ARGONNE NATIONAL LABORATORY
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Argonne, Illinois

A REVIEW OF THE ARGONNE NATIONAL LABORATORY
RADIATION EXPOSURE EXPERIENCE
FOR THE YEARS 1959-1961

by

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Industrial Hygiene and Safety Division

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ABSTRACT

A general analysis of the Argonne National Laboratory experience with radiation exposure of employees was made by means of machine-processed records. Distribution of employee exposures according to Age, Years of Employment, Laboratory Division, Job Group, and Sex were determined for a three-year period. A 23.6% increase in the number of employees monitored occurred from 1959 to 1961. The number of measurable exposures increased 107%. The greatest influence on the increase in measurable exposure was probably due to a change to a more sensitive film and from a one-week to a two-week film-wearing period. Evaluation of performance using the factors Frequency Rate, Exposure Rate, and Average Exposure reveals that the Radiation Safety Program is improving in effectiveness. The exposure rate has been reduced by as much as 71.1%, and the average exposure was reduced 42.4%.

A. INTRODUCTION

The primary aim of any Radiation Safety Program is to minimize radiation exposure to man. When work deals primarily with radioactive materials and radiation-producing machines, this goal is not the end point but an on-going improvement of the total work situation. The aim of the Radiation Safety Program then is to improve operations. The Health Physicist tries to control the exposure of employees to radiation by controlling the hazard and/or the exposure dosage of employees. If enough "controlled situations" are allowed to exist in a non-improving situation, it would be possible for a large number of employees to receive exposure to a large amount of radiation. Because of this, it is advisable to review periodically the effectiveness of the Radiation Safety Program. A good measure of the effectiveness of a program is to determine whether there is a decrease of employee exposure. An increase in the number or degree of employee exposures to radiation would indicate the need for more effective supervisory controls or better methods of operating.

There are a number of questions to be asked in reviewing the radiation exposure experience of a work force. Among these are:

- (a) What are the ages of employees who receive radiation exposures?
- (b) How much experience do they have with the company?
- (c) What type of work do they do?
- (d) What are their general duties and responsibilities?
- (e) What is the direction taken by the Laboratory exposure trends?

This study is limited to answering the above questions.

B. PROCEDURE

The radiation-exposure data were taken from measurements made with personnel-monitoring film. The data were put onto punched cards, each of which contained the employee's identification, date of the exposure, film identification, and radiation exposure. One card was punched for each monitoring film. Each card was then visually checked for errors against the source documents and corrected as necessary.

Master name cards were punched from employee status information supplied by the Personnel Department of the Laboratory. Each card contained the employee's identification number, effective date of the job status, name, birthdate, employment date, laboratory group code, job classification code, and sex.

The data were transferred from each deck of cards to tape by means of the IBM-1401 machine. Two tapes, one containing details of radiation-exposure data and one containing employment status information were made. The two tapes, which were written in binary coded decimal were processed through the IBM-704 and binary tapes were produced. The binary tapes were used as input tapes for the 704 program to produce the necessary reports.

C. PRESENTATION OF DATA

1. Tables Showing Distribution of Exposures

The frequency-distribution tables, such as Table I, are the print-outs from the 704. The employee's status at the time of his latest film reading within a given year was used to place the employee in a class or group interval. It is possible that some employees changed groups in a given year.

As an example, assume the following: An employee was assigned film from July 1959 to July 1960. From July through December 1959 he was in the Idaho Division; in January 1960 he joined Industrial Hygiene and Safety, and in July 1960 he transferred to Reactor Operations. At time of latest exposure (given in Table VII), he would be counted as being in the Idaho Division on December 31, 1959. In 1960 he would be counted in Reactor Operations, which is the class interval into which he belonged at the time of his latest film reading on July 31, 1960. A small error is incurred by counting the employee only in the group interval that he was in at the time of his last film reading in the year.

The Expected frequencies under the major column heading No. of Employees Assigned Film in Tables I-IX, XI-XIII, and XV-XVII are calculated frequencies. They were determined on the basis that the number of employees assigned film is distributed in the same proportion as the total laboratory population for each class interval. The Expected values were calculated as

$$\text{Total No. of Employees Assigned Film} \times \frac{\text{No. of Laboratory Employees in Each Class Interval}}{\text{Total Laboratory Population}}$$

The Actual frequencies are the observed frequencies.

Similarly, the Expected number of employees with measurable exposures were calculated by means of the relationship

$$\text{Total No. of Employees with Measurable Exposures} \times \frac{\text{Actual No. of Employees Assigned Film in Each Class Interval}}{\text{Total Number of Employees Assigned Film}}$$

A chi-square test revealed that the actual frequencies of employees assigned film was not proportional to the frequencies of the total Laboratory population. Also, the frequency distribution of the actual number of employees with measurable exposures was not proportional to the frequency distribution of the number of films assigned with the exception of the distributions in Tables II, III, and V. The Expected and Actual frequencies of employees with measurable readings in Tables II, III, and V show an insignificant difference. The difference was considered insignificant if there was a probability of 0.05 or greater that the calculated distribution would describe the actual distribution.

The term MPL in the last two columns of the distribution Tables I-IX, XI-XIII, and XV-XVII refers to weekly maximum permissible levels. The MPL for 1959 through June 1960 was 300 mrem/week. From July 1960 through 1961, the MPL was 300 mrem/2 weeks. If, during any film-wearing

period in the year, an employee's film exposure exceeded the maximum permissible level, he was counted in the next-to-the-last column. The employee was counted only once in the year. Each time a film reading exceeded the permissible level it was counted in the last column on the right. The last column shows that some employees exceeded the weekly MPL more than once. These two columns will reveal class or group intervals that may be receiving relatively large or small amounts of radiation exposures.

Table XVIII shows the distribution of employees by range of exposures. The distribution is also expressed in accumulated percent to show the exposure level below which most of the exposures occur. The distribution of employees is based upon the employee's accumulated radiation exposure for the given year.

Table XIX gives the values for the indices of exposure experience that are used in evaluating the effectiveness of Radiation Safety Program⁽¹⁾ The indices were determined as follows:

Frequency Rate = $(N/M) \times 10^6$ = Number of Exposed Film/ 10^6 Manhours.

Exposure Rate = $\Sigma r/NH$ = mr/hr.

Average Exposure = $\Sigma r/N$ = Average exposure in milliroentgens as recorded on the films.

where N = Number of films with a measurable reading of 25 mr or greater.

M = Total manhours worked by all employees for the stated period based upon the Accounting Department's figures of paid manhours with absence manhours deducted.

r = The readings in milliroentgens on each film with a measurable reading of 25 mr or greater.

H = The number of hours that each film with a measurable reading was worn.

