ORNL-4795

Applied HEALTH PHYSICS and SAFETY

Annual Report 1971

OAK RIDGE NATIONAL LABORATORY

OPERATED BY UNION CARBIDE CORPORATION • FOR THE U.S. ATOMIC ENERGY COMMISSION

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HEALTH PHYSICS DIVISION

APPLIED HEALTH PHYSICS AND SAFETY ANNUAL REPORT FOR 1971

K. Z. Morgan, Director

W. S. Snyder, Assistant Director

D. M. Davis, Department Head

JUNE 1972

OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37830
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UNION CARBIDE CORPORATION
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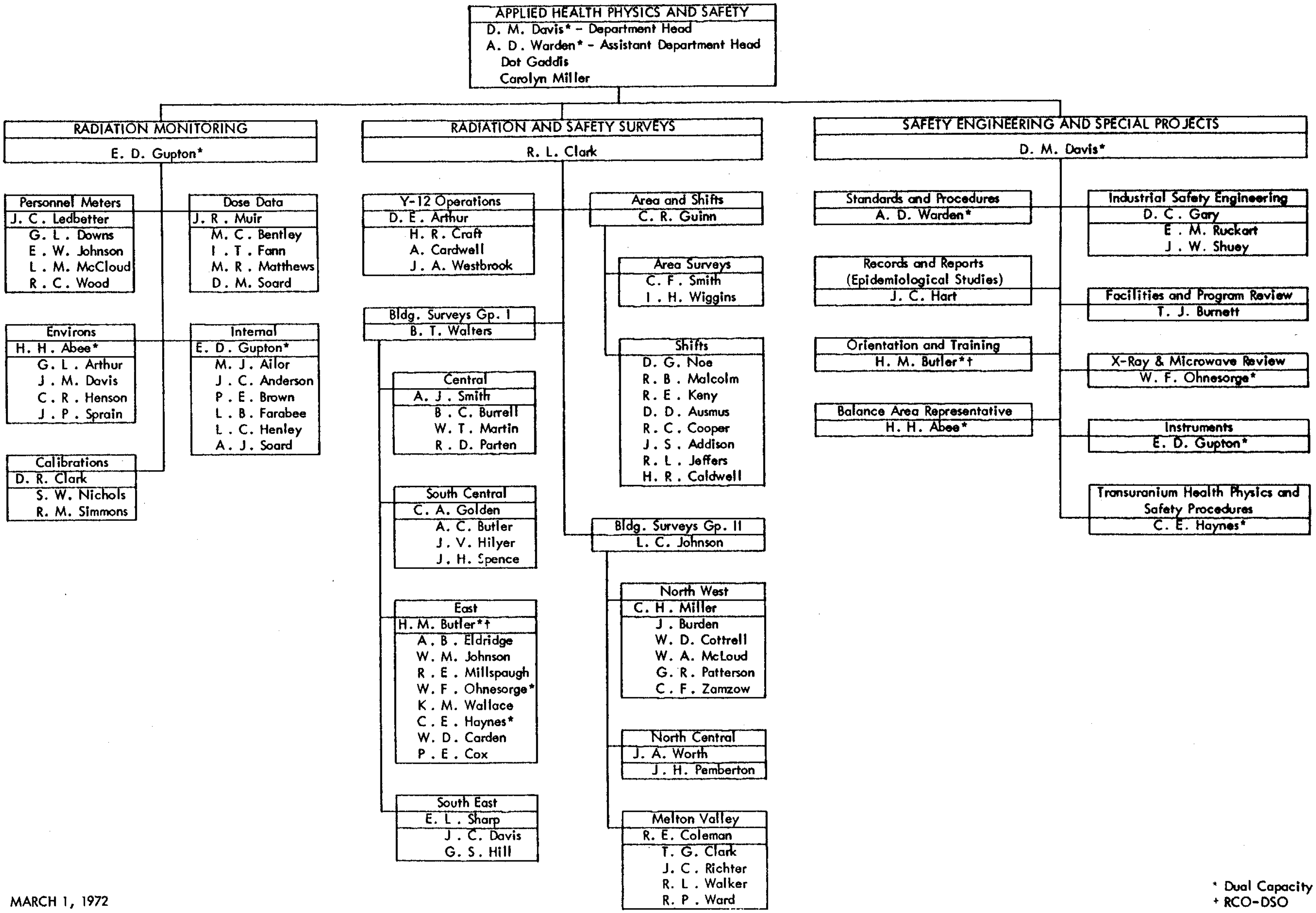

MARCH 1, 1972

1.0 ORGANIZATION CHART

2.0 SUMMARY

There were no external or internal exposures to personnel which exceeded the standards for radiation protection as defined in AEC Manual Chapter 0524.

There were no accidental releases of gaseous or liquid waste from the Laboratory which were of a level that required a report to the AEC.

Ten unusual occurrences involving radioactive materials were recorded during 1971. This is one more than the nine recorded for 1970. However, the nine recorded in 1970 was the lowest number since the system of reporting unusual occurrences was established in 1960. The average number reported for the past five years (1966-1970) was 15.6.

The safety record for 1971 was very good. As compared to 1970, there were 12.5 percent fewer Medical Treatment Cases, 22.5 percent fewer Serious Injuries, and 20 percent fewer Disabling Injuries. The Disabling Injury frequency rate for 1971 was 0.61 as compared with a frequency rate of 0.76 for 1970.

3.0 RADIATION MONITORING

It is the policy of the Oak Ridge National Laboratory to monitor the exposure to personnel and to the environment due to radiation and radioactive materials related to Laboratory operations.

3.1 Personnel Monitoring

All persons who enter Laboratory areas where there is a likelihood of exposure to radiation or radioactive materials are monitored for the kinds of exposure they are likely to sustain. External radiation dosimetry is accomplished mainly by means of film badges, pocket ion chambers, and hand exposure meters. Internal exposure is determined from bio-assays and in vivo counting.

3.1.1 Dose Analysis Summary, 1971

(a) External Exposures - No employee received a whole body radiation dose which exceeded the standards for radiation protection, AEC Chapter 0524. The highest whole body dose received by an employee was about 4.95 rem or 41 percent of the maximum permissible annual dose. The range of doses for persons using ORNL badge-meters is shown in Table 3.1.1.

As of December 31, 1971, no employee had a cumulative whole body dose which exceeded the recommended maximum permissible dose as based on the age proration formula 5(N-18) (Table 3.1.2). No employee had an average annual exposure rate that exceeded 5 rem per year of employment (Table 3.1.3).

The highest cumulative dose to the skin of the whole body received by an employee during 1971 was about 8 rem or 27 percent of the maximum permissible annual skin dose of 30 rem.

As of December 31, 1971, the highest cumulative dose of whole body radiation received by an employee was approximately 96 rem. This dose was accrued over an employment period of about 28 years and represented an average exposure of about 3.4 rem per year.

The highest cumulative hand exposure recorded during 1971 was about 31 rem or 41 percent of the recommended maximum permissible annual dose to the extremities.

The average of the ten highest whole body doses of ORNL employees for each of the years 1967 through 1971 are shown in Table 3.1.4. The highest individual dose for each of those years is shown, also.

The average annual dose to ORNL employees for the years 1967 through 1971 is the subject of Table 3.1.5. This rather arbitrary quantity is obtained by dividing the sum of all doses for the year by the number of employees involved.

(b) Internal Exposures - There was no case of internal exposure for which the deposition of radioactive materials within the body was estimated to have averaged as much as one-half a maximum permissible body burden for the year.

Four employees have estimated body burdens of transuranic alpha emitters slightly less than 50 percent of the recommended maximum permissible value.[1] The ICRP recommends, Publication 6, paragraph 86(a), that individuals who exceed 50 percent of a maximum permissible body burden be placed on a work assignment where the potential for internal exposure is reduced.

3.1.2 External Dose Techniques

(a) Film Meters - Film meters are issued to all persons who have access to ORNL facilities in which there is a likelihood of radiation exposures for which monitoring is required. Photo-badge-meters are assigned to all ORNL employees, and to certain other persons who are authorized to enter ORNL facilities. Temporary meters may be issued in lieu of photo-badge-meters for short-term use.

NTA (nuclear track) film packets are included in all film meters. The NTA films are processed routinely if the badge-meter is assigned to an individual who normally works where there may be exposure to neutrons; otherwise the films would be processed only in the event of a nuclear accident.

Beta-gamma sensitive films from badge-meters issued to full-time employees are processed routinely each calendar quarter (or more frequently, if necessary). Films used in other meters are processed as conditions of use may require. Films from meters issued to visitors are processed if there is a likelihood that a radiation exposure was incurred.

High-level radiation dosimetry components of the badge meters (sulfur, gold, indium, and metaphosphate glass) are for use in the event that doses exceed the capability of the monitoring films.

(b) Pocket Meters - Pocket meters (indirect reading, ionization chambers) are made available at all principal points of entry to ORNL premises. A pair of pocket meters is carried for the duration of a work shift by persons who work in an area where the potential for an exposure of 20 mR or more exists during the work shift. Pocket

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[1] AEC Manual Chapter 0502 requires an evaluation of the radiation exposure status of an employee when monitoring techniques indicate that a body burden equals or exceeds 50 percent of a maximum permissible limit.

meter pairs are processed each day by Health Physics technicians and readings of 20 mR or more are reported daily to supervision. Pocket meters are used for a day-to-day record of integrated exposure.

