listed, the average annual collective dose per reactor, average measurable dose per worker, and average collective dose per megawatt-year were found to be 153 person-rem, 0.22 rem, and 0.2 person-rem/MW-yr, respectively. All of these values, at both types of facilities, are lower than those found for the 5 year period ending in 1996, with the exception of the average collective dose per megawatt-year at PWRs, which remained the same.

TABLE 4.5
BOILING WATER REACTORS LISTED IN ASCENDING ORDER OF COLLECTIVE DOSE PER REACTOR***
1993 - 1997

1993				
Site Name	Collect. Dose per Site*	Dose per Worker	Dose per MW-Yr	CR**
FERMI 2	35	0.10	0.0	0.00
MILLSTONE POINT 1	81	0.27	0.1	0.15
HOPE CREEK 1	98	0.14	0.1	0.05
LIMERICK 1,2	217	0.17	0.1	0.02
BIG ROCK POINT	152	0.36	3.0	0.26
SUSQUEHANNA 1,2	335	0.23	0.2	0.05
RIVER BEND 1	180	0.21	0.3	0.14
VERMONT YANKEE	217	0.26	0.5	0.08
FITZPATRICK	232	0.16	0.4	0.14
PEACH BOTTOM 2,3	552	0.31	0.3	0.17
PERRY	278	0.23	0.6	0.03
BROWNS FERRY 1,2,3	870	0.24	1.3	0.08
NINE MILE POINT 1,2	633	0.27	0.5	0.14
GRAND GULF	332	0.18	0.4	0.07
HATCH 1,2	669	0.39	0.6	0.18
COOPER STATION	391	0.35	0.9	0.20
DUANE ARNOLD	407	0.39	1.0	0.34
OYSTER CREEK	416	0.16	0.8	0.07
QUAD CITIES 1,2	849	0.39	0.9	0.24
LASALLE 1,2	854	0.50	0.6	0.33
PILGRIM	435	0.33	0.8	0.03
BRUNSWICK 1,2	872	0.30	1.9	0.17
WASHINGTON NUCLEAR 2	469	0.34	0.6	0.19
MONTICELLO	494	0.52	1.1	0.30
CLINTON	498	0.40	0.7	0.09
DRESDEN 2,3	1,655	0.60	1.7	0.38

1994				
Site Name	Collect. Dose per Site*	Dose per Worker	Dose per MW-Yr	CR**
VERMONT YANKEE	38	0.17	0.1	0.00
GRAND GULF	56	0.12	0.0	0.03
CLINTON	63	0.15	0.1	0.00
NINE MILE POINT 1,2	149	0.19	0.1	0.02
COOPER STATION	79	0.24	0.3	0.00
BIG ROCK POINT	119	0.38	2.4	0.14
DUANE ARNOLD	120	0.24	0.2	0.03
LIMERICK 1,2	275	0.18	0.1	0.00
PILGRIM	200	0.26	0.4	0.00
FERMI 2	213	0.19	—	0.00
SUSQUEHANNA 1,2	442	0.28	0.2	0.02
BROWNS FERRY 1,2,3	855	0.26	1.0	0.05
PEACH BOTTOM 2,3	579	0.27	0.3	0.09
FITZPATRICK	322	0.20	0.5	0.10
HOPE CREEK 1	326	0.18	0.4	0.05
LASALLE 1,2	726	0.40	0.5	0.08
MILLSTONE POINT 1	391	0.30	1.0	0.01
MONTICELLO	395	0.50	0.8	0.17
DRESDEN 2,3	833	0.36	1.2	0.05
HATCH 1,2	864	0.39	0.7	0.20
BRUNSWICK 1,2	999	0.33	0.8	0.05
RIVER BEND 1	519	0.23	0.9	0.06
QUAD CITIES 1,2	1,128	0.52	1.7	0.31
PERRY	691	0.33	1.3	0.03
OYSTER CREEK	844	0.35	2.0	0.24
WASHINGTON NUCLEAR 2	866	0.46	1.1	0.20

1995				
Site Name	Collect. Dose per Site*	Dose per Worker	Dose per MW-Yr	CR**
FERMI 2	28	0.07	0.0	0.00
MONTICELLO	44	0.22	0.1	0.00
BIG ROCK POINT	54	0.26	0.9	0.18
PERRY	64	0.11	0.1	0.00
RIVER BEND 1	85	0.13	0.1	0.00
OYSTER CREEK	90	0.12	0.1	0.00
LIMERICK 1,2	260	0.16	0.1	0.02
BROWNS FERRY 1,2,3	409	0.16	0.4	0.00
VERMONT YANKEE	182	0.25	0.4	0.00
HOPE CREEK 1	196	0.13	0.2	0.07
PEACH BOTTOM 2,3	398	0.21	0.2	0.03
COOPER STATION	228	0.21	0.5	0.02
SUSQUEHANNA 1,2	476	0.27	0.3	0.05
HATCH 1,2	488	0.33	0.4	0.10
LASALLE 1,2	512	0.32	0.3	0.02
CLINTON	316	0.27	0.4	0.01
FITZPATRICK	327	0.26	0.6	0.03
BRUNSWICK 1,2	683	0.26	0.5	0.00
GRAND GULF	342	0.22	0.4	0.01
DUANE ARNOLD	357	0.32	0.8	0.01
QUAD CITIES 1,2	736	0.36	0.7	0.01
NINE MILE POINT 1,2	759	0.33	0.5	0.12
DRESDEN 2,3	875	0.35	1.4	0.07
WASHINGTON NUCLEAR 2	456	0.27	0.6	0.03
PILGRIM	482	0.37	0.9	0.00
MILLSTONE POINT 1	620	0.68	1.2	0.16

1996				
Site Name	Collect. Dose per Site*	Dose per Worker	Dose per MW-Yr	CR**
COOPER STATION	48	0.10	0.1	0.00
PILGRIM	116	0.22	0.2	0.00
LIMERICK 1,2	234	0.14	0.1	0.00
BROWNS FERRY 1,2,3	384	0.22	0.2	0.02
PEACH BOTTOM 2,3	282	0.17	0.1	0.02
SUSQUEHANNA 1,2	289	0.20	0.1	0.02
NINE MILE POINT 1,2	290	0.18	0.2	0.02
FERMI 2	157	0.11	0.3	0.00
HOPE CREEK 1	158	0.15	0.2	0.01
BIG ROCK POINT	208	0.60	4.7	0.23
HATCH 1,2	441	0.29	0.3	0.05
DRESDEN 2,3	456	0.26	0.7	0.00
VERMONT YANKEE	231	0.24	0.5	0.00
MONTICELLO	240	0.32	0.5	0.06
DUANE ARNOLD	270	0.25	0.6	0.06
PERRY	307	0.19	0.3	0.00
CLINTON	350	0.30	0.6	0.06
FITZPATRICK	357	0.26	0.6	0.02
GRAND GULF	357	0.23	0.3	0.03
BRUNSWICK 1,2	716	0.26	0.6	0.09
WASHINGTON NUCLEAR 2	373	0.26	0.6	0.02
LASALLE 1,2	819	0.29	0.8	0.03
MILLSTONE POINT 1	431	0.58	—	0.17
OYSTER CREEK	449	0.24	0.9	0.07
RIVER BEND 1	473	0.23	0.6	0.07
QUAD CITIES 1,2	1,025	0.46	1.2	0.08

1997				
Site Name	Collect. Dose per Site*	Dose per Worker	Dose per MW-Yr	CR**
FERMI 2	49	0.08	0.1	0.00
OYSTER CREEK	50	0.10	0.1	0.00
BIG ROCK POINT	55	0.21	2.5	0.00
VERMONT YANKEE	57	0.22	0.1	0.00
DUANE ARNOLD	63	0.18	0.1	0.00
FITZPATRICK	91	0.14	0.1	0.00
GRAND GULF	105	0.20	0.1	0.12
MONTICELLO	106	0.27	0.3	0.00
LIMERICK 1,2	234	0.16	0.1	0.06
LASALLE 1,2	316	0.19	—	0.02
BROWNS FERRY 1,2,3	516	0.25	0.3	0.05
CLINTON	172	0.23	—	0.00
COOPER STATION	174	0.16	0.3	0.00
MILLSTONE POINT 1	195	0.19	—	0.02
BRUNSWICK 1,2	411	0.19	0.3	0.00
NINE MILE POINT 1,2	429	0.30	0.3	0.04
SUSQUEHANNA 1,2	433	0.26	0.2	0.10
DRESDEN 2,3	467	0.17	0.4	0.01
PEACH BOTTOM 2,3	490	0.26	0.3	0.09
WASHINGTON NUCLEAR 2	251	0.21	0.4	0.01
PERRY	272	0.18	0.3	0.00
QUAD CITIES 1,2	654	0.26	0.7	0.01
RIVER BEND 1	347	0.21	0.5	0.04
HOPE CREEK 1	350	0.20	0.5	0.00
HATCH 1,2	722	0.37	0.5	0.20
PILGRIM	588	0.36	1.2	0.06

* For sites with more than one operating reactor, the collective dose per reactor is obtained by dividing the collective dose for the site by the number of reactors.

** CR is the ratio of the annual collective dose delivered at individual doses exceeding 1.5 rem to the collective dose. For '94 - '97 data, the CR value was determined from the individual Form 5 submittals.

*** All doses are in rem.

TABLE 4.6
PRESSURIZED WATER REACTORS LISTED IN ASCENDING ORDER OF COLLECTIVE DOSE PER REACTOR***
1993 - 1997

1993

Site Name	Collect. Dose per Site*	Dose per Worker	Dose per MW-Y	CR**
SEABROOK	6	0.05	0.0	0.00
WATERFORD 3	15	0.08	0.0	0.00
COOK 1,2	44	0.07	0.0	0.00
HARRIS	31	0.09	0.0	0.00
PRAIRIE ISLAND 1,2	106	0.20	0.1	0.00
COMANCHE PEAK 1,2	109	0.12	0.1	0.03
CRYSTAL RIVER 3	60	0.09	0.1	0.00
INDIAN POINT 3	60	0.13	0.4	0.00
OCONEE 1,2,3	237	0.16	0.1	0.00
POINT BEACH 1,2	186	0.33	0.2	0.16
KEWAUNEE	106	0.24	0.2	0.06
SOUTH TEXAS 1,2	251	0.22	1.5	0.04
ARKANSAS 1,2	268	0.14	0.2	0.01
BRAIDWOOD 1,2	273	0.26	0.1	0.03
TURKEY POINT 3,4	275	0.22	0.2	0.08
DIABLO CANYON 1,2	281	0.19	0.1	0.03
FORT CALHOUN	157	0.22	0.4	0.01
FARLEY 1,2	333	0.26	0.2	0.12
WOLF CREEK 1	183	0.19	0.2	0.01
VOGTLE 1,2	367	0.27	0.2	0.11
SEQUOYAH 1,2	372	0.23	0.9	0.08
SURRY 1,2	383	0.27	0.3	0.09
GINNA	193	0.23	0.5	0.08
PALO VERDE 1,2,3	592	0.28	0.2	0.16
CATAWBA 1,2	396	0.25	0.2	0.07
CALVERT CLIFFS 1,2	405	0.28	0.3	0.14
SALEM 1,2	408	0.11	0.3	0.07
THREE MILE ISLAND 1	206	0.11	0.3	0.01
BYRON 1,2	432	0.32	0.2	0.09
CALLAWAY 1	225	0.20	0.2	0.02
MCGUIRE 1,2	463	0.27	0.3	0.14
ST. LUCIE 1,2	492	0.34	0.4	0.16
SAN ONOFRE 1,2,3	767	0.35	0.4	0.14
MILLSTONE POINT 2,3	557	0.27	0.4	0.16
PALISADES	289	0.32	0.7	0.13
SUMMER 1	297	0.26	0.4	0.08
BEAVER VALLEY 1,2	621	0.30	0.5	0.12
ZION 1,2	643	0.36	0.4	0.22
ROBINSON 2	337	0.28	0.7	0.11
DAVIS-BESSE	348	0.28	0.5	0.11
MAINE YANKEE	377	0.37	0.6	0.13
HADDAM NECK	408	0.41	0.9	0.25
NORTH ANNA 1,2	908	0.33	0.6	0.28
INDIAN POINT 2	675	0.45	1.0	0.23

