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National Institute for Occupational Safety and Health

Review of the General Steel Industries Special Exposure Cohort (SEC) Petition-00105 and the NIOSH SEC Petition Evaluation Report

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Review of the General Steel Industries Special Exposure Cohort (SEC) Petition-00105 and the NIOSH SEC Petition Evaluation Report	Page 2 of 51
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CONTENTS

CONTENTS

ABBREVIATIONS AND ACRONYMS

AEC	Atomic Energy Commission
AMAD	activity median aerodynamic diameter
AWE	Atomic Weapons Employer
CATI	Computer-Assisted Telephone Interview
CFR	*Code of Federal Regulations*
Ci	curie: unit of activity
DOE	U.S. Department of Energy
DOL	U.S. Department of Labor
DR	dose reconstruction
EEOICPA	Energy Employees Occupational Illness Compensation Program Act of 2000
EML	Environmental Measurements Laboratory
ER	(SEC Petition) Evaluation Report
FOIA	Freedom of Information Act
FR	Federal Register
FUSRAP	Formerly Utilized Sites Remedial Action Program
GSI	General Steel Industries
HY	High Yield (steel)
ICRP	International Commission on Radiological Protection
IMBA	Integrated Modules for Modular Bioassay Analysis
IREP	Interactive RadioEpidemiological Program
MCNP	Monte Carlo Nuclear Particle: a family of radiation transport computer codes developed by the Los Alamos National Laboratory
NARA	National Archives and Records Administration

NIOSH	National Institute for Occupation Safety and Health
NRC	U.S. Nuclear Regulatory Commission
OCAS	Office of Compensation Analysis and Support
ORAUT	Oak Ridge Associated Universities Team
ORNL	Oak Ridge National Laboratory
PFG	photofluorography
R	roentgen: unit of exposure
rem	roentgen equivalent man: unit of effective dose
SC&A	Sanford Cohen & Associates
SEC	Special Exposure Cohort
SRDB	Site Research Database
SRQD	(NIOSH) Site Research Query Database
TBD	Technical Basis Document

EXECUTIVE SUMMARY

During the meeting of the Advisory Board on Radiation and Worker Health held in Albuquerque, New Mexico, on February 17–19, 2009, S. Cohen & Associates (SC&A) was tasked by the Board to review the NIOSH SEC Petition Evaluation Report of Petition SEC-00105—General Steel Industries (GSI) (Buker et al. 2008). This report concludes:

> *Based on its full research of the class under evaluation, NIOSH found no part of the subject class for which it cannot estimate radiation doses with sufficient accuracy. This class includes all individuals who worked in any location at the General Steel Industries site, located on 1417 State Street, Granite City, Illinois, from January 1, 1953 through June 30, 1966, and/or during the residual period from July 1, 1966 through December 31, 1992.*

FINDINGS

We have a number of findings on this report.

Finding 1. Lack of Radiation Monitoring Data for 1953–1963

The lack of radiation monitoring data for the 11-year period 1953–1963 precludes a bounding assessment of external exposures to direct penetrating radiation. There were four reported incidents during this period: (1) a worker who was not a radiographer mistakenly took home a ^{60}Co source; (2) [REDACTED] who was not a radiographer, remained inside an Army tank being radiographed with the betatron; (3) [Worker A], a betatron operator, reported he was involved in an incident with "Betatron II" (presumably the new betatron) just prior to the beginning of the Landauer film badge monitoring program; (4) an employee, of St. Louis Testing, a GSI contractor, reported finding an unsecured ^{60}Co source that may have exposed GSI employees. These incidents, especially the worker's taking home a ^{60}Co source, indicate a serious breakdown of radiation controls.

Finding 2. Incomplete Monitoring of Workers: 1964–1966

The film badge dosimetry records for 1964–1966 list the names of 89 workers, who are believed to have been members of the betatron teams or radiographers who used sealed sources. Former workers have reported that the badges were stored in a rack just outside the New Betatron Building, and that they were required to take off their badges whenever they left the betatron buildings. Consequently, the monitoring of even these workers was incomplete, since it did not cover exposures they might have received outside the betatron building. Areas in 10 Building, including the restroom, were potentially exposed while the betatron was in operation. Furthermore, some of these workers may have worked as layout men who were in intimate contact with castings immediately after betatron radiography. They would not have been wearing their badges while performing such duties.

The monitored workers represent a small fraction of the total GSI workforce. One incident that occurred during this period involved a worker who was inside a casting while it was radiographed with a betatron. He was not a radiographer and was therefore not monitored.

Finding 3. Lack of Documentation

There are few contemporary records to document operations at GSI during the operational period. The available records comprise purchase orders for uranium radiography spanning the period 1958–1963, correspondence between General Steel and Mallinckrodt regarding payment of a single invoice for radiography prior to February 1958, a December 1953 memo referring to betatron radiography at General Steel Castings (as GSI was then known), and Landauer film badge dosimetry reports for 1964–1973. There is no information on the extent of uranium radiography at GSI prior to March 1, 1958, except for a February 28, 1958, memo requesting payment for an earlier invoice (Brownfield 1958). Consequently, it does not appear to be possible to determine the exposure of workers to uranium from January 1, 1953, the assumed start of uranium handling operations, to March 1, 1958.

There are no records regarding the radioactive sources used for radiography. For example, the "small" ^{60}Co source used in 6 Building was variously described as having an activity of less than one curie or 0.25 Ci. The large source was described as 80 Ci; however, we could not determine when it was acquired. Given the 5.27 half-life of this nuclide, the date of acquisition would affect its activity at various times during the operation of GSI. Given the paucity of documentation, it is difficult to establish suitable parameters for dose reconstruction.

Finding 4. Film Badge Dosimetry Dependence on Photon Energies and Exposure Geometry

The response of a film badge dosimeter is highly dependent on the angle of the incident radiation, especially if the radiation source is behind a person wearing a film badge on the front of his body. To a smaller extent, the film badge response varies with the energy of the incident photons. Consequently, given the complex exposure conditions at GSI, the film badge records are at best an approximate measure of the radiation doses received by their wearers.

Finding 5. Lack of Validation of Models of Radiation Exposure of Betatron Operators

Even for the period of time for which film badge dosimetry reports are available, there is no agreement between the measured and the modeled exposures. In SC&A 2008, we have presented a detailed critique of the models of external exposure developed by Allen and Glover (2007). We have performed an independent analysis to demonstrate that the exposures to betatron radiation and to activated steel could be higher than those predicted by the NIOSH model. However, we do not claim that our model is definitive, based as it is on a limited set of exposure scenarios and extensive conjectures on exposure durations and geometries.

The film badge data indicates that the vast majority of weekly reports list doses of less than the reporting level of 10 mrem. These results call both the NIOSH and SC&A models into question. Conversely, neither model explains how one worker received a dose of 2,470 mrem in one week during the period of covered operations, or how another worker was reported to have received a dose of 7,590 mrem in one week after the end of AEC operations at GSI. Although the latter dose is, strictly speaking, outside the scope of this review, it does call into question the exposure conditions at GSI. Since there is no basis for believing that the operating conditions were significantly different in the later years, except for the absence of uranium, such a dose report should be considered in evaluating the models of external exposure.

In short, neither the film badge data nor the modeled exposures can be used to establish an upper bound to the external exposures of betatron operators that is claimant favorable and scientifically correct.

Finding 6. Underestimate of External Exposure of Unmonitored Workers

Allen and Glover (2007) make a seemingly arbitrary distinction between two classes of workers. Betatron operators and workers who handle metal within 2 hours of irradiation are assigned a higher exposure, ranging from 2.1 to 6.3 R/y, depending on the calendar year, while all other workers are assigned a dose of about 1.7 R/y. The latter exposure rate is based on a calculated exposure rate of 0.72 mR/h in shielded areas of the plant. SC&A (2008) has calculated exposure rates far in excess of this value in locations accessible to workers not involved in radiography, including a rate in excess of 1 R/h on the roof while the 80 Ci ^{60}Co was in use. Given the lack of any systematic program of radiation protection to bar access to these areas during betatron or ^{60}Co radiography, and the fact that the exposures of these other workers were not monitored, it does not appear to be possible to bound their radiation exposures in a manner that is scientifically correct and claimant favorable. Thus, the distinction between the external exposures assigned to these two classes of workers is not adequately justified and could result in a significant underestimate of the external exposures of some of the workers that are assigned the lower exposures.

Finding 7. Dose Reconstructions Not Based on Best Available Science

SC&A (2008) has documented a number of scientific errors in Appendix BB. Most notable is a 20-fold error in calculating the dose rate from irradiated uranium, which we found in the computer program files used by NIOSH. Although this error increases the dose rate and is therefore claimant favorable, it is not scientifically correct. The calculated values are therefore not acceptable for use in dose reconstructions.

Finding 8. Incomplete Model Used for Exposure Assessments

It would appear that the model used by NIOSH for the 208 dose reconstructions completed by October 3, 2008, the date of the ER, is incomplete. We base this conclusion first on the response by NIOSH to some findings in the "Issue Resolution Matrix for SC&A Findings on Appendix BB to TBD-600[0]," dated June 19, 2008. In response to Issue 10: "Errors in Calculating Dose Rates from Uranium," NIOSH wrote:

> *To the extent modeled doses are used, any errors in this calculation will be corrected. However NIOSH has obtained film badge results for betatron*

operators. We are in the process of comparing this data to the modeled estimates provided by both the appendix and SC&A.

Our review of Case [B] indicates that NIOSH did use doses modeled by Allen and Glover (2007). To the best of our knowledge, NIOSH has not revised this model. NIOSH made similar comments in response to other SC&A findings regarding the scientific validity of the Appendix BB models.

Other indications that the NIOSH model is incomplete are given by Buker et al. (2008). In section 7.3.4.1, under the heading "Neutron Dose," is the statement, "A study is in place to determine the photon-to-neutron ratio." As we found in our audit of Case [B], NIOSH has neglected the neutron dose in performing dose reconstructions.

Given the undetermined status of the model, we find that the dose reconstructions performed by NIOSH to date do not meet the standard of scientific accuracy.

Finding 9. Underestimate of Beta Dose

The beta dose assigned to GSI workers may be underestimated. Freshly cast uranium ingots may have enhanced concentrations of the short-lived progeny of ^{238}U on the surface, leading to a significant increase in the beta dose over aged natural uranium metal. Furthermore, uranium ingots were handled not only by the betatron workers but also by chainmen who transferred the ingots from the trucks or railway cars on which they arrived at the plant to the plant's own railway system. Such workers would also have been exposed to the beta rays from the uranium, but they are not assigned such exposures in the guidance for dose reconstruction of Allen and Glover (2007).

Finding 10. Lack of Consistency in Assigning External Exposures

Because of an error in calculating the external exposure to irradiated uranium, Allen and Glover (2007) assign a disproportionately high exposure rate to workers handling uranium following radiography while underestimating (in modeling terms) exposures to the betatron and to irradiated steel. This results in exposure rates that vary from year to year. By contrast, SC&A (2008) estimated that the bounding external exposures to direct penetrating radiation did not vary significantly over the duration of AEC operations. The dose reconstruction approach prescribed by NIOSH can inappropriately assign a dose to a betatron operator working in 1961 that would be 3 times the dose to one working in 1965.