(c) Hand Exposure Meters - Hand exposure meters are film-loaded finger rings used to measure hand exposure. Hand exposure meters are issued to persons for use during operations where it is likely that the hand dose is such as to exceed 1 rem during the week. They are issued and collected by Radiation and Safety Surveys Section personnel who determine the need for this type of monitoring and arrange for a processing schedule.

(d) Metering Resume - Shown in Table 3.1.6 are the quantities of personnel metering devices used and processed during 1971. The number of films processed is less than the number issued, because those which are issued for accident dosimetry only are not processed unless there is a likelihood of exposure.

3.1.3 Internal Dose Techniques

(a) Bio-assay - Urine and fecal samples are analyzed for the purpose of making internal dose determinations. The frequency of sampling and the type of radiochemical analysis performed are based upon each specific radioisotope and the exposure potential. Because of the small quantities of radioactive material in most samples, qualitative analyses are not feasible, and only quantitative analyses for predetermined isotopes are performed routinely.

In most cases bio-assay data require interpretation to determine the dose to the person; computer programs are used for evaluation of extensive data on urinary excretion of ^{239}Pu. An estimate of dose is made for all cases in which it appears that one-fourth of a body burden, averaged over a calendar year, may be exceeded.

The analyses performed by the Applied Health Physics and Safety Radiochemical Lab during 1971 are summarized in Table 3.1.7.

(b) Whole Body Counter - The Whole Body Counter (an in vivo gamma spectrometer) may be used for determining internally deposited quantities of most radionuclides which emit gamma rays.

During the calendar year 1971 there were 332 whole body or thorax counts of ORNL employees. Of these counts, 319 indicated no detectable activity of significance, and all indicated less than 25 percent of a permissible body burden.

(c) Counting Facility - The Applied Health Physics and Safety counting facility determines radioactivity content of samples submitted by groups within the Department. A summary of analyses is in Table 3.1.8.

3.1.4 Reports

Routine reports of personnel monitoring data are prepared and distributed to Divisional supervision and to Applied Health Physics and Safety staff.

(a) Pocket Meter Data - A report is prepared daily of the names, ORNL division, and readings for pocket meter readings which were 20 mR or greater during the previous 24 hours.

A computer-prepared report, which includes all pocket meter data for the previous week, and summary data for the calendar quarter, is published and distributed weekly.

(b) External Dosimetry Data - A computer-prepared report, which includes data of recorded skin dose and whole body dose for the previous calendar quarter and totals for the current year, is published and distributed quarterly.

(c) Bio-Assay Data - A computer-prepared report, which includes data of sample status and results for the previous week, is published and distributed weekly. A quarterly and an annual report of results are prepared and distributed.

(d) Whole Body Counter Data - Preliminary results of analysis are reported on a card form soon after counting is done.

A computer-prepared report, which includes data collected during the previous calendar quarters of the calendar year, is published and distributed quarterly.

3.1.5 Records

Permanent records of personnel monitoring data are maintained for each person who is assigned an ORNL photo-badge-meter.

3.2 Environs Monitoring

The Health Physics Division monitors for airborne radioactivity in the East Tennessee area by the use of three separate monitoring networks. The local air monitoring (LAM) network consists of 22 stations which are positioned in relation to ORNL operational activities; the perimeter air monitoring (PAM) network consists of nine stations which are located near the perimeter of the AEC-controlled area; and the remote air monitoring (RAM) network consists of eight stations which are located outside the AEC-controlled area at distances of from 12 to 75 miles from ORNL.[2] The monitoring networks provide for the collection of (1) airborne radioactivity by air

[2]For maps showing location of station, see ORNL-4423, Applied Health Physics and Safety Annual Report for 1968.

filtration techniques, (2) radioparticulate fallout material by impingement on gummed paper trays, and (3) rainwater for measurement of fallout occurring as rainout. The filter data are representative of radioparticulate matter which might be considered respirable; the gummed paper data are representative of radioparticulate fallout; and the rainwater data provide information on the soluble and insoluble fractions of the radioactive content of fallout material.

Low-level radioactive liquid wastes originating from ORNL operations are discharged, after preliminary treatment, to White Oak Creek, which is a small tributary of the Clinch River. The radioactive content of White Oak Creek discharge is determined at White Oak Dam which is the last control point along the stream prior to entry of White Oak Creek waters into Clinch River waters. Water samples are collected also at a number of locations along the Clinch River, beginning at a point above the entry of waste into the River via White Oak Creek and ending at Center's Ferry (near Kingston, Tennessee) about 16 miles downstream from the confluence of White Oak Creek and the Clinch River. Water samples are analyzed for gross radioactivity and for specific radionuclides present in detectable quantities. The concentration of each nuclide detected is compared with its respective MPC_w value as specified by AEC Manual Chapter 0524, and the resulting fractions summed to arrive at the percent MPC_w in the Clinch River.

Samples of ORNL potable water are collected daily, composited and stored. At the end of each quarter these composites are analyzed radiochemically for ^{90}Sr content and are assayed for long-lived gamma emitting radionuclides by gamma spectrometry.

Raw milk samples are collected at 12 sampling stations located within a radius of 50 miles from ORNL. Samples are taken on a weekly basis from eight stations which are located outside the AEC-controlled area within a 12-mile radius of ORNL. Samples are collected every five weeks from the four remaining stations, all of which are located outside the 12-mile radius up to distances of about 50 miles. The purpose of the milk sampling program is twofold: first, samples collected in the immediate vicinity of ORNL provide data by which one may evaluate the possible effect of waste releases originating from ORNL operations; second, samples collected remotely to the immediate vicinity of the ORNL area provide background data which are essential in establishing a proper index from which releases of radioactive materials originating from Oak Ridge operations may be evaluated.

Background gamma radiation measurements are made at a number of locations in the East Tennessee area. These measurements are taken with a calibrated G-M and scintillation-type detectors at a distance of three feet above the surface of the ground.

Fish from the Clinch River are sampled during the spring and summer and analyzed for their radioactive content. The radionuclide concentrations in fish are related quantitatively to potential human intake of radioactivity through consumption of fish.

3.2.1 Atmospheric Monitoring

(a) Air Concentrations - The average concentrations of beta radioactivity in the atmosphere, as measured with filters from the LAM, PAM, and RAM networks during 1971, were as follows:

Network	Concentration (μCi/cc)
LAM	4.3×10^{-13}
PAM	2.3×10^{-13}
RAM	2.3×10^{-13}

The LAM network value of 4.3×10^{-13} μCi/cc is about 0.01 percent of the $MPCU_a$[3] based on occupational exposure of 3×10^{-9} μCi/cc. Both the PAM and RAM network values represent ~0.2 percent of the $MPCU_a$ of 1×10^{-10} μCi/cc applicable to releases to uncontrolled areas. A tabulation of data for each station in each network is given in Table 3.2.1. The weekly values for each network are illustrated in Table 3.2.2.

(b) Fallout (Gummed Paper Technique) - Radioparticulate fallout as measured by the LAM, PAM, and RAM networks did not change significantly from the values observed in 1970. Table 3.2.3 presents a tabulation of the average concentration measured at each station within each network. Table 3.2.4 gives the average concentration for each network by weeks.

(c) Rainout (Gross Analysis of Rainwater) - The average concentration of radioactivity in rainwater collected from the three networks during 1971 was as follows:

Network	Concentration (μCi/cc)
LAM	4.4×10^{-8}
PAM	5.1×10^{-8}
RAM	6.4×10^{-8}

The average concentration in each network was about 1.1 times greater than the values observed during 1970. The average concentration measured at each station within each

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[3]The $MPCU_a$ is defined as the maximum permissible concentration for an unknown mixture of radioisotopes in air. AEC Manual Chapter 0524, Appendix, Annex 1, gives exposure values applicable to various mixtures of radionuclides and establishes guide lines for deriving the $(MPCU)_a$.

network is presented in Table 3.2.5. The average concentration for each network for each week is given in Table 3.2.6.

(d) Atmospheric Radioiodine (Charcoal Cartridge Technique) - Atmospheric iodine sampled at the perimeter stations averaged 1.1×10^{-14} μCi/cc during 1971. This average represents about 0.01 percent of the maximum permissible inhalation concentration of 1×10^{-10} μCi/cc applicable to ^{131}I released to uncontrolled areas. The maximum concentration observed at any one station for one week was 6.1×10^{-14} μCi/cc, at PAM 32, the perimeter station located at Midway Gate.

The average radioiodine concentration at the local stations was 4.1×10^{-14} μCi/cc. This concentration is less than 0.01 percent of the maximum permissible inhalation concentration for occupational exposure. The maximum concentration at any one station for one week was 152×10^{-14} μCi/cc, at LAM 4, located west of the Settling Basin.

Table 3.2.7 presents the ^{131}I weekly average concentration data for both the Plant area (LAM) and the perimeter area (PAM) air monitoring networks.