1994

Site Name	Collect. Dose per Site*	Dose per Worker	Dose per MW-Yr	CR**
CALLAWAY 1	14	0.07	0.0	0.00
SAN ONOFRE 2,3	32	0.06	0.0	0.00
BEAVER VALLEY 1,2	44	0.09	0.0	0.00
FORT CALHOUN	23	0.11	0.0	0.00
SOUTH TEXAS 1,2	47	0.07	0.0	0.00
THREE MILE ISLAND 1	40	0.09	0.1	0.00
COMANCHE PEAK 1,2	90	0.09	0.1	0.02
INDIAN POINT 2	48	0.13	0.1	0.06
PRAIRIE ISLAND 1,2	109	0.23	0.1	0.00
INDIAN POINT 3	58	0.11	—	0.00
PALISADES	60	0.15	0.1	0.00
ROBINSON 2	63	0.15	0.1	0.00
KEWAUNEE	72	0.20	0.2	0.00
MAINE YANKEE	84	0.28	0.1	0.02
POINT BEACH 1,2	170	0.31	0.2	0.01
ARKANSAS 1,2	172	0.13	0.1	0.00
MILLSTONE POINT 2,3	188	0.15	0.1	0.01
SALEM 1,2	188	0.20	0.1	0.05
NORTH ANNA 1,2	193	0.19	0.1	0.00
CATAWBA 1,2	207	0.16	0.1	0.01
VOGTLE 1,2	217	0.21	0.1	0.01
SEABROOK	113	0.13	0.2	0.00
FARLEY 1,2	125	0.24	0.2	0.03
HADDAM NECK	135	0.29	0.3	0.17
GINNA	138	0.20	0.3	0.00
BYRON 1,2	280	0.29	0.1	0.02
DAVIS-BESSE	144	0.17	0.2	0.00
SEQUOYAH 1,2	292	0.18	0.2	0.02
BRAIDWOOD 1,2	298	0.24	0.2	0.01
ZION 1,2	306	0.26	0.2	0.02
PALO VERDE 1,2,3	462	0.23	0.2	0.07
OCONEE 1,2,3	537	0.28	0.3	0.08
SURRY 1,2	378	0.25	0.3	0.00
WATERFORD 3	191	0.16	0.2	0.00
MCGUIRE 1,2	397	0.24	0.2	0.07
HARRIS	222	0.20	0.3	0.00
CALVERT CLIFFS 1,2	454	0.31	0.3	0.00
CRYSTAL RIVER 3	228	0.21	0.3	0.02
WOLF CREEK 1	235	0.22	0.2	0.01
TURKEY POINT 3,4	476	0.32	0.4	0.03
COOK 1,2	479	0.27	0.4	0.01
ST. LUCIE 1,2	505	0.27	0.4	0.05
DIABLO CANYON 1,2	590	0.25	0.3	0.05
SUMMER 1	374	0.24	0.7	0.00

1995

Site Name	Collect. Dose per Site*	Dose per Worker	Dose per MW-Yr	CR**
DAVIS-BESSE	7	0.03	0.0	0.00
CRYSTAL RIVER 3	8	0.04	0.0	0.00
SUMMER 1	13	0.05	0.0	0.00
WOLF CREEK 1	14	0.06	0.0	0.00
PRAIRIE ISLAND 1,2	107	0.21	0.1	0.00
INDIAN POINT 3	67	0.11	0.4	0.00
MCGUIRE 1,2	138	0.11	0.1	0.00
COMANCHE PEAK 1,2	179	0.19	0.1	0.00
POINT BEACH 1,2	190	0.35	0.2	0.04
VOGTLE 1,2	199	0.21	0.1	0.00
OCONEE 1,2,3	304	0.19	0.1	0.09
COOK 1,2	203	0.15	0.1	0.00
SEABROOK	102	0.13	0.1	0.00
TURKEY POINT 3,4	215	0.19	0.2	0.00
KEWAUNEE	109	0.26	0.2	0.00
SALEM 1,2	218	0.17	0.4	0.02
CALVERT CLIFFS 1,2	235	0.20	0.2	0.00
BRAIDWOOD 1,2	236	0.21	0.1	0.01
GINNA	136	0.18	0.3	0.06
FORT CALHOUN	139	0.22	0.3	0.00
DIABLO CANYON 1,2	286	0.18	0.1	0.06
SOUTH TEXAS 1,2	291	0.20	0.1	0.00
BYRON 1,2	306	0.28	0.2	0.06
WATERFORD 3	153	0.14	0.2	0.00
PALO VERDE 1,2,3	482	0.26	0.1	0.05
HARRIS	174	0.16	0.2	0.01
SEQUOYAH 1,2	358	0.22	0.2	0.02
NORTH ANNA 1,2	367	0.24	0.2	0.05
CALLAWAY 1	187	0.18	0.2	0.00
ARKANSAS 1,2	386	0.17	0.3	0.03
SURRY 1,2	406	0.22	0.3	0.10
ST. LUCIE 1,2	413	0.28	0.3	0.07
MILLSTONE POINT 2,3	416	0.25	0.3	0.51
THREE MILE ISLAND 1	213	0.17	0.3	0.00
ROBINSON 2	215	0.20	0.3	0.00
BEAVER VALLEY 1,2	453	0.29	0.3	0.02
SAN ONOFRE 1,2,3	455	0.24	0.3	0.00
CATAWBA 1,2	462	0.24	0.2	0.03
FARLEY 1,2	463	0.29	0.4	0.08
ZION 1,2	797	0.44	0.5	0.15
HADDAM NECK	442	0.44	1.0	0.14
PALISADES	462	0.38	0.8	0.10
INDIAN POINT 2	548	0.32	0.9	0.07
MAINE YANKEE	653	0.56	27.7	0.26

1996

Site Name	Collect. Dose per Site*	Dose per Worker	Dose per MW-Y	CR**
SEABROOK	10	0.05	0.0	0.00
THREE MILE ISLAND 1	16	0.06	0.0	0.00
HARRIS	17	0.04	0.0	0.00
INDIAN POINT 3	22	0.08	0.0	0.00
WATERFORD 3	27	0.08	0.0	0.00
INDIAN POINT 2	54	0.14	0.1	0.00
MAINE YANKEE	56	0.14	0.1	0.00
PRAIRIE ISLAND 1,2	112	0.20	0.1	0.00
MILLSTONE POINT 2,3	126	0.13	0.3	0.17
SAN ONOFRE 2,3	129	0.10	0.1	0.00
SOUTH TEXAS 1,2	137	0.12	0.1	0.00
OCONEE 1,2,3	257	0.17	0.1	0.00
DIABLO CANYON 1,2	176	0.12	0.1	0.00
TURKEY POINT 3,4	187	0.16	0.1	0.00
SUMMER 1	97	0.14	0.1	0.00
PALO VERDE 1,2,3	302	0.18	0.1	0.00
ARKANSAS 1,2	203	0.14	0.1	0.02
SURRY 1,2	209	0.21	0.1	0.07
COOK 1,2	214	0.19	0.1	0.00
FARLEY 1,2	232	0.20	0.2	0.09
MCGUIRE 1,2	238	0.15	0.1	0.00
CALVERT CLIFFS 1,2	239	0.20	0.2	0.00
KEWAUNEE	126	0.27	0.3	0.03
SEQUOYAH 1,2	265	0.19	0.1	0.00
POINT BEACH 1,2	276	0.27	0.3	0.01
COMANCHE PEAK 1,2	288	0.20	0.2	0.00
NORTH ANNA 1,2	291	0.24	0.2	0.05
SALEM 1,2	300	0.18	—	0.01
CATAWBA 1,2	302	0.19	0.2	0.01
BRAIDWOOD 1,2	334	0.25	0.2	0.00
DAVIS-BESSE	167	0.18	0.2	0.00
ROBINSON 2	167	0.16	0.3	0.00
GINNA	168	0.17	0.5	0.00
WOLF CREEK 1	171	0.17	0.2	0.00
HADDAM NECK	175	0.26	0.5	0.06
ST. LUCIE 1,2	385	0.27	0.3	0.06
ZION 1,2	437	0.28	0.3	0.05
BEAVER VALLEY 1,2	449	0.27	0.4	0.05
FORT CALHOUN	226	0.31	0.6	0.00
VOGTLE 1,2	452	0.32	0.2	0.09
BYRON 1,2	455	0.28	0.3	0.03
CALLAWAY 1	248	0.25	0.2	0.12
PALISADES	318	0.29	0.5	0.13
CRYSTAL RIVER 3	353	0.30	1.2	0.05

1997

Site Name	Collect. Dose per Site*	Dose per Worker	Dose per MW-Yr	CR**
DAVIS-BESSE	10	0.05	0.0	0.0
CALLAWAY 1	12	0.05	0.0	0.0
ROBINSON 2	13	0.04	0.0	0.0
FORT CALHOUN	41	0.16	0.1	0.0
POINT BEACH 1,2	92	0.14	0.5	0.0
PALISADES	48	0.14	0.1	0.0
NORTH ANNA 1,2	103	0.12	0.1	0.0
KEWAUNEE	56	0.20	0.2	0.0
ARKANSAS 1,2	119	0.10	0.1	0.0
ZION 1,2	119	0.13	1.0	0.0
COMANCHE PEAK 1,2	146	0.17	0.1	0.0
OCONEE 1,2,3	223	0.16	0.1	0.0
VOGTLE 1,2	158	0.16	0.1	0.0
GINNA	81	0.15	0.2	0.0
PALO VERDE 1,2,3	246	0.16	0.1	0.0
PRAIRIE ISLAND 1,2	174	0.23	0.2	0.0
SALEM 1,2	175	0.20	0.6	0.1
DIABLO CANYON 1,2	219	0.17	0.1	0.0
WATTS BAR 1	112	0.11	0.13	0.0
CALVERT CLIFFS 1,2	229	0.21	0.2	0.0
BYRON 1,2	241	0.16	0.1	0.0
MILLSTONE POINT 2,3	253	0.18	—	0.0
CATAWBA 1,2	266	0.17	0.1	0.0
SOUTH TEXAS 1,2	273	0.17	0.1	0.0
FARLEY 1,2	278	0.25	0.2	0.2
WATERFORD 3	148	0.13	0.2	0.0
HARRIS	149	0.13	0.2	0.0
BEAVER VALLEY 1,2	306	0.22	0.3	0.0
MAINE YANKEE	153	0.15	—	0.0
SURRY 1,2	320	0.24	0.2	0.0
BRAIDWOOD 1,2	321	0.19	0.2	0.0
SUMMER 1	163	0.20	0.2	0.0
SAN ONOFRE 2,3	341	0.21	0.2	0.0
CRYSTAL RIVER 3	179	0.18	—	0.0
SEABROOK	186	0.12	0.2	0.0
THREE MILE ISLAND 1	204	0.19	0.3	0.0
SEQUOYAH 1,2	414	0.21	0.2	0.0
TURKEY POINT 3,4	414	0.26	0.3	0.1
INDIAN POINT 3	234	0.15	0.5	0.0
MCGUIRE 1,2	492	0.22	0.3	0.1
WOLF CREEK 1	265	0.27	0.3	0.0
COOK 1,2	550	0.30	0.5	0.1
ST. LUCIE 1,2	646	0.28	0.5	0.1
INDIAN POINT 2	367	0.27	1.0	0.0

* For sites with more than one operating reactor, the collective dose per reactor is obtained by dividing the collective dose for the site by the number of reactors.

