

GSI Dose Estimation Comparison

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The following comparisons of NIOSH and SC&A dose estimates for workers at GSI was assembled from a review of various white papers and matrix notes, starting with the latest and working backwards in time. Based on this review, a summary of the latest modeled doses proposed by NIOSH and SC&A for various exposure scenarios is provided. It does not include some additional exposure scenarios that were evaluated and not used (i.e, they were determined not to represent the limiting source of exposure). The summary is categorized by time frame (Radium Era and Cobalt Era) as well as by worker category (Radiographer and Other) so that four exposure categories were established.

Photon Dose

Radiographers – Radium Era

	SC&A	NIOSH
Ra-226 sources in radiography room	9.69 R/yr ^a	N/A ^b
Ra-226 source outside radiography room	9.39 R/yr ^c	3.573 R/yr ^d
St. Louis Testing sources	2.771 R/yr ^e	2.671 R/yr ^f
Betatron Operator	1.35 R/yr ^g	0.620 R/yr ^h
Layout Man	N/A ⁱ	4.483 R/yr ^j

- a) 9.39 R/yr from the “fishing pole technique” estimate plus 0.296 R/yr during the shot (Ref. 1, page 7. Fishing pole technique estimate ref. 2 pg 6 & 7)
- b) NIOSH did not develop an estimate of Ra sources inside the radiography room
- c) 9.39 R/yr from the “fishing pole technique” only. SC&A did not develop a dose estimate specifically for the use of Ra-226 sources outside the radiography room (ref. 2 pg 6 & 7) Using other methods, SC&A bound the dose between 9 and 20 R/yr. Matrix recommends using 12 R/yr based on AEC limit.
- d) 5.411 R/yr for the fishing pole technique divided between 2 radiographers plus 0.868 R/yr at the boundary (ref 3 pg 15 & 16)
- e) Full time next to boundary plus one incursion of the boundary per shift (ref 2 pg 10)
- f) Full time next to boundary Ref 3 pg 22

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- g) (Ref 6 pg 3)
- h) Value varies by year (ref 5 pg 28)
- i) SC&A indicated bounding dose would be from radium source work (ref. 6 page 2 & 3)
- j) New Betatron building estimate used for all years except half the value for 1966 (ref 4 pg 5)

Others – Radium Era

	SC&A	NIOSH
Ra-226 sources in radiography room	2.087 R/yr ^a	N/A ^b
Ra-226 source outside radiography room	1.978 R/yr ^c	1.353 R/yr ^d
St. Louis Testing sources	2.771 R/yr ^e	1.336 R/yr ^f
Betatron Operator	1.35 R/yr ^g	0.620 R/yr ^h
Layout Man	N/A ⁱ	4.483 R/yr ^j

- a) 25% of time near door of radiography room (ref 1 pg 7)
- b) NIOSH did not develop an estimate of Ra sources inside the radiography room
- c) Inferred from 0.07 mR/shift for an incursion plus 2 mR/hr at boundary (ref. 1 pg 6)
- d) 0.567 R/yr walking through area plus 0.786 R/yr at the boundary (ref. 3 pg 16 & 17)
- e) Assumes full time next to boundary for all workers (Ref 2 pg 10)
- f) Assumes half time next to boundary for non-radiographers (Ref 3 pg 22)
- g) Assuming dose for operator may be applicable to others (Ref 6 pg 3)
- h) Value varies by year (ref 5 pg 28). Value intended for those routinely working in betatron building.
- i) SC&A indicated bounding dose would be from radium source work (ref. 6 page 2 & 3)
- j) New Betatron building estimate used for all years except half the value for 1966 (ref 4 pg 5)

Radiographers – Cobalt Era

	SC&A	NIOSH
Co-60 sources in radiography room	1.170 R/yr ^a	1.170 R/yr ^b
Co-60 source outside radiography room	N/A ^c	0.868 ^d
St. Louis Testing sources	2.771 R/yr ^e	2.671 R/yr ^f
Betatron Operator	1.35 R/yr ^g	0.557 R/yr ^h