Some employees wore several films in a given monitoring period. The average exposure is a film average. It closely approximates the employee averages since approximately 95% of the employees wear one film during a given monitoring period. Only 0.6% of the employees wear more than two films in a monitoring period and these employees wear three films.

2 Graphic Presentations

The frequency polygons, such as in Figs. 1-6, are presentation of the data in Tables I-VI. The uppermost curve in each figure represents the distribution for all the Laboratory employees. The middle curve

represents the distribution for employees who were assigned monitoring film. The bottom curve is the distribution for employees who received measurable exposures. By taking the difference between the top curve and the middle curve one gets the distribution for employees not assigned film. By taking the difference between the middle curve and bottom curve, one gets the distribution for employees assigned film but receiving no measurable exposures.

Figures 7-15 are histograms representing the data in Tables VII-IX, XI-XIII, and XV-XVII. In the same manner as was described for the frequency polygon, one can take the difference between the overlapping histograms and determine the distribution for employees not assigned film and the number of employees assigned film but receiving no measurable exposures.

The curves in Figs. 16-18 represent the cumulative distribution of the data from Table XVIII. The data have been accumulated on a "less than" basis; thus, the curve shows the number of persons who received less than the stated exposures.

The data for the Indices of Exposure Experience are plotted in Figs. 19-21. Trend lines have been fitted to each curve using the high-low mid-point method. The trend lines give a better picture of a resultant direction of the cyclic movements described by the curves.

D. DISCUSSION

1. General

The employees at the Laboratory are monitored on an "as needed" basis. As a result, a little less than half of the employees are assigned personal monitoring devices. In 1961, for instance, 2317 or 45.5% of the Laboratory employees were monitored. Of these, 1182 or 51.0% received measurable exposures. A measurable exposure is one that measures 25 mr or more. Tables I through III show that from 1959 to 1961 the increase in the number of employees with measurable readings is greater than the increase in the number monitored. The explanation for the greater increase in employees with measurable readings is that the Laboratory changed to a more sensitive monitoring film and extended the wearing period from one week to two weeks in July 1960. Thus, many employees whose exposure measurements formerly were slightly below the threshold of detection began to show measurable exposures.

2. Age at Time of Latest Film Reading within the Year, Tables I-III

The mean ages (plus or minus one standard deviation) shown below indicate that the distribution of the ages of employees assigned film and of those receiving measurable exposures are similar. The slight differences are considered as fluctuations due to chance.

Year	MEAN AGE IN YEARS PLUS OR MINUS ONE STANDARD DEVIATION			
	All Laboratory Employees	Employees Assigned Film	Employees with Measurable Exposure	Employees with Exposures ≥ Weekly MPL
1959	35.77 ± 10.68	36.33 ± 9.63	35.18 ± 9.63	35.55 ± 8.16
1960	35.73 ± 10.68	35.95 ± 9.80	35.58 ± 9.49	34.34 ± 8.61
1961	35.73 ± 10.89	36.27 ± 9.84	35.61 ± 9.39	33.94 ± 9.40

(The standard deviation from the mean is only approximate since the distribution has a moderately positive skew as shown in Figs. 1-3.)

The average age over the 3-year period is 35.5 ± 9.5 years. Using the above figures for employees with measurable exposures, one can infer that 95.45% of the employees that receive measurable exposures are between the ages of 17.5 and 55.5.

Table I
CALENDAR YEAR 1959

AGE AT TIME OF LATEST FILM READING WITHIN THE YEAR - BODY FILM DATA

Range in Years	No. of Employees	No. of Employees Assigned Films		No. of Films Assigned	No. of Employees with Measurable Exposures		No. of Films with Measurable Readings	No. of Employees Exposed, Equal or Greater MPL	No. of Films, Equal or Greater MPL
		Expected ¹	Actual		Expected ^{2*}	Actual			
- 16	0	0	0	0	0	0	0	0	0
17 - 20	92	40	15	205	5	1	2	0	0
20 - 23	411	180	116	2813	35	37	177	2	3
23 - 26	339	148	141	5008	43	47	242	5	5
26 - 29	409	179	187	8121	57	70	402	7	16
29 - 32	422	185	197	8346	60	68	397	14	17
32 - 35	482	211	231	10617	70	76	615	15	28
35 - 38	450	197	236	10311	72	74	468	7	11
38 - 41	432	189	219	9758	67	65	376	9	14
41 - 44	364	159	173	7697	53	45	264	7	15
44 - 47	242	106	108	4633	33	35	235	4	10
47 - 50	185	81	68	2814	21	16	69	2	3
50 - 53	153	67	67	2972	20	16	39	1	2
53 - 56	102	45	36	1548	11	7	13	0	0
56 - 59	78	34	32	1612	10	5	12	1	1
59 - 62	70	31	30	1496	9	4	27	2	2
62 - 65	38	17	14	587	4	4	18	0	0
65 -	10	4	4	60	1	1	1	0	0
Total	4279	1873	1874	78598	571	571	3357	76	127

¹ Expected on the basis of distributing the number of film proportionally to the Age distribution.

^{2*} Expected on the basis of distributing the No. of Employees with Measurable Readings proportionally to the distribution of No. of Employees Assigned Films.

Figure 1
CALENDAR YEAR 1959

AGE AT TIME OF LATEST FILM READING
WITHIN THE YEAR - BODY FILM DATA

Table II
CALENDAR YEAR 1960

AGE AT TIME OF LATEST FILM READING WITHIN THE YEAR - BODY FILM DATA

Range in Years	No. of Employees	No. of Employees Assigned Films		No. of Films Assigned	No. of Employees with Measurable Exposures		No. of Films with Measurable Readings	No. of Employees Exposed, Equal or Greater MPL	No. of Films, Equal or Greater MPL
		Expected*	Actual		Expected**	Actual			
- 16	0	0	0	0	0	0	0	0	0
17 - 20	159	71	21	301	10	7	30	1	1
20 - 23	452	203	165	2615	77	72	301	4	7
23 - 26	388	174	177	4397	83	75	404	8	10
26 - 29	434	195	223	7214	105	125	526	3	3
29 - 32	458	206	215	7202	101	106	575	8	13
32 - 35	442	199	220	7340	103	110	639	9	19
35 - 38	490	220	254	8310	119	130	592	9	23
38 - 41	477	214	236	8226	111	114	476	8	11
41 - 44	400	180	187	6319	88	81	295	3	4
44 - 47	305	137	136	4297	64	57	301	3	7
47 - 50	196	88	79	2449	37	30	128	2	3
50 - 53	171	77	77	2249	36	34	81	2	5
53 - 56	118	53	47	1646	22	16	21	0	0
56 - 59	78	35	27	884	13	14	36	0	0
59 - 62	75	34	33	1232	15	11	43	1	2
62 - 65	51	23	16	674	8	9	25	0	0
65 -	16	7	3	108	1	1	1	0	0
Total	4710	2116	2116	65463	993	992	4474	61	108

*Expected on the basis of distributing the number of film proportionally to the Age distribution.