** CR is the ratio of the annual collective dose delivered at individual doses exceeding 1.5 rem to the collective dose. For '94 - '97 data, the CR value was determined from the individual Form 5 submittals.

*** All doses are in rem.

TABLE 4.7a
5-YEAR TOTALS AND AVERAGES LISTED IN ASCENDING ORDER OF COLLECTIVE DOSE PER BWR

1993 - 1997

Site Name*	Number of Reactor Years	Annual Collective Dose per Reactor	Total Coll. Dose per Site (rem)	Workers with Meas. Doses	Avg. Meas. Dose (rem)	Total MW-yrs	Average Collective Dose per MW-yr
FERMI 2	5	96	482	3,905	0.12	2,815.5	0.2
BIG ROCK POINT	5	118	588	1,539	0.38	229.1	2.6
LIMERICK 1,2	10	122	1,220	7,528	0.16	9,837.1	0.1
VERMONT YANKEE	5	145	725	3,001	0.24	2,318.8	0.3
COOPER STATION	5	184	920	4,151	0.22	2,547.6	0.4
SUSQUEHANNA 1,2	10	198	1,975	7,917	0.25	9,179.4	0.2
BROWNS FERRY 1,2,3	15	202	3,034	13,274	0.23	6,597.3	0.5
HOPE CREEK 1	5	226	1,128	6,854	0.16	4,282.2	0.3
NINE MILE POINT 1,2	10	226	2,260	8,477	0.27	7,267.8	0.3
PEACH BOTTOM 2,3	10	230	2,301	9,359	0.25	9,500.5	0.2
GRAND GULF	5	238	1,192	5,929	0.20	5,360.6	0.2
DUANE ARNOLD	5	243	1,217	4,110	0.30	2,294.4	0.5
MONTICELLO	5	256	1,279	3,098	0.41	2,371.8	0.5
FITZPATRICK	5	266	1,329	6,317	0.21	3,095.6	0.4
CLINTON	5	280	1,399	4,780	0.29	2,948.8	0.5
HATCH 1,2	10	318	3,184	8,874	0.36	6,745.0	0.5
RIVER BEND 1	5	321	1,604	7,487	0.21	3,815.4	0.4
PERRY	5	322	1,612	7,066	0.23	3,944.7	0.4
LASALLE 1,2	10	323	3,227	9,579	0.34	5,869.5	0.5
MILLSTONE POINT 1	5	344	1,718	4,336	0.40	1,539.6	1.1
PILGRIM	5	364	1,821	5,552	0.33	2,620.7	0.7
BRUNSWICK 1,2	10	368	3,681	13,623	0.27	5,881.7	0.6
OYSTER CREEK	5	370	1,849	8,045	0.23	2,691.7	0.7
DRESDEN 2,3	10	429	4,286	12,104	0.35	4,000.5	1.1
QUAD CITIES 1,2	10	439	4,392	11,076	0.40	4,468.4	1.0
WASHINGTON NUCLEAR 2	5	483	2,415	7,622	0.32	3,836.2	0.6
Grand Totals and Averages	185		50,838	185,603	0.27	116,059.9	0.4
Averages Per Reactor-Year			275	1,003		627.4	

* Sites where not all reactors had completed 5 full years of commercial operation as of 12/31/97 are not included.

TABLE 4.7b
5-YEAR TOTALS AND AVERAGES LISTED IN ASCENDING ORDER OF COLLECTIVE DOSE PER PWR
1993 - 1997

Site Name*	Number of Reactor Years	Annual Collective Dose per Reactor	Total Coll. Dose per Site (rem)	Workers with Meas. Doses	Avg. Meas. Dose (rem)	Total MW-yrs	Average Collective Dose per MW-yr
PRAIRIE ISLAND 1,2	10	61	608	2,820	0.22	4,805.4	0.1
SEABROOK	5	83	417	3,539	0.12	4,875.8	0.1
INDIAN POINT 3	5	88	441	3,542	0.12	1,503.8	0.3
POINT BEACH 1,2	10	91	914	3,354	0.27	3,700.0	0.2
KEWAUNEE	5	94	469	1,967	0.24	2,037.5	0.2
SOUTH TEXAS 1,2	10	100	999	6,012	0.17	8,882.1	0.1
OCONEE 1,2,3	15	104	1,558	7,866	0.20	10,316.1	0.2
WATERFORD 3	5	107	534	3,982	0.13	4,793.9	0.1
ARKANSAS 1,2	10	115	1,148	8,237	0.14	7,879.3	0.1
FORT CALHOUN	5	117	586	2,549	0.23	2,075.1	0.3
HARRIS	5	119	593	4,059	0.15	3,916.8	0.2
SALEM 1,2	10	129	1,289	8,269	0.16	3,571.1	0.4
DAVIS-BESSE	5	135	676	3,523	0.19	4,012.0	0.2
THREE MILE ISLAND 1	5	136	679	4,805	0.14	3,824.4	0.2
CALLAWAY 1	5	137	686	3,607	0.19	5,274.2	0.1
PALO VERDE 1,2,3	15	139	2,084	9,349	0.22	15,612.3	0.1
VOGTLE 1,2	10	139	1,393	5,728	0.24	10,688.2	0.1
GINNA	5	143	716	3,782	0.19	2,053.5	0.3
BRAIDWOOD 1,2	10	146	1,462	6,463	0.23	9,193.2	0.2
COOK 1,2	10	149	1,490	6,623	0.22	7,812.2	0.2
MILLSTONE POINT 2,3	10	154	1,540	7,423	0.21	4,767.5	0.3
DIABLO CANYON 1,2	10	155	1,552	8,233	0.19	9,738.3	0.2
CALVERT CLIFFS 1,2	10	156	1,562	6,405	0.24	7,281.2	0.2
FARLEY 1,2	10	156	1,556	6,155	0.25	7,348.6	0.2
TURKEY POINT 3,4	10	157	1,567	6,640	0.24	6,263.2	0.3
ROBINSON 2	5	159	795	4,034	0.20	3,042.2	0.3
CATAWBA 1,2	10	163	1,633	7,873	0.21	9,915.4	0.2
CRYSTAL RIVER 3	5	166	828	4,136	0.20	2,590.7	0.3
SEQUOYAH 1,2	10	170	1,701	8,240	0.21	7,638.6	0.2
SURRY 1,2	10	170	1,696	7,133	0.24	6,875.9	0.2
BYRON 1,2	10	171	1,714	6,595	0.26	9,249.8	0.2
SAN ONOFRE 2,3	10	172	1,724	7,559	0.23	9,296.4	0.2
MCGUIRE 1,2	10	173	1,728	8,396	0.21	8,885.6	0.2
WOLF CREEK 1	5	174	868	4,274	0.20	5,097.9	0.2
NORTH ANNA 1,2	10	186	1,862	7,414	0.25	8,088.7	0.2
BEAVER VALLEY 1,2	10	187	1,873	7,189	0.26	6,486.6	0.3
SUMMER 1	5	189	944	4,448	0.21	3,842.6	0.2
ZION 1,2	10	230	2,302	7,246	0.32	5,812.1	0.4
PALISADES	5	235	1,177	3,982	0.30	2,848.6	0.4
ST. LUCIE 1,2	10	244	2,441	8,603	0.28	6,823.0	0.4
MAINE YANKEE	5	265	1,323	3,879	0.34	2,082.5	0.6
INDIAN POINT 2	5	338	1,692	5,313	0.32	3,474.1	0.5
Grand Totals and Averages	345		52,820	241,246	0.22	254,276.4	0.2
Averages Per Reactor-Year			153	699		737.0	

* Sites where not all reactors had completed 5 full years of commercial operation as of 12/31/97 are not included. San Onofre is included in the compilation even though Unit 1 is no longer in operation.

In some cases, the plants having the lower values for most of the parameters shown in Tables 4.7a and b are the newer plants. Some of the older, smaller plants, such as Big Rock Point, also appear near the top of the listings because they report small collective doses. However, the ratio of collective dose to megawatt-years is generally higher for these plants because of their limited power generation capability.

The largest contributor to the collective dose is usually associated with outages at a site. In analyzing collective dose trends, it is useful to examine the outage data for reactors to look for a relationship between the collective dose and the outage information for the reactors. Figure 4.5 displays the total number of outage days for BWRs and PWRs respectively. The collective dose and average measurable dose are also plotted to allow for the comparison of outage duration to collective dose.

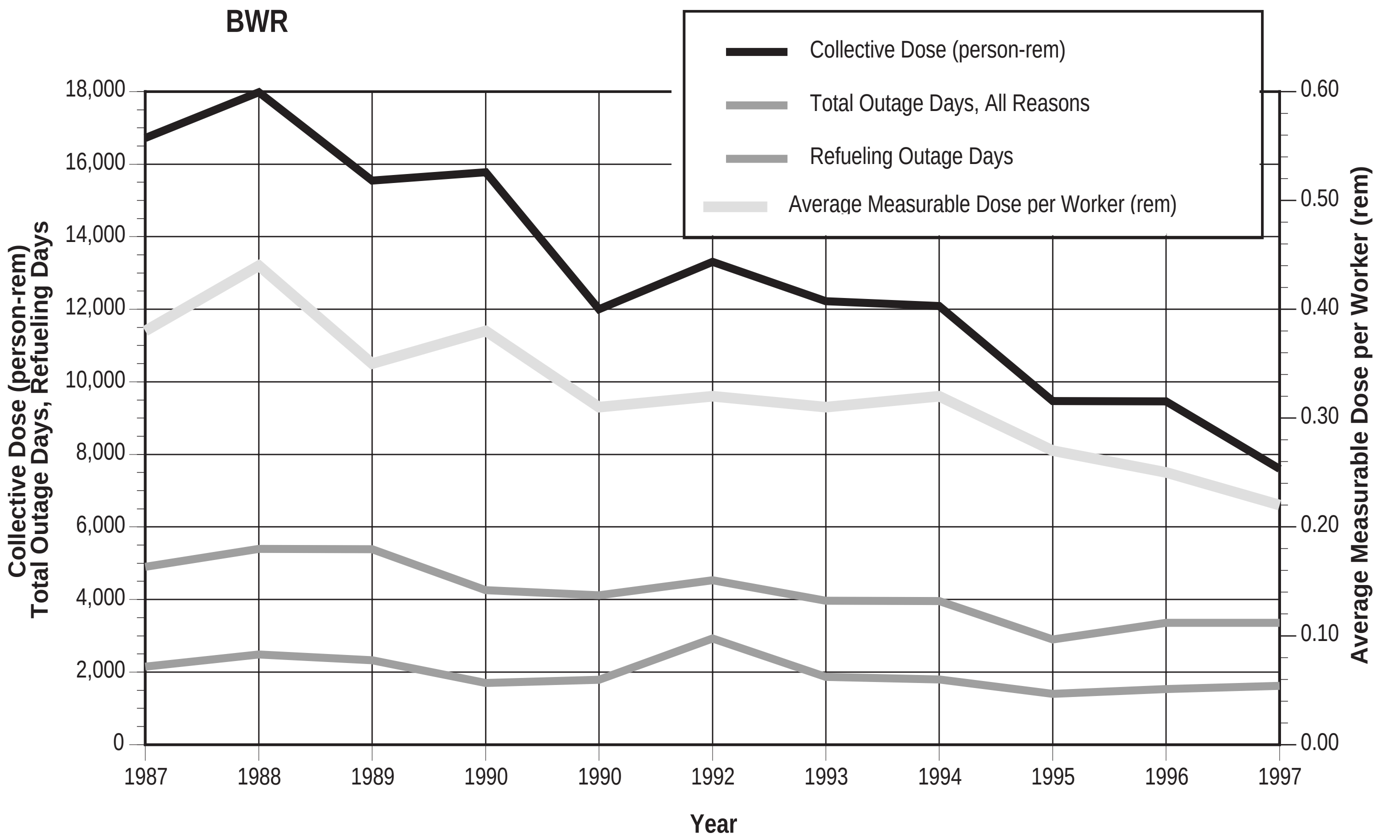
4.6 Collective Dose by Work Function and Employee Type

