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External Radiation Monitoring at the Y-12 Facility During the 1948-1949 Period

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ACRONYMS AND ABBREVIATIONS

AEC	Atomic Energy Commission, one of the predecessor agencies of DOE
DOE	U.S. Department of Energy
E	expected or mean dose
EU	enriched uranium
eV	electron volt
hr	hour
IAEA	International Atomic Energy Agency
ID	identification
K-25	K-25 Plant, later the Oak Ridge Gaseous Diffusion Plant
keV	one thousand electron volts
MDL	minimum detectable limit
MeV	one million electron volts
mm	millimeter
mR	milliroentgen, a unit of radiation exposure
mrem	millirem, a unit of radiation dose
NBS	National Bureau of Standards, now the National Institute for Standards and Technology
NIOSH	National Institute for Occupational Safety and Health
NR	no reading/no response
ORAU	Oak Ridge Associated Universities
ORAUT	ORAU Team
PIC	pocket ionization chamber
R1	PIC reading
R2	sensitive film reading under open window
R3	sensitive film reading under 1 mm-thick cadmium shield
R4	insensitive film reading under 1 mm-thick cadmium shield
TEC	Tennessee Eastman Corporation
UCC	Union Carbide Corporation
Y-12	Y-12 Plant, now the Y-12 National Security Complex

1.0 PURPOSE

The purpose of this report is to discuss and summarize the 1948-1949 external monitoring data that are available for use in dose reconstruction for workers at the Y-12 facility in Oak Ridge, Tennessee. These 1948-1949 external monitoring data were previously made available to Oak Ridge Associated Universities (ORAU), along with other data for use in epidemiological studies of workers at Y-12 and other Department of Energy (DOE) facilities in Oak Ridge, Tennessee (Watkins et al. 1993, 1997). In this document the word "facility" is used as a general term for an area, building, or group of buildings that served a specific purpose. It does not necessarily connote an "atomic weapons employer facility" or a "DOE facility" as defined in the Energy Employees Occupational Illness Compensation Program Act of 2000 (42 U.S.C. § 7384l(5) and (12)).

2.0 BACKGROUND

The Y-12 Plant, now the Y-12 National Security Complex, was first conceived in the fall of 1942 by engineers of the Manhattan Engineer District of the U.S. Army Corps of Engineers, and construction of the first building was completed in 1943 (Wilcox 2001; ORAUT 2009a). The Tennessee Eastman Corporation (TEC) operated Y-12 from 1943 to May 1947. During this period, operations at Y-12 primarily involved the use of the electromagnetic separation process to enrich uranium, and the enriched product was shipped to Los Alamos for use in the construction of nuclear weapons. Until the latter part of 1945, Y-12 converted UO_3 to UCl_4, which was subsequently enriched by the electromagnetic separation process using two calutron stages (termed "alpha" and "beta"). In the latter part of 1945, Y-12 discontinued the use of the alpha calutron stage and began receiving UF_6 from the Oak Ridge Gaseous Diffusion Plant, also called the K-25 Plant. The UF_6 from K-25 was converted into UCl_4, enriched using the beta calutrons, converted to UF_4, and shipped to Los Alamos. In these early days of Y-12, TEC relied entirely on facility monitoring to measure and control both occupational external and internal radiation exposures to workers. The nature of the work at the Y-12 facility in these early years primarily resulted in occupational internal exposure from uranium dust particles, which was a greater potential hazard than occupational external exposure (Dupree et al. 1994).

In May 1947, management of Y-12 was assigned to the Union Carbide Corporation (UCC) and the emphasis at Y-12 was directed away from enrichment of uranium to the fabrication of parts for nuclear weapons (Williams 1948, ORAUT 2009a). Numerous changes have occurred over the years in the fabrication procedures, but the general procedures have remained essentially the same. Enriched uranium (EU) typically was received at Y-12 in the form of UF_6, converted to UF_4, reduced to a metal, and then fabricated into weapon parts. These fabrication processes involved casting, rolling, forming, and machining of the EU metal and recycling of the EU salvage. In addition to facility monitoring to measure and control the radiation exposure to workers, an external dosimetry program was started in 1948 to monitor individual personnel working in the Assay Laboratories, Radiographic Shop, Spectrographic Shop, and the "Metal" Machine Shops. Other groups of workers were added in July 1948, January 1949, and July 1949. The occupational external monitoring since 1950 has previously been reviewed in reports by ORAUT (2009a) and Kerr et al. (2010a,b,c).

3.0 EXTERNAL RADIATION MONITORING DEVICES

Doses from external radiation exposure to beta particles and photons (x-rays or gamma rays) at the Y-12 facility during 1948-1949 were measured using Victoreen pocket ionization chambers (PICs) exchanged on a daily basis and film badge dosimeters exchanged on a weekly basis (Souleyrette 2003; ORAUT 2009a). The minimum detectable limits (MDLs) for these dose measurements during this period were approximately 5 mrem for the PICs and 30 mrem for the film badge dosimeters.