**Expected on the basis of distributing the No. of Employees with Measurable Readings proportionally to the distribution of No. of Employees Assigned Films.

Figure 2
CALENDAR YEAR 1960

AGE AT TIME OF LATEST FILM READING
WITHIN THE YEAR - BODY FILM DATA

Table III
CALENDAR YEAR 1961

AGE AT TIME OF LATEST FILM READING WITHIN THE YEAR - BODY FILM DATA

Range in Years	No. of Employees	No. of Employees Assigned Films		No. of Films Assigned	No. of Employees with Measurable Exposures		No. of Films with Measurable Readings	No. of Employees Exposed, Equal or Greater MPL	No. of Films, Equal or Greater MPL
		Expected ^a	Actual		Expected ^b	Actual			
- 16	0	0	0	0	0	0	0	0	0
17 - 20	195	89	20	226	10	7	12	0	0
20 - 23	499	227	169	2508	86	80	368	7	24
23 - 26	440	200	177	3419	90	89	615	19	36
26 - 29	442	201	246	5515	125	149	673	9	16
29 - 32	496	226	252	5753	129	135	522	7	9
32 - 35	444	202	228	5445	116	135	613	7	17
35 - 38	499	227	259	6134	132	152	690	17	33
38 - 41	499	227	262	6211	134	125	524	6	18
41 - 44	429	195	216	5039	110	110	371	5	6
44 - 47	371	169	184	3947	94	65	314	8	12
47 - 50	215	98	83	1707	42	36	129	2	4
50 - 53	185	84	77	1642	39	35	114	2	2
53 - 56	133	61	59	1314	30	30	63	0	0
56 - 59	87	40	26	590	13	7	32	1	1
59 - 62	74	34	32	816	16	15	30	1	1
62 - 65	59	27	23	586	12	11	50	1	1
65 -	22	10	4	51	2	1	2	0	0
Total	5089	2317	2317	50903	1180	1182	5122	92	180

^aExpected on the basis of distributing the number of film proportionally to the Age distribution.

^bExpected on the basis of distributing the No. of Employees with Measurable Readings proportionally to the distribution of No. of Employees Assigned Films.

Figure 3
CALENDAR YEAR 1961

AGE AT TIME OF LATEST FILM READING
WITHIN THE YEAR - BODY FILM DATA

3. Years of Employment at Time of Latest Film Reading within the Year, Tables IV-VI

The shapes of the distribution curves for employees by years of employment have remained about the same for 1959, 1960, and 1961. Figures 4-6 show that after the first few years the high and low points move to the right one year with each succeeding year. The means and the medians of the overall distributions differ by only a few tenths of a year. The means and medians for each year were calculated to be as follows:

Year	YEARS OF EMPLOYMENT					
	All Employees		Employees Assigned Film		Measurable Exposures	
	Mean	Median	Mean	Median	Mean	Median
1959	5.32	3.79	5.88	4.28	5.37	3.62
1960	5.54	3.54	5.84	4.04	5.62	4.02
1961	5.42	3.81	6.16	4.50	5.85	4.43

The medians show that one-half of the employees were at the Laboratory less than four years. One-half of the employees assigned film were at the Laboratory 4.5 years or less, and one-half the employees receiving measurable exposures were at the Laboratory less than 4.5 years. In addition, 41% of the employees who exceeded the weekly maximum permissible level in 1959 and 1960 were employed 4.5 years or less. In 1961, 52% of the employees who exceeded weekly MPL had 4.5 years or less experience at the Laboratory.

Table IV
CALENDAR YEAR 1959

YEARS OF EMPLOYMENT AT TIME OF LATEST FILM READING WITHIN THE YEAR - BODY FILM DATA

Range in Years	No. of Employees	No. of Employees Assigned Films		No. of Films Assigned	No. of Employees with Measurable Exposures		No. of Films with Measurable Readings	No. of Employees Exposed, Equal or Greater MPL	No. of Films, Equal or Greater MPL
		Expected ^a	Actual		Expected ^a	Actual			
- .5	612	268	173	2136	53	43	111	0	0
.5 - 1.5	603	264	218	7611	66	76	288	8	13
1.5 - 2.5	530	232	232	9530	71	73	450	7	13
2.5 - 3.5	469	205	238	11366	73	88	566	11	18
3.5 - 4.5	217	95	92	4109	28	33	249	5	7
4.5 - 5.5	159	70	80	3800	24	25	85	0	0
5.5 - 6.5	104	46	61	3362	19	26	122	5	8
6.5 - 7.5	121	53	54	2615	16	23	183	6	10
7.5 - 8.5	194	85	96	4486	29	41	403	5	9
8.5 - 9.5	232	102	115	5682	35	26	181	4	5
9.5 - 10.5	214	94	112	4913	34	22	131	5	9
10.5 - 11.5	240	105	128	6252	39	26	145	7	9
11.5 - 12.5	181	79	88	3706	27	19	155	3	6
12.5 - 13.5	139	61	73	3812	22	26	173	5	12
13.5 - 14.5	86	38	38	1846	12	10	46	2	2
14.5 - 15.5	61	27	28	1164	9	4	8	1	2
15.5 - 16.5	81	35	29	1285	9	6	13	2	4
16.5 - 17.5	27	12	16	810	5	4	48	0	0
17.5 - 18.5	9	4	3	113	1	0	0	0	0
18.5 -	0	0	0	0	0	0	0	0	0
Total	4279	1875	1874	78598	572	571	3357	76	127

^aExpected on the basis of distributing the number of film proportionally to the Years of Employment distribution.

^bExpected on the basis of distributing the No. of Employees with Measurable Readings proportionally to the distribution of No. of Employees Assigned Films.