(e) Milk Analysis - The average concentration of ^{131}I in raw milk samples collected near ORNL (within 12-mile radius) during 1971 ranged between 0.13 and 10.1 pCi/l and the average of samples collected from stations located more remotely from ORNL ranged between 0 and 10 pCi/l. The upper and lower limits of the average values were obtained by equating all values which were less than the minimum detectable level, 10 pCi/l, to zero for the lower limit and to 10 pCi/l for the upper limit. Table 3.2.8 gives the quarterly average and maximum values obtained from samples collected near ORNL and remote from ORNL.

The average concentration of ^{90}Sr in raw milk samples collected near ORNL was 11.4 pCi/l. The average concentration in the samples collected remote from ORNL was 9.4 pCi/l. Table 3.2.9 presents the quarterly average and maximum values obtained from both sampling areas.

The yearly average values for both ^{131}I and ^{90}Sr fall within the limits of FRC Range I daily intake guides, if one assumes an intake of 1 liter of milk per day.

(f) ORNL Stack Releases - The ^{131}I releases from ORNL stacks are summarized in Table 3.2.10.

3.2.2 Water Monitoring

(a) White Oak Lake Waters - A total of 8,945 curies of tritium and 8.9 beta curies of radioactivity other than tritium were released to the Clinch River during 1971 compared to 9,473 curies of tritium and 14 beta curies of other radionuclides released in 1970 (Table 3.2.11). Yearly discharges of specific radionuclides to the Clinch River, 1966 through 1971, are shown in Table 3.2.12.

The calculated average concentrations of the significant radionuclides in the Clinch River at Clinch River Mile (CRM) 20.8 (the point of entry of White Oak Creek into the River) are presented in Table 3.2.13. The percent MPC_w did not exceed 0.8 percent for any month during 1971 (Table 3.2.14).

(b) Clinch River Water – The measured average concentrations and the percent of MPC_w of radionuclides in the Clinch River at Melton Hill Dam (CRM 23.1), about three miles upstream, and at Center's Ferry (CRM 4.5), about 16 miles downstream from the entry of White Oak Creek, are given in Table 3.2.13.

(c) Potable Water – The average concentrations of ^{90}Sr in potable water at ORNL during 1971 were as follows:

Quarter Number	Concentration ^{90}Sr (μCi/ml)
1	4.1×10^{-10}
2	2.7×10^{-10}
3	5×10^{-10}
4	8.6×10^{-10}
Average for year	5.1×10^{-10}

The average value of 5.1×10^{-10} represents 0.17 percent of the MPC_w for drinking water applicable to individuals in the general population.

(d) Background Measurements – Background measurements were made each five weeks at a number of locations (established in 1961) in the East Tennessee area. The average background level during 1971 as measured at these stations was 9.3 μR/hr. Average background readings and the location of each station are presented in Table 3.2.15.

(e) Radionuclides in Clinch River Fish – Several species of fish were sampled from the Clinch River during the spring and summer of 1971. The fish were prepared for radiochemical analysis in a manner analogous to human utilization. Ten fish of each species were composited and the samples were analyzed, by gamma spectrometry and radiochemical techniques, for the critical radionuclides contributing significantly to the potential radiation dose to man. The data are tabulated in pCi/kg of wet weight (Table 3.2.16) for each radionuclide of significance. An estimate of man's intake of radionuclides from eating the fish is made by assuming an annual rate of fish consumption of 14 pounds. An estimated percentage of maximum permissible intake is calculated by assuming a maximum permissible intake of fish to be comparable to a daily intake of 2.2 liters of water containing the MPC_w of these radionuclides for a period of one year.

3.2.3 Environmental Monitoring Samples

A listing of environmental monitoring samples processed by type sample, type of analyses, and number of samples is given in Table 3.2.17.

3.3 Health Physics Instrumentation

The Health Physics Division shares with the Instrumentation and Controls Division the responsibility for the selection of electronic radiation monitoring instruments used in the ORNL health physics program. Normally, the Health Physics Division is responsible for determining the need for new instrument types and modifications to existing types, for specifying the health physics requirements and for approval of the design. The Health Physics Division is also responsible for calibrating all instruments used in the health physics program and is allocated the funds for maintenance of these instruments. Maintenance is performed or cross-ordered by the Instrumentation and Controls Division.

Non-electronic personnel monitoring devices are designed, tested, calibrated and maintained by Health Physics Division personnel.

3.3.1 Instrument Inventory

The electronic instruments used in the health physics program are divided, for convenience in servicing and calibrating, into two classes: the first class includes battery-powered portable instruments; the second class includes the stationary instruments that are AC powered. Portable instruments are assigned and issued to the Radiation and Safety Surveys Complexes. Stationary instruments are the property of the ORNL division which has the monitoring responsibility in the area in which the instrument is located. Table 3.3.1 lists portable instruments assigned at the end of 1971; Table 3.3.2 lists stationary instruments at the X-10 site in use at the end of 1971.

There was a decrease of seven stationary instruments and a decrease of two portable instruments during the year.

Inventory and Service Summaries for health physics instruments are prepared on an IBM 360. These computer-programmed reports enable the Instruments Group to maintain a current inventory on most health physics instrument requirements.

The allocation of stationary health physics monitoring instruments at the X-10 site by division is shown in Table 3.3.3.

3.3.2 Calibration Facility

The Health Physics Division maintains a calibration facility for the calibration and maintenance of portable radiation instruments and personnel metering devices. The facility is equipped with calibration sources, remote control devices, and shop space for the use of Instrumentation and Controls Division maintenance personnel. Health Physics personnel assign, arrange for maintenance of, calibrate, provide delivery services for, and maintain inventory and servicing data of all portable health physics instruments.

Portable instruments should be serviced (1) whenever repairs are needed, (2) at least once each two months for those which have replacement-type batteries, and (3) at least once each three months for those instruments which have "permanent" (rechargeable) batteries. The number of calibrations of portable instruments for 1971 is shown in Table 3.3.4.

Stationary instruments are calibrated by Calibrations Group personnel or by Radiation and Safety Surveys personnel who use sources which are designed, standardized, and provided by the Calibrations Group.

Table 3.1.1 Dose Data Summary for Laboratory Population Involving Exposure to Whole Body Radiation—1971

Group	Number of Rem Doses in Each Range							Total
	0-1	1-2	2-3	3-4	4-5	5-6	6 up	
ORNL Employees	4781	61	13	5	2	0	0	4862
ORNL-Monitored Non-Employees	104	0	0	0	0	0	0	104
TOTAL	4885	61	13	5	2	0	0	4966

Table 3.1.2 Average Rem Per Year Since Age 18—1971

	Number of Doses in Each Range				Total
	0-2.5	2.5-5.0	5.0-7.5	7.5 up	
ORNL Employees	4856	6	0	0	4862

Table 3.1.3 Average Rem Per Year of Employment at ORNL—1971

	Number of Doses in Each Range				Total
	0-2.5	2.5-5.0	5.0-7.5	7.5 up	
ORNL Employees	4847	15	0	0	4862

Table 3.1.4 Average of the Ten Highest Whole Body Doses and the Highest Individual Dose by Year

Year	Average of the Ten Highest Doses (Rem)	The Highest Dose (Rem)
1967	4.01	5.10
1968	4.11	4.71
1969	2.84	3.79
1970	2.79	4.04
1971	3.41	4.95

Table 3.1.5 Average Annual Whole Body Dose to the Average ORNL Employee

Year	Average Dose (Rem)
1967	0.142
1968	0.114
1969	0.088
1970	0.074
1971	0.073

Table 3.1.6 Personnel Meter Services

	1969	1970	1971
A. Pocket Meter Usage			
1. Number of Pairs Used			
ORNL	128,024	95,524	96,668
CPFF	7,228	12,844	8,528
Total	135,252	108,368	105,196
2. Average Number of Users per Quarter			
ORNL	1,149	998	907
CPFF	120	143	132
Total	1,269	1,141	1,039
B. Film Usage			
1. Films Used in Photo-Badge-Meters			
Beta-Gamma	20,930	19,710	18,400
NTA	10,360	9,760	9,110
2. Films Used in Temporary Meters			
Beta-Gamma	8,440	5,800	6,700
NTA	2,730	1,880	2,170
C. Films Processed for Monitoring Data			
1. Beta-Gamma	21,800	20,700	19,500
2. NTA	1,400	1,230	1,110
3. Hand Meter	1,100	970	1,480

Table 3.1.7 Radiochemical Lab Analyses—1971

Radionuclide	Urine	Feces	Milk	Soil	Other	Controls
Plutonium, Alpha	955	24		14		450
Trans Plutonium, Alpha	501	20				450
Uranium, Alpha	337			14		50
Strontium, Beta	725	8	436			80
Cesium-137	150					
Tritium	130					10
Iodine-131			436			52
Other	35	11			50	
TOTALS	2833	63	872	28	50	1092

Table 3.1.8 Counting Facility Analyses—1971

Types of Samples	Number of Samples			Unit Total
	Alpha	Beta	Gamma	
Facility Monitoring				
Smears	58,120	59,490		117,610
Air Filters	21,118	21,118		42,236
Environs Monitoring				
Air Filters	1,713	1,713		3,426
Fallout		1,412		1,412
Rain Water		1,262		1,262
Surface Water	102	272		374
Milk			427	427

