GSI White Paper
Issues Raised in February 21, 2013 Work Group Meeting
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Background

During the meeting of the TBD-6000 Work Group on February 21, 2013, the Work Group requested that NIOSH provide details pertaining to three issues. The issues were:

1. Describe the external dose estimate NIOSH intends to use for non-radiographers prior to 1963.
2. Describe how individual cases will be assigned to different job categories.
3. Describe the internal dose estimate that will be used.

This paper provides the requested information.

Non-Radiographer Dose Estimate pre-1963 (Radium Era)

Prior to the Work Group meeting, NIOSH provided a white paper summarizing the dose estimates made by NIOSH and SC&A for various tasks at GSI (NIOSH 2013). When discussing the use of radium radiography (prior to 1963) both agreed the majority of radiography with the small isotopic sources occurred inside the radiography room, but NIOSH had not produced a dose estimate for that scenario. In the summary, NIOSH indicated their intent to use the SC&A estimate. Some issues with that estimate were discussed in the Work Group meeting and NIOSH was asked to develop and describe the model they intend to use.

In developing a model, the survey of the radiography room performed in August of 1962 was deemed the best available data since it represented actual measurements. This survey, however, was performed with Co-60 sources in place and after the shielding of the room had been modified. Therefore, the survey measurements must be adjusted to make them applicable to the radium radiography.

The initial license application to the Atomic Energy Commission from GSI (dated 4/18/1962) indicated the walls of the radiography room were 16” thick solid concrete (AEC 1962). On

September 7, 1962, GSI sent the AEC a copy of a survey of the radiography room (Kleber 1962). The survey report indicated measurements were made on June 24 and August 1 of 1962. This survey report also indicated the walls were 24 inches thick and included a sketch of the room with the annotation "Shows additional shielding added during June-July 1962". Therefore, it is assumed that an additional 8 inches of concrete were added to the room in June and July of 1962 prior to the survey performed on August 1, 1962.

As described in a previous white paper (NIOSH 2011), the two 500 mg radium sources were used until they were replaced with two Co-60 sources of strength 0.28 Ci and 0.26 Ci in 1962. The exposure rate from the two radium sources is actually slightly higher than from the Co-60 sources. This difference as well as the difference in shielding effectiveness and shielding thickness must be accounted for to determine the exposure rates from the radium radiography.

From the previous white paper, the two radium sources would each produce an exposure rate of 4.44 R/hr at one foot while the Co-60 sources would produce an exposure rate of 3.98 R/hr and 3.69 R/hr at one foot. Two sources together would then produce an exposure rate of 8.88 R/hr for the radium sources and 7.67 R/hr for the Co-60 sources. The half-value layer (HVL) of concrete for Radium and Co-60 is 6.9 cm and 6.2 cm, respectively (Williams and Wilkins 1998). Therefore, 24 inches of concrete would reduce the exposure rate from the Co-60 sources by a factor of 912. Also, 16 inches of concrete would reduce the Radium exposure rate by a factor of 59.

The survey performed August 1, 1962 indicated the maximum reading one meter above the floor outside the room was 1.2 mR/hr while the average was 0.15 mR/hr. The report further indicated the 0.15 mR/hr average included a background level of 0.05 mR/hr and that most readings did not exceed the background level.

Based on shielding and source strength, the maximum observed reading of 1.2 mR/hr through 24 inches of concrete would require that both Co-60 sources be exposed at a distance of 32 inches from the survey meter, 24 of which is the concrete wall. Thus, both sources would have been only 8 inches from the inside wall, while the survey meter was in contact with the outside of the wall. This would not represent a realistic scenario for an individual routinely working near the radiography room. Even if an individual always worked next to the room, it is not reasonable to assume he was always pressed against the wall and always immediately adjacent to where the sources were being used. The initial license application (AEC 1962) indicates the sources are normally place inside the castings and normally four to six feet from the wall of the room. Also, an interview with a former radiographer (SC&A 2011) indicates two radium sources could be used to make separate exposures with lead blocks used to shield each film from the source used for the adjacent exposure. Lastly, it would be very difficult to place and remove two sources with accurate enough timing to achieve the appropriate film exposure. Based on this, it is unlikely two sources were used simultaneously without some shielding between them.

For the reasons discussed above, this estimate will use the average reading of 0.15 mR/hr from the 1962 survey. This will account for the fact that the individual could be working anywhere along the length or the room or the sources could be used anywhere along the length of the shooting area inside the room. It does not reduce the estimate to account for the fact that the sources are often placed inside casting or that they are not normally placed that close to the inside of the wall. It also does not reduce the dose estimate to account for the likelihood that a particular individual did not likely stay pressed against the wall of the room 100% of his work year. However, the estimate will consider that the measurements were taken with 2 sources exposed. Even though it was reported that both sources would sometimes be exposed (SC&A 2011), it was also reported that radiographers would shield one source from the other so that each film would receive the proper exposure. This implies the combined effect of two sources near the same location would not occur.