3.1 POCKET IONIZATION CHAMBERS

The Victoreen PICs were condenser-type ionization chambers that were used with a separate charger and charge reader (Price 1958; Handloser 1959). The PICs were charged to a known voltage by inserting them into the charger, which connected an internal power supply across the chambers. The charge reader, a string electrometer, indicated the charge. The PICs were the size of fountain pens and had clips similar to those on fountain pens so they could be carried securely in the pocket of a shirt or coverall. Exposure to ionizing radiation discharged the chamber, and the decrease in voltage provided a measurement of a worker's radiation exposure. The PICs were calibrated using integrated exposures of 100, 200, and 300 mR from a radium source (Struxness 1948a).

Properly operating PICs were not affected by charge leakage over a period of a few days, but their use was generally restricted to 1 day (Price 1958; Handloser 1959). At Y-12 and most other DOE sites, it was general practice to provide each worker with two PICs, and the lower exposure reading was taken as the significant reading because any malfunction of a PIC resulted in a charge decrease indicating a higher exposure. Malfunctions of a PIC were usually due to either charge leakage across the insulators or mechanical shock such as being dropped onto the floor.

The energy response of the PICs, like film, was not flat but peaked at low photon energies (Price 1958; Handloser 1959). At photon energies of approximately 0.3 −1.2 MeV, the energy response was linear, but it was about 1.4 times the linear response at a photon energy of approximately 0.1 MeV. Below 0.1 MeV, the response dropped rapidly because the photons underwent significant attenuation in the walls of the PICs. The readings indicated by the PICs were much less than the actual doses at photon energies below about 40 keV. The walls of the PICs were thin enough to allow some response to beta particles with energies of approximately 1 MeV or more.

3.2 FILM BADGE DOSIMETERS

The first film badge dosimeter used at Y-12 was the same badge used at the Oak Ridge National Laboratory (West 1993; ORAUT 2009a) and described by Thornton, Davis, and Gupton (1961). This film badge was an AEC Catalog Number PF-1B film badge manufactured by the A. M. Sample Machine Company in Knoxville, Tennessee (Patterson et al. 1957; ORAUT 2009a). The photographic film in the badge was encased in a protective cover of stainless steel with a clip for attachment to the pocket or collar of a shirt or coverall (Handloser 1959). One portion of the film (shielded window) was covered by a 1-mm-thick cadmium filter to determine the penetrating whole-body dose from photons (gamma rays and high-energy x-rays), and the uncovered portion of the film (open window) was used to determine the skin dose from low-energy x-rays and beta particles (Handloser 1959).

The film badge dosimeters used at Y-12 from 1948 to 1963 contained DuPont type 552 film packets (Souleyrette 2003). These packets contained two film emulsions: (1) a so-called sensitive 502 emulsion with an effective dose range of approximately 30 mrem to 10 rem, and (2) a so-called insensitive 510 emulsion with an effective dose range of approximately 500 mrem to 20 rem (Craft, Ledbetter, and Hart 1952; Thornton, Davis, and Gupton 1961; Parrish 1979). Film badge dosimeters typically exhibited about the same sensitivity to beta and gamma radiation; that is, a 1-rem dose of beta particles yielded about the same response in the film as 1 rem of gamma rays (Auxier 1967). Thus, the MDLs of the film badge dosimeters were approximately the same for beta particles and gamma rays (ORAUT 2009a).

The DuPont 552 film packets were calibrated using x-rays, beta particles from a natural uranium slab, and gamma rays from a radium source (Struxness 1949). The gamma-ray calibrations used integrated exposures of 100, 250, 500, 750, and 1,000 mrem from the radium source (Struxness

1948a). The film badges were calibrated for beta particles by placing the film badge face down on the slab of natural uranium (Struxness 1949). The dose rate to skin from the beta particles at the surface of the natural uranium slab was taken to be 270 mR/hr (Murray 1948). The currently accepted value for the dose rate to skin from beta particles at the surface of a natural uranium slab is approximately 235 mrem/hr (DOE 2004). If one makes the common assumption that 1 mR/hr is approximately equal to 1 mrem/hr (Whyte 1959; NBS 1962), the beta-particle calibrations during the 1948-1949 period provide conservative estimates of a Y-12 worker's exposure to beta particles during that period.

4.0 Y-12 EXTERNAL DOSE DATABASE

External monitoring records for 1950 to 1988 were provided by the Y-12 staff from 1978 through the 1980s for use in epidemiologic studies by the Center for Epidemiologic Research of the Oak Ridge Associated Universities (Watkins et al. 1993, 1997). These records contained gamma, beta, and neutron monitoring records for individuals, summarized by quarters. For some time, it was assumed that no external monitoring records were available prior to 1950. Following considerable investigation, including interviews with knowledgeable Y-12 staff members, it was discovered that a limited set of external monitoring data did exist for 1948 and 1949 (West 1980). Further investigation resulted in the retrieval of a single electronic file with 11,492 weekly monitoring records. Each record in the file included film badge ID, date of weekly readings, four dose fields, and descriptive comments. The four dose fields consisted of the PIC dose reading (R1) and three photographic film dose readings (R2, R3, and R4). Efforts were made to link the film badge ID in the Y-12 pre-1950 external monitoring file with Y-12 worker names and departments in the established ORAU DOE facility database. A total of 233 distinct individuals were identified among the 11,492 records in the dataset.

