NUREG-0714
Vol. 1

Occupational Radiation Exposure

Twelfth Annual Report 1979

U.S. Nuclear Regulatory Commission

Office of Resource Management

B. Brooks, S. McDonald, E. Richardson

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GPO Printed copy price: $5.50

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Manuscript Completed: May 1982
Date Published: August 1982

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U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

PREVIOUS REPORTS IN THE SERIES

NUREG-0714 will become the permanent identification number for the Occupational Radiation Exposure report series. The following is a list of all previous reports published in this series, and their separate identification numbers.

WASH1350-R1 through WASH1350-R6
First - Sixth Annual Report of the Operation of the U.S. AEC's Centralized Ionizing Radiation Exposure Records and Reports System, US Atomic Energy Commission.

NUREG-75/108 *Seventh Annual Occupational Radiation Exposure Report for Certain NRC Licensees - 1974,* U. S. Nuclear Regulatory Commission, Oct. 1975.

NUREG-0119 *Eighth Annual Occupational Radiation Exposure Report for 1975,* U. S. Nuclear Regulatory Commission, Oct. 1976.

NUREG-0322 *Ninth Annual Occupational Radiation Exposure Report for 1976,* U. S. Nuclear Regulatory Commission, Oct. 1977.

NUREG-0463 *Tenth Annual Occupational Radiation Exposure Report for 1977,* U. S. Nuclear Regulatory Commission, Oct. 1978.

NUREG-0593 *Eleventh Annual Occupational Radiation Exposure Report for 1978,* U. S. Nuclear Regulatory Commission, Jan. 1981.

NUREG-0714, Vol. 1 *Twelfth Annual Occupational Radiation Exposure Report for 1979,* U. S. Nuclear Regulatory Commission, Aug. 1982.

OCCUPATIONAL RADIATION EXPOSURE

TWELFTH ANNUAL REPORT 1979

SUMMARY

This report summarizes the occupational exposure data that is maintained in the U.S. Nuclear Regulatory Commission's Radiation Exposure Information and Reports System (REIRS). This report is usually published on an annual basis and is available at all NRC public document rooms.

The bulk of the information contained in the report was extracted from annual statistical reports submitted by all NRC licensees subject to the reporting requirements of 10 CFR §20.407. Four categories of licensees - operating nuclear power reactors, fuel fabricators and reprocessors, industrial radiographers, and manufacturers and distributors of specified quantities of byproduct materials - also submit personal identification and exposure information for terminating employees pursuant to 10 CFR §20.408, and some analysis of this data is also presented in this report.

Annual reports were received from 73% of the 8,700 NRC licensees subject to 10 CFR §20.407. Extrapolation of the data to account for that not reported indicated that approximately 327,000 individuals were monitored. Of these, only 167,000 (51%) received measurable doses and incurred a collective dose of 63,600 man-rems; both of these figures show about a 20% increase over last year's values. The average doses remained about the same as those found for 1978, with the average dose for all monitored individuals being 0.20 rem and the average for those individuals having a measurable dose being 0.40 rem. As was the case in 1978, approximately 10% of the individuals monitored received doses greater than 0.50 rem; however, they incurred most (76%) of the collective dose. Less than 0.1% of those monitored received doses greater than 5 rems. For those wishing to make more detailed comparisons of the 1978 and 1979 data, several sections of the 1978 report (NUREG-0593) are reproduced in Appendix A.

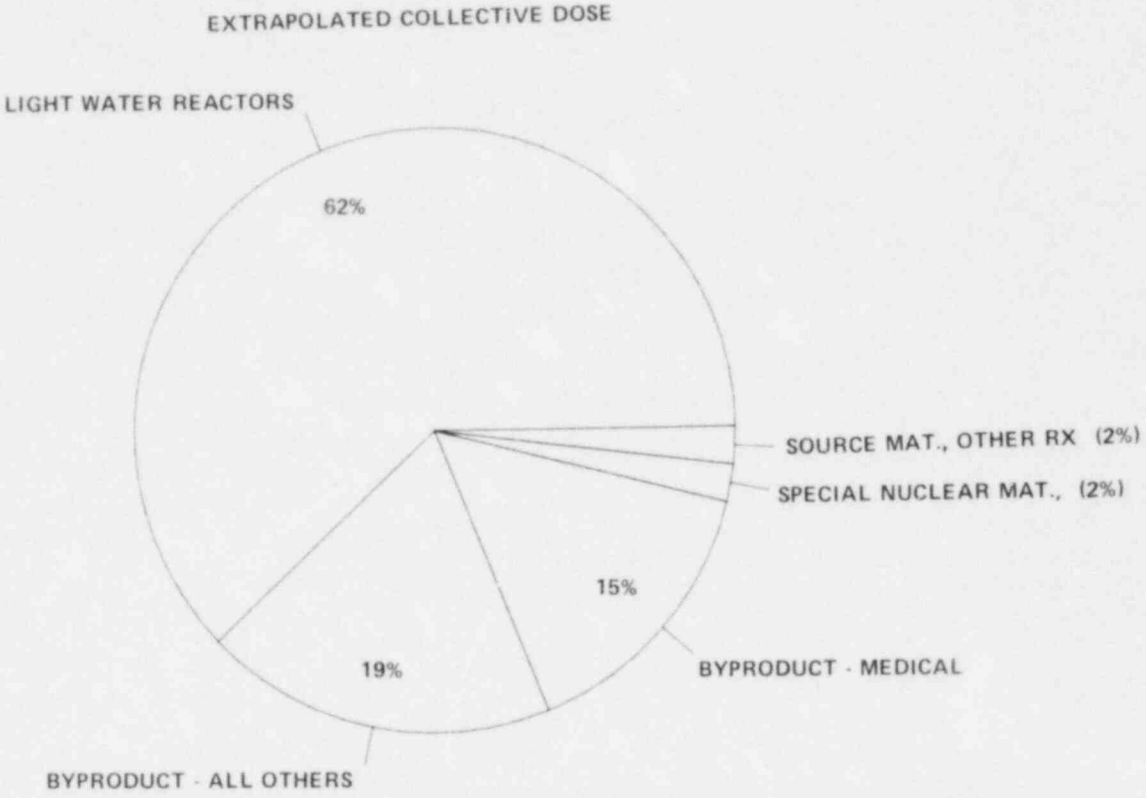
Very few comparisons were made with the 1975 voluntary data since the 1975 figures were extrapolated from limited data (only 18% of the licensees reported). Overall, however, it was found that the extrapolated number of individuals monitored in 1979 was about the same as that found in 1975 (326,000), but the collective dose increased by about 11,400 man-rems (22%) from the 51,840 man-rems estimated for 1975.

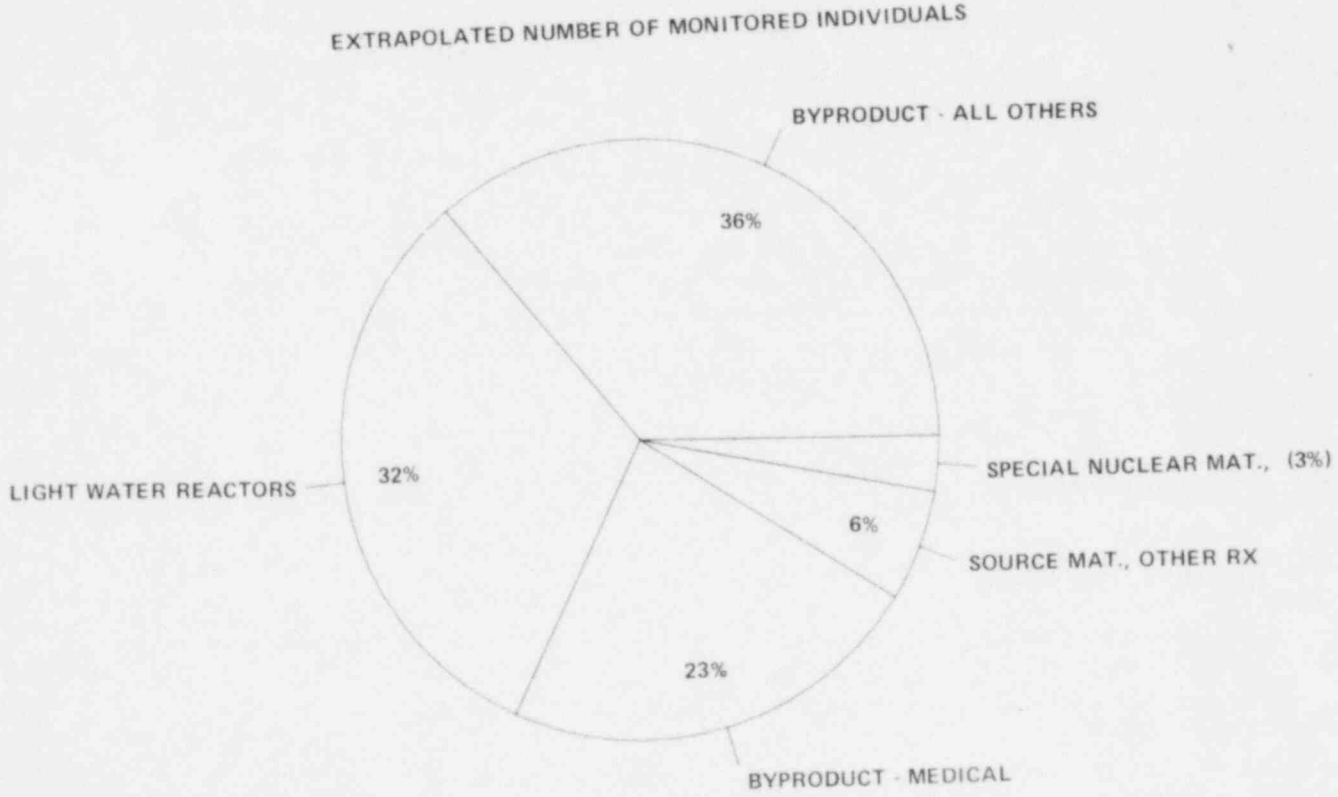
As shown in Figure A, licensed nuclear power facilities monitored 32% of the total number of individuals monitored in 1979, and these individuals received about 62% of the collective dose. Extrapolations of the reported data indicated that medical licensees monitored a large part of the total number of individuals (23%), but these medical workers incurred only 15% of the collective dose. However, all nuclear power facilities are licensed by the NRC, whereas medical institutions in the 26 Agreement States are not licensed by the NRC and are not included in this report. Licensees using NRC-licensed byproduct material for non-medical purposes monitored some 36% of the total number of monitored individuals, and these individuals received 19% of the total collective dose.

FIGURE A

DISTRIBUTION OF EXTRAPOLATED COLLECTIVE DOSE AND MONITORED INDIVIDUALS

1979





The remaining types of licensees - research reactors and those using source and special nuclear material for various purposes - monitored only 9% of the 326,000 monitored individuals, and it was calculated that they received about 4% of the collective dose.

Approximately 130,000 termination records with exposure information for 57,000 individuals terminating employment during 1979 were received from the 500 covered NRC licensees and were entered in the Commission's Radiation Exposure Information and Reports System. Examinations of these records revealed that most of these individuals were employed at one or more nuclear power facilities. Some 1,750 individuals were employed by two or more of the covered NRC licensees during one calendar quarter of 1979. Their average individual dose was found to have declined to 0.46 rem from a high of 1.00 rem in 1972. It was also found that 3,190 individuals were employed at two or more nuclear power facilities during the calendar year 1979. The average measurable dose incurred by these workers was found to be 0.94 rem and 160 workers were found to have annual doses exceeding 5 rems.

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I. 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 assure that the standards for protection against radiation set cut in 10 CFR Part 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 Part 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* of AEC licensees that were considered to involve the greatest potential for significant occupational doses and of AEC facilities and contractors exempt from licensing. Annual reports for each of the years 1969 through 1973 summarized 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 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 Division of Operational and Environmental Safety at Germantown, Maryland.

In May 1975, NRC published a notice of proposed amendment to its regulations that, if adopted, would extend to all specific licensees the requirement for the submission of an annual statistical summary report of personnel monitoring data. Comments on the proposal raised questions regarding the value of the data to be obtained and the burden imposed on licensees. In an attempt to gather the information needed to answer these questions, as well as to test the assumption that the four categories of licensees then required to report still involved the greatest potential for significant doses, the NRC requested all specific licensees to voluntarily submit a statistical summary report for calendar year 1975. Analysis of the data presented in NUREG-0419 [Ref. 1] revealed that only 18% of the approximately 8,000 licensees responded;

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* Commercial nuclear power reactors; industrial radiographers; fuel processors, fabricators, and reprocessors; manufacturers and distributors of specified quantities of byproduct material.

therefore, it was decided that all specific licensees would be required to submit an annual report for at least two years.

On September 29, 1978, 10 CFR §20.407 was amended to require that all NRC specific licensees submit annual radiation exposure reports for both calendar years 1978 and 1979. The report was to be a statistical summary report exactly like those that had been required of the previously named four categories of NRC licensees. The requirements in 10 CFR §20.408 for the submission of certain personal and exposure information for individuals terminating employment, however, continue to apply only to these four categories. This document summarizes the annual exposure information that was reported by the 51 types of NRC specific licensees subject to the reporting requirements of §20.407 and the termination data submitted by four categories of licensees. Presently, all of 10 CFR Part 20 is under review, and the data collected during these two years will be taken into consideration when changes to Part 20 are proposed. This document, however, does not represent the evaluation that is referred to in footnote 2 to 10 CFR §20.407.

II. LIMITATIONS OF THE DATA

All of the figures compiled in this report relating to exposures and/or 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. However, it may not be directly suitable for use in the assessment of risk to the individuals involved because many other factors should be taken into account.

Monitoring requirements are based, in general, on 10 CFR §20.202 which requires licensees to monitor individuals who receive or are likely to receive a dose in any calendar quarter in excess of 25% of the applicable quarterly limits. For adults the quarterly limit for the whole body is 1.25 rems, so that 0.312 rem per quarter is the level above which monitoring is required. Depending on the administrative policy of each licensee, persons such as visitors and clerical workers may also be provided with monitoring devices for identification or convenience, although the probability of their being exposed to significant levels of radiation is extremely small. Licensees are given the option of reporting the dose distribution of only those individuals for whom monitoring is required, or the dose distribution of all those for whom monitoring is provided. Many licensees elect to report the latter; however, this may 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.

One source of error that is present in the calculation of the annual collective dose (i.e., the summation of each monitored person's whole body dose) incurred by workers is the assumption that the midpoint of the dose range is the mean dose of the individuals reported in each dose range. This allows the collective dose to be calculated without knowing each person's actual annual dose by multiplying the number of individuals in each dose range by the midpoint of the range, and then summing these products. Past experience has shown that the actual mean dose of the individuals reported in each range is less than the midpoint. Thus, the collective doses presented in this report may be 10% higher than the sum of the actual individual doses.

Another source of error that may be present is in the extrapolation of the reported information to account for the 2,300 licensees (27%) that did not submit an annual exposure report. The method* used to do this assumes that the data for these licensees is similar to that of the reporting licensees. This may or may not actually be the case.

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*The extrapolated figures were obtained by dividing the reported figures by the fraction of the licensees reporting.

The average dose per individual, as well as the dose distributions shown for groups of licensees, also could have been affected by the multiple reporting of individuals who were monitored by two or more licensees during the year. Since individuals are not identified in the annual reports, an individual who was monitored by five different licensees would have been counted once on each report. Therefore, when the data were summed to determine the total number of individuals monitored by a group of licensees, this person would be counted as five individuals rather than as one. This could also affect the distribution of doses because the individual has been counted five times in the lower dose ranges rather than one time in the higher range in which his actual accumulated dose (the sum of his doses incurred at each facility) would have placed him. This source of error is found primarily in the summations of the data reported by power reactor facilities since they employ many short term workers. Further discussions of this is provided in Section V.C.

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

Due to the many sources of errors in the data itself, as well as in the extrapolations, no attempt was made to place a bound on any of the table values. Some other problems and shortcomings in the collection and interpretation of the data are discussed in Section III.A.

III. SUMMARY OF ANNUAL DATA BY PROGRAM CODE

III.A. Definitions of Program Codes for the Use of Byproduct Materials* and Summary of Data

In order to assign the 6,300 reports submitted by NRC licensees to a type of licensed material and activity, the five-digit number which the NRC assigns to each license to designate the major activity of the licensee was utilized. The NRC uses some 51 program codes to classify the approximately 8,700 licensees that are subject to the reporting requirement of §20.407. Some of these "program codes" narrowly define an activity that corresponds to an industrial segment, such as radiography, while others have such broad definitions that they could simultaneously be part of several industrial segments. This is especially true for the Institutional and Academic program codes which permit the use of radionuclides in both research and instruction/training activities [Ref. 2]. Also, the NRC may change licensing procedures such that program codes may be added or deleted, the definitions of program codes may change slightly from year to year, and a licensee may change its activities or amount of licensed material so that they may be assigned a different program code from year to year. In addition, many of the NRC licensees having two or more NRC licenses, or an NRC license and one or more State licenses, provided only one annual report covering all individuals that were monitored. Therefore, the spectrum of radioactive materials and activities encompassed by licensees in one category may be even broader than is indicated in the descriptions of the program codes.

The submission of a single report for two or more license numbers, each of which may have a different program code, also caused problems in the collation of the data. Since the data on the single report could not be separated by program code, all of the information (number of individuals monitored and their collective dose) was credited to the program code describing the activity and material thought to be the source of the majority of the incurred dose. This methodology probably results in an upward bias in these program codes and a downward bias in the other "secondary" program codes. The bias would have less effect on categories of licensees that encompass most of the primary and secondary program codes, but may be considerable for some categories consisting of a small number of program codes.

This methodology may also cause some difficulty in comparing 1978 and 1979 data for the various license categories. For instance, in 1978 a licensee may have submitted only one report for two or more license numbers (having different program codes) and all of the data would have been credited

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* Byproduct materials are man-made radioactive materials (except special nuclear material) yielded in, or made radioactive by, exposure to the radiation incident to the process of producing or utilizing special nuclear materials. Although byproduct materials do include activation products from nuclear reactors and plutonium-beryllium neutron sources, they do not include activation products from other neutron sources such as Californium-252 or accelerators.

to only one of them. In 1979, however, the licensee may have decided to submit a report for each different license number so that the information would be divided among the appropriate license categories. Another possibility is that for one year the licensee may only have had one license number so that all the data were credited to that license category. The following year, the licensee may have changed his activity somewhat and obtained an additional license which was in another category. If one report was then submitted for both license numbers, the data may have been credited to a different license category from that to which it was credited the first year.

In order to facilitate the description of these 51 program codes, they were grouped into 29 functional categories. Following the descriptions of the program codes in each of the 29 categories is a summary of the annual data reported by those types of licensees. A comparison of some of the data with that reported in 1978 is also included and Appendix A contains several sections of the 1978 report (NUREG-0593) so that more detailed comparisons may be made. Tables 1, 2 and 3 on the following pages present the 1979 data in tabular form.

III.A.1. Academic-Broad and Academic-Other Licenses (Program Codes 01100 and 01200)

Academic-Broad and Academic-Other licenses are issued to educational institutions to allow them to use radionuclides for teaching, training, and some research purposes. The Broad licenses are usually issued to the larger institutions where there is often quite a diversity in the utilization of various radionuclides. The kinds and uses of radionuclides may change frequently, even at the same institution. Academic-Other licenses are more limited in scope, and changes in the types and uses of radionuclides may necessitate the NRC's approval and issuance of amendments to the license. Typical uses include tracer studies in biology, chemistry and physics, the demonstration of equipment and gauges, irradiation of materials, carbon-14 dating, calibration of equipment, the identification of substances in compounds, etc.

Reports were credited to a total of 304 license numbers, or 73% of the 414 licenses having an Academic-Broad or an Academic-Other program code. Several institutions having one of these licenses and one or more other types of NRC license, such as irradiator and research reactor licenses, included all monitored individuals on one report. Since the exposure information was not separated by license number, about 20% of the reports may have included exposure resulting from other types of activities. Some 108 reports indicated that personnel monitoring was not required or not provided. Thirty-five reports had two or more license numbers and program codes, but all except ten of them were credited to one of the two program codes in this group. The 161 reports indicating that monitoring was done were summed to reveal that a total of 24,639 individuals were monitored and that 8,449 of them received measurable exposures. Other than an accidental overexposure of 13.60 rems (see Appendix B), the highest dose was between four and five rems, and 97.4% of the doses were less than 0.50 rem. The collective dose was calculated to be 951 man-rems, which yielded an average measurable dose per worker of 0.11 rem. The average annual collective dose per license was estimated to be three man-rems.

TABLE 1

DISTRIBUTION OF ANNUAL WHOLE BODY EXPOSURES BY LICENSE PROGRAM CODE
1979

LICENSE CATEGORY & (PROGRAM CODE)		Total no. monitored	Exposure ranges (rems)																
			Less than measurable	Measurable <0.10	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	7.00-8.00	8.00-9.00	9.00-10.00	10.00-11.00	11.00-12.00	12+
BYPRODUCT MATERIAL CODES																				
Academic																				
Academic-Broad	(01100)	16,481	10,380	4,654	981	289	73	38	50	11	3	1	0	0	0	0	0	0	0	1
Academic-Other	(01200)	8,158	5,810	1,936	266	101	26	4	11	3	1									
Medical																				
Institutional-Broad	(02110)	24,649	13,831	7,770	1,740	739	250	137	147	23	9	3								
Institutional-Other	(02120)	35,035	12,276	12,748	4,445	2,724	1,138	554	924	133	46	18	15	7	5	1	1			
Private Practice	(02200)	1,162	560	353	134	58	28	14	12	3										
Teletherapy	(02300)	2,473	955	903	327	177	42	28	35	4	2									
Other Medical	(02400)	460	340	112	3	3	1	1												
Medical Distribution	(02500)	278	96	119	28	21	7	3	4											
Pacemakers, Instit.	(02600)	0																		
Marketing																				
Marketing-Broad	(03211)	5,539	2,876	1,415	594	235	103	70	122	43	32	30	9	10						
Marketing-Other	(03212)	5,498	3,528	1,630	203	72	25	15	14	6	2	1	2							
Radiography																				
Radiography, one location	(03310)	1,952	1,075	493	181	92	34	23	38	12	1	3								
Radiography, multi. locations	(03320)	10,017	3,090	2,296	1,133	834	514	338	560	206	91	31	11	6	3	1	0	1	1	1
Research & Development																				
R & D-Broad	(03610)	12,205	9,326	2,553	196	82	22	5	11	10										
R & D-Other	(03620)	6,458	4,922	1,335	111	32	7	8	17	10	11	4	1							
Other Byproduct																				
Well Logging	(03110)	8,723	1,411	2,121	2,173	1,315	637	369	524	117	30	9	6	3	4	0	3	0	0	1
Other Measuring Systems	(03120)	14,185	9,103	4,115	667	198	39	21	27	6	1	0	1	0	1	0	1			
Nuclear Laundry	(03218)	39	18	8	7	3	2	0	1											
Leak Test	(03220)	174	87	68	11	4	2	0	2											
Waste Disposal-Burial	(03231)	34	5	10	10	4	2	0	3											
Waste Disposal-Other	(03232)	512	257	135	47	25	7	5	18	17	1									
Power Sources	(03400)	24	17	7																
Irradiator, <10,000 Ci	(03510)	1,385	901	362	82	29	8	0	2	0	0	0	1							
Irradiator, >10,000 Ci	(03520)	350	283	37	13	5	0	1	4	2	4	0	1							
Civil Defense	(03710)	1,909	399	1,494	1	15														
TOTAL BYPRODUCT		157,700	82,451	46,674	13,353	7,057	2,957	1,634	2,526	606	234	100	47	26	13	2	5	1	1	3

TABLE 1 (Cont.)

DISTRIBUTION OF ANNUAL WHOLE BODY EXPOSURES BY LICENSE PROGRAM CODE
1979

LICENSE CATEGORY & (PROGRAM CODE)		Total no. monitored	Exposure ranges (rems)																
			Less than measurable	Measurable <0.10	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	7.00-8.00	8.00-9.00	9.00-10.00	10.00-11.00	11.00-12.00	12+
SOURCE MATERIAL CODES																				
Uranium Mills	(11100)	1,485	411	456	253	210	84	35	32	2	2									
Uranium Sol. Mines	(11500)	0																		
Other Uranium <150 kg.	(11200)	124	96	21	2	5														
Other Uranium >150 kg.	(11300)	1,245	643	283	134	95	50	22	14	4										
UF_6 Production Plants	(11400)	654	134	194	120	150	33	13	10											
SPECIAL NUCLEAR MATERIAL CODES																				
Fuel Fab. & Reprocessing																				
Plutonium Fuel Fab. & Scrap Recovery	(21110)	644	430	183	13	7	7	1	3											
Plutonium Fuel Fab.	(21120)	1,228	753	220	78	69	28	26	37	14	3									
UF_6 Cnvrsn, U Fuel Fab. & Scrap Recovery	(21210)	3,386	1,265	727	654	367	195	120	55	3										
Uranium Fuel Fab. & Scrap Recovery	(21220)	216	87	105	13	8	3													
Uranium Fuel Fab.	(21230)	4,372	2,012	1,615	369	190	77	42	52	13	2									
Fuel Reprocessing	(43110)	100	34	24	19	14	7	2												
Other SNM																				
Uranium Other Uses, Incl. R & D	(21240)	862	577	210	41	15	5	8	6											
Plutonium Other Uses, Incl. R & D	(21130)	2,262	1,722	423	80	32	5													
Unencapsulated SNM	(22110)	190	166	11	1	4	1	0	7											
Neutron Sources	(22120)	884	673	185	16	3	2	0	5											
Power Sources	(22130)	0																		
Uranium Sources	(22200)	59	40	10	1	7	0	0	1											
Other SNM Sources	(22140)	216	153	51	7	4	1													
Institutional Cardiac Pacemakers	(22160)	32	15	8	3	1	4	0	1											
Fuel Storage	(23100)	184	55	44	26	27	12	12	8											
SNM Storage	(23200)	2,873	2,740	130	2	1														
REACTOR CODES																				
Research & Test Reactors																				
Test Reactors	(42140)	0																		
Research Reactors	(42150)	2,972	2,106	699	77	28	14	8	30	9	1									
Critical Experiment Facilities	(42160)	31	12	19																
Power Reactors																				
Gas Cooled Power Reactors	(41120)	1,271	1,149	120	2															
Light Water Power Reactors	(41111)	105,174	41,101	24,301	9,846	8,159	5,189	3,479	7,934	3,307	1,251	477	86	28	13	2	0	0	1	
Total Source, SNM, & Reactor		130,464	56,374	30,039	11,757	9,396	5,717	3,768	8,195	3,352	1,259	477	86	28	13	2	0	0	1	
GRAND TOTAL		288,164	138,825	76,713	25,110	16,453	8,684	5,402	10,721	3,958	1,493	577	133	54	26	4	5	1	2	3

TABLE 2

ANNUAL EXPOSURE DATA BY LICENSE PROGRAM CODE

1979

LICENSE CATEGORY & (PROGRAM CODE)		FRACTION & % OF LICENSES REPORTING		Reports showing monitoring was not required & not provided	Reports showing monitoring was done	Reports credited to other program codes***	Total number of persons monitored	Average individual dose (rems)	No. of persons with measurable doses	Average measurable dose (rems)	Total collective dose (man-rems)	Collective dose per license (man-rems)	*Extrapolated no. of persons monitored	*Extrapolated no. with measurable doses	*Extrapolated collective dose (man-rems)	**Ratio CR
BYPRODUCT MATERIAL CODES																
Academic																
Academic-Broad	(01100)	59/65	(91%)	5	51	3	16,481	0.04	6,101	0.12	723	12	18,110	6,700	790	0.13
Academic-Other	(01200)	245/349	(70%)	103	110	32	8,158	0.03	2,348	0.10	228	1	11,650	3,350	330	0.08
Medical																
Institutional-Broad	(02110)	93/103	(90%)	0	90	1	24,649	0.07	10,818	0.14	1,569	17	27,390	12,020	1,740	0.14
Institutional-Other	(02120)	1,435/1,712	(84%)	49	1,345	11	35,035	0.16	22,759	0.25	5,777	4	41,710	27,090	6,880	0.24
Private Practice	(02200)	169/308	(55%)	34	124	11	1,162	0.10	602	0.20	118	1	2,110	1,090	210	0.14
Teletherapy	(02300)	378/438	(86%)	14	126	238	2,473	0.12	1,518	0.19	289	1	2,880	1,770	340	0.15
Other Medical	(02400)	36/63	(57%)	8	25	3	460	0.02	120	0.07	9	<1	810	210	20	0.00
Medical Distribution	(02500)	43/57	(74%)	10	15	18	278	0.11	182	0.18	32	1	380	250	40	0.09
Pacemakers, Instit.	(02600)	7/9	(78%)	3	0	4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Marketing																
Marketing-Broad	(03211)	38/46	(83%)	6	32	0	5,539	0.19	2,663	0.39	1,040	27	6,670	3,210	1,250	0.54
Marketing-Other	(03212)	171/213	(80%)	47	108	11	5,498	0.04	1,970	0.12	231	1	6,870	2,460	290	0.21
Radiography																
Radiography, one location	(03310)	138/149	(93%)	8	128	0	1,952	0.12	877	0.27	236	2	2,100	940	250	0.32
Radiography, multi. locations	(03320)	203/221	(92%)	9	194	0	10,017	0.32	6,027	0.54	3,225	16	10,890	6,550	3,510	0.48
Research & Development																
R & D-Broad	(03610)	85/96	(89%)	13	68	4	12,205	0.02	2,879	0.09	252	3	13,710	3,230	280	0.13
R & D-Other	(03620)	330/447	(74%)	113	194	18	6,458	0.03	1,536	0.14	222	1	8,730	2,080	300	0.45
Other Byproduct																
Well Logging	(03110)	67/87	(77%)	8	56	2	8,723	0.35	7,312	0.42	3,050	46	11,330	9,500	3,960	0.37
Other Measuring Systems	(03120)	1,891/2,849	(66%)	1,168	614	104	14,185	0.04	5,077	0.10	521	<1	21,490	7,690	790	0.12
Nuclear Laundry	(03218)	4/4	(100%)	0	4	0	39	0.13	21	0.26	5	1	39	21	5	0.14
Leak Test	(03220)	22/38	(58%)	6	13	3	174	0.07	87	0.13	11	1	300	150	20	0.14
Waste Disposal-Burial	(03231)	2/2	(100%)	0	2	0	34	0.29	29	0.33	10	5	34	29	10	0.24
Waste Disposal-Other	(03232)	12/15	(80%)	0	8	4	512	0.21	255	0.42	106	9	640	320	130	0.56
Power Sources	(03400)	6/6	(100%)	2	3	1	24	0.01	7	0.05	<1	<1	24	7	<1	0.00
Irradiator, <10,000 Ci	(03510)	128/175	(73%)	21	15	90	1,385	0.04	484	0.12	57	<1	1,900	660	80	0.12
Irradiator, ≥10,000 Ci	(03520)	46/52	(88%)	3	15	28	350	0.11	67	0.56	37	1	400	80	40	0.74
Civil Defense	(03710)	51/94	(54%)	6	25	3	1,909	0.04	1,510	0.05	81	1	3,540	2,800	150	0.00
Total Byproduct		5,659/7,598	(74%)	1,636	3,365	589	157,700	0.11	75,249	0.23	17,829	3	193,710	92,210	21,410	

*The extrapolated figures were obtained by dividing the reported number (individuals or collective dose) by the fraction of the licenses reporting.

**The ratio of the annual collective dose delivered at annual individual doses exceeding 1.5 rems to the total collective dose.

***The total number of individuals and collective dose given in these reports were included in the figures shown for other program codes.

TABLE 2 (Cont.)

