**SC&A S. COHEN & ASSOCIATES**
AN EMPLOYEE-OWNED COMPANY

June 29, 2005

Mr. David Staudt
Center for Disease Control and Prevention
Acquisition and Assistance Field Branch
Post Office Box 18070
626 Cochrans Mill Road – B-140
Pittsburgh, PA 15236-0295

Re: Contract No. 200-2004-03805, Task Order 1: Document No. SCA-TR-TASK1-0009c
Draft Review of NIOSH Site Profile for the Atomic Energy Operations at the Iowa Army Ammunition Plant (IAAP) — Final Integrated Version

Dear Mr. Staudt:

S. Cohen & Associates (SC&A, Inc.) is pleased to submit our Final Integrated Version of the Review of NIOSH Site Profile for the Atomic Energy Operations at the Iowa Army Ammunition Plant (IAAP). This draft review of the IAAP site profile combines two partial preliminary reports reviewing Rev. 01 of the TBD that SC&A submitted to the National Institute of Occupational Safety and Health and the Advisory Board on Radiation and Worker Health on April 18 and April 22, 2005 (SCA-TR-TASK1-0009 and SCA-TR-TASK1-0009b, respectively). It also includes some new elements of the review that SC&A has added since that time based on comments on the preliminary reviews, as well as site expert interviews that have been declassified by the Department of Energy.

Sincerely,

J J Mauro

John Mauro, PhD, CHP
Project Manager

cc: P. Ziemer, PhD, Board Chairperson
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*Final Draft*

# ADVISORY BOARD ON

# RADIATION AND WORKER HEALTH

## *National Institute of Occupational Safety and Health*

## Review of NIOSH Site Profile
## for the
## *Atomic Energy Operations at the Iowa Army Ammunition Plant (IAAP)*
## *Final Integrated Version*

**Contract No. 200-2004-03805**
**Task Order No. 1**

**SCA-TR-TASK1-0009c**

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*Disclaimer*

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| S. COHEN & ASSOCIATES:<br>***Technical Support for the Advisory Board on Radiation & Worker Health Review of NIOSH Dose Reconstruction Program*** | Document No.<br>SCA-TR-TASK1-0009c<br>Effective Date:<br>Draft – June 29, 2005<br>Revision No. 0 (Draft) |
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| Task Manager: ____________________ Date: _________<br>Joseph Fitzgerald | Supersedes:<br>SCA-TR-TASK1-0009 and<br>SCA-TR-TASK1-0009b |
| Project Manager: __________________ Date: _________<br>John Mauro | |

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# ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| ABRWH | Advisory Board on Radiation and Worker Health<br>(also referred to as Advisory Board or Board) |
| AEC | Atomic Energy Commission |
| AMAD | Activity Median Aerodynamic Diameter |
| BAECP | Burlington Atomic Energy Commission Plant |
| CFR | *Code of Federal Regulations* |
| DOE | U.S. Department of Energy |
| DOE-HQ | U.S. Department of Energy Headquarters |
| DU | depleted uranium |
| EEOICPA | Energy Employees Occupational Illness Compensation Program Act |
| EPA | U.S. Environmental Protection Agency |
| EU | enriched uranium |
| FS | firing site |
| g | grams |
| g/y | grams per year |
| $g/cm^2$ | grams per square centimeter |
| GM | geometric mean |
| GSD | geometric standard deviation |
| HE | high explosive |
| HEU | highly enriched uranium |
| HMX | high melting explosives |
| IAAP | Iowa Army Ammunition Plant |
| ICRP | International Commission of Radiation Protection |
| IFI | in-flight-insertable |
| IOP | Iowa Ordnance Plant |
| keV | kiloelectron volts |
| kg | kilogram |
| LANL | Los Alamos National Laboratory |
| LLNL | Lawrence Livermore National Laboratory |
| m | meter |
| m/s | meters per second |
| $m^3/s$ | cubic meters per second |

| | |
|---|---|
| MDL | minimum detectable level |
| mg | milligrams |
| MIRD | Medical Internal Radiation Dose |
| mm | millimeters |
| mrad/h | milliard per hour |
| mrem/h | millirem per hour |
| mSv | milliseiverts |
| NCRP | National Council on Radiation Protection |
| NIOSH | National Institute for Occupational Safety and Health |
| NRC | U.S. Nuclear Regulatory Commission |
| NTA | Eastman Kodak Nuclear Track Film Type A |
| OCAS | Office of Compensation Analysis and Support |
| ORAU | Oak Ridge Associated Universities |
| PA | posterioanterior |
| ppm | parts per million |
| POC | probability of causation |
| PNNL | Pacific Northwest National Laboratory |
| PPE | personnel protective equipment |
| R&D | research and development |
| rem | rem |
| SEC | Special Exposure Cohort |
| SOP | Standard Operating Procedure |
| STAR | Stability ARray |
| TBD | Technical Basis Document |
| TEPC | tissue equivalent photon counters |
| TIB | Technical Information Bulletin |
| TLD | thermoluminescent dosimeter |
| µCi/y | microcurie per year |
| µg/m$^3$ | microgram per cubic meter |
| µm | micron or micrometer |

# 1.0 EXECUTIVE SUMMARY

This final draft report by S. Cohen and Associates (SC&A, Inc.) is the integrated evaluation of the site profile, *Technical Basis Document for Atomic Energy Operations at the Iowa Army Ammunition Plant (IAAP)*, ORAUT-TKBS-0018, Revision 01 (ORAU 2005). Revision 01 of the Technical Basis Document (TBD) was issued on March 14, 2005, and incorporates major technical changes to the original TBD (i.e., Revision 00 (ORAU 2004)) that had been issued April 16, 2004. This review of the IAAP site profile combines two partial preliminary reports reviewing Rev. 01 of the TBD that SC&A submitted to the National Institute of Occupational Safety and Health (NIOSH) and the Advisory Board on Radiation and Worker Health (referred to as "Advisory Board" or "Board" in the present report) on April 18 and April 22, 2005 (SCA-TR-TASK1-0009 (SC&A 2005a) and SCA-TR-TASK1-0009b (SC&A 2005b), respectively). It also includes some new elements of the review that SC&A has added since that time based on comments on the preliminary reviews, as well as site expert interviews that have been declassified by the Department of Energy (DOE).

SC&A prepared the two reports in response to a special request by the Advisory Board. SC&A began reviewing the IAAP site profile on March 17, 2005, three days after the revised TBD was issued. As contractor to the Board, SC&A's directive was to review the TBD and assist the Board in evaluating the technical merit and credibility of the revised TBD as guidance for dose reconstructions for former IAAP workers. The urgency for SC&A to conduct this review was largely influenced by a Special Exposure Cohort (SEC) petition that was under review at that time by the Board and by NIOSH. Due to significant changes that had been incorporated in Revision 01 of the TBD, the Board concluded that an informed, fair, and final decision regarding the SEC petition would have to await a critical assessment of the revised TBD. During its April 25–27, 2005, meeting in Cedar Rapids, Iowa, the Board voted to recommend that the SEC be granted to Atomic Energy Commission (AEC) workers employed at IAAP between 1949 and 1975. The present combined review of the IAAP TBD was prepared in order to complete and finalize the preliminary and partial work that was done to support the Board's requirements for its April 25–27 meeting.

This review of the IAAP TBD was unprecedented in that it required that SC&A be allowed access to classified documents that contained data that NIOSH had used to develop the model for estimating external doses during 1949–1962 (the "generic pit" model). The generic pit model was constructed in order to protect classified data relating to the design of nuclear warheads that were assembled at IAAP during that period. For this review of the IAAP TBD, the need to assess classified information mandated significant changes to our standard review procedures. In past reviews of other TBDs, SC&A's approach has been to engage a team of scientists where every member independently assessed the entire document before coming together for a critical open discussion. To accommodate the need for a review of classified material, two members of the SC&A team (and two Board members) with Q-clearances inspected classified documents that NIOSH had selected for use in its dose model. They prepared an analysis that was not reviewed by the rest of the team, but was submitted to DOE for declassification. The report was declassified in its entirety and was submitted to the Board (SC&A 2005b). The classified review itself, while critical to a broader understanding of key dose assessment models and assumptions, was constrained in a number of important ways. First, due to time limitations and the logistics of scheduling appropriately cleared SC&A, Advisory Board, and NIOSH personnel, the duration of the review was limited to 1.5 days. Second, SC&A was unable to conduct a wider survey of classified records pertinent to its TBD evaluation, but had to rely on what NIOSH had pre-selected for review instead. However, despite these constraints, the SC&A team was able to arrive at firm conclusions regarding the generic pit.

In parallel with the classified review, which was focused on the validity of the generic pit model and on interviews with former IAAP workers with security clearances (these interviews were also submitted for declassification), the rest of the SC&A team conducted a broader review of the site profile, including the adequacy and accuracy of film badge data, the analysis of sources of internal dose, etc. This review of the TBD and associated unclassified material was presented in another partial report (SC&A 2005a).

A conference call, in which the authors of the TBD, DOE staff, NIOSH staff, some Board members, and SC&A team members participated, provided clarification and information to SC&A on critical points. Furthermore, site expert interviews were also crucial in allowing SC&A to finalize this review. Attachment 1 lists the questions SC&A submitted to the Board and to NIOSH. Attachment 2 shows the list of documents that were requested by SC&A. Attachment 3 is reserved for the conference call transcript (not available at this time). Attachment 4 presents a summary of the site expert interviews. Attachment 5 contains the draft agenda for the April 12–13, 2005, review of classified records at DOE offices in Germantown, Maryland. Attachment 6 presents SC&A's independent assessment of dose rates from external exposure to various hypothetical weapons components, modeled on the generic pit described in the TBD. Attachment 7 is a reproduction of a memo from Jack Fix of the Battelle Northwest Division regarding neutron dosimetry at IAAP.

The SC&A review of the IAAP site profile was performed in accordance with Board-approved review procedures, which require that each site profile be evaluated against five measures of adequacy (also referred to as review criteria): (1) completeness of data sources, (2) technical accuracy, (3) adequacy of data, (4) site profile consistency, and (5) regulatory compliance. The SC&A review of the IAAP TBD determined that the degree to which the TBD satisfies the first three objectives and the last objective differs for different time periods of operation of the facility. SC&A has concerns in all four areas. In regards to consistency with other site profiles, the essential features of the IAAP site profile are unique among those reviewed by SC&A and therefore cannot be readily compared to the other profiles.

## Summary of Findings

***Finding 1:*** The external dose rate from the generic pit is likely to bound the external dose rates that may have been experienced by Line I workers from single pits at a distance of 1 meter prior to 1963. However, SC&A has concerns regarding the use of dose rates from the generic pit for worker dose reconstruction.

***Finding 2:*** SC&A has concerns and reservations about the "work factor" used to derive annual external doses prior to 1963. As a result, there are serious questions as to whether the work-factor calculation method is scientifically valid and claimant favorable. Furthermore, the work factor may not address pre-1963 doses to non-Line I radiation workers, such as security guards and other personnel who entered storage areas.  In addition, it may not capture doses due to incidents.

***Finding 3:*** The reconstruction of external doses in the pre-1963 period uses a bounding estimate based on the calculated dose rates from a bare, generic pit, while the external doses in the 1963–1974 period are based on film badge dosimetry records and other data.  The generic pit model was constructed because of the paucity of film badge records during these early years of operation, and because national security considerations prevent NIOSH from revealing the details of the actual weapons assemblies that were handled at IAAP.  The generic pit was therefore designed to be a bounding, claimant-favorable model that is not based on classified data.  However, it is also not based on a valid scientific analysis of the actual conditions of radiation exposure during that time period.  The result is a sharp discontinuity between the external doses estimated for that period and for the 1963–1974 period, because the external dose assessments for these two periods use very different methodologies.  The inconsistent methods of dose reconstruction for these two periods could result in an inequitable resolution of claims from workers exposed during these two periods.

***Finding 4:*** The statistical significance or representativeness of annual dose distributions for 1963–1967 (Table 6.4 of TBD) is not clearly established, since only a limited number of radiation workers were monitored prior to 1968.  Furthermore, missed doses due to the erratic use of film badges cannot be estimated.  This problem is compounded by the paucity of data for reliably assigning monitored workers to radiological job categories.

***Finding 5:*** It may not be possible to accurately determine external doses from Am-241, due to the low sensitivity of the film badges to the low-energy photons emitted by this radionuclide.

***Finding 6:*** Film badges worn on the lapel or collar may not accurately represent organ doses.  Therefore, adjustment factors are needed, at least for some groups of workers.

***Finding 7:*** NIOSH did not consider all significant sources of data and information relevant to dose reconstruction.  In general, there is an over-reliance on theoretical modeling for purposes of deriving upper-bound estimates at the expense of identifying and applying available radiological and operational information to achieve “a substantial basis of fact,” as stipulated in 42 CFR 82.

***Finding 8:*** SC&A’s classified review substantiated the basis for the use of the 1993–2003 Pantex neutron-to-photon ratios as a claimant-favorable surrogate for IAAP neutron dose estimates.  However, workers whom we interviewed said that neutron dose rate and spectral measurements had been taken at IAAP by a DOE laboratory.  The lack of a review of actual IAAP data raises concerns both about the accuracy and reasonableness of the neutron-to-photon ratio proposed in the TBD and about the completeness of NIOSH’s document research.

***Finding 9:*** External dose estimates for unmonitored workers are claimant favorable for non-radiological workers.  However, they are not scientifically valid nor claimant favorable for unmonitored workers who were frequently in the proximity of radioactive materials.

***Finding 10:*** The radon concentrations presented in the TBD are not scientifically valid or claimant favorable, due partly to a scientifically incorrect choice of data from Pantex in Texas for use in Iowa, which has much higher radon levels than Texas.

***Finding 11:*** Assumptions about worker exposures to medical x-rays are not uniformly claimant favorable.

***Finding 12:*** Tritium exposure estimates are exceedingly claimant favorable, but some of the assumptions that yield the higher dose estimates are not scientifically valid.

# 2.0 SCOPE AND INTRODUCTION

Under the Energy Employees Occupational Illness Compensation Program Act (EEOICPA or the Act) and Federal regulations defined in Title 42, *Code of Federal Regulations*, Part 82, *Methods for Radiation Dose Reconstruction Under the Energy Employees Occupational Illness Compensation Program* (42 CFR 82), the Advisory Board is mandated to conduct an independent review of the methods and procedures used by NIOSH and its contractors for dose reconstruction. As contractor to the Advisory Board, SC&A has been charged under Task 1 to support the Advisory Board in this effort by independently evaluating a select number of site profiles that correspond to specific facilities at which energy employees worked and were exposed to ionizing radiation.

The present review of *Technical Basis Document for Atomic Energy Operations at the Iowa Army Ammunition Plant (IAAP)*, ORAUT-TKBS-0018, Revision 01 (ORAU 2005), is part of the series of site profile reviews prepared to support the Advisory Board's deliberations. SC&A critically evaluated this site profile in order to:

- Determine the completeness of the information gathered by NIOSH in preparing the site profile, with a view to assessing the adequacy and accuracy of these data to support dose reconstruction
- Assess the technical merit of the data and information
- Assess NIOSH's use of the data in dose reconstructions

The IAAP began operations in 1941, primarily to develop, use, and test a wide variety of ordnance items. In the late 1940s, IAAP began research, development, and fabrication of high explosive (HE) ordnance related to the development, testing, maintenance, retrofits, assembly, and disassembly of nuclear weapons. It appears that the first nuclear weapon assembly operation began in March 1949 with the Mark IV pit.[1] However, based on a review of the TBD and its supporting documentation, there appears to be some uncertainty as to when fissile material was first introduced onsite—it could have been as early as 1949 or as late as 1955. The uncertainty appears to be related to whether the activities at the site related to the weapons program from 1949 until 1955 were limited to the non-nuclear components of weapons, or whether fissile and other radioactive materials were handled at the facility during this time period. According to the TBD, the components of the weapons handled at IAAP prior to 1955 appear to have been limited to non-fissile material, such as the tamper, which is the hollow sphere consisting of high explosives. The fissile material, consisting of a second hollow sphere of highly enriched uranium or weapons grade plutonium, was inserted into the tamper. Prior to 1955, in order to preclude an accidental nuclear detonation, the pits were not inserted into the tamper until the weapons were assembled in flight. For this reason, weapons of this design were referred to as in-flight-insertable (IFI) weapons. NIOSH believes that, though HE related to weapons assembly were handled at IAAP prior to 1955, fissile material was not actually handled onsite until 1955, because the weapons assembled at IAAP were of the IFI design. The TBD cites literature in support of this hypothesis. Nevertheless, in order to give the benefit of the doubt to the claimants, NIOSH decided to develop the TBD on the conservative assumption that there were

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[1] The term "pit" is used in the TBD and its supporting documentation to refer to the hollow sphere of plutonium or uranium that comprised the core of the devices.

fissile materials on site beginning in 1949, when nuclear weapons assembly work started at IAAP. SC&A concurs with this decision.