REFERENCES FOR EXECUTIVE SUMMARY

Allen, D. and S. Glover, 2007. "Site Profiles for Atomic Weapons Employers That Worked Uranium and Thorium Metals - Appendix BB: General Steel Industries," Battelle-TBD-6000, Appendix BB, Rev. 0. http://www.cdc.gov/niosh/ocas/pdfs/tbd/b-6000-apbb-r0.pdf

Buker, L., R. Clark, M. Domal, and J. Guido, 2008. "SEC Petition Evaluation Report Petition SEC-00105." http://www.cdc.gov/niosh/ocas/pdfs/sec/gsi/gsier.pdf

S. Cohen & Associates (SC&A) 2008. "Review of 'Site Profiles for Atomic Weapons Employers That Worked Uranium and Thorium Metals - Appendix BB: General Steel Industries,' Battelle-TBD-6000, Appendix BB, Rev. 0." http://www.cdc.gov/niosh/ocas/pdfs/abrwh/scarpts/scagsireview.pdf

1.0 INTRODUCTION

During the meeting of the Advisory Board on Radiation and Worker Health held in Albuquerque, New Mexico, on February 17–19, 2009, S. Cohen & Associates (SC&A) was tasked by the Board to review the NIOSH SEC Petition Evaluation Report (ER) of Petition SEC-00105—General Steel Industries (GSI) (Buker et al. 2008).[1]

This site has been extensively studied by NIOSH, the Advisory Board, and SC&A over the past 3 years. A time line of meetings and interviews with former workers, reports that were prepared by NIOSH and by SC&A, correspondence with workers and with their advocates, meetings of the Advisory Board's work groups that were assigned responsibility for this site, and other significant events, is presented in section 2.0 of this review.

1.1 SCOPE

The scope of this review is to address specific issues of concern raised in the petition and NIOSH's response to these concerns, as given in the ER. In the course of this assessment, SC&A reviewed selected documents that were considered relevant to the petition, including the following:

- Documents that were referenced in the petition
- Documents referenced or cited in the ER and the site profile (Allen and Glover 2007)
- Documents contained in the NIOSH Site Research Query Database (SRQD)

The purpose of this review is to provide the Board with an independent assessment of issues and concerns that surround the petition and NIOSH's response and proposed methods for accommodating these issues/concerns. Findings identified in SC&A's review are intended to provide the Board with an overview of potential issues that may impact the feasibility of dose assessment. Following a formal, multistep issues resolution process, any unresolved findings may then be used by the Board for determining whether radiation doses can be estimated with sufficient accuracy, as defined in 42 CFR §83.13(c)(1); since this final determination lies within the purview of the Board and occurs at the end of a formal resolution process, SC&A does not draw conclusions from its findings in this report.

1.2 TECHNICAL APPROACH AND REVIEW CRITERIA

The approach used by SC&A to perform this review follows the protocols described in the draft report prepared by SC&A entitled, "Board Procedures for Review of Special Exposure Cohort Petitions and Petition Evaluation Reports, Revision 1" (SC&A 2006b), and the "Report to the Working Group on Special Exposure Cohort Petition Review" (SC&A 2006a). The latter is a set of draft guidelines prepared by a Board-designated work group for evaluation of SEC petitions performed by NIOSH and the Board. The former is a set of draft procedures prepared by SC&A and approved for use by SC&A on an interim basis at the 38th Meeting of the Advisory Board on

[1] This report is sometimes referred to by the acronym *ER* in this review.

Radiation and Worker Health on June 16, 2006. The procedures are designed to help ensure compliance with Title 42, Part 83, of the *Code of Federal Regulations* (42 CFR 83) and implement the guidelines provided in the report of the working group.

The key review criteria listed below were identified in the report of the work group; the individual criteria have differing degrees of applicability depending on the details of a particular SEC petition and evaluation report.

- Timeliness
- Fairness
- Understandability
- Consistency
- Credibility and validity of datasets, including pedigree of the data, methods used to acquire the data, relationship to other sources of information, and internal consistency
- Representativeness and completeness of the exposure data with respect to the area of the facility, the time period of exposure, the types of workers, and processes covered by the data

The work group guidelines also recommend that NIOSH include in its SEC evaluation a demonstration that it is feasible to reconstruct individual doses for the cohort, including sample dose reconstructions.

SC&A's implementation of the SEC review process includes the following steps:

- Conduct a critical review of the petition and relevant reports, documents, and data that are enclosed and/or referenced in the petition/reports.
- Identify additional issues/concerns that emerged from SC&A's document review, which are independent of those stated in the petition.
- As part of the SEC review, develop a technical position for issues identified in the petition, as well as SC&A's independent findings.

SC&A's report with its findings will subsequently undergo a multistep resolution process. Resolution includes a transparent review and discussion of draft findings with members of the Board's Work Group on TBD-6000/6001, Appendix BB; petitioners; claimants; and interested members of the public. This resolution process is intended to ensure that each finding is evaluated on its technical basis in a fair and impartial manner.

2.0 BACKGROUND

The site in question, located in Granite City, Illinois, was originally the Commonwealth Division of the General Steel Castings Corporation, later known as the Castings Division of General Steel Industries, Inc. (GSI). This facility performed betatron radiography of uranium for the Uranium Division of the Mallinckrodt Chemical Works in St. Charles, Missouri, which was under contract to the U.S. Atomic Energy Commission (AEC). This activity resulted in potential radiation exposures of some workers at this site. However, the facility also performed radiography of steel castings, its principal product, during the contract period. The radiological assessments of workers exposed to radiation from the weapons-related activities therefore encompass these other sources of radiation exposure.

A series of four meetings were held in July and August 2006 that brought together former GSI workers for the purpose of collecting information on the GSI plant, based on the recollections of these workers (SimmonsCooper 2006a, 2006b; [Court Reporter] 2006a, 2006b). The meetings were organized by advocates for the workers: the GSI copetitioner, [REDACTED], and the late Christine Ramspott. NIOSH staff and contractor personnel attended two meetings on August 21 and 22 ([Court Reporter] 2006a, 2006b). Redacted transcripts of these meetings are posted on the NIOSH/OCAS Web site.

On June 25, 2007, NIOSH issued Appendix BB to "Site Profiles for Atomic Weapons Employers that Worked Uranium and Thorium Metals" (Allen and Glover 2007). According to this appendix:

> *This document serves as an appendix to Battelle-TBD-6000, Site Profiles for Atomic Weapons Employers that Worked Uranium and Thorium Metals. This appendix describes the results of document research specific to this site.*

During Meeting 48 of the Advisory Board on Radiation and Worker Health, held in Richland, Washington, on July 17–19, 2007, the Board directed SC&A to perform a review of "Site Profiles for Atomic Weapons Employers that Worked Uranium and Thorium Metals," Battelle-TBD-6000 (Scherpelz 2006), as well as Appendix BB. We reviewed the main report and delivered a working draft of our report to the Board on September 14, 2007 (SC&A 2007).[2]

Following the Board meeting, two sets of public comments on Appendix BB were submitted to Larry Elliot, Director of OCAS, by [REDACTED] Christine Ramspott (2007) and by the GSI copetitioner (2007). The Board asked SC&A to respond to these comments as part of its review of Appendix BB.

On October 9, 2007, Robert Anigstein of SC&A, the lead author of this review, met with a group of former employees of General Steel Industries who had worked at the Castings Division in Granite City, Illinois, as well as with other site experts. Two members of the NIOSH/OCAS staff attended as observers but did not participate in the discussions. A voice recording was

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[2] As of the date of this review, the SC&A report has not been reviewed for compliance with the Privacy Act and is therefore not available to members of the public.

made of the proceedings; NIOSH later prepared a written summary of the recording (Anigstein 2007). During the course of the meeting, the site experts shared their recollections of activities at the site, answered questions, prepared sketches of the layout, and provided written documentation. Immediately after this meeting, NIOSH (2007) held a Town Hall meeting for former GSI workers at the same location.

This author held further communications with some of the attendees at the earlier meeting, as well as other site experts, by telephone, e-mail, and regular mail. The purpose of these contacts was to elicit more details about the layout of the site, the operation of the equipment, and general work practices that helped us to perform an independent assessment of the radiation exposures of GSI workers and to evaluate Appendix BB.

[GSI petitioner] (2008) filed an SEC petition on behalf of former GSI employees and their survivors that was received by NIOSH on February 25, 2008. In a Federal Register Notice dated June 17, 2008, NIOSH (2008a) announced that the petition has met the minimum qualifications for review and evaluation.

On March 17, 2008, we issued a review of Appendix BB (SC&A 2008). Erratum sheets correcting two tables in the report were sent out on March 20, and a revised version which complies with the Privacy Act was released on April 21. Our review raised a number of issues regarding the analyses of radiation exposures performed by NIOSH and their underlying assumptions.

On May 2, 2008, we distributed our "Issue Resolution Matrix for SC&A Findings on Appendix BB" that listed 13 issues excerpted from SC&A 2008. We presented these findings at a meeting of the Advisory Board's Work Group on Procedures on May 20, 2008. On May 14, we issued a briefing and summary of our review of Appendix BB, which served as the basis of an illustrated presentation at the same meeting of the Work Group.

The next major development took place at the meeting of the Advisory Board that was held in St. Louis on June 26, 2008. The Board formed a new work group for the review of Battelle-TBD-6000 and -6001, including appendices, with a special focus on Appendix BB. Prior to this time, our reviews of these reports were under the aegis of the Work Group on Procedures. However, given the significant effort that went into these reviews, which commanded a proportionate effort on the part of the Work Group on Procedures, the Board felt that it would be more expeditious to turn over this responsibility to a new work group.

On October 3, 2008, NIOSH issued its evaluation report of the GSI SEC petition (Buker et al. 2008). On October 31, NIOSH (2008b) issued a white paper that included a review and analysis of film badge dosimetry reports on GSI workers for the period of January 1964 through December 1973, obtained by NIOSH from Landauer. NIOSH also cited some perceived inconsistencies in SC&A 2008. Anigstein (2008) responded to the white paper in a report to the Work Group on TBD-6000/6001, Appendix BB on November 8—a Privacy Act-cleared version of the report was issued on November 18. The response included an independent analysis of the film badge reports during the period of AEC operations, i.e., reports spanning the period of January 1964 to July 1966.

The first meeting of the Work Group on TBD-6000/6001, Appendix BB was held in Cincinnati on November 10, 2008. The meeting included a discussion of the Appendix BB issues matrix with NIOSH's responses to the 13 issues in that matrix. There was further discussion of the NIOSH (2008) white paper and of our responses (Anigstein 2008) to that report. The second meeting of the Work Group was held in Cincinnati on March 11, 2009. Most of the discussion centered on film badge dosimetry data.

Following the first Work Group meeting, we performed further analyses of the Landauer film badge data, including dosimetry reports for the period after AEC operations, namely July 1966–December 1973. We issued several brief reports and memoranda pertaining to these records and to our analyses.