ANNUAL EXPOSURE DATA BY LICENSE PROGRAM CODE
1979

LICENSE CATEGORY & (PROGRAM CODE)	FRACTION & % OF LICENSEES REPORTING	Reports showing monitoring was not required & not provided	Reports showing monitoring was done	Reports credited to other program codes***	Total number of persons monitored	Average individual dose (rems)	No. of persons with measurable doses	Average measurable dose (rems)	Total collective dose (man-rems)	Collective dose per license (man-rems)	*Extrapolated no. of persons monitored	*Extrapolated no. with measurable doses	*Extrapolated collective dose (man-rems)	**Ratio CR
SOURCE MATERIAL CODES														
Uranium Mills (11100)	18/27 (67%)	3	12	1	1,485	0.19	1,074	0.27	289	16	2,220	1,600	430	0.12
Uranium Sol. Mines (11500)	3/4 (75%)	3	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00
Other Uranium <150 kg. (11200)	55/64 (86%)	23	9	23	124	0.03	28	0.12	3	<1	150	30	<10	0.00
Other Uranium ≥150 kg. (11300)	191/258 (74%)	68	33	90	1,245	0.12	602	0.25	155	1	1,680	810	210	0.13
UF_6 Production Plants (11400)	2/2 (100%)	0	2	0	654	0.20	520	0.26	134	67	654	520	134	0.06
SPECIAL NUCLEAR MATERIAL CODES														
Fuel Fab & Reprocessing														
Plutonium Fuel Fab. & Scrap Recovery (21110)	3/3 (100%)	0	3	0	644	0.04	214	0.11	24	8	644	214	24	0.09
Plutonium Fuel Fab. (21120)	2/2 (100%)	0	2	0	1,228	0.16	475	0.40	192	96	1,228	475	192	0.38
UF_6 Cnvrsn, U Fuel Fab. & Scrap Recovery (21210)	5/5 (100%)	0	5	0	3,386	0.18	2,121	0.29	605	121	3,386	2,121	605	0.08
Uranium Fuel Fab & Scrap Recovery (21220)	3/3 (100%)	0	2	1	216	0.06	129	0.10	12	4	216	129	12	0.00
Uranium Fuel Fab (21230)	7/7 (100%)	0	7	0	4,372	0.10	2,360	0.18	419	60	4,372	2,360	419	0.19
Fuel Reprocessing (43110)	1/1 (100%)	0	1	0	100	0.16	66	0.24	16	16	100	66	16	0.00
Other SNM														
Uranium-Other Uses, incl. R&D (21240)	16/16 (100%)	2	7	7	862	0.05	285	0.15	42	3	862	285	42	0.11
Plutonium Other Uses, incl. R&D (21130)	5/6 (83%)	4	1	0	2,262	0.02	540	0.09	50	10	2,730	650	60	0.00
Unencapsulated SNM (22110)	19/21 (90%)	7	3	9	190	0.07	24	0.56	13	1	210	30	10	0.39
Neutron Sources (22120)	191/220 (87%)	73	34	84	884	0.00	211	0.11	22	<1	1,020	230	30	0.17
Power Sources (22130)	1/1 (100%)	0	0	1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Uranium Sources (22200)	28/34 (82%)	3	5	20	59	0.07	19	0.25	5	<1	70	20	10	0.16
Other SNM Sources (22140)	40/50 (80%)	14	11	15	216	0.03	63	0.09	6	<1	270	80	10	0.00
Institutional Pacemakers (22160)	103/180 (57%)	52	5	46	32	0.16	17	0.31	5	<1	60	30	10	0.14
Fuel Storage (23100)	6/8 (75%)	0	2	4	184	0.26	129	0.36	47	8	250	170	60	0.13
SNM Storage Only (23200)	6/8 (75%)	0	4	1	2,873	0.00	133	0.05	7	1	3,830	180	10	0.00
REACTOR CODES														
Research & Test Reactors														
Test Reactors (42140)	4/4 (100%)	0	0	4	0	0.00	0	0.00	0	0	0	0	0	0.00
Research Reactors (42150)	67/72 (93%)	3	28	33	2,972	0.04	866	0.17	146	2	3,200	930	160	0.33
Critical Experiment Facilities (42160)	3/4 (75%)	0	1	2	31	0.03	19	0.05	1	<1	40	30	0	0.00
Power Reactors														
Gas Cooled Reactors (41120)	1/1 (100%)	0	1	0	1,271	0.00	122	0.05	6	6	1,271	122	6	0.00
Light Water Reactors (41111)	69/69 (100%)	0	69	0	105,174	0.38	64,073	0.62	39,759	576	105,174	64,073	39,759	0.54
GRAND TOTALS	6,339/8,668 (73%)	189	3,615	929	288,164	0.20	149,339	0.40	59,787	9	327,350	167,360	63,630	

*The extrapolated figures were obtained by dividing the reported number (individuals or collective dose) by the fraction of the licenses reporting.

**CR is the ratio of the annual collective dose delivered at annual individual doses exceeding 1.5 rems to the total collective dose.

***The total number of individuals and collective dose shown in these reports were included in the figures given for other program codes.

TABLE 3

ANNUAL EXPOSURE DATA BY LICENSE TYPE

1979

License category	No. of monitored individuals reported	Workers with measurable doses reported	Collective dose, man-rems	Extrapolated individuals monitored	Extrapolated workers with measurable doses	Extrapolated collective dose, man-rems	Average individual dose, rems	Average measurable dose, rems
Byproduct Material								
Academic	24,639	8,449	951	29,760	10,050	1,120	0.04	0.11
Medical	64,057	35,999	7,794	75,280	42,430	9,230	0.12	0.22
Marketing	7,100	2,416	383	9,600	3,450	650	0.05	0.16
*Manufacturing & Distribution	3,937	2,217	888	3,937	2,217	888	0.23	0.40
Radiography	11,969	6,904	3,461	12,990	7,490	3,760	0.29	0.50
Research & Development	18,663	4,415	474	22,440	5,310	580	0.03	0.11
Other Byproduct Material	27,335	14,849	3,878	39,700	21,260	5,190	0.14	0.26
TOTAL BYPRODUCT MATERIAL	157,700	75,249	17,829	193,710	92,210	21,420	0.11	0.24
Source Material								
TOTAL	3,508	2,224	581	4,700	2,960	780	0.17	0.26
Special Nuclear Material								
Fuel Fab. & Reprocessing	9,946	5,365	1,268	9,946	5,365	1,268	0.13	0.24
Other SNM	7,562	1,421	197	9,300	1,680	240	0.03	0.14
TOTAL SNM	17,508	6,786	1,465	19,250	7,050	1,510	0.08	0.22
Research Reactors & Crit. Exp. Fac.	3,003	885	147	3,240	960	160	0.05	0.17
Gas Cooled Power Reactors	1,271	122	6	1,271	122	6	0.00	0.05
Light Water Power Reactors	105,174	64,073	39,759	105,174	64,073	39,759	0.38	0.62
GRAND TOTALS	288,164	149,339	59,787	327,350	167,360	63,630	0.21	0.40

*Subset of "Marketing" meeting the criteria in §20.408(a)(4) that have previously been required to report.

Extrapolation of this data to account for the number of licensees that did not report indicates that there may be a total of 29,760 individuals being monitored annually, and a collective dose of 1,120 man-rems being incurred. These figures show increases of 31% and 22%, respectively, over the number of Academic-Broad licensees that reported in 1979. This could be due in part to a 99% increase in the number of Academic-Broad licensees that reported in 1979.

III.A.2. Institutional-Broad, Institutional-Other, and Teletherapy Licenses (Program Codes 02110, 02120, and 02300)

Institutional-Broad licenses are usually issued to larger medical institutions to allow them to use a wide range of radionuclides in medical research, diagnosis, and therapy. The Institutional-Other licenses are normally issued to a hospital, medical center, or other medical facility to allow the use of radionuclides in well established, more routine, diagnostic and therapeutic procedures. The use of radionuclides in research and diagnosis encompasses *in vivo* and *in vitro* analyses. Therapeutic applications of radionuclides focus on cancer treatment either by drugs containing radionuclides or by beam therapy. Institutions and physicians desiring to use the radiation emitted by a sealed source, usually a fairly large cobalt-60 source, for therapeutic purposes are also issued a separate teletherapy license. These three codes were grouped because more than half of the institutions having a Teletherapy license also had an Institutional license, and many of them filed one report covering all license numbers.

Reports were credited to a total of 1,906 license numbers, or 85% of the 2,253 licenses having one of these three program codes. Reports for 63 licenses indicated that personnel monitoring was not required and not provided. Some 282 reports had two or more license numbers and program codes, but all except 23 of them were credited to one of the three program codes in this group. The 1,561 reports indicating that monitoring was done were summed to reveal that a total of 62,157 individuals were monitored, and that 35,095 of them received measurable exposures. The highest reported dose was between nine and ten rems, while 94% of the individuals received doses that were less than 0.50 rem. The collective dose was calculated to be 7,635 man-rems which yielded an average measurable dose per worker of 0.22 rem, and an average collective dose per license of about four man-rems. It should be noted that most of the licensees in this group also possess and use x-ray machines and radionuclides (such as radium) that produce and emit ionizing radiation but are not licensed by the NRC. Many of these licensees reported all monitored individuals, many of whom may have received the major portion of their exposure from non-licensed sources of radiation. Therefore, particularly for these types of licenses, one should not infer that all of the collective dose is due to exposure to NRC-licensed material.

Extrapolation of this data to account for those licensees not reporting indicates there may be a total of 71,980 individuals being monitored, and a collective dose of 8,690 man-rems being incurred. This is an increase of about ten percent over the figures reported for 1978.

III.A.3. Private Practice Licenses (Program Code 02200)

Private Practice licenses are usually issued to a physician or a group of physicians to allow the use of radionuclides in well established diagnostic

and therapeutic procedures in their offices. A total of 169 licenses, or 55% of the 308 licenses assigned a Private Practice program code, were credited with submitting an annual report. Reports for 34 licenses stated that personnel monitoring was not required and not provided, and eleven reports having two or more license numbers and program codes were credited to other program codes. The 124 reports indicating that monitoring was done were summed to reveal that a total of 1,162 individuals were monitored and that 602 of them received measurable exposures. The highest dose reported was between two and three rems, while 95% of the doses were less than 0.50 rem. The collective dose was calculated to be 118 man-rems to yield an average measurable dose per worker of 0.20 rem, and an average collective dose per license of about one man-rem. As was the case for Institutional and Teletherapy licensees, many of these licensees probably included individuals exposed to non-NRC licensed sources of radiation in their annual reports.

Extrapolation of this data to account for the number of licensees not reporting indicates that there may be a total of 2,110 individuals being monitored and a collective dose of 210 man-rems being incurred. The number of individuals monitored and the number receiving measurable doses is about the same as that reported in 1978. The collective dose, however, decreased by about 50 percent. This may be partly due to the fact that the number of these licenses decreased by 14% and a higher percentage of them reported.

III.A.4. Other Medical Licenses (Program Code 02400)

Other Medical licenses are issued to individuals or facilities to allow the use of radionuclides in medical activities that were not described above, such as those of veterinarians and clinical labs performing in-vitro analysis. A total of 36, or 57% of the 63 licenses assigned an Other Medical program code, were credited with submitting an annual report. Reports for eight licenses stated that personnel monitoring was not required and not provided, and three reports having two or more license numbers and program codes were credited to other program codes. The 38 reports indicating that monitoring was done were summed to reveal that a total of 460 individuals were monitored, and that 120 received measurable exposures. The highest dose was between one-half and one rem. The collective dose was calculated to be nine man-rems to yield an average measurable dose per worker of 0.7 rem, and an average collective dose per license that is less than one man-rem.

Extrapolation of this data to account for those licensees not reporting indicates that there may be some 810 individuals being monitored, and a collective dose of 20 man-rems being incurred. These figures are less than those reported for 1978 which may be partially due to the fact that the number of these licenses decreased by about ten percent.

III.A.5. Medical Distribution Licenses (Program Code 02500)

These licenses are issued to nuclear pharmacies to allow them to distribute radiopharmaceuticals to hospitals and physicians. They usually purchase various radioactive materials in bulk from larger firms, prepare individual patient doses, and accumulate them in a central location so that they can be readily distributed.

Reports were credited to a total of 43, or 75% of the 57 licenses assigned a Medical Distribution license. Reports for ten licenses stated that monitoring was not required and not provided, and 18 reports having two or more license numbers and program codes were credited to other program codes. The 15 reports indicating that personnel were monitored were summed to reveal that a total of 278 individuals were monitored and that 182 of them received measurable doses. The highest doses were between one and two rems, while 95% of the doses were less than 0.50 rem. The collective dose was calculated to be 32 man-rems, which yielded an average measurable dose per worker of 0.17 rem, and an average collective dose per license of about one man-rem.

Extrapolation of this data to account for those not reporting indicates that there may be some 380 individuals being monitored, and a collective dose of 40 man-rems being incurred. The number of monitored individuals increased by almost 50% over that reported in 1978 while the collective dose remained the same. This resulted in a decrease in the average doses.

III.A.6. Institutional Byproduct Pacemaker Licenses (Program Code 02600)

These licenses are issued to medical facilities and physicians to allow the surgical implantation of pacemakers that are powered by a device containing byproduct materials. None of this type of pacemaker is presently being manufactured, and there were only nine such licenses in effect during 1978 and 1979. Seven of the nine licenses were credited with submitting a 1979 annual report. Three reports stated that monitoring was not required and not provided, and, as was the case in 1978, the data for the remaining four license numbers were combined with other license numbers having Institutional program codes. Since the devices are constructed such that any individual handling them would receive only minimal exposure, the reports were credited to the other program codes.

III.A.7. Well Logging Licenses (Program Code 03110)

Well Logging licenses are issued to firms to allow the use of radionuclides for surveying wells to obtain geological information. This testing procedure is primarily used in oil exploration to identify underground oil and water. Annual reports were credited to a total of 67, or 77% of the 87 licenses assigned a Well Logging program code. Reports for eight licenses stated that personnel monitoring was not required and not provided, and two reports having two or more license numbers were credited to other program codes. The 56 reports indicating monitoring was done were summed to reveal that a total of 8,723 individuals were monitored, and that 7,312 of them received measurable doses. Other than the accidental overexposure which exceeded 12 rems (see Appendix B), the highest dose was between nine and ten rems, and 81% of the doses were less than 0.50 rem. The collective dose was calculated to be 3,050 man-rems to yield an average measurable dose per worker of 0.42 rem, and an average collective dose per license of about 46 man-rems.

These figures are larger than those reported for 1978 because a report for a large Well Logging licensee was erroneously credited to another program code. Correcting for this, the figures for 1978 should have been as follows: 8,559 monitored individuals, 6,886 workers with measurable doses, a collective dose of 2,478 man-rems, an average individual dose of 0.29 rem, an average measurable dose of 0.36 rem, and an average collective dose per license of

40 man-rems. Extrapolation of these figures yields 10,830 monitored individuals, and a collective dose of 3,140 man-rems. These are about five percent and 25 percent, respectively, less than those (11,330 individuals and 3,960 man-rems) extrapolated from the 1979 data.

III.A.8. Other Measuring Systems Licenses (Program Code 03120)

These licenses are issued to allow the use of measuring devices that contain radionuclides. This group includes such devices as gas chromatographs and gauges which are frequently used for measuring the level of material, quality control testing in industrial processes, and for soil and construction testing services. In many cases, the licensee is not required to provide personnel radiation monitoring because of the inherent safety of the devices. Frequently, the equipment is serviced and leak tested by the manufacturer or lessor of the equipment.

A total of 1,891 license numbers, or 66% of the 2,849 licenses assigned an Other Measuring Systems program code, were credited with submitting an annual report. Reports for 1,168 licenses stated that personnel monitoring was not required and not provided, and 104 reports having two or more license numbers and program codes were credited to other program codes. The 614 reports indicating that personnel monitoring was done were summed to reveal that a total of 14,185 individuals were monitored, and that 5,077 of them received measurable exposures. The highest dose was between nine and ten rems, while 99% of the doses were less than 0.50 rem. The collective dose was calculated to be 521 man-rems, which yielded an average measurable dose per worker of 0.10 rem, and an average collective dose per license that was less than one man-rem.

Extrapolation of this data to account for the number of licensees not reporting indicates that there may be some 21,490 individuals being monitored, and a collective dose of 790 man-rems being incurred. Respectively, these figures are about 13% less and 22% larger than those calculated for 1978. The average measurable dose remained about the same.

III.A.9. Marketing-Broad and Marketing-Other Licenses* (Program Codes 03211 and 03212)

Marketing-Broad and Marketing-Other licenses are issued to allow the manufacture and distribution of radionuclides in various forms for a number of diverse purposes. Again, the Broad licenses are issued to the larger facilities having a more comprehensive radiological protection program, and the Other licenses are usually issued to the smaller firms requiring a more restrictive license. Some firms are medical suppliers that process, package or distribute products such as diagnostic test kits, radioactive surgical implants, and tagged radiochemicals for use in medical research, diagnosis and therapy. Other 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

* Includes the category "Manufacturers and Distributors" that was previously required to report annually. See Section IV.A.1.

and smoke detectors and radiochemicals for non-medical research. Other firms are involved with the manufacture, assembly and distribution of various products that contain radionuclides.

A subset, usually called "Manufacturers & Distributors," of this group is one of the four categories of licensees that has been required to submit annual reports to the NRC for the past 10 years. This subset consists of approximately 28 licensees that process and distribute large quantities of byproduct material as defined in 10 CFR §20.408(a)(4). Information reported by this subset in 1979 is further discussed in Section IV.A.1. The following figures and analysis are based on reports for all licenses having program codes 03211 or 03212, including the subset.

Reports were credited to a total of 209 license numbers, or 81% of the 259 licenses assigned one of the Marketing program codes. Reports for 53 licenses stated that personnel monitoring was not required and not provided. Seven reports having two or more license numbers and program codes were credited to various other program codes. The 140 reports indicating that monitoring was done were summed to reveal that 11,037 individuals were monitored, and that 4,633 of them received measurable exposures. The highest dose was between six and seven rems, while 96% of the doses were less than 0.50 rem. The collective dose was calculated to be 1,271 man-rems, to yield an average measurable exposure per worker of 0.27 rem, and an average collective dose per license of about six man-rems.

Extrapolation of this data to account for those not reporting indicates that there may be some 13,540 individuals being monitored and a collective dose of 1,540 man-rems being incurred. These figures are quite a bit less than those found for the 1978 data, primarily because a report submitted by a licensee belonging in the Well Logging category was erroneously assigned a Marketing program code. Correcting for this, the figures for 1978 would be as follows: 10,795 monitored individuals, 4,009 workers with measurable doses, a collective dose of 1,346 man-rems, an average individual dose of 0.13 rem, an average measurable dose of 0.34 rem, and an average collective dose per licensee of about six rems. Extrapolation of these figures yields 12,700 monitored individuals and a collective dose of 1,580 man-rems. These are quite similar to those extrapolated from the 1979 data.

III.A.10. Nuclear Laundry Licenses (Program Code 03218)

Nuclear Laundry licenses are issued to allow the cleaning of protective clothing contaminated with radioactive material. Firms in this industry often provide nuclear cleaning services as part of a full line of uniform rental or health physics services.

All four of the licenses assigned a Nuclear Laundry program code were credited with submitting an annual report. Summing these reports, each of which indicated that monitoring was done, yielded a total of 39 monitored individuals, 21 of whom received measurable doses. Ninety-two percent of the doses were less than 0.50 rem, and the collective dose was found to be five man-rems. The average annual dose per worker having a measurable exposure was 0.26 rem, and the average collective dose per license was about one man-rem. The number of individuals and the collective dose are several times larger

than those found in 1978, but the average measurable dose only slightly increased.

III.A.11. Leak Test Licenses (Program Code 03220)

Many facilities own or lease equipment, such as gauges or industrial radiographic cameras, that contains radioactive material and has to be periodically tested for leakage. This is usually done by swabbing the potentially contaminated surfaces of the device or, in some cases, the surface of the sealed source, and analyzing the swab for radioactive contamination. Leak Test licenses are issued to allow other firms to conduct the leak testing of these devices, and to possess small amounts of radioactive material in order to detect and measure the quantities of materials deposited on the leak test samples.

A total of 22, or 58% of the 38 licenses assigned a Leak Test program code, were credited with submitting an annual report. Reports for six licenses stated that monitoring was not required or not provided. The 13 reports indicating that personnel monitoring was done were summed to reveal that a total of 174 individuals were monitored and that 87 of them received measurable exposures. The highest dose was between one and two rems, while 98% of the individuals received doses less than 0.50 rem. The collective dose was calculated to be 11 man-rems to yield an average measurable dose per worker of 0.13 rem, and an average collective dose per license of about one man-rem.

Extrapolation of this data to account for those licensees not reporting indicates that there may be a total of 300 individuals being monitored and a collective dose of about 20 man-rems being incurred. These figures are twice those found for the 1978 data, probably because there were nearly twice as many Leak Test licenses. Also, as was the case last year, these figures are probably overestimates because two of the larger licensees reporting are involved in activities where exposures may be incurred from non-NRC licensed sources of radiation.

III.A.12. Waste Disposal Licenses, Burial and Other (Program Codes 03231 and 03232)

Waste Disposal licenses are issued to allow the removal, transportation, storage, or burial of radioactive wastes. There were two firms licensed to operate a burial ground for radioactive wastes, and there were fifteen firms having Waste Disposal-Other licenses which authorized them to collect packaged waste material, transport it, and temporarily store it before transporting it to an authorized burial ground.

A total of 14, or 82% of the 17 licenses assigned a Waste Disposal program code, were credited with submitting an annual report. Four reports having two or more license numbers and program codes were credited to other program codes, usually that for Research and Development. The ten reports indicating that personnel monitoring was done were summed to reveal that a total of 546 individuals were monitored, and that 284 of them received measurable doses. The highest dose was between three and four rems, while 90% of the doses were less than 0.50 rem. The collective dose was calculated to be 116 man-rems, which yielded an average measurable dose per worker of 0.41 rem, and an average collective dose per license of about seven man-rems.

Extrapolation of the data to account for the three licensees not reporting indicates that there may be some 670 individuals being monitored and a collective dose of 140 man-rems being incurred. These figures are considerably larger than those found in the 1978 data (360 individuals and 100 man-rems), as is the average measurable dose which increased from 0.28 rem to 0.41 rem.

III.A.13. Industrial Radiography Licenses, Single and Multiple Locations (Program Codes 03310 and 03320)

These licenses are issued to allow the use of sealed radioactive materials, usually in exposure devices or "cameras," that primarily emit gamma rays for non-destructive testing of pipeline weld joints, steel structures, boilers, aircraft and ship parts, and for other high stress alloy parts. Some firms are licensed to conduct such activities in one location, usually in plant, and others perform radiography at multiple sites in the field.

A total of 341 licenses, or 92% of the 370 licenses assigned a Radiography program code, were credited with submitting an annual report. Seventeen reports stated that monitoring was not required and not provided. The 322 reports indicating that monitoring was done were summed to reveal that a total of 11,969 individuals were monitored, and that 6,904 of them received measurable doses. Other than the accidental overexposure of 17.0 rems (see Appendix B), the highest dose was between 11 and 12 rems, while 84% of those monitored had doses less than 0.50 rem. The collective dose was estimated to be 3,461 man-rems, which yielded an average measurable dose per worker of 0.50 rem, and an average collective dose per license of about ten man-rems.

Extrapolation of this data to account for those not reporting indicates that there may be some 12,990 individuals being monitored and 3,760 man-rems being incurred. Compared to the 1978 data, the number of monitored individuals decreased somewhat, while the collective dose increased by about 30%. This resulted in an increase in the average measurable dose from 0.44 rem to 0.50 rem, which is contrary to the trend exhibited during the previous several years. See Section IV.A for further analysis of the information reported by radiography firms.

III.A.14. Power Source Licenses (Program Code 03400)

Power source licenses are issued to allow the use of byproduct material to generate heat and power. The military possesses all six of these licenses and all of them were credited with submitting annual reports. Two stated that monitoring was not required and not provided, and one was credited to another program code. The three reports stating that monitoring was done were summed to reveal that a total of 24 individuals were monitored. Seven of them received measurable doses, but all were less than 0.10 rem. The collective dose was 0.35 rem, and the average measurable dose was 0.05 rem. In 1978 there was only one such license, and the report indicated that no one was required to be monitored.

III.A.15. Irradiator Licenses, Less Than or More Than 10,000 Curies (Program Codes 03510 and 03520)

Irradiator licenses are issued to allow the use of large sources of radiation, usually cobalt-60, to produce effects requiring high radiation

levels. Primary uses include medical and non-medical research, usually by universities, and industrial uses, such as the sterilization of medical products and drugs, staining of glass, and treating of hard woods, plastics, and semi-conductor materials, etc.

Annual reports were credited to a total of 174 licenses, or 76% of the 227 licenses assigned an Irradiator program code. A majority of the reports, (118) having two or more license numbers, were credited to other program codes - usually those for medical or academic institutions. Twenty-four reports stated that monitoring was not required and not provided. The 30 reports indicating that monitoring was done were summed to reveal that a total of 1,735 were monitored, and that 551 of them received measurable doses. The highest doses were between five and six rems, while 99% of the doses were less than 0.50 rem. The collective dose was calculated to be 94 man-rems, which yielded an average measurable dose per worker of 0.17 rem, and an average collective dose per license of less than one man-rem.

Extrapolation of this data to account for those not reporting indicates that there may be some 2,300 individuals being monitored, and a collective dose of 120 man-rems being incurred. The number of monitored individuals decreased by some 1,330 from that monitored in 1978, while the collective dose decreased by only 20 man-rems. This resulted in slight increases in the average doses.

III.A.16. Research and Development Licenses, Broad and Other (Program Codes 03610 and 03620)

These licenses are issued to allow the use of radionuclides in research that is not related to health care or life sciences. There is a large diversity in the kinds of research and uses of radionuclides in non-medical research. Again the Broad licenses are issued to larger facilities having a more comprehensive radiation protection program, where the types of research being conducted may fluctuate rapidly. Typical activities include environmental analysis, food quality studies, aerospace and engineering applications, and product development.

Annual reports were credited to a total of 415, or 76% of the 543 licenses assigned a Research and Development program code. One hundred and twenty-six reports stated that monitoring was not required and not provided, and 22 reports having two or more license numbers and program codes were credited to other program codes. The 262 reports indicating that monitoring was done were summed to reveal that 18,663 individuals were monitored, and that 4,415 of them received measurable doses. The highest dose was between five and six rems, while 99% of the doses were less than 0.50 rem. The collective dose was calculated to be 474 man-rems, which yielded an average measurable dose per worker of 0.11 rem and an average collective dose per license of about one man-rem.

Extrapolation of this data to account for those not reporting indicates that there may be some 22,440 individuals being monitored and 580 man-rems being incurred. These figures increased by about 15 and 35 percent, respectively, while the average measurable dose remained about the same as that reported in 1978.

III.A.17. Civil Defense Licenses (Program Code 03710)

These licenses are issued to allow the use of radionuclides for training individuals in civil defense activities, such as calibrating and demonstrating the use of radiation survey and monitoring equipment.

A total of 51 licenses, or 54% of the 94 licenses assigned a Civil Defense program code, were credited with submitting an annual report. Six reports stated that monitoring was not required and not provided, and three reports having two or more license numbers were credited to other program codes. The 25 reports indicating that monitoring was done were summed to reveal that 1,909 individuals were monitored, and that 1,510 of them received measurable doses. All of the doses were less than 0.50 rem. The collective dose was calculated to be 81 man-rems, which yielded an average measurable dose per worker of 0.05 rem, and an average collective dose per license of about one man-rem.

Extrapolation of this data to account for those not reporting indicates that there may be 3,540 individuals being monitored and 150 man-rems being incurred. These figures are slightly larger than those found in the 1978 data, but the average doses remained about the same. This could be partially due to the fact that only 54% of this license category reported in 1979, compared to 76% that reported in 1978.

III.B. Definition of Program Codes for the Use of Source Materials* and Summary of Data

III.B.1. Uranium Mill and Mining Licenses (Program Codes 11100 and 11500)

These licenses are issued to allow the extraction of uranium from uranium ore. In milling operations, the ore is crushed, ground to a fine mesh, and chemically treated to convert the uranium to a form called yellowcake. The only mining operation licensed by the NRC is solution mining, which is *in situ* leaching of ore bodies to extract uranium. Only a very small amount of uranium is mined this way.

A total of 21 licenses, or 68% of the 31 licenses assigned one of these program codes, were credited with submitting an annual report. Three of the reports from mills, and all three reports from solution mines stated that monitoring was not required or not provided. The twelve reports from mills that indicated that monitoring was done were summed to reveal that 1,485 individuals were monitored and that 1,074 of them received measurable doses. The highest dose was between three and four rems, while 90% of the doses were less than 0.50 rem. The collective dose was estimated to be 289 man-rems, which yielded an average measurable dose per worker of 0.27 rem, and an average collective dose per license of about 14 man-rems.

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* Source materials are materials essential to the production of special nuclear materials. Source materials include uranium (and depleted uranium produced as tailings) and thorium, both of which are naturally occurring and radioactive. Other naturally occurring radioactive materials, such as radium and polonium, are not regulated by the NRC.

Extrapolation of this data to account for those not reporting indicates that there may be some 2,220 individuals being monitored, and 430 man-rems being incurred. The number of individuals is about twice as large as that derived from the 1978 data, while the collective dose is about 2.3 times as large, which resulted in increases in the average doses. This may have been partially due to a 70% increase in the number of Mill licenses.

III.B.2. Uranium-Other Licenses, Less Than or More Than 150 Kilograms (Program Codes 11200 and 11300)

The majority of Uranium-Other licenses are issued to allow the use of refined uranium and/or thorium for fabrication, research, and manufacture of consumer products. Included are ceramics, tile, and glassware industries; manufacturers of refractories, uranium shields, fuel elements, and analytical standards; and other uses not specifically classified. A smaller number of these licenses are issued to allow the possession of uranium and/or thorium for uses other than processing or fabrication of any kind, such as distribution and storage. An even smaller number of these licenses are issued to allow the use of uranium in subcritical assemblies.

A total of 246 licenses, or 73% of the 322 licenses assigned one of the programs codes, were credited with submitting an annual report. Reports for 91 of the licenses stated that personnel monitoring was not required and not provided. One hundred and thirteen of the reports having two or more license numbers were credited to other program codes, usually those of Institutional-Other, Research and Development, or Academic. The 42 reports indicating that monitoring was done were summed to reveal that 1,370 individuals were monitored, and that 631 of them received measurable doses. The highest dose was between seven and eight rems, while 93% of the doses were less than 0.50 rem. The collective dose was estimated to be 158 man-rems, which yielded an average measurable dose per worker of 0.25 rem, and an average collective dose per license of about one man-rem.

Extrapolation of this data to account for those licensees not reporting indicates that there may be 1,830 individuals being monitored, and a collective dose of 220 man-rems being incurred. These values are slightly smaller than those derived from the 1978 data, as are the number of licenses having one of these program codes. The average doses, however, increased somewhat.

III.B.3. Uranium Hexafluoride Production Licenses (Program Code 11400)

These licenses are issued to allow the conversion of yellowcake to uranium hexafluoride (UF_6). There were only two commercial production facilities operating in 1979, as there were in 1978. These two facilities reported monitoring a total of 654 individuals, 520 of whom received measurable doses. The highest dose was between one and two rems, while 91% of the doses were less than 0.50 rem. The collective dose was estimated to be 134 man-rems, which yielded an average measurable dose per worker of 0.26 rem. These figures are only slightly larger than those reported in 1978.

III.C. Definition of Program Codes for the Use of Special Nuclear Materials* and Summary of Data

III.C.1. Uranium Hexafluoride Conversion, Uranium and Plutonium Fuel Fabrication and Scrap Recovery Licenses (Program Codes 21110, 21120, 21210, 21220, and 21230)

These licenses are issued to allow the processing and fabrication of reactor fuels. In most uranium facilities, where light water reactor fuels are processed, uranium hexafluoride product enriched in the isotope U-235 is converted to solid uranium dioxide pellets and inserted into zirconium tubes. The tubes are fabricated into fuel assemblies which are shipped to nuclear power plants. On a much smaller scale, fuel assemblies containing plutonium oxide pellets are similarly fabricated and used in reactors for experimental purposes. Some facilities also perform chemical operations to recover the uranium and plutonium from scrap and other off-specifications materials.

Annual reports were credited to all 20 of the licenses assigned one of these program codes, and they all indicated that monitoring was done. The reports were summed to reveal that 9,846 individuals were monitored, and that 5,299 of them received measurable doses. The highest dose was between three and four rems, while 95% of the doses were less than 0.50 rem. The collective dose was calculated to be 1,252 man-rems, which yielded an average measurable dose per worker of 0.24 rem, and an average collective dose per license of about 63 man-rems. The number of monitored individuals and the collective dose are about 25% smaller than those extrapolated from the 1978 data so that the average doses remained about the same.

These licensees have been required to submit annual reports for the last eleven years, and they were previously grouped into the category "Fuel Fabricating & Reprocessing," see Section IV.A.

III.C.2. Fuel Reprocessing Licenses (Program Code 43110)

Fuel Reprocessing licenses are issued to allow the separation of usable uranium and plutonium from spent nuclear fuel. There is only one licensed commercial facility that has ever reprocessed fuel, and it has been shut down since 1972. However, the licensee was still doing some decontamination work and storing radioactive waste at the facility, and they submitted an annual report covering 100 monitored individuals, 66 of whom received measurable doses. The highest dose was less than one rem, and 91% of the doses were less than 0.50 rem. The collective dose was calculated to be 16 man-rems which yielded an average measurable dose per worker of 0.24 rem. Since no fuel reprocessing is being done, this category is usually included with those of the Fuel Fabricators (see Section IV.A). In February 1982, the Department of Energy assumed possession and control of this reprocessing facility to conduct waste solidification activities necessary for final decommissioning. During the period, the NRC license will, in effect, be suspended, and no reports will be filed with the NRC.

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* Special nuclear materials include plutonium, uranium-233, uranium enriched in the isotopes of uranium-235 or uranium-233, and any material artificially enriched in any of these materials.

III.C.3. Plutonium or Uranium in Other Uses, Including Research and Development Licenses (Program Codes 21130 and 21240)

These licenses are issued to allow the use of enriched uranium and plutonium for purposes such as academic training and in research and development activities associated with nuclear fuel. Annual reports were credited to a total of 21, or 95% of the 22 licenses assigned one of these program codes. Reports for six licenses stated that monitoring was not required and not provided. Seven other reports having two or more license numbers were credited to other program codes, usually Academic or Research and Development. The eight reports indicating that monitoring was done were summed to reveal that 3,124 individuals were monitored, and that 825 workers received measurable doses. While the highest dose was between one and two rems, 99% of the doses were less than 0.50 rem. The collective dose was calculated to be 92 man-rems, to yield an average measurable dose per worker of 0.11 rem, and an average collective dose per license of about four man-rems.

Extrapolation of this data to account for those licensees not reporting indicates that there may be 3,590 individuals being monitored and a collective dose of 100 man-rems being incurred. Respectively, these figures are about eight percent and fifty-five percent less than those derived from the 1978 data. This resulted in a decrease in the average doses.

III.C.4. Unencapsulated SNM Licenses (Program Code 22110)

Unencapsulated Special Nuclear Material (SNM) licenses are usually issued to allow the use of small quantities of unencapsulated SNM for purposes such as biological and chemical testing, for calibration sources, etc. Annual reports were credited to a total of 19 or 90% of the 21 licenses assigned an Unencapculated SNM program code. Reports for seven licenses stated that monitoring was not required and not provided. Nine reports having two or more license numbers were credited to groups having other program codes, such as Well Logging, Research and Development, and Research Reactors. The three remaining reports were summed to find that 190 individuals were monitored, 24 of whom received measurable exposures. The highest dose was between one and two rems, while 96% of the doses were less than 0.50 rem. The collective dose was calculated to be 13 man-rems, to yield an average measurable dose per worker of 0.56 rem. One of these reports, showing monitoring results for 110 individuals was from a firm that fabricates neutron sources, an activity that is atypical of the majority of licensees included in this group. Therefore, the extrapolated number of monitored individuals (210) and collective dose (10 man-rems) may be too high.