Each plant is required by its Technical Specifications to submit an annual report in accordance with Regulatory Guide 1.16 that provides the collective dose of workers monitored at each plant site by employee type (plant, utility, or contractor) and by work and job functions. A copy of the report submitted for each reactor site is provided in Appendix D, and much of the data are graphically represented for each site in Appendix E. Tables 4.8 through 4.13 summarize the 1997 data for BWRs, PWRs, and LWRs. Table 4.8 shows that, at both BWRs and PWRs, about 67% of the collective dose is incurred during routine and special maintenance activities. Also, the portion of the collective dose incurred during most of the other activities is similar at the two types of plants.

One should note that the collective doses obtained from these reports are not used in any other tables in this document. This is because the Technical Specifications of each plant require only 80% of the plant's collective dose be accounted for, and some utilities may use the results of self-reading pocket dosimeters instead of the results of the dosimeter of record (usually thermoluminescent dosimeters) in compiling the data. Also, when examining the number of personnel shown on these reports, it should be remembered that individuals who perform tasks in more than one category may be counted more than once.

Table 4.9 shows that for the past 10 years, the percentage of collective dose attributed to routine maintenance has been greater than that of special maintenance. This may be indicative of a trend showing a reduction in TMI-related activities and a greater emphasis on steady-state routine maintenance. Overall, values have been fairly stable over the years with these two categories, special maintenance and routine maintenance, always accounting for the majority of the collective dose. Some of the fluctuations shown in the percentage of the dose incurred during refueling activities (particularly in 1992 through 1995, when it increased to over 11%) is due to the fact that some sites include doses other than those directly associated with fuel movement in this category. Figure 4.6 graphically shows the trends in the collective

Figure 4.5
Outage Days, Average Dose, and Collective Dose



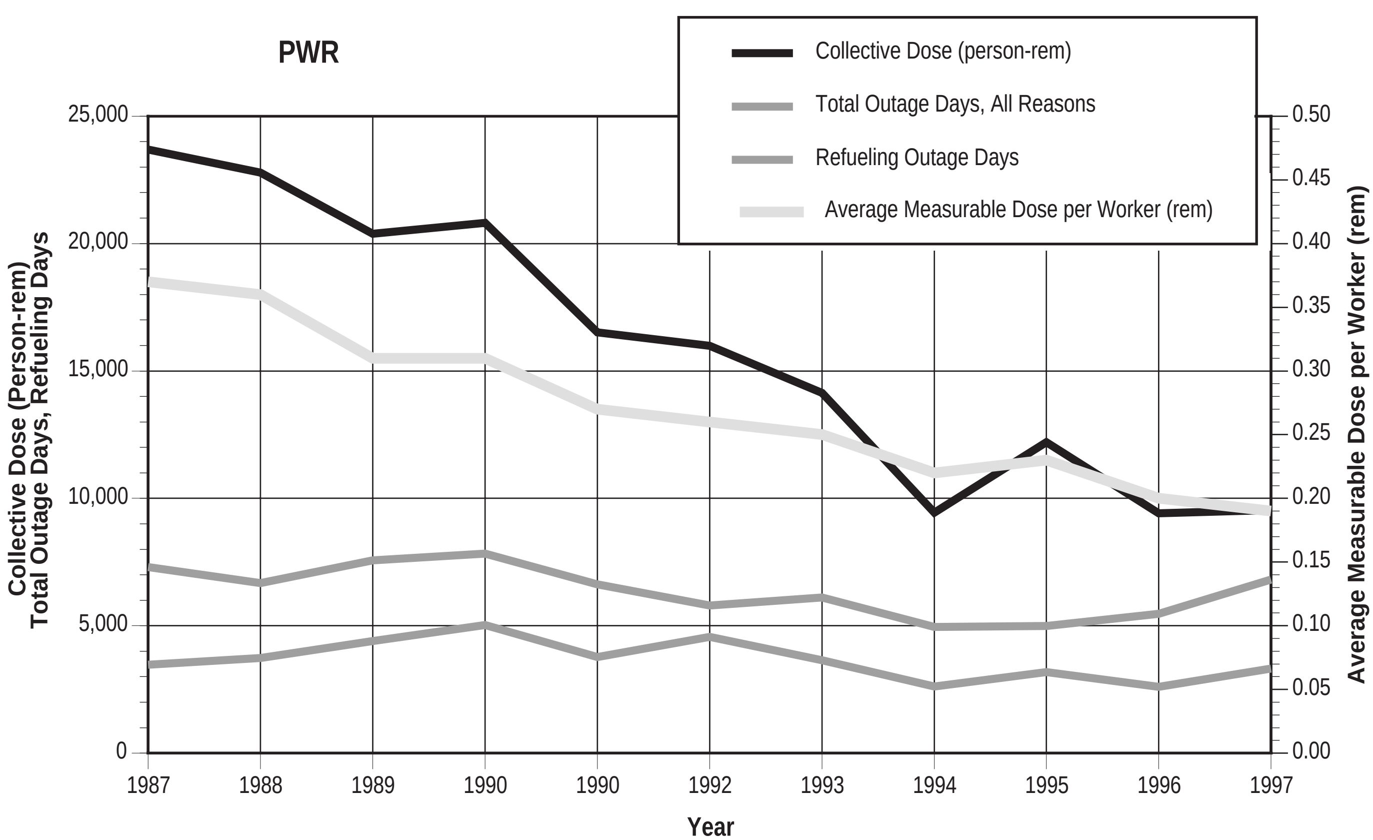


TABLE 4.8

ANNUAL COLLECTIVE DOSE

BY WORK FUNCTION AND PERSONNEL TYPE

1997

WORK AND JOB FUNCTION	STATION EMPLOYEES PERSON-REM	STATION EMPLOYEES % OF TOTAL	UTILITY EMPLOYEES PERSON-REM	UTILITY EMPLOYEES % OF TOTAL	CONTRACT WORKERS PERSON-REM	CONTRACT WORKERS % OF TOTAL	TOTAL PER WORK FUNCTION PERSON-REM	TOTAL PER WORK FUNCTION % OF TOTAL
BOILING WATER REACTORS								
REACTOR OPS & SURV	835	11.3%	79	1.1%	394	5.3%	1,308	17.7%
ROUTINE MAINTENANCE	1,470	19.9%	106	1.4%	2,094	28.3%	3,671	49.6%
IN-SERVICE INSPECTION	54	0.7%	8	0.1%	392	5.3%	454	6.1%
SPECIAL MAINTENANCE	265	3.6%	62	0.8%	820	11.1%	1,148	15.5%
WASTE PROCESSING	76	1.0%	5	0.1%	52	0.7%	133	1.8%
REFUELING	161	2.2%	105	1.4%	417	5.6%	682	9.2%
TOTAL	2,861	38.7%	365	4.9%	4,170	56.4%	7,396	100.0%
PRESSURIZED WATER REACTORS								
REACTOR OPS & SURV	513	5.5%	23	0.2%	374	4.0%	909	9.8%
ROUTINE MAINTENANCE	1,377	14.8%	296	3.2%	2,407	25.9%	4,080	43.9%
IN-SERVICE INSPECTION	83	0.9%	100	1.1%	626	6.7%	808	8.7%
SPECIAL MAINTENANCE	367	4.0%	152	1.6%	1,749	18.8%	2,268	24.4%
WASTE PROCESSING	104	1.1%	3	0.0%	123	1.3%	229	2.5%
REFUELING	280	3.0%	42	0.5%	671	7.2%	994	10.7%
TOTAL	2,723	29.3%	616	6.6%	5,950	64.1%	9,289	100.0%
ALL LIGHT WATER REACTORS								
REACTOR OPS & SURV	1,348	8.1%	102	0.6%	768	4.6%	2,217	13.3%
ROUTINE MAINTENANCE	2,847	17.1%	402	2.4%	4,502	27.0%	7,751	46.5%
IN-SERVICE INSPECTION	136	0.8%	108	0.6%	1,018	6.1%	1,262	7.6%
SPECIAL MAINTENANCE	632	3.8%	214	1.3%	2,569	15.4%	3,416	20.5%
WASTE PROCESSING	180	1.1%	8	0.0%	175	1.0%	363	2.2%
REFUELING	441	2.6%	147	0.9%	1,088	6.5%	1,676	10.0%
TOTAL	5,585	33.5%	981	5.9%	10,119	60.7%	16,685	100.0%