Beginning in 1955, the primary activities at the facility involving HE and fissile material included the assembly and testing[2] of complete weapons. These are collectively referred to as Line I operations. At that time, a radiological monitoring program was initiated consisting of the issuance of film badges to some workers, radiological surveys, continuous air monitoring, and specialized training for weapons assembly workers. In 1963, the film badges were exchanged on a biweekly schedule. In 1964, the exchange frequency was reduced to once every 4 weeks. Monitoring of internal exposures began in 1962.

From the perspective of historical dose reconstruction, based on the availability of relevant radiological monitoring data, it is convenient to divide the operations at IAAP into three time periods, as follows:

(1) 1949–1955: No radiological monitoring data upon which to base dose reconstructions (there is reason to believe that there was no fissile material onsite during these years)

(2) 1955–1962: Only limited radiological monitoring data available for use in dose reconstruction

(3) 1963–1974: A steady increase in available radiological monitoring data in terms of the number of dosimeter readings; however, the number of monitored workers grew slowly and many workers exposed to significant levels of radiations were never issued badges

The TBD distinguishes these three time periods because of the differences in the radiological monitoring data available for dose reconstruction. In addition, all of the data and supporting documentation provided in the TBD for dose reconstruction in the post-1962 time period are based on unclassified or declassified data, while a large portion of the data and descriptions of operations used by NIOSH to support dose reconstruction for the time period prior to 1963 are based on classified information.

In accordance with directives provided by the Advisory Board and compliance with Board-approved review procedures prepared by SC&A, this report is organized into the following sections:

1.0 Executive Summary
2.0 Scope and Introduction
3.0 Assessment Criteria, Method, and Chronology for Review
4.0 Site Profile Strengths
5.0 Findings
6.0 Observations
7.0 Completeness, Adequacy, Technical Accuracy, and Regulatory Compliance

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[2] The term “testing” is used here to refer to experiments and simulated testing of mock pits, not the actual detonation of nuclear weapons.

# 3.0 ASSESSMENT CRITERIA AND METHODS

Under Task 1, SC&A is charged with evaluating the approach set forth in a limited number of site profiles used by NIOSH for dose reconstruction. These documents are reviewed for their completeness, technical accuracy, adequacy of data, consistency with other site profiles, and compliance with the stated objectives, as defined in *SC&A Standard Operating Procedure for Performing Site Profile Reviews* (SC&A 2004b). The present review is specific to the IAAP site profile and supporting documents, though some of its elements may also apply to other site profiles.

## 3.1 OBJECTIVES

### 3.1.1 Objective 1: Completeness of Data Sources

SC&A reviewed the site profile with respect to Objective 1, which requires an identification of principal sources of data and information that are applicable to the development of the site profile. The two elements examined under this objective include (1) determining if the site profile made proper use of available data that is relevant and significant to dose reconstruction, and (2) investigating whether other relevant and significant sources are available but were not used in the development of the site profile. For example, if relevant data were discovered that the TBD has not taken into consideration, this would constitute a completeness-of-data deficiency. The Oak Ridge Associated Universities (ORAU) site profile document database and the references cited in the TBD were evaluated to determine the completeness of data collected by NIOSH in the development of the site profile.

### 3.1.2 Objective 2: Technical Accuracy

Under Objective 2, SC&A is required to perform a critical assessment of the methods used in the site profile to develop technically defensible guidance or instruction. This includes an evaluation of field characterization data, source-term data, technical reports, standards and guidance documents, and literature related to processes that occurred at IAAP. The goal of this objective is to evaluate whether the technical approach used by NIOSH in the interpretation and analysis of data is scientifically sound and takes appropriate account of uncertainties.

### 3.1.3 Objective 3: Adequacy of Data

For Objective 3, SC&A is required to determine whether the data and guidance presented in the site profile are sufficiently detailed and complete to conduct dose reconstruction, and whether a defensible approach has been developed when there are insufficient data. In addition, this objective requires SC&A to assess the credibility of the data used for dose reconstruction. Here, the intent is to identify gaps in the facility data that may influence the outcome of the dose reconstruction process. For example, data would be considered inadequate if a group of workers had the potential to be exposed to neutrons, but were not monitored for neutron exposure. In addition, SC&A would also assess the approach that NIOSH uses to estimate missed doses.

### 3.1.4 Objective 4: Consistency Among Site Profiles

This objective requires SC&A to identify common elements among site profiles completed or reviewed to date, as appropriate. SC&A determined that the IAAP TBD (ORAU 2005) is unique among those reviewed so far. It addresses early operational and record-keeping deficiencies in a way that is different from other Atomic Weapons Employers in that a generic pit and a work factor were devised to estimate external doses during the early years of operation. These elements are not present in any of the other site profiles reviewed by SC&A. The hypothetical model of the generic pit, coupled to the work factor, which was introduced in order to protect classified weapons design data, is also unique to the IAAP site profile among those reviewed so far. In the case of the film badge data, the IAAP TBD is the only one reviewed so far where there were systematic missed doses among monitored workers due to the erratic wearing of film badges. Issues relating to pit storage and exposure geometry have also not occurred in other site profiles reviewed so far. Hence no assessment of consistency with other site profiles was done in this report. A consistency check will be made with Pantex if the Board asks SC&A to review the profile of that site.

### 3.1.5 Objective 5: Regulatory Compliance

Objective 5 requires SC&A to evaluate the degree to which the site profile complies with stated policy and directives contained in 42 CFR 82. In addition, SC&A evaluated the TBD for adherence to general quality assurance policies and procedures utilized for the performance of dose reconstructions.

In order to place the above objectives into the proper context as they pertain to the site profile, it is important to briefly review key elements of the dose reconstruction process, as specified in 42 CFR 82. Federal regulations specify that a dose reconstruction can be broadly placed into one of three discrete categories. These three categories differ greatly in terms of their need for accuracy and completeness of dose data, as explained below.

***Category 1.*** Least challenged by any deficiencies in available dose and monitoring data are dose reconstructions that are aimed at developing a *minimum* dose estimate. In such cases even a partial assessment (or minimized doses) corresponds to a probability of causation (POC) value in excess of 50%, and assures compensability of the claim. Such partial or incomplete dose reconstructions with a POC ≥ 50% may, in some cases, involve only a limited amount of external or internal exposure data. In extreme cases, even a total absence of a positive measurement may suffice for an assigned organ dose that results in a POC ≥ 50%. For this reason, dose reconstructions in behalf of this category may only be marginally affected by incomplete or missing data, or uncertainty in the measurements. In fact, regulatory guidelines recommend the use of a partial or incomplete dose reconstruction, the minimization of dose, and the exclusion of uncertainty for reasons of process efficiency, as long as this limited effort produces a POC of ≥ 50%.

***Category 2.*** A second category of dose reconstruction is defined by Federal guidance, which recommends the use of worst-case assumptions. The purpose of worst-case assumptions in dose reconstruction is to derive *maximal* or highly improbable dose assignments. For example, a worst-case assumption may place a worker at a given work location 24 hours per day, 365 days per year. The use of such maximized (or upper-bound) values, however, is limited to those instances where the resultant maximized doses yield POC values below 50%, in which case the claimants are not compensated. For this second category, the dose reconstructor needs only ensure that all potential internal and external exposure pathways have been considered.

As was the case with minimum doses, the benefit of worst-case assumptions and the use of maximized doses in dose reconstruction is efficiency. Efficiency is again achieved by the fact that maximized doses *avoid* the need for *precise* data and eliminate the need for consideration of the uncertainty of the dose. Lastly, the use of bounding values in dose reconstruction minimizes any controversy regarding the decision to deny a claim.

To satisfy this type of a dose reconstruction, the TBD must, at a minimum, provide information and data that clearly identify (1) all potential radionuclides, (2) all potential modes of exposure, and (3) upper limits for each contaminant and mode of exposure. Thus, for external exposures, maximum dose rates must be identified in time and space that correspond to a worker's employment period and work locations; similarly, in order to maximize internal exposures, highest air concentrations and surface contaminations must be identified.

***Category 3.*** The most complex and challenging dose reconstruction represents cases where the case cannot be dealt with under one of the two categories above. For instance, when a minimum dose estimate does not result in compensation, a next step is required to make a more complete estimate. Or when a worst-case dose estimate that involves assumptions that may be highly unrealistic results in a POC greater than 50%, compensation is not necessarily justified. A more refined estimate may be required either to deny or to compensate. In dose reconstructions that may be represented as "reasonable," NIOSH has committed to resolve uncertainties in favor of the claimant. According to 42 CFR 82, NIOSH interprets "reasonable estimates" of radiation dose as follows:

> *. . . estimates calculated using a substantial basis of fact and the application of science-based, logical assumptions to supplement or interpret the factual basis.* ***Claimants will in no case be harmed by any level of uncertainty involved in their claims, since assumptions applied by NIOSH will consistently give the benefit of the doubt to claimants.*** [Emphasis added.]

In order to achieve the objectives described above, SC&A reviewed each of the six sections of the site profile, their supplemental attachments, supporting documentation, and selected classified records. The main goal of the evaluation was to assess the ability of the site profile to support the three aforementioned categories of dose reconstructions. In addition, SC&A interviewed a number of former IAAP workers and site experts. The following briefly describes major sections of the site profile and our method of review.

Section 1 of the TBD provides a brief introduction. Though not explicitly addressed in the introduction, it is appropriate to acknowledge the fact that neither the Act nor 42 CFR 82, which implements the Act, requires a site profile. Site profiles were developed by NIOSH as a resource available to dose reconstructors. Furthermore, SC&A understands that site profiles are living documents, which may be revised, refined, and supplemented with technical information bulletins (TIBs), as required, to help dose reconstructors. Site profiles are not intended to be prescriptive or necessarily complete in terms of addressing every possible issue that may be relevant to any given dose reconstruction. SC&A kept these limitations in mind when evaluating the TBD.

Section 2 describes the site and the facility, the operational history, and the processes. This is an extremely important part of the site profile, because these descriptions and the supporting data serve as the underpinning for subsequent sections. This section, along with the appendices to the TBD, describes the facilities and processes that are relevant to dose reconstruction. Our review of this section examines whether all the potentially important site activities and processes are adequately described, and whether the characterization of the source terms is sufficient to support dose reconstruction. This review was particularly challenging, because much of the data relevant to dose reconstruction for time periods prior to 1963 are classified.

Section 3 provides a set of procedures for reconstructing workers' exposures to medical x-rays that were required for employment at the facility. SC&A reviewed this section for technical adequacy and claimant favorability.

Section 4 of the site profile provides background information and guidance to dose reconstructors for estimating environmental doses to unmonitored workers outside of the facilities during working hours. Environmental exposures may be the result of routine and episodic airborne emissions from the facility. SC&A reviewed this section from the perspective of the source terms and the atmospheric transport, deposition, and resuspension models used to derive estimates of external and internal exposures.

Section 5 presents background information and guidance to dose reconstructors for deriving occupational internal doses to workers. This section was reviewed with respect to background information and guidance regarding (1) the types, mixes, and chemical forms of the radionuclides that workers may have inhaled or ingested; (2) the recommended assumptions for use in reconstructing internal doses (based on models, whole-body counts, and bioassay data, when available); (3) the methods recommended for use in the reconstruction of missed internal dose; and (4) the methods for characterizing uncertainty in reconstructed internal doses.

Section 6 presents background information and data used for deriving occupational external doses to workers. This is by far the most critical section of the TBD and was given the greatest attention in our review. This section was reviewed for the quality and completeness of the technical information, the assumptions pertaining to exposure scenarios, and the energy distribution of external radiation to which workers may have been exposed. SC&A also reviewed the approach in the TBD for converting external dosimetry data to organ-specific doses, the methods for the reconstruction of missed external doses, and the characterization of uncertainty in the reconstructed external doses.

## 3.2 A CHRONOLOGY OF EVENTS

### 3.2.1 Overall Review

Our review began on March 17, 2005, with an initial evaluation of the TBD. SC&A then developed a list of questions that was transmitted to the Board and NIOSH in two memos dated March 22 and March 31, 2005 (see Attachment 1). A list of both classified and unclassified documents and records was submitted to NIOSH in a letter dated April 11, 2005, requesting assistance in obtaining access to these documents (see Attachment 2). After a more detailed review of the TBD and its unclassified supporting documentation, a factual-accuracy conference call was held with members of the Advisory Board and NIOSH on April 8, 2005. This conference call was recorded and transcribed. On April 12 and 13, 2005, two SC&A team members with Q-clearances, joined by two Board members, visited the Department of Energy (DOE) offices in Germantown, Maryland, where the classified documents used by NIOSH in preparing the TBD are stored. On April 13, 2005, a second conference call was held with the Advisory Board and NIOSH. The purpose of this call was two-fold: to continue our factual-accuracy review and to discuss our initial findings. This conference call was also recorded and transcribed (see Attachment 3). In addition, SC&A conducted interviews with site experts (see Attachment 4).

### 3.2.2 Classified Review, April 12–13, 2005

Two SC&A team members, along with two members of the Advisory Board, participated in a review of some of the classified information that NIOSH utilized in preparing the TBD. This review was conducted in conjunction with NIOSH staff over a one and one-half-day period (April 12–13, 2005) in a secure facility at the DOE headquarters building in Germantown, Maryland. The documents that were reviewed were selected by NIOSH and included the following:

- IAAP History Reports (NARA)—classified
- Health Physics Analysis of Doses Received at the Iowa Ordinance Plant, PNNL-ETD-0385 (PNNL)—classified
- Annual Weapons Program Report, Volume 2—Retired Weapons (DOE-HQ)—classified
- University of Iowa records (selected dosimetry information)
- DOE incident reports (selected)
- Pantex tritium and depleted uranium (DU) monitoring data
- Agency for Toxic Substances and Disease Registry health consultation
- Oak Ridge National Laboratory—Indoor Radiological Survey

A draft agenda for the classified review session is provided as Attachment 5.

# 4.0 SITE PROFILE STRENGTHS

In developing a TBD, the assumptions used must be fair, consistent, and scientifically robust, and uncertainties and inadequacies in source data must be explicitly addressed. The development of the TBD must also consider efficiency in the process of analysis of individual exposure histories, such that claims can be processed in a timely manner. With this perspective in mind, there were a number of strengths identified in the IAAP TBD (ORAU 2005).

For the cases where film badge readings are reported as below the limits of detection, NIOSH recommends the guidance in OCAS-IG-001 (NIOSH 2000), which is to assume a lognormal distribution with a geometric mean (GM) of one-half the lower limit of detection and a geometric standard deviation (GSD) of 1.52. This approach is scientifically valid and claimant favorable. However, NIOSH should explain how adjustments to doses recorded by the film badges would be made in such cases, and how other adjustment factors, including estimates of neutron exposure, are accounted for in this process.