III.C.5. Neutron Sources, Power Sources, Uranium Sources, and Other Special Nuclear Material Sources Licenses (Program Codes 22120, 22130, 22200, and 22140)

These licenses are issued to allow the use of various quantities of special nuclear material for a number of purposes, such as heat sources in power generators; sources of neutrons for instrument calibration; teaching and demonstration purposes; and well logging and other industrial applications.

Annual Reports were credited to a total of 260, or 85% of the 305 licenses assigned one of these program codes. Reports for 90 of the licenses stated

that monitoring was not required and not provided, and 121 reports having two or more license numbers were credited to groups having different program codes, usually Academic or Research and Development. The 49 reports indicating that monitoring was done were summed to reveal that 1,159 individuals were monitored, and that 293 of them received measurable doses. The highest dose was between one and two rems, while all but nine of the individuals received doses that were less than 0.50 rem. The collective dose was calculated to be 33 man-rems, which yielded an average measurable dose per worker of 0.12 rem, and an average collective dose per license that was less than one man-rem.

Extrapolation of this data to account for those not reporting indicates that there may have been 1,360 individuals being monitored, and a collective dose of 50 man-rems being incurred. These figures are about 40% less than those found in 1978 which may be partially due to the fact that the number of these types of licensees decreased by about 15%. The average doses remained the same as those reported for 1978.

III.C.6. Institutional Cardiac Pacemaker Licenses (Program Code 22160)

These licenses are issued to medical facilities and physicians to allow the surgical implantation of pacemakers that are powered by a device containing special nuclear material. Very few new nuclear pacemakers are currently being manufactured.

A total of 103, or 57% of the 180 licenses assigned this program code, were credited with submitting an annual report. Reports for 52 licenses stated that monitoring was not required and not provided, and 46 reports were combined with another license number which had a different program code. In nearly every case these reports were credited to one of the Institutional program codes. The five reports indicating that monitoring was done were summed to reveal that 32 individuals were monitored, and that 17 of them received measurable doses. The highest dose was between one and two rems, while 84% of the doses were less than 0.50 rem. The collective dose was calculated to be five man-rems, which yielded an average measurable dose per worker of 0.31 rem, and an average collective dose per license that was less than 1 man-rem.

Extrapolation of this data to account for those not reporting results in 60 monitored individuals and a collective dose of 10 man-rems. These figures are about the same as those found in the 1978 data, however, it is doubtful that any significant doses were received from the SNM pacemakers in either year. Many of the individuals involved with pacemakers are cardiologists who also work with x-ray machines during cardiac catheterization and fluoroscopy procedures. They would receive the majority of their doses from these non-NRC licensed sources of radiation.

III.C.7. Fuel Storage and SNM Storage Only Licenses (Program Codes 23100 and 23200)

These licenses are issued to allow the storage of items containing special nuclear material, such as new or spent reactor fuel elements, and sealed sources not being used. Operating nuclear reactors do not require such a license to store their own fuel.

Annual reports were credited to six of the eight Fuel Storage licenses and six of the eight SNM Storage Only licenses. Five of the twelve reports were combined with those for other license numbers and were credited to other program codes. The two Fuel Storage reports stating that monitoring was done were summed to reveal that 184 individuals were monitored and that 129 of them received measurable doses. The highest dose was between one and two rems, while 88% of the doses were less than 0.50 rem. The collective dose was calculated to be 47 man-rems, which yielded an average measurable dose per worker of 0.36 rem, and an average collective dose per license of about 8 man-rems. Extrapolation of this data to account for those not reporting results in 250 monitored individuals and a collective dose of 60 man-rems. The number of individuals is about 60% larger than the 1978 value, while the collective dose decreased slightly. This resulted in the average measurable dose decreasing to a value less than half of that (0.94 rem) found in 1978.

The data reported by the four SNM Storage Only licensees, which stated that monitoring was provided, is quite different from that of the Fuel Storage licensees. These reports revealed that some 2,873 individuals were monitored, and that only 133 individuals received measurable doses - all of which were less than 0.50 rem. The collective dose was calculated to be seven man-rems which resulted in an average measurable dose of 0.05 rem. One reason for the difference in the doses reported by these licensees may be that some of the employees of the Fuel Storage licensees also assist in the removal and transfer of the fuel which could result in higher doses. Extrapolation of the SNM Storage Only data to account for those not reporting results in 3,830 monitored individuals and a collective dose of 10 man-rems. These figures are much greater than those found in the 1978 data, primarily because one of these facilities reported monitoring an additional 1,400 individuals.

III.C.8. Water Cooled Power Reactor Licenses (Program Code 41111)

These licenses are issued to utilities to allow them to use special nuclear material in a reactor to produce heat to generate electricity to be sold to consumers. There are two types of reactors having this program code - pressurized water reactors and boiling water reactors - each of which uses water as the primary coolant.

Reports were received from all 68 of the commercially operating power reactors. Facilities having more than one licensed reactor at one site submitted one report covering all reactors at that site. They all indicated that monitoring was done and were summed to reveal that a total of 105,174 individuals were monitored, some 64,073 of whom received measurable doses. Other than the accidental overexposures reported by Surry (see Appendix B), the highest dose that an individual received at any one facility was between eight and nine rems, while 80% of the doses were less than 0.50 rem. The collective dose was calculated to be 39,759 man-rems, which yielded an average measurable dose per worker of 0.62 rem, and an average collective dose per reactor of 585 man-rems. See Section IV.A for further analysis of the data reported by power reactors.

III.C.9. Gas Cooled Power Reactor Licenses (Program Code 41120)

These licenses are issued to utilities to allow the use of special nuclear material in a reactor to produce heat to generate electricity to be sold to

consumers. Helium is used as the primary coolant. Fort St. Vrain near Greeley, Colorado, is the only such reactor in operation in the U.S. In 1979 they monitored 1,271 individuals, only 122 of whom received measurable doses, and all of the doses were less than 0.25 rem. Although the utility did not declare the plant to be in commercial operation until July 1979, the following table displays the plant's exposure experience for the six years 1974 through 1979.

TABLE 4
ANNUAL DOSES AT FORT ST. VRAIN
1974-1979

Year	No. of individuals with annual doses in ranges (rems)			Total no. of individuals monitored	Annual collective dose (man-rems)	Gross electrical MW-yrs. generated	Average measurable dose per worker (rems)
	No measurable dose	Measurable <0.10	0.10-0.25				
1974	1,597	63	1	1,661	3.3	0.0	0.05
1975	1,263	0	0	1,263	0.0	0.0	0.00
1976	1,362	25	0	1,387	1.3	2.8	0.05
1977	946	55	1	1,002	2.9	29.8	0.05
1978	896	34	0	930	1.7	75.7	0.05
1979	1,149	120	2	1,271	6.4	16.0	0.05

III.C.10. Test, Research, and Critical Reactor Licenses (Program Codes 42140, 42150, and 42160)

These licenses are issued to allow the use of special nuclear material in various types of reactors for purposes other than to commercially produce electrical power. The majority of them are operated by universities. The test and research reactors are available to perform experiments to study radiation effects, and to produce radionuclides to be used in research and by the radiopharmaceutical industry. Critical reactors are fueled facilities that can achieve criticality so that experiments using various types and configurations of fuel and different moderators can be performed.

A total of 74 licenses, or 93% of the 80 licenses assigned one of these program codes, were credited with submitting an annual report. Three reports stated that monitoring was not provided, and 39 reports having two or more license numbers were credited to other program codes, usually the Academic or the Research and Development program codes. All but one of the 29 reports indicating that personnel monitoring was done were from Research Reactor licensees, and they were summed to reveal that 3,003 individuals were monitored, and that 885 of them received measurable doses. The highest dose was between three and four rems, while 98% of the doses were less than 0.50 rem. The collective dose was calculated to be 147 man-rems, which yielded an average measurable dose per worker of 0.17 rem, and an average collective dose per license of about two man-rems.

Extrapolation of this data to account for those not reporting indicates that there may be 3,240 individuals being monitored and a collective dose of 160 man-rems being incurred. The number of monitored individuals is slightly less than that extrapolated from the 1978 data, but the collective dose is 60 man-rems less. Therefore, the average doses decreased slightly.

IV. FURTHER ANALYSIS OF THE ANNUAL EXPOSURE DATA

IV.A. Annual Exposure Data for Four Categories* of Licensees

This section presents and analyzes the annual exposure data submitted by the four categories of licensees that have been required to report such data since 1968 in a manner similar to that found in previous occupational radiation exposure reports. This should facilitate the comparison of the 1979 data with that of data for other years and the observation of any trends that might exist.

IV.A.1. Composite Annual Dose Distributions

Table 5 is a compilation of the statistical reports submitted by four categories of NRC licensees for calendar year 1979. It shows the number of individuals that incurred a cumulative whole body dose that fell within one of the 18 dose ranges, and the percentage that this number is of the total number monitored. It also shows the collective dose calculated to have been received by these individuals. The table reveals that 40% of the 131,027 individuals monitored during 1979 received exposures that were too small to be detected by personnel radiation monitoring devices and that a small fraction of the individuals incurred doses that exceeded 5 rems. However, these individuals incurred about two percent of the collective dose.

It should be pointed out that very few of the annual exposures that exceed 5 rems are classified as personnel overexposures. Although 1.25 rems is the quarterly limit set forth in paragraph (a) of 10 CFR §20.101, paragraph (b) permits licensees, under certain conditions, to allow a worker to receive a whole body dose of 3 rems per calendar quarter (up to 12 rems annually). The conditions are that (1) the licensee must have determined and recorded the worker's prior accumulated occupational dose to the whole body, and that (2) the worker's whole body dose when added to his accumulated occupational dose does not exceed 5(N-18) rems where "N" equals the individual's age in years. Although there is no annual limit, annual exposures that exceed 12 rems indicate that a whole body exposure in excess of the applicable quarterly limits has occured and should have been reported. A discussion of various types of overexposures that may occur is given in Section VI.

A summary of the annual whole body exposures reported to the Commission by the four categories of NRC licensees required to submit reports during the past ten years is presented in Table 6. About 95% of the exposures have consistently remained less than 2 rems, and the number of individuals receiving an annual dose in excess of 5 rems has decreased from 410 in 1977 to 171 in 1979.

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* Commercial nuclear power reactors; industrial radiographers; fuel processors, fabricators and reprocessors; manufacturers and distributors of specified quantities of byproduct material.

TABLE 5

DISTRIBUTION OF ANNUAL WHOLE BODY DOSE BY LICENSE CATEGORY

1979

LICENSE CATEGORY	Whole body dose ranges (rems)																		
	No measurable exposure	Measurable <0.10	0.10-0.25	0.25-0.50	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	10.0-11.0	11.0-12.0	>12.0	Totals
*POWER REACTORS (LWRs)																			
No. of Individuals	41,101	24,301	9,846	8,159	5,189	3,479	7,934	3,307	1,251	477	86	28	13	2	0	0	1		105,174
**Percent in range	39%	23%	9%	8%	5%	3%	8%	3%	1%										
No. of man-rems	0	1,215	1,723	3,060	3,243	3,044	11,901	8,268	4,378	2,147	473	182	97	17			11		39,759
**Percent in range	0%	3%	4%	8%	8%	8%	30%	21%	11%	5%	1%								
RADIOGRAPHY																			
No. of Individuals	5,065	2,789	1,314	926	548	361	598	218	92	34	11	6	3	1	0	1	1	1	11,969
**Percent in range	42%	23%	11%	8%	5%	3%	5%	2%	1%										
No. of man-rems	0	139	230	347	343	316	897	545	322	153	60	39	23	9	0	11	11	17	3,462
**Percent in range	0%	4%	7%	10%	10%	9%	26%	16%	9%	4%	2%	1%	1%						
FUEL FABRICATION & REPROCESSING																			
No. of Individuals	4,581	2,874	1,146	655	317	191	147	30	5										9,946
**Percent in range	46%	29%	12%	7%	3%	2%	1%												
No. of man-rems	0	144	201	246	198	167	220	75	17										1,268
**Percent in range	0%	11%	16%	19%	16%	13%	17%	6%	1%										
***MANUFACTURING & DISTRIBUTION																			
No. of Individuals	1,719	1,118	556	206	80	58	91	37	27	29	8	9							3,938
**Percent in range	44%	28%	14%	5%	2%	1%	2%	1%	1%	1%									
No. of man-rems	0	56	97	77	50	51	137	93	94	131	44	58							888
**Percent in range	0%	6%	11%	9%	6%	6%	15%	11%	11%	15%	5%	6%							
TOTALS																			
No. of Individuals	52,466	31,082	12,862	9,946	6,134	4,089	8,770	3,592	1,375	540	105	43	16	3	0	1	2	1	131,027
**Percent in range	40%	24%	10%	8%	5%	3%	7%	3%	1%										
No. of man-rems	0	1,554	2,251	3,730	3,834	3,578	13,155	8,981	4,811	2,431	577	279	120	26	0	11	22	17	45,377
**Percent in range	0%	3%	5%	8%	8%	8%	29%	20%	11%	5%	1%	1%							

*Includes all reactors that reported although all of them may not have been in commercial operation for a full year.

**The ranges in which the percentage of individuals or of collective dose are not shown have less than 0.5% in the range.

***A subset of "Marketing" that includes the 28 licensees meeting the criteria in 20.408 that have previously been required to report.

TABLE 6

SUMMARY OF ANNUAL WHOLE BODY EXPOSURES
FOR FOUR CATEGORIES OF LICENSEES

1968–1979

Year	Total Number Individuals Monitored	Percent of Individuals With Doses < 2 Rems	Percent of Individuals With Doses > 5 Rems	Number of Individuals With Doses > 12 Rems
1968	36,836	97.2%	0.5%	3
1969	31,176	96.5%	0.5%	7
1970	36,164	96.1%	0.6%	0
1971	36,311	95.3%	0.7%	1
1972	44,690	95.7%	0.5%	8
1973	67,862	95.0%	0.5%	1
1974	85,097	96.4%	0.3%	1
1975	78,713	94.8%	0.5%	1
1976	92,773	95.0%	0.4%	3
1977	98,212	94.5%	0.3%	1
1978	105,893	95.2%	0.1%	3
1979	131,027	95.7%	0.1%	1

Table 7 summarizes the annual exposure data reported by four categories of licensees for the years 1973 through 1979. Primarily reflecting the growth in the number of workers employed at the increasing number of nuclear power facilities, the total number of individuals monitored by the four categories increased to a seven-year high of 131,027, as did the number receiving a measurable exposure which increased to 78,561. The total collective dose also increased significantly from last year's value, but the average individual dose remained at 0.35 rem and the average measurable dose decreased slightly to 0.58 rem.

Table 8, which lists the program codes in descending order of the extrapolated collective dose, shows that nuclear reactors, one of the program codes in this group, reported a collective dose that was at least six times that of any other single program code. This resulted in the power reactors having the highest average measurable and individual doses, as can be seen in Table 9.

Since personnel monitoring data has frequently been found to have log-normal distributions [Ref. 3], trends in data reported by these four categories of licensees during the years 1973 through 1979 might be more easily observed from log-probability plots of the data. If the data are log-normally distributed, the data points should form a straight line when plotted on log-probability paper on which cumulative probabilities are laid off on the vertical axis at distances proportional to the corresponding number of standard deviations above or below the median, and the dose is plotted on the horizontal axis which has a logarithmic scale. Distributions in which there are annual doses that exceed 2 rems frequently depart from a straight line because of the licensees' efforts to meet various recommendations and limits.

Figure 1 displays log-probability plots of the data reported by four categories (summed to form a single group) of NRC licensees for each of the years 1974 through 1979. One can see that with the exception of the higher percentage of doses less than 2 rems in 1974, and the smaller percentage of doses greater than 4 rems in 1978 and 1979 (shown by a shift upward of the curves), the distribution of doses changed very little. Also, shown at the bottom of Figure 1 are the values of CR which is defined to be the ratio of the annual collective dose delivered at doses exceeding 1.5 rems per year to the total annual collective dose. This is one of the parameters that the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) recommended to be shown for occupational dose distributions to aid in the comparison of exposure data. The draft of the latest UNSCEAR report [Ref. 3] states that normal values of CR lie between 0.05 and 0.50.

The values of CR are shown for each of the years 1974 through 1979, and one can see that CR was smallest in 1979, indicating that the portion of the collective dose due to doses greater than 1.5 rems has continued to decrease. It should also be noted that a change in the value of CR does not necessarily imply a comparable change in the average individual dose or in the total collective dose. All of these parameters should be examined in order to study trends in occupational exposure, and they will all be shown at the bottom of each log-probability plot.

TABLE 7

ANNUAL EXPOSURE DATA FOR FOUR CATEGORIES OF LICENSEES

1973 - 1979

LICENSE CATEGORY	Calendar year	Number of licensees reporting	Total no. individuals monitored	No. individuals with measurable exposure	Total collective dose man-rems	Average dose (rems) per individual (based on total monitored)	Average dose (rems) per worker (based on measurable exposure)	Collective dose per license, man-rems	CR**
* Commercial Light Water Reactors	1979	69	105,174	64,073	39,759	0.38	0.62	576	0.54
	1978	68	77,523	47,245	31,910	0.41	0.67	462	0.58
	1977	65	71,904	44,233	32,731	0.46	0.74	504	0.61
	1976	62	66,800	36,715	26,555	0.40	0.72	428	0.62
	1975	54	54,763	28,034	21,270	0.39	0.76	394	0.64
	1974	53	62,044	21,904	14,083	0.23	0.64	266	0.62
	1973	41	44,795	16,558	14,337	0.32	0.87	350	
Industrial Radiography	1979	341	11,969	6,904	3,461	0.29	0.50	10	0.47
	1978	337	13,093	6,685	2,950	0.23	0.44	9	0.43
	1977	339	10,569	6,197	3,159	0.30	0.51	9	0.45
	1976	321	11,245	6,222	3,629	0.32	0.58	11	0.51
	1975	291	9,178	4,693	2,796	0.30	0.60	10	0.53
	1974	319	8,792	4,943	2,938	0.33	0.59	9	0.51
	1973	341	8,206	5,328	3,354	0.41	0.63	10	
Fuel Fabrication and Reprocessing	1979	21	9,946	5,365	1,268	0.13	0.24	60	0.16
	1978	20	11,305	6,100	1,525	0.13	0.25	76	0.24
	1977	21	11,496	7,004	1,725	0.15	0.25	82	0.34
	1976	24	11,227	5,285	1,830	0.16	0.35	76	0.41
	1975	24	11,614	5,602	3,175	0.27	0.57	132	0.54
	1974	26	11,064	4,728	2,836	0.26	0.60	109	0.61
	1973	27	10,610	5,056	2,400	0.23	0.47	89	
Manufacturing and Distribution	1979	28	3,937	2,219	888	0.23	0.40	32	0.55
	1978	27	3,973	1,886	851	0.21	0.45	32	0.61
	1977	30	4,243	2,459	1,329	0.31	0.54	44	0.63
	1976	24	3,501	1,976	1,226	0.35	0.62	51	0.67
	1975	19	3,367	1,859	1,188	0.35	0.64	63	0.64
	1974	24	3,340	1,827	1,050	0.31	0.57	44	0.63
	1973	34	4,251	1,925	1,177	0.28	0.61	35	
Grand Totals and Averages	1979	459	131,027	78,561	45,376	0.35	0.58	100	0.52
	1978	453	105,894	61,916	37,236	0.35	0.60	82	0.56
	1977	455	98,212	59,893	38,944	0.40	0.65	86	0.59
	1976	428	92,773	50,198	33,240	0.36	0.66	78	0.60
	1975	388	78,922	40,188	28,429	0.36	0.71	73	0.62
	1974	422	85,240	33,402	20,907	0.25	0.63	50	0.60
	1973	443	67,862	28,867	21,268	0.31	0.74	48	

* Includes all LWRs that reported, although all of them may not have been in commercial operation for a full year.

** CR is the ratio of the annual collective dose delivered at annual doses exceeding 1.5 rems to the total annual collective dose. (See Section IV.A.1.)

TABLE 8

LICENSE PROGRAM CODE IN DESCENDING ORDER OF EXTRAPOLATED COLLECTIVE DOSE

1979

License Category and (Program Code)		Extrapolated Collective dose, man-rems	Collective Dose per License, man-rems
1. Light Water Power Reactors	(41111)	39,759	576
2. Institutional-Other	(02120)	6,880	4
3. Well Logging	(03110)	3,960	46
4. Radiography-Multiple Loc.	(03320)	3,510	16
5. Institutional-Broad	(02110)	1,740	17
6. Manuf. & Dist.-Broad	(03211)	836	60
7. Other Measuring Systems	(03120)	790	<1
8. Academic-Broad	(01100)	790	12
9. UF_6 Convrsn. Fuel Fab. & Scrap Recovery	(21210)	605	121
10. Uranium Mills	(11100)	430	16
11. Uranium Fuel Fabrication	(21230)	419	60
12. *Marketing-Broad	(03211)	410	17
13. Teletherapy	(02300)	340	1
14. Academic-Other	(01200)	330	1
15. Res. & Dev. - Other	(03620)	300	<1
16. Res. & Dev. - Broad	(03610)	280	3
17. Radiography-Single Loc.	(03310)	250	2
18. *Marketing-Other	(03212)	240	2
19. Private Practice	(02200)	210	1
20. Other Uranium ≥150 Kg.	(11300)	210	1
21. Plutonium Fuel Fabrication	(21120)	192	96
22. Research Reactors	(42150)	160	2
23. Civil Defense	(03710)	150	1
24. UF_6 Production Plants	(11400)	134	67
25. Waste Disposal-Other	(03232)	130	9
26. Irradiator, <10,000 Ci	(03510)	80	<1
27. Fuel Storage	(23100)	60	8
28. Plutonium-Other Uses	(21130)	60	10
29. Manuf. & Dist-Other	(03212)	52	4
30. Uranium-Other Uses	(21240)	42	3
31. Irradiator, ≥10,000 Ci	(03520)	40	1
32. Medical Distribution	(02500)	40	1
33. Plutonium Fuel Fab. & Scrap Recovery	(21110)	24	8
34. Neutron Sources	(22120)	30	<1
35. Other Medical	(02400)	20	<1
36. Leak Test	(03220)	20	1
37. Fuel Reprocessing	(43110)	16	16
38. Uranium Fuel Fab. & Scrap Recovery	(21220)	12	4
39. Unencapsulated SNM	(22110)	10	<1
40. Instit. Cardiac Pacemaker	(22160)	10	<1
41. Uranium Sources	(22200)	10	<1
42. Waste Disposal-Burial	(03231)	10	5
43. Other SNM Sources	(22140)	10	<1
44. SNM Storage, Only	(23200)	10	1
45. Gas Cooled Power Reactors	(41120)	6	6
46. Nuclear Laundry	(03218)	5	1
47. Other Uranium <150 Kg.	(11200)	10	<1
48. Critical Exper. Facilities	(42160)	<10	<1
49. Power Sources	(03400)	<1	<1
50. Uranium Solution Mines	(11500)	0	0
51. Power Sources	(22130)	No Data	No Data
52. Pacemakers, Instit.	(02600)	No Data	No Data
53. Test Reactors	(42140)	No Data	No Data

* Excluding the subset "Manufacturing & Distribution."

TABLE 9

LICENSE PROGRAM CODE IN DESCENDING ORDER OF AVERAGE MEASURABLE DOSE

1979

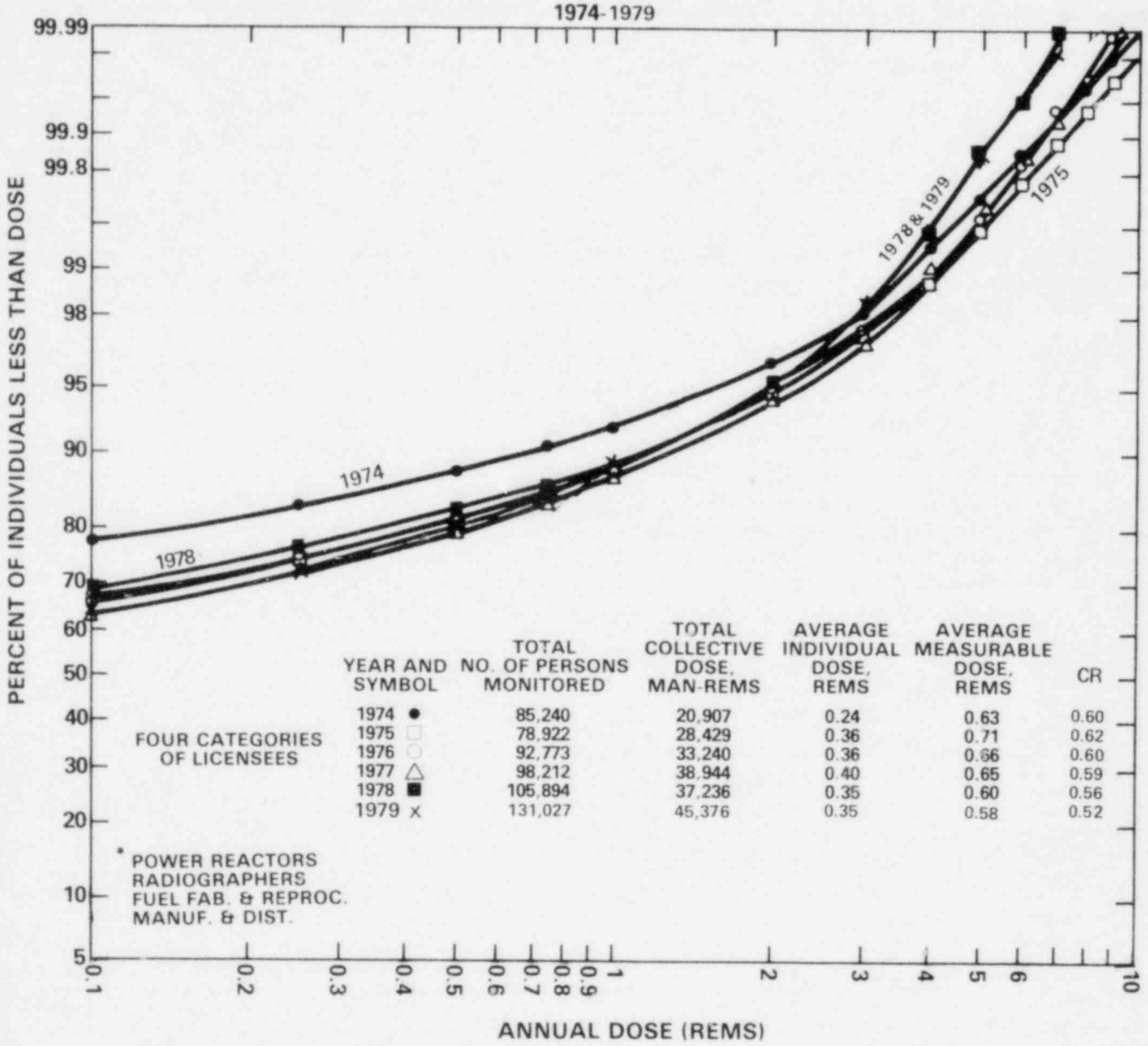
License Category and (Program Code)		Average Measurable Dose, rems	Average Individual Dose, rems	Ratio** CR
1. Light Water Power Reactors	(41111)	0.62	0.38	0.54
2. Irradiator, ≥10,000 Ci	(03520)	0.56	0.11	0.74
3. Unencapsulated SNM	(22110)	0.56	0.07	0.39
4. Radiography-Multiple Loc.	(03320)	0.54	0.32	0.48
5. Manuf. & Distrib. - Broad	(03211)	0.44	0.27	0.56
6. Well Logging	(03110)	0.42	0.35	0.31
7. Waste Disposal-Other	(03232)	0.42	0.21	0.56
8. Plutonium Fuel Fab.	(21120)	0.40	0.16	0.38
9. Fuel Storage	(23100)	0.36	0.26	0.13
10. *Marketing-Broad	(03211)	0.33	0.12	0.44
11. Waste Disposal-Burial	(03231)	0.33	0.29	0.24
12. Inst. Cardiac Pacemaker	(22160)	0.31	0.16	0.14
13. UF_6 Convrsn. Fuel Fab & Scrap Recovery	(21210)	0.29	0.18	0.08
14. Radiography-Single Loc.	(03310)	0.27	0.12	0.32
15. Uranium Mills	(11100)	0.27	0.19	0.12
16. Nuclear Laundry	(03218)	0.26	0.13	0.14
17. UF_6 Production Plants	(11400)	0.26	0.20	0.06
18. Institutional-Other	(02120)	0.25	0.16	0.24
19. Other Uranium >150 Kg.	(11300)	0.25	0.12	0.13
20. Uranium Sources	(22200)	0.25	0.07	0.16
21. Fuel Reprocessing	(43110)	0.24	0.16	0.00
22. Private Practice	(02200)	0.20	0.10	0.14
23. Teletherapy	(02300)	0.19	0.12	0.15
24. Medical Distribution	(02500)	0.18	0.11	0.09
25. Uranium Fuel Fab.	(21230)	0.18	0.10	0.19
26. Manuf. & Distrib.-Other	(03212)	0.17	0.06	0.34
27. Research Reactors	(42150)	0.17	0.04	0.33
28. Institutional-Broad	(02110)	0.14	0.07	0.14
29. Uranium-Other Uses	(21240)	0.15	0.05	0.11
30. Res. & Dev.-Other	(03620)	0.14	0.03	0.45
31. Leak Test	(03220)	0.13	0.07	0.14
32. *Marketing-Other	(03212)	0.12	0.04	0.17
33. Academic-Broad	(01100)	0.12	0.04	0.13
34. Irradiator, <10,000 Ci	(03510)	0.12	0.04	0.12
35. Other Uranium <150 Kg.	(11200)	0.12	0.03	0.00
36. Neutron Sources	(22120)	0.11	0.00	0.17
37. Plutonium Fuel Fab. & Scrap Recovery	(21110)	0.11	0.04	0.09
38. Other Measuring Systems	(03120)	0.10	0.04	0.12
39. Academic-Other	(01200)	0.10	0.03	0.08
40. Uranium Fuel Fab. & Scrap Recovery	(21220)	0.10	0.06	0.00
41. Other SNM Sources	(22140)	0.09	0.03	0.00
42. Plutonium-Other Uses	(21130)	0.09	0.02	0.00
43. Res. & Dev.-Broad	(03610)	0.09	0.02	0.13
44. Other Medical	(02400)	0.07	0.02	0.00
45. Civil Defense	(03710)	0.05	0.04	0.00
46. Gas Cooled Power Reactors	(41120)	0.05	0.00	0.00
47. SNM Storage, Only	(23200)	0.05	0.00	0.00
48. Power Sources (Byproduct)	(03400)	0.05	0.01	0.00
49. Critical Exper. Facilities	(42160)	0.05	0.03	0.00
50. Uranium Solution Mines	(11500)	No monitoring required		
51. Power Sources (SNM)	(22130)	No data for this program code		
52. Pacemakers, Instit.	(02600)	No data for this program code		
53. Test Reactors	(42140)	No data for this program code		

* Excluding the subset "Manufacturing & Distribution."

** The ratio of the fraction of the collective dose due to annual doses greater than 1.5 rems in the observed distribution to fraction of the UNSCEAR reference distribution.

Figure 1

Annual Dose Distributions for
Four Categories of Licensees*
1974-1979



YEAR AND SYMBOL	TOTAL NO. OF PERSONS MONITORED	TOTAL COLLECTIVE DOSE, MAN-REMS	AVERAGE INDIVIDUAL DOSE, REMS	AVERAGE MEASURABLE DOSE, REMS	CR
FOUR CATEGORIES OF LICENSEES					
1974 ●	85,240	20,907	0.24	0.63	0.60
1975 □	78,922	28,429	0.36	0.71	0.62
1976 ○	92,773	33,240	0.36	0.66	0.60
1977 △	98,212	38,944	0.40	0.65	0.59
1978 ■	105,894	37,236	0.35	0.60	0.56
1979 X	131,027	45,376	0.35	0.58	0.52

* POWER REACTORS
RADIOGRAPHERS
FUEL FAB. & REPROC.
MANUF. & DIST.

IV.A.2. Annual Dose Distributions for Commercial Power Reactors

Figure 2 presents log-probability plots of the annual dose distribution reported by nuclear power facilities for each of the years 1974 through 1979. Since the number of individuals monitored by these facilities comprise some 80% of the total number of monitored individuals reported by the four categories of licensees shown in Figure 1, the curves look very similar to those in that figure. The average individual doses are slightly higher, as are the values of CR, indicating that a large percentage of the cumulative dose incurred by power reactor workers was due to doses exceeding 1.5 rems than was that of the group of four categories of licensees. The values of CR range from 0.64 in 1975 to 0.54 in 1979, exhibiting a trend toward a smaller percentage of individuals receiving higher doses, especially in thos exceeding 4 rems. This may be the result of increased regulatory efforts to ensure that personnel exposure are kept "as low as reasonably achievable" (ALARA). However, the increasing number of individuals monitored by nuclear power facilities results in this category of NRC licensees having the largest collective dose, as was seen in Table 8.

Table 10 presents a summary of the annual exposure and production data that have been reported by the two types of U.S. commercial nuclear power facilities, PWRs and BWRs for the years 1973 through 1979. It can be seen that there was a considerable increase in the number of workers receiving measurable doses and in the collective dose between 1978 and 1979. The gross electrical energy generated remained about the same such that the collective dose per megawatt-year of electricity generated rose from a value of 1.0 in 1978 to that of 1.3 in 1979. The value of this parameter has been greater for BWRs than PWRs for the last six years, as has the number of workers monitored per reactor, the collective dose per reactor, and the average measurable dose per worker. Figure 3 graphically displays annual data reported by BWRs and PWRs. A more detailed presentation and analysis of the annual exposure information reported by nuclear power reactors can be found in NUREG-0713, Vol. 1, "Occupational Radiation Exposure at Commercial Nuclear Power Reactors, 1979."