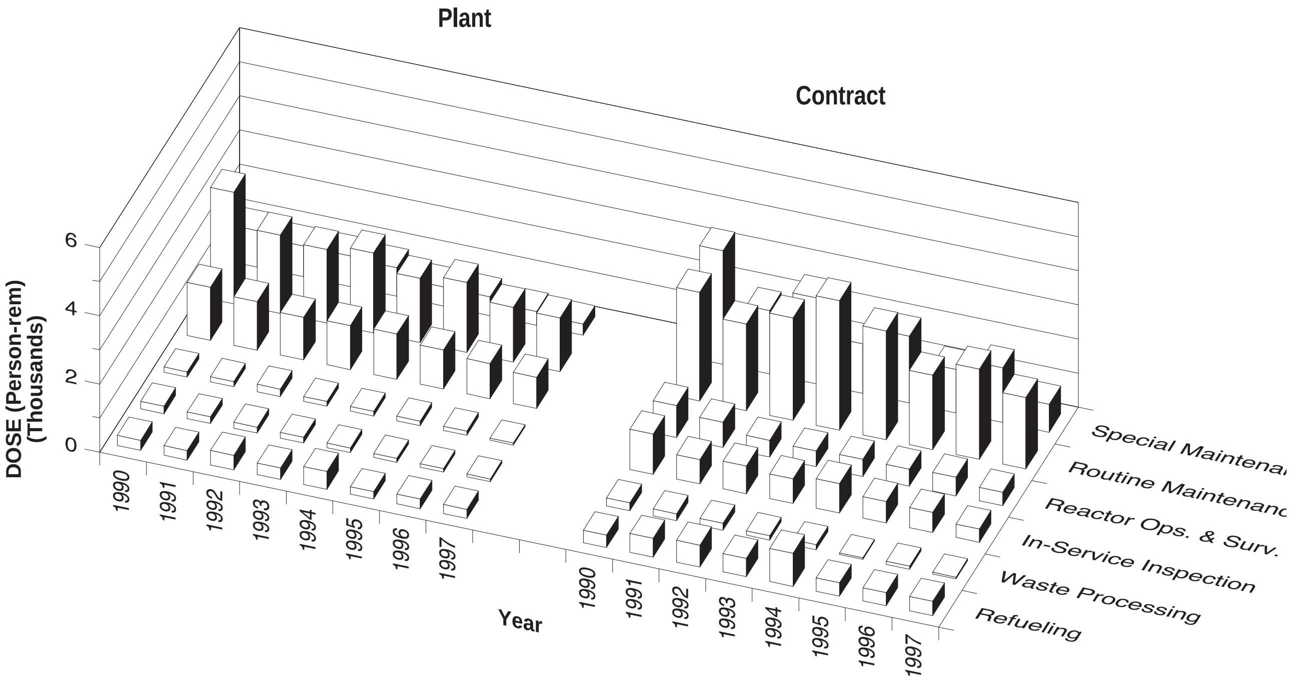
TABLE 4.9

PERCENTAGES OF ANNUAL COLLECTIVE
DOSE AT LWRs BY WORK FUNCTION
1986 - 1997

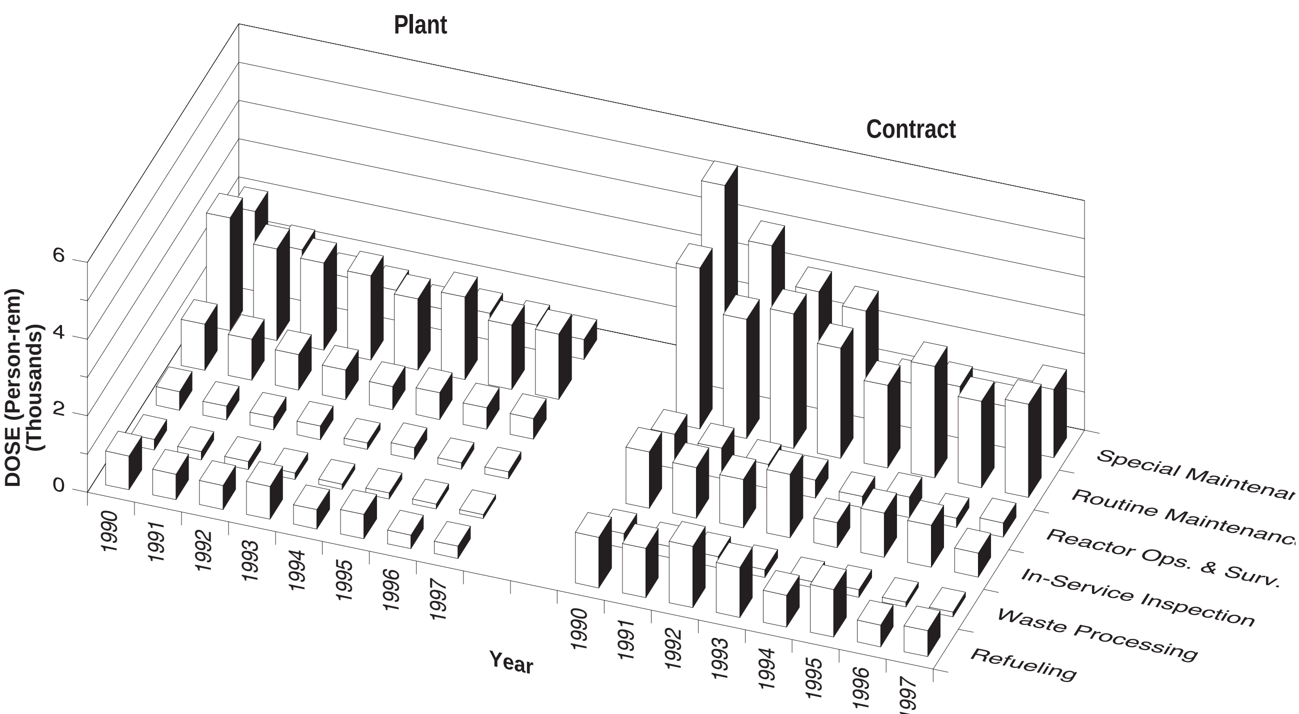
WORK FUNCTION	PERCENTAGE OF COLLECTIVE DOSE EACH YEAR											
	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
REACTOR OPERATIONS AND SURVEILLANCE	12.8%	11.9%	11.0%	12.2%	12.3%	14.0%	11.6%	11.2%	12.8%	13.5%	13.0%	13.3%
ROUTINE MAINTENANCE	33.2%	35.0%	37.7%	36.2%	36.5%	36.1%	38.7%	42.0%	42.7%	43.5%	44.6%	46.5%
IN-SERVICE INSPECTION	8.3%	8.0%	8.7%	9.5%	8.8%	8.9%	9.2%	10.8%	8.5%	10.4%	10.8%	7.6%
SPECIAL MAINTENANCE	35.5%	33.2%	30.1%	31.3%	31.6%	28.2%	25.8%	22.0%	19.9%	18.5%	20.3%	20.5%
WASTE PROCESSING	4.0%	3.9%	3.6%	3.4%	3.0%	3.1%	3.1%	2.5%	2.7%	2.4%	2.4%	2.2%
REFUELING	6.2%	8.1%	8.8%	7.3%	7.7%	9.7%	11.5%	11.4%	13.3%	11.7%	8.7%	10.0%

Figure 4.6
Collective Dose by Work Function and Personnel Type 1990 – 1997

Boiling Water Reactors



Pressurized Water Reactors



dose by work function and type of personnel for the years 1990 through 1997 for BWRs and PWRs separately. The general decrease in collective dose is also apparent among most of these activities.

Table 4.10 presents the distribution of the collective dose for 1997 at all LWRs among five occupational categories. As in past years, maintenance personnel incurred the majority (65%) of the collective dose with contractor maintenance personnel receiving about twice as much as the station maintenance employees combined. None of the values listed changed significantly from those found for 1987 through 1996. The collective doses shown in Tables 4.8 and 4.10 do not equal those shown in other tables in the report because they are the sum of the doses taken from the type of annual reports shown in Appendix D rather than the collective dose that was calculated from the annual reports submitted pursuant to 10 CFR 20.2206.

Another use made of the reports submitted under Regulatory Guide 1.16 shown in Appendix D is in proportioning the collective dose obtained from the § 20.2206 annual reports into the work functions and personnel types shown in Appendix C. This was done in the following way:

(1) The collective dose incurred by workers in the work function “Reactor Operations and Surveillance” on each plant’s annual report submitted pursuant to their technical specifications (the first number in the last column in Appendix D) was determined.

(2) The ratio of this dose to the total collective dose (the last number in the last column in Appendix D) was calculated and multiplied by the total collective dose that had been obtained from the § 20.2206 annual reports. This product is the collective dose shown in the column headed “Operations” in Appendix C.

(3) The collective dose shown in the column headed “Maintenance and Others” in Appendix C was determined by first summing the collective doses incurred by workers in the five remaining functions given in Appendix D and then calculating the fraction that this dose is of the total collective dose. This fraction was multiplied by the total collective dose calculated from the § 20.2206 annual reports to yield the collective dose shown in this column of Appendix C.

(4) A similar procedure was followed in determining the collective dose for the columns headed “Contractor” and “Station & Utility” in Appendix C.

TABLE 4.10

ANNUAL COLLECTIVE DOSE

BY OCCUPATION AND PERSONNEL TYPE

1997

OCCUPATION	STATION EMPLOYEES PERSON-REM	STATION EMPLOYEES % OF TOTAL	UTILITY EMPLOYEES PERSON-REM	UTILITY EMPLOYEES % OF TOTAL	CONTRACT WORKERS PERSON-REM	CONTRACT WORKERS % OF TOTAL	TOTAL PER WORK FUNCTION PERSON-REM	TOTAL PER WORK FUNCTION % OF TOTAL
BOILING WATER REACTORS								
MAINTENANCE	1,523	20.6%	279	3.8%	3,102	41.9%	4,904	66.3%
OPERATIONS	589	8.0%	30	0.4%	251	3.4%	870	11.8%
HEALTH PHYSICS	453	6.1%	20	0.3%	299	4.0%	772	10.4%
SUPERVISORY	159	2.1%	8	0.1%	65	0.9%	232	3.1%
ENGINEERING	138	1.9%	29	0.4%	453	6.1%	619	8.4%
TOTAL	2,861	38.7%	365	4.9%	4,170	56.4%	7,396	100.0%
PRESSURIZED WATER REACTORS								
MAINTENANCE	1,381	14.9%	519	5.6%	3,999	43.0%	5,899	63.5%
OPERATIONS	515	5.5%	27	0.3%	270	2.9%	812	8.7%
HEALTH PHYSICS	512	5.5%	16	0.2%	771	8.3%	1,299	14.0%
SUPERVISORY	171	1.8%	14	0.2%	346	3.7%	531	5.7%
ENGINEERING	144	1.6%	39	0.4%	564	6.1%	747	8.0%
TOTAL	2,723	29.3%	616	6.6%	5,950	64.1%	9,289	100.0%
ALL LIGHT WATER REACTORS								
MAINTENANCE	2,904	17.4%	798	4.8%	7,101	42.6%	10,803	64.7%
OPERATIONS	1,104	6.6%	57	0.3%	521	3.1%	1,682	10.1%
HEALTH PHYSICS	965	5.8%	36	0.2%	1,070	6.4%	2,071	12.4%
SUPERVISORY	330	2.0%	22	0.1%	411	2.5%	763	4.6%
ENGINEERING	282	1.7%	67	0.4%	1,017	6.1%	1,366	8.2%
TOTAL	5,585	33.5%	981	5.9%	10,119	60.7%	16,685	100.0%

4.7 Number of Personnel by Work Function and Employee Type

Half of the information presented in the statistical annual reports shown in Appendix D concerns the number of various types of personnel that performed certain work functions. Tables 4.11 and 4.12 sum this information to show the percentage of personnel by work function and occupation. The major problem in interpreting the numbers shown in these tables is that the same person may perform several work functions during the year so that the total number of personnel obtained by summing those shown in the various work functions would be inflated. However, Table 4.12 is still useful in showing the percentage of personnel associated with each of the six work functions shown. About 51% of the personnel performed routine or special maintenance functions, 28% were involved with reactor operations and surveillance, and the remaining 21% were divided among the other three work functions.

Table 4.12 shows the percentage of personnel in each of five occupational categories at BWRs, PWRs, and LWRs. The workers were similarly distributed at BWRs and PWRs. The largest difference occurred in the health physics personnel for 1997. Health physics personnel at PWRs received about twice the percentage of the collective dose than for BWRs. Overall, 54% of the personnel were contractors, 38% were station employees, and 8% were utility employees in 1997.

Table 4.13 presents the average annual dose incurred by workers in the five occupational categories in 1997. These averages were calculated by dividing the collective dose reported for these groups (see Table 4.11) by the number of individuals shown in Table 4.12. It shows that, in most instances, the maintenance personnel incur the highest average doses. Examination of the values of the averages given in Table 4.13 is subject to several sources of error: (1) the number of individuals may be inflated because the same plant contractor employee may work at several plants so that the employee would be counted more than once in a summary such as Table 4.13; (2) the occupations are not clearly defined so that workers performing certain tasks in one plant may be classified as being in one occupation and be included in a different one at another plant; and (3) some plants count only those workers whose doses exceed 0.10 rem while other plants count all workers regardless of the dose received. Because of these factors, the usefulness of the numbers of individuals obtained from the reports provided in Appendix D is limited; therefore, they are not used to develop any other statistics in this document.