Basic characteristics of the 1948-1949 dataset are as follows. Each film badge ID in the file had 26, 52, 78, or 104 records, corroborating that monitoring results were recorded on a weekly basis during this period. As listed in Table 4-1, 3,599 of the records were reported for 1948, and 7,893 were

Table 4-1. Number of total and non-null records from Y-12 monthly external monitoring data for 1948-1949

. Month	Monthly external monitoring records	
	1948	1949
	Records / Non-null Records*	Records / Non-null Records*
January	130 / 0	564 / 165
February	104 / 0	564 / 150
March	104 / 0	564 / 162
April	130 / 41	705 / 186
May	104 / 77	564 / 148
June	104 / 60	564 / 186
July	535 / 162	840 / 272
August	428 / 146	672 / 255
September	428 / 144	840 / 271
October	535 / 201	672 / 203
November	428 / 164	672 / 200
December	569 / 208	672 / 215
Total	**3,599 / 1,203**	**7,893 / 2,413**

*At least one of R1, R2, R3, or R4 values was not null.

reported for 1949. Based on a total of 4 weekly monitoring records during some months and 5 weekly weekly monitoring records during other months, the data in Table 4-1 indicates that the total number of monitored Y-12 workers was approximately 26 during the first half of 1948, 107 during the second half of 1948, 141 during the first half of 1949, and 168 during the second half of 1949. Although each record in the dataset had a value for all four dose fields (i.e., R1, R2, R3, and R4), many of the results were recorded as "NR" (i.e., "no reading" or "no response"). In fact, 7,876 or 69% of the 11,492 total records reported NR in each of the four dose fields. Therefore, only 3,616 of the records supplied any information on occupational external doses. The information provided by these 3,616 records is summarized in the next section.

5.0 EVALUATION OF 1948-1949 EXTERNAL DOSE DATA

All results in this section are based on all records occurring in a month, although an individual worker could provide multiple weekly records each month. The doses listed as PIC readings are referred to as R1. Doses from readings of sensitive film with open window, sensitive film shielded, and insensitive film shielded are referred to as R2, R3, and R4, respectively. The doses in the fields R2, R3, and R4 were based on film badges that had a typical MDL of 30 mrem.

Table 5-1 presents by month and year the number of non-null R2-R4 records, the number of these records equal to zero, and the number of these records with a dose equal to the MDL of 30 mrem. From January through March 1948, all dose field readings were blank. During later periods of 1948 and 1949, it is apparent that nearly all recorded doses for R2, R3, and R4 were set equal to the value of the MDL. In addition, there were only 60 and 61 recorded dose for R3 and R4, respectively, for the year 1949. Therefore, R2, R3, and R4 provided very few specific radiation doses, and 30 mrem was an upper bound on the actual dose received during the weekly monitoring period for film badges.

Table 5-1. Number of R2, R3, and R4 records from Y-12 monthly external monitoring records and number equal to 0 and to the MDL (30 mrem)

R2: Sensitive Film - Open Window						
Month	1948			1949		
	N	N = 0	N = 30	N	N = 0	N = 30
January	0	0	0	98	0	94
February	0	0	0	93	0	90
March	0	0	0	100	0	99
April	40	14	0	102	0	102
May	76	29	0	101	0	101
June	60	7	5	139	0	139
July	142	0	124	232	0	232
August	140	0	140	196	0	196
September	137	0	136	200	0	200
October	200	0	200	158	0	158
November	161	0	161	156	0	156
December	200	0	200	169	0	169
Total R2	**1,156**	**50 (4%)**	**966**	**1,744**	**0 (0%)**	**1,736**

R3: Sensitive Film - Cd Shielded						
Month	1948			1949		
	N	N = 0	N = 30	N	N = 0	N = 30
January	0	0	0	56	0	56
February	0	0	0	3	0	3
March	0	0	0	1	0	1
April	40	14	0	0	0	0
May	76	29	0	0	0	0
June	60	7	5	0	0	0
July	142	0	124	0	0	0
August	140	0	140	0	0	0
September	137	0	137	0	0	0
October	200	0	200	0	0	0
November	161	0	161	0	0	0
December	200	0	200	0	0	0
Total R3	**1,156**	**50 (4%)**	**966**	**60**	**0 (0%)**	**60**

R4: Insensitive Film - Cd Shielded						
Month	1948			1949		
	N	N = 0	N = 30	N	N = 0	N = 30
January	0	0	0	56	0	56
February	0	0	0	3	0	3
March	0	0	0	1	0	1
April	40	19	0	0	0	0
May	76	35	0	0	0	0
June	60	8	0	0	0	0
July	142	0	142	0	0	0
August	139	0	139	0	0	0
September	143	0	143	0	0	0
October	200	0	200	0	0	0
November	161	0	161	1	0	0
December	200	0	200	0	0	0
Total R4	**1,161**	**62 (5%)**	**985**	**61**	**0 (0%)**	**60**

Figure 5-1 shows the sum of all the weekly records in each dose field by month. In 1948, the monthly dose sums were nearly identical for R2, R3, and R4, with the exception of a slightly lower R4 dose in July. The monthly sums for the PIC readings starting in July 1948 were generally about one-third as large as film badge sums in the fields R2, R3, and R4. In 1949, the monthly PIC sums were about one-third or less of the R2 sums, with the exception of the period from March through June, when the R2 sums dipped much lower.