Table 3.2.1 Concentration of Beta Radioactivity in Air—1971
(Filter Paper Data—Weekly Average)

Station Number	Location	Long-Lived Activity 10^{-13} μCi/cc	Particles[a] Per 1000 ft^3
	Laboratory Area		
HP-1	S 3587	2.6	0
HP-2	NE 3025	3.8	0.01
HP-3	SW 1000	3.3	0.01
HP-4	W Settling Basin	3.3	0
HP-5	E 2506	13.8	0.47
HP-6	SW 3027	3.6	0
HP-7	W 7001	3.3	0
HP-8	Rock Quarry	3.4	0
HP-9	N Bethel Valley Rd.	3.5	0
HP-10	W 2075	3.6	0.03
HP-16	E 4500	3.7	0
HP-20	HFIR	3.7	0
Average		4.3	0.04
	Perimeter Area		
HP-31	Kerr Hollow Gate	2.2	0
HP-32	Midway Gate	2.3	0
HP-33	Gallaher Gate	2.0	0
HP-34	White Oak Dam	2.2	0
HP-35	Blair Gate	2.3	0
HP-36	Turnpike Gate	2.6	0
HP-37	Hickory Creek Bend	1.9	0
HP-38	E EGCR	2.3	0
HP-39	Townsite	2.5	0
Average		2.3	0
	Remote Area		
HP-51	Norris Dam	2.2	0
HP-52	Loudoun Dam	2.3	0
HP-53	Douglas Dam	2.2	0
HP-54	Cherokee Dam	2.3	0
HP-55	Watts Bar Dam	2.5	0
HP-56	Great Falls Dam	2.4	0
HP-57	Dale Hollow Dam	2.2	0
HP-58	Knoxville	2.2	0
Average		2.3	0

[a]Detection limit - 10^4 d/24 hrs per particle by autoradiographic technique.

Table 3.2.2 Concentration of Beta Radioactivity in Air as Determined from Filter Paper Data—1971 (System Average - by Weeks)

Week Number	Units of 10^{-13} μCi/cc			Week Number	Units of 10^{-13} μCi/cc		
	LAM's	PAM's	RAM's		LAM's	PAM's	RAM's
1	1.7	0.76	0.71	29	3.9	3.0	2.9
2	1.1	0.59	0.49	30	6.1	3.5	4.0
3	0.9	0.63	0.65	31	2.4	1.4	1.6
4	1.2	0.68	0.69	32	1.2	1.1	0.75
5	1.2	0.91	0.84	33	5.1	2.6	2.6
6	1.2	0.82	0.86	34	3.5	1.5	1.7
7	1.8	1.1	1.2	35	5.8	2.9	2.2
8	2.2	1.3	1.4	36	8.5	1.5	1.8
9	2.4	1.9	1.7	37	34.0	1.1	1.0
10	2.3	1.3	1.6	38	2.1	0.90	1.1
11	2.9	1.7	1.8	39	0.7	0.65	0.59
12	3.5	2.0	2.6	40	1.3	0.99	0.83
13	3.9	2.6	2.8	41	1.3	1.2	0.75
14	4.7	2.9	2.8	42	1.9	1.1	1.1
15	6.0	4.3	4.0	43	0.8	0.51	0.50
16	8.0	5.3	5.7	44	3.4	0.57	0.55
17	8.3	5.7	6.5	45	0.9	0.66	0.50
18	6.2	4.1	4.0	46	1.1	0.77	0.82
19	8.5	6.9	6.4	47	1.1	0.51	0.57
20	7.2	5.1	3.8	48	1.1	0.44	0.74
21	10.5	7.1	7.0	49	0.7	0.34	0.51
22	8.9	5.5	6.0	50	0.6	0.78	0.42
23	8.2	5.0	5.7	51	2.3	1.4	1.0
24	5.9	3.9	4.0	52	1.1	0.40	0.47
25	6.6	4.4	4.8				
26	7.0	4.6	4.4				
27	6.3	3.8	4.7				
28	4.1	2.3	2.5	Average	4.3	2.3	2.3

Table 3.2.3 Radioparticulate Fallout—1971
(Gummed Paper Data—Weekly Average)

Station Number	Location	Long-Lived Activity 10^{-4} $\mu Ci/ft^2$	Total[a] Particles Per Sq. Ft.
	Laboratory Area		
HP-1	S 3587	0.51	0.13
HP-2	NE 3025	0.58	0.25
HP-3	SW 1000	0.47	0
HP-4	W Settling Basin	0.56	0.19
HP-5	E 2506	0.84	1.06
HP-6	SW 3027	0.56	0.19
HP-7	W 7001	0.48	0
HP-8	Rock Quarry	0.51	0.02
HP-9	N Bethel Valley Rd.	0.51	0.08
HP-10	W 2075	1.34	1.75
HP-16	E 4500	0.55	0.08
HP-20	HFIR	0.45	0
Average		0.61	0.31
	Perimeter Area		
HP-31	Kerr Hollow Gate	0.54	0
HP-32	Midway Gate	0.63	0.08
HP-33	Gallaher Gate	0.45	0
HP-34	White Oak Dam	0.47	0
HP-35	Blair Gate	0.50	0
HP-36	Turnpike Gate	0.55	0
HP-37	Hickory Creek Bend	0.49	0
HP-38	E EGCR	0.42	0
HP-39	Townsite	0.59	0
Average		0.52	0.01
	Remote Area		
HP-51	Norris Dam	0.49	0
HP-52	Loudoun Dam	0.40	0
HP-53	Douglas Dam	0.41	0.06
HP-54	Cherokee Dam	0.43	0.06
HP-55	Watts Bar Dam	0.51	0
HP-56	Great Falls Dam	0.39	0
HP-57	Dale Hollow Dam	0.48	0
HP-58	Knoxville	0.48	0
Average		0.45	0.01

[a]Detection limit - 10^4 d/24 hr per particle by autoradiographic technique.

Table 3.2.4 Radioparticulate Fallout Measurements[a] as Determined by Autoradiographic Techniques—1971 (Gummed Paper Data - System Average by Weeks)

Week Number	Particles/ft^2			Week Number	Particles/ft^2		
	LAM's	PAM's	RAM's		LAM's	PAM's	RAM's
1				29	0.08	0.22	
2				30			
3				31			
4				32			
5	0.17			33	0.17		0.38
6	0.33			34			
7	0.08			35	0.08		
8	0.17		0.13	36	0.50		
9	0.08			37	2.92		
10	0.08			38	0.08		0.25
11	0.08			39			
12	0.17			40			
13				41			
14	0.17			42			
15	0.42			43			
16	6.92			44	1.17		
17				45			
18	0.08			46	0.67		
19				47			
20		0.11		48			
21	0.08			49			
22				50			
23		0.11		51			
24				52			
25	1.42						
26	0.08						
27	0.25						
28				Average	0.31	0.01	0.01

[a]Detection limit - 10^4 d/24 hr per particle.

Blank entries are zero.

Table 3.2.5 Concentration of Beta Radioactivity in Rainwater—1971
(Weekly Average by Stations)

Station Number	Location	Activity in Collected Rainwater, μCi/ml
	Laboratory Area	
HP-7	West 7001	4.4×10^{-8}
	Perimeter Area	
HP-31	Kerr Hollow Gate	4.9×10^{-8}
HP-32	Midway Gate	5.0
HP-33	Gallaher Gate	5.9
HP-34	White Oak Dam	5.0
HP-35	Blair Gate	5.7
HP-36	Turnpike Gate	4.1
HP-37	Hickory Creek Bend	4.0
HP-38	E EGCR	7.3
HP-39	Townsite	4.1
Average		5.1×10^{-8}
	Remote Area	
HP-51	Norris Dam	7.4×10^{-8}
HP-52	Loudoun Dam	5.8
HP-53	Douglas Dam	7.3
HP-54	Cherokee Dam	7.0
HP-55	Watts Bar Dam	6.2
HP-56	Great Falls Dam	7.0
HP-57	Dale Hollow Dam	6.2
HP-58	Knoxville	4.5
Average		6.4×10^{-8}

Table 3.2.6 Weekly Average Concentration of Beta Radioactivity in Rainwater—1971 (Units of 10^{-8} μCi/ml)

Week Number	LAM's	PAM's	RAM's	Week Number	LAM's	PAM's	RAM's
1	2.6	2.0	4.2	29	4.2	4.6	5.9
2	2.4	3.2	1.9	30	1.9	4.1	3.8
3	0.8	2.3	2.7	31	2.6	3.0	2.9
4	1.8	1.6	3.5	32	2.9	3.5	4.6
5	*	*	6.7	33	5.9	4.9	4.3
6	3.4	2.6	3.5	34	1.3	2.2	7.5
7	1.9	3.5	7.1	35	*	*	*
8	3.3	3.5	3.1	36	*	*	1.1
9	2.4	2.5	1.6	37	5.1	4.0	3.8
10	4.3	4.4	7.2	38	0	1.5	1.5
11	4.1	5.7	6.0	39	4.5	2.1	1.0
12	6.1	8.6	6.5	40	*	2.9	2.0
13	6.8	7.1	6.9	41	1.1	1.5	1.5
14	8.8	8.9	9.3	42	0	2.0	1.7
15	6.2	6.5	6.5	43	2.0	2.3	1.6
16	*	*	*	44	*	1.3	15.1
17	10.4	8.7	6.9	45	0.70	1.6	2.7
18	10.9	8.6	12.0	46	*	*	*
19	*	15.5	14.1	47	2.7	2.8	4.9
20	8.7	9.2	12.9	48	0.60	1.0	1.8
21	14.5	21.9	12.0	49	2.3	0.6	1.3
22	*	*	13.1	50	0	0.8	1.2
23	10.8	9.8	17.2	51	0.70	1.2	1.5
24	11.7	9.8	15.1	52	*	*	13.5
25	12.5	16.5	18.6				
26	14.5	*	20.1				
27	*	5.7	19.1				
28	14.4	9.4	10.9	Average	4.4	5.1	6.4

*No rainfall.