NIOSH makes a concerted effort to place an upper bound on many exposure scenarios that may have occurred at the IAAP. Many of these scenarios were unique to IAAP, including occupational and environmental exposures to tritium and some aspects of exposure to DU. These scenarios include the following:

- Venting tritium containers
- Burning explosives containing residual DU
- Hydroshots, which involved blowing up simulated pits made of DU
- Machining baratols, which were the explosives surrounding the DU ball

In assessing internal exposures to DU, NIOSH recommends assuming either Lung Clearance Type M or S, depending on the organ of concern, in order to ensure that the claimant is given the benefit of the doubt. Some other aspects of the estimation of internal exposure to DU are also scientifically defensible and claimant favorable. For instance, the TBD assumes that drinking water for the site was obtained from nearby Mathes Lake, which could have been contaminated by runoff of uranium associated with hydroshots. This assumption is made despite the fact that the levels of uranium found in the lake are consistent with typical background levels. Assuming that the water samples cited in the TBD are representative of all years of facility operation, the approach recommended in the TBD to address drinking water exposures from DU in runoff is scientifically valid and claimant favorable.

A third example of a TBD strength in relation to DU concerns the modeling of the DU that was released during the burning of explosives. Based on information cited in the literature, NIOSH estimates that 2,000 g/y of DU was burned along with high explosives in the Explosive Disposal Area. The TBD reports that the burning of DU was frequent; hence it is appropriate to model atmospheric dispersion using standard Gaussian dispersion models for ground-level releases.[3]

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[3] In general, even if releases are intermittent rather than continuous, it is appropriate to use average annual dispersion coefficients for deriving annual doses, as long as the releases are frequent (e.g., at least once a week) and randomly distributed. The reason this approach is acceptable is that the variation in meteorological conditions will average out over the course of a year, resulting in annual exposures that are not very different than if the releases were in fact uniform and continuous.

NIOSH assumes that all of the DU is aerosolized. Atmospheric dispersion factors are listed for 100 m, 500 m, and 1,000 m. The dose reconstructor is instructed to use the distance that is most appropriate and claimant favorable for individual dose reconstructions. The model assumes a wind speed of 2 m/s that blows toward the receptor 25% of the time. In addition, no credit is taken for lofting of the plume caused by the heat of the fire. On the premise that the source term, event frequency, and assigned distances are correct and/or conservative,[4] resultant doses are likely to be scientifically valid and claimant favorable.

NIOSH's adoption of a neutron-to-photon ratio with a GM of 0.79 and a GSD of 1.57 appears to be claimant favorable in light of the empirical data and Monte Carlo simulations, which indicate that the true neutron-to-photon ratios were likely to be lower by perhaps a factor of 2. However, as noted later in this report, this approach ignores actual neutron dose rate and spectral measurements performed at IAAP.

The assessment of environmental tritium doses is also claimant favorable. Based on effluent data gathered at the site from 1965 through 1970, NIOSH assumes a maximum annual release of 26,000 μCi/y of tritiated water. NIOSH further assumes that the release is diluted in a plant stack vent flow rate of 0.3 $m^3$/s, with no credit taken for atmospheric dispersion between the release point and the receptor location, and that the wind blows in the direction of the receptor 25% of the time. This approach is commonly described as an NCRP Level 1 screening analysis, which is considered highly conservative, since no credit is taken for atmospheric dispersion. Applying the maximum annual tritium source term to all years of operation is highly claimant favorable.

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[4] SC&A did not verify these parameters.

# 5.0 FINDINGS

***Finding 1: The external dose rate from the generic pit is likely to bound the external dose rates that may have been experienced by Line I workers from single pits at a distance of 1 meter prior to 1963. However, SC&A has concerns regarding the use of dose rates from the generic pit for worker dose reconstruction.***

Since NIOSH concluded that (1) film badge data for the period 1949–1962 were too sparse for dose reconstruction, and (2) radiation fields from actual pits handled during that period could not be used because the data are classified, NIOSH created a novel approach to lay the basis for dose estimation. The creation of a hypothetical "generic pit" that would have a dose rate higher than any actual pit handled at IAAP was central to this approach. A limited number of NIOSH personnel (with Q-clearance) conducted a review of relevant classified documents, which characterized pits and weapon assemblies handled at IAAP prior to 1963. Based on this information, NIOSH constructed a generic pit that would result in an overestimate of the dose rates from the actual weapons. The mass of plutonium was chosen because it is approximately the mass in the Trinity nuclear device and the Nagasaki bomb. The diameter was chosen to result in a thin spherical shell, which minimizes self-absorption and thus maximizes the dose rate.

The following describes our understanding of the dose reconstruction approach adopted in the TBD (ORAU 2005) for Line I workers prior to 1963. Line I workers were exposed to external radiation mainly because they physically handled pits. Based on a listing of the weapons provided in Appendix B of the TBD, it is clear that a large variety of devices were assembled, disassembled, refurbished, and/or maintained by these workers.

Evidence in support of NIOSH's claim that the generic pit has a dose *rate* greater than those handled at IAAP in the pre-1963 period could not be disclosed publicly because it involved classified data about the characteristics of the pits that were handled before 1963. It was, therefore, not included in the TBD. In a compromise that balances national security against the need for transparency in dose reconstruction, NIOSH granted access to these classified documents to two members of SC&A and two Board members, all with Q-clearances. This partial access obtained by the audit team and the Board allowed some independent review of NIOSH's claim that the dose rate from the generic pit was higher than any actual pit handled at IAAP prior to 1963. Hence, while the documentary basis of NIOSH's claim could not be made public because of national security considerations, the Board and its contractor, SC&A, could provide assurance to the public that they had reviewed the materials independently to verify NIOSH's claim about the generic pit dose rate, as well as other classified issues relating to the dose reconstruction in the pre-1963 period.

The review of the classified material considered relevant assumptions and parameters as provided in classified documentation, primarily *Health Physics Analysis of Dose Received at the Iowa Ordnance Plant* (PNNL-ETD-0385, Traub et al. 2005), including mass, radioactive components, pit geometry, cladding, isotopic composition, and radioactive impurities. Based on an examination of the documents made available by NIOSH and the classified discussion that took place, the SC&A team's Q-cleared members concurred with NIOSH's conclusion that the generic pit dose rate exceeded the dose rate of all pits handled at IAAP. SC&A cautions that this conclusion was based on a partial examination of the documents, because not all requested documents were available. However, the available documentation, as well as the frank classified discussion, led the SC&A team members to have a high degree of confidence that NIOSH is correct in claiming that the generic pit dose rate is higher than any of the pits handled at IAAP (as per the list in the TBD).

SC&A independently calculated dose rates from a generic pit modeled after the description in Appendix D of the TBD (see Attachment 6). Using a more sophisticated model that employed an anthropomorphic phantom, we found that the dose rate at 1 m from a plutonium pit with an isotopic composition based on a reported composition of weapons-grade plutonium was somewhat higher (48 vs. 33 mrem/h) than the dose rate reported in the TBD. We believe the difference is primarily attributable to different assumptions about the isotopic composition. However, we found that if the worker was in more intimate contact with the pit, the rate increased to 135 mrem/h.

There are many other issues in the actual calculation of a scientifically valid dose. Therefore, a claimant-favorable dose rate at a distance of 1 m does not necessarily assure a dose reconstruction that is claimant favorable. Moreover, as discussed in Section 7.4, the introduction of a hypothetical construct (i.e., the generic pit model), due to the legitimate need to protect classified data on weapons design, raises issues of regulatory compliance in dose reconstruction.

SC&A also has other concerns regarding the use of the overall generic pit approach for dose reconstructions. These are discussed in Finding 2.

***Finding 2: SC&A has concerns and reservations about the "work factor" used to derive annual external doses prior to 1963. As a result, there are serious questions as to whether the work-factor calculation method is scientifically valid and claimant favorable. Furthermore, the work factor may not address pre-1963 doses to non-Line I radiation workers, such as security guards and other personnel who entered storage areas. In addition, it may not capture doses due to incidents.***

NIOSH developed the work factor to represent the effective exposure duration of pre-1963 workers to the generic pit. NIOSH divided the entire period of operation of the IAAP into four eras. The work factor is based on film badge data from Era 3, spanning the years 1962–1967, and Era 4, from 1968–1974. The film badge data were compared to calculated dose rates from actual pits handled in each of these two eras. The effective exposure duration for each year in each era was computed as follows:

- NIOSH calculated the hourly dose rate at a distance of 1 m from each pit that was handled from 1962 to 1974. These calculations were based on classified data on these pits and could not be independently verified by SC&A.

- Weighted average dose rates were calculated for Era 3 and for Era 4, based on the pits handled during these two eras, yielding era dose rates of 1.08 and 1.48 mrem/h, respectively (see Table 6.5 of the TBD).

- A hypothetical annual dose for each era was calculated by multiplying the appropriate era dose rate by an assumed work year of 2,000 hours. This estimated annual dose (2,160 mrem for Era 3 and 2,960 mrem for Era 4, as listed in Table 6.5 of the TBD) is the dose to a hypothetical individual located at a distance of 1 m from a pit for 2,000 hours.

- The actual annual dose received by workers during each year from 1962 to 1974 was calculated from the GM of the non-zero film badge dosimeter readings for that year, modified for $H_p(10)$.

- The work factor for a given year is the ratio of the actual annual $H_p(10)$ dose to the era dose.

- NIOSH calculated the GM and GSD of the work factors for the period 1962–1974.

- To calculate the external annual dose to workers for each of the years 1949–1962, NIOSH first determined the hourly dose rate 1 m from the generic pit, using the MCNP code.

- Based on the calculated photon spectra and the known energy response characteristics of the film badge dosimeters used at IAAP, NIOSH then determined the hourly dose rate that would have been recorded by these dosimeters.

- Finally, NIOSH calculated an estimated annual dose rate for each year by multiplying this adjusted hourly dose rate, corrected for the ingrowth of Am-241, by the assumed work-year of 2,000 hours.

SC&A has the following scientific concerns about the work factor:

- The non-zero film badge data for 1962–1974 exclude missed doses that have not been evaluated and cannot be evaluated based on the data in the TBD. Considerable work and investigation is likely to be required to determine whether scientifically and statistically valid estimates of this component of missed dose can be estimated.

- There are several reasons why workers' exposures to the weapons handled in the 1949–1962 period may not have been comparable to the exposures of workers in 1962–1974 period. First, formal work practices may have been different. Second, the production activities themselves may have been different. Finally, earlier handling and working of weapons assembly and disassembly may have differed from the later periods, simply on account of less experience in the earlier period, necessitating more contact with or work near the pits. Hence the exposure duration and geometry may well have been different.

- A typical workweek at IAAP was 40–50 hours. Since the late 1950s was a period of heavy production of nuclear weapons, the working hours may have been longer during that time than during Eras 3 and 4, on which the work factor was based. Hence, the comparison of Eras 1 and 2 to Eras 3 and 4 may not be valid.

- NIOSH implicitly assumed that the radiation field experienced by the workers could be scaled to the radiation field at 1 m from each of the real pits handled during the entire period of operation. The relative contribution of the external radiation from a single pit to the total radiation field may have been different in the 1949–1962 and 1962–1974 eras. In that case, the work factor methodology would be invalid.

There are also some statistical issues associated with the estimate apart from the question of missed dose in the non-zero film badge readings:

- The use of a lognormal distribution of work factors is not claimant favorable for estimating individual doses. Use of such a distribution assumes that the distribution characterizes, in a claimant-favorable way, the experience of an individual worker, whose specific tasks and doses over the years may be different than those of others whose data are in the same pool. SC&A has suggested in a separate report to the Board and to NIOSH that the use of fixed, 95th percentile values are more claimant favorable in most cases than the use of the entire lognormal distribution.

- The post-1962 doses need correction factors for each organ, notably those in the pelvic area. This indicates that a work factor may need to be estimated for each organ, creating new uncertainties.

Additional questions about the validity of the work factor arise from site expert interviews. SC&A was not able to confirm the basic assumptions behind this calculation from the data that were made available during the classified review process or from unclassified data. These assumptions are that the proximity of the worker to the individual pit and the duration of exposure to each pit were the same during the 1949–1962 and the 1962–1974 time periods. Most important, as stated earlier, NIOSH assumed that the radiation field experienced by the workers during these two time periods could be scaled to the radiation field at 1 m from each of the real pits handled during the entire period of operation.

SC&A has not been able to corroborate these assumptions by the limited interviews with former production line workers. Attachment 4 contains a summary of the collective experience of approximately a dozen IAAP production, production control, security, and safety workers, as recounted in the interviews. In fact, workers recounted instances where they were exposed to more than one pit during routine operations (e.g., assembly, disassembly, and inspection) and in storage areas (e.g., security guards).

With respect to the guards, who were not monitored for radiation exposure, former workers indicated that the area radiation measurements recorded for the pit storage areas were among the highest at IAAP (in various Yard C pit storage areas, annual area readings of 18.2, 16.9, 14.6, 11.7, and 7.8 rem were recorded by photon monitors, for an average of 1–2 mrem/h), and the distances between the guards' locations and the pit arrays were actually smaller than that between the pits and the area monitors, making an even higher dose rate likely for the guards, assuming no intervening shielding. This may invalidate the assumption in the TBD that, for dose assessment purposes, guards can be treated the same as line production workers. The radiation exposures of the security guards need to be evaluated further by NIOSH.

The time individual workers were in the immediate proximity of the pit (i.e., within 1 m) apparently varied with the specific program, the skill of the particular worker, the quality assurance process required, and the number of units processed per day. It is unclear how the GM work factor of 0.153, which equates to 1.22 hours per 8-hour day at 1 m from the pit, can be reconciled with the accounts of the former workers. Such a low work factor also does not take into account the considerable direct contact during specific work processes, which would increase overall dose, particularly to the torso (which necessitated lead aprons in similar operations at Pantex) and to extremities.[5] Finally, there may have been significant differences in incidents in the pre-1963 period and those occurring in the 1962–1974 period. It therefore appears that a work factor deriving from the later period may not reflect the frequency or radiological conditions that may have typified earlier incidents.

For the above reasons, SC&A concludes that:

- The work factor is of questionable scientific and statistical validity.

- The use of the work factor would not result in dose estimates that are demonstrably claimant favorable.

***Finding 3: The reconstruction of external doses in the pre-1963 period uses a bounding estimate based on the calculated dose rates from a bare, generic pit, while the external doses in the 1963–1974 period are based on film badge dosimetry records and other data. The generic pit model was constructed because of the paucity of film badge records during these early years of operation, and because national security considerations prevent NIOSH from revealing the details of the actual weapons assemblies that were handled at IAAP. The generic pit was therefore designed to be a bounding, claimant-favorable model that is not based on classified data. However, it is also not based on a valid scientific analysis of the actual conditions of radiation exposure during that time period. The result is a sharp discontinuity between the external doses estimated for that period and for the 1963–1974 period, because the external dose assessments for these two periods use very different methodologies. The inconsistent methods of dose reconstruction for these two periods could result in an inequitable resolution of claims from workers exposed during these two periods.***

In the TBD, NIOSH has adopted an approach for reconstructing pre-1963 doses based on the generic pit model, and doses for the 1963–1974 period using film badge data. This results in a discontinuity in dose estimates in 1963. This is illustrated in Figure 6.8 of the TBD and in Appendix G, where photon dose estimates made by NIOSH for the period of operation are shown.

By far, the largest fraction of the external photon dose from a bare, unshielded pit composed of 15-year-old plutonium, at a distance of 100 cm from the body, is contributed by Am-241. According to NIOSH, maximum ingrowth of Am-241 occurred by 1960 (ORAU 2005, Appendix G). This conclusion is based on historical evidence that plutonium was first produced in 1945. NIOSH thus made the conservative, claimant-favorable assumption that all pits handled during the period 1949–1960 were made of plutonium produced in 1945. In the years following 1960,

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[5] As of April 2005, NIOSH was considering a dose assessment model for IAAP extremity exposures.

NIOSH assumed that the plutonium was 15 years old. Although the TBD contains some general observations regarding the role of IAAP and other nuclear weapons facilities, no specific reason is given for the 15-year cutoff of Am-241 ingrowth. Lower dose rates prior to 1960 reflect less Am-241 ingrowth, as described in Tables 6.6 and 6.7 of the TBD and in Appendix G.