Figures 5-2 through 5-5 show monthly descriptive statistics for R1, R2, R3, and R4, respectively, where statistics were based on only nonblank values (i.e., excluding the NRs). The 75th percentile for R1 was near 30 mrem for the entire period (April 1948-December 1949), indicating that approximately three-fourths of the PIC readings each month had a value of 30 mrem or less. However, maximum R1 readings were generally above 60 mrem after October 1948. For R2 from July 1948 through 1949, the 25th percentile, median, and 75th percentile were all 30 mrem, suggesting that a dose of 30 mrem might have been assigned if a weekly badge reading during the month fell below MDL. For R3 from July 1948 through March 1949, it appears that a dose of 30 mrem was assigned if a weekly badge reading was below the MDL, and from April 1949 to December 1949, it appears that a dose of zero was assigned if a weekly badge reading was below the MDL. For R4, the MDL was 500 mrem, but it appears that much lower dose values were assigned based on the lowest recorded value of either R2 or R3 during the same period. Several very high maximum doses were recorded for R2, including 760 mrem in July 1948 and 2,500 mrem in both January and February 1949 (see Figure 5-3). With the exception of one R3 dose of 640 mrem in July 1948, R3 and R4 have only weekly doses of 30 mrem from July 1948 through March 1949 and then no additional dose records except one weekly R4 dose of 30 mrem in November (see Figures 5-4 and 5-5). No weekly doses above 30 mrem were recorded for R4 in either 1948 or 1949.

The two very high weekly R2 doses in January and February 1949 to a worker in the Chemical Department (Dept. 2619) suggest a large skin dose that may not have been detected by the PICs. These two high R2 doses do not appear to be due to beta particles because the ratio of R2 to R3 of approximately 100:1 is much larger than the expected beta-to-gamma dose ratio from exposure to uranium. The two high R2 readings in January and February 1949 are more likely the result of exposure to very-low energy photons leaking from an X-ray spectrograph or other devices, a problem that was noted in early Health Physics reports (Struxness 1948b,c). The R2 reading from the 502 sensitive film under the open window of a film badge show a response to photons with energies less than 0.1 MeV that is as much as 15-20 times greater than the response to photons of higher energies (Handloser 1959; Thornton, Davis, and Gupton 1961), whereas PICs have trouble detecting photons with energies less than 0.1 Mev because they are heavily attenuated in the wall materials of the PICs as discussed previously in Section 3.1. The high R2 reading for another worker in the Fire Department (Dept. 2093) in July 1948 appears to be an artifact for a couple of reasons: (1) the R2 and R3 readings for the skin and whole-body doses are nearly equal (see Figures 5.3 and 5.4), and (2) the high R3 reading for the whole-body dose is not observed in either the R1 or R4 readings for the worker (see Figures 5.2 and 5.5). The recorded R3 dose of 640 mrem was greater than either the R1 MDL of 5 mrem or the R4 MDL of 500 mrem.