TABLE 4.11

NUMBER OF PERSONNEL*

BY WORK FUNCTION AND PERSONNEL TYPE

1997

WORK AND JOB FUNCTION	STATION EMPLOYEES NUMBER	STATION EMPLOYEES % OF TOTAL	UTILITY EMPLOYEES NUMBER	UTILITY EMPLOYEES % OF TOTAL	CONTRACT WORKERS NUMBER	CONTRACT WORKERS % OF TOTAL	TOTAL PER WORK FUNCTION NUMBER	TOTAL PER WORK FUNCTION % OF TOTAL
BOILING WATER REACTORS								
REACTOR OPS & SURV	6,452	12.9%	1,337	2.7%	4,927	9.9%	12,716	25.5%
ROUTINE MAINTENANCE	7,092	14.2%	1,585	3.2%	12,827	25.7%	21,504	43.0%
IN-SERVICE INSPECTION	637	1.3%	125	0.3%	2,123	4.2%	2,885	5.8%
SPECIAL MAINTENANCE	1,839	3.7%	486	1.0%	3,916	7.8%	6,241	12.5%
WASTE PROCESSING	1,034	2.1%	144	0.3%	926	1.9%	2,104	4.2%
REFUELING	1,407	2.8%	720	1.4%	2,384	4.8%	4,511	9.0%
TOTAL	18,461	37.0%	4,397	8.8%	27,103	54.2%	49,961	100.0%
PRESSURIZED WATER REACTORS								
REACTOR OPS & SURV	13,225	17.5%	2,244	3.0%	7,168	9.5%	22,637	29.9%
ROUTINE MAINTENANCE	8,792	11.6%	2,667	3.5%	12,984	17.2%	24,443	32.3%
IN-SERVICE INSPECTION	932	1.2%	798	1.1%	3,947	5.2%	5,677	7.5%
SPECIAL MAINTENANCE	2,820	3.7%	1,080	1.4%	8,458	11.2%	12,358	16.3%
WASTE PROCESSING	1,283	1.7%	96	0.1%	2,946	3.9%	4,325	5.7%
REFUELING	1,965	2.6%	473	0.6%	3,829	5.1%	6,267	8.3%
TOTAL	29,017	38.3%	7,358	9.7%	39,332	52.0%	75,707	100.0%
ALL LIGHT WATER REACTORS								
REACTOR OPS & SURV	19,677	15.7%	3,581	2.8%	12,095	9.6%	35,353	28.1%
ROUTINE MAINTENANCE	15,884	12.6%	4,252	3.4%	25,811	20.5%	45,947	36.6%
IN-SERVICE INSPECTION	1,569	1.2%	923	0.7%	6,070	4.8%	8,562	6.8%
SPECIAL MAINTENANCE	4,659	3.7%	1,566	1.2%	12,374	9.8%	18,599	14.8%
WASTE PROCESSING	2,317	1.8%	240	0.2%	3,872	3.1%	6,429	5.1%
REFUELING	3,372	2.7%	1,193	0.9%	6,213	4.9%	10,778	8.6%
TOTAL	47,478	37.8%	11,755	9.4%	66,435	52.9%	125,668	100.0%

* Workers may be counted in more than one category. The number of personnel in Table 4.11 should be considered to be more accurate than the number of personnel in Table 4.10, because the actual total number of individuals in each profession was provided by some plants in an attempt to correct for the multiple counting of individiuals.

TABLE 4.12

NUMBER OF PERSONNEL*

BY OCCUPATION AND PERSONNEL TYPE

1997

OCCUPATION	STATION EMPLOYEES NUMBER	STATION EMPLOYEES % OF TOTAL	UTILITY EMPLOYEES NUMBER	UTILITY EMPLOYEES % OF TOTAL	CONTRACT WORKERS NUMBER	CONTRACT WORKERS % OF TOTAL	TOTAL PER WORK FUNCTION NUMBER	TOTAL PER WORK FUNCTION % OF TOTAL
BOILING WATER REACTORS								
MAINTENANCE	6,664	14.0%	2,073	4.3%	17,588	36.9%	26,325	55.2%
OPERATIONS	3,800	8.0%	412	0.9%	1,765	3.7%	5,977	12.5%
HEALTH PHYSICS	2,312	4.8%	722	1.5%	1,702	3.6%	4,736	9.9%
SUPERVISORY	2,164	4.5%	154	0.3%	1,534	3.2%	3,852	8.1%
ENGINEERING	2,455	5.1%	696	1.5%	3,664	7.7%	6,815	14.3%
TOTAL	17,395	36.5%	4,057	8.5%	26,253	55.0%	47,705	100.0%
PRESSURIZED WATER REACTORS								
MAINTENANCE	10,154	15.1%	2,842	4.2%	21,040	31.3%	34,036	50.7%
OPERATIONS	7,144	10.6%	911	1.4%	2,405	3.6%	10,460	15.6%
HEALTH PHYSICS	5,258	7.8%	501	0.7%	6,869	10.2%	12,628	18.8%
SUPERVISORY	1,688	2.5%	304	0.5%	1,651	2.5%	3,643	5.4%
ENGINEERING	1,854	2.8%	999	1.5%	3,523	5.2%	6,376	9.5%
TOTAL	26,098	38.9%	5,557	8.3%	35,488	52.9%	67,143	100.0%
ALL LIGHT WATER REACTORS								
MAINTENANCE	16,818	14.6%	4,915	4.3%	38,628	33.6%	60,361	52.6%
OPERATIONS	10,944	9.5%	1,323	1.2%	4,170	3.6%	16,437	14.3%
HEALTH PHYSICS	7,570	6.6%	1,223	1.1%	8,571	7.5%	17,364	15.1%
SUPERVISORY	3,852	3.4%	458	0.4%	3,185	2.8%	7,495	6.5%
ENGINEERING	4,309	3.8%	1,695	1.5%	7,187	6.3%	13,191	11.5%
TOTAL	43,493	37.9%	9,614	8.4%	61,741	53.8%	114,848	100.0%

* Workers may be counted in more than one category. The number of personnel in this table is considered to be more accurate than the number of personnel in Table 4.10 because the actual total number of individuals in each category was provided by some plants in an attempt to correct for the multiple counting of individuals.

TABLE 4.13
AVERAGE DOSES BY OCCUPATION AND PERSONNEL TYPE*
1997

OCCUPATION	STATION			UTILITY			CONTRACT			TOTAL		
	COLL. DOSE	NUMBER OF EMPLOYEES	AVG. DOSE	COLL. DOSE	NUMBER OF EMPLOYEES	AVG. DOSE	COLL. DOSE	NUMBER OF EMPLOYEES	AVG. DOSE	COLL. DOSE	NUMBER OF EMPLOYEES	AVG. DOSE
BOILING WATER REACTORS												
MAINTENANCE	1,523	6,664	0.23	279	2,073	0.13	3,102	17,588	0.18	4,904	26,325	0.19
OPERATIONS	589	3,800	0.15	30	412	0.07	251	1,765	0.14	870	5,977	0.15
HEALTH PHYSICS	453	2,312	0.20	20	722	0.03	299	1,702	0.18	772	4,736	0.16
SUPERVISORY	159	2,164	0.07	8	154	0.05	65	1,534	0.04	232	3,852	0.06
ENGINEERING	138	2,455	0.06	29	696	0.04	453	3,664	0.12	619	6,815	0.09
TOTAL	2,861	17,395	0.16	365	4,057	0.09	4,170	26,253	0.16	7,396	47,705	0.16
PRESSURIZED WATER REACTORS												
MAINTENANCE	1,381	10,154	0.14	519	2,842	0.18	3,999	21,040	0.19	5,899	34,036	0.17
OPERATIONS	515	7,144	0.07	27	911	0.03	270	2,405	0.11	812	10,460	0.08
HEALTH PHYSICS	512	5,258	0.10	16	501	0.03	771	6,869	0.11	1,299	12,628	0.10
SUPERVISORY	171	1,688	0.10	14	304	0.05	346	1,651	0.21	531	3,643	0.15
ENGINEERING	144	1,854	0.08	39	999	0.04	564	3,523	0.16	747	6,376	0.12
TOTAL	2,723	26,098	0.10	616	5,557	0.11	5,950	35,488	0.17	9,289	67,143	0.14
ALL LIGHT WATER REACTORS												
MAINTENANCE	2,904	16,818	0.17	798	4,915	0.16	7,101	38,628	0.18	10,803	60,361	0.18
OPERATIONS	1,104	10,944	0.10	57	1,323	0.04	521	4,170	0.12	1,682	16,437	0.10
HEALTH PHYSICS	965	7,570	0.13	36	1,223	0.03	1,070	8,571	0.12	2,071	17,364	0.12
SUPERVISORY	330	3,852	0.09	22	458	0.05	411	3,185	0.13	763	7,495	0.10
ENGINEERING	282	4,309	0.07	67	1,695	0.04	1,017	7,187	0.14	1,366	13,191	0.10
TOTAL	5,585	43,493	0.13	981	9,614	0.10	10,119	61,741	0.16	16,685	114,848	0.15

* Workers may be counted in more than one category, but the actual total number of individuals in each category was used when it was provided by the plant.

4.8 Graphical Representation of Dose Trends in Appendix E

Each page of Appendix E presents two types of graphs for one site. One graph plots selected dose-performance indicators from 1973 through 1997, and the other indicates the collective dose by job function for 1978 through 1997. The dose and performance indicators shown in the top graph illustrate the history of the collective dose per reactor for the site, the rolling 3-year average collective dose per reactor, and the electricity generated at the site. These data are plotted, beginning with the plant's first full year of commercial operation, and continuing through 1997. Data for years when the plant was not in commercial operation have been included when available. However, any data reported prior to 1973 are not included. The 3-year average collective dose per reactor data is included because it provides a better overall indication of the plant's general trend in collective dose. This average is determined by summing the collective dose for the current year and the previous 2 years and then dividing this sum by the number of reactors reporting during those years. Depicting dose trends using a 3-year average reduces the sporadic effects on annual doses of refueling operations (usually a 2- to 3-year cycle) and occasional high-dose maintenance activities, and gives a better idea of collective dose trends over the life of the plant. The annual average collective dose per reactor for all reactors of the same type is also shown on the graph.

The second type of graph at the bottom of each page in Appendix E displays the breakdown of collective dose by job function and employee type for the years 1978 through 1997. The horizontal axis lists the six job functions of reactor operations, routine maintenance, in-service inspection, special maintenance, waste management, and refueling operations, and the vertical axis indicates collective dose at each site. This representation shows the job functions where most of the dose was accumulated as well as the division of the collective dose between plant and contract workers. The data are taken from the submittals presented in Appendix D and therefore represent at least 80% of the collective dose at each site. Only those reactors that have completed at least 1 full year of commercial operation are presented in Appendix E.

5 TRANSIENT WORKERS AT NRC LICENSED FACILITIES

5.1 Termination Reports

Under the revised 10 CFR 20, licensees are required to submit NRC Form 5s to the Commission for each individual who is required to be monitored at the end of the monitoring year or upon the individual's termination of employment at the facility. The "termination reports" submitted in accordance with the old § 20.408, listing the individual's complete dose history during employment at the facility, are no longer required.