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Layout Man	9.2 R/yr ⁱ	4.483 R/yr ^j
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- a) Agreement with NIOSH (ref 1 pg 9)
- b) Full time at maximum survey location (ref. 3 pg. 18)
- c) SC&A indicated this scenario was rare (ref. 1 pg 9)
- d) (ref. 3, pg 20)
- e) Full time next to boundary plus one incursion of the boundary per shift (ref 2 pg 10)
- f) Full time next to boundary Ref 3 pg 22
- g) (Ref 6 pg 3)
- h) Value varies by year (ref 5 pg 28).
- i) Layout man dose applicable only to new betatron building (Ref 6 pg 3)
- j) New Betatron building estimate used for all years except half the value for 1966 (ref 4 pg 5)

Others – Cobalt Era

	SC&A	NIOSH
Co-60 sources in radiography room	1.170 R/yr ^a	1.170 R/yr ^b
Co-60 source outside radiography room	N/A ^c	1.348 R/yr ^d
St. Louis Testing sources	2.771 R/yr ^e	1.336 R/yr ^f
Betatron Operator	1.35 R/yr ^g	0.557 R/yr ^h
Layout Man	9.2 R/yr ⁱ	4.483 R/yr ^j

- a) Agreement with NIOSH (ref 1 pg 9)
- b) Full time at maximum survey location (ref. 3 pg. 18)
- c) SC&A indicated this scenario was rare (ref. 1 pg 9)
- d) 0.562 R/yr walking through area plus 0.786 R/yr at the boundary (ref. 3 pg 21)
- e) Assumes full time next to boundary for all workers (Ref 2 pg 10)
- f) Assumes half time next to boundary for non-radiographers (Ref 3 pg 22)
- g) Assuming dose for operator may be applicable to others (Ref 6 pg 3)
- h) Value varies by year (ref 5 pg 28). Value intended for those routinely working in betatron building.
- i) Layout man dose applicable only to new betatron building (Ref 6 pg 3)
- j) New Betatron building estimate used for all years except half the value for 1966 (ref 4 pg 5)

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Neutron Dose

The source of neutron exposure is from the operation of the betatron. Thus, neutron doses are included in the betatron operator dose estimate (which includes others working in the betatron building) and the layout man dose estimate. The estimates are based on the same models and results used in the photon analysis.

Beta Dose

Sources of beta radiation are from exposure to uranium metal (both irradiated and intrinsic) and from the irradiated steel.

The uranium beta dose modeled by NIOSH utilized the SC&A model from its original Appendix BB review. Therefore, there appears to be agreement on this approach.

NIOHS estimates of beta doses from exposure to irradiated steel rely on the SC&A model that was included in their initial Appendix BB review. In their last white paper review, SC&A pointed out that the MCNPX version used (version 26e) was an early version of the applicable capability and the latest (version 27e) provided different results. There is no disagreement from NIOSH.

Agreement

- Both SC&A and NIOSH appear to agree that the dose to the layout man is the bounding exposure scenario during the cobalt era, even though current estimates differ. This bounding scenario is true for both radiographers and others categories.
- In the last SC&A review, SC&A pointed out that the layout man estimate used by NIOSH for all years was only really applicable to the new betatron which was not built until 1963. NIOSH agrees with this. Because NIOSH and SC&A agree on this point, radium radiography becomes the bounding exposure scenario in the radium era. This is true of radiographers but unclear for others.

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Unresolved Issues

NIOSH and SC&A have different exposure models for the two bounding scenarios discussed below. The differences exist primarily in the input parameters or assumptions used.

Layout man scenario

For the layout man scenario, NIOSH estimated doses at various locations in and around the new betatron building from a variety of betatron shot scenarios. These scenarios were then combined with the work scenario developed by SC&A (using worker input) to produce the highest dose rate at the layout man location while producing 10 mrem per week at the film badge rack.