Figure 4
CALENDAR YEAR 1959

YEARS OF EMPLOYMENT AT TIME OF
LATEST FILM READING WITHIN THE
YEAR - BODY FILM DATA

Table V
CALENDAR YEAR 1960

YEARS OF EMPLOYMENT AT TIME OF LATEST FILM READING WITHIN THE YEAR - BODY FILM DATA

Range in Years	No. of Employees	No. of Employees Assigned Films		No. of Films Assigned	No. of Employees with Measurable Exposures		No. of Films with Measurable Readings	No. of Employees Exposed, Equal or Greater MPL	No. of Films, Equal or Greater MPL
		Expected	Actual		Expected ^a	Actual			
- .5	539	242	188	1699	88	69	176	3	3
.5 - 1.5	866	389	341	7793	160	169	877	8	10
1.5 - 2.5	459	206	197	6265	92	91	323	4	6
2.5 - 3.5	448	201	196	6696	92	99	493	4	9
3.5 - 4.5	420	189	228	8335	107	119	542	6	11
4.5 - 5.5	199	89	83	2956	39	45	212	7	10
5.5 - 6.5	142	64	71	2591	33	33	133	0	0
6.5 - 7.5	101	45	60	2326	28	35	155	1	1
7.5 - 8.5	118	53	56	1947	26	33	199	6	10
8.5 - 9.5	185	83	90	3218	42	58	323	5	7
9.5 - 10.5	226	102	120	4302	56	53	229	4	11
10.5 - 11.5	212	95	110	3741	52	41	136	2	5
11.5 - 12.5	228	102	121	4453	57	55	219	3	5
12.5 - 13.5	178	80	81	2653	38	30	128	2	9
13.5 - 14.5	137	62	75	2869	35	28	199	4	9
14.5 - 15.5	82	37	34	1283	16	9	39	0	0
15.5 - 16.5	63	28	23	815	11	9	24	1	1
16.5 - 17.5	71	32	24	803	11	9	22	0	0
17.5 - 18.5	28	13	16	637	8	6	44	1	1
18.5 -	8	4	2	81	1	1	1	0	0
Total	4710	2116	2116	65463	992	992	4474	61	108

^aExpected on the basis of distributing the number of film proportionally to the Years of Employment distribution.

^bExpected on the basis of distributing the No. of Employees with Measurable Readings proportionally to the distribution of No. of Employees Assigned Films.

Figure 5
CALENDAR YEAR 1960

YEARS OF EMPLOYMENT AT TIME OF
LATEST FILM READING WITHIN THE
YEAR - BODY FILM DATA

Table VI
CALENDAR YEAR 1961

YEARS OF EMPLOYMENT AT TIME OF LATEST FILM READING WITHIN THE YEAR - BODY FILM DATA

Range in Years	No. of Employees	No. of Employees Assigned Films		No. of Films Assigned	No. of Employees with Measurable Exposures		No. of Films with Measurable Readings	No. of Employees Exposed, Equal or Greater MPL	No. of Films, Equal or Greater MPL
		Expected	Actual		Expected ²⁰	Actual			
- .5	584	266	160	1123	82	49	136	4	6
.5 - 1.5	761	346	311	5775	159	157	824	18	41
1.5 - 2.5	680	310	303	6929	155	185	895	13	20
2.5 - 3.5	378	172	186	4297	95	98	304	6	10
3.5 - 4.5	397	181	188	4459	96	104	447	7	14
4.5 - 5.5	395	180	214	4971	109	124	484	7	17
5.5 - 6.5	186	85	80	2092	41	53	197	2	3
6.5 - 7.5	137	62	74	1922	38	43	169	2	4
7.5 - 8.5	99	45	58	1688	30	30	179	4	5
8.5 - 9.5	110	50	53	1391	27	33	155	4	5
9.5 - 10.5	175	80	86	2128	44	48	268	3	4
10.5 - 11.5	227	103	123	2908	63	60	233	4	11
11.5 - 12.5	200	91	105	2450	54	52	209	6	12
12.5 - 13.5	221	101	124	2909	63	55	204	3	8
13.5 - 14.5	169	77	77	1810	39	26	108	5	9
14.5 - 15.5	135	61	74	1867	38	34	168	4	11
15.5 - 16.5	76	35	35	752	18	9	59	0	0
16.5 - 17.5	55	25	24	523	12	7	22	0	0
17.5 - 18.5	73	33	25	511	13	8	18	0	0
18.5 -	31	14	17	398	9	7	43	0	0
Total	5089	2317	2317	50903	1185	1182	5122	92	180

¹Expected on the basis of distributing the number of film proportionally to the Years of Employment distribution.

²⁰Expected on the basis of distributing the No. of Employees with Measurable Readings proportionally to the distribution of No. of Employees Assigned Films.

Figure 6
CALENDAR YEAR 1961

YEARS OF EMPLOYMENT AT TIME OF
LATEST FILM READING WITHIN THE
YEAR - BODY FILM DATA

4. Laboratory Division at Time of Exposure to External Radiation, Tables VII-X

Table X shows the order of the Laboratory Divisions with respect to number of employees who receive measurable exposures. By pairing the rank order for any two of the three years and applying the data to the formula

$$\rho = 1 - \frac{6\sum D^2}{N(N^2 - 1)}$$

where ρ is the rank order correlation, D is the difference between the paired items, and N is the number of items, one gets the following correlations:

<u>Paired Years</u>	<u>Rank Order Correlation (ρ)</u>
1959 & 1960	0.77
1959 & 1961	0.86
1960 & 1961	0.93

It can be seen that the rank order has remained fairly constant. However, Table X reveals that a further study should be made of the combined divisions "Other Scientific" (Appendix A). The combined scientific divisions were not expected to rank so high on number of measurable exposures.

The Plant Services Division is the Division that has the largest number of employees who receive measurable exposures. This division includes reclamation and plant maintenance personnel. The exposures are received mostly by reclamation personnel who perform almost all of the significant decontamination work for the Laboratory.

The number of employees who receive measurable exposures in the combined divisions "Other Scientific" increased by 99 employees from 1959 to 1961. This increase in number of films with measurable exposure is attributed to the increase of low amount of exposure detected by extending the monitoring period and by using a more sensitive film. It should be noted in Tables VII-IX that the large increase occurred in 1960 when the Laboratory changed to the two-week monitoring period and a more sensitive film. The number of employees with measurable exposures increased considerably for nearly all divisions at that time. Employees receiving measurable exposures increased 73.7% from 1959-1960 while the increase in number monitored was 12.9%. The changes in numbers of employees assigned film were not so significant.

Tables VII-IX show that the Chemistry and Reactor Operations Divisions have the largest number of employees who exceeded the weekly MPL. The relative comparison of these two divisions to the total Laboratory population is as follows:

Year	PERCENTAGE CONTRIBUTED TO TOTAL EXPERIENCE BY COMBINED CHEMISTRY AND REACTOR OPERATIONS			
	Total Population	Employees Assigned Film	Employees with Measurable Exposure	Employees Exposed ≥ MPL
1959	6.5	8.9	16.1	52.6
1960	6.0	8.1	11.3	62.2
1961	7.6	9.6	13.3	60.8

The exposures in the Chemistry Division were incurred on the most part by personnel working in cyclotron-connected operations. The exposures received by the Reactor Operations Division were incurred by reactor operators involved in fuel changes, removing of samples from the reactor, and work involving reactor modification. Most of these exposures are connected with carefully controlled work.