Increasing the average measured exposure of 0.15 mR/hr to account for the stronger radium source strength and the 8 inch difference in shielding thickness, results in an exposure rate of 2.67 mR/hr. However, the report indicated the 0.05 mR/hr background level was included in that measurement which means only 0.1 mR/hr was due to the Co-60 sources. Using this value, the estimated average exposure rate outside the wall would be 1.78 mR/hr. If it is further assumed that both radium sources were not routinely used side by side and the second source (when used) was adequately shielded to avoid additional exposure to film, the exposure rate outside the wall can be reduced by two, resulting in an estimated exposure rate of 0.89 mR/hr. This exposure rate for 975 hr/yr (30% of 3250 hr) results in an annual exposure of 868 mR.

Assignment of Individual Cases to Radiographer vs. non-Radiographer Dose Estimate pre-1963 (Radium Era)

During the working group meeting February 21, 2013, a dose estimate for radiographers was agreed upon. The estimate results in a triangular distribution with the maximum dose set to the annual dose limit of 12 rem (15 rem in 1953 and 1954). The mode value was to be 9.69 rem and the minimum 6.279 rem. While the maximum value was based on the regulatory limit, the other two values were based on a calculation utilizing the same description of a technique (the fishing pole technique) but different parameters reported by a former radiographer. A large part of the dose in both these estimates resulted from the placing and removing of the radium sources using the fishing pole technique. This estimate is applicable to anyone who may have routinely placed or removed sources using this technique (radiographers) but is not applicable to those who did not.

For those that did not place sources, the non-radiographer dose estimate is more applicable. That estimate assumes someone is working next to the radiography room 100% of their time. In order to assign claims to one category or the other, a two step process is proposed. The process would assign a claim the radiographer dose if:

Step 1 – the job title given to DOL matches one of the titles listed below:

The job titles considered possible radiographers includes any variation of the following list.

- Quality Control
- Film reader
- Radiographer
- Inspector
- Betatron
- Magnaflux operator
- Metallurgy department
- X-ray

Step 2 – indications from the telephone interview that the individual may have performed radiography. In the case of no telephone interview, initial claim forms and other information are reviewed.

In order to test the process, 284 GSI cases existing in the claim database were searched for these job titles (and variations) resulting in 21 claims matching the list. While the telephone interview would also be reviewed when a dose estimate is performed, not all were reviewed for this exercise. Instead, they were reviewed if:

- They were one of the 21 selected from the first step;
- They had a job title listed as "unknown" or a variation of unknown; or
- The Energy Employees last name matched a name on the Landauer film badge reports.

Of the 21 claims assigned as radiographers by job title, 11 were confirmed to be radiographers by telephone interview or dose records. Ten could not be confirmed to be radiographers. Of the 10 unconfirmed, 1 was a Quality Control Inspector (two other QC inspectors were confirmed), 8 were inspectors (other than QC inspectors) and 1 was a magnaflux operator.

The magnaflux operator only worked a few months at GSI and likely was not a radiographer since radiographer was generally considered a more senior job. Interviews with the inspectors (other than QC inspectors) indicated they most likely were not radiographers but inspected dimensions and other aspects of the castings. The one QC inspector that could not be confirmed was likely not a radiographer based on his telephone interview. However, there is no discernible difference between the description of his job duties and that of some of the non-QC inspectors reviewed. This combined with the confirmation that two QC inspectors can be confirmed to be radiographers illustrates the need to include any type of "inspector" in the radiography category.

Besides the 21 claims above which were categorized based on job title, an additional 23 telephone interviews were reviewed for claims with job titles of "unknown". Most of the 23 "unknown" claims had job titles or a description of their work provided in the telephone interview. Others had work locations identified that indicated the individual was not a radiographer. Three had neither. One of those worked entirely during the residual contamination period and that dose estimate would not be affected by this determination. The second worked at GSI for only one day so it is unlikely he would have been trained at radiography. The third had no information about job title or duties or location. This one was considered a radiographer due to lack of information. However, the employee worked through the period when film badges were issued and his name did not appear in film badge records so it is likely he was not actually a radiographer.

An additional two of the 23 “unknown” claims were considered radiographers because of their telephone interviews. One of them was confirmed to be a radiographer by dose records and information in the phone interview. The remaining one could not be confirmed by any other means. The claim was added because of a description of magnaflux operator. However, the employee worked through the period when film badges were issued and his name did not appear in film badge records so it is likely he was not actually a radiographer.

Landauer dose records included only the last name of employees issued badges. Thirty one names from the claims database matched a last name from the Landauer records. Of those, 11 had already been added in previous steps. Two were added to the list of radiographers based on their telephone interviews. The remaining 18 contained information in job titles, description of duties or other information that indicated they did not perform radiography. Most of the 18 were the result of a common last name. For example, one name appears in the dose records that matched 6 different claims. The individual actually associated with that dose record could be confirmed thereby indicating the other 5 were not actually listed on the dose records. Even in the case of an uncommon name, the actual radiographer was confirmed but an additional case with the same uncommon name appeared in the claims database. This resulted in the realization that using these dose records to confirm a person was a radiographer is not foolproof and must be considered with other evidence.