3.0 REVIEW OF SEC PETITION

The cover letter of the SEC petition filed by the GSI petitioner claims that "NIOSH did not have a body to conclude this [that the probability of causation was less than 50%] with in my father's case, nor did they have the quantity or quality of the use of the two betatron machines and facility conditions to properly conclude their findings." The author interviewed the GSI petitioner to clarify these statements in the petition. She explained that she meant that her father was deceased. Since he didn't have a badge, NIOSH had no concrete proof on which to base his dose reconstruction. Her implication was that since NIOSH could not examine his body, and in the absence of a dosimeter, they had no evidence for assessing his radiation exposure. She also made reference to the two betatrons that were used at GSI, and questioned if NIOSH knew that the betatrons were used simultaneously. A summary of the interview appears as attachment 1 to the present review. [GSI petitioner] (2009) provided comments on the interview report in an e-mail to this author, with a copy to Paul Ziemer, Chair of the Work Group on TBD-6000/6001, Appendix BB, which was received after the summary of the interview was prepared and distributed to the Work Group.

In her petition, the GSI petitioner also states that production and maintenance workers, such as her father, [REDACTED], and [REDACTED], all of whom worked at GSI, were not issued any radiation monitoring devices. She correctly observes that film badges were available in 1950. (In fact, they were already used in the 1940s.)

A list of references is attached to the petition. These references cite Web sites that were visited by the petitioner and summarize relevant information which she found there. They are listed and discussed below in the order in which they appear. Only the first citation lists a URL that we could identify.

1. Listed as nuke.worker.com (actually http//:www.nukeworker.com). The petition states:

   (General Steel Cleanup 1993) Go to Illinois - Granite City Steel - states previous occupant General Steel Industries 1417 State St. GSI was custodian of (2) betatron-government owned machines. 1993 cleanup residual radioactive material survey shows amounts in excess of government guidelines.

This Web page refers to the Granite City Steel site. Granite City Steel was the owner of the former GSI site at the time the site was cleaned up under the FUSRAP program. The cited information was utilized by Allen and Glover (2007) and by SC&A (2008). Although Allen and Glover failed to explicitly note the presence of two betatrons, Buker et al. (2008) do discuss this issue. Since the buildings housing the two machines were about 400 feet apart, an individual exposed to radiation from one machine could not simultaneously receive any significant radiation from the other one. Our review explicitly addressed the two machines, since their operating characteristics and exposure conditions were different.

2. "Betatron and betatron machines dangers . . . . Dr. Laughlin tried to quantify radiation exposure through dosimetry. Device or badge was available as of 1950. (Badges were available, not used per attached affidavits)." The closest match we found is an obituary of

Dr. John S. Laughlin, the former chair of the Department of Medical Physics at the Memorial Sloan-Kettering Cancer Center, which appeared in *The New York Times* on December 25, 2004. The obituary states, "Dr. Laughlin's *later* [italics added] research addressed the dangers of radiation and tried to quantify exposure for medical workers, scientists and the public, in a field known as dosimetry." We agree that film badges and other dosimeters were in use as early as the late 1940s, and that workers other than radiographers and their assistants were apparently not issued dosimeters at GSI. This point is not disputed by either NIOSH or SC&A.

3. "Office of Legacy Management Granite City Steel site. . . . States (2) betatron machines housed at this site. Doesn't give GSI as previous occupant but cleanup dates are the same. Granite City Steel is located on 20th street. No address given in this article. General Steel Industries is at 1417 State St. (full address should be mandatory)"

The information cited is not in dispute. The issue of the two betatrons is discussed under citation 1.

4. "ACS Radiation Exposure and Cancer . . . This site explains the dangers of ionizing radiation, how it may not show up for years after exposure and its effects on DNA. This website relates beta rays to ionizing radiation and much more."

This site, maintained by the American Cancer Society, contains information on the carcinogenic effects of ionizing radiation. Such information is explicitly addressed by the Interactive RadioEpidemiological Program (IREP) that is used by DOL to estimate probability of cancer causation from exposures to radiation.

5. "DOE listings of nuclear facilities. . . . Gives a list of facilities beryllium metal was provided to by beryllium vendors. Granite City Steel listed as one, no address given. AWE/DOE (represents ownership change) Granite City Steel used to own General Steel Industries at 1417 State St."

This Web site, maintained by the Federation of American Scientists, displays a DOE Federal Register (FR) notice published January 17, 2001, that lists facilities covered by EEOICPA. The FR notice first describes the three types of covered facilities:

- Atomic weapons employer facilities, as defined in section 3621 (4) of the Act;
- Department of Energy facilities, as defined by section 3621 (12) of the Act; and
- Beryllium vendors, as defined by section 3621 (6) of the Act.

This description is followed by a list that combines all three types of facilities, listed alphabetically by State. The petitioner seems to have misunderstood the statement, "The following list indicates private firms that processed, produced, or provided beryllium metal for the Department, as defined by the Act." She apparently took it to mean that all facilities on the list were beryllium vendors, rather than just those identified by the notation *BE*. When asked about this during her interview, the GSI petitioner did not recall the basis of her observation.

6. "Energy Employees Occupational Illness Compensation Act of 2000. (States AWE/DOE represents ownership change. (Granite Steel was General Steel Industries) [*sic*]."

In response to a question during her interview, the GSI petitioner said the issue was that Granite City Steel was at 20th Street, while GSI was at 1417 State Street. This issue was resolved by DOL in EEOICPA Circular No. 08-02, which specifies the location of the covered facility as 1417 State Street. During the residual period, it was also known as the South Plant of Granite City Steel.

7. "Residual Radioactive Summary . . . States ... '[*sic*] Documentation reviewed indicates that there is potential for SIGNIFICANT RESIDUAL CONTAMINATION in which weapons-related production occurred 1958–1994 - Granite City Steel formerly was General Steel Industries (no street address given; address should be given in reports)"

We could not find a Web site with that title. However, residual contamination is explicitly addressed by Allen and Glover (2007).

In section E.5 of the Special Exposure Cohort Petition—Form B, the GSI petitioner answered "Yes" to the question, "Is the petition based on one or more unmonitored, unrecorded, or inadequately monitored or recorded exposure incidents?" She then cites the affidavits of two workers, [Worker B], a welder, and [Worker D], a laborer, that they were never offered nor did they receive any radiation monitoring devices, and that they were not warned about the dangers of radiation exposure. These statements are reiterated in sections F.1 and F.2 of Form B.

Two affidavits from former workers are attached to the petition. One is from [Worker D], who is identified as [REDACTED], who worked at GSI during the residual period. His affidavit suggested that the betatrons were used in various buildings throughout the plant. The author interviewed [Worker D] to clarify these statements in his affidavits. During the interview, [Worker D] said that he was sure that the betatrons did not leave the betatron buildings, and that he had confused the Magnaflux machines with the betatrons. His account is consistent with that of other workers and with the NIOSH and SC&A assessments of radiation exposures at the GSI facility. A summary of the interview appears as attachment 2 to the present review.

Other observations in [Worker D's] affidavit include criticisms of the Energy Employees Occupational Illness Compensation Program and an alleged lack of concern of the mills in Granite City for the welfare of the workers and of residents in the surrounding community.

In a separate letter, [Worker D] contrasts the EEOICPA to the Veterans Administration's compensation program for exposure to Agent Orange. Following the mandate of the Agent Orange Act of 1991, the VA presumes that any veteran who served in Vietnam (between 1962 and 1975 [reviewer's note]) and who contracted one of a number of specified diseases (mostly cancers) had been exposed to Agent Orange and that the disease was caused by such exposure. This is unlike EEOICPA, under which compensation is awarded only if the probability of causation is greater than 50%. [Worker D] makes an interesting observation. However, since both the Agent Orange Act and EEOICPA are acts of Congress, it is our understanding that neither NIOSH nor DOL has any discretion in determining how compensation should be awarded to energy employees or their survivors.

A second affidavit is from [Worker B], whom the GSI petitioner identifies as [REDACTED]. His affidavit could be interpreted to imply that betatrons were used in the 8, 9, and 10 buildings. During my interview with [Worker B], he agreed that the castings were taken on rail cars to the betatron building, which was located near the center of the 10 Building. That account is also consistent with our understanding of the operation of the betatrons at GSI. A summary of the interview appears as attachment 3 to the present review.

The next enclosure is a printout, dated 3/3/05, of a page from a Web site of the Environmental Measurements Laboratory (EML), a government-owned, government-operated facility, then part of DOE, now under the U.S. Department of Homeland Security. (That Web site is no longer maintained by EML and could not be accessed at the time this review was prepared.) The printout summarizes findings of a survey performed by a team from the Oak Ridge National Laboratory (ORNL), as reported by Murray and Brown (1994). The referenced document is part of the GSI site research database (SRDB) and is cited by SC&A (2008).

Following the printout is an aerial photograph of the GSI foundry in Granite City. Although lacking attribution, the photo appears to be the same as one that was published in the GSI magazine for September 1963 (GSI 1963) shown in SC&A 2008, Figure figure 1. Also included are photos that we assume to be from inside the plant, and a brief description of the Castings Division (i.e., the GSI Granite City facility), most likely from GSI 1963. Although illustrative, this page contains no new information that would affect the radiological assessment of GSI operations.

The last enclosure is a hand-drawn plan of a portion of the GSI foundry that indicates the location of the (new) betatron and of a restroom used by the workers, as well as several other buildings in the facility. These locations are consistent with a plan of the entire facility (GSCC 1969) that was furnished to this author during the meeting with former GSI workers and other site experts (Anigstein 2007). The location of the restroom, not identified on the plant plan, is consistent with another drawing that had been provided by a former worker.[3]

[3] [REDACTED], former GSI worker, private communication with Robert Anigstein, SC&A, Inc., January 2008.

4.0 AUDITS OF DOSE RECONSTRUCTIONS

As part of Task 4, auditing dose reconstructions performed by NIOSH, we reviewed two dose reconstructions of former GSI workers. We found significant issues in both cases.

4.1 CASE [A]

Case [A] was a former GSI employee who was diagnosed with chronic myelocytic leukemia. NIOSH performed a dose reconstruction based on the default radiation exposures prescribed by Allen and Glover (2007). The probability of causation was found to be 43.04%; compensation was therefore denied. We have several observations and findings related to this case.

4.1.1 Occupational External Dose

The employee was assigned an external exposure rate of 0.72 mR/h during the period of covered operations at GSI. Given an assumed annual exposure duration of 2,400 hours, the annual exposure was 1.73 R/y. This was in accord with Allen and Glover (2007), who specify this exposure rate for workers who did not normally work in the betatron building nor with irradiated steel within 2 hours of betatron exposure. However, we question whether this assignment is scientifically valid or claimant favorable.

According to the NIOSH summary of the Computer-assisted Telephone Interviews (CATIs) with the employee's two surviving children, his duties consisted of maintenance, which was described as taking "care of all the buildings and the machinery." He was said to work "all over the plant." His duties apparently took him to the betatron buildings, since the interview report states, "One time he was told to get out of the betatron building because 'it was too high.' "

We have a number of issues regarding the assignment of external exposure in this case. The exposure rate of 0.72 R/h was based on calculations of skyshine and/or penetrations of the shield walls by the primary betatron beam. However, as shown by SC&A (2008), a number of locations outside the betatron buildings could have had exposure rates that were significantly higher, due to the incomplete shielding of the New Betatron Building and its proximity to the production area. These rates were as high as 208 mR/h on the roof, 25 mR/h in the break area, and 24 mR/h in the restroom. As a maintenance worker, he may have at times been on the roof of the building, which was unshielded. He certainly may have used the restroom.