Table VII
CALENDAR YEAR 1959

LABORATORY DIVISION AT TIME OF EXPOSURE TO EXTERNAL RADIATION - FILM DATA

Division Name	No. of Employees	No. of Employees Assigned Films		No. of Films Assigned	No. of Employees with Measurable Exposures		No. of Films with Measurable Readings	No. of Employees Exposed, Equal or Greater MPL	No. of Films, Equal or Greater MPL
		Expected	Actual		Expected**	Actual			
1. Plant Protection	134	59	131	6686	40	1	1	0	0
2. Plant Services	421	184	215	8254	66	72	659	7	11
3. Other Adm. and Gen. Services	852	373	112	3074	34	35	70	1	2
4. Idaho Division	83	36	79	2606	24	62	401	1	2
5. Metallurgy Division	203	89	163	7885	50	32	182	4	4
6. Chemical Engineering Division	212	93	208	9912	63	29	107	0	0
7. Reactor Engineering Research	324	142	148	6145	45	64	202	6	7
8. Chemistry Division	216	95	109	4788	33	38	297	15	30
9. Remote Control Engineering Division	70	31	16	668	5	7	88	2	4
10. Other Scientific	937	410	327	12667	100	75	168	2	3
11. Reactor Operations	63	28	58	2859	18	54	686	25	47
12. Central Shops	440	193	137	4829	42	56	173	9	13
13. Industrial Hygiene and Safety	126	55	73	3658	22	36	283	3	3
14. Fire Protection	44	19	42	2039	13	0	0	0	0
15. Other Technical Services	154	67	56	2528	17	10	40	1	1
Total	4279	1874	1874	78598	572	571	3357	76	127

*Expected on the basis of distributing the number of film proportionally to the Division distribution.

**Expected on the basis of distributing the No. of Employees with Measurable Readings proportionally to the distribution of No. of Employees Assigned Films.

Figure 7
CALENDAR YEAR 1959

LABORATORY DIVISION AT TIME OF
EXPOSURE TO EXTERNAL RADIATION -
FILM DATA

Table VIII
CALENDAR YEAR 1960

LABORATORY DIVISION AT TIME OF EXPOSURE TO EXTERNAL RADIATION - FILM DATA

Division Name	No. of Employees	No. of Employees Assigned Films		No. of Films Assigned	No. of Employees with Measurable Exposures		No. of Films with Measurable Readings	No. of Employees Exposed, Equal or Greater MPL	No. of Films, Equal or Greater MPL
		Expected	Actual		Expected ^a	Actual			
1. Plant Protection	129	58	126	5186	59	11	12	0	0
2. Plant Services	458	206	233	6450	109	125	596	7	9
3. Other Adm. and Gen. Services	950	427	157	2495	74	51	75	0	0
4. Idaho Division	155	70	150	3572	70	98	751	0	0
5. Metallurgy Division	224	101	192	7573	90	88	350	6	7
6. Chemical Engineering Division	223	100	222	7934	104	99	229	0	0
7. Reactor Engineering Research	310	139	152	4814	71	73	237	0	0
8. Chemistry Division	215	97	107	4087	50	50	410	14	24
9. Remote Control Engineering Division	76	34	28	936	13	13	126	1	2
10. Other Scientific	1114	500	375	9885	176	150	349	3	3
11. Reactor Operations	70	31	65	2472	30	62	749	24	57
12. Central Shops	464	208	137	3616	64	71	154	1	1
13. Industrial Hygiene and Safety	123	55	76	2821	36	49	336	5	5
14. Fire Protection	43	19	41	1620	19	23	32	0	0
15. Other Technical Services	156	70	55	2002	26	29	68	0	0
Total	4710	2115	2116	65463	991	992	4474	61	108

^aExpected on the basis of distributing the number of film proportionally to the Division distribution.

^{**}Expected on the basis of distributing the No. of Employees with Measurable Readings proportionally to the distribution of No. of Employees Assigned Films.

Figure 8
CALENDAR YEAR 1960

LABORATORY DIVISION AT TIME OF
EXPOSURE TO EXTERNAL RADIATION -
FILM DATA

Table IX
CALENDAR YEAR 1961

LABORATORY DIVISION AT TIME OF EXPOSURE TO EXTERNAL RADIATION - FILM DATA

Division Name	No. of Employees	No. of Employees Assigned Films		No. of Films Assigned	No. of Employees with Measurable Exposures		No. of Films with Measurable Readings	No. of Employees Exposed, Equal or Greater MPL	No. of Films, Equal or Greater MPL
		Expected*	Actual		Expected**	Actual			
1. Plant Protection	123	56	120	3107	61	39	53	0	0
2. Plant Services	481	219	238	4463	121	124	542	10	11
3. Other Adm. and Gen. Services	1002	456	208	3524	106	72	156	4	5
4. Idaho Division	217	99	212	5430	108	117	689	4	4
5. Metallurgy Division	230	105	184	4576	94	90	359	2	4
6. Chemical Engineering Division	247	112	246	5660	125	86	228	1	1
7. Reactor Engineering Research	313	143	173	3869	88	103	310	3	4
8. Chemistry Division	294	134	134	3138	68	72	388	11	14
9. Remote Control Engineering Division	78	36	34	645	17	19	137	1	2
10. Other Scientific	1150	524	349	6990	178	174	454	3	3
11. Reactor Operations	93	42	89	2322	45	87	1036	45	121
12. Central Shops	496	226	140	2558	71	75	168	2	2
13. Industrial Hygiene and Safety	132	60	89	2121	45	68	434	6	9
14. Fire Protection	44	20	42	1126	21	27	58	0	0
15. Other Technical Services	189	86	59	1374	30	29	110	0	0
Total	5089	2318	2317	50903	1178	1182	5122	92	180

*Expected on the basis of distributing the number of film proportionally to the Division distribution.

**Expected on the basis of distributing the No. of Employees with Measurable Readings proportionally to the distribution of No. of Employees Assigned Films.

Figure 9
CALENDAR YEAR 1961

LABORATORY DIVISION AT TIME OF
EXPOSURE TO EXTERNAL RADIATION -
FILM DATA

Table X

RANK ORDER OF LABORATORY DIVISION AT TIME OF EXPOSURE TO EXTERNAL
RADIATION BY NO. OF EMPLOYEES WITH MEASURABLE EXPOSURES

Division	Rank Order from Highest to Lowest No.			Division	Rank Order from Highest to Lowest No.		
	1959	1960	1961		1959	1960	1961
Other Scientific	1	1	1	Other Adm. and General Serv.	9	9	9.5
Plant Services	2	2	2	Metallurgy Division	10	5	5
Reactor Engineering	3	6	4	Chemical Engineering Div.	11	3	7
Idaho Division	4	4	3	Other Technical Services	12	12	13
Central Shops	5	7	8	Remote Control Engineering	13	14	15
Reactor Operations	6	8	6	Plant Protection	14	15	12
Chemistry Division	7	10	9.5	Fire Protection	15	13	14
Industrial Hygiene and Safety	8	11	11				

5. Job Group at Time of Exposure to External Radiation, Tables XI-XIV

The Job Groups define to some extent the type of work being done by the employees in the distributions. For example, Administrative Staff personnel are primarily engaged in the managerial aspect of the Laboratory, whereas Scientific Staff personnel are primarily engaged in research and development work. The Technician assists the Scientist in setting up projects for experiment and is responsible for securing data. The category of Maintenance includes all job groups whose responsibility it is to service the Laboratory's physical plant. These would include the Carpenters, Painters, Electricians, Pipefitters, etc. The category of Services includes job groups that provide a supporting service to the scientific and other Laboratory personnel. The two job groups included in this category that are most significant in view of receiving exposures to radioactivity are the Special Materials Representatives and Reclamation Men. Personnel in either job group frequently encounter radioactive materials. The Clerical category includes Secretaries, Stenographers, Clerks, Typists, etc., and the Central Shops category includes all job groups that are commonly associated with the shops, such as Machinists, Welders, Grinders, etc. The category of Reactor Operators includes those who operate and maintain the reactors of the Laboratory.