In conclusion, the 2 step process resulted in 26 claims being assigned to the radiographer category with 12 of them being confirmed by either telephone interview or dose records or both. It is likely additional claims would be added to the category if every telephone interview had been reviewed for this exercise. While it is likely some who were not radiographers were included in the list, every individual known to be a radiographer and to have a claim was identified in the proposed process.

Internal Dose Estimate

The internal dose estimate will start with the airborne concentration agreed to in a previous Work Group meeting and reported to the full Board in December 2013. The concentration to be used is the 95th percentile of a surrogate data set resulting in an airborne concentration of 68.7 dpm/m^3.

The airborne is assumed to be present when handling uranium metal. The uranium shot scenario provided by workers and used in the external dose estimates is a 60 minute shot with 15 minutes between shots, with no one present during the 60 minute shot. The exposure to the airborne in that area is then 20% of the total time working with uranium. The time worked with uranium was estimated from purchase orders. This only represents the inhalation of uranium while handling uranium metal. There is also the possibility of uranium corrosion products being deposited on the floor resulting in resuspended contamination being inhaled at other times.

An analysis of the settling of airborne contamination was conducted as part of the Battlle-TBD-6000 review. The analysis concluded that the maximum contamination can be determined by assuming the airborne contamination settles at a rate of 0.00075 m/s for 30 days. Starting with the 95th percentile airborne concentration (68.7 dpm/m^3) this would result in a surface contamination of 1.34×10^5 dpm/m^2.

This contamination level can be used to estimate the airborne activity due to the resuspension of the contamination. ORAUT-OTIB-0070 provides a value of 1×10^{-6} m^{-1} during the residual period. However, for the period of time between the handling of uranium metal, the contamination is not "aged" nor would the conditions in the facility be considered "quiescent". Because of this the use of the default value in OTIB-0070 may not be applicable. ORAUT-OTIB-0070, however, does supports a factor 10 higher under the conditions described above. Therefore, the TBD will use a resuspension factor of 1×10^{-5} m^{-1} during the operational period of the site and 1×10^{-6} m^{-1} during the residual period.

Applying these resuspension factors to the surface contamination value results in airborne contamination of 1.34 dpm/m^3 to be applied for 3250 hours per year and to all people during the operational period. During the residual period, the value of 0.134 dpm/m^3 will be applied.

Ingested activity will be determined using OCAS-TIB-009. According to TIB-9, the daily ingestion can be estimated as 20% of the airborne concentration in one cubic meter of air. The assumption of TIB-9 assumes an 8 hour work day. This value can be adjusted to a 3250 hour work year by dividing the value by 8 hours then multiplying it by 3250 hours. This results in an ingestion rate of 5582 dpm per year or 15.3 dpm per calendar day. 3250 hours per year is used for both resuspended airborne and ingestion since surface contamination is not necessarily limited to the shooting area. By assuming contamination levels similar to where the uranium was routinely handled, this represents a claimant favorable estimate.

All individuals will receive the same internal dose estimate. This is due to the fact that the highest airborne activity would be located in the betatron buildings where the uranium was positioned for an x-ray. Others besides radiographers also frequented the building and would be exposed regardless of their task.

As indicated in Appendix BB revision 0, inhalation and ingestion values will be multiplied by 1.01 to account for fission products that may have been produced during the x-ray examination. A summary of the values discussed in show in the table below.

Start Date	End Date	Uranium work (hr/yr)	Inhalation from Handling (dpm/day)	Inhalation from resuspension (dpm/day)	Total inhalation (dpm/day)	Ingestion (dpm/day)
1/1/1953	6/30/1961	337.5	15.40	14.41	29.81	15.45
7/1/1961	6/30/1962	437.5	19.96	14.41	34.37	15.45
7/1/1962	6/30/1963	125	5.70	14.41	20.12	15.45
7/1/1963	6/30/1965	28	1.28	14.41	15.69	15.45
7/1/1965	6/30/1966	13	0.59	14.41	15.01	15.45
After 6/30/1966				1.44	1.44	15.45

Note: the values after 6/30/1966 are to be reduced using depletion factors in ORAUT-OTIB-0070.

References

AEC 1962, Initial Byproduct Material License for General Steel Industries with application, Atomic Energy Commission, NRC Accession Number ML093431334, April 18, 1962

Kleber 1962, Letter transmitting survey of radiographic exposure facility to the James Mason, AEC, NRC Accession Number ML093431294, September 7, 1962

NIOSH 2011, Battelle-TBD-6000 Appendix BB General Steel Industries Dose Estimates for Portable Radiography Sources, NIOSH white paper, August 2011

NIOSH 2013, *GSI Dose Estimation Comparison*, January 2013

SC&A 2011, *Update of the Use of Sealed Radioactive Sources at General Steel Industries*, SC&A draft white paper, October 2011

Williams and Wilkins 1998, *Handbook of Health Physics and Radiological Health*, Third Edition