This case exemplifies the arbitrary distinction between the betatron team and steel workers who handled or repaired castings following radiography, on the one hand, and all other GSI employees. Since this employee was reported to have been in the betatron building, this distinction breaks down. Former workers have testified that the betatron building was "like Grand Central Station," with various tradesmen going in and out in the course of their duties. There were two reported incidents of workers who were not part of the betatron team being exposed in the shooting room while the betatron was operating. Furthermore, Allen and Glover (2007) do not indicate to which category workers performing radiography with sealed radioactive sources, some of which was performed outside the betatron buildings, should be assigned. Given the lack of guidance, such workers could also be assigned the external exposure rate of 0.72 mR/h, which does not account for the significantly higher potential exposures from these procedures.

4.1.2 Occupational Medical Dose

The employee was assumed to have had an annual chest x-ray as a condition of his employment. However, he was assigned a mean organ dose of 18.4 mrem per examination during each year of employment during the covered period. This is the dose to the bone marrow of a male from conventional radiography of the chest prior to 1970 assigned in ORAUT-OTIB-0006 (Kathren and Shockley 2005). It is significantly less than the dose of 276 mrem from photofluorography (PFG) prior to January 31, 1962. According to that document, "Dose estimates for PFG represent absolute upper limits and must be used to ensure claimant favorability in the absence of more specific information." Consequently, the higher dose should be assigned to the assumed chest x-rays for the years 1953–1954 and 1956–1962. This would result in an additional organ dose of 2.32 rem, which could be significant, given that the total average calculated dose was about 14.2 rem.

According to Allen and Glover (2007), information to be used in dose reconstruction from medical x-rays is provided in ORAUT-OTIB-0006. In this case, however, the guidance in that document does not appear to have been correctly applied.

4.1.3 Occupational Internal Dose

The occupational internal dose was calculated from the assumed intake of uranium dust, which is based on the annual intakes of betatron operators listed by Allen and Glover (2007, section BB.5.3). Those intakes have two components. One is the dust generated during the handling of the uranium metal prior to and following radiography. The airborne uranium activity concentrations are based on the daily weighted average concentrations in the vicinity of an operator engaged in uranium slug production and canning. This assumption is plausible and claimant favorable. The second component is based on the areal concentrations of uranium on the floor. As discussed in SC&A 2008, we believe that the method used by NIOSH to estimate surficial contamination is fundamentally flawed and is not claimant favorable. The following is excerpted from that report.

> *In our review of the main report (Scherpelz 2006), SC&A took issue with the use of the settling velocity of 5 μm AMAD aerosols to determine surface contamination levels, since that approach neglected the sloughing off of large flakes of uranium oxide that fall directly onto the floor and that would make a significant contribution to the uranium contamination. The same concerns apply to the Appendix [BB]. The observation . . . that the surface contamination level of 1,170 dpm/100 cm^2 is ". . . reasonably close to the maximum value of 540 dpm/100 cm^2 measured in a 1989 survey" does not support the calculated value. The GSI facility in Granite City continued to operate for another 7 years after the cessation of uranium handling activities. It would be expected that normal housekeeping activities during this time, as well as additional attrition between 1973 and 1989, when the site was controlled by the Granite City Steel Division of*

National Steel Corporation, would have caused more than a 2-fold reduction in the surface contamination levels.

We also dispute the assumption of a resuspension factor (RF) of 1×10^{-6} to calculate the concentrations of resuspended dust between uranium handling operations. Such an RF had been proposed in NUREG-1720 (Abu-Eid et al. 2002) as a bounding value for decommissioned facilities. The authors assumed that the surfaces at these facilities will have been cleaned or washed during decommissioning. Such cleaning would remove most of the loosely bound contaminants, resulting in a smaller RF for the residual contamination. This low RF value is invalid for an active industrial facility where recently deposited contaminants are loosely bound to floors and other surfaces.

We agree that the assignment of the inhalation exposure of a betatron operator to a maintenance worker is bounding and claimant favorable. However, we disagree with the calculation of the airborne activity between uranium handling operations, which is neither scientifically valid nor claimant favorable. This component of the internal exposure becomes increasingly significant during the later years of the period of covered operations, when the uranium radiography tapers off and the exposure between handling operations has the potential of becoming the dominant component of internal exposure. It is the principal source of internal exposure during the residual period.

We also disagree with the assessment of the ingestion of uranium dust, which is discussed extensively in section 7.2 of our review of Battelle-TBD-6000 (SC&A 2007). We believe that NIOSH's methodology of estimating intakes by ingestion is neither scientifically valid nor claimant favorable. Furthermore, the guidance provided Allen and Glover (2007, section BB.5) does not provide suggested ingestion rates, although it does so for inhalation rates. The guidance in section BB.6 that "ingestion rate must be included and will be based on this average air intake and OCAS-TIB-009" again does not provide guidance on intakes. We were not able to reproduce the intakes from uranium ingestion cited in the DR (dose reconstruction)DR Report. The DR Report did not include a clear description of the methodology and assumptions used to calculate the ingestion intake rates used as input to IMBA.

That being said, internal exposure to uranium is a very small contributor to the dose to the red bone marrow, the target organ in the dose reconstruction of this particular employee. However, we address the subject here as a generic issue for all dose reconstructionDRs for this site.

4.2 CASE [B]

Case [B] was an employee who worked as a Grinder/Inspector at GSI from [REDACTED], 1941, through [REDACTED], 1971, and who was diagnosed with lung cancer on [REDACTED], 1971. NIOSH performed a dose reconstruction based on the default radiation exposures prescribed in Appendix BB. The probability of causation was found to be 49.23%; compensation was therefore denied. SC&A has several observations and findings related to this case.

4.2.1 Occupational External Dose

The employee was assigned external exposures during each year of covered operations at GSI that are specified by Allen and Glover (2007, section BB.4.5) for betatron operators. We have a number of issues with that assignment.

The external exposures developed by Allen and Glover are based on the assumption that the workers were exposed for 2,400 hours per year, or an average of 46 hours per week. The claimant's widow affirms that he worked 12 h/d, 6 days per week during at least 1 year during the covered period. This is consistent with information given by former GSI workers. These workers, including betatron operators, estimated that, during peak years, the work week ranged from 50 to 80 h. They agreed that 65 hours per week was a reasonable average. (Anigstein 2007)

The description of the employee's duties during most of the covered period is that of an [REDACTED]. This position corresponds most closely to the layout man described by SC&A (2008). The limiting external exposure of that individual is calculated to be 33.3 mR/shift. Assuming 406 shifts per year (65 h/week × 50 weeks/y ÷ 8 h/shift = 406), his limiting annual exposure would be 13.5 R/y, slightly less than what we calculated for a betatron operator. The exposures listed by Allen and Glover for 1953–1962 range from 5.1 to 6.3 R/y, while those for 1963–1965 range from 2.1 to 2.8 R/y.[4]

Because the radiation exposures of this employee were not monitored, he should be assigned the most claimant-favorable plausible exposure.

4.2.2 Occupational Medical Dose

The employee was assumed to have had an annual chest x-ray as a condition of his employment. However, he was assigned a mean organ dose of 84 mrem per examination during each year of employment during the covered period. This is the dose to the lung of a male from conventional radiography of the chest prior to 1970 assigned in ORAUT-OTIB-0006 (Kathren and Shockley 2005). It is significantly less than the dose of 1.26 rem from photofluorography (PFG) prior to January 31, 1962. As quoted in section 4.1.2 of this review, "Dose estimates for PFG represent absolute upper limits and must be used to ensure claimant favorability in the absence of more specific information." Consequently, the higher dose should be assigned to the assumed chest x-rays for the years 1953–1962. This would result in an additional organ dose of 11.76 rem, which could be significant, given that the total average calculated dose was about 88.6 rem.

According to Allen and Glover (2007), information to be used in dose reconstruction from medical x-rays is provided in ORAUT-OTIB-0006. As in the case discussed in section 4.1.2 of this review, the guidance in that document does not appear to have been correctly applied.

[4] The exposure for 1966 is based on 6 months of covered activities and is therefore not strictly comparable.

4.2.3 Occupational Internal Dose

The occupational internal dose was calculated from the assumed intake of uranium dust, as prescribed by Allen and Glover (2007). Although the job description of this worker does not indicate that he handled uranium metal, he was assigned the same intakes of uranium as the betatron operators. The decision to assign these intakes to this employee is claimant favorable, since we do not know his actual exposure to uranium dust. However, the same comments about the adequacy of NIOSH's assessment of uranium intakes that were made in section 4.1.3 of this review apply to this employee. Since the target organ is the lung, the inhalation of uranium plays a much more significant role in the dose reconstruction than it does in the previous case.

5.0 REVIEW OF EVALUATION REPORT (ER)

The discussion in this section of the review is keyed to the sections of the ER.

5.1 SECTION 3.1: PETITIONER-REQUESTED CLASS DEFINITION AND BASIS

According to Buker et al. (2008), the petitioner class definition encompasses, "all individuals who worked in any location at the General Steel Industries site, located on 1417 State Street, Granite City, Illinois, from January 1, 1953 through December 31, 1966, and/or during the residual period from January 1, 1967 through December 31, 1992." A similar definition is found in the Federal Register Notice announcing that the GSI SEC petition has met the minimum qualifications for review and evaluation. However, the SEC petition and attached correspondence filed by the GSI petitioner, with a *Received* stamp dated February 25, 2008, do not mention these dates. It would be helpful if NIOSH identified the source of this information.

5.2 SECTION 3.2: CLASS EVALUATED BY NIOSH

The "Class Evaluated by NIOSH" is almost identical to the class defined by the petitioners, except that the demarcation of the period of AEC activities and the residual period was changed from December 31, 1966, to June 30, 1966, which is in accord with the DOL ruling on this site. However, the termination of the residual period appears to be in error. According to Bechtel National, Inc. (1994), as well as Murray and Brown (1994), the cleanup of the Old Betatron Building took place in June 1993. Allen and Glover (2007) state that the residual period extends until December 31, 1993, which is consistent with this information. The class definition is thus inconsistent with the history of the site and with Appendix BB.

5.3 SECTION 4.3: FACILITY EMPLOYEES AND EXPERTS

Section 4.3 of the ER summarizes meetings held with former GSI employees. The meetings held on August 21 and 22, 2006 ([Court Reporter] 2006a, 2006b), are listed as a single meeting. Since they were held on two different days and a number of people, including congressional staff members, attended one meeting but not the other, and since a separate transcript was furnished for each meeting, it would be more accurate to refer to them as two separate meetings. Furthermore, a Town Hall meeting (NIOSH 2007) is not mentioned. We suggest that this section of the ER be revised to indicate the six separate meetings with former GSI employees.

5.4 SECTION 5.0: RADIOLOGICAL OPERATIONS RELEVANT TO THE CLASS EVALUATED BY NIOSH

Section 5.0 reiterates earlier statements in the ER that the residual period ends December 31, 1992, which is contrary to the December 31, 1993, date cited by Allen and Glover (2007).

5.5 SECTION 5.1: GENERAL STEEL INDUSTRIES PLANT AND PROCESS DESCRIPTIONS

Section 5.1 begins with a history of the General Steel Castings Corporation, the predecessor company to GSI, and lists the original owners as the Baldwin Locomotive Works and American Steel Foundries. A third owner, the American Locomotive Company, should be included for the sake of historical accuracy. More important, the ER fails to mention that the bond issue floated on June 21, 1929 enabled the company to build a plant in Eddystone, Pennsylvania as well as acquiring the Commonwealth Steel Corporation in Granite City, Illinois. The Eddystone plant was the source of the second ("new") betatron installed at the GSI Granite City foundry in late 1963.

