TO: Advisory Board on Radiation and Worker Health Work Group on TBD-6000
FROM: Robert Anigstein and John Mauro, SC&A
SUBJECT: Review of NIOSH Estimates of External Exposures at GSI
DATE: April 23, 2013

Review of NIOSH Estimates of External Exposures at GSI

On April 1, 2013, David Allen (2013) transmitted a White Paper on GSI, providing details on (1) how NIOSH intends to estimate doses from external radiation to nonradiographers prior to 1963; (2) how individual cases will be assigned to different job categories; and (3) how internal doses will be estimated. The same day, Ted Katz, Designated Federal Official to the Advisory Board, sent an e-mail message asking SC&A review this report. This memo includes our response to the discussion of external exposure in Allen's White Paper, as well as responding to an issue raised at the February 21, 2013, meeting of the Work Group on TBD-6000. The NIOSH estimates of internal dose will be discussed in a later document.

1 Response to NIOSH White Paper

The following discussion is keyed to Allen (2013) and follows the same sequence as Allen.

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

In the first section of the White Paper following the introductory "Background" section, Allen (2013) derived an exposure rate to nonradiographers at a location outside the GSI radiographic facility—a roofless concrete block structure located in the No. 6 Building. He based his analysis on a report of a radiation protection survey performed by Nuclear Consultants Corp. (NCC) on August 1, 1962. NCC performed measurements inside and outside the radiographic facility with two ^{60}Co sources, with activities of 260 and 280 mCi, respectively, exposed inside the exposure area. The description of this facility that is presented in the GSI correspondence with the AEC is inconsistent. In the original application, dated March 7, 1962 (NRC 2009), the room is described as having "walls constructed of 16 inches of solid concrete block." The small room inside the facility, described as a viewing room, has walls 8 in thick "made from cement blocks." The application includes calculations of exposure rates outside this facility from the 300 mCi ^{60}Co sources that GSI wanted to acquire, taking credit for the shielding afforded by the 16-in concrete walls, and concludes that the maximum exposure rates would be 1.48 mR/h, which is well within the 2 mrem/h limit specified in 10 CFR 20, paragraph 20.105 (b)(1), which went into effect on January 1, 1961 (AEC 1960).

Since, according to GSI, the source would seldom be exposed for more than 2–3 h per 8-h shift, the maximum exposure rate in 7 d, assuming three shifts per day, 7 d/week, would be 93 mR (1.48 mR/h × 3 h/shift × 3 shifts/d × 7 d ≈ 93 mR). Thus, the exposure rate is within the 100 mrem limit for any 7-d period specified in paragraph 20.105 (b) (2).[1] Finally, paragraph

[1] We note that AEC (1960, 20.4 (c)(1)) stated that 1 rem is equivalent to 1 R due to X or γ radiation.

20.105 (a) limits the exposure of an individual in such an unrestricted area to 0.5 rem per calendar year. Assuming a 48-h week, which was used in establishing radiation protection standards at that time, an employee would spend 2400 h/y on the job. The maximum exposure during that time would be 1,332 mR (1.48 mR/h × 3 h/shift × 2400 h/y ÷ 8 h/shift = 1,332). The 500 mrem/y limit would be met if the occupancy factor for any one individual were <0.375 (500 ÷ 1,332 ≈ 0.375). Since the application states that the closest work area (to the radiographic facility) is 15–20 ft away, the occupancy factor of an area immediately adjacent to the walls could be assumed to be much less than 37.5%. It is therefore quite clear that GSI assumed that the existing facility would be in compliance with 10 CFR 20 with respect to radiation levels in unrestricted areas.

Allen (2013) assumed that GSI increased the thickness of the walls to 24 in. He based his conclusion on statements made in the NCC survey report regarding the thickness of the walls, and a notation at the bottom of a drawing in the report that referred to additional shielding added in June–July 1962. According to [redacted], a former GSI [redacted] who was employed during the Radium Era, steel shields were added when GSI started to use sources other than radium (Anigstein 2011). This is the only additional shielding that has been reported. It would appear to be illogical for GSI to have gone to the expense of thickening the walls in June-July 1962, after they were granted a license in April and procured the ^{60}Co sources in May, and before a survey was performed to determine whether or not the existing shielding was acceptable. It appears more likely that there was an error or miscommunication between the plant personnel and NCC, both in terms of the thickness of the walls and the date that the steel plates were installed. The original GSI application refers to the steel plates being present. Based on [redacted]' account, it would seem likely that they were installed at the time of the application, since the radiographers were not adequately protected while sitting in the office during exposures. While we cannot rule out the walls' being reinforced, there is not enough evidence for this to be the basis of the calculation of exposures of nonradiographers during the radium era.