SC&A believed that many of the shot scenarios developed by NIOHS were unrealistic. They also commented that it was not appropriate to normalize the dose rates to 10 mrem per week at the badge rack location. Instead, SC&A's estimate of dose to the layout man was based on 100% of the shots being the same as that used in their original Appendix BB review. This scenario is listed as RR_ST_No in Table 3 of the January 2012 NIOSH white paper. That table provides dose rates in the control room for that shot scenario as 1.42 mr/hr at the door, 0.41 mr/hr at the desk, and 0.65 mr/hr in the center of the room. With the betatron operating 41% of the time, a 65 hr work week would produce more than 10 mrem on a film badge worn by an operator in the control room, even at the lowest dose rate location. Since the badge would also receive some amount of exposure while in the badge rack and also while the operator was exposed to irradiated steel, the scenario appears to be unrealistic. If the three control room dose rates were averaged, and the time spent utilizing this shooting scenario were adjusted to 10 mrem/week in the control room (based on the average dose rate), the SC&A layout man dose estimate would be reduced to less than 4.2 R/yr. This is reasonably close to the NIOSH dose estimate of 4.48 R/yr. It does not appear there will be significant differences in the layout man dose if the betatron operator badge is limited to 10 mrem/yr.

Radium Source Scenario

After interviewing workers, SC&A concluded that most radium radiography occurred in the radiography room of the 6 building. NIOSH agrees with this. SC&A developed a model for inside the radiography room, while NIOSH developed a model for outside the room (radiography in the other areas of the facility). The primary dose to radiographers in both models is that received while using the "fishing pole technique" to place and retrieve the source. SC&A developed a dose of 9.39 R/yr from this technique, utilizing the worst case parameters provided by a former worker. NIOSH used the midpoint of the ranges and assumed at least two radiographers shared the duties (thus divided this dose by 2). SC&A

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also reviewed dose records from an individual part time radiographer and prorated it to full time. Based on the assumptions used for prorating the dose, the range developed was approximately 9 R/yr to 20 R/yr. Lastly, for most of this the time period under evaluation, the regulatory dose limit was 3 rem per calendar quarter or essentially 12 rem per yr. Based on a statement GSI made to the AEC that no one had exceeded the annual limit and the average was below 25% of that limit, the maximum dose can be established as falling between 3 R/yr and 12 R/yr.

If the NIOSH model is revised to assume one radiographer received the entire dose from the “fishing pole technique” and the SC&A estimate of the exposure during the shot in the radiography room was added, the new estimate would be 5.707 R/yr.

The dose estimate for other workers from radium radiography inside the radiography room was developed by SC&A. The result (2.09 R/yr) is bounding compared to estimates for radiography outside the room (1.98 R/yr inferred from SC&A review, 1.35 R/yr NIOSH). NIOSH did not develop an estimate for radium radiography inside the room. NIOSH agrees with the SC&A estimate for exposure to non-radiographers from radium radiography.

NIOSH developed an exposure estimate for others from St. Louis Testing radiography. The estimate was 1.34 R/yr which would not be the bounding scenario given 2.09 R/yr exposures from radium radiography. However, the NIOSH estimate was based on assuming the individual was near the boundary only 50% of his workday. SC&A disagreed with applying that factor. If 100% occupancy is to be applied, the St. Louis Testing exposure estimate becomes the bounding dose at 2.77 R/yr in the radium era. However, during the interview with the former Administrator of St. Louis Testing, the Administrator indicated this work occurred in the mid or early 1960s. He then recalled that it started while they were working on the St. Louis Arch. SC&A noted that construction of the Arch began in 1963 which would be during the cobalt era.

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REFERENCES

- 1) SC&A, October 2011, *Update of the Use of Sealed Radioactive Sources at General Steel Industries*, SC&A draft white paper
- 2) SC&A, September 2011, *Review of NIOSH Report on Portable Radiography Sources at GSI*, SC&A draft white paper
- 3) NIOSH, August 2011, *Battelle-TBD-6000 Appendix BB General Steel Industries Dose Estimates for Portable Radiography Sources*, NIOSH white paper
- 4) NIOSH, March 2012, *Addendum to Dose Estimates for Betatron Operations*, NIOSH white paper
- 5) NIOSH, January 2012, *Response to Battelle-TBD-6000 Appendix BB General Steel Industries: Dose Estimate for Betatron Operations*, NIOSH white paper.
- 6) SC&A, March 25, 2012, *Review of NIOSH Report: Addendum to Dose Estimates for Betatron Operations*, SC&A memo
- 7) SC&A, March 2012, *Response to Battelle-TBD-6000 Appendix BB General Steel Industries: Dose Estimate for Betatron Operations*, SC&A draft white paper

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