The second paragraph of this section cites three references to support the period of AEC-related activities at GSI, including "GSI, 1991." This reference is actually a memorandum signed by W. Alexander Williams of the Department of Energy (Williams 1991), and should be cited as such. The same paragraph further states, "This work was performed in areas of the facility which were part of what was later known as the South Plant." This statement is confusing to a reader not already familiar with the history of operations at GSI. It would be better to state that the work was performed at the GSI facility in Granite City. After cessation of operations, the property was purchased by the Granite City Steel Division of National Steel Corporation, which referred to it as the South Plant to distinguish it from its original plant, which was located north of the GSI facility. This clarification is important since DOL had earlier received, and NIOSH had evaluated, claims from former employees of Granite City Steel who were not involved with the operations at GSI.

5.6 SECTION 5.2.2: EXTERNAL RADIOLOGICAL EXPOSURE SOURCES FROM GENERAL STEEL OPERATIONS

Section 5.2.2 describes the external exposures of GSI workers during the betatron radiography of steel and uranium. The author distinguishes the exposures during setup and during post-x-ray activities and states that there was no exposure during the setup for steel radiography because the steel was not activated. He reiterates a statement to this effect by Allen and Glover (2007) but ignores information presented by SC&A (2008, section 2.2.4) that steel castings were subjected to multiple, repeated radiographic exposures. Therefore, in setting up for a new shot, workers would be exposed to steel activated during previous irradiations. This is documented by several communications from former GSI betatron operators to SC&A, which were transmitted by e-mail to members of the Advisory Board Work Group on Procedures on May 28, 2008, with copies to key NIOSH staff members. These communications are the primary sources of information on radiographic procedures at GSI and should have been utilized in the preparation of the ER.

In the third paragraph of this section, the author discusses the potential exposures of employees during betatron operations. He cites Murray and Uziel (1992) in saying the betatrons were housed inside a building with "ten-foot-thick shield wall[s]." Actually, Murray and Uziel reported a survey of the New Betatron Building only. Figure 3 of that report shows that the shield walls did not, in fact, completely surround the shooting room, nor, according to the scale in the figure, were they 10-ft-thick, varying from 8 to 9 feet. The failure of Allen and Glover (2007) to account for the gap in the shield wall led to a significant underestimate of the potential exposures outside the building. Skyshine and penetration of the shield are by no means the limiting exposure pathways at locations outside the shooting room.

The fourth paragraph lists sources of radiation exposure following betatron radiography, but limits the discussion to ingots and to the betatron apparatus. The term “ingot” is properly applied to uranium but not to the activated steel castings, which the author may or may not have meant to include. The term photo-neutron reaction does not encompass other reactions, such as proton emission, which are also possible. The author failed to note the comment regarding this usage by SC&A (2008).

5.7 SECTION 5.2.2.1: PHOTON

Section 5.2.2.1 reiterates the sources of external photon exposure discussed in section 5.2.2. It omits any mention of radiation from the photoactivation products of irradiated steel castings.

5.8 SECTION 5.2.2.2: BETA

Section 5.2.2.2 describes sources of beta radiation. Its description of the beta decay of ^{234m}Pa is inaccurate for the purpose of dosimetric calculations. Although this nuclide does emit a beta particle with an *endpoint* energy of 2.27 (not 2.28) MeV, the mean energy of the beta radiation is 819 keV. The author also mentions beta radiation from fission and activation products in irradiated uranium. This gives the misleading impression that such radiation was considered by Allen and Glover (2007) in estimating doses from nonpenetrating radiation to GSI workers, while, in fact, it was not. SC&A (2008) has addressed such radiation and concluded that it makes a minor contribution to doses to superficial organs; however, this fact should be explicitly addressed in the ER.

5.9 SECTION 5.2.2.3: NEUTRON

Section 5.2.2.3 discusses the sources of neutron radiation. This section contains the statement,

> *During X-ray operations, potential neutron exposures were possible from photo-neutron interactions and delayed neutrons from photofission interactions; however, this did not result in a significant exposure source because neutrons resulted from secondary radiations from the X-ray interactions with matter in the X-ray area.*

This statement neglects the exposure of betatron operators to neutron radiation from the betatron target while the betatron is operating.

5.10 SECTION 5.2.3: INCIDENTS

Section 5.2.3 states in its entirety, “A review of General Steel Industries’ records did not uncover any radiological incidents that were associated with AEC operations, or that could not be accounted for using the information and documentation available to NIOSH." This statement is incorrect and misleading. Since all records of GSI operations at Granite City were destroyed when the plant ceased to operate, no review was possible.

A number of incidents were reported by former workers during the various outreach meetings and affidavit testimony. One incident involved a ^{60}Co radiography source that was taken home by a worker who mistook it for a plumb bob (Anigstein 2007). The source was strong enough to be detected from an airplane carrying a Geiger counter ([Court Reporter] 2006a). A former employee of St. Louis Testing reported an incident in which a 250 mCi ^{60}Co source had not been properly secured by the worker on the previous shift (Anigstein 2007). The foreman on the next shift called the St. Louis Testing employee because the survey meter was pegged, and he thought the problem was with the meter. This foreman or one of his workers would have been exposed to the unshielded source until the source was secured.

There were two cases of workers who were not betatron operators or radiographers who were inside a casting while it was being radiographed with the betatron beam (SimmonsCooper 2006b, [Court Reporter] 2006a, Anigstein 2007). Since the radiation exposures of such workers were not monitored, there is no record of their doses. These incidents occurred during the tenure of [Supevisor A] as supervisor of the betatron operations. In a follow-up interview on July 8, 2009, [Supervisor A] believed that the first incident, involving a worker named [REDACTED], now deceased, occurred about 1953. The second incident, involving a man whose first name was [REDACTED], occurred about 1964, after the GSI Eddystone plant shut down.

Another incident was reported in an affidavit of [Worker A] (2006), who stated, "In 1963, the day before President Kennedy was shot, I was involved in a nuclear accident at the plant and exposed to radiation from Betatron II." He reported that he was hospitalized following the accident. No further details are available. The date would have been November 21, 1963, which is 4 days before the starting date of the Landauer film badge dosimetry program, according to the Landauer records obtained by NIOSH.

5.11 SECTION 5.2.4: RESIDUAL RADIOACTIVITY PERIOD AT THE GENERAL STEEL INDUSTRIES SITE

Section 5.2.4 of the ER reiterates the statement in Section 3.2, which states that NIOSH defined the date of the end of the residual period as December 31, 1992, and adds that this is based on the start of DOE site remediation under FUSRAP, which occurred in 1963. No explanation is given for why the residual period did not extend until the end of site remediation, which occurred in June 1963, nor why the end of the residual period is different from the date cited by Allen and Glover (2007), which is December 31, 1993.

In summarizing DOE-sponsored activities at the site, the ER refers to residual radioactive contamination "in the X-ray building." The building in question is referred to as the "Old Betatron Building" in the FUSRAP reports. Since there were two betatron buildings on the site, the reference in the ER is unclear.

5.12 SECTION 6.2: AVAILABLE GENERAL STEEL INDUSTRIES EXTERNAL MONITORING DATA

Section 6.2 states:

> *Based on a review of the information available to NIOSH, including the available purchase order requisitions and personnel interviews, NIOSH determined that the potential for exposure during 1964 was higher than in any previous year during the operational period at General Steel Industries.*

We have several issues with that statement. First, according the Allen and Glover (2007), the greatest period of uranium radiography was July 1, 1961–June 30, 1962, during which time 437.5 hours may have been devoted to this work. By contract, in 1964 such activity occupied only 28 hours per year. In fact, Allen and Glover (2007, section BB.4.5) list a photon exposure of 6.321 R/y in 1961 but only 2.220 R/y in 1964. Furthermore, although 1964 saw the initial operation of the second betatron at GSI, this would have a minor effect on the radiation exposures of the operators, since they could only be in one building at a time, during which time they would receive no significant exposure from the operations in the other betatron building. Finally, no mention is made of the potential exposures to other radiation sources during the pre-1964 period, such as a 250-kVp x-ray machine, and ^{60}Co and perhaps ^{192}Ir sources.[5] Some of the incidents discussed in section 5.10 of this review occurred in this earlier period.

We agree that most of the film badge monitoring data indicates that the doses were lower than the doses from external exposure to direct penetrating radiation calculated by Allen and Glover (2007). However, there are exceptions. One worker was reported to have received a dose of 2,470 mrem in one week in 1965, while the exposure for the entire year prescribed in Appendix BB is 2,135 mR. Other workers had 1-week doses that were significantly higher than expected, if based on the weekly averages of the annual exposures listed by Allen and Glover.

There are several other issues with the film badge data. One is the dependence of the film badge response on the angle of the incident radiation, which could affect the response of the film badge to residual radiation from the activated betatron apparatus. While setting up the metal to be radiographed, the operator would typically have his back to the betatron instrument. Since his badge was worn on the front of his body, the radiation would be shielded by his body. According to ICRP (1994, table A.22) the angular dependence factors for radiation incident at 180º—i.e., the ratio H'(10,180º) ÷ H'(10,0º)—range from < 0.01 for $E_\gamma \leq 30$ keV to 0.62 for $E_\gamma =$ 10 MeV. This ratio can be used to estimate the shielding factor for the body, and indicates that for 10-MeV photons incident on the back of the worker, a film badge worn in front of his body would register only 62% of the incident radiation, while for 30-keV photons, less than 1% of the radiation would be recorded. These ratios, calculated for a sphere of tissue-equivalent material, may not exactly represent the exposure geometry and radiation field experienced by the worker, but provide a rough approximation of the directional dependence of the film badge dosimeters. A more exact determination could be performed by modeling the response of the film badge

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[5] It is not clear if GSI owned any ^{192}Ir sources, of if they were only brought on site and handled by personnel of St. Louis Testing, a GSI contractor.

using the MCNP computer codes, or by actual measurements with a precise anthropomorphic phantom.

Since there is no information on the quality of this radiation—SC&A was not able to model the activation, although it has been widely reported—it would be difficult if not impossible to derive a correction factor for this shielding.[6] This may explain why the exposure to the activated betatron apparatus, which, according to the SC&A (2008) analysis, would have been the dominant source of exposure of betatron operators radiographing steel castings, was not reflected in the film badge dosimetry reports.

Another issue is the energy dependence of the film badge dosimetry. The exposure conditions at GSI were different from those in most other facilities. Before relying on the film badges to validate its model of worker exposures, NIOSH should characterize the spectrum of the photons incident on the film badge, including angular corrections, and compare it to the spectrum of the radiation source used to calibrate the badges. Only by means of such a comparison can the film badge readings be meaningfully translated into radiation doses. Even then, the dose registered by the film badge would be meaningful only if the radiation field were consistent with the anteroposterior (AP) exposure geometry.

5.13 SECTION 7.1.2: EXTERNAL MONITORING DATA PEDIGREE REVIEW

In discussing the film badge dosimetry reports that NIOSH obtained from Landauer, the ER states:

> *These data are significant because radiographers were considered to be the highest exposed workers at the site. Therefore, these data provide a clear indication of the actual external doses of the highest exposed workers at General Steel Industries.*

We agree that, *on average*, radiographers, including the so-called isotope operators (workers who performed radiography using sealed radioactive sources, primarily ^{60}Co) had the potential for receiving the highest doses. However, this observation does not account for the incidents discussed in section 5.10 of this review, which involved workers who were not monitored or for whom film badge records were not obtained for the period of time when the incident occurred.