Table 3.2.7 Weekly Average Concentration of ^{131}I in Air—1971
(Units of 10^{-14} μCi/cc)

Week Number	LAM's	PAM's	Week Number	LAM's	PAM's
1	2.0	0.9	29	1.8	0.8
2	1.9	0.8	30	10.9	1.1
3	3.3	0.8	31	10.0	1.5
4	1.4	0.7	32	4.8	0.8
5	2.8	0.9	33	5.0	1.1
6	1.8	0.9	34	2.4	1.8
7	1.3	0.7	35	4.7	1.4
8	2.4	0.7	36	3.2	1.6
9	4.0	0.7	37	5.2	1.3
10	3.7	1.0	38	3.2	1.3
11	3.9	0.8	39	2.6	1.4
12	2.5	0.6	40	3.8	0.9
13	1.9	0.7	41	4.8	1.4
14	26.6	1.0	42	3.2	1.0
15	2.3	0.9	43	4.6	1.3
16	3.5	0.9	44	3.0	1.4
17	1.9	0.9	45	3.0	1.2
18	4.3	0.9	46	3.0	2.0
19	4.3	1.7	47	2.7	1.0
20	4.8	1.2	48	4.0	1.1
21	1.8	0.8	49	2.9	1.3
22	4.1	1.3	50	3.0	1.0
23	5.8	1.4	51	3.7	0.8
24	4.1	1.3	52	2.5	1.0
25	4.7	0.8			
26	5.2	0.8			
27	3.7	1.2			
28	3.5	1.6	Average	4.1	1.1

Table 3.2.8 Concentration of ^{131}I in Raw Milk—1971
(Units of pCi/l)

Quarter	Near ORNL		Remote from ORNL	
	Average*	Maximum	Average*	Maximum
1	0.12-10.0	13	0-10	10
2	0.17-10.1	18	0-10	10
3	0.2 -10.1	21	0-10	10
4	0 -10.0	10	0-10	10
Annual	0.13-10.1		0-10	

*See text, paragraph 3.2.1(e).

Table 3.2.9 Concentration of ^{90}Sr in Raw Milk—1971
(Units of pCi/l)

Quarter	Near ORNL		Remote from ORNL	
	Average	Maximum	Average	Maximum
1	11	25	9.8	15
2	12	32	9.7	14
3	12	27	9.9	12
4	10	29	7.5	10
Annual	11.4		9.4	

Table 3.2.10 Discharge of ^{131}I from ORNL Stacks—1971*

Stack Number	Curies	
	Total for Year	Monthly Average
2026	0	0
3039	2.95	0.246
3020	0	0
7512	0	0
7911	0.51	0.043
Total	3.46	0.289

*Data furnished by Operations Division.

Table 3.2.11 Liquid Waste Discharged to Clinch River—1971

	Curies	
	Total for Year	Monthly Average
Beta Activity other than Tritium	8.9	0.74
Tritium	8,945	745
Transuranic Alpha Emitters	0.05	0.004

Table 3.2.12 Yearly Discharges of Radionuclides to Clinch River
(Curies)

Year	^{137}Cs	^{106}Ru	^{90}Sr	TRE*(-Ce)	^{144}Ce	^{95}Zr	^{95}Nb	^{131}I	^{60}Co	^{3}H
1966	1.6	29	3.0	4.9	0.1	0.67	0.67	0.24	7	3093
1967	2.7	17	5.1	8.5	0.2	0.49	0.49	0.91	3	13273
1968	1.1	5	2.8	4.4	0.03	0.27	0.27	0.31	1	9685
1969	1.4	1.7	3.1	4.6	0.02	0.18	0.18	0.54	1	12247
1970	2.0	1.2	3.9	4.7	0.06	0.02	0.02	0.32	1	9473
1971	0.9	0.5	3.4	2.9	0.05	0.01	0.01	0.21	0.8	8945

*Tri-Valent Rare Earths.

Table 3.2.13 Radioactivity in Clinch River—1971

Location	Concentration of Radionuclides of Primary Concern Units of 10^{-8} μCi/ml							% MPC_w
	^{90}Sr	^{144}Ce	^{137}Cs	$^{103-106}Ru$	^{60}Co	^{95}Zr-^{95}Nb	^{3}H	
Melton Dam[a]	0.05	0.03	< 0.01	0.12	0.03	< 0.01	< 100	< 0.21
Clinch River at White Oak Creek[b]	0.05	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	115	< 0.20
Center's Ferry[a]	0.10	0.03	0.09	0.20	0.08	< 0.01	185	< 0.44

[a] Measured values.

[b] Values given for this location are calculated values based on the concentrations of wastes released from White Oak Dam and the dilution afforded by the Clinch River; they do not include radioactive materials (e.g., fallout) that may enter the river upstream from CRM 20.8.

Table 3.2.14 Calculated Percent MPC_w of ORNL Radioactivity Releases in Clinch River Water Below the Mouth of White Oak Creek—1971

Month	% MPC_w
January	0.72
February	0.37
March	0.80
April	0.23
May	0.23
June	0.23
July	0.19
August	0.19
September	0.12
October	0.12
November	0.09
December	0.36
Average	0.20

Table 3.2.15 Background Radiation in East Tennessee Area—1971

Stations	μR/hr
Great Falls	8.8
Dale Hollow	8.9
Crossville	8.2
Watts Bar	9.9
Rockwood	8.1
Wartburg	8.7
Kingston	8.8
Oliver Springs	11.9
Lenoir City	8.6
Clinton	9.7
Norris	8.5
Powell	10.8
Halls Cross Roads	9.9
Strawberry Plains	9.6
Cherokee	8.7
Average	9.3

Table 3.2.16 Radionuclide Content of Clinch River Fish—1971

Species	pCi/kg Wet Weight			Estimated % MPI
	^{90}Sr	^{106}Ru	^{137}Cs	
White Crappie	135	≤ 180	343	≤ 0.38
Smallmouth Buffalo	108	≤ 315	336	≤ 0.32

Table 3.2.17 Environmental Monitoring Samples—1971

Sample Type	Type of Analyses	Number Samples
Monitoring network filters	Gross beta, autoradiogram	1710
Gummed paper fallout trays	Gross beta, autoradiogram	1502
Rain water	Gross beta	757
White Oak Dam effluent	Gross beta, radiochemical, gamma spectrometry	520
Clinch River water	Gross beta, radiochemical, gamma spectrometry	12
Raw milk	Radiochemical	428
Potable water	Radiochemical, gamma spectrometry	4
Soil samples	Radiochemical, Plutonium and Uranium	9

Table 3.3.1 Portable Instrument Inventory—1971

Instrument Type	Instruments Added 1971	Instruments Retired 1971	In Service Jan. 1, 1972
G-M Survey Meter	32	31	489
Cutie Pie	4	17	441
Alpha Survey Meter	12	1	260
Neutron Survey Meter	0	0	104
Miscellaneous	0	1	27
TOTAL	48	50	1324

Table 3.3.2 Inventory of Facility Radiation Monitoring Instruments for the Year—1971

Instrument Type	Installed During 1971	Retired During 1971	Total Jan. 1, 1972
Air Monitor, Alpha	1	1	100
Air Monitor, Beta	0	1	178
Lab Monitor, Alpha	2	5	171
Lab Monitor, Beta	3	4	211
Monitron	0	5	222
Other	3	5	124
TOTAL	9	21	1006

Table 3.3.3 Health Physics Facility Monitoring Instruments
Divisional Allocation at X-10 Site—1971

ORNL Division	α Air Monitor	β Air Monitor	α Lab Monitor	β Lab Monitor	Monitron	Other	Total
Analytical Chemistry	6	14	17	19	15	6	77
Chemical Technology	49	49	63	33	39	36	269
Chemistry	9	9	20	25	20	8	91
Metals and Ceramics	11	6	14	4	5	10	50
Isotopes	14	29	25	43	54	20	185
Operations	2	51	7	30	63	20	173
All Others	9	20	25	57	26	24	161
TOTAL	100	178	171	211	222	124	1006

Table 3.3.4 Calibrations Résumé—1971

	1970	1971
Portable Instruments Calibrated		
Beta-Gamma	3,228	3,315
Neutron	327	369
Alpha	797	876
Pocket Chambers and Dosimeters	1,401	2,044
Films Calibrated	1,402	2,712

4.0 RADIATION AND SAFETY SURVEYS

It is the policy of the Oak Ridge National Laboratory that radiation and safety surveys shall be performed at a frequency and to the extent necessary to assure safe working conditions.