The results of dose reconstruction, applying the approaches specified in the TBD for photon doses for the periods 1949–1962 and 1963–1974, are shown in Table 1, below. The photon doses in the three energy ranges are taken from Appendix G of the TBD. The doses for the 1949–1962 period are based on the MCNP-calculated hourly dose rates at 1 m from the generic pit, an assumed 2,000-hour work-year, and the work factor discussed earlier. The doses for the 1963–1964 period are based on the film badge data for each year, adjusted for the energy-response of the film badge and corrected for $H_p(10)$.

Table 1 shows the following results:

- The GM values of total photon doses between 1949 and 1962 range from 6,861 to 10,239 mrem/y. The values for 1949–1962, listed in Table 1, have an arithmetic mean of 8,916 mrem/y

- The GM values of total photon doses between 1963 and 1974 range from 418 to 1,391 mrem/y, for an arithmetic mean of 912 mrem/y.

It is evident from Table 1 that there is a sharp decline in the estimated doses in 1963 that is due to the different methods of dose reconstruction for the pre-1963 and post-1962 periods. This difference is about 1 order of magnitude. Compensation decisions for pre-1963 workers would thus be based on bounding estimates driven by the need to protect national security data, rather than on a scientific analysis of the radiological conditions actually prevailing at IAAP during that time. Compensation decisions for post-1962 workers, on the other hand, would be based on an assessment of dosimetry records for that period.

There is, of course, general agreement that national security data on pit design cannot be and should not be disclosed. The resulting discrepancy in the estimated doses, however, would make for compensation decisions that are not equitable for claimants who were exposed during these two periods, or scientifically valid for the earlier period. This finding is made, notwithstanding SC&A's other comments on the issues relating to the gaps in the post-1962 film badge records, such as cohort badging and its effect on the post-1962 dose estimates (see Finding 4).

**Table 1. Annual Median External Photon Doses─$H_P(10)$ (mrem/y)**

| Year | <30 keV | 30-250 keV | >250 keV | Total |
|---|---|---|---|---|
| 1949 | 243 | 5699 | 919 | 6861 |
| 1950 | 257 | 6039 | 974 | 7270 |
| 1951 | 272 | 6379 | 1029 | 7680 |
| 1952 | 283 | 6634 | 1070 | 7987 |
| 1953 | 293 | 6889 | 1112 | 8294 |
| 1954 | 304 | 7145 | 1153 | 8602 |
| 1955 | 315 | 7400 | 1194 | 8909 |
| 1956 | 326 | 7655 | 1235 | 9216 |
| 1957 | 337 | 7910 | 1276 | 9523 |
| 1958 | 344 | 8080 | 1304 | 9728 |
| 1959 | 355 | 8335 | 1345 | 10,035 |
| 1960 | 362 | 8505 | 1372 | 10,239 |
| 1961 | 362 | 8505 | 1372 | 10,239 |
| 1962 | 362 | 8505 | 1372 | 10,239 |
| 1963 | 39 | 923 | 149 | 1111 |
| 1964 | 15 | 347 | 56 | 418 |
| 1965 | 19 | 446 | 72 | 537 |
| 1966 | 21 | 487 | 79 | 587 |
| 1967 | 22 | 515 | 83 | 620 |
| 1968 | 30 | 698 | 113 | 841 |
| 1969 | 25 | 584 | 94 | 703 |
| 1970 | 43 | 1014 | 164 | 1221 |
| 1971 | 49 | 1156 | 186 | 1391 |
| 1972 | 34 | 789 | 127 | 950 |
| 1973 | 46 | 1090 | 176 | 1312 |
| 1974 | 44 | 1039 | 168 | 1251 |

***Finding 4: The statistical significance or representativeness of annual dose distributions for 1963–1967 (Table 6.4 of TBD) is not clearly established, since only a limited number of radiation workers were monitored prior to 1968. Furthermore, missed doses due to the erratic use of film badges cannot be estimated. This problem is compounded by the paucity of data for reliably assigning monitored workers to radiological job categories.***

In Table 8 of Revision 00 of the TBD (ORAU 2004), NISOH indicates that, for the period 1963–1967, only 3% to 7% of IAAP workers were monitored for external penetrating radiation; slightly more than in earlier years, albeit the number of dosimeter readings increased, as shown in Table 6.4 of Revision 01 of the TBD. Interviews with former workers also revealed that many workers did not wear their badges in these early years. Those that did wear badges attached them to their lapels or collars, whereas the maximum radiation exposure was likely at waist level. According to these workers, there was limited enforcement of good health physics practices. For instance, airborne tritium release alarms were often turned off, or the alarm set point was raised to avoid alarms. While some of these issues are addressed by NIOSH (e.g., excluding zero badge readings and planning to include a correction factor for badge geometry), others remain unresolved.

With a reported 300–400 workers on Line I at that time, it is not clear what jobs were performed by this handful of badged workers (some workers moved between jobs regularly), and whether these jobs are truly representative of jobs that entailed exposure to external radiation. University of Iowa researchers established that a number of workers who entered radiation areas of the plant were not badged, even after 1963. Security guards were not monitored, although they were responsible for overseeing the receiving and shipping of weapon assemblies and for guarding storage areas housing multiple pits. However, radiographers and Line I supervisors were routinely badged; thus, production workers and guards are under-represented in the NIOSH dose assessment model.

The worker outreach meetings conducted by NIOSH on July 29, 2004, revealed that IAAP workers sometimes did not wear their film badges, even when they were working with radioactive materials, such as assembly and disassembly of nuclear warheads. According to the TBD (p. 41):

> *During worker outreach meetings in July 2004, a new issue with missed dose was identified. The issue concerned the radiological monitoring practices at the site. Through discussions with former IAAP workers who conducted both assembly and disassembly, NIOSH discovered that film badge dosimeters may not have been worn all of the time. One worker indicated that he always wore his film badge, while another indicated that he would only wear it when one was given to him. Through this discussion, it became apparent that in general workers were supposed to wear their film badges, but strict adherence was not necessarily enforced. As a result, a third scenario occurred in which a worker was issued a dosimeter badge but did not wear it during exposure to radiation. When this badge would be processed, this could also result in a zero reading. The effect of these three scenarios is that there is likely some missed or unrecorded dose (Figure 6.4). As shown in Figure 6.4, in 1966 approximately half of the dosimeter readings were below the detectable or reporting level.*

One of the results of this situation is that the missed dose resulting from exposure below the limit of detection is not distinguishable from missed dose when the worker did not wear his/her badge. NIOSH has attempted to resolve this issue in a claimant-favorable way by dropping all zero badge readings from the statistical analysis that is used in the TBD for external dose estimation.

This approach is claimant favorable for non-radiological workers or for those workers who had only minimal exposure to nuclear materials or other sources of radiation. This is not the case for workers with exposures at the high end of the range. Appendix F of the TBD shows graphs depicting the lognormal distributions of the non-zero data. Dosimeter readings at the high end of the range are consistently higher than the corresponding values on the curves fitted to these data. This calls into question the use of lognormal distributions to represent these data. The approach used to fitting the non-zero data points does not, on the face of it, appear to be claimant favorable for the most exposed workers if the fitted values are used in the dose reconstruction.

This approach to missed dose also leaves a significant issue of how the non-zero badge readings are to be interpreted in relation to total dose. Because of the intermittent wearing of the badges by some workers, the badges may not have recorded all of the occupational exposure of the worker during the given time period. In view of the potential for missed dose in badges with non-zero readings, NIOSH's conclusion that dropping badges with zero readings "overestimates the true dose" is not statistically supportable, especially as NIOSH has so far identified only one worker who remembers wearing his badge whenever he was in radiation areas. This is clearly insufficient as a basis for establishing a statistically valid approach, even for workers in the same job category as this individual.

A claimant-favorable approach to dose reconstruction not only involves dropping zero dose readings from the analysis (which is a necessary first step), but also requires the development of a statistically valid procedure for estimating the missed doses in the non-zero badge readings.

Adjusting the dosimeter records for the missed dose due to erratic wearing of film badges requires the following steps:

- The fraction of time during the work year that workers who had non-zero film badge readings wore badge needs to be estimated, along with a measure of the variability of that time estimate.

- The typical radiological conditions (i.e., dose rates) prevailing at the times when badges were worn relative to the times when they were not need to be established.

- The above information needs to be classified by job category, so that the proper adjustment factors can be applied to the records of the claimant for whom the dose reconstruction is being done.

These factors are likely to be very difficult or impossible to estimate for IAAP.

A final aspect of the available film badge records is that it is unclear whether IAAP had adopted the practice of cohort badging. The job number and partial classification data gathered by University of Iowa researchers indicates that this may have been the case. The assumption in the TBD that "workers who directly handled radioactive materials at IAAP are expected to have been routinely monitored and dosimetry data should be available" was made without analysis of the possibility of cohort badging at IAAP.

***Finding 5: It may not be possible to accurately determine external doses from Am-241, due to the low sensitivity of the film badges to the low-energy photons emitted by this radionuclide***.

Some film badges of that era employed a filter of 1 g/cm$^2$ of lead. The calculated attenuation of 60 keV photons by such a filter is over 98%. Hence, we have some doubt that the recorded external $H_P(10)$ dose from Am-241 can be determined with any reasonable certainty. This issue applies to both post-1962 and pre-1963 dose reconstructions because the 1962–1974 film badge data are used to derive the work factor, which is an integral part of the model developed in the TBD to address 1949–1963 dose reconstructions.

***Finding 6: Film badges worn on the lapel or collar may not accurately represent organ doses. Adjustment factors are therefore needed for organ doses.***

In the July 29, 2004, worker outreach meetings conducted by NIOSH, the issue of the location of the organ relative to the dose and the location of the badge was brought up by the workers:

> *Workers reported experiencing heat and tingling in the pelvic area and legs when working in close proximity to the pits and weapons. Badges were issued to workers in these areas, but the badges were worn on the collar, not the pelvis.*

Furthermore:

> *Dosimeter badges were approximately 2 inches in length and 1 inch wide. Dosimeter badges were generally worn on collars (lapels), however, most of the work and materials were at waist level or below.*

SC&A raised this issue with NIOSH during the conference call of April 13, 2005. NIOSH agreed that organ-specific correction factors needed to be developed to account for the organ-versus-film badge geometry issue. NIOSH has estimated that a factor of 2.5 would apply to organs in the pelvic area.

The adjustment factor would vary by organ and would apply to Line I workers on the assumption that they were exposed only to the pit they were working on. However, Line I workers may have been exposed to more than one pit at a time. Finally, SC&A has not investigated whether adjustment factors may be necessary for other workers, such as security guards, in part because the data for such an analysis do not exist.

***Finding 7: The IAAP TBD did not consider all relevant and significant sources of data and information important to dose reconstruction. In general, there is an over-reliance on theoretical modeling for purposes of deriving upper-bound estimates at the expense of identifying and applying available radiological and operational information to achieve "a substantial basis of fact," as stipulated by 42 CFR 82.***

Site expert interviews indicate that the following relevant records were generated during the operation of IAAP and were transferred to Pantex in 1974:

- Landauer film badge dosimeter design and calibration information (available from Landauer, according to company personnel). *Significance: It may be possible to confirm actual dosimeter specifications and response from company records.*

- Battelle neutron dose rate and spectral measurements (identified by SC&A and requested from Battelle on April 7, 2005). *Significance: The neutron-to-photon ratios derived from Pantex data are surrogates for neutron dose rate and spectral measurements at IAAP, which the Battelle measurements can provide.*

- Contamination and area radiation survey records. *Significance: Interviewed workers attest to the routine workplace surveys that took place; these measurements would enable an assessment of potential sources of radiation exposure over time, would serve to complement the relatively small number of intermittent film badge readings in the early years, and would enable an assessment of radiation fields in production areas where multiple pits were being handled.*

- Routine facility swipe test data. *Significance: Would confirm or refute the TBD assertion that there is no evidence of surface contamination of assemblies and pits, and no breaches of pit cladding.*

- Routine bioassay records. *Significance: Would validate the dose assessments based on workplace concentrations of tritium and the strip chart air monitoring results.*

- Production and safety standard procedures. *Significance: Would ascertain prescribed worker procedures regarding assembly and disassembly of devices, and pit storage requirements, and would clarify radiation protection and monitoring practices.*

- Classified incident reports. *Significance: The paucity of reported production-related radiological incidents at IAAP (those reported as radiation-related typically involve radiography incidents), as compared with the comparable Pantex operational history, may be suggestive of an incomplete record of such occurrences, some of which may have been classified on national security grounds.*

A number of these records were not identified, requested, nor reviewed by NIOSH for their significance to the TBD and to dose reconstruction. According to NIOSH, some of these may have been “mis-boxed” at Pantex, and therefore not yet located.

Additional records sources that should be pursued include the TN&Associates repository in Oak Ridge, Tennessee; the Rock Island Arsenal Archives in Illinois; and records collections at Rocky Flats, the Y-12 Plant, the Savannah River Site, and the DOE Albuquerque Operations Office. A comprehensive classified review of IAAP records held at Pantex would be important to ascertain the status and availability of key records.

***Finding 8: SC&A’s classified review substantiated the basis for the use of the 1993–2003 Pantex neutron-to-photon ratios as a claimant-favorable surrogate for IAAP neutron dose estimates. However, workers whom we interviewed said that neutron dose rate and spectral measurements had been taken at IAAP by a DOE laboratory. The lack of a review of actual IAAP data raises concerns both about the accuracy and reasonableness of the neutron-to-photon ratio proposed in the TBD and about the completeness of NIOSH’s document research.***

According to Section 6.2.2 of the TBD, the neutron film badge dosimetry employed at IAAP was inadequate and the neutron contribution to doses from HEU and weapons-grade plutonium was significant. Figure 6.2 of the TBD shows 129 neutron-to-photon ratios that range from about 0.03 to about 0.6, with a GM of 0.135 and a GSD of 2.02. Furthermore, according to the TSD, the measured neutron-to-photon ratio is likely to be an underestimate because the NTA film did not accurately measure the dose delivered by neutrons with energies less than 800 keV. (In fact, the NTA film has a lower neutron energy threshold of about 700 keV and has limited sensitivity to neutrons below about 1 MeV.) Based on MCNP calculations of the generic pit, and a further claimant-favorable adjustment, NIOSH doubled the GM of the neutron-photon ratio to 0.27, and assigned a rounded value of 2.0 to the GSD.

As indicated in Section 6.5.4 of the TBD, NIOSH also reviewed the neutron-to-photon ratios observed at Pantex during the period of 1993 through 2003. Figure 6.9 of the TBD indicates that the neutron-to-photon ratios tend to follow a lognormal distribution, with a GM of 0.79 and a GSD of 1.57. According to NIOSH, these neutron-to-photon ratios are conservative for the purpose of dose reconstruction at IAAP because the photon doses at Pantex were measured with TLDs worn below lead aprons. As a result, the photon dose is reduced, resulting in a neutron-to-photon ratio that is biased high. On this basis, NIOSH elected to use the Pantex-based neutron-to-photon ratios with a GM of 0.79 and a GSD of 1.57 for reconstructing neutron doses at IAAP.

The neutron dose derived in this manner is then adjusted by the ICRP 60 neutron weighting factor, which is a function of the neutron energy spectrum. As noted in the TBD: ". . . the neutron energy distribution for the generic pit was relatively evenly split between the fission and fast neutrons." In the case of a real pit, the cladding would slow the fast neutrons, causing a downward shift in the neutron energy spectrum. NIOSH therefore made the claimant-favorable assumption that fission neutrons (with energies of 0.1–2 MeV) would account for 100% of the neutron dose. The ICRP 60 correction factor of 1.91 for fission spectra neutrons was therefore applied to the estimated neutron doses.