5.14 SECTION 7.2.1: EVALUATION OF BOUNDING PROCESS-RELATED INTERNAL DOSES

Section 7.2.1 refers to the method prescribed by Allen and Glover (2007) to calculate the intake of uranium dust during uranium handling operations (i.e., setting up and removing the uranium

[6] We do not agree with the assertion by Allen and Glover (2007) that the radiation is from activation products in the aluminum cone. First, the Allis-Chalmers betatron manual specifically refers to the betatron tube being radioactive, not the cone (Allis-Chalmers 1951). Second, Jack Schuetz, the former Allis-Chalmers maintenance engineer and more recently a NIOSH contractor, firmly denied that the radiation came from the cone. Finally, our MCNPX simulation showed very little activation of the aluminum after irradiation with the betatron beam—orders of magnitude less than would be required to produce the radiation field measured by Mr. Schuetz.

ingots before and after betatron radiography). No mention is made of the prescribed methods for estimating uranium intakes between uranium handling operations, which is most of the time that the workers spent in the plant. These methods, which are based on Battelle-TBD-6000, are discussed in section 4.1.3 of this review. We do not agree that these methods are scientifically correct or claimant favorable.

We have an editorial comment on the statement in the second paragraph of Section 7.2.1, "As assessed in Battelle-TBD-6000, the bounding exposure scenario assumes that grinding would start on a freshly X-rayed piece of steel every 2 hours." Such an assessment was made in Appendix BB, not in the main document, as the quotation implies. Another issue is that the radiological assessment of internal exposure to the inhalation of steel dust is limited to the intake of ^{53}Fe, an activation product that is assumed to be in the dust. From a purely scientific standpoint, we disagree with this assumption: SC&A (2008, Table 10) lists 42 radionuclides that might be present in HY-80 steel—a common alloy cast at GSI—following betatron irradiation. Iron-53 accounts for less than 0.1% of the total internal dose from this scenario. However, we agree that exposure to steel dust resulted in no significant doses of radiation.

5.15 SECTION 7.2.3: METHODS FOR BOUNDING INTERNAL DOSE AT GENERAL STEEL

Section 7.2.3 states that intakes of uranium dust were based on air monitoring data from other facilities, while those during the residual period were based on resuspension from contaminated surfaces. In fact, as stated in section 5.14 of this review, intakes during the operational period also included contributions from resuspended dust in between uranium handling operations.

5.16 SECTION 7.2.3.2: METHODS FOR BOUNDING RESIDUAL PERIOD INTERNAL DOSE

Section 7.2.3.2 describes the assessment of internal doses during the residual period based on assumptions about contamination levels and a resuspension factor, as discussed by Allen and Glover (2007). We disagree with these methods, which are also used to estimate uranium intakes in between uranium handling operations during the operational period. This issue is discussed in section 4.1.3 of this review.

5.17 SECTION 7.2.4: INTERNAL DOSE RECONSTRUCTION FEASIBILITY CONCLUSION

Section 7.2.4 states, "NIOSH concludes that the methods described in Battelle-TBD-6000 and Battelle-TBD-6000 Appendix BB provide reasonable approaches to conservatively bound internal doses for all members of the class under evaluation." We disagree with this conclusion for reasons discussed in sections 4.1.3 and 5.16.

5.18 SECTION 7.3.1: EVALUATION OF BOUNDING PROCESS-RELATED EXTERNAL DOSES

Section 7.3.1 of the ER contains several subsections, which are discussed together in this section of the present review. Section 7.3.1.1 states, "The radiographers are considered to be the maximally-exposed group of workers based on the potential sources for external radiation." This assertion overlooks the potential exposures of other workers who were not monitored, as discussed in section 5.13 of the present review. Furthermore, section 7.3.1.1 repeats the assertion made earlier in the ER that 1964 represents the year of maximum potential exposures. We disagree with this statement, as discussed in section 5.12 of the present review. One of our objections is that the simultaneous operation of two betatrons did not pose the potential for higher exposures to individuals, since each betatron required a separate team, consisting of an operator, an assistant, and a film reader. An operator would have had a full schedule, resulting in the same period of exposure per shift. It is true that the increased work may have led to more overtime work, leading to greater periods of exposure per week.

Other employees (non-radiographers)

Under the heading "Other employees (non-radiographers)," this section of the ER discusses and then dismisses one of the exposure scenarios developed by SC&A (2008). That scenario was used to calculate exposure rates outside the shooting room in the New Betatron Building while the betatron was used to radiograph a casting that was left on the railroad track at the edge of the shooting room. Using the betatron in that orientation required overriding limit switches, which could be accomplished by flipping the head of the instrument (i.e., rotating it through 180º). The ER dismisses this scenario, saying, "However, operators indicated this was not done until after a particular supervisor left the company (Meeting Minutes, October 9, 2007 [Anigstein 2007]) after the AEC contract period ended."

Although [Supervisor A], the supervisor in question, did remain at GSI until after the AEC contract period ended, he had been promoted and moved to another division not involved with betatron operations at an earlier time.[7] [Supervisor B], the supervisor who took over after [Supervisor A], ordered the betatron operator to override the limit switches (Anigstein 2007). The Landauer film badge dosimetry reports for 1964 list the name "[Surname of Supervisor A]" on weekly reports through the week of November [REDACTED]; this name is not found on any later report. Thus, it appears most likely that [Supervisor A] was transferred to his new position by the end of that week, if not sooner. Having been issued a film badge, it is highly unlikely that he would continue being involved with betatron operation but not be monitored. Furthermore, the name "[Surname of Supervisor B]" is first found on the report for the week of January [REDACTED], 1965. However, that report indicates that there were nine previous reports for this individual, which would have begun in November 1964. Thus, it would appear [Supervisor B] started work in the betatron at about the same time [Supervisor A] left that facility.[8]

Further evidence is furnished by the headings of the Landauer film badge dosimetry reports. The reports for the weeks starting January 25, 1965 and later are addressed as follows:

[7] [Supervisor A], private communication with Robert Anigstein, SC&A, Inc., November 5, 2008.

[8] According to [Supervisor A], another employee, [Worker C], took over his supervisory duties when he was transferred and before [Supervisor B] took charge. The surname of [Worker C] is listed in the film badge reports during the entire covered period.

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This information clearly shows that [Supervisor B] was in charge of the betatron operation, starting at least in early 1965. Therefore, the practice modeled in our scenario may have taken place during at least part of the covered period (i.e., January 1965–June 30, 1966).

Since the scenarios modeled by SC&A (2008) most likely did occur during the covered period, they need to be addressed in the ER. We calculated exposure rates of 24 and 25 mR/h in the restroom and the break area, respectively, while the betatron was used to radiograph castings on the railroad track. We must point out that the exposure geometry in this scenario was selected as an example, based on information from former betatron operators. It is possible that other plausible orientations of the betatron and the castings could have resulted in higher exposure rates in these locations. A similar observation applies to exposure rates on the roof, which were calculated with the beam aimed horizontally. In reality, the beam could be angled upwards to radiograph the lower portion of a round hollow casting, such as the one illustrated in SC&A 2008, figures 19 and 20. Our purpose in performing these exposure calculations was to point out that the exposure rates could be significantly higher than those calculated by Allen and Glover (2007). We do not represent them as yielding the maximum exposure rates of workers outside the shooting room.

Beta

Under the heading "Beta," this section refers to exposures to beta rays from handling uranium ingots, and ascribes the discussion of exposure times to Allen and Glover (2007). These authors, in turn, state that the beta dose was calculated according to Scherpelz (2006, section 6.3). Our calculations of the beta dose from uranium (SC&A 2008, section 2.6.2) yielded higher results because of our bounding assumption that the radial surface of the slice (corresponding to the surface of the uncut uranium ingot) would have an enhanced concentration of the short-lived progeny of ^{238}U, namely ^{234}Th and ^{234m}Pa. The latter nuclide is a powerful beta emitter; hence, the beta dose would be higher to skin exposed to this surface.

According to the ER, "The time period and exposure rates were conservative enough to bound any beta dose from steel-handling operations as well." We disagree with this conclusion. During the later years of the covered period, the uranium radiography declined steadily, so the beta dose from exposure to steel following radiography became relatively more significant. For instance, in 1965, the last full year of covered operations, we estimated the annual dose to the skin of the hands and forearms to be 3.3 rads, of which 1.4 rads was from uranium and 1.9 rads from steel. Allen and Glover (2007, section BB.4.5) stipulate a dose of 1.179 rads during this time, or about one third as much.

Neutron

In the "Neutron" section, the ER states, "As with other facilities, neutron doses can be determined using the photon-to-neutron ratio." Our detailed calculations (summarized in SC&A

2008, table 2) show that the neutron:photon ratio can range from 2% to 99% for the exposure geometries that we modeled. For exposures to activated steel and to radiographic sources other than the betatron, the ratio is zero. Thus, establishing a comprehensive ratio would require additional analyses.

5.19 SECTION 7.3.3: GENERAL STEEL OCCUPATIONAL X-RAY EXAMINATIONS

We agree that doses from occupational radiographic examinations can be estimated using ORAUT-OTIB-0006 (Kathren and Shockley 2005). However, in the two cases from GSI that we have examined, the methodology prescribed in this guide was not applied in a claimant-favorable manner. As discussed in sections 4.1.2 and 4.2.2 of the present review, the dose reconstructions did not assume that the examinations utilized photofluorography (PFG) prior to January 31, 1962, as prescribed in ORAUT-OTIB-0006.

5.20 SECTION 7.3.4.1: METHODS FOR BOUNDING OPERATIONAL PERIOD EXTERNAL DOSE

Photon Dose

Under the heading "Photon Dose" in section 7.3.4.1 of the ER, the author summarizes the Landauer film badge reports for the weeks beginning January 6, 1964 through June 27, 1966. We have independently reviewed these reports and found two minor discrepancies. We found 23 reported values of 10 mrem or greater, not 22 as cited in the ER. Furthermore, the ER states, "no individual had more than one reading above the 10 mrem recording limit during this time frame." In fact, one worker had doses of 10 mrem and 290 mrem during two separate weeks in 1964.

More important, we disagree with the calculation of the 95th percentile weekly dose, based on these data. The author calculated a mean weekly dose to the 89 workers of 10.35 mrem with a standard deviation of 2.75 mrem. She then uses these values to estimate a 95th percentile weekly dose of 14.87 mrem. We have reproduced the calculated values of the mean; however, we obtained a value of 2.68 mrem for the standard deviation of the weekly dose of the 89 workers, considering the actual number of badge reports during the covered period, as reported by Landauer. Another issue with this method is that it gives equal weight to the dosimetry reports for each of the 89 workers. The total number of badge reports for each of the 11 workers who had reported weekly readings > 10 mrem ranges from 8 to 134. The weekly averages should be weighted by the number of badge reports.

These issues aside, we note that the calculation of the 95th percentile dose, based on the mean and the standard deviation, is valid only for data that has a normal distribution. Our analysis of these data, reported by Anigstein (2008), shows that the distribution of the average weekly dosimetry reports for the 89 workers is neither normal nor lognormal. Consequently, the method used to derive a bounding weekly dose is not scientifically correct nor is it claimant favorable.