However, the Form 5s submitted to the NRC upon an individual's termination of employment serve the same function as the previous requirements with regard to the analysis of transient workers at NRC-licensed facilities. The following analysis examines the workers who had more than one Form 5 dose record at more than one NRC-licensed facility during the monitoring year. These workers are defined to be transient in that they worked at more than one facility during the monitoring year.

The term "monitoring year" is used here in accordance with the definition of a year given in § 20.1003, which defines a year as "the period of time beginning in January used to determine compliance with the provisions of this part. The licensee may change the start date of the monitoring year used to determine compliance provided that the change is made at the beginning of the monitoring/calendar year and that no day is omitted or duplicated in consecutive years".

5.2 Transient Workers at NRC Facilities

Examination of the data reported for workers who began and terminated two or more periods of employment with two or more different facilities within one monitoring year is useful in many ways. For example, the number and average dose for these "annual transients" can be determined from examining these data.

Additionally, the distribution of the doses received by transient workers can be useful in determining the impact that the inclusion of these individuals in each of two or more licensees' annual reports has on the annual summary (as reported in Appendices B and F) for all nuclear power facilities, and all NRC licensees combined (one of the problems mentioned in Section 2). Table 5.1 shows the "actual distribution" of transient worker doses as determined from the above-mentioned Form 5 termination reports and compares it with the "reported distribution" of the doses of these workers as they would have appeared in a summation of the annual reports submitted by each of the licensees.

TABLE 5.1

EFFECTS OF TRANSIENT WORKERS ON ANNUAL STATISTICAL COMPILATIONS

1997

License Category	Number of Individuals with TEDE in the Ranges (rem)												Total Number Monitored	Number with Measurable Exposure	Collective TEDE (person-rem)	Average TEDE (rem)	Average Meas. TEDE (rem)
	No Meas'ble Exposure	Meas'ble <0.10	0.10-0.25	0.25-0.5	0.50-0.75	0.75-1.0	1.0-2.0	2.0-3.0	3.0-4.0	4.0-5.0	5.0-6.0	>6					
POWER REACTORS																	
FORM 5 SUMMATION ①	80,163	41,759	19,951	13,396	5,394	2,240	1,671	59	3				164,636	84,473	17,136	0.10	0.20
TRANSIENTS - AS REPORTED	30,558	17,143	9,355	6,492	2,525	1,167	900	74	27				68,241	37,683	8,484	0.12	0.23
TRANSIENTS- ACTUAL ③	8,896	7,216	4,279	4,006	2,377	1,334	1,804	314	68				30,294	21,398	8,484	0.28	0.40
CORRECTED DISTRIBUTION (1-(2-3))	**58,501**	**31,832**	**14,875**	**10,910**	**5,246**	**2,407**	**2,575**	**299**	**44**				**126,689**	**68,188**	**17,136**	**0.14**	**0.25**
ALL LICENSEES																	
FORM 5 SUMMATION ①	89,101	44,983	21,187	14,332	5,932	2,606	2,241	226	63	6			180,677	91,576	19,841	0.11	0.22
TRANSIENTS - AS REPORTED	40,265	20,837	10,506	7,015	2,727	1,105	795	24	2				83,276	43,011	8,722	0.10	0.20
TRANSIENTS- ACTUAL ③	9,237	7,322	4,338	4,101	2,439	1,364	1,867	325	71	1			31,065	21,828	8,722	0.28	0.40
CORRECTED DISTRIBUTION (1-(2-3))	**58,073**	**31,468**	**15,019**	**11,418**	**5,644**	**2,865**	**3,313**	**527**	**132**	**7**			**128,466**	**70,393**	**19,841**	**0.15**	**0.26**

Because >95% of these transients are reported by nuclear power facilities, these data were considered separately. Table 5.1 shows that the power reactor transient data constitute the vast majority of the transient worker exposure. The nonreactor licensees account for only 2% of the transient workforce.

The following definitions apply to Table 5.1:

Form 5 Summation	The summation of the TEDE from each of the Form 5s submitted for the monitoring year. This is the summation of each dose record grouped by licensee and individual. This distribution takes into account multiple Form 5s for an individual at one NRC-licensed facility but not multiple exposures at multiple licensees.
Transients - As Reported	This distribution represents the population of transient workers as they were reported by each licensee. This distribution is the subset of all Form 5s where individuals were monitored at more than one licensee during the monitoring year. This is the summation of dose records grouped by individual and by licensee, so the distribution represents how the transient worker population would appear within the total distribution of all workers. This distribution takes into account multiple Form 5s for an individual at one NRC-licensed facility but not multiple exposures at multiple licensees.
Transients - Actual	This is the actual distribution for transient workers summed per individual. This represents the true number of individuals and places each individual in the correct dose range. This distribution accounts for multiple records per individual and multiple licensees.
Corrected Distribution	This distribution represents the correction of the reported distribution by subtracting the difference in the reported and actual distribution for transient workers. This represents the most accurate dose distribution for the licensee category and accounts for the multiple reporting of individuals.

Table 5.1 illustrates the impact that the multiple reporting of these transient individuals had on the summation of the exposure reports for 1997. Because each licensee reports the doses received by workers while monitored by the particular licensee during the year, one would expect that a summation of these reports would result in individuals being counted several times in dose ranges lower than the range in which their total accumulated dose (the sum of the personnel monitoring results incurred at each facility during the year) would actually place them. Thus, while the total collective dose would remain the same, the number of workers, their dose distribution, and average dose would be affected by this multiple reporting. This was found to

be true because too few workers were reported in the higher dose ranges. For example, in 1997, Table 5.1 shows that the summation of annual reports for reactor licensees indicated that 62 individuals received doses greater than 2 rem. After accounting for those individuals who were reported more than once, the corrected distribution indicated that there were really 343 workers who received doses greater than 2 rem. Correcting for the multiple counting of individuals also has a significant effect on the average measurable dose for these workers. The corrected average measurable dose for transient workers is twice as high as the value calculated by the summation of licensee records. The transient workers represent 31% of the workforce that receives measurable dose and increases the average measurable dose for all licensees by 18% from 0.22 rem to 0.26 rem. It should be noted that this analysis of transient workers does not include workers who may have been exposed at facilities that are not required to report to the NRC REIRS database (see Section 1), Agreement State licensees, or Department of Energy facilities.

One purpose of the REIRS database, which tracks occupational radiation exposures at NRC-licensed facilities, is to identify individuals who may have exceeded the occupational radiation exposure limits because of multiple exposures at different facilities throughout the year. The REIRS database stores the radiation exposure information for an individual by their unique identification number and identification type [Ref. 18, Section 1.5] and sums the exposure for all facilities during the monitoring year. An individual exceeding the TEDE 5 rem per year regulatory limit would be identified in Table 5.1 in one of the dose ranges >5 rem. In 1997, no individual was discovered to have exceeded the limit as a result of the correction for transient workers. Since 1985, there have been no additional transient workers identified as having received a dose of >5 rem that have not appeared in the annual reports received by the Commission. This reflects the industry's continuing concerted efforts to keep the total annual doses of all workers under 5 rem and shows that such reductions can be accomplished without increasing the collective dose because the collective dose has decreased during this same time period.

6 EXPOSURES TO PERSONNEL IN EXCESS OF REGULATORY LIMITS

6.1 Control Levels

Exposures in excess of regulatory limits are sometimes referred to as "overexposures." The phrase "exposures in excess of regulatory limits" is preferred to "overexposures" because the latter suggests that a worker has been subjected to an unacceptable biological risk, which may, or may not, be the case.

The implementation date for the revised 10 CFR 20 was January 1, 1994. The separate limits on internal and external exposure in the old 10 CFR 20 are no longer applicable. The revised 10 CFR 20 now includes requirements for summing internal and external dose equivalents to yield TEDE and to implement a similar limitation system for organs and tissues (such as the gonads, red bone marrow, bone surfaces, lung, thyroid, and breast). The dose equivalent limits for the skin of the whole body and for the extremities have been revised, and a new limit for dose equivalent to the lens of the eye has been added. The revised 10 CFR 20.1201 limits the TEDE of workers to ionizing radiation from licensed material and other sources of radiation within the licensee's control. The revised 10 CFR 20 no longer contains quarterly exposure limits but has reporting requirements for planned special exposures (PSEs)*. The annual TEDE limit for adult workers is 5 rem.

The revised 10 CFR 20.2202 and 10 CFR 20.2203 require that all persons licensed by the NRC submit reports of all occurrences involving personnel radiation exposures that exceed certain control levels, thus providing for investigations and corrective actions as necessary. Based on the magnitude of the exposure, the occurrence may be placed into one of three categories:

(1) Category A

10 CFR 20.2202(a)(1) - a TEDE to any individual of 25 rem or more; an eye dose equivalent of 75 rem or more; or a shallow-dose equivalent to the skin or extremities of 250 rad or more. The Commission must be notified immediately of these events.

(2) Category B

10 CFR 20.2202(b)(1) - a TEDE to any individual of 5 rem or more; an eye dose equivalent of 15 rem or more; or a shallow-dose equivalent to the skin or extremities of 50 rem or more in a 24-hour period. The Commission must be notified within 24 hours of these events.

* See 10 CFR 20.1206, 20.2204 and Regulatory Guide 8.35 for more information on PSEs and their reporting requirements.

(3) Category C

10 CFR 20.2203 - In addition to the notification required by 20.2202 (category A and B occurrences), each licensee must submit a written report within 30 days after learning of any of the following occurrences: (1) Any incident for which notification is required by 20.2202; or (2) Doses that exceed the limits in 20.1201, 20.1207, 20.1208, 20.1301 (for adults, minors, the embryo/fetus of a declared pregnant worker, and the public, respectively), or any applicable limit in the license; or (3) Levels of radiation or concentrations of radioactive material that exceed any applicable license limit for restricted areas or that, for unrestricted areas, are in excess of 10 times any applicable limit set forth in this part or in the license (whether or not involving exposure of any individual in excess of the limits in 20.1301); or (4) For licensees subject to the provisions of the Environmental Protection Agency's generally applicable environmental radiation standards in 40 CFR 190, levels of radiation or releases of radioactive material in excess of those standards, or of license conditions related to those standards.

6.2 Limitations of the Data

It is important to note that this summary of events includes ***only***:

- Occupational radiation exposures in excess of regulatory limits
- Events at NRC-licensed facilities
- Final dose of record assigned to an individual

It ***does not*** include:

- Medical misadministrations to medical patients
- Exposures in excess of regulatory limits to the general public
- Agreement State-licensed activities or Department of Energy facilities
- Other radiation-related violations, such as high dose rate areas or effluent limits
- Exposures to dosimeters that, upon evaluation, have been determined to be high dosimeter readings only and are not assigned to an individual as the dose of record by the NRC

Care should be taken when comparing the summary information presented here with other reports and analyses published by the NRC or other agencies. Various reports may include other types of "overexposure" events; therefore, the distinctions should be noted.

The analysis and summary of incidents presented here involving exposures in excess of regulatory limits represent the status of events as of the publication of this report. Exposure events of this type typically undergo a long review and evaluation process by the licensee, the NRC inspector for the regional office, and NRC headquarters. Preliminary dose estimates submitted by licensees are often conservatively high and do not represent the final (record) dose assigned for the event. It is therefore not uncommon for an "overexposure" event to be reassessed and the final assigned dose to be categorized as not having been in excess of the regulatory limits. In other cases, the exposure may not be identified until a later date, such as during the next scheduled audit or inspection of the licensee's exposure records.