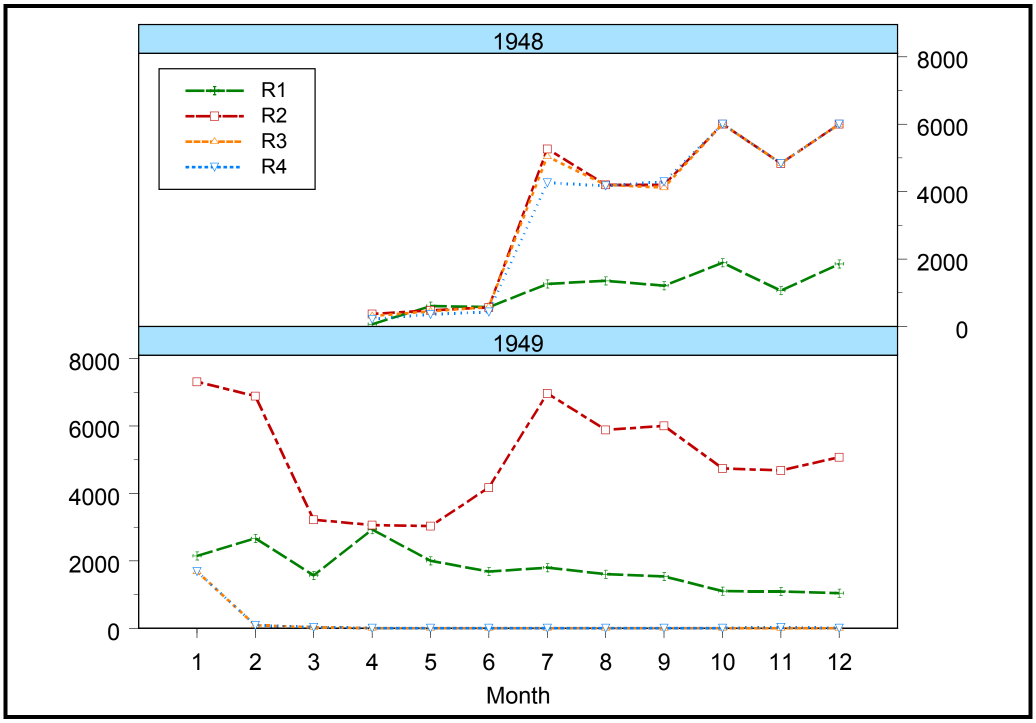

Figure 5-1. Sums of Y-12 weekly recorded doses in mrem by month and year for 1948-1949

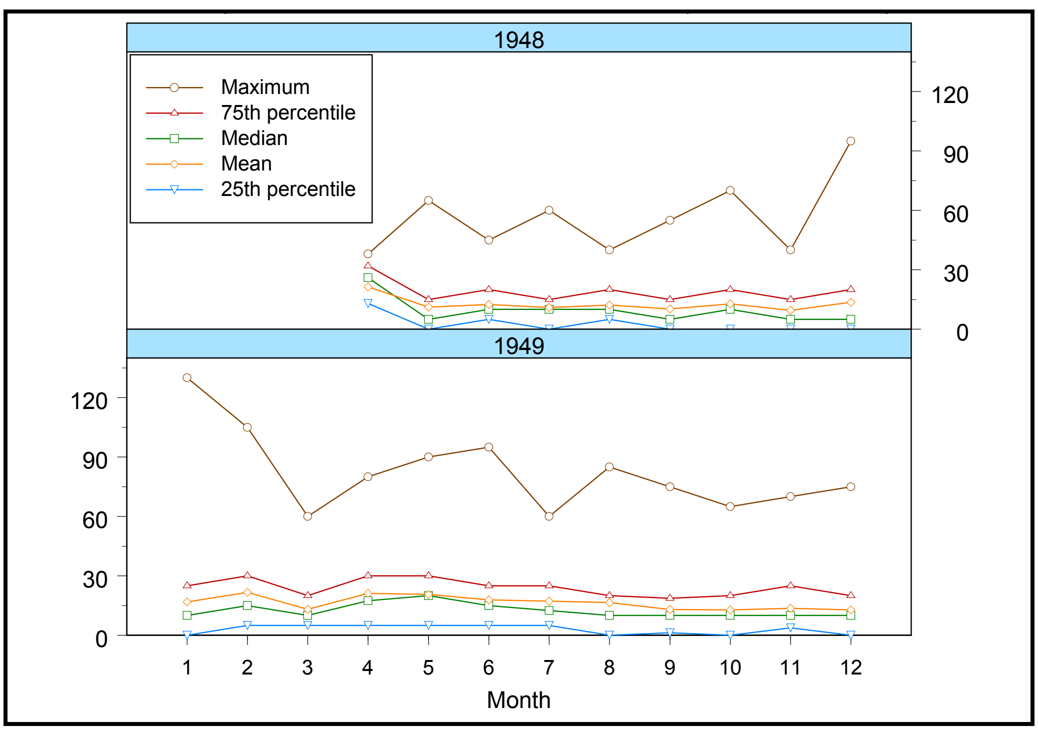

Figure 5-2. Statistics for Y-12 weekly R1 doses in mrem by month and year (NRs excluded).