The ER next states, "these data confirm that the Battelle-TBD-6000 Appendix BB method for assigning external dose can be considered bounding for all employees." We disagree with this statement. In one case, an employee named [REDACTED] had a recorded dose of 2,470 mrem for the week of 06/[REDACTED]/1965. This would represent a 1-week exposure far in excess of the average weekly exposure based on the annual exposure of 2,135 mR assigned by Allen and Glover (2007). Another instance of high dose was reported for the week of 11/[REDACTED]/1972, when a worker named [REDACTED] received a recorded dose of 7,590 mrem. Although this reported exposure occurred after the covered period, there is no reason to believe that the operations at GSI had changed between 1966 and 1972. This indicates a potential for incidents leading to higher exposures than predicted by the model developed by Allen and Glover.

Beta Dose

Under the heading "Beta Dose," the ER describes the methodology of calculating the doses from external exposure to beta rays adopted by Allen and Glover (2007). We found several issues with this methodology, which are discussed under the heading "Beta" in section 5.18 of this review.

Neutron Dose

Under the heading "Neutron Dose" is the statement, "A study is in place to determine the photon-to-neutron ratio." We have to reserve further comments on the neutron dose assessment until we have had a chance to review the aforementioned study.

5.21 SECTION 7.3.5: EXTERNAL DOSE RECONSTRUCTION FEASIBILITY CONCLUSION

Section 7.3.5 of the ER states, "By modeling external dose from radiographer film badge data, dose estimates are plausible and bounding." We interpret this statement to refer to the methodology of deriving 95th percentile doses from the Landauer film badge reports for 1964–1966, which we discuss in section 5.20 of this review. We disagree with this statement, as discussed in the previous section. We agree that the methodology for estimating external doses during the residual period is bounding and claimant favorable.

5.22 SECTION 7.4.1: LACK OF MONITORING DATA

Section 7.4.1 of the ER states:

> *NIOSH* ***has compared is in the process of comparing*** *the dosimetry data to the modeled estimates provided by both Battelle-TBD-6000 Appendix BB and the SC&A analysis. Based on a this* ***[sic] preliminary*** *assessment of the comparison, the dosimetry data support the finding that the dose reconstruction approach in Battelle-TBD-6000 presents a bounding approach for the workers at the General Steel Industries site, which includes the proposed worker class dose that is evaluated in this report.* [Emphasis added.]

The emphasized text in the first line seems to indicate that the ER is an unfinished draft—we cannot conclude if the comparison has been completed or is in progress. Likewise, the term "preliminary assessment" indicates a work in progress. Furthermore, it is not clear if the reference in the third line to "Battelle-TBD-6000" is to the main document (Scherpelz 2006) or to the appendix (Allen and Glover 2007). Although Scherpelz (2006) does present methods for dose reconstruction, we presume that in this instance, the author meant to refer to Allen and Glover 2007.

5.23 SECTION 7.4.2: UNDERESTIMATED EXTERNAL DOSE MODELING

Section 7.4.2 of the ER states:

> *NIOSH has obtained film badge results for the betatron operators and* ***has compared is in the process of comparing*** *these data to the modeled doses. As discussed previously,* ***this comparisonbased [sic] on a preliminary assessment of the comparison****, indicates the dosimetry data support that the dose reconstruction approach in Battelle-TBD-6000 presents a bounding approach for the workers at the General Steel Industries site, which includes the proposed worker class dose that is evaluated in this report*. [Emphasis added.]

The emphasizeditalicized text again indicates that the analysis, if not the ER itself, is a work in progress. We again do not know if the comparison has been completed or is in progress.

5.24 SECTION 7.6: SUMMARY OF FEASIBILITY FINDINGS FOR PETITION SEC-00105

In section 7.6, the author concludes that it is feasible to complete dose reconstructions for GSI employees during the covered period, citing as evidence the fact that dose reconstructions have been completed for 208 out of 238 claimants. At the direction of the Board, we have reviewed two claims for which dose reconstructions were completed and which were denied compensation. As discussed in section 4.0 of this review, we found serious deficiencies in both cases.

We agree that, with a few exceptions, Allen and Glover (2007) do provide guidance to enable health physicists to perform dose reconstructions. The exceptions are vague instructions for assessing intakes of uranium dust via the ingestion pathway, and ambiguity on assigning workers who may have performed radiography using sealed sources outside the betatron buildings the radiation exposures prescribed for betatron operators or those prescribed for the general worker population. These issues aside, we find that the guidance provided by Allen and Glover is neither claimant favorable nor scientifically valid.

5.25 SECTION 9.0: CLASS CONCLUSION FOR PETITION SEC-00105

In section 9.0, the final section, the author concludes:

> *NIOSH's guiding principle in conducting these dose reconstructions is to ensure that the assumptions used are fair, consistent, and well-grounded in the best available science. Simultaneously, uncertainties in the science and data must be handled to the advantage, rather than to the detriment, of the petitioners. When adequate personal dose monitoring information is not available, or is very*

> *limited, NIOSH may use the highest reasonably possible radiation dose, based on reliable science, documented experience, and relevant data to determine the feasibility of reconstructing the dose of an SEC petition class. NIOSH contends that it has complied with these standards of performance in determining the feasibility or infeasibility of reconstructing dose for the class under evaluation.*

We find that these guiding principles have not been observed in the case of former GSI employees. The basis of this conclusion is discussed in section 6 of this review.

6.0 FINDINGS

We do not agree that the methods of dose reconstruction cited by Buker et al. (2008) are bounding, claimant favorable, or scientifically correct. We base this conclusion on a number of issues with the NIOSH analyses which are summarized below. Most of these issues are discussed in greater detail in the preceding sections of this review.

Issue 1. Lack of Radiation Monitoring Data for 1953–1963

The lack of radiation monitoring data for the 11-year period 1953–1963 precludes a bounding assessment of external exposures to direct penetrating radiation. There were four reported incidents during this period: (1) a worker who was not a radiographer mistakenly took home a ^{60}Co source; (2) [REDACTED], who was not a radiographer, remained inside an Army tank being radiographed with the betatron; (3) [Worker A], a betatron operator, reported he was involved in an incident with "Betatron II" (presumably the new betatron) just prior to the beginning of the Landauer film badge monitoring program; (4) an employee of St. Louis Testing, a GSI contractor, reported finding an unsecured ^{60}Co source which may have exposed GSI employees. These are based on contemporary accounts of GSI employees ([Worker A] passed away after submitting an affidavit on November 25, 2006) and of the former employee of St. Louis Testing. There may have been other incidents unknown to the small number of former employees who shared their recollections of GSI operations. A more complete discussion is presented in section 5.10 of this review.

These incidents, especially the worker's taking home a ^{60}Co source, indicate a serious breakdown of radiation controls. It is not possible to assign bounding exposures under such conditions. Given these conditions, we do not believe that extrapolating the film badge dosimetry reports back to 1953 provides a valid basis for dose reconstruction during this period.

Issue 2. Incomplete Monitoring of Workers: 1964–1966

The film badge dosimetry records for 1964–1966 list the names of 89 workers, who are believed to have been members of the betatron teams or radiographers who used sealed sources. Former workers have reported that the badges were stored in a rack just outside the New Betatron Building, and that they were required to take off the badge whenever they left the betatron buildings. Consequently, the monitoring of even these workers was incomplete, since it did not cover exposures they might have received outside the betatron building. Areas in 10 Building, including the restroom, were potentially exposed while the betatron was in operation. Furthermore, some of these workers may have worked as layout men who were in intimate contact with castings immediately after betatron radiography. They would not have been wearing their badges while performing such duties.

The monitored workers represent a small fraction of the total GSI workforce. One incident that occurred during this period involved a worker identified only by the first name "[REDACTED]," who was inside a casting while it was radiographed with a betatron (see section 5.10 of this review). He was not a radiographer and was therefore not monitored.

Issue 3. Lack of Documentation

There are few contemporary records to document operations at GSI during the operational period. The available records comprise purchase orders for uranium radiography spanning the period 1958–1963, correspondence between General Steel and Mallinckrodt regarding payment of a single invoice for radiography prior to February 1958, a December 1953 memo referring to betatron radiography at General Steel Castings (as GSI was then known), and Landauer film badge dosimetry reports for 1964–1973. There is no information on the extent of uranium radiography at GSI prior to March 1, 1958, except for a February 28, 1958, memo requesting payment for an earlier invoice (Brownfield 1958). Consequently, it is impossible to determine the exposure of workers to uranium from January 1, 1953, the assumed start of uranium handling operations, to March 1, 1958.

There are no records regarding the radioactive sources used for radiography. We queried the Illinois Emergency Management Agency, Division of Nuclear Safety regarding these sources, and were told that the State has no records pertaining to the period when GSI was in operation, since that was prior to Illinois' becoming an NRC Agreement State in 1987. The Agency referred us to NRC Region III, which includes Illinois. The Region III office in turn referred us to NRC Headquarters in Rockville, Maryland. Our inquiry was referred to the NRC Public Document Room. A researcher informed us that the facility had earlier received a FOIA request regarding GSI, and that a search of the archives showed that there were no records available. We were informed that it was the policy of NRC to turn over records of old radioactive materials licenses to the National Archives and Records Administration (NARA). NARA normally destroys such records that are more than 30 years old. Consequently, the only information regarding the radiography sources is based on the recollections of former GSI employees of events that took place 40–50 years ago. For example, the "small" ^{60}Co source used in 6 Building was variously described as having an activity of less than one curie or 0.25 Ci. The large source was described as 80 Ci; however, we could not determine when it was acquired. Given the 5.27-y half-life of this nuclide, the date of acquisition would affect its activity at various times during the operation of GSI.

The existence of the two Allis-Chalmers betatrons is documented in a report of a FUSRAP survey, which found the machines still on the former GSI site (Cottrell and Carrier 1990). The only written documentation specific to the operating characteristics of these units is a data sheet on betatron tubes furnished to GSI after the period of AEC operations and a report based on the personal recollections of a former Allis-Chalmers employee (Schuetz 2007). However, copious information is available about the operating characteristics of Allis-Chalmers betatrons in general.

Given the paucity of documentation, it is difficult to establish suitable parameters for dose reconstruction.

Issue 4. Film Badge Dosimetry Dependence on Photon Energies and Exposure Geometry

As discussed in section 5.12 of this review, the response of a film badge dosimeter is highly dependent on the angle of the incident radiation, especially if the radiation source is behind a person wearing a film badge on the front of his body. To a smaller extent, the film badge response varies with the energy of the incident photons. Consequently, given the complex exposure conditions at GSI, the film badge records are at best an approximate measure of the radiation doses received by their wearers.