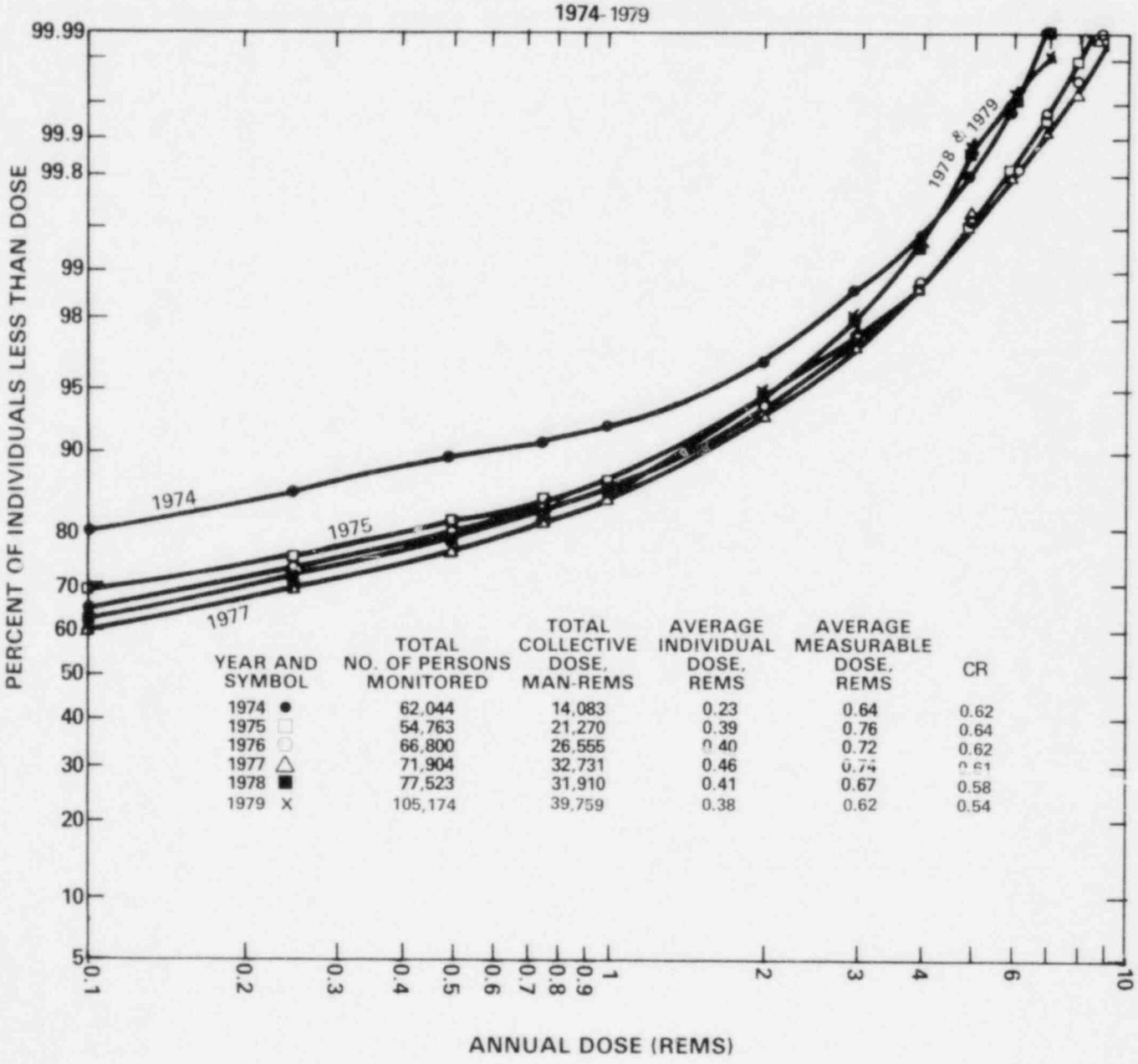
IV.A.3. Annual Dose Distributions for Industrial Radiographers

Figure 4 presents log-probability plots of the annual dose distributions reported by NRC-licensed industrial radiography firms for each of the years 1974 thourgh 1979. The plot for 1979 has shifted down from that of the plot for 1978, indicating more individuals with doses in the higher ranges, and reflecting a large value of CR (0.47) from that found in 1978 (0.43). The average measurable dose per person also increased from 0.44 rem to 0.50 rem.

Figure 5 presents log-probability plots of the annual dose distributions reported by the two types of radiography licensees: those licensed to perform radiography at a single location, in plant; and those licensed to perform radiography at multiple locations, in the field. One can see that a larger percentage of the individuals monitored by the second type continued to receive higher doses than those monitored by the first. This is reflected in the higher values of the average doses and of CR for the multiple location licensees and the shift downward in the 1979 plot of these licensees. As was seen in Table 9, the multiple location radiography licensees had the fourth highest average measurable dose of the 53 types of NRC licensees.

Figure 2

Annual Dose Distributions of
Commercial Power Reactors
1974-1979



YEAR AND SYMBOL	TOTAL NO. OF PERSONS MONITORED	TOTAL COLLECTIVE DOSE, MAN-REMS	AVERAGE INDIVIDUAL DOSE, REMS	AVERAGE MEASURABLE DOSE, REMS	CR
1974 ●	62,044	14,083	0.23	0.64	0.62
1975 □	54,763	21,270	0.39	0.76	0.64
1976 ○	66,800	26,555	0.40	0.72	0.62
1977 △	71,904	32,731	0.46	0.74	0.61
1978 ■	77,523	31,910	0.41	0.67	0.58
1979 X	105,174	39,759	0.38	0.62	0.54

TABLE 10*

SUMMARY OF ANNUAL EXPOSURES REPORTED BY NUCLEAR POWER FACILITIES

1973 - 1979

Year	Reactor Type	Number of Reactors Included	Total Number of Man-Rems	No. of Workers With Measurable Doses	Total Megawatt-Yrs. Generated	Average Annual Dose (Rems/Worker)	Average No. of Man-Rems Per Reactor	Average No. of Workers Per Reactor	Man-Rems Per Megawatt-Yr.
1973	PWR	12	9,399	9,440	3,770	1.00	783	787	2.5
	BWR	12	4,564	5,340	3,394	0.85	380	445	1.3
	Total	24	13,963	14,780	7,164	0.94	582	616	1.9
1974	PWR	20	6,627	9,697	6,824	0.68	331	485	1.0
	BWR	14	7,095	8,769	4,059	0.81	507	626	1.7
	Total	34	13,722	18,466	10,883	0.74	404	543	1.3
1975	PWR	26	8,268	10,884	11,983	0.76	318	419	0.7
	BWR	18	12,611	14,607	5,786	0.86	701	812	2.2
	Total	44	20,879	25,491	17,769	0.82	475	579	1.2
1976	PWR	30	13,807	17,588	13,325	0.79	460	586	1.0
	BWR	23	12,626	17,859	8,586	0.71	549	776	1.5
	Total	53	26,433	35,447	21,911	0.75	499	669	1.2
1977	PWR	34	13,469	20,878	17,346	0.65	396	614	0.8
	BWR	23	19,042	21,388	9,098	0.89	828	930	2.1
	Total	57	32,511	42,266	26,444	0.77	570	742	1.2
1978	PWR	39	16,713	25,720	19,840	0.65	429	659	0.8
	BWR	25	15,096	20,278	11,774	0.74	604	811	1.3
	Total	64	31,809	45,998	31,614	0.69	497	719	1.0
1979	PWR	42	21,437	38,828	18,249	0.55	510	924	1.2
	BWR	25	18,322	25,245	11,671	0.73	733	1,010	1.6
	Total	67	39,759	64,073	29,920	0.62	593	956	1.3

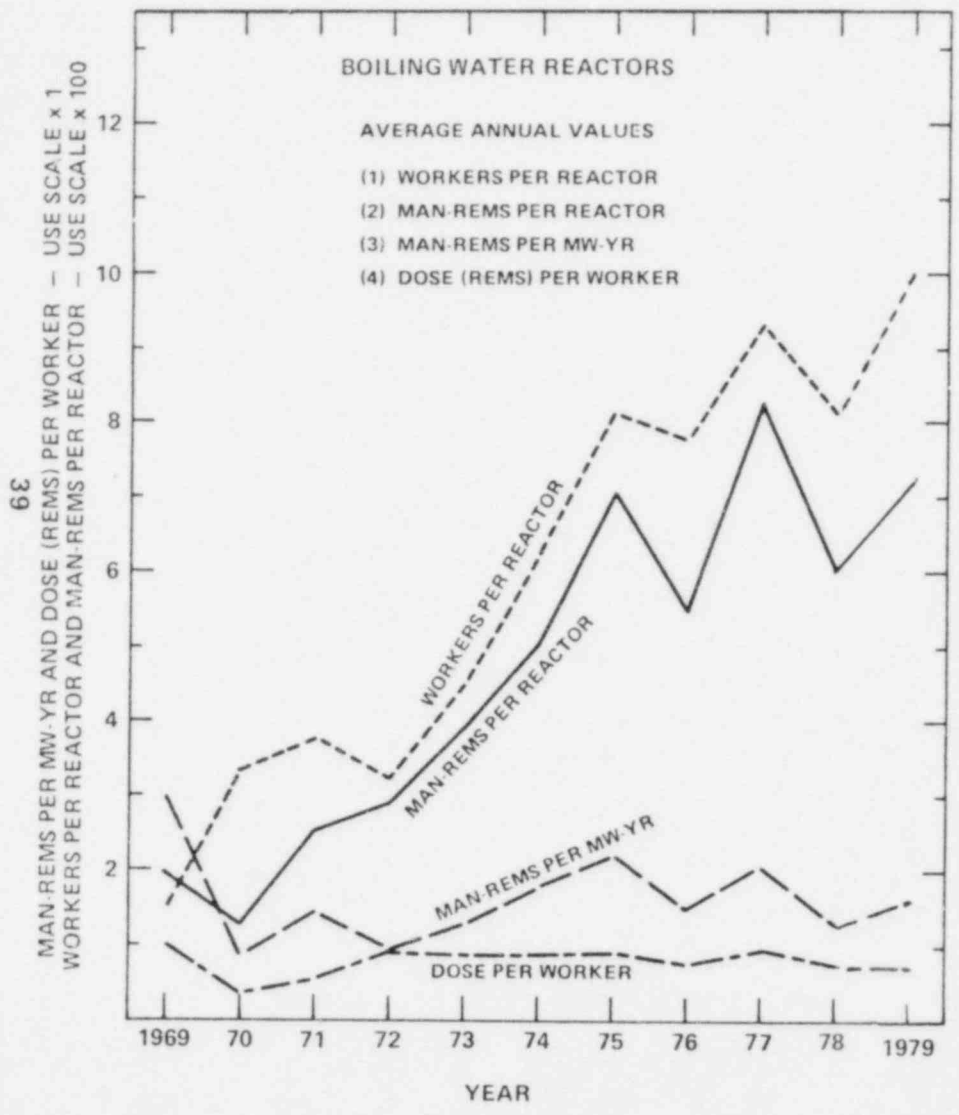
*The figures on this table are based on the number of nuclear power reactors that had been in commercial operation for at least one year as of December 31 of each of the years indicated.

FIGURE 3

PLOTS OF AVERAGE ANNUAL VALUES

AT BOILING AND PRESSURIZED WATER REACTORS

1969 - 1979



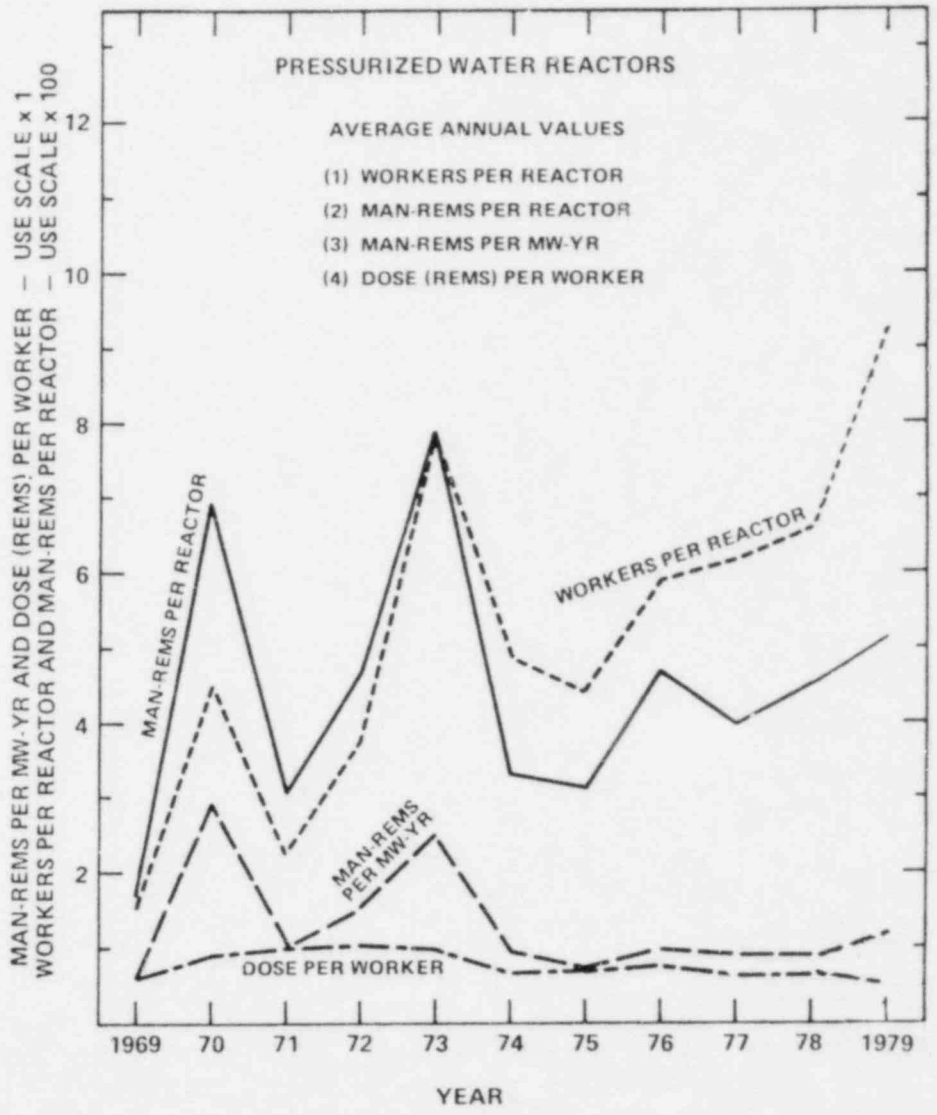
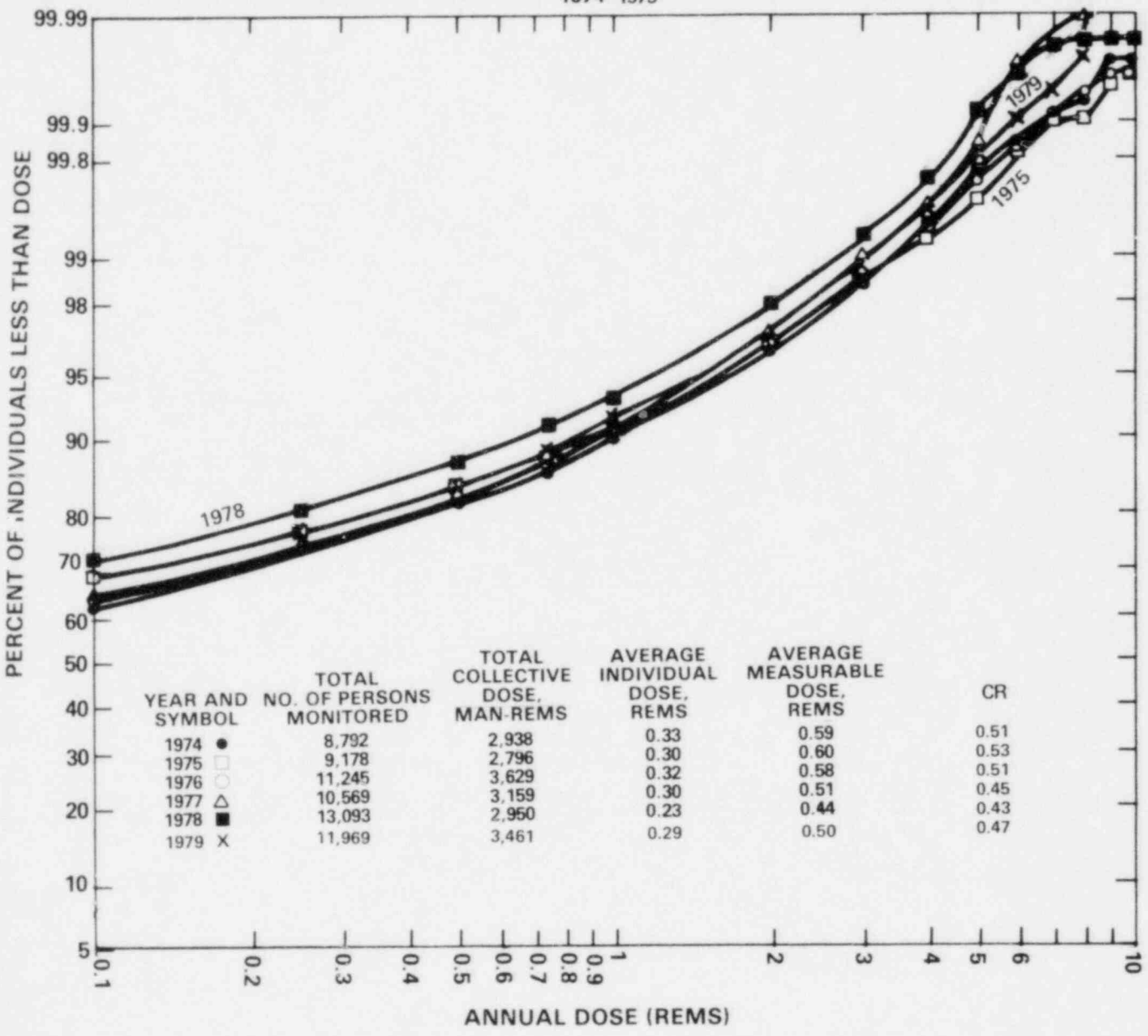


Figure 4

Annual Dose Distributions of
Industrial Radiographers

1974- 1979

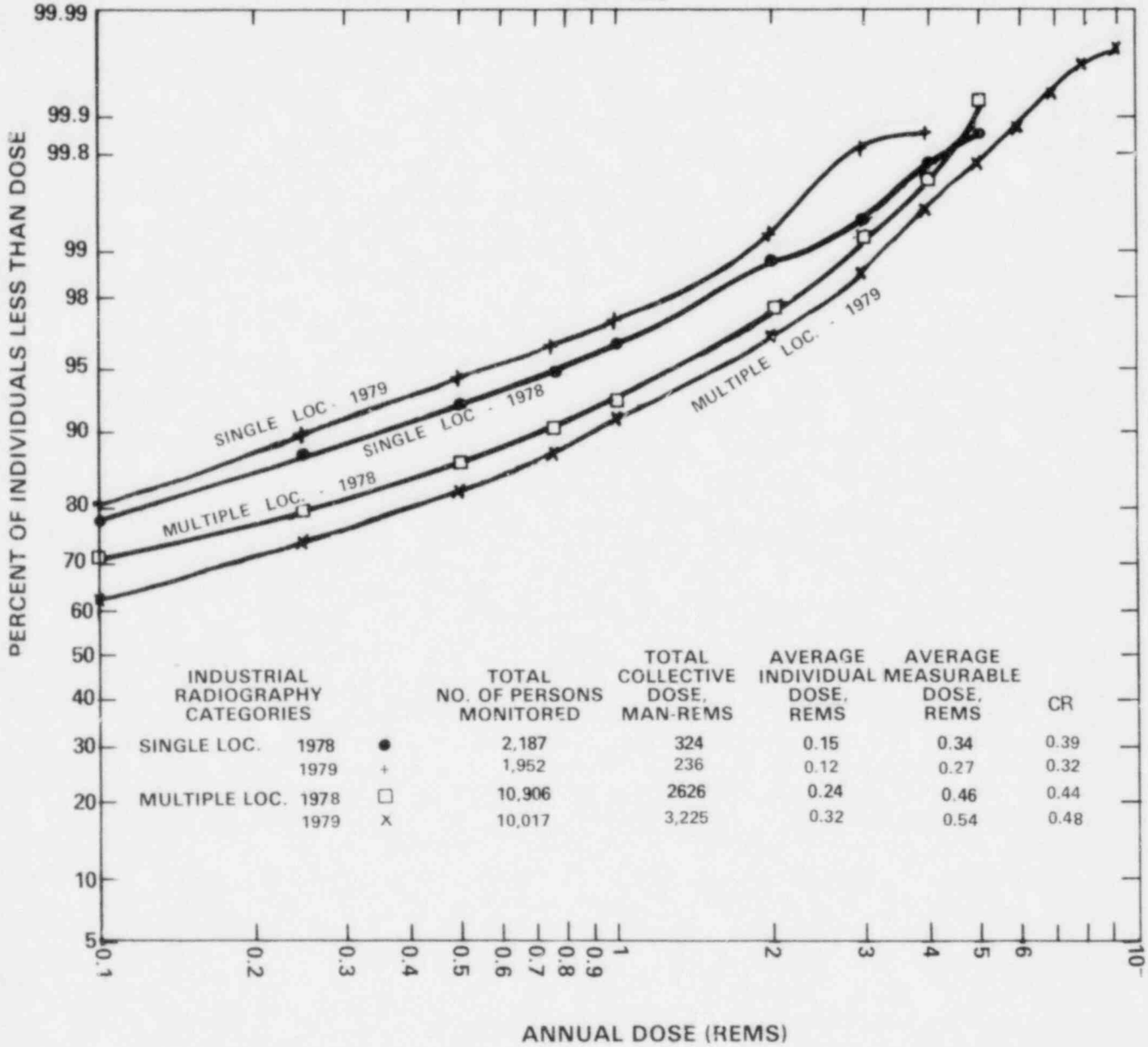


YEAR AND SYMBOL	TOTAL NO. OF PERSONS MONITORED	TOTAL COLLECTIVE DOSE, MAN-REMS	AVERAGE INDIVIDUAL DOSE, REMS	AVERAGE MEASURABLE DOSE, REMS	CR
1974 ●	8,792	2,938	0.33	0.59	0.51
1975 □	9,178	2,796	0.30	0.60	0.53
1976 ○	11,245	3,629	0.32	0.58	0.51
1977 △	10,569	3,159	0.30	0.51	0.45
1978 ■	13,093	2,950	0.23	0.44	0.43
1979 X	11,969	3,461	0.29	0.50	0.47

Figure 5

Annual Dose Distributions of Two Types of Industrial Radiography Licensees

1974-1979



INDUSTRIAL RADIOGRAPHY CATEGORIES			TOTAL NO. OF PERSONS MONITORED	TOTAL COLLECTIVE DOSE, MAN-REMS	AVERAGE INDIVIDUAL DOSE, REMS	AVERAGE MEASURABLE DOSE, REMS	CR
SINGLE LOC.	1978	●	2,187	324	0.15	0.34	0.39
	1979	+	1,952	236	0.12	0.27	0.32
MULTIPLE LOC.	1978	□	10,906	2626	0.24	0.46	0.44
	1979	X	10,017	3,225	0.32	0.54	0.48

In looking at the average doses, one should bear in mind that licensees may elect to monitor individuals other than those directly associated with radiographic activities and the handling of the radioactive material. In this case, the number of individuals reported will be greater than the number of persons actually conducting radiography, and the average dose will be less than that likely to be incurred by a full-time radiographer [Ref. 4]. In an attempt to determine the magnitude of this problem, a report, "An Economic Study of the Radionuclides Industry" [Ref. 2], was examined. Based on a survey of certain NRC and Agreement State licensees, this report estimated that there were a total of 4,500 monitored individuals directly associated with the production of radiographs using radioactive material in the U.S. during 1978, and those individuals contributed 3,400 person-years of work in this field. Since about half of the States are Agreement States and would have licensed the material rather than the NRC, these figures have been divided in half to obtain a rough estimate of the number of radiographers using NRC-licensed material. Dividing the collective dose, 2,950 man-rems calculated from the NRC licensees' annual reports, by this estimated number of radiographers (2,350), one obtains an average dose per radiographer of 1.3 rems. The number of man-years of work contributed by these radiographers could similarly be estimated to be 1,700 man-years, and the division of the collective dose by this number would yield 1.7 rems as the average dose that would have been received by a radiographer working full-time during 1978. These averages are 3 and 4 times that of the average measurable dose (0.44 rem), developed from the information reported by the NRC licensees in 1978. One should realize that NRC licensees may monitor and report everyone remotely associated with the licensed material, such as secretaries, security personnel, visitors, repairmen, janitors, etc., that may have been exposed for a few minutes or a year. It should not be assumed that the average developed from this data is for a homogeneous population directly involved in one particular activity for the entire year.

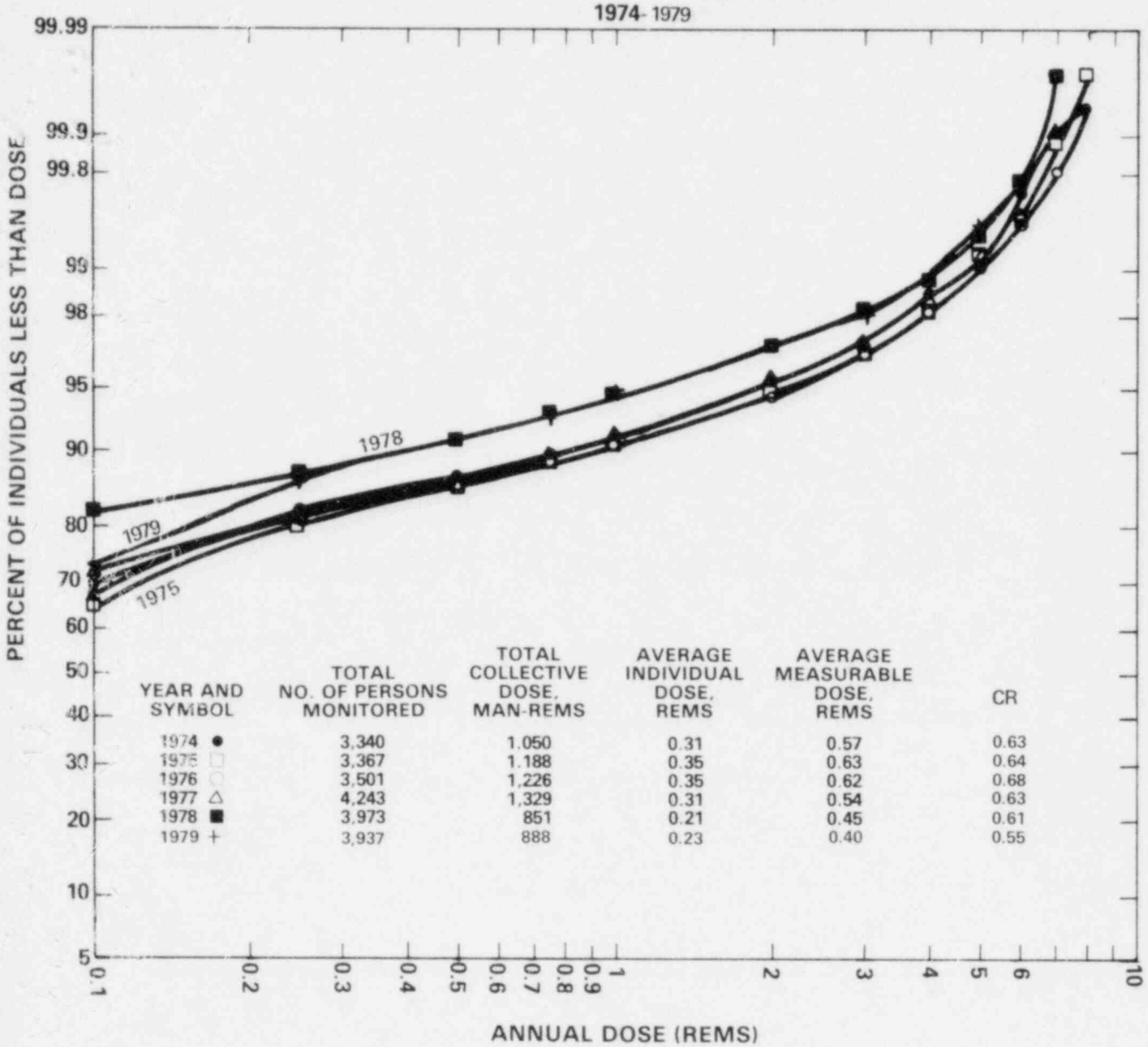
IV.A.4. Annual Dose Distributions for Manufacturers and Distributors

Figure 6 presents log-probability plots of the annual dose distributions reported by Manufacturers and Distributors, a subset of NRC's Marketing licensees. One can see a definite decrease in the collective dose in 1978 and 1979 from that of previous years, and the average measurable dose declined to 0.40 rems in 1979. The value of CR also fell to a low of 0.55 in 1979, but it is still larger than that of the other three categories in this group of four, as it has been since 1973.

As is the case with the Marketing category, this subset is comprised of two types of Manufacturing and Distribution licensees - those issued Broad licenses and those issued Other licenses. The dose distributions reported by these two types, 14 licensees of each, are plotted in Figure 7. One can see that the values of all of the parameters are usually higher for the Broad licensees. One reason might be that the Broad licenses allow the possession of much larger quantities of materials. Fifty-six percent of the collective dose was incurred by workers whose annual doses exceeded 1.5 rems (CR = 0.56), which makes this category have the third highest value of CR. Also, as shown in Table 10, this group was also one of five types of NRC licensees having an average measurable dose in excess of 0.40 rems. This is an improvement over 1978, however, when the average measurable dose for this category was 0.51 rems and the value of CR was 0.64.

Figure 6

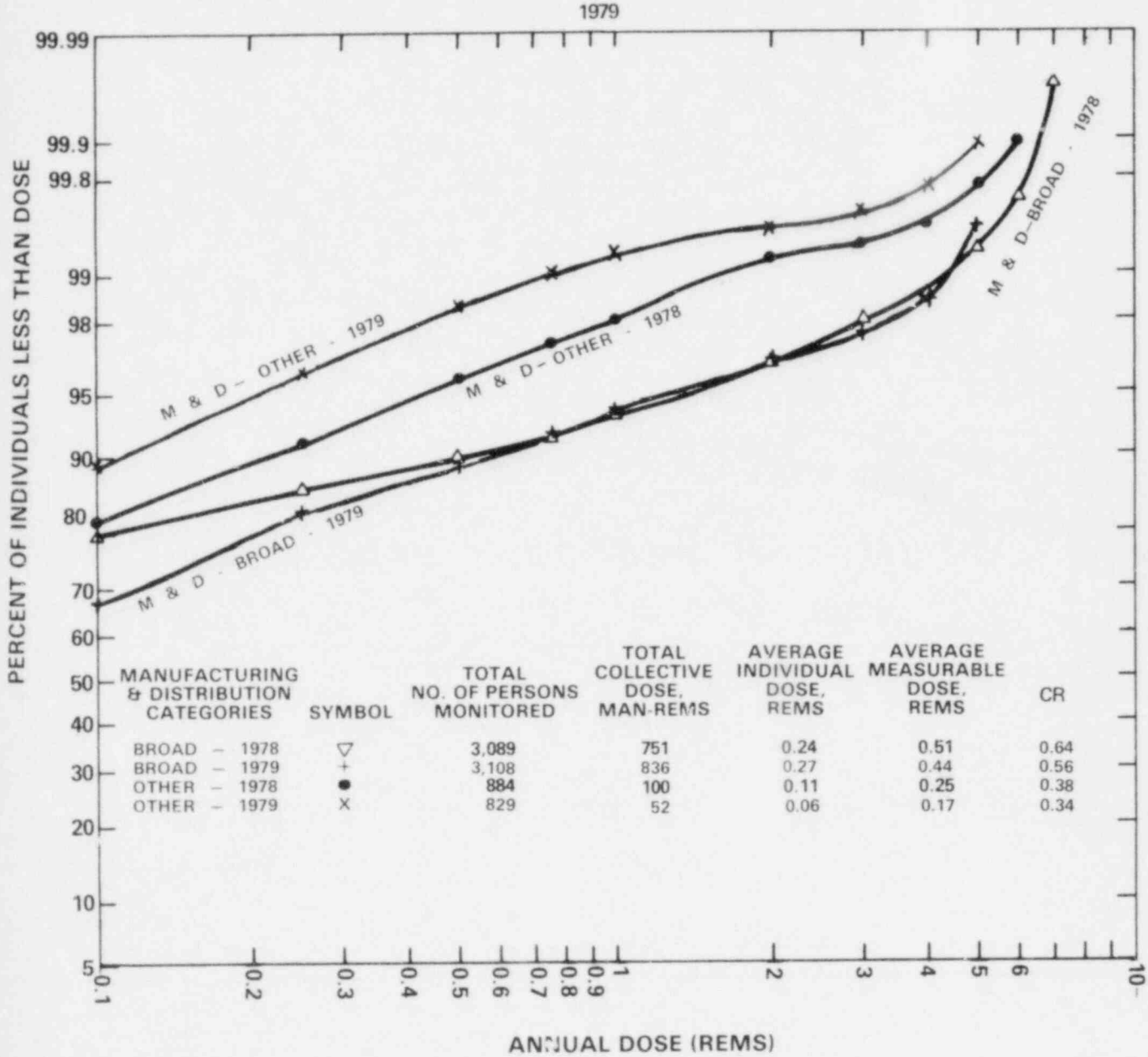
Annual Dose Distributions of
Manufacturers and Distributors
1974-1979



YEAR AND SYMBOL	TOTAL NO. OF PERSONS MONITORED	TOTAL COLLECTIVE DOSE, MAN-REMS	AVERAGE INDIVIDUAL DOSE, REMS	AVERAGE MEASURABLE DOSE, REMS	CR
1974 ●	3,340	1,050	0.31	0.57	0.63
1975 □	3,367	1,188	0.35	0.63	0.64
1976 ○	3,501	1,226	0.35	0.62	0.68
1977 △	4,243	1,329	0.31	0.54	0.63
1978 ■	3,973	851	0.21	0.45	0.61
1979 +	3,937	888	0.23	0.40	0.55

Figure 7

Annual Dose Distributions of Two Types of Manuf. & Dist. Licensees



MANUFACTURING & DISTRIBUTION CATEGORIES	SYMBOL	TOTAL NO. OF PERSONS MONITORED	TOTAL COLLECTIVE DOSE, MAN-REMS	AVERAGE INDIVIDUAL DOSE, REMS	AVERAGE MEASURABLE DOSE, REMS	CR
BROAD – 1978	▽	3,089	751	0.24	0.51	0.64
BROAD – 1979	+	3,108	836	0.27	0.44	0.56
OTHER – 1978	●	884	100	0.11	0.25	0.38
OTHER – 1979	X	829	52	0.06	0.17	0.34

IV.A.5. Annual Dose Distributions for Fuel Fabricators and Reprocessors

Figure 8 presents log-probability plots of the annual dose distributions reported by fuel fabricators and reprocessors for each of the years 1974 through 1979. The curves tend to shift upward each year and the average measurable dose has declined from 0.60 rem to 0.24 rem, as has the ratio CR which fell from 0.61 to 0.16.