Tables XI-XIII and Figs. 10-12 show that the Technicians have the largest number of employees and films with measurable readings. Table XIV shows that, in relation to the number of employees assigned film, the Technicians have received more than their proportionate share of measurable exposures.

Table XIV also shows that the Reactor Operators receive more than their proportionate share of the measurable exposures. They represent a small percentage of the employees with measurable exposures, but a rather high percentage of the employees that exceed the weekly maximum permissible levels. Practically every Reactor Operator receives a measurable exposure, and nearly as many employees in this group exceed weekly MPLs as in the Technician group.

Table XI
CALENDAR YEAR 1959

JOB GROUP AT TIME OF EXPOSURE TO EXTERNAL RADIATION - FILM DATA

Job Group	No. of Employees	No. of Employees Assigned Films		No. of Films Assigned	No. of Employees with Measurable Exposures		No. of Films with Measurable Readings	No. of Employees Exposed, Equal or Greater MPL	No. of Films, Equal or Greater MPL
		Expected ^a	Actual		Expected	Actual			
A. Administrative Staff	271	119	108	4116	33	22	94	2	3
B. Scientific Staff	1041	456	533	23488	162	139	591	11	20
C. Technicians	733	321	459	20967	140	175	1128	23	33
D. Maintenance	390	171	201	7437	61	68	193	2	3
E. Services	333	146	218	10781	66	28	525	7	11
F. Clerical	560	245	67	1717	20	12	14	0	0
G. Shops	329	144	113	3726	34	52	168	9	13
H. Reactor Operators	37	16	37	1996	11	37	569	21	42
I. Miscellaneous	585	256	138	4370	42	38	75	1	2
Total	4279	1874	1874	78598	569	571	3357	76	127

^aExpected on the basis of distributing the number of film proportionally to the Job Group distribution.

^aExpected on the basis of distributing the No. of Employees with Measurable Readings proportionally to the distribution of No. of Employees Assigned Films.

Figure 10
CALENDAR YEAR 1959

JOB GROUP AT TIME OF EXPOSURE TO
EXTERNAL RADIATION - FILM DATA

Table XII
CALENDAR YEAR 1960

JOB GROUP AT TIME OF EXPOSURE TO EXTERNAL RADIATION - FILM DATA

Job Group	No. of Employees	No. of Employees Assigned Films		No. of Films Assigned	No. of Employees with Measurable Exposures		No. of Films with Measurable Readings	No. of Employees Exposed, Equal or Greater MPL	No. of Films, Equal or Greater MPL
		Expected*	Actual		Expected**	Actual			
A. Administrative Staff	325	146	121	3205	57	39	105	0	0
B. Scientific Staff	1093	491	567	18476	266	267	883	12	20
C. Technicians	865	389	571	19927	268	330	1939	21	32
D. Maintenance	440	198	232	5801	109	115	232	0	0
E. Services	344	155	221	8500	104	72	484	7	9
F. Clerical	619	278	83	1613	39	17	30	0	0
G. Shops	341	153	111	2856	52	61	139	1	1
H. Reactor Operators	44	20	44	1731	21	43	577	18	44
I. Miscellaneous	639	287	166	3354	78	48	85	2	2
Total	4710	2117	2116	65463	994	992	4474	61	108

*Expected on the basis of distributing the number of film proportionally to the Job Group distribution.

**Expected on the basis of distributing the No. of Employees with Measurable Readings proportionally to the distribution of No. of Employees Assigned Films.

Figure 11
CALENDAR YEAR 1960

JOB GROUP AT TIME OF EXPOSURE TO
EXTERNAL RADIATION - FILM DATA

Table XIII
CALENDAR YEAR 1961

JOB GROUP AT TIME OF EXPOSURE TO EXTERNAL RADIATION - FILM DATA

Job Group	No. of Employees	No. of Employees Assigned Films		No. of Films Assigned	No. of Employees with Measurable Exposures		No. of Films with Measurable Readings	No. of Employees Exposed, Equal or Greater MPL	No. of Films, Equal or Greater MPL
		Expected*	Actual		Expected**	Actual			
A. Administrative Staff	336	153	131	2420	67	51	132	2	2
B. Scientific Staff	1153	525	605	14004	309	288	957	15	20
C. Technicians	1020	464	665	16121	339	399	2137	25	40
D. Maintenance	471	214	248	4763	126	116	265	5	6
E. Services	358	163	233	6026	119	116	548	7	8
F. Clerical	652	297	90	1292	46	28	42	0	0
G. Shops	347	158	114	2084	58	71	159	2	2
H. Reactor Operators	58	26	58	1559	30	57	756	33	97
I. Miscellaneous	694	316	173	2634	88	56	126	3	5
Total	5089	2316	2317	50903	1182	1182	5122	92	180

*Expected on the basis of distributing the number of film proportionally to the Job Group distribution.

**Expected on the basis of distributing the No. of Employees with Measurable Readings proportionally to the distribution of No. of Employees Assigned Films.