However, NTA dosimetry records are not the only data available for reconstructing neutron doses at IAAP. From interviews with former workers, SC&A learned that Battelle Northwest Laboratory (now Pacific Northwest National Laboratory) had performed actual measurements of neutron spectra and doses at IAAP during production operations. NIOSH subsequently contacted a PNNL health physicist who interviewed one of two Battelle researchers on what was confirmed to be a multi-year survey of neutron spectra measurements conducted at a number of DOE nuclear weapons facilities. In a memorandum to file dated April 6, 2005 (see Attachment 7), it is noted that:

- One of the first trips to IAAP to measure neutron dose rates from pits and weapons assemblies took place in 1972
- Some of the information regarding the neutron dose rates measured in this and subsequent trips to IAAP may be classified
- Measurements were made with "rem-meters, TEPCs [tissue equivalent photon counters], and multi-spheres"
- Neutron measurements were recalled as being "comparable" to those taken at Pantex.

NIOSH has confirmed that a neutron dosimetry analysis by Battelle did take place at IAAP. It informed SC&A that it was attempting to retrieve available data. The discovery by SC&A of a crucial record of IAAP data raises questions regarding the comprehensiveness of the NIOSH data review and whether the data set being used is sufficiently complete. NIOSH has indicated that the use of the Pantex neutron-to-photon ratio is more claimant favorable than the use of the Battelle data. However, the existence of actual dosimetric data raises the question of whether it is scientifically supportable to use Pantex data in preference to IAAP data to estimate neutron doses at IAAP, given that 42 CFR 82 requires that preference be given to actual measurements over surrogate data in the hierarchy of dose reconstruction.

***Finding 9: External dose estimates for unmonitored workers are claimant favorable for non-radiological workers. They are not scientifically valid or claimant favorable for unmonitored workers who were frequently in the proximity of radiological materials.***

The TBD states that external exposures were experienced primarily by personnel who worked in facilities at Line I, the Yard C storage area, the Explosive Disposal Area, and the Firing Site, and that these workers represented only a small fraction of the workers at the facility. Film badges were used for area monitoring at a number of locations, including various assembly buildings, Gravel Gerties, and Storage Igloos. Dosimeters used for area monitoring were collected bi-weekly from 1962 to the end of operations. About 70% of the badges in the non-storage areas had readings less than the minimum detection limit (MDL) of 10 mR. Figure 4.1 of the TBD plots the cumulative probability distribution of the biweekly exposures and reveals a GM of 6 mR per 2 weeks with a GSD of 4.6. Assuming 2,080 work hours per year, worker external exposures for those years had a GM of 37 mR/y and a GSD of 4.6. In order to give the benefit of the doubt to the claimant, the TBD suggests that the dose reconstructor may also assume an upper-bound dose of 260 mrem/y for unexposed (non-Line I) workers.

As applied to individuals who are believed to have had job responsibilities with little potential for occupational facility external exposure, this approach appears to be scientifically correct and modestly claimant favorable for the years during which these environmental measurements were made. The extent to which these doses apply to years prior to 1962, however, is uncertain. SC&A also questions the scientific basis for using dosimeter MDL values as a means for deriving the “upper-bound” environmental dose of 260 mrem/yr for “non-line 1” workers. The use of this value is not claimant favorable for storage area workers, who were not monitored.

Figure 4.2 of the TBD presents area dosimetry data collected from 1962 to 1974 for the Fissile Material Storage Area. Discussions with NIOSH regarding the storage areas revealed that these readings, which ranged from about 100 mR to 2,000 mR over any given 2-week period, were taken from within the storage areas (i.e., Storage Igloos), and that these storage areas were only occasionally entered by workers to retrieve and replace pits, and for inventory purposes. However, another group of IAAP workers was exposed to significant, and possibly higher, levels of radiation during many of their working hours. These were security guards who would likely have spent much of their time inside the Storage Igloos, as attested by the interviews summarized in Attachment 4. The maximum exposure of a security guard whose post was in the location that had the highest recorded readings could have exceeded 10 R/y. Moreover, it is our understanding that such individuals were not classified as radiation workers and therefore were not monitored. The TBD makes no reference to this group of individuals and their significant potential exposures.

***Finding 10: The radon concentrations presented in the TBD are not scientifically valid or claimant favorable, due partly to a scientifically incorrect choice of data from Pantex in Texas for use in Iowa, which has much higher radon levels than Texas.***

The only available radon measurements at IAAP were conducted between 1989 and 1991, over 15 years after the period of operations. Since the measurements cannot be linked to specific buildings, these data cannot be used for dose reconstruction for workers who occupied the Gravel Gerties. However, according to the TBD, the mean, the standard deviation, and the GM of these measurements are less than a comparable set of measurements from Pantex. NIOSH therefore adopted radon levels measured in underground buildings at Pantex as surrogate data for calculating radon exposures of IAAP workers in the Gravel Gerties. These radon concentrations have a GM of 1.51 pCi/L and a GSD of 1.75.

However, radon levels in structures are highly dependent on the specific geographic locations. In light of the regional and even local variations in radon levels, the assumption that measured radon levels at Pantex are representative of the radon levels at IAAP, which is stated in the TBD, is not warranted. This is especially so in light of the fact that Iowa has high background radon levels; by contrast, Texas has relatively low radon levels, according to William Field of the University of Iowa (Field 2005).

Data gathered by the Iowa Department of Public Health and by Dr. Field (Field 2005) indicate that radon levels of several hundred picocuries per liter are quite plausible for the Gravel Gerties:

> *The Iowa Department of Public Health has numerous documented indoor radon gas concentrations in Iowa exceeding 400 pCi/L. . . I have personally measured many underground service tunnels and crawl spaces in Iowa that exceed 200 pCi/L.*

However, no firm or statistically supportable value can reasonably be established without building a structure that would closely resemble the Gravel Gerties and actually carrying out radon measurements over a suitable period of time. Dr. Field (Field 2005) believes that 10 pCi/L is the "lowest possible value" of radon level that can be used to make minimum dose estimates for IAAP:

> *Based on what we know about radon occurrence in Iowa in underground structures, over 50% exceed a year-long average radon concentration of 4 pCi/l. Given the construction of these facilities I would use 10 pCi/L as the lowest possible value. We do not know about ventilation patterns so that is a real unknown.*[6]

Further information is found in the *National Residential Radon Survey* (EPA 1993). According to this EPA report, Iowa has the highest average levels of indoor radon in U.S. households. The report presents the results of a survey that included measurements made in 5,694 homes, drawn from a survey of 11,423 homes. This population was drawn from an eligible universe of nearly 72 million households out of the 93 million households in the United States. EPA collected data

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[6] Dr. William Field, personal e-mail communication with Arjun Makhijani, May 27, 2005.

in three categories: (1) lowest lived-in level; (2) average concentration over all lived-in levels; and (3) average concentration in the lowest level of non-living space. The average for Iowa is 3.64 pCi/L, while the average for Texas is 0.83 pCi/L, which is among the lowest in the country.

In view of the above considerations, SC&A concurs with Professor Field's recommendation that 10 pCi/L be used as the radon concentration for minimum dose calculations. No reasonable dose estimate or upper-bound estimate can be made for the Gravel Gerties, given the lack of site-specific data and the special nature of the structures.

***Finding 11: Assumptions about worker exposures to medical x-rays are not uniformly claimant favorable.***

According to the TBD, the dose reconstructor should assume that (1) all workers received an annual posterioanterior (PA) chest x-ray from 1947 through 1975, (2) assembly workers received semi-annual PA chest x-rays, and (3) radiography workers received quarterly PA chest x-rays. If the job description is not known, the dose reconstructor should assume semi-annual PA chest x-rays. The dose reconstructor should employ the standard organ doses provided in ORAUT-OTIB-0006 (ORAU 2003) for different time periods of employment. Table 3.2 of the TBD lists the parameters of lognormal distributions of doses to various organs of workers who are assumed, on the basis of their job category, to have received lumbar spine x-rays at IAAP. The guidance for reconstructing occupationally related medical x-ray exposures was based on information gathered during the worker outreach meeting, limited IAAP records, and an assumption that medical x-ray practices at IAAP were similar to those at Pantex and Rocky Flats.

For the most part, this guidance seems reasonable, claimant favorable, and consistent with other site profiles. However, given the time frame of facility operation, there is good reason to believe that fluoroscopic examinations may have also been employed in the early period. If such examinations were employed, the exposures could have been substantially higher than those described in the TBD. In addition, we are concerned about the examination frequency that is most appropriate when a worker cannot be assigned to a specific worker category. It would be more appropriate to give the claimant the benefit of the doubt by assigning a dose corresponding to a quarterly chest x-ray rather than a semi-annual one.

***Finding 12: Tritium exposure estimates are exceedingly claimant favorable, but some of the assumptions that yield the higher dose estimates are not scientifically valid.***

According to Section 5.1 of the TBD, tritium reservoirs were shipped to IAAP beginning in 1954. NIOSH assumes that Line I workers experienced tritium intakes every year from 1954 until 1975. Since no bioassay data are available, NIOSH employs (1) air-sampling data gathered at IAAP from 1959 through 1964, (2) models simulating the handling of the tritium containers, and (3) experience and data gathered at the Pantex facility in the 1970s and 1980s, as the basis for estimating tritium intakes at IAAP. NIOSH explains that information gathered from interviews with a radiation safety engineer at Pantex (who also worked for a time at IAAP), and process similarities between the two facilities provide reasonable assurance that Pantex data can be used as a surrogate for tritium exposures at IAAP.

For tritium, NIOSH developed a model that assumed two sealed tritium containers (referred to as "JP containers") were vented per day, and that the head space, which had a calculated volume of 0.0136 $m^3$, had a tritium concentration equal to the release limit of 90 uCi/$m^3$. Based on these data, the daily release rate was calculated to be 2.445 uCi, and was assumed to be uniformly mixed in the interior volume of the Gravel Gertie, which was 437 $m^3$. A bounding air concentration of 2.043 µCi/$m^3$ was derived by assuming no building ventilation and a continuous buildup of tritium over 1 year. Workers were assumed to have a breathing rate of 1.2 $m^3$/hr and to be exposed to this concentration for 2,000 hours per year. This resulted in a tritium intake of 4,902 µCi/yr and an effective dose of 0.331 rem/yr, assuming that the tritium was in the form of water vapor. NIOSH believes that this model of tritium exposures is conservative, because two urine samples analyzed biweekly from selected individuals who worked in areas with high potentials for tritium intake did not detect tritium intakes. If the exposures postulated by the models had occurred, the TBD states that positive results would have been observed in the bioassay program. For these reasons, NIOSH believes that the hypothetical models for tritium intake by Line I workers place an upper bound on the potential exposures. Furthermore, the TBD states that if tritium intakes occurred, they were likely primarily elemental tritium, as opposed to tritiated water. This assumption is characterized in the TBD as a further conservative assumption embedded in the analysis.

On the assumption that the quantities of tritium released during operations were, in fact, accurately characterized in the TBD, SC&A concludes that the methodologies employed in the TBD to reconstruct historical tritium exposures to Line I workers represent a bounding analysis that is highly claimant favorable. The below-MDL results for the two urine samples also provide a marginal basis for supporting the conclusion that NIOSH's model for tritium dose is claimant favorable. However, the assumptions of complete oxidation, no removal of tritium by ventilation, and that all the tritium remained within the structure are not scientifically reasonable. Claimant-favorable dose estimates could be made without such extreme assumptions.

# 6.0 OBSERVATIONS

1. No mention is made in the TBD (ORAU 2005) of the extensive use of "flash x-ray" technology, which was used during hydroshots to perform high-speed diagnostic analyses of high explosives at the moment of detonation. NIOSH needs to ascertain whether the energies involved were detectable by the film badge dosimeters that were worn by the radiographic operators during the period when this equipment was used at IAAP.

2. The accuracy of air-sampling techniques employed during the hydroshots and in the FS-12 tunnel requires further evaluation. The methodology used to collect and analyze the air samples has an impact on the results. For example, use of wet chemistry for analysis of filters versus counting with a scintillation detector would result in different values if appropriate correction factors were not applied.

3. Trace amounts of plutonium were detected in IAAP drummed waste, raising questions regarding incidents or circumstances where the encapsulation of pits may have been breached. A routine environmental survey conducted by T N & Associates, Inc., (TN&A 2001) noted that waste being shipped to Pantex contained trace amounts of plutonium (estimated at a concentration level of 16 mg/kg). While the source of this contamination may have been discarded swipes or analytic samples, the presence of fissile material, regardless of amount, brings into question the assertions that no instances can be identified where encapsulated pits had been breached, and that no weapons assemblies or components were received with surface contamination. A review of available records, both classified and unclassified, has yet to identify the likely source of this contamination. NIOSH should perform a further document review to resolve this issue.

4. Section 5.4 of the TBD mentions encapsulated sources of enriched uranium, thorium, and "perhaps" Po-210, yet there is no subsequent treatment of those radionuclides in the discussion of external doses. For example, as stated on page 34 of the TBD, some weapons may have contained $^{210}$PoBe initiators with the capsule or the pit. There is no mention of how this may affect external exposure or the neutron energy spectra. Also, there is no mention of what was done with those radiation sources after disassembly. NIOSH notes that these sources were encapsulated or sealed. Therefore, it was assumed that they were not sources of air contamination or resuspension that could lead to internal radionuclide deposition. However, the possibility of nicking the pits during handling or the possible presence of tramp uranium and plutonium on the surface of the pits indicates that workers may have been internally exposed to other radionuclides besides tritium and DU. Furthermore, the fact that these sources were encapsulated does not preclude the presence of tramp material, which may have significantly contaminated exterior surfaces. The NIOSH assumption of "careful control of contamination *before* release of components to production. . ." [emphasis added] does not preclude internal exposures. This conclusion requires verification of the procedures used before the pits were handled and weapons were assembled, especially since bioassay data have not been recovered. In addition, swipe samples apparently were collected from the pits, but the results were not reported; nor were the limits of detection reported for the swipe samples for the radionuclides of interest (i.e., isotopes of uranium, plutonium, and thorium). Uncertainty

about internal doses from incidents therefore remains an issue. Resolving this issue would require documentation about screening of surfaces for the presence of tramp material, knowledge of engineering controls in work environments, and whether respirators were used to eliminate this uncertainty in the absence of routine bioassay data (except for tritium).

5. In the interest of efficiency, NIOSH uses assumptions that are sometimes excessively conservative and scientifically implausible. One example, cited in Finding 12, are the models used to reconstruct the doses to environmental releases of tritium and the tritium doses to Line I workers inside the Gravel Gerties. As another example, on page 31 of the TBD, the mass of oxidized DU is estimated by multiplying the volume of the dust by 11 $g/cm^3$, the density of solid $UO_2$. The bulk density of the loosely packed powder, however, is less than 2 $g/cm^3$. Although this assumption is claimant favorable, it is not scientifically valid.

6. In Section 2.2.2, the TBD contains the following statement from a report identified as Mitchell 2003:

> *. . . it was the military's responsibility to mate the AEC-delivered warhead to the military's delivery system, usually a missile.* ***Working two 12-hour shifts, (seven days a week)*** *at the Burlington Plant, this* ***new*** *design entered the stockpile in December 1956 in an* ***"Emergency Capabilities"*** *status as the W-25 warhead.* [Emphases added.]

   NIOSH assumed a work year of 2,000 hours in deriving the work factor used to estimate pre-1963 external doses. The actual work year would not matter if the work hours were the same in the pre-1963 and post-1962 eras. The statement quoted above calls this assumption into question.

7. The assessment of exposures to DU in the TBD includes a number questionable assumptions and parameter values. In Section 5.2 of the TBD, NIOSH explains that workers may have been internally exposed to airborne particles of DU as a result of (1) disassembly of old DU bomb parts, (2) hydrotesting (which involved the implosion of simulated weapons made of DU), and (3) machining of baratols, which are the explosive charges that encased the DU pits. As explained in the TBD, very little air sampling was done to monitor exposures of workers to airborne DU, because DU was believed to be relatively non-radiotoxic. SC&A has the following observations about NIOSH's DU dose estimation assumptions and procedures:

   - On page 27 of the TBD, it is stated that DU particle sizes have a lognormal distribution of 0.1 to 1 µm, yet the assumed size is 1 µm. The GM of such a distribution is about 0.3 µm. ICRP has published dose coefficients for this particle size—the effective dose from inhalation of Type M U-238 is about 50% greater than for 1 µm AMAD. Using 0.3 µm would result in dose estimates that are larger by a factor of 2. Hence, the choice of 1 µm is not scientifically valid or claimant favorable.