Figure 9 presents log-probability plots of the 1979 annual dose distributions reported by the six types of licensees that are usually lumped together to form this group. It can be seen that a higher percentage of the workers engaged in plutonium fuel fabrication activities received annual doses in excess of 1.5 rems than did those employed in the other five activities, and they had the highest average dose, as was the case in 1978. Licensees with program code 21210 (uranium hexafluoride conversion, uranium fuel fabrication and scrap recovery) reported monitoring about 1,300 fewer individuals than they did in 1978, but they still reported the largest collective dose of those in this group. However, the doses were distributed such that only eight percent of the collective dose was incurred by workers whose annual dose exceeded 1.5 rems (CR = 0.08), and the average measurable dose was 0.28 rem.

IV.B. Annual Exposure Data for the Remaining Categories of Licensees

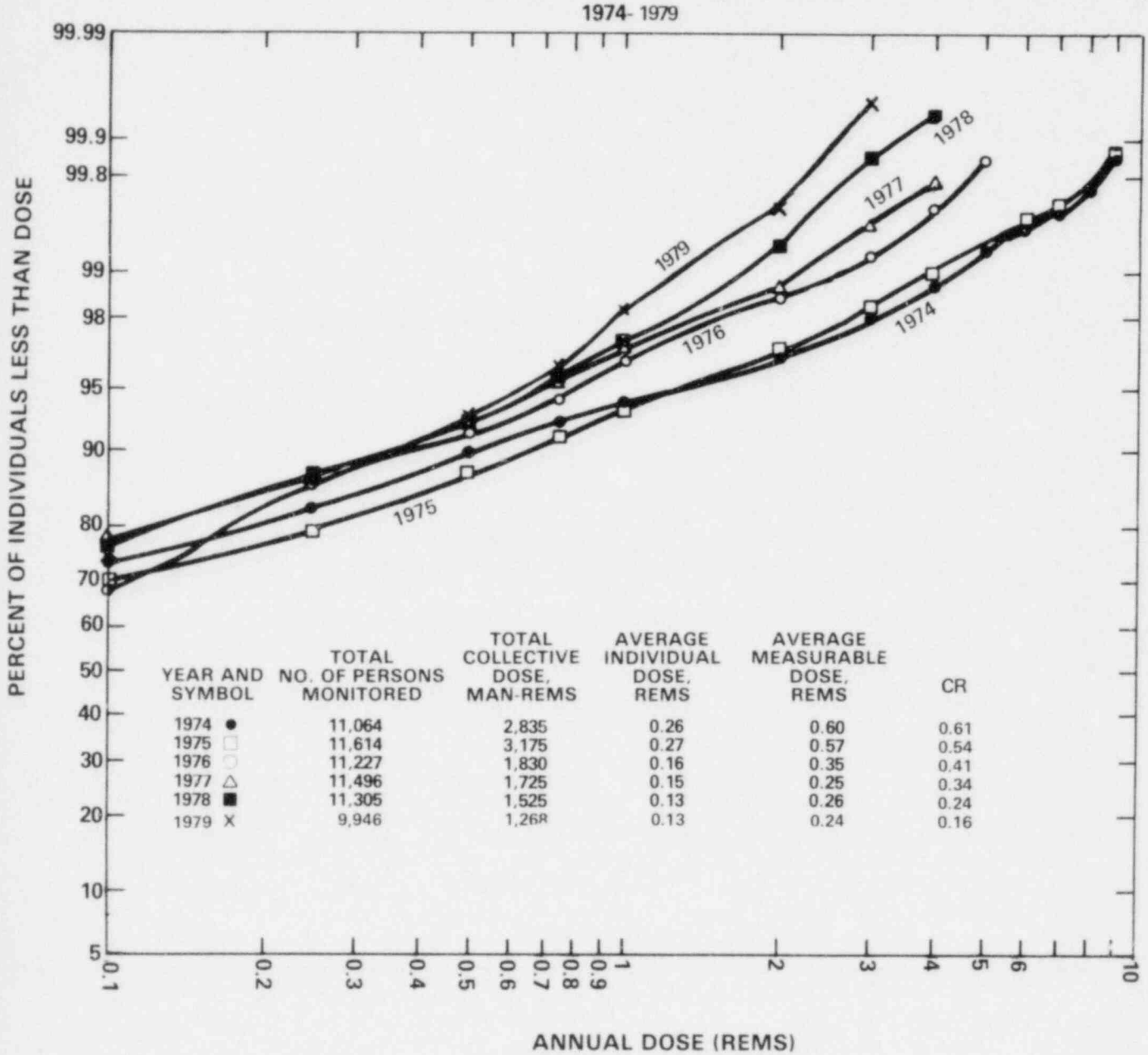
IV.B.1. Annual Dose Distributions for Medical Licensees

Figure 10 presents log-probability plots of the dose distributions reported by six categories of medical licensees. The value of CR was found to be smaller for nearly all of these types than that found in 1978. The collective dose reported by the Institutional-Other type continued to be about three times that reported by all of the other categories of medical licensees combined; however, the number of monitored individuals was also quite large so that the average dose remained small. And the portion (24%) of the collective dose due to doses greater than 1.5 rems remained higher than those of the other medical categories.

As can be seen from Table 3 (page 11), the total occupational collective dose, 9,230 man-rems (about the same as that found in 1978) incurred by workers associated with medical activities involving radioisotopes is second only to that (39,765 man-rems) incurred by workers at nuclear power facilities. It exceeds the sum of the collective doses reported by the other three categories of licensees (radiographers, manufacturers and distributors, and fuel fabricators and reprocessors) that previously submitted annual reports, as was the case in 1978. The doses incurred by medical workers is of particular interest because the majority of workers is young females. In fact, estimates by the U.S. Environmental Protection Agency indicate that 20 to 24 year-old females in the medical field comprise one-fourth of all females in the entire U.S. radiation work force [Ref. 5]. Since some of these females may be in the earliest stages of pregnancy when the doses are received, when fetus is more radiosensitive that the adult human, the total collective occupational dose, 9,230 person-rems, could result in greater somatic-risk than its value implies. These risks should be taken into consideration by the employer and the employee.

Figure 8

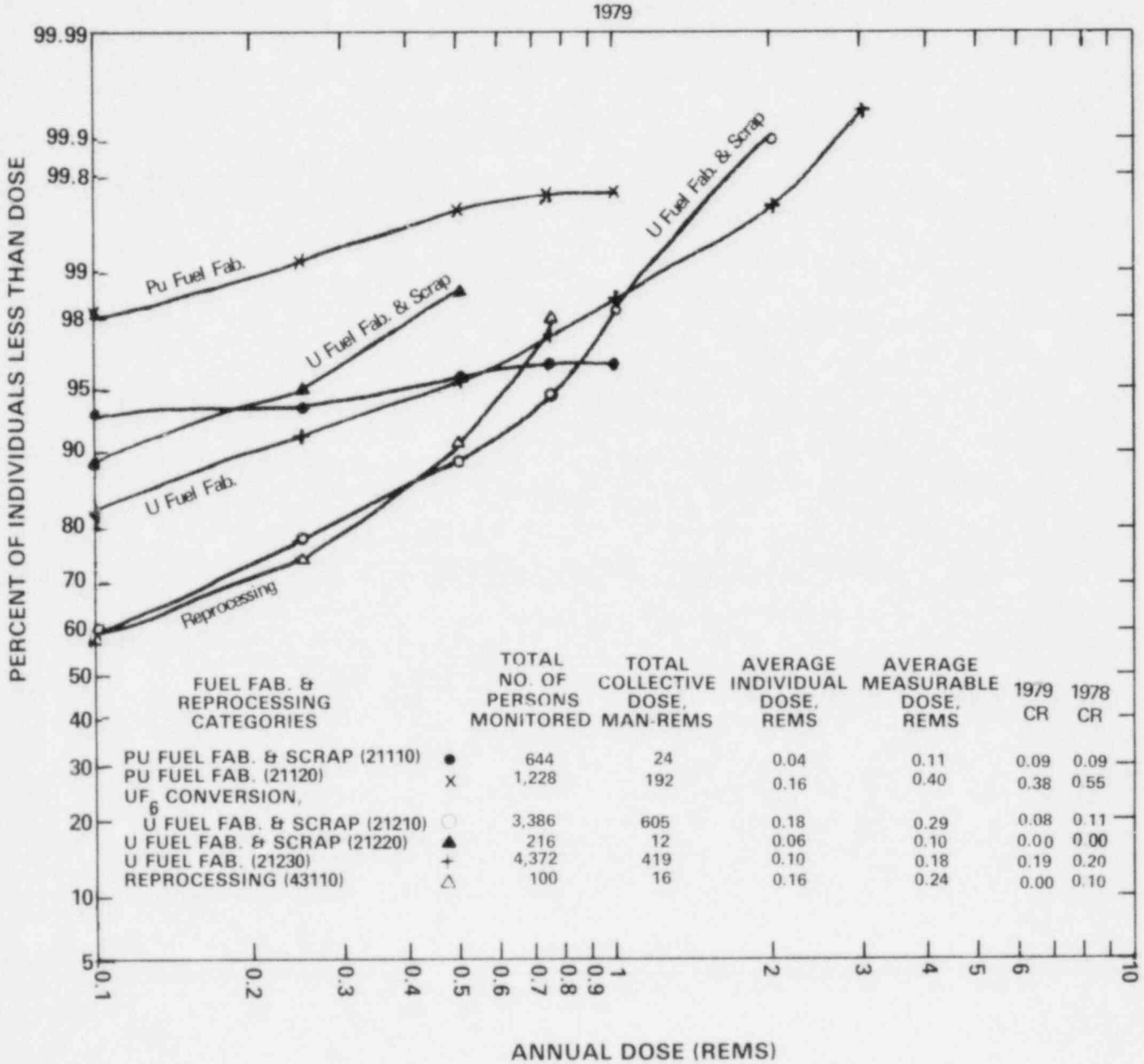
Annual Dose Distributions of
Fuel Fabricators and Reprocessors
1974- 1979



YEAR AND SYMBOL	TOTAL NO. OF PERSONS MONITORED	TOTAL COLLECTIVE DOSE, MAN-REMS	AVERAGE INDIVIDUAL DOSE, REMS	AVERAGE MEASURABLE DOSE, REMS	CR
1974 ●	11,064	2,835	0.26	0.60	0.61
1975 □	11,614	3,175	0.27	0.57	0.54
1976 ○	11,227	1,830	0.16	0.35	0.41
1977 △	11,496	1,725	0.15	0.25	0.34
1978 ■	11,305	1,525	0.13	0.26	0.24
1979 X	9,946	1,268	0.13	0.24	0.16

Figure 9

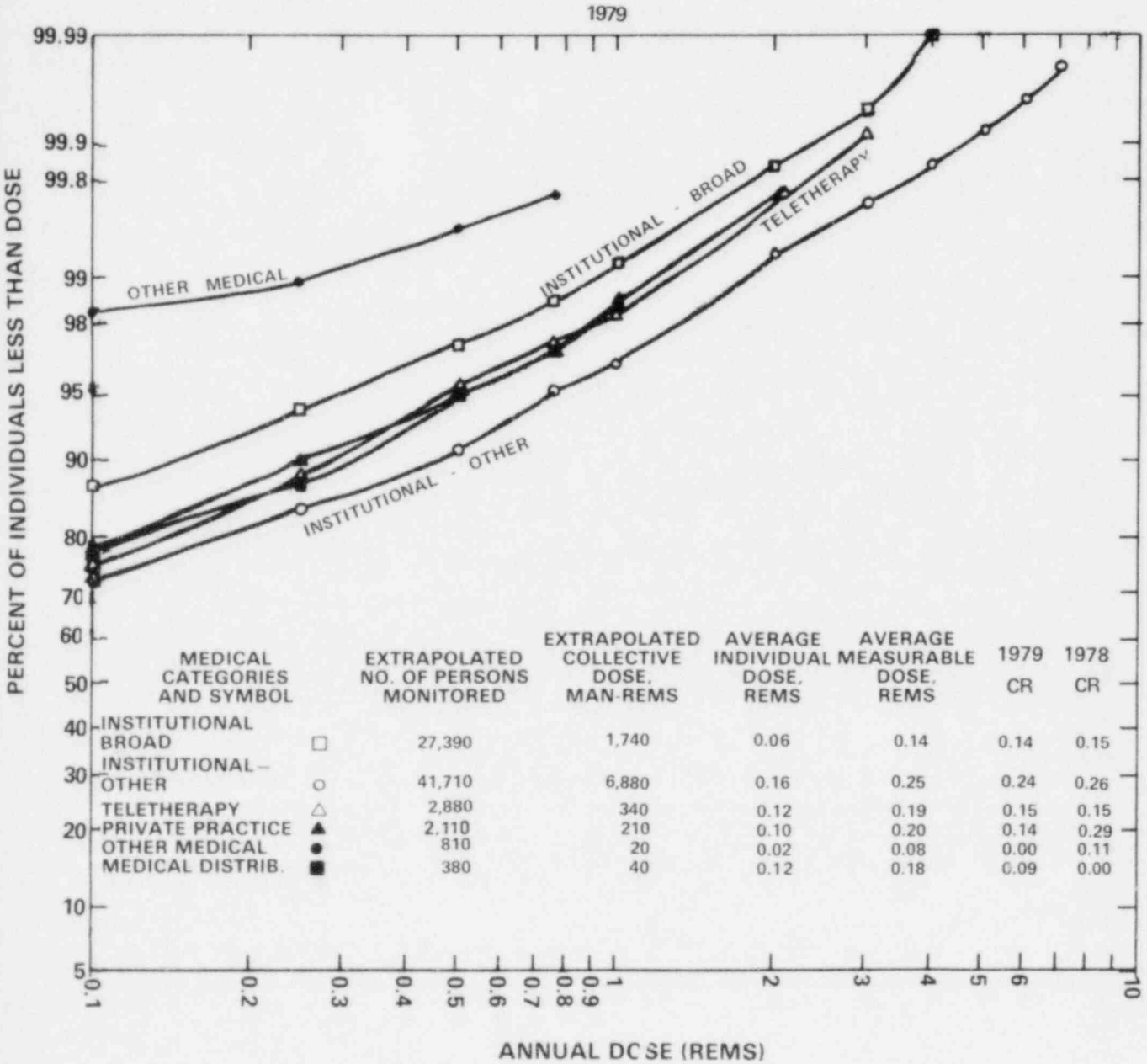
Annual Dose Distributions of Types of Fuel Fab. & Reprocessing Licensees



FUEL FAB. & REPROCESSING CATEGORIES		TOTAL NO. OF PERSONS MONITORED	TOTAL COLLECTIVE DOSE, MAN-REMS	AVERAGE INDIVIDUAL DOSE, REMS	AVERAGE MEASURABLE DOSE, REMS	1979 CR	1978 CR
PU FUEL FAB. & SCRAP (21110)	●	644	24	0.04	0.11	0.09	0.09
PU FUEL FAB. (21120)	X	1,228	192	0.16	0.40	0.38	0.55
UF_6 CONVERSION, U FUEL FAB. & SCRAP (21210)	○	3,386	605	0.18	0.29	0.08	0.11
U FUEL FAB. & SCRAP (21220)	▲	216	12	0.06	0.10	0.00	0.00
U FUEL FAB. (21230)	+	4,372	419	0.10	0.18	0.19	0.20
REPROCESSING (43110)	△	100	16	0.16	0.24	0.00	0.10

Figure 10

Annual Dose Distributions of Types of Medical Licensees



MEDICAL CATEGORIES AND SYMBOL		EXTRAPOLATED NO. OF PERSONS MONITORED	EXTRAPOLATED COLLECTIVE DOSE, MAN-REMS	AVERAGE INDIVIDUAL DOSE, REMS	AVERAGE MEASURABLE DOSE, REMS	1979 CR	1978 CR
INSTITUTIONAL BROAD	□	27,390	1,740	0.06	0.14	0.14	0.15
INSTITUTIONAL – OTHER	○	41,710	6,880	0.16	0.25	0.24	0.26
TELETHERAPY	△	2,880	340	0.12	0.19	0.15	0.15
PRIVATE PRACTICE	▲	2,110	210	0.10	0.20	0.14	0.29
OTHER MEDICAL	●	810	20	0.02	0.08	0.00	0.11
MEDICAL DISTRIB.	■	380	40	0.12	0.18	0.09	0.00

IV.B.2. Annual Dose Distributions for Academic Licensees

Figure 11 displays four log-probability plots of annual dose distributions: one plot for each of the two types of Academic licensees, Broad and Other, for 1979; one plot for the composite of these two types for 1979; and one for the composite of these two types for 1978. One can see that the distributions reported by the two types of academic licensees are quite similar, with the value of CR for each being rather small (0.13 for Broad licensees and 0.08 for Other licensees). The value of CR found for the Institutional and Research and Development licensees having Broad licenses was also found to be about the same or considerably less than that found for the Other types of these licensees. This implies that the greater potential for exposure associated with the more complex activities of most facilities having a Broad license can be compensated by the larger radiation protection program required by the conditions of such a Broad license. A shift upward in the composite plot for 1979 from that of the plot for 1978 reflects the small decrease in the percentage of workers receiving higher doses, primarily due to the decrease in these workers reported by the Academic-Other licensees. The continuing extremely low values of the average doses indicates that the licensees may be monitoring many more people than would be required by the current regulations.

IV.B.3. Annual Dose Distributions for Research and Development Licensees

Four plots similar to those shown for Academic licensees are presented in Figure 12. Contrary to that found for the Broad and Other types of Academic licensees, the dose distributions reported by these two types of Research and Development (R&D) licensees are such that CR was found to be 0.13 for the Broad licensees and 0.45 for the Other licensees. These are quite different from the values of CR calculated from the 1978 dose distributions when CR was 0.24 for R&D-Broad licensees and 0.01 for R&D-Other licensees. Examination of the data revealed that the main reason for the increase in the value of CR for the R&D-Other category was the submittal of a report by a new licensee indicating that 32 individuals received doses greater than one rem. This licensee also has a license for medical distribution, but submitted only one report. Some of the doses were probably incurred during this activity. Both types continued to report large numbers of individuals in the very low dose ranges so the average and the collective doses remained quite small.

IV.B.4. Annual Dose Distributions for *Marketing Licensees

The dose distributions reported by Marketing licensees are shown in Figure 13 via four log-probability plots similar to those presented for the two previous categories. The plot of the 1978 data has been corrected for the error of including a Well Logging licensee in the Marketing-Broad category (as previously explained in Section III.A.9), and the corrected 1978 values for all of the parameters are shown in parentheses. The number of monitored individuals and the collective dose reported by the Broad licensees increased somewhat from the 1978 values, but the doses were distributed such that the CR and the average doses decreased. The distribution of the doses reported by

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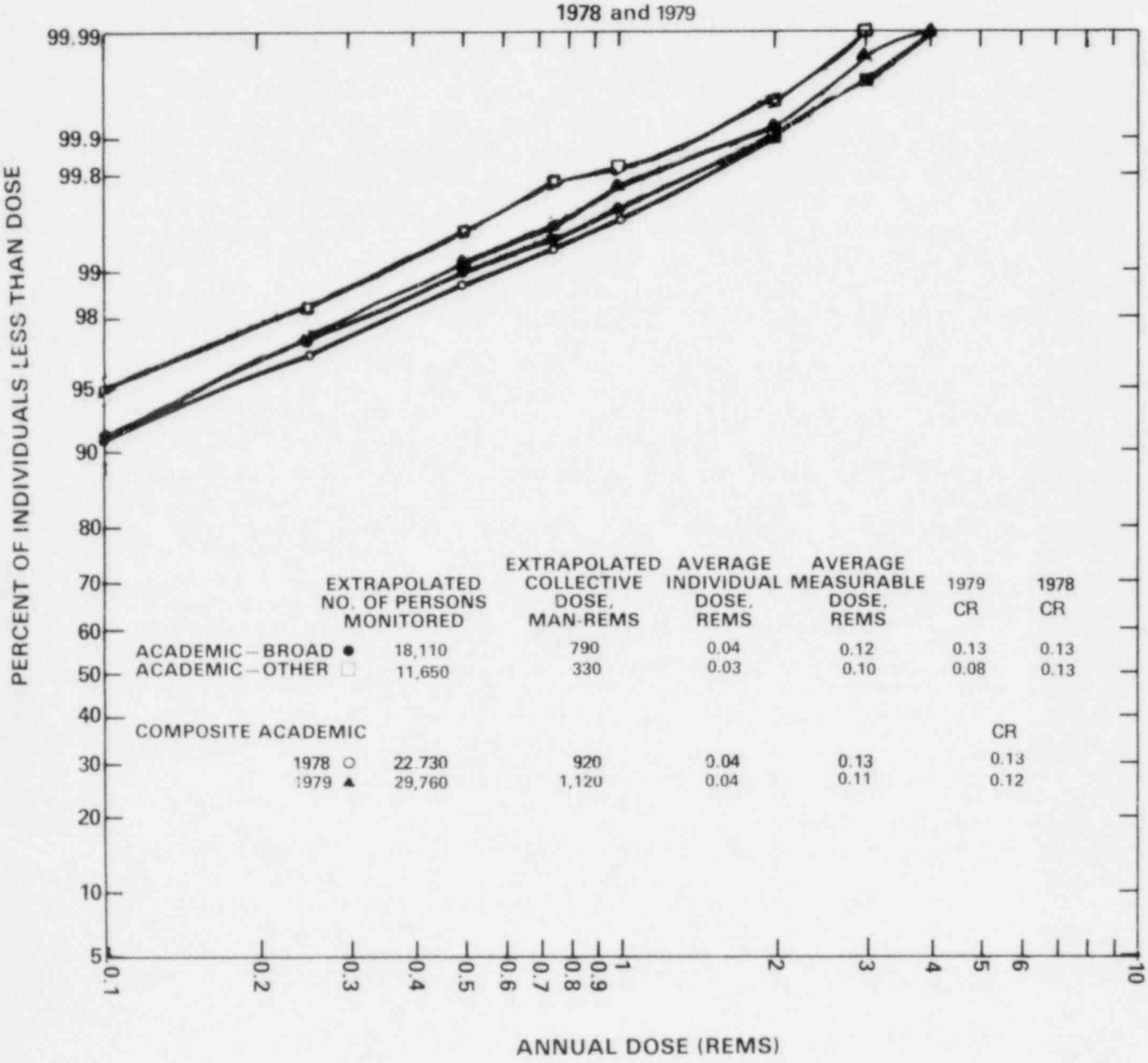
* Excluding the subset "Manufacturing and Distribution."

Figure 11

Annual Dose Distributions of
Academic Licensees
1978 and 1979

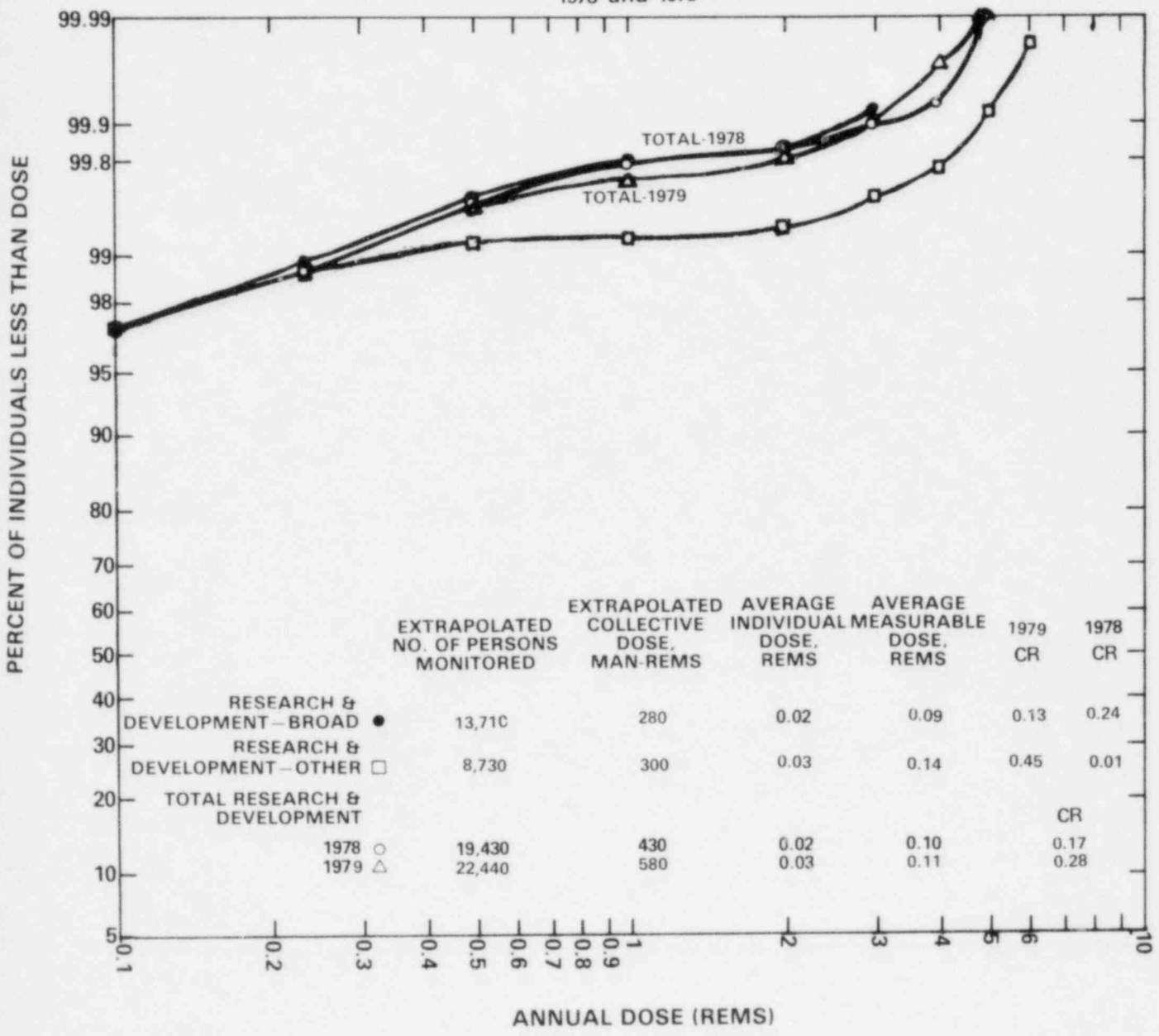


	EXTRAPOLATED NO. OF PERSONS MONITORED	EXTRAPOLATED COLLECTIVE DOSE, MAN-REMS	AVERAGE INDIVIDUAL DOSE, REMS	AVERAGE MEASURABLE DOSE, REMS	1979 CR	1978 CR
ACADEMIC – BROAD ●	18,110	790	0.04	0.12	0.13	0.13
ACADEMIC – OTHER □	11,650	330	0.03	0.10	0.08	0.13
COMPOSITE ACADEMIC					CR	
1978 ○	22,730	920	0.04	0.13	0.13	
1979 ▲	29,760	1,120	0.04	0.11	0.12	

Figure 12

Annual Dose Distributions of
Research & Development Licensees

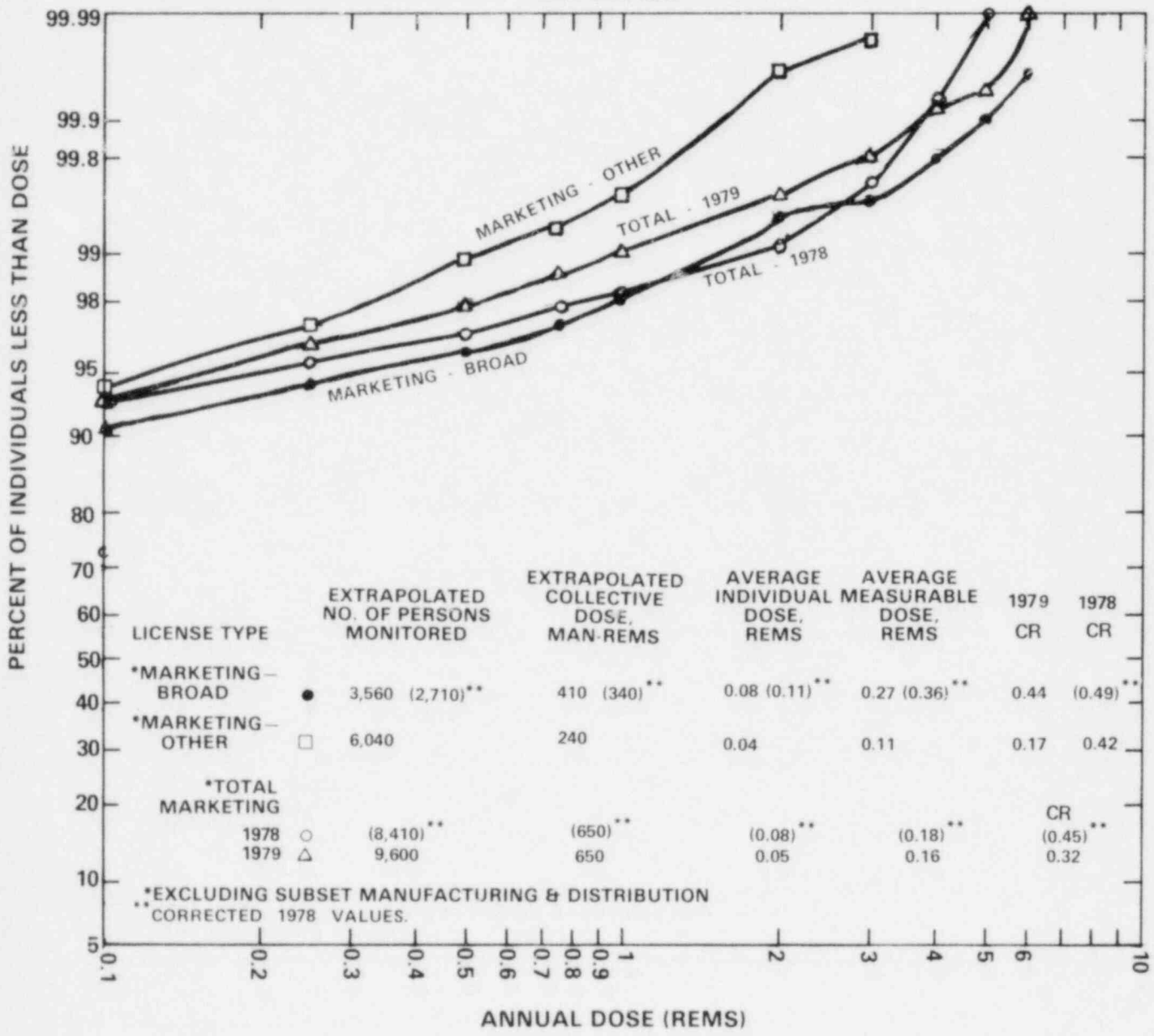
1978 and 1979



	EXTRAPOLATED NO. OF PERSONS MONITORED	EXTRAPOLATED COLLECTIVE DOSE, MAN-REMS	AVERAGE INDIVIDUAL DOSE, REMS	AVERAGE MEASURABLE DOSE, REMS	1979 CR	1978 CR
RESEARCH & DEVELOPMENT—BROAD ●	13,710	280	0.02	0.09	0.13	0.24
RESEARCH & DEVELOPMENT—OTHER □	8,730	300	0.03	0.14	0.45	0.01
TOTAL RESEARCH & DEVELOPMENT						CR
1978 ○	19,430	430	0.02	0.10		0.17
1979 △	22,440	580	0.03	0.11		0.28

Figure 13

Annual Dose Distributions of
Marketing Licensees
1978 and 1979



LICENSE TYPE		EXTRAPOLATED NO. OF PERSONS MONITORED	EXTRAPOLATED COLLECTIVE DOSE, MAN-REMS	AVERAGE INDIVIDUAL DOSE, REMS	AVERAGE MEASURABLE DOSE, REMS	1979 CR	1978 CR
*MARKETING—BROAD	●	3,560 (2,710)**	410 (340)**	0.08 (0.11)**	0.27 (0.36)**	0.44	(0.49)**
*MARKETING—OTHER	□	6,040	240	0.04	0.11	0.17	0.42
*TOTAL MARKETING							
1978	○	(8,410)**	(650)**	(0.08)**	(0.18)**	CR (0.45)**	
1979	△	9,600	650	0.05	0.16	0.32	

*EXCLUDING SUBSET MANUFACTURING & DISTRIBUTION
**CORRECTED 1978 VALUES.

Marketing-Other licensees changed even more so that only 17% of the collective doses was due to doses that exceeded 1.5 rems. The position of the 1979 plot for Total Marketing above that of the 1978 plot reflects these improvements.