Issue 5. Lack of Validation of Models of Radiation Exposure of Betatron Operators

Even for the period of time for which film badge dosimetry reports are available, there is no agreement between the measured and the modeled exposures. In SC&A 2008, we have presented a detailed critique of the models of external exposure developed by Allen and Glover (2007). We have performed an independent analysis to demonstrate that the exposures to betatron radiation and to activated steel could be higher than those predicted by the NIOSH model. However, we do not claim that our model is definitive, based as it is on a limited set of exposure scenarios and extensive conjectures on exposure durations and geometries.
The film badge data, which indicates that the vast majority of weekly reports list doses of less than the reporting level of 10 mrem, calls both the NIOSH and SC&A models into question. Conversely, neither model explains how one worker received a dose of 2,470 mrem in one week during the period of covered operations, or how another worker was reported to have received a dose of 7,590 mrem in one week after the end of AEC operations at GSI. Although the latter dose is, strictly speaking, outside the scope of this review, it does call into question the exposure conditions at GSI. Since there is no basis for believing that the operating conditions were significantly different in the later years, except for the absence of uranium, such a dose report should be considered in evaluating the models of external exposure.

In short, neither the film badge data nor the modeled exposures can be used to establish an upper bound to the external exposures of betatron operators that is claimant favorable and scientifically correct.

Issue 6. Underestimate of External Exposure of Unmonitored Workers

Allen and Glover (2007) make a seemingly arbitrary distinction between two classes of workers. Betatron operators and workers who handle metal within 2 hours of irradiation are assigned a higher exposure, ranging from 2.1 to 6.3 R/y, depending on the calendar year, while all other workers are assigned an exposure of about 1.7 R/y. The latter exposure rate is based on a calculated exposure rate of 0.72 mR/h in shielded areas of the plant. We have calculated exposure rates far in excess of this value in locations accessible to workers not involved in radiography, including a rate in excess of 1 R/h on the roof while the 80 Ci ^{60}Co was in use. Given the lack of any systematic program of radiation protection to bar access to these areas during betatron or ^{60}Co radiography, and the fact that the exposures of these other workers were not monitored, it does not appear to be possible to bound their radiation exposures in a manner that is scientifically correct and claimant favorable. Thus, the distinction between the external exposures assigned to these two classes of workers is not adequately justified and could result in a significant underestimate of the external exposures of some of the workers that are assigned the lower exposures.

Issue 7. Dose Reconstructions Not Based on Best Available Science

SC&A (2008) has documented a number of scientific errors in Appendix BB. Most notable is a 20-fold error in calculating the dose rate from irradiated uranium, which we found in the computer program files used by NIOSH. Although this error increases the dose rate and is therefore claimant favorable, it is not scientifically correct. The calculated values are therefore not acceptable for use in dose reconstructions which, according to the guiding principle cited by Buker et al. (2008, section 9.0) are to be "well-grounded in the best available science."

Issue 8. Incomplete Model Used for Exposure Assessments

It would appear that the model used by NIOSH for the 208 dose reconstructions completed by October 3, 2008, the date of the ER, is incomplete. We base this conclusion first on the response by NIOSH to some findings in the "Issue Resolution Matrix for SC&A Findings on Appendix BB to TBD-600[0]," dated June 19, 2008. In response to Issue 10: "Errors in Calculating Dose Rates from Uranium," NIOSH wrote:

> *To the extent modeled doses are used, any errors in this calculation will be corrected. However NIOSH has obtained film badge results for betatron operators. We are in the process of comparing this data to the modeled estimates provided by both the appendix and SC&A.*

Our review of Case [B] (see section 4.2.1 of this review) indicates that NIOSH did use doses modeled by Allen and Glover (2007). To the best of our knowledge, NIOSH has not revised this model. NIOSH made similar comments in response to other SC&A findings regarding the scientific validity of the Appendix BB models.

Other indications that the NIOSH model is incomplete are given by Buker et al. (2008). In section 7.3.4.1, under the heading "Neutron Dose" is the statement, "A study is in place to determine the photon-to-neutron ratio." As we found in our audit of Case [B], NIOSH has neglected the neutron dose in performing dose reconstructions. Furthermore, section 7.4.2 states, "NIOSH has obtained film badge results for the betatron operators and ***has compared is in the process of comparing*** these data to the modeled doses [emphasis added]." This sentence obviously requires editing: we cannot judge if the comparison has been completed or is in process. In either case, to the best of our knowledge, the results of any such comparison have not been communicated to the Board or to SC&A.

Given the undetermined status of the model, we find that the dose reconstructions performed by NIOSH to date do not meet the standard of scientific accuracy.

Issue 9. Underestimate of Beta Dose

The beta dose assigned to GSI workers may be underestimated. As discussed under the heading "Beta" in section 5.18 of this review, freshly cast uranium ingots may have enhanced concentrations of the short-lived progeny of ^{238}U on the surface, leading to a significant increase in the beta dose over aged natural uranium metal. Furthermore, uranium ingots were handled not only by the betatron workers but also by chainmen who transferred the ingots from the trucks or railway cars on which they arrived at the plant to the plant's own railway system. Such workers would also have been exposed to the beta rays from the uranium, but they are not assigned such exposures in the guidance for dose reconstruction of Allen and Glover (2007).

Issue 10. Lack of Consistency in Assigning External Exposures

Because of an error in calculating the external exposure to irradiated uranium, Allen and Glover (2007) assign a disproportionately high exposure rate to workers handling uranium following radiography while underestimating (in modeling terms) exposures to the betatron and to irradiated steel. This results in exposure rates that vary from year to year. By contrast, SC&A (2008) estimated that the bounding external exposures to direct penetrating radiation did not vary significantly over the duration of AEC operations. The dose reconstruction approach prescribed by NIOSH can inappropriately assign a dose to a betatron operator working in 1961 that would be 3 times the dose to one working in 1965.

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ATTACHMENT 1: REPORT OF INTERVIEW WITH [GSI PETITIONER]

From: Robert Anigstein, SC&A June 24, 2009
To: Distribution

On June 24, 2009, at approximately 3:30 P.M., EDT, I spoke with the GSI petitioner, whom I contacted at [REDACTED]. The petitioner had submitted an SEC petition for General Steel Industries (GSI).

I asked her to clarify the statement in the cover letter of her petition: NIOSH did not have a body to conclude this [that the probability of causation was less than 50%] with in my father's case. She explained that the statement meant that her father had died in the 1970s. Since he didn’t have a badge, NIOSH had no concrete proof on which to base his dose reconstruction. I then asked her to clarify the second part of her statement: nor did they have the quantity or quality of the use of the two betatron machines and facility conditions to properly conclude their findings. She said she meant that the evaluation report did not mention two betatrons at any given time, and wondered if they [NIOSH] knew the betatrons were used simultaneously.

I then asked her about some of the references in the list that is part of the petition. She said that the issue raised via reference 6 was that Granite City Steel was at 20th Street while GSI was at 1417 State Street. I explained that we are aware that Granite City Steel had purchased the GSI site, and she confirmed that that was what that was about. I next asked about the statement in conjunction with reference 5 (“DOE listings of nuclear facilities”) that beryllium metal was provided to Granite City Steel. She did not recall the basis for that statement. I next said that I could not find a Web site corresponding to reference 7, “Residual Radioactive Summary,” however, I said the residual contamination, cited under that reference, was taken into account. She said her reason for mentioning it was to include the class up to the 1992 (*sic*) cleanup, including the cleanup crew.

Comment: The GSI petitioner referred to the ER when she apparently meant Appendix BB. Since the ER was written after the petition, she is correct in stating that NIOSH had not explicitly addressed the issue of the two betatrons which, in fact, were in use simultaneously, albeit in different buildings that were about 400 feet apart.

On June 24, following the interview, I sent the GSI petitioner an e-mail containing the above text of my report of this interview and asked her to let me know if she had any corrections, additions or other comments, or if she agreed with my report. She has not responded as of this date.

ATTACHMENT 2: INTERVIEW WITH [WORKER D]

From: Robert Anigstein, SC&A June 19, 2009
To: Distribution

Record of Telephone Conversation

On June 16, 2009, at approximately 9:30 P.M., EDT, I spoke with [Worker D], whom I contacted at [REDACTED]. [Worker D] had prepared an affidavit that was submitted by the GSI petitioner as part of the SEC petition for General Steel Industries (GSI).

I asked him to clarify the statement in his affidavit: Primarily they would use the betatron machines to x-ray castings in buildings 8, 9, and 10. I asked if he meant that they took the castings from 8, 9, and 10 and then x-rayed them with the betatron. He replied that his memory of all this is "pretty faint." He recalled a building where they took the castings. He mentioned that his [REDACTED] ([Worker B]) worked there for years after him and years before him and implied that he might have a better memory of the operations. I told him that I had talked to [Worker B] that afternoon, and that he agreed with me that the castings were brought to the betatron building which was next to building 10. [Worker D] said he couldn't remember exactly, but that it was in that area, and added that [my account] seemed about right.

In his affidavit, [Worker D] had also stated, "The betatron machines themselves were portable so they too were moved place to place." I observed that it was my understanding and that of [the former GSI betatron operators] that I talked to, that the betatron was mounted on a crane inside the betatron building and that it could not leave the building. [Worker D] said they had little portable units that were taken out, but he didn't know if they were actually called betatrons but were called Magnaflux machines. I described my understanding of the Magnaflux machines as magnetic devices that did not emit [ionizing] radiation.

Later in his affidavit, [Worker D] stated, "The betatron machines were also used in 6 and 7 buildings to x-ray tank hulls and turrets." I asked if I was correct in saying that he didn't believe that the betatron machines were actually taken to buildings 6 or 7. He replied, "No, if they had a casting, I remember they had a railroad car that would go across buildings on a track and they could put the castings on a railroad car and run it to the betatron building and pluck it off with a crane and put into the betatron building." He was sure that the betatron did not leave the building. He guessed that there was some confusion in his mind about the betatron versus the Magnaflux. I mentioned that there was a portable x-ray machine, but [Worker D] said a portable would have been only for light castings.

Followup E-mail Communication

On June 17, I prepared a draft summary of our telephone conversation and inserted it into an e-mail message to [Worker D] ([REDACTED]). In my message, I asked [Worker D] to review the report and let me know if it correctly summarizes our discussion. In an e-mail that I received on June 17 at 11:50:45 PM EDT, [Worker D] replied, "I have read your transcript of our telephone conversation and I would attest that it accurately reflects that conversation."

Comment: [Worker D's] account is entirely consistent with our understanding of the operation of the betatrons at GSI.

ATTACHMENT 3: INTERVIEW WITH [WORKER B]

From: Robert Anigstein, SC&A — July 13, 2009
To: Distribution

On June 16, 2009, at approximately 12:30 P.M., EDT, I spoke with [Worker B], whom I contacted at [REDACTED]. [Worker B] had prepared an affidavit that was submitted by the GSI petitioner as part of the SEC petition for General Steel Industries (GSI).

I asked him to clarify the statement in his affidavit that he "worked primarily in buildings #8, #9, and #10 where the betatron machine was in operation." I explained that it was my understanding that the betatron machine operated in the betatron building, which was adjacent to these buildings. He described the 10 building, and recollected that the betatron was right in the middle of it. I said that the betatron building connected to the center of the 10 building—[Worker B] agreed. I said that the rail cars went straight through the 10 building to the betatron building—[Worker B] again agreed. I then asked if it was his recollection that the castings were taken to the betatron building. He said "Yes," that he assumed they used the railroad tracks to push them in and out of the building.

Comment: [Worker B's] account is entirely consistent with our understanding of the operation of the new betatron at GSI.

On June 18 I sent [Worker B] the above text of my report of this interview via the U.S. Postal Service, along with a letter asking him to let me know if he had any corrections, additions or other comments, or if he agreed with my report. He has not responded as of this date.