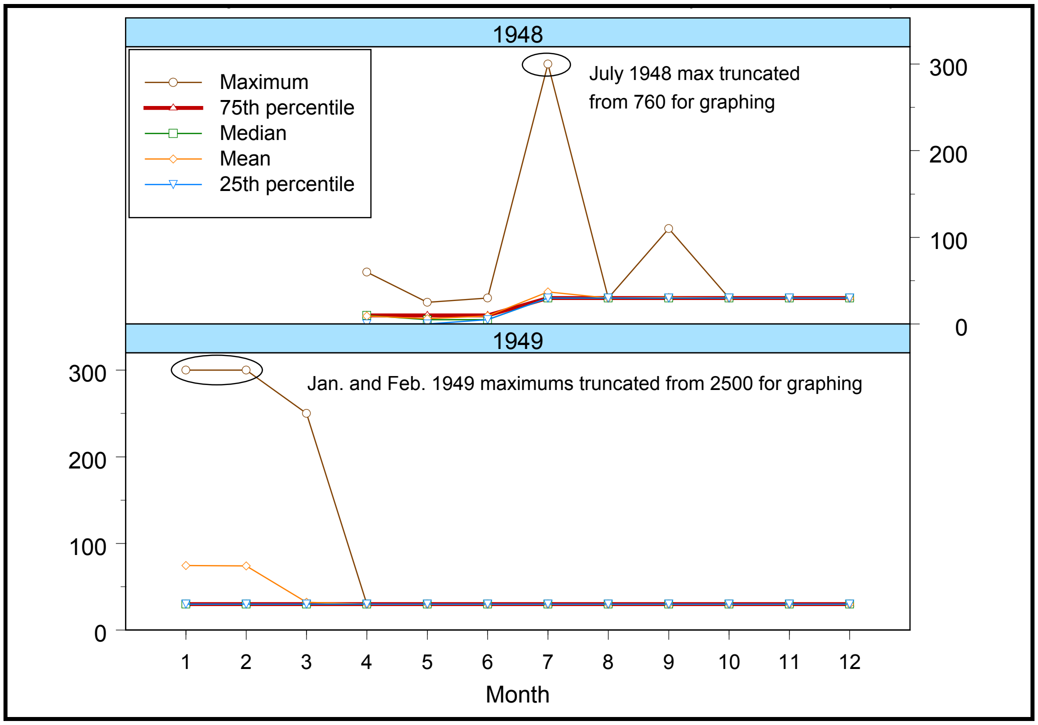

Figure 5-3. Statistics for Y-12 weekly R2 doses in mrem by month and year (NRs excluded).

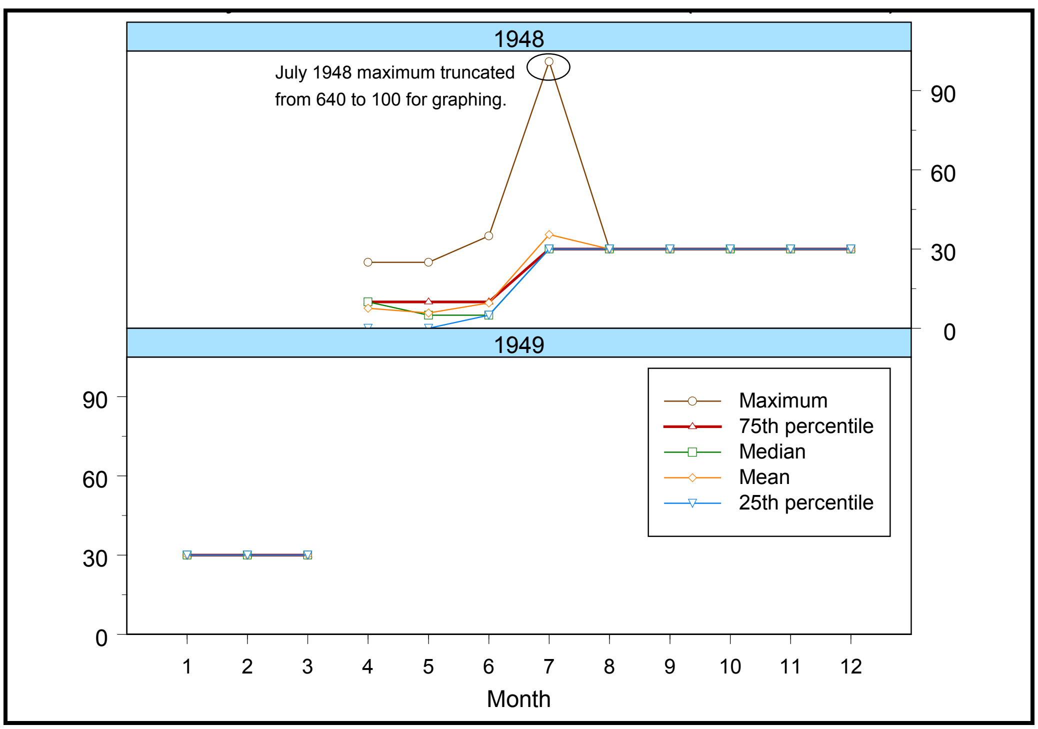

Figure 5-4. Statistics for Y-12 weekly R3 doses in mrem by month and year (NRs excluded).