IV.B.5. Annual Dose Distributions for Other Industrial Byproduct Licensees

Figure 14 presents log-probability plots of the major categories of licensees using byproduct materials for other industrial purposes. One can see that workers monitored by Well Logging and Waste Disposal-Other licensees have the highest average measurable doses of those in this group and, as shown in Table 10, places them among the ten categories of licensees having the highest measurable doses. Well Logging has the largest collective dose of those in this group and, as it did in 1978, has the third largest collective dose (Table 8) of all NRC licensees. However, the distribution of the doses reported by Well Logging licensees is such that only 31% of the collective dose was incurred by individuals that received doses greater than 1.5 rems, while Waste Disposal-Other and Irradiators had 56% and 36%, respectively.

In Figure 14, one can see that the plot for Other Measuring Systems shows that some individuals are likely to receive doses exceeding 1.5 rems; however, the extremely low average doses imply that many more people may be being monitored than would be required by current regulations. Plots of the distributions of composites of all the categories included in the group "Other Byproduct" (as shown in Table 1) for 1978 and 1979 are included in Figure 14 for comparison purposes. The shift downward in the composite plot of the 1979 data from that of the 1978 data reflects the slightly higher values of the average doses and CR for 1979. This was due to the fact that all but one category (Irradiators-Total) reported larger collective doses than in 1978, and the average doses of all but one category (Waste Disposal-Other) increased.

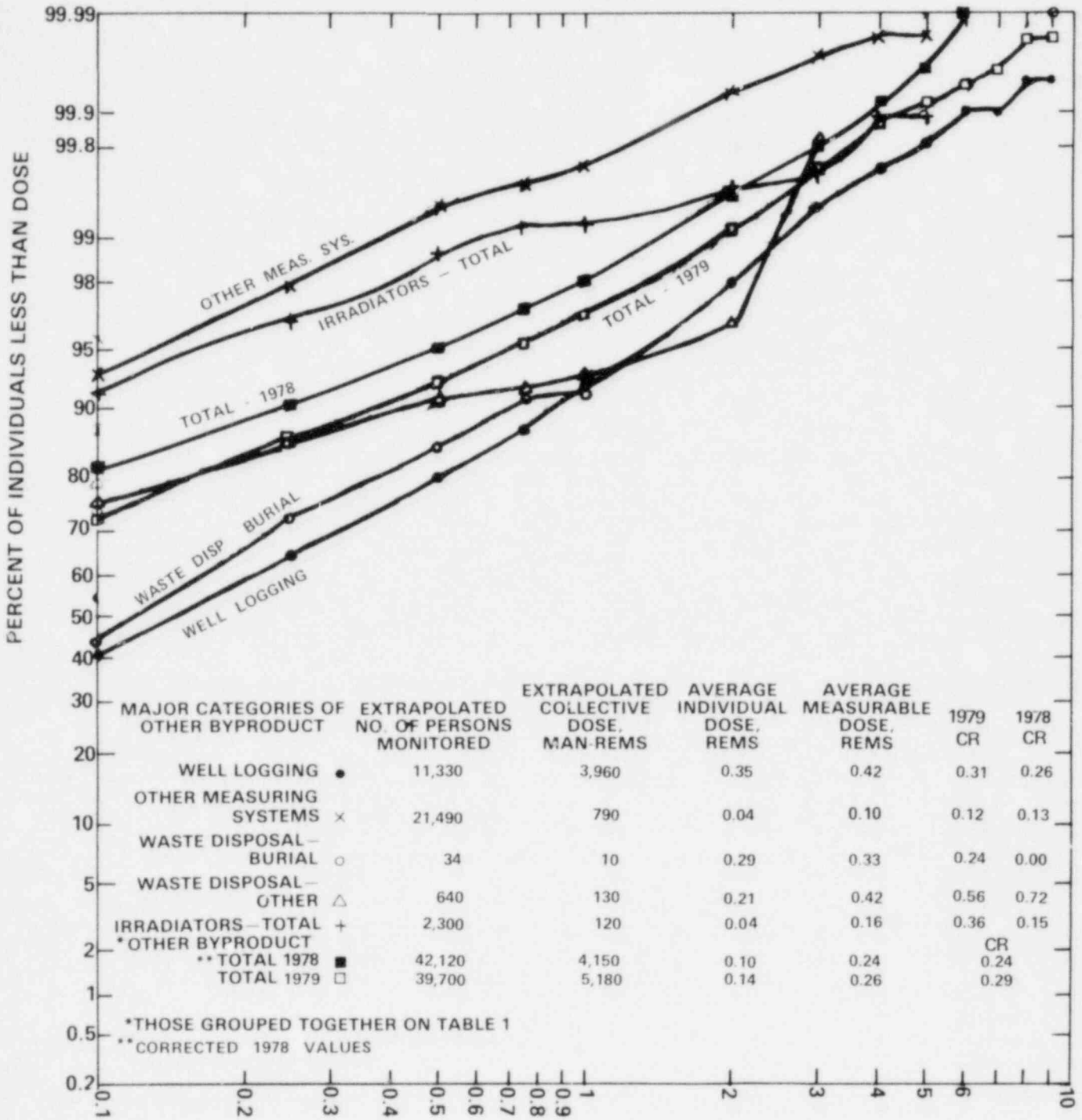
IV.B.6 Annual Dose Distributions for the Remaining Groups of Source and Special Nuclear Material Licensees

Figure 15 presents log-probability plots of composites (i.e., Source Material, Other SNM, and Research Reactors) of the data reported by the remaining categories of NRC licensees. Plots of composites of the data reported by the categories (Four Categories and Byproduct Material) of NRC licensees previously discussed are also shown for comparison. The distribution of doses reported by Other SNM licensees in which no one received a dose greater than two rems and CR was only 0.11, placed its plot above that of the others. From Table 2 (page 9), it can be seen that the values of CR for most of the ten categories in this group are fairly low, as were the average doses. The category "Unencapsulated SNM" had the highest value of CR (0.39) and average measurable dose (0.56) as was discussed in Section III.C.4 (page 23). As shown in Figure 15, the distribution of the doses reported for the "Source Material" group was such that the average measurable dose was only 0.26 rems and CR was 0.12 which is about the same as that found for 1978.

Figure 15 also shows that the value of CR (0.33) calculated for Research Reactor licensees is less than that found for 1978, but it is still higher than that of any of the other composite groups shown except that of the Four Categories of licensees that were previously required to report pursuant to §20.407. The average measurable dose (0.17 rem), however, is next to the lowest average dose for these groups. The Figure also indicates that the

Figure 14

Annual Dose Distributions of
Other Byproduct Licensees
1978 and 1979



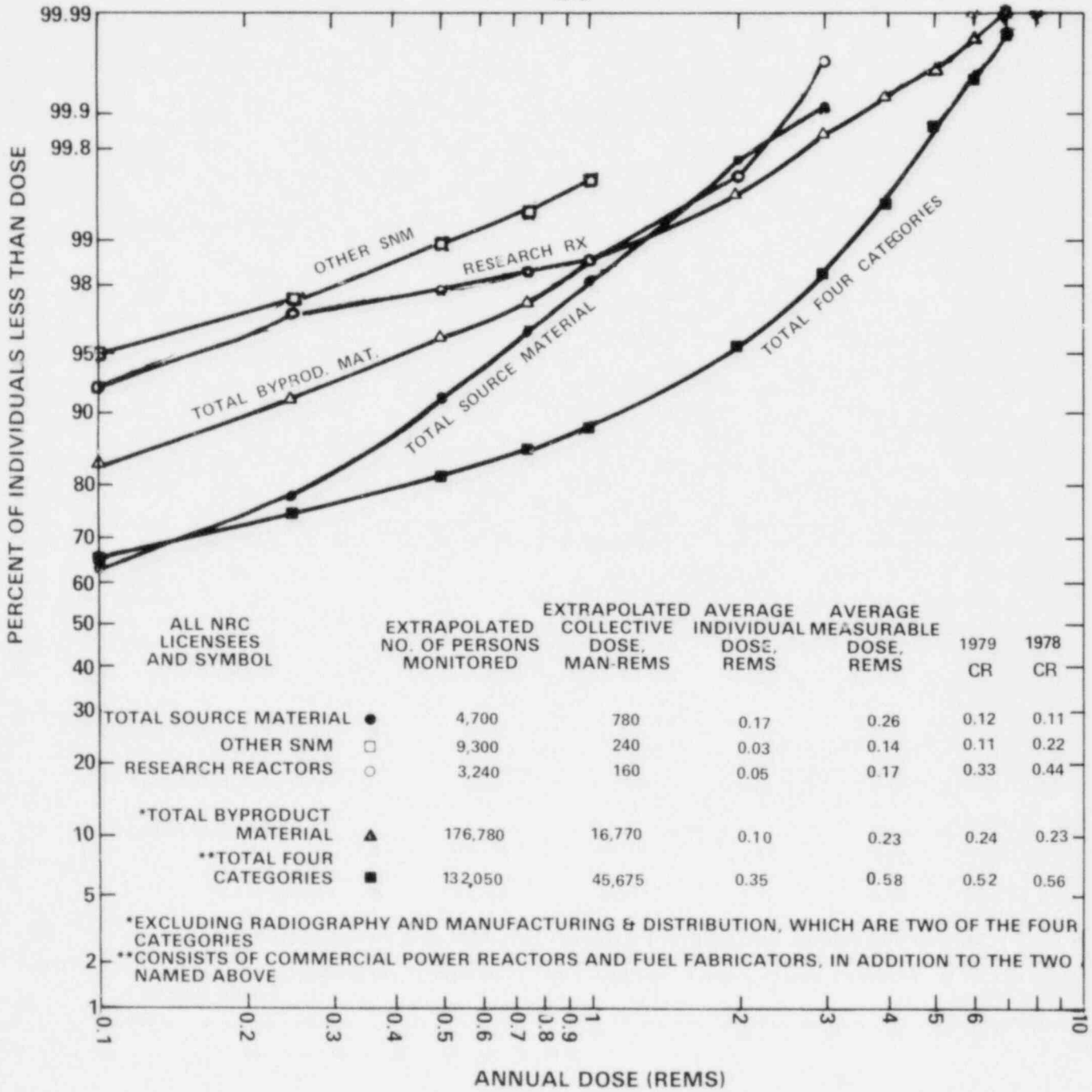
MAJOR CATEGORIES OF OTHER BYPRODUCT		EXTRAPOLATED NO. OF PERSONS MONITORED	EXTRAPOLATED COLLECTIVE DOSE, MAN-REMS	AVERAGE INDIVIDUAL DOSE, REMS	AVERAGE MEASURABLE DOSE, REMS	1979 CR	1978 CR
WELL LOGGING	●	11,330	3,960	0.35	0.42	0.31	0.26
OTHER MEASURING SYSTEMS	×	21,490	790	0.04	0.10	0.12	0.13
WASTE DISPOSAL – BURIAL	○	34	10	0.29	0.33	0.24	0.00
WASTE DISPOSAL – OTHER	△	640	130	0.21	0.42	0.56	0.72
IRRADIATORS – TOTAL	+	2,300	120	0.04	0.16	0.36	0.15
*OTHER BYPRODUCT						CR	
**TOTAL 1978	■	42,120	4,150	0.10	0.24	0.24	
TOTAL 1979	□	39,700	5,180	0.14	0.26	0.29	

*THOSE GROUPED TOGETHER ON TABLE 1
**CORRECTED 1978 VALUES

Figure 15

Annual Dose Distributions of
All NRC Licensees

1979



ALL NRC LICENSEES AND SYMBOL		EXTRAPOLATED NO. OF PERSONS MONITORED	EXTRAPOLATED COLLECTIVE DOSE, MAN-REMS	AVERAGE INDIVIDUAL DOSE, REMS	AVERAGE MEASURABLE DOSE, REMS	1979 CR	1978 CR
TOTAL SOURCE MATERIAL	●	4,700	780	0.17	0.26	0.12	0.11
OTHER SNM	□	9,300	240	0.03	0.14	0.11	0.22
RESEARCH REACTORS	○	3,240	160	0.05	0.17	0.33	0.44
*TOTAL BYPRODUCT MATERIAL	▲	176,780	16,770	0.10	0.23	0.24	0.23
**TOTAL FOUR CATEGORIES	■	132,050	45,675	0.35	0.58	0.52	0.56

*EXCLUDING RADIOGRAPHY AND MANUFACTURING & DISTRIBUTION, WHICH ARE TWO OF THE FOUR CATEGORIES

**CONSISTS OF COMMERCIAL POWER REACTORS AND FUEL FABRICATORS, IN ADDITION TO THE TWO NAMED ABOVE

133,340 individuals monitored by the Four Categories of licensees incurred a collective dose (45,690 man-rems) that is more than twice as large as that incurred by the 194,020 individuals estimated to have been monitored by the remaining types of NRC licensees. The average measurable dose calculated for the group of Four Categories is also about twice that of any of the other four groups but it remains less than one rem.

IV.C. Health Implications of Average Annual Doses

If any biological effects are caused by exposures to radiation in the work place, the effects are likely to occur only after many years because the most important effects are cancer induction and genetic damage leading to the transmission of hereditary diseases. A vast amount of scientific information is available from which estimates of these risks can be made. Much of this information has been obtained from epidemiologic studies of human populations at levels of exposures considerably higher than those normally experienced in the work place. Complementary to this, information obtained from many animal and cell biology studies have greatly enhanced our knowledge and understanding of the biological effects of ionizing radiation. Although using this information to estimate risks in the work place introduces uncertainties, these uncertainties can be dealt with in such a manner that the risk is not likely to be underestimated. Thus, the discussion below is likely to overstate the health implications rather than understate them.

Cancer induction as a result of radiation exposure has been examined by many organizations having scientific and medical expertise in the subject. One of these, the National Academy of Sciences (NAS), completed a comprehensive review of the biological effects of ionizing radiation in 1980 and published its findings (Ref. 7). Based on this report, a large working population receiving one million man-rems might suffer an estimated 100 to 200 additional cancers over the remaining years of their lives. This risk estimate can be applied to the 63,630 man-rems shown in Table 3 and the 167,360 workers who received measurable exposures. The result is that for the total work force exposed in 1979, the number of additinal cancer deaths would be less than ten. This addition is made to the 25,000 cancer deaths or so that would occur in this approximately 170,000 workers normally without exposure to this amount of radiation. Perhaps more meaningful to the individual workers are the health implications to the worker receiving the average dose of 0.40 rems and the maximum dose of 15 rems or so during 1979. The estimated risk of dying of cancer during the remainder of life is less than one chance in 10,000 for the average dose and one chance in 1,000 for the highest dose. Should a worker receive 0.40 rems per year continuously during his entire working career his risk of dying from cancer will increase by about 1% of the normal risk. These risks can be compared to the American Cancer Society's estimates of one chance in four of having cancer and one chance in seven of dying of cancer.

The potential genetic effects from a worker population receiving about 65,000 man-rems is very small compared to genetic damages that normally occur spontaneously in this population. Based again on the 1980 NAS report, from zero to four serious genetic diseases could be induced in first generation children of the 170,000 exposed* workers and from three to 60 in all future generations. This number is compared to the approximately 100,000 serious genetic defects that occur normally in one million live births.

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* Assuming that each of them will have one child in the future.

V. TERMINATION EXPOSURE DATA - 10 CFR §20.408

A. Terminations, 1969 - 1979

In 1969 NRC/AEC began requiring four categories* of its licensees to submit personal identification and exposure information upon the termination of each monitored person's employment or work assignment in the licensee's facility. Some 519,000 such records have been received for approximately 240,000 individuals who had terminated on or before December 31, 1979. The figures given for the number of reports and for the number of individuals are different because numerous individuals have terminated more than once over the years and because some individuals may have had external doses reported to more than one part of their body, as well as estimates of internal depositions of radioactive material, each of which is counted as one record. Table 11 provides a breakdown of this information for individuals terminating during each of the ten calendar years and shows that the number of such reports has increased each year. Since the majority of termination reports are now submitted by nuclear power utilities, the number of records and individuals that they reported is displayed separately.

B. Transient Workers per Calendar Quarter

One use that is being made of the information contained in the termination reports is the examination of the doses being received by short-term workers. Since nearly half of the termination reports indicated periods of exposure that were less than 90 days, it is possible that several thousand individuals could have been employed by two or more licensees during the same calendar quarter. Thus, by defining a "transient" worker to be a radiation worker who began and terminated employment at two different licensed facilities within one calendar quarter, one could examine the doses of those workers that move so rapidly from facility to facility.

Table 12 displays some of the information gathered from these termination reports that were submitted by the four categories of covered licensees. The number of these workers has increased more than twentyfold during the years 1972 through 1979, but appears to be leveling off somewhat. This increase probably reflects the rate of growth of the nuclear power industry and its need for short-term workers. Thus, the figures obtained from reports submitted by power reactors are shown separately. The table also shows that the average individual dose (which is close to being a quarterly dose for these workers) has tended to decrease during this time and has remained at 0.46 rem during the last two years. Examinations of these records also revealed that some individuals have worked for as many as five different NRC licensees during one quarter. However, very few instances have been found in which a worker may have slightly exceeded his quarterly limit of 3 rems as a result of his working at two different licensed facilities within one calendar quarter. That is not to say, however, that no other workers' doses have exceeded the

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* Operating nuclear power reactors; industrial radiographers; fuel processors, fabricators, and reprocessors; and manufacturers and distributors of specified quantities of byproduct material.

TABLE 11

TERMINATION REPORTS SUBMITTED TO THE NRC
1969 - 1979

YEAR	All Four Categories*		Power Reactor Licensees	
	Number of Termination Records	Number of Terminating Individuals	Number of Termination Records	Number of Terminating Individuals
1969	5,009	3,992	790	727
1970	8,606	6,069	2,126	1,908
1971	12,955	8,874	2,246	2,197
1972	15,685	10,353	4,997	3,888
1973	19,985	15,588	11,525	9,071
1974	30,389	21,499	16,946	11,603
1975	44,676	27,415	38,376	22,627
1976	70,230	40,079	63,593	35,294
1977	87,403	41,532	80,232	36,524
1978	95,372	43,839	84,696	37,180
1979	129,139	56,453	113,929	47,840

* Commercial nuclear power reactors; industrial radiographers; fuel processors, fabricators, and reprocessors; manufacturers and distributors of specified quantities of byproduct materials.

TABLE 12

TRANSIENT WORKERS PER CALENDAR QUARTER

1972 - 1979

Year	No. of Workers Terminated by 2 or more Licensees Within One Quarter	Collective Dose (Man-rems)	Average Individual Dose (Rem)
All Covered Licensees			
1972	69	63	0.91
1973	157	138	0.88
1974	332	170	0.51
1975	709	508	0.72
1976	1299	904	0.70
1977	1481	870	0.59
1978	1570	720	0.46
1979	1809	836	0.46
Power Reactor Facilities			
1972	57	57	1.00
1973	146	123	0.84
1974	285	158	0.55
1975	684	493	0.72
1976	1257	889	0.71
1977	1437	851	0.59
1978	1500	680	0.45
1979	1754	802	0.46

quarterly limit because the records of those who were employed by a second licensee for a period spanning the end of a calendar quarter could not be examined in this manner, and the records of those employed by other than the four categories of NRC licensees are not submitted to the NRC.

C. Transient Workers per Calendar Year

Since the number of transient workers per calendar quarter comprise only a small percentage of the total number of individuals terminating each year, it was decided to change the parameters such that the records of more workers could be examined. This was done by selecting the records of all individuals who began and terminated two or more periods of employment with two different licensees within one calendar year and by summing each worker's whole body doses. An examination of this data would allow one to determine the average individual dose for these workers as well as to help determine the impact that the inclusion of these individuals in each of two or more licensees' annual reports had on the statistics obtained from the compilation of the annual reports submitted by groups of licensees. (This is one of the problems mentioned in Section II.)

Since more than 95% of these workers are reported by nuclear power plants, only the records of these workers were examined. Table 13a presents the actual distribution of their doses as determined from the above-described termination reports and compares it to the distribution of the whole body doses as they would have been compiled from annual statistical reports submitted by the nuclear power facilities. For each of the years, 1977, 1978, and 1979, there were approximately 3,200 workers that were employed at two or more nuclear power facilities during the year such that each one would have been counted as about two and a half workers in a compilation of these reports. In 1979 these workers incurred a collective dose of 3,014 man-rems which resulted in an average measurable dose of 1.05 rems rather than the 0.49 rem one would calculate from a compilation of the reports. These values are about 20% smaller than those found in 1977. One can see that each year the actual distribution of the doses of these workers was such that there were about twice as many individuals incurring doses greater than 2 rems than would have been indicated in a compilation of the annual statistical reports.

Table 13b illustrates the impact that the multiple reporting of these transient workers had on the staff's compilations of the annual statistical reports for the same three years. Since each nuclear power facility reports the distribution of the doses received by workers while monitored by that particular facility during the year, one would expect 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 about the same, the total number of workers and the average dose would be affected by this multiple reporting. This was found to be true. Each year there were about 3,300 too many workers indicated as having received measurable doses, and there were too few workers with doses in the higher ranges. For example, in 1977 the compiled annual reports indicated that 270 individuals received doses greater than five rems, while the corrected compilation indicated that there were at least 351 such workers. In 1979 these figures decreased to 130 and 160, respectively, so that there was a difference of only 30 individuals.

TABLE 13a

Actual and Compiled Dose Distributions of Transient Workers Per Calendar Year at LWRs

Type of Distribution and Year	Number of Individuals with Whole Body Doses in the Ranges (Rems)																		Total Workers	Total Man-Rems	Avg. Dose (Rems)	Avg. Meas. Dose (Rems)
	Less than Measurable	Measurable < 0.10	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	7.00-8.00	8.00-9.00	9.00-10.00	10.00-11.00	11.00-12.00	>12.0				
ACTUAL DISTRIBUTION OF TRANSIENTS – 1977	228	782	300	236	184	151	500	381	213	100	50	23	11	2					3,161	[b]3,776	1.19	1.29
COMPILED DISTRIBUTION OF TRANSIENTS – 1977	1,594	2,357	804	768	552	417	1,013	362	55	8	5								7,935	[b]3,776	0.48	0.60
ACTUAL DISTRIBUTION OF TRANSIENTS – 1978	302	869	316	286	166	144	462	293	159	106	46	15	2	0	1				3,167	[b]3,193	1.01	1.11
COMPILED DISTRIBUTION OF TRANSIENTS – 1978	2,025	2,402	916	780	495	377	859	246	51	11	0	2							8,164	[b]3,193	0.39	0.52
ACTUAL DISTRIBUTION OF TRANSIENTS - 1979	312	713	317	300	229	212	541	339	150	46	24	6	1						3,190	[b]3,014	0.94	1.0
COMPILED DISTRIBUTION OF TRANSIENTS – 1979	1,832	2,171	1,020	846	678	375	814	225	35	2	1								7,999	[b]3,014	0.38	0.49

TABLE 13b

Effects of Transient Workers on Annual Statistical Compilations

[a]COMPILED STATISTICAL DISTRIBUTION – 1977	27,671	15,523	6,750	5,179	3,300	2,500	6,174	2,838	1,130	569	141	66	36	21	6				71,904	32,731	0.46	0.74
[c]ADJUSTED STATISTICAL DISTRIBUTION – 1977	26,305	13,948	6,246	4,647	2,932	2,234	5,661	2,857	1,288	661	186	89	47	23	6				67,130	32,643	0.49	0.80
[a]COMPILED STATISTICAL DISTRIBUTION –1978	30,278	17,785	7,002	5,537	3,410	2,507	6,415	2,989	1,079	418	67	26	8	0	0	0	0	2	77,523	31,910	0.41	0.68
[c]ADJUSTED STATISTICAL DISTRIBUTION – 1978	28,555	16,252	6,402	5,043	3,081	2,274	6,018	3,036	1,189	513	113	39	10	0	1	0	0	2	72,526	31,823	0.44	0.72
[a]COMPILED STATISTICAL DISTRIBUTION –1979	46,236	24,421	9,848	8,159	5,189	3,479	7,934	3,307	1,251	477	86	28	13	2	0	0	1		110,431	39,765	0.36	0.62
[c]ADJUSTED STATISTICAL DISTRIBUTION – 1979	44,716	22,963	9,145	7,613	4,740	3,316	7,661	3,421	1,366	521	109	34	14	2	0	0	1		105,622	39,591	0.38	0.65

[a] Based on data submitted by all reactors, although all of them may not have been in commercial operation for a full year.

[b] Collective dose found by summing the actual doses reported for these workers on their termination reports.

[c] Distribution found by subtracting the actual from the compiled distribution shown in Table 14a and then subtracting this difference from the compiled statistical distribution shown in Table 14b.

And, since the number of these transient workers receiving measurable doses is only about 3% or 4% of the total number receiving measurable doses during the year, their impact on the statistics derived from compilations of the annual summary reports does not appear to be too great.

VI. PERSONNEL OVEREXPOSURES - 10 CFR §20.403 AND 10 CFR §20.405

A. Types of Overexposures

One requirement of the above-referenced sections of Part 20, Title 10, Chapter 1, Code of Federal Regulations, is that all persons licensed by the NRC must submit reports of all incidents involving personnel radiation exposures that exceed certain levels. Based on the magnitude of the exposure, the reports may be placed into one of three categories:

1. Category A

   10 CFR §20.403(a) - Exposure of the whole body of any individual to 25 rems or more; exposure to the skin of the whole body of any individual to 150 rems or more; or exposure of the extremities (feet, ankles, hands or forearms) of any individual to 375 rems or more. The Commission must be notified immediately of these events.

2. Category B

   10 CFR §20.403(b) - Exposure of the whole body of any individual to 5 rems or more; exposure of the skin of the whole body of any individual to 30 rems or more; or exposure of the extremities to 75 rems or more. The Commission must be notified within 24 hours of these events.

3. Category C

   10 CFR §20.405 - Exposure of an individual to radiation or concentrations of radioactive material that exceeds any applicable quarterly limit in Part 20 or in the licensee's license, but is less than the values given above. This includes reports of whole body exposures that exceed 1.25 rems, or that exceed 3 rems, as previously discussed on page 28. Reports of skin exposures that exceed 7.5 rems and extremity exposures that exceed 18.75 rems are included, and reports of exposures of individuals to concentrations in excess of the levels given in 10 CFR §20.103 and Appendix B, usually fall into this category as well. These reports must be submitted to the Commission within 30 days of the occurrence.

A short description of the incidents occurring in 1979 that resulted in nine individuals receiving exposures of the magnitude indicated in Category A or B is given in Appendix B to this report.

B. Summary of Overexposures

Table 14 summarizes all of the occupational overexposures to external sources of radiation as reported by Commission licensees pursuant to §20.403 and §20.405 during the years 1977 through 1979. In 1979, it shows the number of individuals that incurred various types of overexposures while employed by one of several types of licensees. Most of the overexposures included in the "All Others" category come from research facilities and universities. In 1979 the total number of individuals reported as being overexposed was 67, a

TABLE 14

PERSONNEL OVEREXPOSURES TO EXTERNAL RADIATION

1977 - 1979

Year	License Category	Persons and Doses	Type of Overexposure								
			Whole Body Doses (rems)			Skin Doses (rems)			Extremity Doses (rems)		
			>1.25<5 .00	>5.00<25	>25	>7.5<30.0	>30<150	>150	>18.75<75.00	>75<375	>375
1979	Industrial Radiography	No. of Persons	8[a]	3							
		Sum of Doses (rems)	25.9	34.6							
	Power Reactor Facilities	No. of Persons	15	1		5	1	2[b]	1	1[c]	
		Sum of Doses (rems)	34.8	10.0		94.6	40.0	327	54.0	147	
	Medical Facilities	No. of Persons	11						2		
		Sum of Doses (rems)	21.7						60.0		
	Marketing and Manuf. &	No. of Persons							10		
		Sum of Doses (rems)							265.1		
	All Others	No. of Persons	1	2[d]		2			2		
		Sum of Doses (rems)	3.1	29.0		31.1			89.6		
1979	Totals	No. of Persons	35[a]	6[d]		7	1	2[b]	15	1[c]	
		Sum of Doses (rems)	85.5	73.6		125.7	40.0	327	468.1	147	
1978	Totals	No. of Persons	16	5	1	2			2	1	
		Sum of Doses (rems)	51.3	73.5	27.3	18.2			49.1	150	
1977	Totals	No. of Persons	45	2	1	3			10		1
		Sum of Doses (rems)	98.6	23.2	220	39.9			224.8		630

[a]One of these persons simultaneously received an extremity overexposure of 46 rems which is not shown in the Extremity section of the table.

[b]Two of these persons simultaneously received extremity overexposures of 161 and 166 rems which are not shown in the Extremity section of the table.

[c]This person simultaneously received a skin overexposure of 13 rems which is not shown in the Skin section of the table.

[d]One of these persons simultaneously received an extremity overexposure of 45 rems which is not whown in the Extremity section of the table.

considerable increase from the number (27) reported in 1978, but more consistent with the number reported in previous years. In 1979 the highest whole body overexposure was 17.0 rems, while in 1978 it was 27.3 rems,and in 1977 it was 220 rems.

There were a few (6) reports of personnel exposures to airborne concentrations of radioactive materials in excess of applicable limits in 1979. There were two instances in which the estimated intake of radioactive material exceeded the quarterly intake limit, equivalent to exposure for 520 hours at the maximum permissible concentrations (MPC-hours) compared to one case in 1978. One of the two incidents reported in 1979 exceeded the annual intake limit, equivalent to 2000 MPC-hours, and is also described in Appendix B.

References

1. Cool, W. S., "Occupational Radiation Exposure at NRC-Licensed Facilities 1975," U.S. Nuclear Regulatory Commission, NUREG-0419, March 1978.

2. Centaur Associates, Inc., "An Economic Study of the Radionuclides Industry," February 12, 1980, Contract #NRC-07-78-431.

3. United Nations, "Draft of Annex H to the Report of the Scientific Committee on the Effects of Atomic Radiation", General Assembly of Official Records, November 16, 1981, United Nations, New York.

4. Personal Communication with S. McGuire, Office of Standards Development, U.S. Nuclear Regulatory Commission.

5. Cook, J., Nelson, D., "Occupational Exposures to Ionizing Radiation in the United States: A Comprehensive Summary for 1975," U.S. Environmental Protection Agency, EPA 520/4-80-001, November 1980.

6. U.S. Nuclear Regulatory Commission, "Report to Congress on Abnormal Occurrences January-March 1980, "USNRC Report NUREG-0090, Vol. 3, No. 1, September 1980.

7. National Academy of Sciences, "The Effects on Populations of Exposure to Low Levels of Ionizing Radiation: 1980," Committee on the Biological Effects of Ionizing Radiations, July 1980. Available from the National Academy Press, 2101 Constitution Avenue, N.W., Washington, D.C. 20418.

APPENDIX A

SECTION III AND TABLES 8 AND 10 OF THE
1978 ANNUAL REPORT, NUREG-0593

III. SUMMARY OF ANNUAL DATA BY PROGRAM CODE

A. Definitions of Program Codes for the Use of Byproduct Materials* and Summary of Data

In order to assign the 6,300 reports submitted by NRC licensees to a type of licensed material and activity, the five-digit number which the NRC assigns to each license to designate the major activity of the licensee was utilized. The NRC uses some 51 program codes to classify the approximately 8,300 licensees that are subject to the reporting requirement of §20.407. Some of these "program codes" narrowly define an activity that corresponds to an industrial segment, such as radiography, while others have such broad definitions that they could simultaneously be part of several industrial segments. This is especially true for the Institutional and Academic program codes which permit the use of radionuclides in both research and instruction/training activities.[2] Also, the NRC may change licensing procedures such that program codes may be added or deleted, or the definition of the program code may change slightly from year to year. In addition, many of the NRC licensees having two or more NRC licenses, or an NRC license and one or more State licenses, provided only one annual report covering all individuals that were monitored. Therefore, the spectrum of radioactive materials and activities encompassed by licensees in one category may be even broader than is indicated in the descriptions of the program codes.

The submission of a single report for two or more license numbers, each of which may have a different program code, also caused problems in the collation of the data. Since the data on the single report could not be separated by program code, all of the information (number of individuals monitored and their collective dose) was credited to the program code describing the activity and material thought to be the source of the majority of the incurred dose. This methodology probably results in an upward bias in these program codes and a downward bias in the other "secondary" program codes. The bias would have less effect on categories of licensees that encompass most of the primary and secondary program codes, but may be considerable for some categories consisting of a small number of program codes.

In order to facilitate the description of these 51 program codes, they were grouped into 29 functional categories. Following the descriptions of the

*Byproduct materials are man-made radioactive materials (except special nuclear material) yielded in, or made radioactive by, exposure to the radiation incident to the process of producing or utilizing special nuclear materials. Although byproduct materials do include activation products from nuclear reactors and plutonium-beryllium neutron sources, they do not include activation products from other neutron sources such as Californium-252 or accelerators.

[2] Centaur Associates, Inc., "An Economic Study of the Radionuclides Industry," February 12, 1980, Contract #NRC-07-78-431.

program codes in each of the 29 categories is a summary of the annual data reported by those types of licensees. A comparison of some of the data with that extracted from annual reports voluntarily submitted by about 18% of the NRC licensees in 1975 is also included. Tables 1, 2, and 3 present the 1978 data in tabular form, and Appendix A presents the 1975 data in the form of certain tables taken from the previously referenced report NUREG-0419[3].

1. Academic-Broad and Academic-Other Licenses (Program Codes 01100 and 01200)

Academic-Broad and Academic-Other licenses are issued to educational institutions to allow them to use radionuclides for teaching, training, and some research purposes. The Broad licenses are usually issued to the larger institutions where there is often quite a diversity in the utilization of various radionuclides. The kinds and uses of radionuclides may change frequently, even at the same institution. Academic-Other licenses are more limited in scope, and changes in the types and uses of radionuclides may necessitate the NRC's approval and issuance of amendments to the license. Typical uses include tracer studies in biology, chemistry and physics, the demonstration of equipment and gauges, irradiation of materials, carbon-14 dating, calibration of equipment, the identification of substances in compounds, etc.