- The use of the 1974 resuspension data, as described on page 28 of the TBD, is not necessarily claimant favorable, because DU deposited in prior years had time to "weather in"—be eroded, washed away, or move downward into the soil. Therefore, the dust loading due to resuspension in 1974 is likely to underestimate the resuspension factor and associated dust loading for earlier years.

- Section 5.2.2 of the TBD addresses potential internal exposure to inhaled DU due to the machining of baratols. Barotols were the plastic explosives that encased the DU spheres that simulated real weapons. During machining of baratols, some of the DU frequently became nicked and aerosolized. The machining of barotols was replaced by pressing of explosives in about 1962. The TBD explains that inhalation exposures via this pathway were likely small and intermittent, when compared to other DU exposure scenarios. In order to place an upper bound on the possible exposures associated with nicking, the TBD assumed that the DU dust loading was 2% of the maximum permissible concentration for 20 hours per week. These assumptions appear to be somewhat arbitrary. They should be documented. In the absence of documentation or analysis, there is no assurance that they represent a reasonable upper bound for this scenario.

- On page 30 of the TBD, the assumed ingestion rate is inconsistent with the EPA *Exposure Factors Handbook* (EPA 1997) and is much lower than typical values recommended for use in site assessment.

- Section 5.2.3 of the TBD states, "The median airborne release fraction was 3 x $10^{-4}$ and the median respirable fraction was 0.5; the upper bound values for the same parameters were 2 x $10^{-3}$ and 0.3." This statement, which is copied from the DOE Handbook, contains a self-contradiction. If the median fraction was 0.5, how can 0.3 be an upper bound? Table A.41d of the Handbook reproduces the published experimental data. These data show a maximum airborne fraction of particles of respirable size = $5.9 \times 10^{-4}$ from 1 kg of "DUO" dropped from a height of 3 m. The details of the ash collection are unknown; the handling may have stirred up dust as the ashes were swept into bags, etc. Consequently, the highest observed airborne fraction of respirable particles should be used as a fixed, conservative, claimant-favorable value. This is about the same value as the upper bound cited in the TBD, but is four times the median value.

- Section 5.2.4 of the TBD states that the median value for the airborne release fraction for the free fall spill of $UO_2$ from a height of 1 m is 0.00008. Given the assumed particle size (respirable fraction of 0.5), this value for the release fraction seems unreasonably low. Is the DOE value selected for $UO_2$ airborne release derived from experiments? Why is it much lower than the values given in the TBD for ash from DU burning (page 30 of the TBD), although the citation is the same? Also, the upper-bound value for the respirable fraction for DU ash is less than the median value. This is an error.

- On page 31 of the TBD, the median value of the 1-m spill data is not claimant-favorable inasmuch as the 3-m data have a maximum respirable release fraction that is 15 times higher. The assumptions about the volume of air and the exposure duration are unsupported. The dispersion is the result of handling and processing the material—a person performing this work would experience a higher air concentration than if the dust were uniformly dispersed in a medium-sized room, as is assumed in the TBD. There is also no justification for limiting the exposure to 1 hour per day. The DU intake could be much higher than is estimated by the TBD, especially since the value is treated as a constant upper bound.

- External exposures of workers to DU are discussed in Section 6.2.3 of the TBD. NIOSH used MCNP to model the bremsstrahlung spectra from U-238 spheres, which are depicted in Figure 6.3. NIOSH appears to have made the same error as in other site profiles, in that it assumed that only the bremsstrahlung from beta rays emitted by Pa-234m, a member of the short-lived progeny of U-238, contributes to the external dose. In fact, as was documented in the SC&A report: "Audit of Case No. 1 from the Blockson Chemical Company" (SC&A 2004a), omitting the γ-rays emitted during the decay of the short-lived progeny of U-238 could lead to an 80% underestimate of the organ dose. This observation pertains to the scientific accuracy of the NIOSH analysis—NIOSH did not utilize these results in its assessment of external exposure to DU at IAAP. NIOSH did cite the results of an analysis of the external dose from a semi-infinite slab of natural uranium metal—certainly a limiting case for the present analysis. The $H_p(10)$ dose rate was 2 mrad/h, while the $H_p(0.07)$ dose rate was 230 mrad/h. The $H_p(10)$ doses would most likely be recorded by the film dosimeters, while the $H_p(0.07)$ doses, primarily due to β-rays and low-energy, may not have been recorded.

- Skin and extremity doses are not explicitly addressed in this revision of the TBD, but are held in reserve for future consideration (see Section 6.5.5 of the TBD). In light of the analysis cited in Section 6.2.3 of the TBD, it appears that external exposure to DU is not an important contributor to the deep dose as compared to the other sources of photon exposures. However, skin and extremity doses appear to be potentially significant and are to be the subject of a future revision to the TBD.

- One of the scenarios that could have resulted in the intake of airborne particles of DU was hydroshots performed at the South Firing Site 6 (FS-6). During these tests, most personnel were about 1 mile away from the test, but some personnel were located in bunkers close to ground zero. After the tests, the personnel in the bunkers drove to the test site to retrieve instruments. These workers did not wear respirators. The TBD states that several hundred hydroshots were performed, with only a limited amount of air sampling. The highest airborne DU concentration, 21.82 µg/m$^3$, was observed in the FS-12 tunnel that connected ground zero to the bunker; the highest airborne concentration at 100 m from ground zero was 9.12 µg/m$^3$ (see Table 5.2 of the TBD). These measured airborne concentrations were used to derive the intakes of DU by personnel at the FS-12 tunnel, at 100 yards, and at 1 mile from the shots. The exposures from each of the several hundred hydroshots were estimated by assuming that each exposure lasted 30 minutes and that the breathing rate was 1.2 $m^3/h$. The TBD provides no rationale for the duration of the exposure, nor is it apparent that the limited number of measurements is representative of the DU airborne concentrations experienced by the workers.

- Section 5.2.1 of the TBD describes methods used to derive the airborne DU levels at other locations at the site. However, the methods described in the TBD do not appear to follow conventional atmospheric dispersion modeling. As a result, it is difficult to judge whether the approach is scientifically valid and claimant favorable.

- The potential for inhalation of resuspended particles of DU during recovery of instruments and the potential for inadvertent ingestion of DU are discussed in the TBD. Inadvertent ingestion due to contamination of hands (page 28 of the TBD) was assessed using an ingestion model that SC&A believes is technically flawed. NIOSH should consider the information provided in EPA's *Exposure Factors Handbook* (EPA 1997). The exposures associated with resuspension were estimated using air-sampling data; exposure durations and Lung Clearance Types appear to be scientifically valid and claimant favorable.

- Work areas where workers picked up and handled pieces of DU are described in the TBD. The description indicates that there may have been a significant potential for shrapnel to penetrate the skin and become lodged in the body. Such incorporation of small pieces of metal may be a source of long-term exposure. For instance, a 10-mg spherical DU metal particle has a radius of only 0.5 mm. This would mean a one-time incorporation of a small fraction of the DU that got onto the hands every time there was a clean-up task would result in a non-negligible body burden. NIOSH estimates hand contamination of 76 mg per clean-up task (page 28). The possibility that frequent cleanup of DU metal may have resulted in significant body burdens needs to be evaluated for IAAP. This evaluation is especially necessary in light of the abnormally high rate of urinary cancer that has been reported by the workers in the NIOSH July 29, 2004, worker outreach meetings.

- Section 5.2.3 of the TBD presents the methods used by NIOSH to estimate the inhalation exposures to workers who bagged the ash produced as a result of burning about 2,000 g/y of DU contained in scrap explosives. It was assumed that about 10 g of DU were bagged per workday. The TBD presents a series of assumptions for predicting the fraction of the bagged DU that may have become airborne during bagging. Many of the assumptions appear to be rather arbitrary since data and scientific analysis are not provided to support them.

# 7.0 COMPLETENESS, ACCURACY, AND DATA ADEQUACY

## 7.1 COMPLETENESS OF DATA

NIOSH has investigated a number of classified and unclassified sources of data and archives in preparing the TBD (ORAU 2005). However, as discussed in Section 5 of the present report, there are a number of sources of data that NIOSH failed to utilize in preparing the TBD. For instance, NIOSH did not use available information on radon in tightly sealed indoor structures in Iowa.

Based on worker interviews conducted by SC&A and an inventory of available records maintained at Pantex, we have concluded that the classified documents provided to SC&A in support of this review do not constitute a complete set of references needed to adequately evaluate the TBD for technical adequacy and completeness of data. A number of interviewees identified key documents that were compiled during the 1949–1974 history of the plant that either have not been located or have not been made available for review. This information includes bioassay data, early film badge dosimetry data, complete radiation and contamination survey data, production and radiation safety procedures, and criticality safety specifications. It is also not clear if additional radiological incident reports, including classified ones, exist for the periods in question and, in particular, before 1959, for which period no radiological incident reports have been located. NIOSH has indicated that earlier feedback from DOE suggested that some records may have even been misplaced as a result of “re-boxing” of IAAP records at Pantex.

Recognizing this significant shortfall, SC&A made a formal request to NIOSH for expedited access to such information, whether classified or unclassified, in a letter dated April 11, 2005 (provided as Attachment 2). A response to this request has not yet been received. It has been rendered moot for most claimants by the decision of the Advisory Board to recommend an SEC for IAAP AEC workers from 1949 to 1974. However, these data will be useful in reconstructing doses for non-SEC cancers.

## 7.2 TECHNICAL ACCURACY

In several areas, NIOSH has adopted reasonable, claimant-favorable approaches to dose estimation. Examples may be found in NIOSH’s approach to some aspects of DU and tritium exposure. However, in other areas, NIOSH’s approach is not scientifically valid even when it is claimant favorable, as in the estimation of tritium doses in the Gravel Gerties.

The most important issue of technical accuracy relates to the generic pit model. As discussed in Section 5 of the present report, SC&A’s classified review corroborated the TBD analysis that the generic pit dose *rate* represents an upper-bound estimation for workplace external radiation fields at a distance of 1 m from a single pit for the pre-1963 period. However, the use of the work factor is questionable on scientific grounds. Furthermore, the use of the generic pit model results in a large discrepancy in the calculated external doses for the pre-1963 period, compared to the external doses, based on dosimetry data, during later periods.

As discussed in Finding 3 (Section 5), the use of the generic pit model for estimating external doses in 1949–1962, and the use of film badge data for later years, produces a sharp discontinuity in the external dose estimates for 1963 and later years. The result is that inequities are introduced into the dose reconstruction for post-1962 workers that are a result of the use of very different methodologies for the two time periods. The pre-1963 methodology was adopted because of the paucity of film badge data for those years, and because the detailed data on the nuclear weapons handled at IAAP during that time are classified. Thus, the dose reconstruction model for the earlier years is neither realistic nor scientifically valid.

The accuracy of external dose reconstructions is further compromised by the method of analyzing the film badge data, as discussed in Section 5 of the present report. The method of dropping zero badge readings, as described in the TBD, does not assure that missed doses due to erratic use of film badges by radiological workers would be captured in a scientifically valid manner. We also question the use of the lognormal distributions derived from these data, which are not claimant favorable for workers whose jobs subjected them to radiation exposures near the high end of the distributions.

Finally, the use of Pantex photon-to-neutron dose ratio, while claimant favorable, does not meet the test of technical accuracy, since NIOSH failed to use available Battelle measurements on neutron dose that were made at IAAP.

## 7.3 DATA ADEQUACY

The film badge data are inadequate for accurate dose reconstruction that would give claimants the benefit of the doubt in the face of substantial uncertainties. This is because:

- Only a limited number of radiation workers were monitored prior to 1968.
- Many exposed workers, including security guards, were never monitored.
- Cohort badging may have been practiced, which precludes an assumption that the workers most at risk were monitored.
- Missed doses due to erratic use of film badges cannot be estimated due to lack of data.

## 7.4 COMPLIANCE WITH REGULATIONS AND PROCEDURES

As described in Sections 5 and 7.2, the generic pit model used for dose reconstructions for pre-1963 workers was adopted because of the paucity of film badge data for those years and because the detailed data on the nuclear weapons handled at IAAP during that time are classified. This raises the question whether these assessments constitute “reasonable estimates” of radiation dose, as defined by 42 CFR 82. The regulation specifies that, “estimates [are to be] calculated using a substantial basis of fact and the application of science-based, logical assumptions to supplement or interpret the factual basis.” SC&A believes that use of the generic pit model broaches a policy question of how “reasonable estimates” can be achieved, in accordance with EEOICPA and 42 CFR 82, when national security considerations take precedence. This issue is particularly important because of the inequities in the dose estimation of pre-1963 workers compared to those in the 1963–1974 period, stemming from the use of the generic pit model for the earlier period.

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# ATTACHMENT 1: KEY QUESTIONS FOR NIOSH/ORAU REGARDING SITE PROFILE DOCUMENTS

March 22, 2005

To: Paul Ziemer and Lewis Wade
From: John Mauro
Subject: TBD for the Atomic Energy Operations at the Iowa Army Ammunitions Plant (IAAP)

In order to expedite the review process for the IAAP TBD, SC&A has prepared an initial set of questions and requests for information. We would like to discuss these matters with representatives of NIOSH and the Board as soon as possible and hope to maintain an active dialogue with them throughout the expedited review process.

General Questions:

1. What is the basis for NIOSH's assertion that pre- or post-1962 film badge data are sufficiently representative to be used as a basis for "co-worker" dose assignment for high-energy photons or neutrons? Can any of the data collected be corroborated or verified?

2. NIOSH accepts DOE documentation that all enriched uranium, plutonium, thorium, and "perhaps Po-210," were encapsulated or sealed, and therefore unavailable for contamination or resuspension that could lead to internal depositions. Without routine bioassay data (except for tritium), regular contamination surveys, or workplace air monitoring results, from the early years, how can NIOSH substantiate this assumption? Did former worker interviews substantiate that there were no instances of radioactive resuspension or release?

3. It is indicated in the site profile regarding the unexplained Cs-137 contamination that "Mr. Shannan said he was unaware of any Cs-137 used at IAAP other than small sealed sources at uCi levels as instrument check sources." However, it seems plausible that either or both Cs-137 and Co-60 (another unexplained source of contamination) may have been used to detect voids in the high explosives (HE) that were produced and formed at IAAP, a common practice at other DOE sites. (A key concern at the time was the presence of "voids" within the explosive that would decrease its effectiveness.) Has NIOSH investigated how such voids were routinely detected using radioactive sources in that era at Pantex and Los Alamos? Assuming that such high activity sources were, in fact, in common use at the site, what potential contribution to worker dose can be assumed?

4. No work locations or job categories are provided in the IAAP profile. How can work factors (relative time spent in proximity to a pit) or even potential exposures (e.g., for specific work activities, such as burning DU) be estimated? Has NIOSH investigated and established any specific work locations or job categories for former IAAP workers that can be used in co-worker dose estimates?

5. If significant quantities of light elements were present in the plutonium pits (e.g., beryllium or oxygen), there could conceivably have been more neutrons released from alpha-n reactions than from spontaneous fission in the even-number plutonium isotopes. How did NIOSH take this possibility into account in its calculations?

6. Did NIOSH consider in its dose calculations the possibility of pits containing U-233 at the IAAP, and, if so, what range of U-232 contamination was assumed in its calculations? (There is evidence in the open literature that U-233 weapons were tested at approximately the same time period as the early years of IAAP operation.)

7. NIOSH assumed that plutonium pits would be considerably more radioactive than pits containing uranium as the fissile material. Therefore, the dose calculations presented in the TBD were based on plutonium pits. However, this assumption may not necessarily be bounding if uranium pits had been fabricated from uranium containing significant contamination from U-232.