4.1 Laboratory Operations Monitoring

During 1971 Radiation and Safety Surveys personnel assisted the operating groups in keeping the contamination, air concentration and personnel exposure levels well below the established maximum permissible limits. Through seminars, safety meetings and informal discussions with supervision, they assisted in reducing or eliminating a number of problems associated with radiation protection at the Laboratory. The following is a brief description of some of the problems and methods of solution.

4.1.1 Replacement of Exhaust Ducts Serving Building 3019 Analytical Laboratories

Air from the Analytical Chemistry Division's hoods and cells in Building 3019 is exhausted through several hundred feet of 36" diameter, overhead, ductwork to HEPA filters near the 3020 stack. This duct is subjected to various corrosive vapors and materials. Much of the duct was replaced in 1966. Routine health physics surveys revealed leaks in the remaining "old" sections. Radiation and Safety Surveys personnel participated in formulating procedures for the replacement of these sections and provided monitoring surveillance throughout the job.

A portable exhauster with a HEPA filter and the duct connecting to the Pilot Plant cell exhaust system were used to maintain a negative pressure in the cells and hoods. Plywood blanks were inserted to minimize inleakage as duct sections were removed. Personnel wore two layers of Contamination Zone clothing and masks. The grossly contaminated duct sections, wrapped in multiple layers of plastic, were successfully transferred to the burial ground. Personnel exposure and spread of contamination were minimal. Replacement ducts were constructed of stainless steel with a much longer life expectancy.

4.1.2 Building 3019 Preparations for Production of High Purity $^{233}UO_2$ for the Light Water Breeder Reactor Program

Chemical Technology Division's preparations for the LWBR program included modifications to the existing solvent extraction system, installation of a "scrap" dissolver, removal and replacement of the old dissolver charging gloved box, and installation of a new ion exchange purification system. Numerous entries into grossly alpha contaminated cells were required. Wash down of cell surfaces enabled use of multiple layers of Contamination Zone clothing and masks rather than air supplied plastic suits. Two-hundred and six Radiation Work Permits were certified for these and related operations. Contamination of personnel and contamination spread was minimal due to close health physics surveillance and the cooperation of all parties involved in implementing contamination control procedures.

4.1.3 Health Physics Assistance during the Design and Construction of the Metals and Ceramics Division High Level Radiation Laboratories in Building 4501 Mezzanine

Assistance was given by Health Physics personnel to the Engineering and Metals and Ceramics Divisions during the planning and construction of two high level radiation laboratories and storage area in Building 4501. Glove Box and hood exhaust systems were utilized for the containment and shielding of irradiated metal specimens during preparation. As a result of this cooperative planning exposure levels to Laboratory personnel were minimized and the Radiation and Contamination Zones were limited to the glove boxes, hoods and storage areas.

4.1.4 Removal of Glove Boxes Grossly Contaminated with ^{243}Am and ^{244}Cm and Associated Waste Products from Building 4507 to Storage

Health Physics personnel were involved in the removal and storage of two glove boxes used in the pilot operation for the purification of transuranium isotopes in Cells 3 and 4 of Building 4507. The glove boxes had been left grossly contaminated (estimated contamination was $> 10\ \mu Ci/ft^3$). As the process lines were broken they were flanged sealed and the boxes were wrapped in plastic. They were then placed in plastic-lined wooden boxes, sealed, and made leak-tight with caulking. Finally, these boxes were placed in metal containers, also made leak-tight, and sent to temporary storage in the ORNL Solid Waste Disposal Yard to await salt mine disposal. The removal and storage procedures were completed without significant personnel exposure or the spread of contamination.

4.1.5 Decontamination and Revisions of Cells 1, 2, and 3, Building 4505, and Removal of Cell Exhaust Ducts and Fan Housing

Health Physics assistance and consultation was provided for the removal of obsolete contaminated equipment and the decontamination of the Cells 1, 2, and 3 in Building 4505. The cells were contaminated, for the most part, with natural thorium and uranium and probed to $8 \times 10^3\ \alpha$ d/m and smeared to 240 α d/m. All equipment was bagged-out and the cells were scrubbed down by plant personnel wearing Contamination Zone clothing and masks. The cell surfaces were then painted and the Contamination Zones removed. Contractor personnel wearing prescribed protective garments removed the contaminated portions of the cell exhaust ducts and fan housing. Filters, ducts, etc., were wrapped in plastic for burial ground disposal. During the entire operation contamination was adequately contained and no significant personnel exposures resulted.

4.1.6 Applied Health Physics and Safety Activities in the Transuranium Research Laboratory during 1971

The TRL Applied Health Physics and Safety staff continued their activities of inspection, testing and operation of all stages of the TRL containment and air-cleaning system and the primary containment of gloved box system.

Applied Health Physics and Safety personnel, as an integral part of the investigating team, continued to collaborate with TRL researchers, assisting them in planning and conducting various experiments with transuranium isotopes. General research areas involved included "inorganic and structural chemistry of the transuranium elements" and "nuclear structure and properties of transuranium isotopes". Studies were carried out at the TRL, ORIC, High Voltage Lab, ORELA and in the basement of EGCR.

A number of training programs were conducted during the year for new staff members and visiting scientists and students.

4.1.7 Annual Survey of X-Ray Equipment

A survey of all registered X-ray installations was completed during the year. There are presently 74 X-ray machines registered. Most aspects of X-ray safety were considered including:

(a) Clear and adequate identification of X-ray machines and work areas in which the machines are located.
(b) X-ray leakage around the machines.
(c) Operation and integrity of interlocks and other safety devices.
(d) Person primarily responsible for X-ray machine and designated operators for same.
(e) Changes in equipment or experiments.
(f) Blueprints and/or diagrams of safety equipment.
(g) Written operating procedures.

As a result of the survey, recommendations were made to improve warning lights on two X-ray diffraction units and for improving a shield on one cabinet type unit. Applied Health Physics and Safety also requested operating procedures and diagrams of safety equipment relative to units in one X-ray diffraction laboratory.

4.1.8 Survey of Microwave Generating Equipment

All divisions at the Laboratory were contacted in determining the location of microwave generating equipment. Generators which could present potential hazards were surveyed. Most of the equipment is used in a way which either isolates or contains the microwaves and no hazard exists or is likely to exist. The equipment found to have the highest potential for producing a hazard was the microwave ovens which are used for heating, drying and cooking. Two ovens were found to be emitting microwaves somewhat above the level set by federal standards and were subsequently repaired. The ovens will be checked periodically since wear, tear and dirt may cause them to emit microwaves at the door seals.

4.1.9 Health Physics Coverage during Transfer of Multicurie Quantities of ^{60}Co

Applied Health Physics and Safety personnel provided survey coverage during the transporting of approximately 16,000 curies of ^{60}Co from Building 3047 to Building 3025. Monitoring was provided during the transfer of the material from the carrier to the new storage facility located in the basement of Building 3025. Momentary readings as high as 10 R/hr at 12" were recorded as the cobalt slugs were transferred from carrier into the irradiator; however, personnel exposures did not exceed 25 mR during the course of the job.

4.1.10 Assistance Provided by Applied Health Physics and Safety Personnel on Salient Items at the HFIR Facility

Health Physics monitoring services were provided during the initial operation and checkout of the pneumatic tube facility operated by the Analytical Chemistry Division for the purpose of activation analyses. Assistance was also provided in subsequent decontamination of the system after fission product release resulting from plutonium sample burnup. Contamination was confined to internal areas of system and no significant exposure to personnel was involved.

Leaks were detected in the systems valve box area using a CAM sniffer hose. Leaks of radioactive gas were, thus, localized and properly controlled.

Assistance was provided in the checkout of tri-axial neutron spectrometer shields at HB-2 and HB-4. These facilities are used for research in neutron diffraction and neutron time of flight spectroscopy. Addition of shielding was advised for gamma and fast neutron scatter around main shields. Capture gamma shielding was used around collimators and thermal neutron shielding around exposed target crystals. The latter shield stopped the main beam in the catcher and the thermal neutron beams coming from the target crystal due to Bragg scattering.

Assistance was provided during the removal and replacement of anion and cation resin in both primary coolant demineralizer cells and the internal modification of the anion tank in the west cell. The resin was contaminated with ^{244}Cm and activation products, which gave dose rates up to 2 R/hr in the work areas. Contamination was confined to zoned areas and the dose to any one person did not exceed 200 mrem during the completion of these operations.

4.1.11 Modification of Cell Process Equipment to Separate and Purify Milligram Quantities of ^{252}Cf, TRU Facility (Building 7920)

Cell process equipment was modified to separate and purify some hundreds of milligrams of ^{252}Cf from SRL pu-al tubes. The modification and repair of the equipment was accomplished using both remote and direct maintenance techniques. The extreme levels of alpha and beta-gamma contamination encountered made containment a difficult problem. The job was accomplished, however, by decontamination of cell surfaces and equipment, using tents over open cell pits and bagging of each tool or item leaving the cell. Personnel exposures were held below permissible limits by flooding cells with water, steel shield covers and remote maintenance techniques. Health Physics personnel advised and assisted in all phases of this program.