Reports were credited to a total of 284 license numbers, or 73% of the 388 licenses having an Academic-Broad or an Academic-Other program code. Several institutions having one of these licenses and one or more other types of NRC license, such as irradiator and research reactor licenses, included all monitored individuals on one report. Since the exposure information was not separated by license number, about 25% of the reports may have included exposure resulting from other types of activities. Some 103 reports indicated that personnel monitoring was not required or not provided. Nineteen reports had two or more license numbers and program codes, but all except three of them were credited to one of the two program codes in this group. The 162 reports indicating that monitoring was done were summed to reveal that a total of 18,253 individuals were monitored and that 5,862 of them received measurable exposures. The highest dose was between 4 and 5 rems, while 98.8% of the doses were less than 0.50 rem. The collective dose was calculated to be 772 man-rems, which yielded an average measurable dose per worker of 0.13 rem. The average annual collective dose per license was estimated to be 3 man-rems.

Extrapolation of this data to account for the number of licensees that did not report indicates that there may be a total of 22,730 individuals being monitored annually, and a collective dose of 920 man-rems being incurred. This can be compared to the figures of 27,000 individuals and 680 man-rems that were extrapolated from the data obtained from the voluntary annual reports for 1975.

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[3]Ibid, Footnote 1, p. 2.

TABLE 1
DISTRIBUTION OF ANNUAL WHOLE BODY EXPOSURES BY LICENSE PROGRAM CODE
1978

License Category & (Program Code)		Total No. Monitored	EXPOSURE RANGES (REMS) Less Than Measurable	Measurable <0.10	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	7.00-8.00	8.00-9.00	9.00-10.00	10.00-11.00	11.00-12.00	12+
BYPRODUCT MATERIAL CODES																				
Academic																				
Academic-Broad	(01100)	9,263	5,478	2,724	683	212	61	44	51	8	1	1								
Academic-Other	(01200)	8,990	6,913	1,558	299	163	33	9	5	6	1	2								
Medical																				
Institutional-Broad	(02110)	23,883	13,798	6,942	1,772	747	265	140	135	30	9	2	0	1	1					
Institutional-Other	(02120)	32,771	11,310	11,784	4,345	2,692	1,115	548	697	177	45	27	10	6	1	2	1	0	1	1
Private Practice	(02200)	1,015	286	343	195	95	37	20	28	6	1	2	2							
Teletherapy	(02300)	2,077	9[illegible]	691	258	129	36	20	26	5										
Other Medical	(02400)	951	620	287	29	6	5	2	1	1										
Medical Distribution	(02500)	194	62	71	26	15	14	4	2											
Pacemakers, Instit.	(02600)	0																		
Marketing																				
Marketing-Broad	(03211)	8,849	3,593	2,142	1,118	831	446	246	317	83	28	23	13	8	1					
Marketing-Other	(03212)	5,461	3,638	1,398	227	77	30	17	42	15	11	3	2	1						
Radiography																				
Radiography, one location	(03310)	2,187	1,246	478	195	110	46	32	54	12	9	2	3							
Radiography, multi. locations	(03320)	10,906	[illegible],162	2,595	935	738	431	276	533	150	52	26	3	2	0	0	1	1	0	
Research & Development																				
R & D-Broad	(03610)	11,319	8,958	2,034	150	115	28	6	11	5	11	1								
R & D-Other	(03620)	6,409	4,732	1,486	138	40	9	2	2											
Other Byproduct																				
Well Logging	(03110)	5,044	1,228	1,545	1,045	539	261	140	184	60	24	9	6	1	0	1	0	0	1	
Other Measuring Systems	(03120)	17,553	[illegible]	3,745	629	156	42	20	24	6	2	2	1	0	0	[illegible]				
Nuclear Laundry	(03218)	14	10	0	[illegible]	1														
Leak Test	(03[illegible])	[illegible]	82	21	11	10	3	1	0	1										
Waste Disposal-Burial	(03231)	[illegible]8	3	10	3	0	2	0	1											
Waste Disposal-Other	(03232)	314	158	90	17	14	2	8	6	8	10	1								
Power Sources	(03[illegible])	[illegible]																		
Irradiator, <10,000 Ci	(03511)	1,272	1,044	184	20	10	3	2	2	1										
Irradiator, >10,000 Ci	(03520)	1,622	1,088	335	122	47	19	8	10	2										
Civil Defense	(03710)	1,033	601	1,097	131	0	2	1	1											

TABLE 1 - Continued
DISTRIBUTION OF ANNUAL WHOLE BODY EXPOSURES BY LICENSE PROGRAM CODE
1978

License Category & (Program Code)		Total No. Monitored	EXPOSURE RANGES (REMS)																
			Less Than Measurable	Measurable <0.10	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	7.00-8.00	8.00-9.00	9.00-10.00	10.00-11.00	11.00-12.00	12+
SOURCE MATERIAL CODES																			
Uranium Mills	(11100)	946	209	277	248	162	23	17	7	2	1								
Uranium Sol. Mines	(11500)	0																	
Other Uranium <150 kg.	(11200)	33	11	21	0	1													
Other Uranium >150 kg.	(11300)	1,439	822	332	117	78	49	18	19	4									
UF_6 Production Plants	(11400)	623	58	274	116	116	27	18	14										
SPECIAL NUCLEAR MATERIAL CODES																			
Fuel Fab. & Processing																			
Plutonium Fuel Fab. & Scrap Recovery	(21110)	680	374	201	77	18	3	2	5										
Plutonium Fuel Fab.	(21120)	1,211	514	311	100	79	45	29	79	41	7	6							
UF_6 Cnvrsn, U Fuel Fab. & Scrap Recovery	(21210)	4,688	2,201	1,256	544	323	180	114	64	6									
Uranium Fuel Fab. & Scrap Recovery	(21220)	242	123	90	21	7	0	1											
Uranium Fuel Fab.	(21230)	4,362	1,942	1,604	408	193	91	41	69	12	1	1							
Fuel Reprocessing	(43110)	122	51	20	15	23	10	0	3										
Other SNM																			
Uranium Other Uses, Incl. R & D	(21240)	386	97	205	43	19	5	2	12	2	0	0	1						
Plutonium Other Uses, Incl. R & D	(21130)	2,290	1,326	737	153	47	22	3	2										
Unencapsulated SNM	(22110)	143	128	2	3	1	1	1	5	2									
Neutron Sources	(22120)	1,641	1,257	327	31	14	6	2	3	0	0	0	1						
Power Sources	(22130)	0																	
Uranium Sources	(22200)	167	148	14	3	0	1	0	0	1									
Other SNM Sources	(22140)	259	218	28	5	4	1	1	2										
Institutional Cardiac Pacemakers	(22160)	30	15	8	1	2	1	0	2	0	1								
Fuel Storage	(23100)	119	65	5	4	5	6	12	21	1									
SNM Storage	(23200)	934	930	4															
REACTOR CODES																			
Research & Test Reactors																			
Test Reactors	(42140)	0																	
Research Reactors	(42150)	2,644	1,780	670	104	27	13	7	23	14	6								
Critical Experiment Facilities	(42160)	0																	
Power Reactors																			
Gas Cooled Power Reactors	(41120)	930	896	34															
Light Water Power Reactors	(41111)	77,523	30,278	17,785	7,002	5,537	3,410	2,507	6,415	2,989	1,079	418	67	26	8	0	0	0	0	2

TABLE 2
ANNUAL EXPOSURE DATA BY LICENSE PROGRAM CODE
1978

License Category & (Program Code)		Fraction (%) of Licenses Reporting	Reports Showing Monitoring was Done	Reports Credited to Other Prog. Code	Total Number of Persons Monitored	Average Individual Dose (REMS)	No. of Persons with Measurable Doses	Average Measurable Dose (REMS)	Total Collective Dose (MAN-REMS)	Average Collective Dose per License (MAN-REMS)	*Extrapolated No. of Persons Monitored	*Extrapolated No. with Measurable Doses	*Extrapolated Collective Dose (MAN-REMS)	**Ratio R
BYPRODUCT MATERIAL CODES														
Academic														
Academic-Broad	(01100)	33/36 (92%)	27	2	9,263	0.06	3,785	0.13	516	16	10,070	4,110	560	0.64
Academic-Other	(01200)	251/352 (71%)	135	17	8,990	0.03	2,077	0.12	256	1	12,660	2,930	360	0.62
Medical														
Institutional-Broad	(02110)	90/95 (95%)	87	3	23,843	0.07	10,045	0.15	1,559	17	25,100	10,570	1,640	0.74
Institutional-Other	(02120)	1434/1644 (87%)	1,362	22	32,771	0.17	21,452	0.25	5,464	4	37,670	24,660	6,280	1.27
Private Practice	(02200)	163/359 (45%)	121	8	1,015	0.20	729	0.28	208	1	2,260	1,620	460	0.72
Teletherapy	(02300)	326/443 (74%)	110	209	2,077	0.11	1,165	0.18	220	1	2,810	1,570	300	1.42
Other Medical	(02400)	56/70 (80%)	38	7	951	0.03	331	0.09	31	1	1,190	410	40	0.53
Medical Distribution	(02500)	34/45 (76%)	12	16	194	0.15	132	0.21	29	1	260	170	40	0.00
Pacemakers, Instit.	(02600)	6/9 (67%)	0	4	0	0	0	0.00	0	0	0	0	0	0.00
Marketing														
Marketing-Broad	(03211)	46/50 (92%)	40	1	8,849	0.24	5,256	0.40	2,124	46	9,620	5,710	2,310	1.81
Marketing-Other	(03212)	183/221 (83%)	131	8	5,461	0.06	1,823	0.18	342	2	6,580	2,200	410	2.00
Radiography														
Radiography, one location	(03310)	138/143 (97%)	135	0	2,187	0.15	941	0.34	324	2	2,250	970	330	1.95
Radiography, multi. locations	(03320)	199/223 (89%)	190	0	10,906	0.24	5,744	0.46	2,626	13	12,250	6,450	2,950	2.16
Research & Development														
R & D-Broad	(03610)	77/77 (100%)	65	4	11,319	0.02	2,361	0.11	266	3	11,319	2,361	266	1.19
R & D-Other	(03620)	305/388 (79%)	181	14	6,409	0.02	1,677	0.07	124	<1	8,110	2,120	160	0.06
Other Byproduct														
Well Logging	(03110)	62/78 (79%)	50	2	5,044	0.27	3,816	0.36	1,358	22	6,380	4,830	1,720	1.72
Other Measuring Systems	(03120)	1852/2555 (71%)	622	71	17,553	0.03	4,522	0.10	461	<1	24,720	6,370	650	0.66
Nuclear Laundry	(03218)	3/4 (75%)	3	0	14	0.07	4	0.22	1	<1	20	10	0	0.00
Leak Test	(03220)	18/21 (86%)	13	0	129	0.09	47	0.25	12	1	150	50	10	1.03
Waste Disposal-Burial	(03231)	1/1 (100%)	1	0	18	0.17	15	0.20	3	3	18	15	3	0.00
Waste Disposal-Other	(03232)	12/13 (92%)	8	3	314	0.28	156	0.57	89	7	340	170	100	3.54
Power Sources	(03400)	1/1 (100%)	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00
Irradiator, <10,000 Ci	(03510)	129/175 (74%)	15	87	1,272	0.02	228	0.11	27	<1	1,720	310	40	0.73
Irradiator, ≥10,000 Ci	(03520)	45/53 (85%)	14	27	1,622	0.05	534	0.16	89	2	1,910	630	100	0.70
Civil Defense	(03710)	78/102 (76%)	40	28	1,833	0.04	1,232	0.06	81	1	2,410	1,620	110	0.05

*The extrapolated figures were obtained by dividing the reported number (individuals or collective dose) by the fraction of the licensees reporting.

**The ratio of the fraction of the collective dose due to annual doses greater than 1.5 rems in the observed distribution to the fraction for the UNSCEAR reference distribution. (See Section IV.A., p.)

TABLE 2 - Continued
ANNUAL EXPOSURE DATA BY LICENSE PROGRAM CODE
1978

License Category & (Program Code)		Fraction (%) of Licenses Reporting	Reports Showing Monitoring was Done	Reports Credited to Other Prog. Code	Total Number of Persons Monitored	Average Individual Dose (REMS)	No. of Persons with Measurable Doses	Average Measurable Dose (REMS)	Total Collective Dose (Man-REMS)	Average Collective Dose per License (Man-REMS)	Extrapolated No. of Persons Monitored	*Extrapolated No. with Measurable Doses	*Extrapolated Collective Dose (Man-REMS)	**Ratio R
SOURCE MATERIAL CODES														
Uranium Mills	(11100)	15/16 (94%)	9	3	946	0.18	737	0.22	166	11	1,010	780	180	0.41
Uranium Sol. Mines	(11500)	2/2 (100%)	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00
Other Uranium <150 kg.	(11200)	46/58 (79%)	2	17	33	0.03	22	0.06	1	<1	40	30	0	0.00
Other Uranium >150 kg.	(11300)	183/289 (63%)	33	89	1,439	0.10	617	0.24	151	1	2,280	980	240	0.79
UF_6 Production Plants	(11400)	2/2 (100%)	2	0	623	0.21	565	0.23	131	66	623	565	131	0.40
SPECIAL NUCLEAR MATERIAL CODES														
Fuel FAB & Reprocessing														
Plutonium Fuel Fab. & Scrap Recovery	(21110)	3/3 (100%)	3	0	680	0.06	306	0.13	41	14	680	306	41	0.45
Plutonium Fuel Fab.	(21120)	2/3 (67%)	2	0	1,211	0.32	697	0.56	389	194	1,810	1,040	580	2.71
UF_6 Cnvrsn, U Fuel Fab & Scrap Recovery	(21210)	5/5 (100%)	5	0	4,688	0.13	2,487	0.24	602	120	4,688	2,487	602	0.52
Uranium Fuel Fab & Scrap Recovery	(21220)	3/3 (100%)	2	1	242	0.05	119	0.05	12	4	242	119	12	0.00
Uranium Fuel Fab	(21230)	7/8 (88%)	7	0	4,362	0.10	2,420	0.18	458	65	4,960	2,750	520	0.97
Fuel Reprocessing	(43110)	1/1 (100%)	1		122	0.19	71	0.32	23	23	122	71	23	0.48
Other SNM														
Uranium-Other Uses, incl. R&D	(21240)	14/17 (82%)	6	6	386	0.15	289	0.20	58	14	470	350	70	1.66
Plutonium Other Uses, incl. R&D	(21130)	4/6 (67%)	1	0	2,290	0.04	964	0.10	101	25	3,420	1,440	150	0.07
Unencapsulated SNM	(22110)	10/15 (67%)	1	5	143	0.13	15	0.99	15	2	210	20	20	2.89
Neutron Sources	(22120)	189/261 (72%)	35	91	1,641	0.02	384	0.11	43	<1	2,280	530	60	0.89
Power Sources	(22130)	1/3 (33%)	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00
Uranium Sources	(22200)	27/36 (75%)	6	17	167	0.02	19	0.22	4	<1	220	30	10	2.85
Other SNM Sources	(22140)	40/64 (63%)	10	15	259	0.03	41	0.20	8	<1	410	60	10	0.93
Institutional Pacemakers	(22160)	87/172 (51%)	5	49	30	0.27	15	0.53	8	<1	60	30	20	2.93
Fuel Storage	(23100)	3/4 (75%)	2	0	119	0.43	54	0.94	51	17	160	70	70	1.77
SNM Storage Only	(23200)	6/10 (60%)	3	3	934	0.00	4	0.05	0	0	1,560	10	0	0.00
REACTOR CODES														
Research & Test Reactors														
Test Reactors	(42140)	4/4 (100%)	0	4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Research Reactors	(42150)	58/76 (76%)	28	28	2,644	0.06	864	0.19	167	3	3,480	1,140	220	2.18
Critical Experiment Facilities	(42160)	1/4 (25%)	0	0	0	0.00	0	0.00	0	0	0	0	0	0.00
Power Reactors														
Gas Cooled Reactors	(41120)	1/1 (100%)	1	0	930	0.00	24	0.05	2	2	930	24	2	0.00
Light Water Reactors	(41111)	69/69 (100%)	69	0	77,523	0.41	47,245	0.68	31,910	462	77,523	47,245	31,910	2.88
TOTALS		6298/8290 (76%)	3,633	861	253,446	0.20	126,031	0.40	50,550	8	287,000	139,930	53,710	

*The extrapolated figures were obtained by dividing the reported number (individuals or collective dose) by the fraction of the licensees reporting.

**The ratio of the fraction of the collective dose due to annual doses greater than 1.5 rems in the observed distribution to the fraction for the UNSCEAR reference distribution. (See Section IV.A., p.)

TABLE 3
ANNUAL EXPOSURE DATA BY LICENSE TYPE
1978

LICENSE CATEGORY	No. of Monitored Individuals Reported	Workers With Measurable Doses Reported	Collective Dose, Man-rems	Extrapolated Individuals Monitored	Extrapolated Workers With Measurable Doses	Extrapolated Collective Dose, Man-rems	Average Individual Dose, Rems	Average Measurable Dose, Rems
Byproduct Material								
Academic	18,253	5,862	772	22,730	7,040	920	0.04	0.13
Medical	60,851	33,854	7,511	69,290	39,000	8,760	0.13	0.22
Marketing	10,337	5,193	1,615	12,230	6,020	1,870	0.15	0.31
*Manufacturing & Distribution	3,973	1,886	851	3,973	1,886	851	0.21	0.45
Radiography	13,093	6,685	2,950	14,500	7,420	3,280	0.23	0.44
Research & Development	17,728	4,038	390	19,430	4,480	430	0.02	0.10
Other Byproduct Material	27,799	10,554	2,121	37,670	14,010	2,730	0.07	0.19
Total Byproduct Material	152,034	68,072	16,210	179,820	79,860	18,840	0.11	0.24
Source Material Total	3,041	1,941	449	3,950	2,350	550	0.14	0.23
Special Nuclear Material								
Fuel Fab. & Reprocessing	11,305	6,100	1,525	12,500	6,770	1,780	0.14	0.26
Other SNM	5,969	1,785	288	8,790	2,540	410	0.05	0.16
Total SNM	17,274	7,885	1,813	21,290	9,310	2,190	0.10	0.23
Research & Test Reactors	2,644	864	167	3,480	1,140	220	0.06	0.19
Gas Cooled Power Reactors	930	24	2	930	24	2	0.00	0.08
Light Water Power Reactors	77,523	47,245	31,910	77,523	47,245	31,910	0.41	0.67
GRAND TOTALS	253,446	126,031	50,551	287,000	139,930	53,710	0.19	0.38

*Subset of "Marketing" meeting the criteria in §20.408(a)(4) that have previously been required to report.

2. Institutional-Broad, Institutional-Other, and Teletherapy Licenses (Program Codes 02110, 02120, and 02300)

Institutional-Broad licenses are usually issued to larger medical institutions to allow them to use a wide range of radionuclides in medical research, diagnosis, and therapy. The Institutional-Other licenses are normally issued to a hospital, medical center, or other medical facility to allow the use of radionuclides in well established, more routine, diagnostic and therapeutic procedures. The use of radionuclides in research and diagnosis encompasses *in vivo* and *in vitro* analyses. Therapeutic applications of radionuclides focus on cancer treatment either by drugs containing radionuclides or by beam therapy. Institutions and physicians desiring to use the radiation emitted by a sealed source, usually a fairly large cobalt-60 source, for therapeutic purposes are also issued a separate teletherapy license. These three codes were grouped because more than half of the institutions having a Teletherapy license also had an Institutional license, and many of them filed one report covering all license numbers.

Reports were credited to a total of 1,850 license numbers, or 85% of the 2,182 licenses having one of these three program codes. Reports for 57 licenses indicated that personnel monitoring was not required or not provided. Some 234 reports had two or more license numbers and program codes, but all except 25 of them were credited to one of the three program codes in this group. The 1,559 reports indicating that monitoring was done were summed to reveal that a total of 58,691 individuals were monitored, and that 32,662 of them received measurable exposures. Other than the accidental overexposure which exceeded 12 rems (see Appendix B) that was reported by a licensee having an Institutional-Other type license, the highest dose was between 11 and 12 rems, while 94% of the doses were less than 0.50 rem. The collective dose was calculated to be 7,243 man-rems which yielded an average measurable dose per worker of 0.22 rem, and an average collective dose per license of about 3 man-rems. It should be noted that most of the licensees in this group also possess and use x-ray machines and radionuclides (such as radium) that are not licensed by the NRC but that do produce and emit ionizing radiation. Many of these licensees reported all monitored individuals, many of whom may have received the major portion of their exposure from non-licensed sources of radiation. Therefore, particularly for these types of licenses, one should not infer that all of the collective dose is due to exposure to NRC-licensed material.

Extrapolation of this data to account for those licensees not reporting indicates there may be a total of 65,580 individuals being monitored, and a collective dose of 8,220 man-rems being incurred. This can be compared to the figures of 88,800 monitored individuals and 11,900 man-rems that were extrapolated from the data obtained from the voluntary annual reports for 1975.

3. Private Practice Licenses (Program Code 02200)

Private Practice licenses are usually issued to a physician or a group of physicians to allow the use of radionuclides in well established diagnostic and therapeutic procedures in their offices. A total of 163 licenses, or 45%

of the 359 licenses assigned a Private Practice program code, were credited with submitting an annual report. Reports for 34 licenses stated that personnel monitoring was not required or not provided, and eight reports having two or more license numbers and program codes were credited to other program codes. The 121 reports indicating that monitoring was done were summed to reveal that a total of 1,015 individuals were monitored and that 729 of them received measurable exposures. The highest dose reported was between 5 and 6 rems, while 91% of the doses were less than 0.50 rem. The collective dose was calculated to be 208 man-rems to yield an average measurable dose per worker of 0.28 rem, and an average collective dose per license of about 1 man-rem. As was the case for Institutional and Teletherapy licensees, many of these licensees probably included individuals exposed to non-NRC licensed sources of radiation in their annual reports.

Extrapolation of this data to account for the number of licensees not reporting indicates that there may be a total of 2,260 individuals being monitored and a cumulative dose of 460 man-rems being incurred. This can be compared to the figures of 4,700 monitored individuals, and 1,320 man-rems that were extrapolated from the voluntary annual reports submitted for 1975. One reason for the large difference in the data for 1975 and 1978 is the fact that the number of these licenses has decreased by 50%.

4. Other Medical Licenses (Program Code 02400)

Other Medical licenses are issued to individuals or facilities to allow the use of radionuclides in medical activities that were not described above, such as those of veterinarians and clinical labs performing in-vitro analysis. A total of 56, or 80% of the 70 licenses assigned an Other Medical license, were credited with submitting an annual report. Reports for 11 licenses stated that personnel monitoring was not required or not provided, and seven reports having two or more license numbers and program codes were credited to other program codes. The 38 reports indicating that monitoring was done were summed to reveal that a total of 951 individuals were monitored, and that 331 received measurable exposures. The highest dose was between 2 and 3 rems, while 99% of the doses were less than 0.50 rem. The collective dose was calculated to be 31 man-rems to yield an average measurable dose per worker of 0.09 rem, and an average collective dose per license of about 1 man-rem.

Extrapolation of this data to account for those licensees not reporting indicates that there may be some 1,190 individuals being monitored, and a collective dose of 40 man-rems being incurred. This can be compared to the figures of 2,200 individuals and 280 man-rems that were extrapolated from the data obtained from the voluntary annual reports for 1975. Again, the large difference may be partially due to the fact that the number of these licenses decreased by about 30% between 1975 and 1978.

5. Medical Distribution Licenses (Program Code 02500)

These licenses are issued to nuclear pharmacies to allow them to distribute radiopharmaceuticals to hospitals and physicians. They usually purchase

various radioactive materials in bulk from larger firms, prepare individual patient doses, and accumulate them in a central location so that they can be readily distributed.

Reports were credited to a total of 34, or 76% of the 45 licenses assigned a Medical Distribution license. Reports for six licenses stated that monitoring was not required, and 16 reports having two or more license numbers and program codes were credited to other program codes. The 12 reports indicating that personnel were monitored were summed to reveal that a total of 194 individuals were monitored and that 132 of them received measurable doses. The highest dose was between 1 and 2 rems, while 90% of the doses were less than 0.50 rem. The collective dose was calculated to be 29 man-rems, which yielded an average measurable dose per worker of 0.21 rem, and an average collective dose per license of about 1 man-rem.

Extrapolation of this data to account for those not reporting indicates that there may be some 260 individuals being monitored, and a collective dose of 40 man-rems being incurred. This can be compared to the figures of 250 monitored individuals and 20 man-rems that were projected from the 1975 voluntary annual reports.

6. Institutional Byproduct Pacemaker Licenses (Program Code 02600)

These licenses are issued to medical facilities and physicians to allow the surgical implantation of pacemakers that are powered by a device containing byproduct materials. None of this type of pacemaker is presently being manufactured, and there were only nine such licenses in effect during 1978. Six of the nine licenses were credited with submitting an annual report. Two reports stated that monitoring was not required, and the data for the remaining four license numbers were combined with other license numbers having an Institutional-Other program code. Since the devices are constructed such that any individual handling them would receive only minimal exposure, the reports were credited to the other program code.

7. Well Logging Licenses (Program Code 03110)

Well Logging licenses are issued to firms to allow the use of radionuclides for surveying wells to obtain geological information. This testing procedure is primarily used in oil exploration to identify underground oil and water. Annual reports were credited to a total of 62, or 79% of the 78 licenses assigned to a Well Logging program code. Reports for ten licenses stated that personnel monitoring was not required or not provided. The 50 reports indicating monitoring was done were summed to reveal that a total of 5,044 individuals were monitored, and that 3,816 of them received measurable doses. The highest dose was between 11 and 12 rems, while 86% of the doses were less than 0.50 rem. The collective dose was calculated to be 1,358 man-rems to yield an average measurable dose per worker of 0.36 rem, and an average collective dose per license of about 22 man-rems.

Extrapolation of this data to account for those not reporting results in a total of 6,380 individuals being monitored, and a collective dose of 1,720 man-rems being incurred. This can be compared to the figures of 6,800 individuals and 3,000 man-rems that were extrapolated from the 1975 voluntary annual reports.

8. Other Measuring Systems Licenses (Program Code 03120)

These licenses are issued to allow the use of measuring devices that contain radionuclides. This group includes such devices as gas chromatographs and gauges which are frequently used for measuring the level of material, quality control testing in industrial processes, and for soil and construction testing services. In many cases, the licensee is not required to provide personnel radiation monitoring because of the inherent safety of the devices. Frequently, the equipment is serviced and leak tested by the manufacturer or lessor of the equipment.

A total of 1,825 license numbers, or 71% of the 2,555 licenses assigned an Other Measuring Systems program code, were credited with submitting an annual report. Reports for 1,132 licenses stated that personnel monitoring was not required or not provided, and 71 reports having two or more license numbers and program codes were credited to other program codes. The 622 reports indicating that personnel monitoring was done were summed to reveal that a total of 17,553 individuals were monitored, and that 4,522 of them received measurable exposures. The highest dose was between 8 and 9 rems, while 99% of the doses were less than 0.50 rem. The collective dose was calculated to be 461 man-rems, which yielded an average measurable dose per worker of 0.10 rem, and an average collective dose per license that was less than 1 man-rem.

Extrapolation of this data to account for the number of licensees not reporting indicates that there may be some 24,720 individuals being monitored, and a collective dose of 650 man-rems being incurred. This can be compared to the figures of 19,700 monitored individuals and 1,120 man-rems that were extrapolated from the 1975 voluntary annual reports.

9. Marketing-Broad and Marketing-Other Licenses* (Program Codes 03211 and 03212)

Marketing-Broad and Marketing-Other licenses are issued to allow the manufacture and distribution of radionuclides in various forms for a number of diverse purposes. Again, the Broad licenses are issued to the larger facilities having a more comprehensive radiological protection program, and the Other licenses are usually issued to the smaller firms requiring a more restrictive license. Some firms are medical suppliers that process, package or distribute products such as diagnostic test kits, radioactive surgical implants, and tagged radiochemicals for use in medical research, diagnosis and therapy. Other firms are suppliers of industrial radionuclides and are involved

*Includes the category "Manufacturers and Distributors" that was previously required to report annually. See Section IV.A.1.

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 non-medical research. Other firms are involved with the manufacture, assembly and distribution of various products that contain radionuclides.

A subset, usually called "Manufacturers & Distributors," of this group is one of the four categories of licensees that has been required to submit annual reports to the NRC for the past 10 years. This subset consists of approximately 25 licensees that process and distribute large quantities of byproduct material as defined in 10 CFR §20.408(a)(4). Information reported by this subset in 1978 is further discussed in Section IV.A.1. The following figures and analysis are based on reports for all licenses having program codes 03211 or 03212, including the subset.

Reports were credited to a total of 229 license numbers, or 85% of the 271 licenses assigned one of the Marketing program codes. Reports for 49 licenses stated that personnel monitoring was not required or not provided. Nine reports had two or more license numbers and program codes, four of which had one of the two program codes in this group. The 171 reports indicating that monitoring was done were summed to reveal that 14,310 individuals were monitored, and that 7,079 of them received measurable exposures. The highest dose was between 7 and 8 rems, while 91% of the doses were less than 0.50 rem. The collective dose was calculated to be 2,466 man-rems to yield an average measurable exposure per worker of 0.34 rem, and an average collective dose per license of about 11 man-rems.

Extrapolation of this data to account for those not reporting indicates that there may be some 16,200 individuals being monitored and a collective dose of 2,720 man-rems being incurred. This can be compared to the figures of 14,200 individuals and 2,060 man-rems that were extrapolated from the 1975 voluntary annual reports.

10. Nuclear Laundry Licenses (Program Code 03218)

Nuclear Laundry licenses are issued to allow the cleaning of protective clothing contaminated with radioactive material. Firms in this industry often provide nuclear cleaning services as part of a full line of uniform rental or health physics services.

Three of the four licenses assigned a Nuclear Laundry program code were credited with submitting an annual report. Summing the three reports, each of which indicated that monitoring was done, yielded a total of 14 individuals that were monitored, four of whom received measurable doses. All of the doses were less than 0.50 rem, and the collective dose was found to be 1 man-rem. The average annual dose per worker having a measurable exposure was 0.22 rem, and the average collective dose per license was less than 1 man-rem. Extrapolation of this data to account for those licensees not reporting indicates

that there may be about 20 individuals being monitored. This is nearly the same as that extrapolated from the 1975 data.

11. Leak Test Licenses (Program Code 03220)

Many facilities own or lease equipment, such as gauges or industrial radiographic cameras, that contains radioactive material and has to be periodically tested for leakage. This is usually done by swabbing the potentially contaminated surfaces of the device or, in some cases, the surface of the sealed source, and analyzing the swab for radioactive contamination. Leak Test licenses are issued to allow other firms to conduct the leak testing of these devices, and to possess small amounts of radioactive material in order to detect and measure the quantities of materials deposited on the leak test samples.

A total of 18, or 86% of the 21 licenses assigned a Leak Test program code, were credited with submitting an annual report. Reports for five licenses stated that monitoring was not required or not provided. The 13 reports indicating that personnel monitoring was done were summed to reveal that a total of 129 individuals were monitored and that 47 of them received measurable exposures. The highest dose was between 2 and 3 rems, while 96% of the individuals received doses less than 0.50 rem. The collective dose was calculated to be 12 man-rems to yield an average measurable dose per worker of 0.25 rem, and an average collective dose per license of about 1 man-rem.

Extrapolation of this data to account for those licensees not reporting indicates that there may be a total of 150 individuals being monitored and a collective dose of about 10 man-rems being incurred. These figures are probably overestimates because two of the larger licensees reporting are involved in activities where exposures may be incurred from non-NRC licensed sources of radiation. Projections from the 1975 annual data indicated only 60 monitored individuals, and a collective dose of 3 man-rems.

12. Waste Disposal Licenses, Burial and Other (Program Codes 03231 and 03232)

Waste Disposal licenses are issued to allow the removal, transportation, storage, or burial of radioactive wastes. There was one firm licensed to operate a burial ground for radioactive wastes, and the thirteen firms having Waste Disposal-Other licenses were authorized to collect packaged waste material, transport it, and temporarily store it before transporting it to an authorized burial ground.

A total of 13, or 93% of the 14 licenses assigned a Waste Disposal program code, were credited with submitting an annual report. One report stated that monitoring was not required, and three reports having two or more license numbers and program codes were credited to other program codes. The nine reports indicating that personnel monitoring was done were summed to reveal that a total of 332 individuals were monitored, and that 171 of them received measurable doses. The highest dose was between 4 and 5 rems, while 94% of the

doses were less than 0.50 rem. The collective dose was calculated to be 92 man-rems, which yielded an average dose per worker of 0.28 rem, and an average collective dose per license of about 7 man-rems.

Extrapolation of the data to account for the one licensee not reporting indicates that there may be some 360 individuals being monitored and a collective dose of 100 man-rems being incurred. This can be compared to the figures of 105 monitored individuals and 84 man-rems extrapolated from the 1975 data.

13. Industrial Radiography Licenses, Single and Multiple Locations (Program Codes 03310 and 03320)

These licenses are issued to allow the use of sealed radioactive materials, usually in exposure devices or "cameras", that primarily emit gamma rays for non-destructive testing of pipeline weld joints, steel structures, boilers, aircraft and ship parts, and for other high stress alloy parts. Some firms are licensed to conduct such activities in one location, usually in plant, and others perform radiography at multiple sites in the field.

A total of 337 licenses, or 92% of the 365 licenses assigned a Radiography program code, were credited with submitting an annual report. Twelve reports stated that monitoring was not required or not provided. The 325 reports indicating that monitoring was done were summed to reveal that a total of 13,093 individuals were monitored, and that 6,685 of them received measurable doses. Other than the accidental overexposure of 21.6 rems (see Appendix B), the highest dose was between 10 and 11 rems, while 88% of those monitored had doses less than 0.50 rem. The collective dose was estimated to be 2,950 man-rems, which yielded an average measurable dose per worker of 0.44 rem, and an average collective dose per license of about 9 man-rems.