There is also some question as to when the radiographic facility was constructed. [redacted] recalled that it was there when he returned to GSI in 1956, [redacted]. Indirect information from another former employee indicates that this structure was erected in 1955. If that were the case, then any scenario involving that building would not be relevant to exposures prior to the time it was constructed.

Aside from this objection to the method of analysis employed by Allen (2013), we also dispute the assumption that this analysis can be used to estimate the exposure of an actual person, given the description of the area surrounding the facility in the GSI application to the AEC. The facility was approximately 60 ft long, in the E-W direction, and 20 wide N to S. Thus the north and south walls would be nearest to the sources. However, according to GSI, the areas within 20 ft of these walls were used for storage and were thus inaccessible to personnel. Only the east and west walls, which were furthest from the exposed sources, were accessible to workers; however, as stated earlier, the nearest work areas were 15–20 feet away. Therefore, Allen's analysis does not lead to a plausible dose to a real person.

Another issue is the limitation of access to the radiographic facility, especially during the early years of the Radium Era. Thanks to the newspaper clipping furnished by [redacted] an advocate for GSI workers, we have confirmed that a radium source was in fact missing in October 1953, as had been related by the [redacted], a former GSI [redacted] According to [redacted] the source had been removed from the radiography room, which was unlocked at the time. When [redacted] returned to GSI in 1956, after [redacted] there was a lock on the door. Thus, nonradiographers may have entered the facility.

We note that there is an apparent inconsistency between this account and the 1955 construction date reported by another worker. We draw no conclusions as to which account is correct, but merely observe that there is uncertainty regarding this structure which again calls into question the validity of any exposure scenario based on this structure. This uncertainty does not invalidate the SC&A model of the exposure of the radiographer using the fishpole technique, since only the part of his exposure while he was inside the facility during the radiographic exposures (0.30 R out of a total of 9.69 R) was derived from the MCNP analysis that utilized a model of this facility.

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

Allen (2013) reported the external doses to radiographers during the Radium Era that were agreed upon at the February 21, 2013, work group meeting. These annual doses were represented by a triangular distribution, with a lower limit of 6.279 rem, a mode of 9.69 rem, and a maximum of 12 or 15 rem, depending on the year. The maximum was set to equal the AEC dose limit in effect at the time. In a recent e-mail, [redacted] the copetitioner, inquired about the documentation of the AEC limits. This prompted us to investigate the time line of the AEC regulations embodied in 10 CFR 20. As it turns out, 10 CFR 20 was first put into effect on February 28, 1957. At that time, the regulation limited doses to blood-forming organs, gonads, and the lens of the eye to 300 mrem/week. This limit had been presented in NBS Handbook 41, dated March 30, 1949 (NBS 1949). The handbook embodied the recommendations of the NCRP, which AEC had agreed to follow, first in regulating its own operations, and later in promulgating rules for AEC licensees. Since the AEC observed the limit of 300 mrem/week (15 rem/y) since about 1949, this limit can assumed to have been followed by GSI during the early years of the operational period.

On January 1, 1961, a revised 10 CFR 20 went into effect. This rule limited doses to a maximum of 3 rem per calendar quarter to a worker if his prior exposure history was known and if his lifetime dose did not exceed 5 (N-18), where N is his age in years. Thus, a worker well past the age of 18 with a sufficiently low cumulative exposure could receive doses as high as 12 rem in any one year. Thus, the upper bound of the triangular distribution should be set at 15 rem per year during the period 1953–1960, and reduced to 12 rem/year during 1961–62.[2]

[2] This is a change in the SC&A position—we had earlier assumed that the AEC 12-rem limit began in 1955.

The more significant issue is the attempt by NIOSH to assign different external exposures to different classes of workers. The discussions at the December 11, 2012, meeting of the Advisory Board prior to the vote on the GSI SEC petition clearly indicated that Board members were under the impression that significantly high doses would be assigned to most, if not all, GSI claimants. All the discussion of exposures during the Radium Era centered on cumulative doses that, in the words of one member, could total as much as 120 rem. It is clear that the Board did not understand that the high doses during the Radium Era discussed by one of us (RA)(i.e., fixed annual doses of 12 or 15 rem, depending on the year) would be applied to as few as 26 out of 284 claimants. SC&A had assumed that NIOSH would employ the same philosophy during the Radium Era as they stated they would apply to the operation of the new betatron: all doses would be reconstructed on the basis of the most claimant-favorable exposure scenario.

