WHITE PAPER

Summary Dose Estimates for GSI

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Background

During the meeting of the TBD-6000 Work Group, held June 20, 2013, the Work Group requested that NIOSH revise its internal dose estimate for General Steel Industries (GSI), as well as provide a summary of the dose estimates to be used in revising Appendix BB as they now stand. This white paper is intended to address both requests.

Uranium Intake Estimate

Following discussions during the Work Group meeting on June 20, 2013, it was decided that the uranium intake estimate for GSI would assume that airborne activity at the 95th percentile concentration was inhaled for a time equal to the full uranium working time. Previously, the NIOSH estimate assumed exposure only for the 20% of the time the betatron operators were in the shooting area, since that is where the uranium was handled. Questions arose about the exposure incurred by other workers who transported the uranium metal to the betatron building. This question is explored here.

Based on worker input, x-ray shots of uranium took 60 minutes each with 15 minutes between them. Furthermore, it was reported that 4 shots were taken on each piece of uranium. This implies the uranium was being moved only about 5% of the time the uranium was in the building (15 minutes out of 300 minutes). Since the uranium had to be positioned in the betatron building and not just moved, it may be reasonable to think that the manipulation of the uranium in the betatron building took more time than moving the same uranium to and from the building. That would imply the time involved in moving uranium around the site would be less than 5% of the time it was in the betatron building.

However, there are several possibilities that could change that assumption. First, it is possible the handling inside the betatron building was more efficient than outside even if inside involved proper placement and not just movement. Second, it is possible the uranium was moved from conveyance to conveyance within the site (fork truck, rail car, crane, etc.) thus representing multiple episodes of handling rather than one each direction. It should however be noted that it is unlikely this occurred in

one area. More likely, the uranium would be moved some distance with each conveyance before being transferred to another conveyance and airborne activity would thus not accumulate in a single area. Lastly, it possible that while the uranium is being moved on a conveyance, additional airborne activity could be produced by vibrations. Again however, this would not occur in a single area but rather all along the path.

With these uncertainties in mind, it was agreed during the June 20th 2013 working group meeting that assuming airborne activity was created during 100% of the uranium working time would be a bounding estimate. With this assumption in place, it becomes the bounding source of internal exposure for everyone on site. Resuspension from contamination was accounted for separately and assumed to be present year round regardless of whether uranium was being worked with or not.

A NIOSH white paper dated April 2013 included an estimate of intakes at GSI. The same estimate is reproduced here but the inhalation intakes from handling uranium metal were increased by a factor of 5. The increase is due to assuming intakes occurred for 100% of the uranium working time rather than 20%. The revised estimate is provided in Table 1 below. The inhalation intake from resuspended material and from ingestion remains the same.

Table 1 – Intake Estimate

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)
10/1/1952	6/30/1961	337.5	76.99	14.41	91.40	15.45
7/1/1961	6/30/1962	437.5	99.80	14.41	114.22	15.45
7/1/1962	6/30/1963	125	28.52	14.41	42.93	15.45
7/1/1963	6/30/1965	28	6.39	14.41	20.80	15.45
7/1/1965	6/30/1966	13	2.97	14.41	17.38	15.45

After 6/30/1966				1.44	1.44	15.45

Note: the values after 6/30/1966 are reduced using depletion factor from ORUAT-OTIB-0070.

Summary of External Dose Estimates

Below is the summary of the external dose estimates currently proposed to be used in revising Appendix BB. Most but not all have been discussed previously in work group meetings. Disagreement still exists for some and others have not been discussed.

First, a dose estimate for administrative personnel was derived in a NIOSH white paper issued in May 2013. The estimate was based on radium radiography in the areas of the plant outside the radiography room. No discussion was held about a dose estimate following the end of radium radiography in 1963. This white paper proposes to continue using that estimate to the end of the covered period. It is intended that this be favorable since dose estimates for radiographers persistently indicated higher exposures during radium radiography than during cobalt radiography and the trend should also apply to administrative personnel.

It should also be noted that with the source of gamma exposure being sealed radium sources, no neutron or non-penetrating dose is produced and those dose estimates are zero. The dose estimates are listed in Table 2 below.