4.1.12 Applied Health Physics and Safety Assistance on Salient Items Conducted at TURF (Building 7930)

Health Physics personnel assisted with advice, consultation and monitoring in the following programs at the TURF Facility:

(1) Construction, design and use of a glove box to contain the "in-cell" end of the manipulator from Cell G when transferring and decontaminating the manipulator.

(2) The transfer, handling, and storage in Cell B of tantalum foils irradiated in an accelerator at Stanford. They were transferred again to the basement of the EGCR for low-background counting.

(3) The transfer and handling of irradiated thermocouples from the EBR II in Idaho to Cell B for testing and examination. One test group of 10 thermocouples read 100 R/hr at $\sim$ 18", and loose contamination on the thermocouples presented problems in handling. However, the work was completed with minimal exposure to personnel.

4.1.13 Transfer of Sodium Metal from MSRE, Building 7503, to TSF, Building 7700

Applied Health Physics and Safety personnel assisted in the transfer of 40 tons of sodium metal from drums at 7503 (MSRE) to the TSF. The sodium metal was melted in the drums and then transferred to large containers where the metal returned to the solid state. Studies were conducted at the TSF involving neutron transport in the sodium. This program was accomplished without incident.

4.1.14 Applied Health Physics and Safety Activities at DOSAR (Building 7710)

Improvements were made in the neutron warning system at the DOSAR Low Energy Accelerator (Building 7712). The neutron monitron was moved into the same area as the accelerator target and an indication of the status of the monitor was added to the control console.

An internal document was prepared entitled "Health Physics and Safety Guidelines for the DLEA Facility", which describes the accelerator and the warning systems and a check list for periodic inspection of the latter.

Planning and preparations for the removal, disassembly, and inspection of the Health Physics Research Reactor (HPRR) core resulted in a minimum of personnel radiation exposure. Although core plates gave readings up to 9 R/hour at 1-1/2", the maximum doses to the hands were less than 400 mR.

Field tests have begun on a ring-type dosimeter for use when handling isotopic neutron sources. The detector consists of a thin polycarbonate film in contact with a ^{238}U foil. Fission fragments, resulting from neutron interactions with the foil, produce damage tracks in the film which are developed in a KOH solution and counted. At present the minimum detectable exposure is about 200 millirems.

4.1.15 Radiation Surveys Made Off Area

Health Physics, on authorized request, also furnished survey coverage for a number of off-area projects. Following is a brief description of some of the items covered.

(a) Transport of Gasbuggy Gas - During February of 1971 two liquid propane tankers containing gas from the nuclearly stimulated Gasbuggy well were transported under escort from Farmington, New Mexico, to Big Lake, Texas. A member of the Radiation and Safety Surveys Section provided escort services during the transfer as minor quantities of radioactivity, mainly tritium, were involved.

(b) Health Physics Assistance during Shale Fracturing Test Operations in New York State - Continuous health physics surveillance was provided during the two Hydro-Fracturing experiments at West Valley, New York, during the year. All personnel exposures were below maximum permissible levels during the injections of the tracers (approximately 2.7 Ci of ^{95}Zr-Nb for each injection).

(c) Health Physics Coverage of the Radio-Isotopic Sand Tracer Project - In a continuation of a project instituted in 1967 a representative of the Radiation and Safety Surveys Section again acted as project health physicist at the Radio-Isotopic Sand Tracer Tests conducted by the Technical Services Group of the Isotopes Division for the U. S. Corps. of Engineers. Two tests were conducted, one at Masonboro Inlet, North Carolina, and one at Point Mugu, California. The tests involved placing radioactive sand, tagged with $^{198-199}Au$, off shore and tracing its movement along the ocean floor by the use of a specially designed radiation detection system. The Health Physics representative provided on-the-job surveillance, served as custodian of radioactive materials as well as assuring that all Federal and State regulations pertaining to the use of radioactive materials were followed. The tests were completed without any significant contamination and/or exposure problems.

(d) Health Physics Assistance in Radiation Survey Conducted at Lake Ontario Ordnance Works (LOOW) - In June, 1971, two members of the Applied Health Physics and Safety Section of the Health Physics Division returned to Lewiston, New York, as members of the USAEC Radiological Assistance Team. This was a continuation of a survey begun in October, 1970, at the LOOW site. Readings were taken at waist level and recorded at twenty or fifty feet intervals across 1,298 acres (excluding the swamps), using low-level NaI scintillation survey instruments. The purpose of the survey was to gain some idea of the amount of decontamination proceedings that might be necessary in order to meet the required regulations for certain stipulated uses of the property.

4.2 Unusual Occurrences

Radiation incidents are classified according to a severity index system developed over the past several years.[4] The method serves to index unusual occurrences according to degree of severity and permits a system of analysis regarding Applied Health Physics and Safety practices among Laboratory operations.

During 1971 there were 10 unusual occurrences recorded which represents an increase of 11 percent over the number reported for 1970 (Table 4.2.1). The number for 1971, ten, is approximately 23 percent below the five-year average of 13 for the years 1967 through 1971. The frequency rate of unusual occurrences among Laboratory divisions involved (Table 4.2.2) is known to vary in relationship to the quantity of radioactive material handled, the number of radiation workers involved, and the radiation potential associated with a particular operation or facility.

Eight of the incidents reported during 1971 involved area contamination that was handled by the regular work staff without appreciable production or program loss. One incident involved the partial shutdown of a facility with several man-hours of effort expended in the cleanup operation. One occurrence involved personnel contamination requiring decontamination under medical supervision.

4.3 Laundry Monitoring

A total of 555,674 articles of wearing apparel was monitored at the laundry during 1971. Approximately eight percent of the items monitored were found to be contaminated. Of the 333,160 khaki garments monitored during the year, only 118 were found contaminated.

A total of 8,332 full face respirators and 5,427 canisters was monitored after cleaning with 1,113 of these requiring further decontamination.

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[4]See ORNL-3665, Applied Health Physics Annual Report for 1968, pp. 14-15.

Table 4.2.1 Unusual Occurrences Summarized for the 5-Year Period Ending with 1971

	1967	1968	1969	1970	1971
Number of Unusual Occurrences Recorded	16	20	12	9	10
A. Number of incidents of minor consequence involving personnel exposure below MPE limits and requiring little or no cleanup effort	5	7	4	2	1
B. Number of incidents involving personnel exposure above MPE limits and/or resulting in special cleanup effort as the result of contamination	11	13	8	7	9
1. Personnel Exposures	5	9	6	1	3
a. Nonreportable overexposures with minor work restrictions imposed	5	9	6	1	3
b. Reportable overexposures with work restrictions imposed	0	0	0	1	0
2. Contamination of Work Area	11	13	8	6	9
a. Contamination that could be handled by the regular work staff with no appreciable departmental program loss	11	13	7	5	8
b. Required interdepartmental assistance with minor departmental program loss	0	0	1	1	1
c. Resulted in halting or temporarily deterring parts of the Laboratory program	0	0	0	0	0

Table 4.2.2 Unusual Occurrence Frequency Rate within the Divisions for the 5-Year Period Ending with 1971

Division	No. of Unusual Occurrences 1967	1968	1969	1970	1971	5-Year Total	Percent Lab. Total (5-Year Period)
Analytical Chemistry	3	4	1		1	9	13.4
Biology		1				1	1.5
Chemical Technology	4	5	4	2	1	16	24.0
Chemistry					1	1	1.5
Inspection Engineering				1		1	1.5
Plant and Equipment		1				1	1.5
Isotopes	4	6	2	3	4	19	28.4
Metals and Ceramics	1	1	1	1	1	5	7.5
Neutron Physics		2				2	2.9
Operations			2	2	2	6	8.9
Physics	1					1	1.5
Reactor	3		1			4	5.9
Solid State			1			1	1.5
TOTALS	16	20	12	9	10	67	100.0

5.0 SAFETY ENGINEERING AND SPECIAL PROJECTS

The safety record for 1971 was very good with decreases in Disabling Injuries, Serious Injuries, and Medical Treatment Injuries. In only one measurement, severity, was there an adverse trend. A fractured wrist failed to knit properly and resulted in a permanent partial injury with heavy time charges.

5.1 Accident Analyses

The Disabling Injury frequency rate for 1971 was 0.61 (1970 - 0.76; average, 1962-71 - 0.93). The Disabling Injury history for ORNL for the seven-year period, 1965-71, is shown in Table 5.1.1. Frequency rates since the inception of Union Carbide as the contractor at ORNL (1948) are shown in Table 5.1.2.

Fourteen divisions did not have a Serious or Disabling Injury in 1971, and 16 have accumulated more than 1,000,000 hours each without a Disabling Injury. Serious and Disabling Injury data for ORNL divisions are shown in Table 5.1.3.

A comparison of injury data for ORNL, Paducah, Y-12, and ORGDP for 1971 is shown in Table 5.1.4. Tables 5.1.5, 5.1.6, and 5.1.7 present ORNL injury data according to accident type, nature of injury, and part of body injured for 1971.