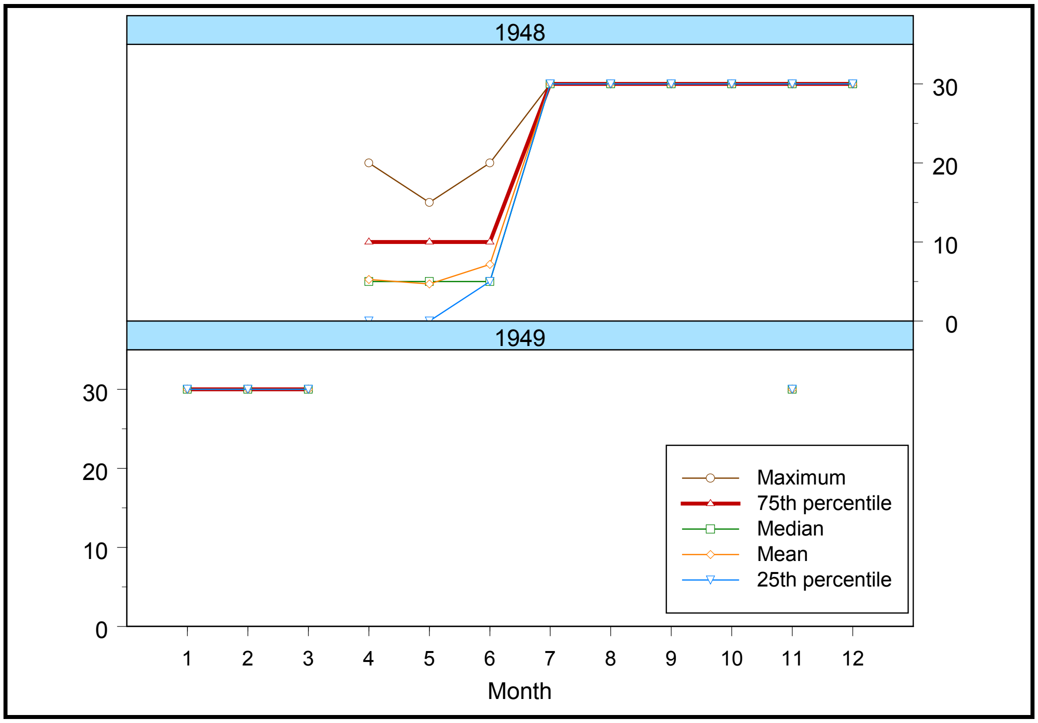

Figure 5-5. Statistics for Y-12 weekly R4 doses in mrem by month and year (NRs excluded).

6.0 Comparison with Regression Approach Estimates for 1948-1949 Quarterly Doses

Mean weekly R1-R4 doses from the 1948-1949 monitoring data are compared in this section with mean quarterly doses for 1948-1949 that were estimated using a regression approach discussed in ORAUT (2005, 2009b) and Kerr et al. (2010a). The most suitable method for examining whether the regression approach provides realistic estimates for dose reconstruction purposes is a comparison of the mean regression doses for each quarter to the quarterly means as determined from Y-12 1948-1949 dose files. The reason that the mean dose is the most appropriate comparison is that mean dose from the regression approach is calculated using both the log of the geometrical mean, μ, and the log of the geometrical standard deviation, σ. Specifically for a given quarter the mean dose on the original scale is calculated as follows:

$$E(\text{dose}) = \exp\left(\mu + 0.5\sigma^2\right).$$

The mean doses on the original scale based on R1-R4 were calculated directly as the quarterly averages with all blanks deleted before the expected values were calculated to ensure that results were not lowered. These data are shown in Table 6.1. It is important to note that each dose entry contained in the external dose database for 1948-1949 represents the average dose per week in the specified quarter and not the entire quarter. In order to make a valid comparison, these values must be scaled up to represent the dose over an entire quarter. Table 6.2 shows the average weekly dose in Table 6.1 multiplied by 12.5 weeks per quarter, assuming 50 working weeks and 2 vacation weeks per year.

Table 6-1. Mean weekly dose estimates from Y-12 dosimetry files for 1948-1949 and mean quarterly dose estimates from regression approach.

Year	Quarter	Y-12 Dose Files for 1948-1949				E(dose), regression[a]
		E(R1)	E(R2)	E(R3)	E(R4)	
1948	1	-----	----	----	----	362.54
	2	12.03	7.98	7.53	5.65	351.66
	3	11.09	32.58	31.86	30.00	341.11
	4	12.20	30.00	30.00	30.00	330.87
1949	1	17.29	59.85	30.00	30.00	320.94
	2	20.12	30.00	----	----	311.31
	3	15.49	30.00	----	----	301.97
	4	13.10	30.00	----	30.00	292.91

a. See ORAUT 2009b (Table 7-1a) and Kerr et al. 2010a (Table 7-1).

Table 6-2. Comparison of mean weekly doses from Table 6-1 scaled up to a full quarter and mean quarterly dose estimates from regression approach.

Year	Quarter	Y-12 Dose Files for 1948-1949				E(dose), regression[a]
		E(R1)	E(R2)	E(R3)	E(R4)	
1948	1	-----	----	----	----	362.54
	2	150.36	99.75	94.13	70.63	351.66
	3	138.63	407.25	398.25	375.00	341.11
	4	152.50	375.00	375.00	375.00	330.87
	Total	**441.49**	**882.00**	**867.38**	**820.63**	**1386.18**
1949	1	216.13	748.13	375.00	375.00	320.94
	2	251.50	375.00	----	----	311.31
	3	193.63	375.00	----	----	301.97
	4	163.75	375.00	----	375.00	292.91
	Total	**825.01**	**1873.13**	**375.00**	**750.00**	**1227.14**

a. See ORAUT 2009b (Table 7-1a) and Kerr et al. 2010a (Table 7-1)