Figure 12
CALENDAR YEAR 1961

JOB GROUP AT TIME OF EXPOSURE TO
EXTERNAL RADIATION - FILM DATA

Table XIV

PERCENT OF EXPOSURE EXPERIENCE REPRESENTED BY EACH JOB GROUP

Job Group	Employees with Assigned Film			Employees with Measurable Exposure			Film with Measurable Exposure			Employees $\geq$ Weekly MPL		
	1959	1960	1961	1959	1960	1961	1959	1960	1961	1959	1960	1961
Administrative Staff	5.8	5.7	5.7	3.9	3.9	4.3	2.8	2.3	2.6	2.3	0	1.1
Scientific Staff	28.4	26.8	26.1	24.3	26.9	24.4	17.6	19.7	18.7	15.7	18.5	11.1
Technicians	24.5	27.0	28.7	30.6	33.3	33.8	33.6	43.4	41.7	26.0	29.6	22.2
Maintenance	10.7	11.0	10.7	11.9	11.6	9.8	5.8	5.2	5.2	2.4	0	3.3
Services	11.6	10.4	10.0	4.9	7.3	9.8	15.6	10.8	10.7	8.7	8.3	4.5
Clerical	3.6	3.9	3.9	2.1	1.7	2.4	0.4	0.7	0.8	0	0	0
Shops	6.0	5.3	4.9	9.1	6.2	6.0	5.0	3.1	3.1	10.2	0.9	1.1
Reactor Operators	2.0	2.1	2.5	6.5	4.3	4.8	17.0	12.9	14.8	33.1	40.8	53.9
Miscellaneous	7.4	7.8	7.5	6.7	4.8	4.7	2.2	1.9	2.4	1.6	1.9	2.8

6. Sex of ANL Employees Exposed to External Radiation, Tables XV-XVII

As a matter of interest, the distribution of male and female employees for each year was determined. It is of interest to note that over the three years the females have received their proportionate share of the measurable exposures. The ratio of females to males that are assigned film is 0.08, and the ratio of females to males that receive measurable exposure is 0.08.

Table XV
CALENDAR YEAR 1959

SEX OF ANL EMPLOYEES EXPOSED TO EXTERNAL RADIATION - BODY FILM DATA

Sex	No. of Employees	No. of Employees Assigned Films		No. of Films Assigned	No. of Employees with Measurable Exposures		No. of Films with Measurable Readings	No. of Employees Exposed, Equal or Greater MPL	No. of Films, Equal or Greater MPL
		Expected*	Actual		Expected*	Actual			
Male	3470	1520	1734	73574	528	545	3306	75	126
Female	809	354	140	5024	43	26	51	1	1
Total	4279	1874	1874	78598	571	571	3357	76	127

*Expected on the basis of distributing the number of film proportionally to the Job Group distribution.

**Expected on the basis of distributing the No. of Employees with Measurable Readings proportionally to the distribution of No. of Employees Assigned Films.

Figure 13
CALENDAR YEAR 1959

SEX OF ANL EMPLOYEES EXPOSED TO
EXTERNAL RADIATION - BODY FILM DATA

Table XVI
CALENDAR YEAR 1960

SEX OF ANL EMPLOYEES EXPOSED TO EXTERNAL RADIATION - BODY FILM DATA

Sex	No. of Employees	No. of Employees Assigned Films		No. of Films Assigned	No. of Employees with Measurable Exposures		No. of Films with Measurable Readings	No. of Employees Exposed, Equal or Greater MPL	No. of Films, Equal or Greater MPL
		Expected	Actual		Expected*	Actual			
Male	3828	1720	1954	61253	910	947	4363	59	105
Female	882	396	162	4210	76	45	111	2	3
Total	4710	2116	2116	65463	992	992	4474	61	108

*Expected on the basis of distributing the number of film proportionally to the Job Group distribution.

**Expected on the basis of distributing the No. of Employees with Measurable Readings proportionally to the distribution of No. of Employees Assigned Films.

Figure 14
CALENDAR YEAR 1960

SEX OF ANL EMPLOYEES EXPOSED TO
EXTERNAL RADIATION - BODY FILM DATA

Table XVII
CALENDAR YEAR 1961

SEX OF ANL EMPLOYEES EXPOSED TO EXTERNAL RADIATION - BODY FILM DATA

Sex	No. of Employees	No. of Employees Assigned Films		No. of Films Assigned	No. of Employees with Measurable Exposures		No. of Films with Measurable Readings	No. of Employees Exposed, Equal or Greater MPL	No. of Films, Equal or Greater MPL
		Expected*	Actual		Expected**	Actual			
Male	4162	1895	2147	47819	1095	1126	5016	90	178
Female	927	422	170	3084	87	56	106	2	2
Total	5089	2317	2317	50903	1182	1182	5122	92	180

*Expected on the basis of distributing the number of film proportionally to the Job Group distribution.

**Expected on the basis of distributing the No. of Employees with Measurable Readings proportionally to the distribution of No. of Employees Assigned Films.

Figure 15
CALENDAR YEAR 1961

SEX OF ANL EMPLOYEES EXPOSED TO
EXTERNAL RADIATION - BODY FILM DATA

7. Distribution of Employees by Range of Exposure, Table XVIII

The distribution of employees by range of exposure shows very little change percentage-wise in the three years 1959-1961. The percentage of employees whose yearly accumulated exposures were less than the weekly MPL of 300 mr was 88.4% in 1959, 90.3% in 1960 and 88.8% in 1961. The yearly accumulated exposure for 99% of the employees in each of the three years was less than the quarterly MPL of 3.0 rem.

The highest accumulated exposure recorded in each year was 5.31 rem in 1959, 5.68 rem in 1960 and 5.99 rem in 1961.

The effect of changing to a two week monitoring period is seen in the slight increase in percentage of employees in each exposure range with the exception of the zero exposure range. The employees reported as having no measurable exposure decreased 8.0% from 1959-1961.

Table XVIII
DISTRIBUTION OF EMPLOYEES BY RANGE OF EXPOSURE

Exposure Range, mr	Number of Employees			Accumulated Totals			Accumulated Percent		
	1959	1960	1961	1959	1960	1961	1959	1960	1961
0	913	891	943	913	891	943	48.7	42.1	40.7
1- 99	559	801	894	1472	1692	1837	78.5	79.9	79.3
100- 199	119	163	157	1591	1855	1994	84.9	87.6	86.0
200- 299	66	57	63	1657	1912	2057	88.4	90.3	88.8
300- 399	41	33	39	1698	1945	2096	90.6	91.9	90.5
400- 499	19	29	32	1717	1974	2128	91.6	93.3	91.8
500- 599	19	24	30	1736	1998	2158	92.6	94.4	93.1
600- 699	9	13	17	1745	2011	2175	93.1	95.0	93.9
700- 799	8	13	11	1753	2024	2186	93.5	95.6	94.3
800- 899	10	5	13	1763	2029	2199	94.1	95.9	94.9
900- 999	7	6	11	1770	2035	2210	94.4	96.2	95.4
1000-1499	25	23	36	1795	2058	2246	95.8	97.2	96.9
1500-1999	20	18	25	1815	2076	2271	96.8	98.1	98.0
2000-2999	36	24	23	1851	2100	2294	98.8	99.2	99.0
3000-3999	18	6	10	1869	2106	2304	99.7	99.5	99.4
4000-4999	4	8	8	1873	2114	2312	99.9	99.9	99.8
5000-5999	1	2	5	1874	2116	2317	100.0	100.0	100.0

Figure 16

DISTRIBUTION OF EMPLOYEES
BY EXPOSURE - 1959

Figure 18

DISTRIBUTION OF EMPLOYEES
BY EXPOSURE - 1960

Figure 17

DISTRIBUTION OF EMPLOYEES
BY EXPOSURE - 1961

8. Evaluation of Performance - Indices of Exposure Experience, Table XIX

Figures 19-21 reveal that the Laboratory Radiation Safety program was quite effective from the third quarter of 1959 to the third quarter of 1960. The exposure rate was reduced 71.1% (1.82 mr/hr) and the average exposure was reduced 42.4% (43.5 mr). Meanwhile, the frequency rate of exposures increased from the third quarter of 1959 to a peak in the first quarter of 1960 and then decreased to the third quarter of 1960. The frequency rate in the third quarter of 1960 still remained higher than in the third quarter of 1959. After the third quarter of 1960, the frequency rate is cyclic, but with a slight downward trend.