Table 2 – External Dose Estimate for Administrative Personnel

	Gamma	Neutron	Non-Penetrating Hands and Forearms	Non-penetrating whole body
10/1952 – 1963	571.5 mr/yr [(a)]	0	0	0
1964 – 6/1966	571.5 mr/yr [(b)]	0	0	0

Notes:

a. From NIOSH White Paper "GSI – Dose Estimate from Radium Radiography to Employees not Routinely Working in Production Areas", May 2013.
b. Post radium era estimate continues radium era estimate as favorable based on radium era estimates for radiographers being bounding.

Next, the doses for the remainder of the plant personnel are summarized. The dose estimates are divided into three time frames. The first being the start of the GSI operational period until a change to the dose limits found in NBS handbook 59 (October 1952 – 1958). The second period is from then to the end of the radium radiography (1959-1963). The third is from the end of the radium radiography until the end of the operational period at GSI (1964-1966).

In the third time period, the dose is based on the estimate for the layout man, which includes a gamma, neutron and beta dose component. The beta dose estimate was based on activation of steel by the betatron. It was pointed out previously that activation rates derived from MCNPX would change in later versions of MCNPX. The values were recalculated using MCNPX 2.7 and the new values entered into the same calculations performed previously to obtain a new non-penetrating dose estimates.

The gamma dose estimate for the first two time periods was agreed to during a working group meeting held on 2/21/2013. These estimates were based on radium radiography and differ only by the maximum dose prescribed by the triangular distribution. Since the radium sources would not produce any neutron or beta radiation, the neutron and non-penetrating dose estimates are zero. There is, however, a significant non-penetrating dose estimate for betatron operators. This opens the possibility that the radium radiography dose estimate could be favorable to most workers but the betatron operator estimate could be favorable to some. Therefore the betatron operator estimate is included as Table 4 for comparison.

Table 3 – External Dose Estimate for Operational Personnel (non-administrative personnel)

	Gamma (rem/yr)	Neutron (rem/yr)	Non-penetrating hand and forearm (rad/yr)	Non-penetrating whole body (rad/yr)
10/1952-1958 [a]	Tri 15/9.69/6.279 [b]	0	0	0
1959 – 1963	Tri 12/9.69/6.279 [b]	0	0	0
1964 -1966	4.483 [c]	0.148 [c]	2.658 [c][d]	1.462 [c][d]

Notes:

a) Dose limit changed from 0.3 rem/week (15 R/yr) to 3 rem/quarter (12 rem/yr) in Addendum to NBS 59 published 4/15/1958.

b) Triangular distribution agreed to in a Work Group meeting on 2/21/2013. The maximum of the distribution was to be the dose limit. The mode was the SC&A estimate contained in "Update on the Use of Sealed Radioactive Sources at General Steel Industries" issued October 2011. The minimum was the NIOSH estimate from "Battelle-TBD-6000 Appendix BB General Steel Industries Dose Estimates for Portable Radiography sources" issued August 2011 and adjusted to 1 radiographer instead of two.
c) Values for 1964 – 6/1966 are for Layout man from NIOSH "Addendum to Dose Estimates for Betatron Operators White Paper" issued March 2012.
d) Non-penetrating dose values adjusted based on new activation calculation using MCNPX 2.7.

Table 4 – External Dose Estimate for Betatron Operators

Year	Photon [(a)] (rem/yr)	Neutron [(b)] (rem/yr)	Non-penetrating Hands and forearms (rad/yr) [(a)]	Non-penetrating whole body (rad/yr) [(a)]
10/1952-1960	0.590	0.050	26.904	2.755
1961	0.620	0.056	30.496	2.946
1962	0.557	0.043	22.863	2.539
1963	0.435	0.019	8.154	1.755
1964	0.406	0.013	4.669	1.569
1965	0.401	0.012	4.130	1.541
1/1966 – 6/1966	0.199	0.006	1.796	0.756

Note:

a) Photon and non-penetrating values in this table come from the NIOSH white paper "Dose Estimates for Betatron Operations" January 2012.
b) Neutron values in this table come from the NIOSH white paper "Addendum to Dose Estimates for Betatron Operations" March 2012.

With the exception of the hand and forearm dose, the total dose in Table 3 is always higher than the doses in the betatron operator table (Table 4). For hands and forearms, the betatron operator total dose is higher many of the years. Therefore, the recommendation in this white paper is to use Table 3 values for claims (including betatron operators) but to use the more favorable values of Table 4 for skin dose of the hands or forearms.