The crux of the matter is that during the past year we have held that the *only* scenario to which doses can be plausibly assigned during the Radium Era is that of the radiographer handling radium sources using the fishpole technique. Although we do not believe that all workers performed radiography, these are the only workers to whom scientifically valid doses can be assigned, and that it is unlikely that these doses were exceeded. Thus, these doses constitute plausible upper bounds for all workers.

To restate the above argument, NIOSH explained that the agreed-upon dose distribution is applicable to radiographers that used the fish pole technique. We agree with this position, but we also believe that this dose distribution places a plausible upper bound on nonradiographers who might have been in the vicinity of work areas where radiography was being performed. This brings us to the essence of our dilemma and to the heart of the SEC issue. We believe that it will be extremely difficult to parse workers into categories, such as radiographers and nonradiographers, in a manner that allows a dose reconstructor to know when to assign doses other than the bounding doses used for radiographers. Recall that one of the reasons SC&A agreed that doses to workers at GSI could be bounded was a statement made in the 1962 AEC licensee application that no worker ever exceeded the occupational dose limits. Without this statement, along with extensive modeling and the film badge data from one radiographer, it would not have been possible for SC&A to agree that doses could be bounded during the Radium Era.

Allen (2013) went on to describe the job categories that would be assigned the bounding doses during the radium era and found that, of the 284 cases, 26 claims fall into those job categories. Allen provided a detailed description of the investigations NIOSH performed that would allow them to parse workers into categories. Notwithstanding these efforts, we believe that it is not appropriate to parse workers in this manner because, based on close inspection of the claims and interviews with the workers, the job category assigned to a worker does not provide assurance that the worker could not have experienced the bounding exposures during a given year. We come to this conclusion because of the apparent limited extent of health physics oversight that was in place during the Radium Era. One might reasonably ask, why then does SC&A believe that the doses could be bounded for all workers? We believe that there is a difference between concluding that doses can be bounded for all workers, and concluding that we have enough

information to parse workers into categories and assign different doses to different categories of workers.

This is an unusual set of circumstances, one that SC&A had not previously encountered, and we believe that NIOSH has no choice but to assign the bounding doses to essentially all workers with the potential for exposure during the radium era.

2 Betatron Exposure Scenarios

A question arose during the February 21, 2013, work group meeting regarding the betatron shooting scenarios. David Allen maintained that the betatron scenario proposed by SC&A was implausible because it would have led to exposures of control film badges in excess of 10 mR per week. We disagree with this assumption for two reasons. First, there is no information on where film badge No. 1, called "Betatron CTL" was stored. Since there was only one such badge, it could have been kept in the Old Betatron Building, which is where [redacted] one of the earlier betatron [redacted] had his office. The 000 control badge should have been stored on the film badge rack, along with all the workers' film badges. Allen correctly pointed out that the reports of this badge always had readings of *M*. The manner in which the dose to this badge was evaluated is explained in the memo from Joseph Zlotnicki, CHP (former Landauer official, currently a member of the SC&A staff) (see Attachment 1). The evaluation of the badges was a multi-step process. Landauer retained a control film that was matched to each batch of films sent to a customer—this film never its premises. When the films were returned from the customer, the in-house control film was developed alongside the other films. The base fog on this film was subtracted from the densitometer readings of all the other films. The remaining "dose" on the 000 customer control badge was evaluated. If this film read less than 50 mrem, and if the reading was lower than that of one-half of the badges issued to workers, the reading was subtracted from that of the other badges, as well as from itself. In these cases, which constituted the vast majority, the control badge would be reported as *M*. Thus, the *M* readings cannot be used to place an upper limit on the cumulative weekly exposure at the film badge location.

Furthermore, as we pointed out earlier (Anigstein and Mauro 2012), we disagree with the NIOSH MCNP model of the New Betatron Building, which used incorrect assumptions about the thickness and density of the control room wall and the absence of equipment, furniture, and internal walls that would have reduced the exposure rate at the film badge rack. We therefore restate our opinion that the betatron shooting scenario described in our earlier report (Anigstein and Olsher 2012) is more realistic and more claimant favorable than the one proposed by NIOSH.

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