When the weekly doses are scaled up to a full quarter as shown in Table 6-2, there are several quarters where the monitoring data for 1948-1949 in columns E(R2), E(R3) and E(R4) surpass the dose estimates based on the regression approach, E(dose), in the last column of the table. However, only the total annual dose for E(R2) in 1949 surpasses the total annual dose, E(dose), based on the regression approach. However, a vast majority of the dose records in the Y-12 1948-1949 monitoring files had a value of 30 mrem which was the MDL for the film badges (see Table 5-1). This indicates that in many cases the dose of 30 mrem was assigned to a worker when the film badge read below the MDL and represented a bounding dose to the worker for that week. In addition, a zero was also entered during some periods to indicate a film badge reading of less than the MDL (see Table 5-1). To assess the possible impact of the dose entries listed as "less than the MDL", the dose records for R2, R3, and R4 with values of zero or 30 mrem were changed to one-half of the MDL or 15 mrem as recommended by NIOSH (2007). These recalculated quarterly doses are summarized in Table 6-3. There were also a few dose entries that had non-zero values that were less than the MDL. It is likely that these represent film readings with a detection limit that was deemed more accurate than the typical MDL of 30 mrem (Morgan 1961). These values were not adjusted in the analysis presented in Table 6-3, though it is clear that adjusting these values by ½ would further reduce the mean quarterly doses derived from the Y-12 1948-1949 external monitoring files.

Table 6-3 shows that when the dose entries listed at the MDL (or alternatively at zero) are adjusted to one half of the MDL, only the mean dose, E(R2), of approximately 566 mrem for the 1st quarter of 1949 surpasses the dose estimate, E(dose), of approximately 321 mrem for that same quarter based on the regression approach. However, the total annual dose for R2 in 1949 is still less than the recommended total annual dose value based on the regression approach. The large mean dose for R2 in the 1st quarter of 1949 is a result of several large outlier values which were noted previously in Section 5 as being the result of the leakage of very low energy photons from an x-ray spectrograph or other device in the Chemical Department (Dept. 2619). In fact, the five highest recorded weekly R2 doses during the first quarter of 1949 were for personnel in this department and accounted for over 60% of the total R2 dose that quarter. However, not everyone in that department has abnormally high R2 doses. If the five outlier R2 doses are removed from the quarterly mean dose, it drops to less than 225 mrem which is almost 100 mrem lower that the quarterly dose estimate of approximately 321 mrem based on the regression analysis (see Table 6-3).

Table 6-3. Comparison of mean weekly doses from Table 6-1 with an adjustment for assigned MDL doses and mean quarterly dose estimates from regression approach.

Year	Quarter	Y-12 Dose Files for 1948-1949[a]				E(dose), regression[b]
		E(R1)	E(R2)	E(R3)	E(R4)	
1948	1	-----	----	----	----	362.54
	2	150.74	147.73	143.11	136.72	351.66
	3	142.81	228.22	218.38	187.50	341.11
	4	157.92	187.50	178.50	187.50	330.87
	Total	**457.46**	**563.45**	**548.99**	**511.72**	**1386.18**
1949	1	222.98	565.72	187.50	187.50	320.94
	2	250.00	187.50	----	----	311.31
	3	196.22	187.50	----	----	301.97
	4	167.38	187.50	----	187.50	292.91
	Total	**836.59**	**1128.22**	**187.50**	**375.00**	**1227.14**

a. Dose entries listed at the MDL of 30 mrem (or alternatively at zero) were set equal to one half of of the MDL or 15 mrem as recommended in NIOSH (2007).

b. See ORAUT 2009b (Table 7-1a) and Kerr et al. 2010a (Table 7-1)

7.0 DISCUSSION

The external monitoring data for the 1948-1949 period at the Y-12 facility have been reviewed in this report. During the 1948-1949 period, both PICs and film badge dosimeters were used at Y-12 (Souleyrette 2003; ORAUT 2009a). The PICs appear to provide the doses of record during this period. This is consistent with practices at other DOE facilities such as the Oak Ridge National Laboratory and Hanford Site (Ostrouchov, Frome, and Kerr 2000). Initially, PICs were considered the primary device for monitoring worker exposures, and film badge dosimeters were considered a valuable adjunct (Hart 1966). This practice was eventually reversed with the film badge dosimeters providing the dose of record, and the PICs becoming the day-to-day means of monitoring worker exposures (Wilson et al. 1990). The switch from PICs to film badge dosimeters to provide the doses of record at Y-12 occurred in 1950 (ORAUT 2010a).

Pre-1950 film badge data have been considered questionable because of frequently changed procedures and a perceived general lack of monitoring quality control during this period (Tankersley 1982). For example, for R2, R3, and R4 in the Y-12 data, it appears that either 0 or 30 mrem might have been assigned if all weekly readings in the month fell below the MDL during certain periods of time. In addition, the very large doses observed in the R2 and R3 film badge responses were sometimes absent in the PIC data (see Figures 5-2 through 5-4). The PIC data were obtained with devices that were very simple to use; they should provide reliable data regarding whole-body doses from gamma rays and high-energy beta particles during the 1948-1949 period. Several R2 readings suggest high exposures to the skin from very low-energy photons that may not have been detected by the PICs (see Figure 5.3). The Y-12 1948-1949 dose studies have clearly demonstrated, however, that the regression approach developed in previous studies provide a reliable and convenient method for use in the reconstruction of potential whole-body doses from photon exposures to workers at the Y-12 facility during the late 1940s and early 1950s (Kerr et al. 2010a; ORAUT 2005).

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