8. Could NIOSH clarify the dates for weapons disassembly, assembly, and retrofitting at IAAP?

9. Why did NIOSH decide to use source-term data rather than radiological field data, such as radiation and contamination surveys, or a combination of both?

10. NIOSH mentions the existence of swipe data in the TBD. Where are the results of these data? Also, what was the methodology used to take swipe samples and analyze the swipes for trace levels of weapons grade plutonium? What was the lower limit of detection for WGP in the swipe samples? Did NIOSH evaluate what the potential inhalation and/or ingestion dose to weapons handlers may have been if the levels of surface contamination on the weapons were just below the limits of detection for swipe samples analyzed at that time?

11. What types of Radiation Generating Devices were used at IAAP?

12. On page 14 of the SEC Petition Evaluation Report, Petition SEC-0006-1, radium is mentioned as a radionuclide present at IAAP. Why was radium excluded from consideration in the TBD?

13. There have been suggestions in the press that a criticality accident may have occurred at IAAP. Has NIOSH investigated these claims? If so, what was the outcome?

14. We suspect that a great deal of experimental work in weapons development was performed in the late 1940s and throughout the 1950s. An example is the use of radioactive lanthanum as a means to evaluate the performance of the implosion device design. Since radioactive lanthanum is an extremely strong gamma emitter and was produced in large quantities at INEEL during the late 1950s, has NIOSH researched the possibility that some workers may have received external exposures that may have been uniquely associated with the early years of weapons experimentation and development?

15. What is the basis for the assumption that workers were 100 m away during burning DU? Furthermore, if workers were closer, the Gaussian diffusion approach used in Section 4.2.2 may not be valid. Did NIOSH evaluate other methods of estimating DU exposure?

16. Is NIOSH using a distribution of neutron to photon ratio of 0.27 with a GSD of 2.0 for its dose calculations as indicated on p. 38? If so, this does not appear to be claimant favorable, as claimed. The graph on p. 37 shows a 95 percent value from the empirical lognormal distribution of just over 0.4. When adjusted for the undercounting of 800 KeV neutrons of up to 40%, a reasonable upper bound based on this data would appear to be about 0.4/0.6 ≈ 0.67. Please explain in greater detail the choice of the parameters on p. 38 as claimant favorable. How are uncertainties arising from the use of area badges for individual dose calculations taken into account? How were considerations relating to the geometry of the area badge locations relative to the source taken into account in estimating the photon-to-neutron ratio?

17. NIOSH notes that the neutron dose ratio "greatly depends on weapon design" (p. 38). How has NIOSH assessed that the generic pit described in Appendix D gives a claimant-favorable value for neutron dose? Have classified computations been done to compare doses estimated for this generic pit to doses expected from actual designs used in the early period?

18. The lognormal fits of weekly dosimeter data from 1962 onward seem to systematically underestimate dose at the high end of the readings. Has NIOSH analyzed this issue? Furthermore, the removal of zero readings (Section 6.3.1) may not give a claimant-favorable value for the total dose, since the zero readings corresponded to workers not wearing badges during periods of potential exposure. Has NIOSH considered the development of an explicit upper bound missed dose for periods when zero doses were recorded and an associated procedure for integrating these doses into the total dose estimate?

19. The external dose from Th-232 decay products seems not to have been considered. If so, the bases for not including exposures from Th-232 should be provided.

20. Has NIOSH evaluated the potential dose from incorporation of DU metal slivers or shrapnel when workers handled pieces of metal to bag them?

<u>Specific Questions</u>:

21. p. 11. In Section 2.2.2 of the TBD, the following statement is quoted from a report identified as Mitchell 2003:

> *. . . it was the military's responsibility to mate the AEC-delivered warhead to the military's delivery system, usually a missile.* ***Working two 12-hour shifts, (seven days a week)*** *at the Burlington Plant, this* ***new*** *design entered the stockpile in December 1956, in an* ***"Emergency Capabilities"*** *status as the W-25 warhead.* [Emphases added.]

The IAAP TBD has modeled exposure to workers that assumes 2,000 hours per year as representative of an average annual working period. In light of the statement made by Mitchell (2003), 2,000 hours per year does not appear appropriate. Are there data available that would suggest a significantly higher number of working hours per year? (In the absence of data, a reasonable assumption might include a 12-hour per day work shift and a 60-hour workweek; an upper-bound value may include an 84-hour workweek.

***p. 11. In addition to the above-cited statement regarding "… the new design," Mitchell (2003) further stated in Section 2.2.2 of the TBD, that:***

> *The sealed pit design weapons precipitated several **fundamental changes** in the nuclear weapons complex. New facility designs were **required** and constructed at **Burlington** and **Pantex** to accommodate production work involving encapsulated SNM for the **first time at either site**.* [Emphases added.]

What was the scope of these "fundamental changes . . . [and] new facility designs" at both Burlington and Pantex? And, to what extent did these changes affect worker exposures that would raise questions about the use of post-1963 data for modeling pre-1963 exposures?

23. p. 16. For environmental dose assessment, Section 4.2.1 identifies annual onsite H-3 releases as being either 6,000 µCi/yr or 26,000 µCi/yr and for claimant favorability assumes the latter. For internal uptake by facility workers, Section 5.1 identified the bounding release value of 1.22 µCi from the headspace of a single JP container, which contained the tritium reservoir. Tritium air concentration was defined for a single Gravel Gertie into which 2 x 1.22 µCi were introduced each day; this would suggest the processing of >21,300 JP containers and at 730 JP container per year per Gravel Gertie involve the steady operation of 36 Gravel Gerties in order to account for the release of 26,000 µCi/yr. Was the release of H-3 from the headspace of JP containers the sole or primary source of H-3 release to the environment and source term for worker exposure?

22. p. 17. Section 4.2.2. NCRP calculation of airborne activity is based on average annual atmospheric dispersion values ($\chi$/Q values), not upper bound. A more conservative, 95th percentile value should be considered, such as that provided in Nuclear Regulatory Commission guidance, which lists default atmospheric conditions as Class F, u = 1 m/s. The values for these conditions, calculated according to the algorithm in the NRC code XOQDOQ, and assuming that the wind blows into the worst sector 25% of the time, are as follows:

| Q = 2.788e-4 g/s | TBD (u = 2 m/s) | | NRC (u = 1 m/s) | |
|---|---|---|---|---|
| Distance (m) | P | C (f = .25) | P | C (f = .25) |
| 100 | 3.5E-3 | 1.22E-07 | 3.07E-02 | 2.14E-06 |
| 500 | 2.00E-04 | 6.97E-09 | 1.96E-03 | 1.37E-07 |
| 1000 | 5.00E-05 | 1.74E-09 | 6.18E-04 | 4.31E-08 |

The assumption in the TBD that the calculated values represent worst-case assumptions is not correct. The NRC methodology (or some comparable method) should be used to calculate the 95th percentile values. As shown above, the increase in concentration is more than one order of magnitude. The 25% wind direction assumption is reasonably conservative.

25. p. 17. In Section 4.2.2, devoted to the environmental intake of depleted uranium from burning sites, the entire estimate of material handled in the burn yard, 2000 g/year, is assumed to be released to the environment. However, it is pointed out in Section 5.2.3 that airborne release fractions from burning depleted uranium are generally $10^{-3}$ or $10^{-4}$ (DOE 1994). Please explain the apparent contradiction.

26. p. 22. Section 4.3 defines ambient external radiation levels for "area radiation monitoring" at locations defined as (1) non-storage areas and (2) storage areas. Figure 4.2 defines area-monitoring data for the years 1963–1974. For Fissile Material Storage Areas, bi-weekly doses ranged as high as 2,000 mR or 6 mR/hr from photons alone. (Potential neutron doses could potentially double this dose rate.) Since it is reasonable to assume that the Fissile Material Storage Areas required continuous surveillance and monitoring by security personnel, as well as routine entry by other workers, the following questions are suggested: (1) How do the area dose rates depicted in Figure 4.2 relate to potential doses received by security personnel possibly assigned full-time to the four storage igloos?, and (2) Based on the shielding afforded by storage igloos, what were the potential dose rates inside the storage igloos to which select personnel would have been exposed upon entry?

27. p. 22. At the bottom of page 22 of the TBD, Mr. Shannan, former Radiation Safety Manager at the IAAP, is quoted as saying that during his employment at the facility, contamination outside or inside the incoming containers was "rare." This section goes on to state that the radionuclides most likely to have resulted in an intake at IAAP were depleted uranium and tritium. Since there are no bioassay records, how is it possible to rule out an internal exposure to plutonium in the course of one of these "rare" contamination incidents? Has NIOSH concluded that the IAAP incident records are complete in regard to all radiological incidents?

28. p. 23. In the bottom paragraph on page 23 of the TBD, it is stated that 122 mrem is indicative of a chronic annual uptake of 430 microcuries of tritium. Then at the bottom of the 2nd paragraph on page 24, a chronic tritium intake estimated to be 4902 microcuries per year is associated with a tritium dose of 0.331 rem/year. Please explain the apparent discrepancy.

29. p. 26. Data from the "FS-12 tunnel" were used for the DU air concentration because the data "were more robust." No information is given regarding the location of the FS-12 tunnel, so that a reviewer cannot determine if that location serves as a suitable surrogate for the air concentrations experienced by the workers.

30. p. 27. Particle sizes have a lognormal distribution of 0.1 – 1 µm, yet the assumed size is 1 µm. The geometric mean of the distribution is about 0.3 µm. ICRP has dose coefficients for this particle size—the effective dose from inhalation of Type M $^{238}$U is about 50% greater than for 1 µm AMAD.

31. p. 27. The factor of 4 decrease at 2 miles from the 1-mile concentration is not claimant favorable. The $\chi/Q$ at 1 mile for Class F, u = 1 m/s is 2.87E-4 while at 2 miles under the same conditions $\chi/Q$ = 1.05E-4, which clearly is not a factor of 4 decrease.

32. p. 27. The argument about the high density of DU is countervailed by the very small particle size, which would minimize deposition.

33. p. 27. The assignment of a 2-hour exposure time, with the parenthetical statement "assumes turbulence type A at 4000 m and 1 m/s drift speed..." is not clear. The logical process needs to be spelled out; otherwise, it cannot be reviewed. A reasonable estimate of the integrated exposure can be made by integrating over the X-axis of the Gaussian puff. The total mass of suspended material is 4,000 kg × 10% ÷ 701 shots = 0.57 kg. Assuming 95th percentile conditions, the integrated intakes for the periods in question are as follows:

| Period of exposure | Total Intake | |
|---|---|---|
| | TBD | Calc |
| December 2, 1965 through March 3, 1969 | 7.63E-02 | 1.06E+01 |
| March 4, 1969 through July 14, 1969 | 4.32E-04 | 5.98E-02 |
| July 15, 1969 through December 31, 1973 | 2.42E-02 | 3.35E+00 |

The calculated intakes, which represent default 95th percentile conditions, are more than 100 times larger than the TBD estimated values. A more realistic, site-specific estimate can be obtained from the STAR (STability ARray) data for Burlington, IA, which are available from the National Climatic Data Center. These data sets can be used as input to various computer codes, which calculate atmospheric dispersion factors.

34. p. 28. The analysis of the ingestion of DU by the cleanup crew does not appear to be scientifically valid. The experiment described in Section C-2.0 is not a valid foundation for the ingestion rate. Ingestion of contaminants by the hand-to-mouth route is notoriously difficult to estimate. It has been the subject of numerous studies, some of which are discussed in the EPA Exposure Factors Handbook. This body of knowledge should be considered and incorporated into the analysis.
35. p. 28. Adopting the second highest air concentration as the constant concentration needs further discussion. The complete data set on which this conclusion is based should be presented.

36. p. 28 . Use of the 1974 resuspension data is not necessarily claimant favorable. Despite there being no additional deposition of DU, the DU previously deposited has had time to "weather in;" therefore, the resuspension factor is likely to have decreased over time.

37. p. 29. Section 5.2.2**.** The assumption that 2% of the MPC is an upper bound should be documented.

38. p. 30. Top of page. The assumed ingestion rate is inconsistent with the EPA Exposure Factors Handbook and is much lower than typical values recommended for use in site assessment.

39. p. 30. Section 5.2.3**.** Six lines up from the end of the first paragraph is the statement: "The median airborne release fraction was 3 x $10^{-4}$ and the median respirable fraction was 0.5; the upper bound values for the same parameters were 2 x $10^{-3}$ and 0.3." This statement, which is copied from the DOE Handbook, contains a self-contradiction: If the median fraction was 0.5, how can 0.3 be an upper bound? Table A.41d of the handbook reproduces the published experimental data. These data show a maximum airborne fraction of particles of respirable size = $5.9 \times 10^{-4}$ from 1 kg of "DUO" dropped from a height of 3 m. The details of the ash collection are unknown; the handling may have stirred up dust as the ashes were swept into bags, etc. Consequently, the highest observed airborne fraction of respirable particles should be used as a fixed, conservative, claimant-favorable value. This is about the same value as the upper bound cited in the TBD, but is 4 times the median value.

40. p. 31. In the third paragraph in Section 5.2.4 of the TBD, it is stated that the median value for the airborne release fraction for the free fall spill of $UO_2$ from a height of 1 meter is 0.00008. Given the assumed particle size (respirable fraction of 0.5), this value for the release fraction seems unreasonably low. Is the DOE value selected for $UO_2$ airborne release derived from experiments? Why is it different from and much lower than the values given in the TBD for ash from DU burning (p. 30), though the citation is the same? Also the upper bound value for the respirable fraction for DU ash is less than the median fraction. This appears to be in error.

41. p. 31. The short paragraph in the middle of the page estimates the mass of oxidized DU by multiplying the volume of the dust by 11 g/cm$^3$, the density of the $UO_2$ crystal. The bulk density of the loosely packed powder, however, is less than 2 g/cm$^3$. Although this assumption is claimant favorable, it is not scientifically correct.

42. p. 31. The use of the median value of the 1-m spill data is not claimant-favorable (see comment in paragraph 40, above), inasmuch as the 3-m data has a maximum respirable release fraction that is 15 times higher. The assumptions about the volume of air and the exposure duration are unsupported. The dispersion is the result of handling and processing the material—a person performing this work would experience a higher air concentration than if the dust were uniformly dispersed in a medium-sized room, as is assumed in the TBD. There is also no justification for limiting the exposure to 1 hour per day. The DU intake could be much higher than estimated by the TBD, especially since the value is treated as a constant upper bound.

43. p. 32. Radon levels measured at Pantex are assumed in the TBD to be “the best indicators of radon exposure at IAAP.” These measured levels given in Table 5.6 appear comparable to the average radon levels in homes of about 1.25 pCi/L (http://www1.umn.edu/eoh/hazards/hazardssite/radon/radonmonitor.html). Since radon levels in structures are very sensitive to the specific geographic locations of these structures, the assumption made in the TBD that measured radon levels at Pantex are representative of the radon levels at IAAP does not appear to be warranted.

44. p. 33. Section 5.4 (Other Sources), page 33 of 79, states:

    > *Enriched uranium (EU), plutonium, thorium, and perhaps Po210 were present at various times during assembly or disassembly of nuclear weapons. All of these sources were encapsulated (sealed), and with the* ***careful control*** *of contamination* ***before*** *release of components to production was allowed, it is unlikely these radioelements would have been available for intake.*
    > [Emphases added.]

    The fact that these sources were encapsulated does not preclude the presence of tramp material, which may have significantly contaminated exterior surfaces. Unless such surfaces were first screened for the presence of tramp material and/or work environments were subject to strict engineering controls, use of anti-Cs, respirators, etc., the above stated assumption of “careful control of contamination **before** release of components to production. . . “ [emphasis added] does not preclude internal exposures. In the absence of bioassays, air monitoring, and/or relevant swipe survey data of nuclear materials, what supportive documents served as the basis for the conclusions stated in Section 5.4?