For these reasons, an attempt is made to keep current the exposure events summary presented here. An event that has been reassessed and determined not to be an exposure in excess of the limits is not included in this report. In addition, events that occurred in prior years are added to the summary in the appropriate year of occurrence. The reader should note that the summary presented here represents a "snapshot" of the status of events as of the publication date of this report. Previous or future reports may not correlate in the exact number of events because of the review cycle and reassessment of the events.

6.3 Summary of Exposures in Excess of Regulatory Limits

Table 6.1 summarizes the occupational exposures in excess of regulatory limits as reported by Commission licensees pursuant to 10 CFR 20.2202 and 10 CFR 20.2203 from 1994 to 1997. Table 6.2 shows the data reported under 10 CFR 20.403 and 10 CFR 20.405 for the period 1985-1993. Note that the categorization criteria changed effective with the revised 10 CFR 20. The dose reporting thresholds have been revised — the skin of the whole body and the extremities now have the same dose limits, and a new set of dose limits has been added for the lens of the eye.

For the period 1990-1993, Table 6.2 shows the number of individuals who exceeded various limits while employed by one of several types of licensees. For the period 1985-1989, only the exposures in excess of regulatory limits reported by licensed industrial radiography firms are shown separately. Most of the occurrences included in the "Others" category come from research facilities, universities, and measuring and well-logging activities.

In 1997, two workers received doses that exceeded the regulatory limit for extremity dose. There were no occurrences where an individual exceeded the regulatory limit for TEDE. One of the exposures in excess of the extremity limit was a "Category A" occurrence, and was reported immediately to the NRC upon discovery as required. There were no occurrences in which individuals received a "Category B" exposure.

The largest of the extremity exposures in excess of the regulatory limit occurred in May of 1997. A “Type A” Broad radiopharmaceutical licensee reported that an employee went home without properly frisking himself for radioactive contamination. When he returned to work the next day, he performed a contamination survey of himself and detected significant levels of contamination on his left thumb. The isotope was determined to be Re-186. The licensee believes that the employee became contaminated while handling contaminated materials with a faulty glove. The licensee reported that the individual received a shallow dose of 534 rem to the palm side of the thumb. This dose is based on the licensee’s measurement and calculation of 4.3 uCi. Lower levels of contamination were found on the back of his right hand and fingers. The root cause was attributed to a failure to follow procedure.

The second extremity exposure in excess of the regulatory limit was reported by a reactor license and occurred in October of 1997. The reactor licensee reported an extremity dose of 51.090 rem from a hot particle. The report stated that the dose was received from licensed activities off-site. The NRC is following up on this report to determine the nature of this exposure occurrence.

6.4 Maximum Exposures Below the NRC Limits

Because few exposures exceed the NRC occupational exposure limits, certain researchers have expressed an interest in a listing of the maximum exposures received at NRC licensees that do not exceed the limits. This would allow an examination of exposures that approach, but do not exceed the limits. Table 6.3 shows the maximum exposures for each dose category required to be reported to the NRC. In addition, the number of exposures in certain dose ranges is shown to reflect the number of exposures that approach the NRC limits.

As can be seen from Table 6.3, few exposures exceed half of the NRC occupational annual limits. The only doses to come within 5% of the limit were the two extremity exposures that exceeded the limit.

TABLE 6.1
OCCUPATIONAL EXPOSURES IN EXCESS OF REGULATORY LIMITS
1994 - 1997

YEAR	LICENSE CATEGORY	PERSONS AND DOSES (REM)	TYPES OF EXPOSURES AND DOSES								
			TEDE (rem)			Lens of the Eye (rem)			Skin/Extremity (rem)		
			<5	5-25	>25	<15	15-75	>75	<50	50-250	>250 rad
1997	INDUSTRIAL RADIOGRAPHY	NO. OF PERSONS									
		SUM OF DOSES									
	POWER REACTORS	NO. OF PERSONS								1[a]	
		SUM OF DOSES								51.1	
	MEDICAL FACILITIES	NO. OF PERSONS									
		SUM OF DOSES									
	MARKETING & MANUFACT.	NO. OF PERSONS									1
		SUM OF DOSES									533.9
	OTHER	NO. OF PERSONS									
		SUM OF DOSES									
1996	INDUSTRIAL RADIOGRAPHY	NO. OF PERSONS		1							
		SUM OF DOSES		8.3							
	POWER REACTORS	NO. OF PERSONS								1[b]	
		SUM OF DOSES								70.6	
	MEDICAL FACILITIES	NO. OF PERSONS									
		SUM OF DOSES									
	MARKETING & MANUFACT.	NO. OF PERSONS									
		SUM OF DOSES									
	OTHER	NO. OF PERSONS									
		SUM OF DOSES									
1995	INDUSTRIAL RADIOGRAPHY	NO. OF PERSONS		1							
		SUM OF DOSES		5.1							
	POWER REACTORS	NO. OF PERSONS									
		SUM OF DOSES									
	MEDICAL FACILITIES	NO. OF PERSONS									
		SUM OF DOSES									
	MARKETING & MANUFACT.	NO. OF PERSONS								2[c]	
		SUM OF DOSES								572	
	OTHER	NO. OF PERSONS									
		SUM OF DOSES									
1994	INDUSTRIAL RADIOGRAPHY	NO. OF PERSONS		2							
		SUM OF DOSES		12.2							
	POWER REACTORS	NO. OF PERSONS							1		
		SUM OF DOSES							34		
	MEDICAL FACILITIES	NO. OF PERSONS									
		SUM OF									
	MARKETING & MANUFACT.	NO. OF PERSONS								1[d]	
		SUM OF DOSES								180	
	OTHER	NO. OF PERSONS									
		SUM OF DOSES									

[a] This exposure was from a hot particle to a localized area of the skin.
[b] This exposure was from a hot particle to a localized area of the skin.
[c] These two exposures (230 rem and 342 rem) were the result of hot particles.
[d] This exposure was from a hot particle to a localized area of the skin.

TABLE 6.2
OCCUPATIONAL EXPOSURES IN EXCESS OF REGULATORY LIMITS
1985 - 1993

YEAR	LICENSE CATEGORY	PERSONS AND DOSES (REM)	TYPES OF EXPOSURES AND DOSES								
			WHOLE BODY (REM)			SKIN (REMS)			EXTREMITY (REMS)		
			(<5)	(5-25)	(>25)	(>7.5<30)	(30-50)	(>150)	(>18.75<75)	(75-375)	(>375)
1993	INDUSTRIAL RADIOGRAPHY	NO. OF PERSONS		1							
		SUM OF DOSES		6							
	POWER REACTORS	NO. OF PERSONS									
		SUM OF DOSES									
	MEDICAL FACILITIES	NO. OF PERSONS	1						3[f]		
		SUM OF DOSES	1.3						187.3		
	MARKETING & MANUFACT.	NO. OF PERSONS	5								
		SUM OF DOSES	10.6								
	OTHER	NO. OF PERSONS	2[a]	1[a]						1	
		SUM OF DOSES	4.0	5.4						275	
1992	INDUSTRIAL RADIOGRAPHY	NO. OF PERSONS									1
		SUM OF DOSES									300-1000
	POWER REACTORS	NO. OF PERSONS	1			4					
		SUM OF DOSES	1.9			57.7					
	MEDICAL FACILITIES	NO. OF PERSONS							4	1	
		SUM OF DOSES							143.6	272	
	MARKETING & MANUFACT.	NO. OF PERSONS									
		SUM OF DOSES									
	OTHER	NO. OF PERSONS	1[b]			1			1		
		SUM OF DOSES	1.9			24.1			40.5		
1991	INDUSTRIAL RADIOGRAPHY	NO. OF PERSONS	2								
		SUM OF DOSES	5.6								
	POWER REACTORS	NO. OF PERSONS									
		SUM OF DOSES									
	MEDICAL FACILITIES	NO. OF PERSONS	2								
		SUM OF DOSES	3.8								
	MARKETING & MANUFACT.	NO. OF PERSONS							1		
		SUM OF DOSES							22.3		
	OTHER	NO. OF PERSONS	1								
		SUM OF DOSES	2.4								
1990	INDUSTRIAL RADIOGRAPHY	NO. OF PERSONS	3	3[c,d]				1[c]		1	2[d]
		SUM OF DOSES	7.2	49.9				6000		111	3962
	POWER REACTORS	NO. OF PERSONS							1		
		SUM OF DOSES							48.8		
	MEDICAL FACILITIES	NO. OF PERSONS	3[e]								
		SUM OF DOSES	8.9								
	MARKETING & MANUFACT.	NO. OF PERSONS									
		SUM OF DOSES									
	OTHER	NO. OF PERSONS	1								
		SUM OF DOSES	2.3								
1989	INDUSTRIAL RADIOGRAPHY	NO. OF PERSONS	3		1				1		
		SUM OF DOSES	8.1		93				72		
	ALL OTHER	NO. OF PERSONS	4			1			2	1	
		SUM OF DOSES	6.6			9.2			105	178	
1988	INDUSTRIAL RADIOGRAPHY	NO. OF PERSONS	3	1						1	
		SUM OF DOSES	8.1	6.1						118	
	ALL OTHER	NO. OF PERSONS	7			4	1	1	1	1	
		SUM OF DOSES	19.34			66.8	61	278	58	127	
1987	INDUSTRIAL RADIOGRAPHY	NO. OF PERSONS	1							1	
		SUM OF DOSES	3.1							180	
	ALL OTHER	NO. OF PERSONS	2	1		5			3		1
		SUM OF DOSES	2.8	7.5		128.4			72.0		650
1986	INDUSTRIAL RADIOGRAPHY	NO. OF PERSONS	2								
		SUM OF DOSES	4.4								
	ALL OTHER	NO. OF PERSONS	3						1	1	2
		SUM OF DOSES	9.6						41.2	115	930
1985	INDUSTRIAL RADIOGRAPHY	NO. OF PERSONS	6	3	1					1	
		SUM OF DOSES	16.7	32.6	27.0					288	
	ALL OTHER	NO. OF PERSONS	7						3	1	
		SUM OF DOSES	11.8						60.2	93	

[a] Same individual exceeded 1.25 rem/qtr limit twice during 1993.
[b] This 1992 exposure was reported in 1994.
[c] This individual received a whole-body dose of 24 rem in addition to a 6000 rem skin dose.
[d] One of these individuals received a 9 rem whole-body dose in addition to a 1070 rem extremity dose.
[e] One of these individuals exceeded the quarterly whole-body dose limits three times in one calendar year.
[f] An additional 1993 exposure was reported in 1994.

TABLE 6.3
MAXIMUM OCCUPATIONAL EXPOSURES FOR EACH EXPOSURE CATEGORY
1997

Exposure Category	Annual Dose Limit 10CFR20*	Maximum Exposure Reported (rem)	Max Dose Percent of the Limit	Number of Individuals with Measurable Dose	Number of Individuals ≥ 25% of the Limit	Number of Individuals ≥ 50% of the Limit	Number of Individuals ≥ 75% of the Limit	Number of Individuals ≥ 95% of the Limit
SDE-ME	50 rem	533.870	> limit	60,967	96	31	9	2 (>limit)
SDE-WB	50 rem	42.000	84%	75,008	5	2	1	0
LDE	15 rem	10.509	70%	74,323	12	1	0	0
CEDE		2.881		4,105				
CDE		29.648		3,376				
DDE		4.465		75,561				
TEDE	5 rem	4.481	90%	77,094	2,238	280	12	0
TODE	50 rem	29.648	59%	62,984	99	4	0	0

* Shaded boxes represent dose categories that do not have specific dose limits defined in 10 CFR 20.