5.2 Summary of Disabling Injuries

Following are summaries of the four Disabling Injuries experienced at ORNL in 1971:

Date of Injury - 2/19/71

An ironworker pulled on one end of a 13' remnant of reinforcing wire mesh while a fellow worker stood on the other end. The end pulled from under the man's feet and flipped over striking the ironworker in the face and resulted in a slight orbital fracture. Surgery was necessary to drain sinus. Time loss: 11 days.

Date of Injury - 5/25/71

A machinist picked a grinder splash guard off the floor and stepped forward to place it on the grinder. His foot struck a short length of conduit which had been lying under the shield. He fell backward, causing a recurrent inguinal hernia. Time loss: 110 days.

Date of Injury - 9/9/71

A machinist stepped on an oil film as he walked across a shop floor. He slipped and fell in a sitting position catching his weight on his right arm. Fracture, right wrist, which failed to knit properly. Estimated Permanent Partial Disability - 50 percent to right lower arm. Time charge: 1800 days.

Date of Injury - 9/26/71

A chemist was riding in a sitting position on the forward platform of an amphibious vehicle. The driver stopped the vehicle suddenly, throwing the chemist off on the beach. He sustained a fractured vertebra. Time loss: 23 days.

5.3 Safety Awards

The Safety Incentive Plan, based on Serious as well as Disabling Injuries, was continued with awards being gift certificates from local stores. Four 1,000,000-hour injury-free periods were attained for a Plant-wide award of $4.00. Group awards varied from $4.00 to $6.00, making total earned awards of from $8.00 to $10.00. An increase of 15 percent in these amounts was negotiated with the gift certificate suppliers.

Table 5.1.1 Disabling Injury History—ORNL, 1971

	1965	1966	1967	1968	1969	1970	1971
Number of Injuries	18	4	4	1	2	5	4
Labor Hours (Millions)	7.7	7.8	8.0	7.8	7.5	6.6	6.5
Frequency Rate	2.34	0.51	0.50	0.13	0.27	0.76	0.61
Days Lost or Charged	2816	231	245	60	67	410	1944
Severity Rate	366	30	31	8	9	63	298

Table 5.1.2 ORNL Disabling Injury Frequency Rates Since Inception of Carbide Contract Compared with Frequency Rates for NSC,* AEC and UCC

Year	ORNL	NSC	AEC	UCC
1948	2.42	11.49	5.25	5.52
1949	1.54	10.14	5.35	4.91
1950	1.56	9.30	4.70	4.57
1951	2.09	9.06	3.75	4.61
1952	1.39	8.40	2.70	4.37
1953	1.43	7.44	3.20	3.61
1954	0.79	7.22	2.75	3.02
1955	0.59	6.96	2.10	2.60
1956	0.55	6.38	2.70	2.27
1957	1.05	6.27	1.95	2.41
1958	1.00	6.17	2.20	2.21
1959	1.44	6.47	2.15	2.16
1960	0.94	6.04	1.80	1.92
1961	1.55	5.99	2.05	2.03
1962	1.45	6.19	2.00	2.28
1963	1.55	6.12	1.60	2.10
1964	1.07	6.45	2.05	2.20
1965	2.34	6.53	1.80	2.40
1966	0.64	6.91	1.75	2.57
1967	0.50	7.22	1.55	2.06
1968	0.13	7.35	1.27	2.24
1969	0.27	8.08	1.52	2.49
1970	0.76	8.87	1.28	2.27
1971	0.61	—	1.31	2.05

*National Safety Council (NSC), all industries.

Table 5.1.3 Injury Statistics by Division—1971

Division	Medical Treatment Cases	Serious Injuries		Disabling Injuries			Exposure Hours (In Millions)
		No.	Freq.	Number	Freq.	Sev.	
Analytical Chemistry	17	1	4.21	0			.238
Chemical Technology	30	1	2.31	0			.433
Chemistry	11	2	11.50	0			.174
Director's	5	1	7.82	0			.128
Environmental Sciences	13	0		0			.101
Health Physics	13	0		0			.292
Instr. and Controls	39	0		0			.509
Mathematics	7	0		0			.258
Metals and Ceramics	21	1	2.05	0			.488
Neutron Physics	4	0		0			.107
Physics	12	3	16.75	0			.179
Reactor	3	0		0			.024
Reactor Chemistry	4	0		0			.142
Solid State	3	0		0			.122
General Engineering	7	0		0			.280
Health	1	0		0			.051
Information	9	0		0			.215
Isotopes	17	1	4.12	1	4.11	95	.243
Laboratory Protection	12	0		0			.144
Operations	34	1	2.79	0			.359
Personnel	13	1	5.69	0			.176
Plant and Equipment	565	25	14.84	3	1.77	1133	1.695
Envr. Prog.	2	0		0			.028
Insp. Engr.	1	0		0			.069
MAN	2	1	17.25	0			.058
PLANT TOTAL	845	38	5.83	4	0.61	298	6.513

Table 5.1.4 Four-Plant Tabulation of Injuries—1971

Plant	Labor Hours (Millions)	Disabling				Serious	
		Number of Injuries	Frequency Rate	Days Lost or Charged	Severity Rate	Number of Injuries*	Frequency Rate
ORNL	6.5	4	0.61	1944	298	38	5.83
ORGDP	5.0	4	0.80	406	81	46	9.19
Y-12	14.0	8	0.57	508	36	136	9.70
Paducah	2.2	3	1.37	280	128	22	10.06

*Includes the number of Disabling Injuries.

Table 5.1.5 Number of Accidents by Types

Type of Accident	Number of Accidents
Struck Against	327
Stuck By	212
Slip, Twist, Overexertion	90
Caught In, On, or Between	63
Fall, Same Level	46
Fall, Different Level	6
Contact, Temperature Extremes	15
Inhalation, Absorption, Ingestion	9
Electrical	1
Other	76
TOTAL	845

Table 5.1.6 Number of Accidents by Nature of Injury

Nature of Injury	Number of Accidents
Laceration, Puncture	300
Contusion, Abrasion	165
Strain	102
Conjunctivitis	30
Sprain	28
Burn (Temperature)	55
Burn (Chemical)	9
Burn (Flash)	1
Fracture, Dislocation	10
Dermatitis	5
Other	140
TOTAL	845

Table 5.1.7 Number of Accidents Relative to Part of Body Injured

Body Area	Percentage	Total Injuries
Head	6.2	53
Eyes	8.5	72
Shoulder-Chest	4.1	35
Back	9.8	83
Arms	10.3	87
Hands	11.1	94
Fingers	35.0	293
Lower Trunk	3.0	26
Legs	7.1	60
Feet	3.4	29
Toes	1.3	11
Internal	0.2	2
TOTAL	100.0	845

6.0 INFORMATIONAL ACTIVITIES

6.1 Visitors and Training Groups

During 1971 there were 71 visitors to Applied Health Physics and Safety, as individuals or in groups, for training purposes. Table 6.1.1 is a listing of training groups which consisted of three or more persons.

Table 6.1.1 Training Groups in Applied Health Physics and Safety Facilities during 1971

Facility	Number	Training Period
AEC Fellowship	6	6/21/71 - 7/23/71
University of Arkansas	7	4/6/71 - 4/8/71
University of Tennessee Co-ops (Physics Department)	3	1/1/71 - 9/1/71[a]
University of North Carolina	7	7/20/71 - 7/22/71
ORAU Ten-Weeks H.P. Course	18	2/1/71 - 4/9/71[b]

[a]Each student participated during one academic quarter (approximately 12 weeks each).

[b]Approximately 25 lecture and field training hours were contributed by ORNL personnel during the period noted above.

6.2 Publications and Papers

P. E. Brown, G. R. Patterson and H. H. Abee, ORNL Whole Body Counter, January 1, 1971, ORNL CF 71-1-71.

P. E. Brown and E. D. Gupton, "Chest Clearance of Inhaled Cobalt-60 Oxide", presented at the Seventeenth Annual Bio-assay and Analytical Chemistry Meeting, Boulder, Colorado, October 13-14, 1971.

H. M. Butler and F. F. Haywood, Radiation Safety Practices, Operation Henre, CEX 65.05, January, 1971.

H. M. Butler, H. W. Dickson, et al., "Radiation Safety in the Operation of a Low-Energy Accelerator", pp. 441-458 of Proceedings of the Second Oak Ridge Conference on the Use of Small Accelerator for Teaching and Research, CONF-700322, March, 1971.

D. M. Davis, Applied Health Physics and Safety Annual Report for 1970, ORNL-4690, August, 1971.

E. D. Gupton, Methods and Procedures for Internal Radiation Dosimetry at ORNL, January, 1971, ORNL CF 71-1-66.

E. D. Gupton, Methods and Procedures for External Radiation Dosimetry at ORNL, January, 1971, ORNL CF 71-1-65.

J. C. Hart, "Legal and Administrative Aspects of Personnel Dosimetry", presented at the Sixteenth Annual Meeting of the Health Physics Society, New York, New York, July 12-15, 1971.

J. C. Hart, "Legal Aspects of Health Physics Records", presented at the Third Biennial Campus Radiation Safety Officers Conference, September 23-24, 1971, Purdue University, West Lafayette, Indiana.

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