Extrapolation of this data to account for those not reporting indicates that there may be some 14,500 individuals being monitored and 3,280 man-rems being incurred. Compared to the last few years, this is a considerable increase in the number of monitored individuals, while the collective dose has remained fairly constant. See Section IV.A for further analysis of the information reported by radiography firms.

14. Power Source Licenses (Program Code 03400)

There is one NRC licensee that uses byproduct material to generate heat and power. The U.S. Air Force uses it in a remote weather station in the arctic. No one is required to be monitored.

15. Irradiator Licenses, Less Than or More Than 10,000 Curies (Program Codes 03510 and 03520)

Irradiator licenses are issued to allow the use of large sources of radiation, usually cobalt-60, to produce effects requiring high radiation levels. Primary uses include medical and non-medical research, usually by

universities, and industrial uses, such as the sterilization of medical products and drugs, staining of glass, and treating of hard woods, plastics, and semiconductor materials, etc.

Annual reports were credited to a total of 174 licenses, or 76% of the 228 licenses assigned an Irradiator program code. A majority of the reports (114) were for two or more licenses, and they were credited to other program codes - usually those for medical or academic institutions. Thirty-one reports stated that monitoring was not required or not provided. The remaining 29 reports indicating that monitoring was done were summed to reveal that a total of 2,894 were monitored, and that 762 of them received measurable doses. The highest dose was between 2 and 3 rems, while 97% of the doses were less than 0.50 rem. The collective dose was calculated to be 116 man-rems, which yielded an average dose per worker of 0.15 rem, and an average collective dose per license of about 1 man-rem.

Extrapolation of this data to account for those not reporting indicates that there may be some 3,630 individuals being monitored, and a collective dose of 140 man-rems being incurred. This compares favorably with the number of monitored individuals that was extrapolated from the 1975 data, but the collective dose is nearly three times as large. This could be due to the fact that such a small number (3%) of these licensees submitted a report in 1975.

16. Research and Development Licenses, Broad and Other (Program Codes 03610 and 03620)

These licenses are issued to allow the use of radionuclides in research that is not related to health care or life sciences. There is a large diversity in the kinds of research and uses of radionuclides in non-medical research. Again the Broad licenses are issued to larger facilities having a more comprehensive radiation protection program, where the types of research being conducted may fluctuate rapidly. Typical activities include environmental analysis, food quality studies, aerospace and engineering applications, and product development.

Annual reports were credited to a total of 382, or 82% of the 465 licenses assigned a Research and Development program code. One hundred-eighteen reports stated that monitoring was not required or not provided, and 18 reports having two or more license numbers and program codes were credited to other program codes. The 246 reports indicating that monitoring was done were summed to reveal that 17,728 individuals were monitored, and that 4,038 of them received measurable doses. The highest dose was between 4 and 5 rems, while 99% of the doses were less than 0.50 rem. The collective dose was calculated to be 390 man-rems, which yielded an average measurable dose per worker of 0.10 rem, and an average collective dose per license of about 1 man-rem.

Extrapolation of this data to account for those not reporting indicates that there may be some 19,430 individuals being monitored and 430 man-rems being incurred. These figures are much smaller than those of 34,300 monitored individuals and 980 man-rems extrapolated from the 1975 data which was provided by only 21% of these licensees.

17. Civil Defense Licenses (Program Code 03710)

These licenses are issued to allow the use of radionuclides for training individuals in civil defense activities, such as calibrating and demonstrating the use of radiation survey and monitoring equipment.

A total of 78 licenses, or 76% of the 102 licenses assigned a Civil Defense program code, were credited with submitting an annual report. Ten reports stated that monitoring was not required or not provided. Twenty-eight reports had two or more license numbers, but only nine of them had different program codes and were credited to other program codes. The 40 reports indicating that monitoring was done were summed to reveal that 1,833 individuals were monitored, and that 1,232 of them received measurable doses. The highest dose was between 1 and 2 rems, and 98% of the doses were less than 0.50 rem. The collective dose was calculated to be 81 man-rems, which yielded an average measurable dose per worker of 0.07 rem, and an average collective dose per license of about 1 man-rem.

Extrapolation of this data to account for those not reporting indicates that there may be 2,410 individuals being monitored and 110 man-rems being incurred. These figures are much smaller than the 8,800 monitored individuals and 370 man-rems extrapolated from the 1975 data, which was provided by only 8% of these licensees.

B. Definition of Program Codes for the Use of Source Materials* and Summary of Data

1. Uranium Mill and Mining Licenses (Program Codes 11100 and 11500)

These licenses are issued to allow the extraction of uranium from uranium ore. In milling operations, the ore is crushed, ground to a fine mesh, and chemically treated to convert the uranium to a form called yellowcake. The only mining operation licensed by the the NRC is solution mining, which is *in situ* leaching of ore bodies to extract uranium. Only a very small amount of uranium is mined this way.

A total of 17 licenses, or 94% of the 18 licenses assigned one of these program codes, were credited with submitting an annual report. Three of the reports from mills and both reports from solution mines stated that monitoring was not required or not provided. The nine reports indicating monitoring was done were summed to reveal that 946 individuals were monitored and that 737 of them received measurable doses. The highest dose was between 3 and 4 rems,

*Source materials are materials essential to the production of special nuclear materials. Source materials include uranium (and depleted uranium produced as tailings) and thorium, both of which are naturally occurring and radioactive. Other naturally occurring radioactive materials, such as radium and polonium, are not regulated by the NRC.

while 95% of the doses were less than 0.50 rem. The collective dose was estimated to be 166 man-rems, which yielded an average measurable dose per worker of 0.22 rem, and an average collective dose per license of about 10 man-rems.

Extrapolation of this data to account for those not reporting indicates that there may be some 1,010 individuals being monitored, and 180 man-rems being incurred. The number of individuals is about the same as that extrapolated from the 1975 data, but the collective dose is only half as much.

2. Uranium-Other Licenses, Less Than or More Than 150 Kilograms (Program Codes 11200 and 11300)

The majority of Uranium-Other licenses are issued to allow the use of refined uranium and/or thorium for fabrication, research, and manufacture of consumer products. Included are ceramics, tile, and glassware industries; manufacturers of refractories, uranium shields, fuel elements, and analytical standards; and other uses not specifically classified. A smaller number of these licenses are issued to allow the possession of uranium and/or thorium for uses other than processing or fabrication of any kind, such as distribution and storage. An even smaller number of these licenses are issued to allow the use of uranium in subcritical assemblies.

A total of 229 licenses, or 66% of the 347 licenses assigned one of the programs codes, were credited with submitting an annual report. Reports for 88 of the licenses stated that personnel monitoring was not required or not provided, and 106 of the reports were combined with those for other license numbers. They were credited to other program codes, usually those of Institutional-Other, Research and Development, or Academic. The 35 reports indicating that monitoring was done were summed to reveal that 1,472 individuals were monitored, and that 639 of them received measurable doses. The highest dose was between 2 and 3 rems, while 94% of the doses were less than 0.50 rem. The collective dose was estimated to be 152 man-rems, which yielded an average measurable dose per worker of 0.24 rem, and an average collective dose per license of about 1 man-rem.

Extrapolation of this data to account for those licensees not reporting indicates that there may be 2,320 individuals being monitored, and a collective dose of 240 man-rems being incurred. These values are about half as large as those extrapolated from the 1975 data when only 3% of the licensees reported.

3. Uranium Hexafluoride Production Licenses (Program Code 11400)

These licenses are issued to allow the conversion of yellowcake to uranium hexafluoride (UF_6). There were only two commercial production facilities operating in 1978. These two facilities reported monitoring a total of 623 individuals, 565 of whom received measurable doses. The highest dose was between 1 and 2 rems, while 91% of the doses were less than 0.50 rem. The collective dose was estimated to be 131 man-rems, which yielded an average

measurable dose per worker of 0.23 rem, and an average collective dose per license of about 66 man-rems. The number of monitored individuals increased only slightly over that reported in 1975, but the collective dose was nearly twice as large.

C. Definition of Program Codes for the Use of Special Nuclear Materials* and Summary of Data

1. Uranium Hexafluoride Conversion, Uranium and Plutonium Fuel Fabrication and Scrap Recovery Licenses (Program Codes 21110, 21120, 21210, 21220, and 21230)

These licenses are issued to allow the processing and fabrication of reactor fuels. In most uranium facilities, where light water reactor fuels are processed, uranium hexafluoride product enriched in the isotope U-235 is converted to solid uranium dioxide pellets and inserted into zirconium tubes. The tubes are fabricated into fuel assemblies which are shipped to nuclear power plants. On a much smaller scale, fuel assemblies containing plutonium oxide pellets are similarly fabricated and used in reactors for experimental purposes. Some facilities also perform chemical operations to recover the uranium and plutonium from scrap and other off-specifications material.

Annual reports were credited to 20, or 91% of the 22 licenses assigned one of these program codes; all of these indicated that monitoring was done. The reports were summed to reveal that 11,183 individuals were monitored, and that 6,029 of them received measurable doses. The highest dose was between 4 and 5 rems, while 93% of the doses were less than 0.50 rem. The collective dose was calculated to be 1,502 man-rems, which yielded an average measurable dose per worker of 0.25 rem, and an average collective dose per license of about 75 man-rems.

Extrapolation of this data to account for the two licensees not reporting indicates that there may be 12,480 individuals being monitored and a collective dose of 1,755 man-rems being incurred. The numbers of monitored individuals is slightly less than that reported in 1975, while the collective dose is about half that reported in 1975. These licensees have been required to submit annual reports for the last ten years, and they were previously grouped into the category "Fuel Fabricating & Reprocessing". For further analysis of the data reported in this group, see Section IV.A.

2. Fuel Reprocessing Licenses (Program Code 43110)

Fuel Reprocessing licenses are issued to allow the separation of usable uranium and plutonium from spent nuclear fuel. There is only one licensed commercial facility that has ever reprocessed fuel, and it has been shut down

*Special nuclear materials include plutonium, uranium-233, uranium enriched in the isotopes of uranium-235 or uranium-233, and any material artificially enriched in any of these materials.

for modification since 1972. The licensee is still storing quantities of radioactive waste at the facility, and they submitted an annual report covering 122 monitored individuals, 71 of whom received measurable doses. The highest dose was between 1 and 2 rems, while 90% of the doses were less than 0.50 rem. The collective dose was calculated to be 23 man-rems which yielded an average measurable dose per worker of 0.32 rem. These values are smaller than those, 209 monitored individuals and 51 man-rems, reported in 1975. Since no fuel reprocessing is being done, this category is usually included with those of the Fuel Fabricators (See Section IV.A).

3. Plutonium or Uranium in Other Uses, Including Research and Development Licenses (Program Codes 21130 and 21240)

These licenses are issued to allow the use of enriched uranium and plutonium for purposes such as academic training and in research and development activities associated with nuclear fuel. Annual reports were credited to a total of 18, or 78% of the 23 licenses assigned one of these program codes. Reports for five licenses stated that monitoring was not required or not provided. Six other reports were combined with other license numbers and were included in groups having other program codes, usually Academic or Research and Development. The seven remaining reports indicating that monitoring was done were summed to reveal that 2,676 individuals were monitored, and that 1,253 received measurable doses. While the highest dose was between 5 and 6 rems, 98% of the doses were less than 0.50 rem. The collective dose was calculated to be 159 man-rems, to yield an average measurable dose per worker of 0.13 rem, and an average collective dose per license of about 9 man-rems.

Extrapolation of this data to account for those licensees not reporting indicates that there may be 3,890 individuals being monitored and a collective dose of 220 man-rems being incurred. In 1975, only one of the 25 such facilities submitted a report from which it was extrapolated that 3,390 individuals were monitored, and that the collective dose was 60 man-rems.

4. Unencapsulated SNM Licenses (Program Code 22110)

Unencapsulated Special Nuclear Material (SNM) licenses are usually issued to allow the use of small quantities of unencapsulated SNM for purposes such as biological and chemical testing, for calibration sources, etc. Annual reports were credited to a total of ten or 67% of the 15 licenses assigned an Unencapsulated SNM program code. Reports for four licenses stated that monitoring was not required or not provided. Five reports were combined with other license numbers and were included in groups having other program codes, such as Well-Logging, Research and Development, and Research Reactors. The one remaining report stated that 148 individuals were monitored, 15 of whom received measurable exposures. The highest dose was between 2 and 3 rems, while 94% of the doses were less than 0.50 rem. The collective dose was calculated to be 15 man-rems, to yield an average measurable dose per worker of 0.99 rem. This report was from a firm that fabricates neutron sources, an activity that is atypical from the majority of licensees included in this group. Therefore, no extrapolations were made in an effort to account for those not reporting. The

extrapolations made from the 1975 data - 2,960 monitored individuals and a collective dose of 310 man-rems - probably were overestimates, because this same firm reported that year also.

5. Neutron Sources, Power Sources, Uranium Sources, and Other Special Nuclear Material Sources Licenses (Program Codes 22120, 22130, 22200, and 22140)

These licenses are issued to allow the use of various quantities of special nuclear material for a number of purposes, such as heat sources in power generators; sources of neutrons for instrument calibration; teaching and demonstration purposes; and well logging and other industrial applications.

Annual Reports were credited to a total of 257, or 71% of the 364 licenses assigned one of these program codes. Reports for 82 of the licenses stated that monitoring was not required or not provided, and 124 reports were combined with other license numbers and were included in groups having different program codes - usually Academic or Research and Development. The remaining 51 reports indicating that monitoring was done were summed to reveal that 2,067 individuals were monitored, and that 444 of them received measurable doses. The highest dose was between 2 and 3 rems, while 99% of the doses were less than 0.50 rem. The collective dose was calculated to be 55 man-rems, which yielded an average measurable dose per worker of 0.12 rem, and an average collective dose per license that was less than 1 man-rem.

Extrapolation of this data to account for those not reporting indicates that there may have been 2,910 individuals being monitored, and a collective dose of 80 man-rems being incurred. This is much less than the 13,200 monitored individuals and 198 man-rems that were extrapolated from the reports voluntarily submitted by only 6% of these licensees in 1975.

6. Institutional Cardiac Pacemaker Licenses (Program Code 22160)

These licenses are issued to medical facilities and physicians to allow the surgical implantation of pacemakers that are powered by a device containing special nuclear material. Very few new nuclear pacemakers are currently being manufactured.

A total of 87, or 51% of the 172 licenses assigned this program code, were credited with submitting an annual report. Reports for 33 licenses stated that monitoring was not required or not provided, and 49 reports were combined with another license number which had a different program code. In nearly every case these reports were credited to one of the Institutional program codes. The five remaining reports indicating that monitoring was done were summed to reveal that 30 individuals were monitored, and that 15 of them received measurable doses. The highest dose was between 3 and 4 rems, while 87% of the doses were less than 0.50 rem. The collective dose was calculated to be 8 man-rems, which yielded an average measurable dose per worker of 0.53 rem, and an average collective dose per license that was less than 1 man-rem.

Extrapolation of this data to account for those not reporting results in 60 monitored individuals and a collective dose of 16 man-rems. No reports were credited to this program code in 1975, and it is doubtful that any significant doses were received from the SNM pacemakers in 1978. Many of the individuals involved with pacemakers are cardiologists who also work with x-ray machines during cardiac catheterization and fluoroscopy procedures. They would receive the majority of their doses from these non-NRC licensed sources of radiation.

7. Fuel Storage and SNM Storage Only Licenses (Program Codes 23100 and 23200)

These licenses are issued to allow the storage of items containing special nuclear material, such as new or spent reactor fuel elements, and sealed sources not being used. Operating nuclear reactors do not require such a license to store their own fuel.

Annual reports were credited to three of the four Fuel Storage licenses and six of the ten SNM Storage Only licenses. One of the Fuel Storage licensees stated that monitoring was not required or not provided, and three reports from SNM Storage Only licensees were combined with those for other license numbers. The two Fuel Storage reports stating that monitoring was done were summed to reveal that 119 individuals were monitored and that 54 of them received measurable doses. The highest dose was between 2 and 3 rems, while 66% of the doses were less than 0.50 rem. The collective dose was calculated to be 51 man-rems, which yielded an average measurable dose per worker of 0.94 rem, and an average collective dose per license of about 17 man-rems. Extrapolation of this data to account for those not reporting results in 160 monitored individuals and a collective dose of 70 man-rems. These values are consistent with those of 130 monitored individuals and 90 man-rems which were extrapolated from the 1975 data.

The data reported by the three SNM Storage Only licensees stating that monitoring was provided is quite different from that of the Fuel Storage licensees. These reports revealed that some 934 individuals were monitored, and that only four individuals received measurable doses - all of which were less than 0.10 rem. One reason for the difference in the doses reported by these licensees may be that some of the employees of the Fuel Storage licensees also assist in the removal and transfer of the fuel which could result in higher doses. Extrapolation of the SNM Storage Only data to account for those not reporting results in 1,560 monitored individuals with no one receiving a measurable dose. The 1975 data indicated only eight monitored individuals and a collective dose of less than 1 man-rem. One reason for the large increase in the number of monitored individuals between the years of 1975 and 1978 would be that the number of these licenses increased from two to ten.

8. Water Cooled Power Reactor Licenses (Program Code 41111)

These licenses are issued to utilities to allow them to use special nuclear material in a reactor to produce heat to generate electricity to be

sold to consumers. There are two types of reactors having this program code - pressurized water reactors and boiling water reactors - each of which uses water as the primary coolant.

Reports were received from all 69 of the commercially operating power reactors. Facilities having more than one licensed reactor at one site submitted one report covering all reactors at that site. They all indicated that monitoring was done and were summed to reveal that a total of 77,523 individuals were monitored, some 47,245 of whom received measurable doses. Other than the two accidental overexposures reported by Trojan (see Appendix B) the highest dose was between 7 and 8 rems, while 78% of the doses were less than 0.50 rem. The collective dose was calculated to be 31,910 man-rems, which yielded an average measurable dose per worker of 0.68 rem, and an average collective dose per reactor of 462 man-rems. See Section IV.A for further analysis of the data reported by power reactors.

9. Gas Cooled Power Reactor Licenses (Program Code 41120)

These licenses are issued to utilities to allow the use of special nuclear material in a reactor to produce heat to generate electricity to be sold to consumers. Helium is used as the primary coolant. Fort St. Vrain near Greeley, Colorado, is the only such reactor in operation in the U.S. In 1978 they monitored 930 individuals, only 34 of whom received measurable doses, and all of the doses were less than 0.10 rem. Although the utility did not declare the plant to be in commercial operation until July 1979, the following table displays the plant's exposure experience for the five years 1974 through 1978.

TABLE 4
ANNUAL DOSES AT FORT ST. VRAIN
1974-1978

Year	No. of Individuals with Annual Doses in Ranges (Rems)			Total No. of Individuals Monitored	Annual Collective Dose (Man-Rems)	Gross Electrical MW-Yrs. Generated	Average Measurable Dose Per Worker (Rems)
	No Measurable Dose	Measurable <0.10	0.10-0.25				
1974	1,597	63	1	1,661	3.3	0.0	0.05
1975	1,263	0	0	1,263	0 0	0.0	0.00
1976	1,362	25	0	1,387	1.3	2.8	0.05
1977	946	55	1	1,002	2.9	29.8	0.05
1978	896	34	0	930	1.7	75.7	0.05

10. Test, Research, and Critical Reactor Licenses (Program Codes 42140, 42150, and 42160)

These licenses are issued to allow the use of special nuclear material in various types of reactors for purposes other than to commercially produce electrical power. The majority of them are operated by universities. The

test and research reactors are available to perform experiments to study radiation effects, and to produce radionuclides to be used in research and by the radiopharmaceutical industry. Critical reactors are fueled facilities that can achieve criticality so that experiments using various types and configurations of fuel and different moderators can be performed.

A total of 63 licenses, or 75% of the 84 licenses assigned one of these program codes, were credited with submitting an annual report. Two reports stated that monitoring was not required, and 33 reports were combined with other license numbers having different program codes. These were usually credited to the Academic or the Research and Development program codes. The 28 reports indicating that personnel monitoring was done were all from Research Reactor licensees, and they were summed to reveal that 2,644 individuals were monitored, and that 864 of them received measurable doses. The highest dose was between 3 and 4 rems, while 98% of the doses were less than 0.50 rem. The collective dose was calculated to be 167 man-rems, which yielded an average measurable dose per worker of 0.19 rem, and an average collective dose per license of about 3 man-rems.

Extrapolation of this data to account for those not reporting indicates that there may be 3,480 individuals being monitored and a collective dose of 220 man-rems being incurred. The number of monitored individuals is about the same as that extrapolated from the 1975 data, but the collective dose is 200 man-rems less.

TABLE 8

LICENSE PROGRAM CODE IN DESCENDING ORDER OF EXTRAPOLATED COLLECTIVE DOSE

1978

LICENSE CATEGORY and (Program Code)		Extrapolated Collective Dose, Man-rems	Average Collective Dose Per License, Man-rems
Light Water Power Reactors	(41111)	31,910	462
Institutional-Other	(02120)	6,280	4
Radiography-Multiple Loc.	(03320)	2,950	13
Well Logging	(03211)	1,740	22
Institutional-Broad	(03110)	1,640	17
*Marketing-Broad	(02110)	1,560	43
Manuf. & Dist.-Broad	(03211)	751	54
Other Measuring Systems	(03120)	650	<1
UF_6 Convrsn. Fuel Fab. & Scrap Recovery	(21210)	602	120
Plutonium Fuel Fabrication	(21120)	580	194
Academic-Broad	(01100)	560	16
Uranium Fuel Fabrication	(21230)	520	65
Private Practice	(02200)	460	1
Academic-Other	(03212)	360	1
Radiography-Single Loc.	(02300)	330	2
*Marketing-Other	(03310)	310	2
Teletherapy	(01200)	300	1
Res. & Dev. - Broad	(03610)	266	3
Other Uranium>150 kg.	(11300)	240	1
Research Reactors	(42150)	220	3
Uranium Mills	(11100)	180	11
Res. & Dev. -Other	(03620)	160	<1
Plutonium-Other Uses	(21130)	150	25
UF_6 Production Plants	(11400)	131	66
Civil Defense	(03710)	110	1
Irradiator, >10,000 Ci	(03520)	105	2
Waste Disposal-Other	(03232)	100	7
Manuf. & Dist.-Other	(03212)	100	8
Uranium-Other Uses	(21240)	70	14
Fuel Storage	(23100)	70	17
Neutron Sources	(22120)	60	<1
Plutonium Fuel Fab. & Scrap Recovery	(21110)	41	14
Other Medical	(02400)	40	1
Medical Distribution	(02500)	40	1
Irradiator, <10,000 Ci	(03510)	40	<1
Fuel Reprocessing	(43110)	23	23
Unencapsulated SNM	(22110)	20	2
Instit. Cardiac Pacemaker	(22160)	20	<1
Uranium Fuel Fab. & Scrap Recovery	(21220)	20	4
Other SNM Sources	(22140)	10	<1
Leak Test	(03220)	10	1
Uranium Sources	(22200)	10	<1
Waste Disposal-Burial	(03231)	3	3
Gas Cooled Power Reactors	(41120)	2	2
Nuclear Laundry	(03218)	0	<1
Other Uranium <150 kg.	(11200)	0	<1
Power Sources	(03400)	0	0
Uranium Solution Mines	(11500)	0	0
Power Sources	(22130)	0	0
SNM Storage, Only	(23200)	0	0
Critical Exper. Facilities	(42160)	0	0
Pacemakers, Instit.	(02600)	No Data	No Data
Test Reactors	(42140)	No Data	No Data

*Excluding the subset "Manufacturing & Distribution."

TABLE 10
LICENSE PROGRAM CODE IN DESCENDING ORDER OF
AVERAGE MEASUREABLE DOSE
1978

LICENSE CATEGORY and (Program Code)		AVERAGE MEASURABLE DOSE, REMS	AVERAGE INDIVIDUAL DOSE, REMS	RATIO** Ω
Unencapsulated SNM	(22110)	0.99	0.13	2.89
Fuel Storage	(23100)	0.94	0.43	1.77
Light Water Power Reactors	(41111)	0.67	0.41	2.88
Waste Disposal-Other	(03231)	0.57	0.28	3.54
Plutonium Fuel Fab.	(21120)	0.56	0.32	2.71
Instit. Cardiac Pacemaker	(22160)	0.56	0.27	2.93
Manuf. & Distrib.-Broad	(03211)	0.51	0.24	3.18
Radiography-Multiple Loc.	(03320)	0.46	0.24	2.16
*Marketing-Broad	(03211)	0.36	0.24	1.07
Well Logging	(03110)	0.36	0.27	1.72
Radiography-Single Loc.	(03310)	0.34	0.15	1.95
Fuel Reprocessing	(43110)	0.32	0.19	0.48
Private Practice	(02200)	0.28	0.20	1.42
Manuf. & Distrib.-Other	(03212)	0.25	0.11	1.86
Institutional-Other	(02120)	0.25	0.17	1.27
Leak Test	(03220)	0.25	0.09	1.03
Other Uranium>150 kg.	(11300)	0.24	0.10	0.79
UF_6 Convrsn, Fuel Fab & Scrap Recovery	(21210)	0.24	0.13	0.52
UF_6 Production Plants	(11400)	0.23	0.21	0.40
Uranium Mills	(11100)	0.22	0.18	0.41
Nuclear Laundry	(03218)	0.22	0.07	0.00
Uranium Sources	(22200)	0.22	0.02	2.85
Medical Distribution	(02500)	0.21	0.15	0.00
Uranium-Other Uses	(21240)	0.20	0.15	1.66
Other SNM Sources	(22140)	0.20	0.03	0.93
Waste Disposal-Burial	(03231)	0.20	0.17	0.00
Research Reactors	(42150)	0.19	0.06	2.18
Uranium Fuel Fab.	(21230)	0.18	0.10	0.97
*Marketing-Other	(03212)	0.17	0.05	2.06
Teletherapy	(02300)	0.18	0.11	0.72
Irradiator, >10,000 Ci	(03520)	0.16	0.05	0.70
Institutional-Broad	(02110)	0.15	0.07	0.74
Academic-Broad	(01100)	0.13	0.06	0.64
Plutonium Fuel Fab. & Scrap Recovery	(21110)	0.13	0.06	0.45
Academic-Other	(01200)	0.12	0.03	0.62
Res. & Dev.-Broad	(03610)	0.11	0.02	1.19
Neutron Sources	(22120)	0.11	0.02	0.89
Irradiator, <10,000 Ci	(03510)	0.11	0.02	0.73
Plutonium-Other Uses	(21130)	0.10	0.04	0.07
Other Measuring Systems	(03120)	0.10	0.03	0.66
Uranium Fuel Fab. & Scrap Recovery	(21220)	0.09	0.05	0.00
Other Medical	(02400)	0.09	0.03	0.53
Res. & Dev.-Other	(03620)	0.07	0.02	0.06
Civil Defense	(03710)	0.06	0.04	0.05
Other Uranium <150 kg.	(11200)	0.06	0.03	0.00
Gas Cooled Power Reactors	(41120)	0.05	0.00	0.00
SNM Storage, Only	(23200)	0.05	0.00	0.00
Power Sources (Byproduct)	(03400)	No monitoring required		
Uranium Solution Mines	(11500)	"		
Power Sources (SNM)	(22130)	"		
Critical Exper. Facilities	(42160)	"		
Pacemakers, Instit	(02600)	No data for this program code		
Test Reactors	(42140)	No data for this program code		

*Excluding the subset "Manufacturing & Distribution".

**The ratio of the fraction of the collective dose due to annual doses greater than 1.5 rems in the observed distribution to fraction of the UNSCEAR reference distribution. (See Section

APPENDIX B

SUMMARY OF OVEREXPOSURES

APPENDIX B

Summary of Overexposures Reported Pursuant to 10 CFR §20.403 1979

Industrial Radiography-License Number 35-17178-01

On December 2, 1979, a radiographer was fired for drunkenness. The following day he returned to the facility, unlocked a projector containing 80 curies of iridium-192, and exposed himself to it. His dosimeter indicated that he received a whole body dose of about 17 rems. All employees were instructed to be more vigilant to stop irrational acts of this nature.

Industrial Radiography-License Number 21-17095-01

On March 7, 1979, while conducting radiographic operations with a 65-curie iridium-192 source at a construction site, a radiographer's assistant received a whole body dose of about nine rems. The radiographer failed to conduct a proper survey and to lock the exposure device when the radiographic shot was completed. The locking mechanism of all exposure devices will be color coded for easy identification of the locked position, and all personnel were reminded of the importance of following procedures.

Industrial Radiography-License Number 42-08456-02

On October 10, 1979, a radiographer and his assistant were using an exposure device with an iridium-192 source to radiograph pipe welds. The assistant accidently locked the source between the locking ball and cable connector leaving the source about two inches up the source tube. The radiographer and his assistant received whole body doses of 8.6 rems and 2.6 rems, respectively, before they discovered that the source was not in its shielded position. Radiographic personnel will be reinstructed in the use of radiation survey instrumentation, and assistant radiographers will demonstrate their competence in their use upon completion of training.

Nuclear Power Facility-License Number DPR-37

On April 14, 1979, a shift supervisor inspected the area beneath the reactor vessel in an effort to determine the source of a water leak. He was unaware that the radioactive in-core detector thimbles had been retracted from the core which had increased the radiation levels, and he received a whole body dose of about 10 rems. The individual was disciplined for an entry that was in violation of adminisrative controls and area postings.

Nuclear Power Facility-License Number DPR-73

On March 29, 1979, a health physics and a chemistry foreman handled highly radioactive valves and bottles while collecting samples of the primary coolant following the accident at Three Mile Island Unit 2. They received extremity doses of 54 rems and 147 rems, respectively. On August 28, 1979, while attempting to isolate leakage from the makeup system in the fuel handling building, six station personnel received skin doses of 166, 161, 40,

29, 26 and 13 rems because the preliminary radiation survey failed to identify the potential for high beta doses. The two workers with the larger skin doses also received extremity doses of 82 and 38 rems, respectively. Further details of the incidents may be found in the "Report to Congress on Abnormal Occurrences" (Ref. 6).

Well Logging Licensee-License Number 42-02964-01

During the routine process of radiation dosimeters that had been worn during the first quarter of 1979, it was found that a well logger may have received a quarterly whole body dose of 14.7 rems. Investigations revealed no incidents during which an actual overexposure should have been received, and it was speculated that the worker may have left the badge on his shirt which could have been left near a source in the shop or on the job, or that he may have worn it while he received a medical x-ray of his thumb. However, these were not proven, and the well logger was assumed to have received this dose.

Academic Institution-License Number 12-00509-03

During the period of August 20 through September 13, 1979, an individual used californium-252 in his research project. As a result of the licensee's failure to conduct an adequate evaluation of the radiation levels and to properly evaluate planned projects, the researcher received a quaterly whole body dose of 14.3 rems and an extremity dose of 45 rems.

Fuel Fabrication-License Number SNM-414

On November 16, 1979, a worker in the licensee's Plutonium Facility was attempting to repair a blender in a glovebox. When the pounded on the shaft of the blender, a mixture of insoluble plutonium and americium-241 was released from the glovebox and he was exposed to concentrations (11,000 MPC-hours) about 20 times greater than the quarterly limit. The individual was removed from work with radioactive materials and placed on a long-term bioassay program for continuing evaluation of his exposure. No more repair operations of this type are to be permitted until all of the potential hazards are assessed and all of the necessary safety precautions are taken. Also, two self-alarming continuous air monitors were installed and incorporated into the facility air sampling program.

NRC FORM 335 (7.77)

U.S. NUCLEAR REGULATORY COMMISSION

BIBLIOGRAPHIC DATA SHEET

1. REPORT NUMBER (Assigned by DDC)
NUREG-0714, Vol. 1

4. TITLE AND SUBTITLE (Add Volume No., if appropriate)
Occupational Radiation Exposure Report
Twelfth Annual Report 1979

2. (Leave blank)

3. RECIPIENT'S ACCESSION NO.

7. AUTHOR(S)
B. Brooks, S. McDonald, E. Richardson

5. DATE REPORT COMPLETED
MONTH: May | YEAR: 1982

9. PERFORMING ORGANIZATION NAME AND MAILING ADDRESS (Include Zip Code)
U. S. Nuclear Regulatory Commission
Office of Resource Management
Division of Data Automation
Washington, DC 20555

DATE REPORT ISSUED
MONTH: August | YEAR: 1982

6. (Leave blank)

8. (Leave blank)

12. SPONSORING ORGANIZATION NAME AND MAILING ADDRESS (Include Zip Code)
U. S. Nuclear Regulatory Commission
Office of Resource Management
Division of Data Automation
Washington, DC 20555

10. PROJECT/TASK/WORK UNIT NO.

11. CONTRACT NO.

13. TYPE OF REPORT
Annual

PERIOD COVERED (Inclusive dates)
Calendar year 1979

15. SUPPLEMENTARY NOTES

14. (Leave blank)

16. ABSTRACT (200 words or less)

This report summarized the information reported for calendar year 1979 by all NRC licensees to the Commission's centralized repository of personnel occupational radiation exposure information. The bulk of the information in the report is derived from annual reports that were required to be submitted by all NRC licensees pursuant to 10CFR 20.407. This is the second year that all NRC licensees were required to submit an annual exposure report. Previously only certain categories - commercial nuclear power reactors, industrial radiographers, fuel fabricators and processors and commercial distributors of byproduct materials - of NRC licensees had submitted such reports. The requirement of 10CFR 20.408 for the submission of termination reports continued to apply to only these four categories, and some analysis of the data contained in these reports is also presented. A brief description of personnel overexposures reported by NRC licensees is included as well.

17. KEY WORDS AND DOCUMENT ANALYSIS

17a. DESCRIPTORS

Not Applicable

17b. IDENTIFIERS/OPEN ENDED TERMS

18. AVAILABILITY STATEMENT
Unlimited

19. SECURITY CLASS (This report)
Unclassified

21. NO. OF PAGES

20. SECURITY CLASS (This page)
Unclassified

22. PRICE
$

NRC FORM 335 (7.77)

120555078877 1 ANN3
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POLICY & PUBLICATIONS MGT BR
PDR NUREG COPY
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