The change to the two-week monitoring period and more sensitive film occurred in the third quarter of 1960. Coincident with this change is a slight upward turn in both the exposure rate and the average exposure. The formula for determining the exposure rate is

$$\text{Exposure Rate} = \frac{\frac{\sum \text{Readings in mr of Each Film with a Measurable Reading}}{\text{No. of Film with Measurable Readings}} \times \text{the Number of Hours Each Film Was Worn}}{}$$

From this it may be seen that in order for the exposure rate to increase, either the sum of the film readings must increase or the number of film with measurable exposures times the hours each film was worn must decrease.

This is particularly true since the frequency rate, which is determined as

$$\text{Frequency Rate} = \frac{\frac{\text{Number of Films with Measurable Readings} \geq 25 \text{ mr}}{\text{Total Manhours Worked by All Employees}} \times 10^6}{}$$

has shown a slightly downward trend. In order for the trend to be downward, the number of films with measurable readings must increase in proportionately greater numbers than the manhours worked. The distributions in Tables I-III show that the number of film with measurable readings increased from 1959 through 1961. The hours worn increased from 40 to 80 hr beginning with the third quarter of 1960; therefore, the sum of the film readings had to increase also in order for the exposure rate to increase. Table XVIII shows that from 1960 through 1961 the number of persons receiving exposures increased in nearly every exposure interval. The same analogy will hold for the trend of the average exposures, where

$$\text{Average Exposure} = \frac{\frac{\sum \text{Readings in mr of Each Film with a Measurable Reading}}{\text{No. of Film with Measurable Readings} \geq 25 \text{ mr}}{}$$

Table XIX
INDICES OF EXPOSURE EXPERIENCE

Calendar Quarter	Frequency Rate	Exposure Rate, mr hr	Average Exposure, mr	Number of Films with Measurable Exposure
59-1	398	2.36	94.3	779
59-2	470	2.14	85.5	791
59-3	506	2.56	102.5	866
59-4	592	2.39	95.6	1049
60-1	730	2.12	84.9	1348
60-2	635	2.78	71.0	1168
60-3	577	0.74	59.0	1063
60-4	543	0.80	63.8	1129
61-1	674	0.91	72.5	1245
61-2	666	0.79	63.4	1485
61-3	630	1.04	83.3	1178
61-4	538	1.04	83.5	1227
62-1	612	0.81	64.6	1232

Figure 19

FREQUENCY RATE - NUMBER OF MEASURABLE EXPOSURES PER MILLION MANHOURS WORKED

Figure 20

EXPOSURE RATE FOR FILM WITH MEASURABLE READINGS DETERMINED QUARTERLY FOR 1959 THROUGH 1961 AND THE FIRST QUARTER 1962

Figure 21

AVERAGE EXPOSURE FOR FILM WITH MEASURABLE READINGS DETERMINED QUARTERLY FOR 1959 THROUGH 1961 AND THE FIRST QUARTER 1962

E. CONCLUSIONS

The combined data for the years 1959, 1960, and 1961 show that the average age of employees receiving measurable exposures is 35.5 years, with 95.45% of the employees in the age range from 17.5 to 55.5 years. However, the radiation safety policy of the Laboratory does not allow employees under the age of 18 to work in radiation areas; therefore, it is unlikely that an employee less than 18 years of age received any exposure to radiation.

The average age of employees that exceed the weekly MPL is 34.6 years, with 95.45% of the employees in the age range from 17 to 52 years.

The years 1960 and 1961 may be taken as being more representative of the exposure experience under the present dosimetry system. These years indicate the distribution of exposures to be approximately a normal distribution with regard to age. The mean age for each year is 35.6 years and the median age is 35.0 years.

The average years of employment for Laboratory employees receiving radiation exposures is 5.5 years over the three-year period. Since the average years of employment for all employees is 5.4 years, the years of employment for employees receiving exposures appears to be distributed about the same as that for the Laboratory population.

The most frequent exposures are incurred by groups of employees involved in reactor operations and maintenance, cyclotron operations and maintenance, and decontamination work. These groups also have the highest frequency of exposure in excess of maximum permissible levels.

The Scientific Staff and Technicians make up an average of 57.7% of the employees that receive measurable exposures. By the same token, they receive an average of 58.7% of the exposures. The Reactor Operators, on the other hand, do not have a large percentage of the total employees receiving exposures, but all of the operators receive exposures.

An increase in the number of exposures recorded occurred when the Laboratory changed from the one-week to the two-week monitoring period. The percentage of employees within a given exposure range has increased slightly.

The trend of the frequency of exposures is on a gradual decline. The trends of the exposure rate and average exposure were downward from the second quarter in 1959 through the first quarter in 1961. The trends changed to a slightly increasing exposure rate and average exposure beginning with the first quarter of 1961. Such results are an indication that the efforts to control radiation exposures to employees is improving in effectiveness.

APPENDIX A

A. Groups Included in "Other Scientific":

1. Temporary Technical Employees
2. Physics Division
3. Biological and Medical Research Division
4. Reactor Drafting Section
5. Solid State Science Division
6. High Energy Physics Division
7. Particle Accelerator Division
8. International Institute of Nuclear Science and Engineering
9. Applied Mathematics Division
10. Radiological Physics Division

B. Groups Included in "Other Technical Services":

1. Electronics Division
2. Health Division
3. Special Materials Department
4. Technical Services Office

C. Groups Included in "Other Administrative and General Services":

1. Technical Information Division
2. Laboratory Director's Office
3. Business Manager's Office
4. Management Systems Department
5. ZGS Construction Management
6. Site Administration
7. Lodging and Food Services
8. Security Division (other than Plant Protection)
9. Graphic Arts Department
10. Legal Department
11. Accounting Department
12. Materials Handling Department
13. Purchasing Department
14. Personnel Department
15. Plant Engineering Division
16. Idaho Branch Administration

REFERENCE

1. J. F. Ege, Jr., IONIZING RADIATION, 4th Edition Accident Prevention Manual For Industrial Operations, Chapter 43, p. 38; National Safety Council, Chicago 11, Illinois (1959).

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