45. p. 34. In the first paragraph in Section 6.2.1 of the TBD, the existence of radiation generating devices and large $Co^{60}$ sources at the IAAP is acknowledged. These sources may have resulted in significant doses to workers, particularly during the period prior to 1963, when radiation was frequently treated irresponsibly by both management and workers in the United States. Moreover, the last sentence of the third paragraph in Section 6.3 states that most of the pocket dosimeter results (allegedly used between 1965 and 1974) appear to be “related to using high level radioactive source (sic) for radiography.” However, the basis for the estimate of the doses prior to 1963, as described in Section 6.5.1.1 of the TBD, is a generic theoretical pit, and does not consider any doses from these sources. Please explain the basis for this assumption.

46. p. 35. At the end the first paragraph in Section 6.2.1 of the TBD, photons resulting from n, gamma interactions in the “nuclear components and building materials” are mentioned as a potential contributor to dose. Yet, no consideration is given to this source in the dose estimate prior to 1963. In particular, we are concerned about the activation of structural materials by thermal neutrons in the presence of moderating materials. Have any calculations been made that corroborate the validity of neglecting these potential contributions to exposure?

47. p. 36. We concur that the external dose from EU is lower than from an equal mass of plutonium, and that the assumption that all the pits were plutonium is claimant favorable.

However, the statement in middle of page: "Since the low energy photon dose from enriched uranium is negligible, only the plutonium pits had the potential for significant low energy photon dose" is incorrect. The dose rate from EU is not negligible; this statement might lead to the neglect of potential radiation sources in other contexts and should be corrected. It is also not clear why the TBD focuses on "low-energy" photons. The MCNP analysis presented later in the TBD addressed all the photon radiation from the generic plutonium pit.

48. p. 38. Section 6.2.3. As it did in the TBD for the Blockson Chemical Company, NIOSH focused exclusively on the bremsstrahlung radiation from $\beta$ rays while overlooking the contribution of X and $\gamma$ rays from the short-lived daughter products of $^{238}$U to the external dose rate. SC&A's calculations of the dose from external exposure to a drum of yellowcake showed that bremsstrahlung contributed less than 20% to the effective dose. Thus, 80% of the dose was overlooked in that case. The external dose from DU is not addressed further in this TBD.

49. p. 44. The TBD states that the $^{241}$Am photopeak contributes 70% of the total dose. In fact, the data presented in Appendix D show that 78% of the dose is due to photons with energies less than 70 keV.

50. p. 44. Since little is known about the dosimeters employed at IAAP, the most conservative assumptions must be used in the dose assessments. Some film badges of that era employed a filter of 1 g/cm$^2$ of lead. The calculated attenuation of 60 keV photons by such a filter is over 98%. Hence, there is serious doubt whether the external dose from $^{241}$Am can be determined from the dosimetry with any reasonable certainty.

51. p. 45. Section 6.4.2. NIOSH should provide more detailed results of the MCNP calculations of the neutron spectra so that the conclusions stated in the TBD can be independently verified. While we agree that the neutron dose from a bare pit of weapons-grade plutonium is a minor component of the external dose, the same is not true if there are significant amounts of plutonium oxide present. The ($\alpha$, n) reaction with oxygen produces a strong neutron source. (See Question 5.) Since the neutron spectra at IAAP are unknown, and since the MCNP calculations apparently rely on classified data, it is not possible to independently assess this potentially significant component of the worker dose.

52. p. 47. Section 6.5.1.1. Equation 6.1 is an expression for $W_f$, the work factor, in terms of $D_{Annual}$, the calculated annual dose, and $D_{ERA}$, the dose rate for a given era, which is derived based on classified information (and therefore cannot be reviewed at this time). The expression $D_{Annual}$ appears again in Equation 6.2 where it is defined in terms of $W_f$. NIOSH should adopt a different symbol if, as it appears, $D_{Annual}$ has a different meaning in the two equations. Otherwise, the definitions are circular.

53. p. 49. Table 6.6 is not understandable. $D_{Generic}$, calculated in Appendix D, is the dose rate from the generic pit *as registered by the dosimeter*. It is not clear what $R_{Am-241}$ represents— it is *not* proportional to the ingrowth of $^{241}$Am, which proceeds at a much faster rate. Thus, we do not understand the meaning of the Modeled Annual Dose.

54. p. 50. Table 6.7 is apparently based on the MCNP calculations. The column headed "Am Component" does in fact increase in proportion to the ingrowth of $^{241}$Am. The last column reproduces the values from Table 6.6, again without explanation. Please explain.

55. p. 51. Section 6.5.3. The prescription for adjusting the dose is not clear.

56. Appendix B. Appendix B contains years of assembly and disassembly for various delivery systems. Some of the disassembly dates are after 1975. Where were these delivery systems disassembled?

57. Appendix D. It is not clear that the assumed mass of 6 kg of plutonium in the bare pit is claimant favorable. It is not logical to assume that all the plutonium-based weapons handled at IAAP were no bigger than the first two plutonium bombs that were made in 1945, given the emphasis on higher yields in the 1950s. Likewise, the EIS for Pantex is not necessarily the definitive statement on the subject. Finally, there are different isotope mixes in different references, all of which are classed as "weapons-grade plutonium." NIOSH needs to specify the isotopic composition of the plutonium that was used for the generic pit analysis. Are the isotopic distributions of plutonium available in the classified literature for each of the pits handled at the IAAP? If not, did NIOSH evaluate doses for the plutonium isotopic distributions characteristic of the full range of potential weapons usable material? For example, did NIOSH evaluate the doses from reactor grade plutonium? (There is evidence in the open literature that the AEC tested weapons composed of reactor grade plutonium.)

58. Appendix D. The IAAP period of facility operation (i.e., 1949–1975) brackets the period of nuclear weapon testing in the Pacific (and, therefore, nuclear weapon production) that involved devices with yields up to 15 megatons. Appendix D describes the 6 kg Pu Generic Pit specifications as ". . . the approximate mass of plutonium used in the Trinity and Nagasaki nuclear devices" and further states that ". . . a mass of 6 kg is considered claimant favorable." Is the use of the Generic Pit as the model source-term for the years 1949 through 1962 a claimant-favorable model?

59. Appendix D. Table D.1 of the TBD identifies photon dose rates by energy groups. Are dose rates cited as mrem/hr defined for the deep dose (i.e., $H_P(10)$)? Is the "Total Photon" dose rate of 33.3 mrem/hr a hypothetical value that would be expected as the "recorded" value for a dosimeter with 100% precision? Is the 14.8 mrem/hr assigned to the "Film Badge Energy" the expected $H_P(10)$ dose rate recorded by a two-element film dosimeter located at a distance of 100 cm from a generic pit?

Information Requested:

1. We request access to the "Top Hat" database to review recorded interviews conducted by NIOSH of IAAP workers.

2. We request access to the number of workers monitored to match the numbers of dosimeters referenced in Table 6.4, Rev. 1. (The number of workers was used in Rev. 0, but was switched to number of dosimeters in Rev. 1.)

3. We request copies of documentation reporting the 15 incidents that involved radioactive materials cited in Appendix E.

4. Table 2.1, in Section 2.2.4 of the TBD, identifies "Significant Radiation Safety Program Events" by year of implementation, along with several references to Ahlstrand in 1956–1958. A review of Ahlstrand 1956(b) and 1958(a) (IAAP Project History Reports) does not provide sufficient data describing radiological policies, worker training, and other issues relevant to radiological safety. However a reference is made to a "Manual of Standard Practices," which apparently was revised routinely over time. Can copies of the "Manual of Standard Practices" (with successive revisions) be made available to SC&A for review?

March 31, 2005

To: Paul Ziemer and Lewis Wade
From: John Mauro
Subject: TBD for the Atomic Energy Operations at the Iowa Army Ammunitions Plant (IAAP). Addendum to IAAP questions (based in part on 3/21/05 interview w/ Univ. of Iowa investigators)

The following are additional questions which supplement the questions contained in our March 22nd letter, and which we would like to discuss with NIOSH and the Board at our upcoming meeting. Some of the questions are new based on our ongoing investigations, including expert interviews, and some represent a further development of several of the questions we raised in our March 22nd letter.

***The TBD notes that nuclear capsules (pits) were stored at IAAP and, according to Appendices A and B, were variously stored at Buildings 1-11 and 1-73, as well as in "igloos" in Yard C from 1965-1974. Stored pits in sufficient numbers and configuration can yield high radiation fields as demonstrated at Pantex in the 1990s during extensive dismantlement of warheads. How did NIOSH characterize this source of potential worker exposure and would it not be a key contributor to unmonitored dose? Where (in which facility) was the standing pit inventory stored at IAAP prior to use of the igloos beginning in 1965? What were the measured radiation fields (including maximum measured neutron and photon) in these facilities (assuming maximum stored pits in criticality safe array)? Is it possible to identify workers whose duties would have included movement of pits into and out of these storage areas? Is it possible that these radiation fields (multiple pit arrays) may have exceeded those of single bare pit handling, as modeled in the TBD? Did NIOSH review Pantex data on maximum radiation field in igloo storage during the 1980s to postulate maximum credible exposure potential at IAAP?***

1. Were high facility area radiation measurements (according to site experts, in some areas ranging from 12-18 rem/year) verified based on available records and evaluated for implications to potential unmonitored worker doses (e.g., to guards assigned to security for pit storage areas)? Has NIOSH established whether the "representativeness" of its recorded dosimeter readings include workers working in or near such potentially high exposure areas?

2. According to site expert interviews,"flash x-ray" technology was apparently used during hydroshots to perform high-speed diagnostic surveys of HE at the moment of detonation. Is NIOSH aware of this x-ray application during hydroshots and has it characterized potential radiation exposure potentials to workers?

3. While the presence of large Co-60 radiographic sources and high-energy x-ray units for purposes of quality assurance surveying of both HE and nuclear packages is acknowledged in the TBD, no characterization of potential radiation fields generated, worker practices, or worker exposures are discussed (except to note that they "had the potential for producing significant exposure to workers if not used properly"). Did

NIOSH consider worker exposure from these sources to be negligible over time? If so, on what basis? If not, why are these routine sources of potential exposure not estimated?

4. The TBD claims that neutron-photon ratios measured at Pantex in the 1980s-1990s can be favorably applied as surrogate values at IAAP, given some of the conservatisms included (e.g., wearing of lead aprons at Pantex). However, it is not clear that these conservatisms necessarily offset what may be fundamental differences in the radiological source terms of the various pit configurations at IAAP during the early years, as compared with the more "mature" campaigns handled by Pantex in the later years. The presence of U-232, U-233, and other isotopic forms in early warheads, as well as differing pit mass ("Hiroshima-sized" pits being the lower bound, not mean), as nuclear weapons development proceeded during the 1950s-1960s makes it critical that the "bare plutonium" pit model is validated as the hypothetical maximum. Has NIOSH's assessment enveloped these and other considerations?

5. Site experts indicate that at times the "quarterly maximum" radiation dose was approached or exceeded by groups of workers at IAAP in certain operations. Did NIOSH find any evidence that this occurred at the site?

6. Warhead disassemblers would have likely been exposed to potentially higher radiation exposure than assemblers, given the aging of plutonium pits (americium ingrowth) and additional handling of DU (with increased oxidation and potential resuspension). Did NIOSH characterize disassembly of warheads in terms of characterizing potential worker exposure under these conditions?

7. The authors of ORAU-TKBS -0018 Rev. 1 assume that the primary dose contributors were from photons and neutrons emanating from an unsealed plutonium-239 "pit" weighing 6 kilograms. During the period up to 1962 and beyond, IAAP appeared to be involved not only in the assembly, disassembly, and maintenance of weapons in the active U.S. nuclear weapons stockpile, but also the development of several nuclear weapons in the design, engineering and testing phases. Given these circumstances, IAAP may have handled radionuclides which are not considered in the TBD. Based on a preliminary review of official unclassified data, we have the following questions:

    - In the early 1960s the Atomic Energy Commission developed and successfully tested a device using fuel-grade or "high-burn-up plutonium normally generated in a nuclear power plant.[1] Radioistopes of concern include plutonium-240, plutonium-241, and plutonium-238.[2] The plutonium was provided in sufficient quantities by the United Kingdom and from U.S. Production reactors to make several weapons.[3] What isotopic distribution of plutonium did NIOSH use in its generic pit calculation presented in Appendix D? Are the isotopic distributions of

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[1] U.S. Department of Energy, Office of Public Affairs, Additional Information Concerning Underground Nuclear Weapons Test of Reactor Grade Plutonium, December 1993.

[2] U.S. Department of Energy, Non-Proliferation and Arms Control Assessment of Weapons –Usable Material Storage and Excess Plutonium Disposition Alternatives, January 1997, pp. 37-39.

[3] U.S. Department of Energy, Defense Nuclear Facility Safety Board, Issue Paper: Plutonium Storage at Major Department of Energy Sites, April 14, 1994.

plutonium available in the classified literature for each of the pits handled at the IAAP? If not, did NIOSH evaluate doses for the plutonium isotopic distributions characteristic of the full range of potential weapons usable material? *Did NIOSH verify whether or not IAAP handled reactor-grade plutonium?*

- Radioisotopes, such as americium and plutonium-238, have been used, respectively, in neutron and heat generators for nuclear weapons.[4,5] *Did NIOSH verify whether or not workers at IAAP handled components containing these radioisotopes and their potential risks?*

- Research and development of weapons fueled by uranium-233 was extensive and continuous from World War II to the early to mid-1960s.[6,7] When U-233 was under development as a nuclear explosive, the major radioisotope of concern was uranium-232, which is 60 million times more radioactive than uranium-238. U-232 is co-produced with U-233 by irradiation of thorium. Separated uranium-233 typically contains 5 to 50 parts per million of uranium-232, which poses a significant potential external dose hazard.[8] *Did NIOSH verify and then consider in its dose calculations the possibility of pits containing U-233 at the IAAP, and, if so, what range of U-232 contamination was assumed in its calculations?*

***ORAU TKBS -0018 Rev. 0, Table 8. (p. 23) indicates that the percentage of workers who received monitoring for exposure to external penetrating radiations ranged between 3% to 7% from 1962 to 1967, and 14% to 26% from 1969 to 1973. Given the paucity of measured exposures, and small number of readings during most of this period, what is the probability, including confidence limits, that this relatively small number of monitored vs. unmonitored workers is likely to estimate representative missed doses?***

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[4] U.S. Department of Energy, Pinellas Plant Facts, GEP-SP-1157, November 1990

[5] U.S Department of Energy, A Material Management and Disposition Plan for Excess Materials at Sandia National Laboratory, Table 1, SAND 2002-1785P, July 2002. P.B-6.

[6] C.W. Forsberg, C.N Hopper, Definition of Usable Uranium-233, Oak Ridge National Laboratory, ORNL-TM-13517, March 1998.

[7] W.K. Woods, LRL Interest in U-233, DUN-677, February 10, 1966.

[8] U.S Department of Energy, Highly-Enriched Uranium Working Group on Environmental, Safety and Health Vulnerabilities Associated with the storage of the Department's Highly Enriched Uranium, DOE-EH-0525, December 1996, pp. 4-5.

8. The oxidation and hydriding of exposed metallic fissile materials are well known in the declassified literature about nuclear weapons. These have been long standing and pervasive problems at all sites producing and handling fissile materials.[9,10] The inherent instability of metallic plutonium and uranium in the presence of open air and moisture are well known to create contamination, inhalation and safety hazards, particularly fires. To what extent did the TBD address these issues?

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[9] U.S Department of Energy, Plutonium Working Group Vulnerability Report on Environmental, Safety and Health Vulnerabilities Associated with the Department's Plutonium Storage, DOE-EH-0415, November 1994.

[10] EH-0525.

# ATTACHMENT 2: OUTSTANDING RECORDS REQUESTED OF NIOSH TO SUPPORT IAAP SITE PROFILE REVIEW

April 11, 2005

Dr. Lewis Wade, Project Officer
U.S. Department of Health and Human Services
200 Independence Avenue, SW
M.S. P-12, Room 715H
Washington, DC 20201

Reference: Email from John Mauro to Paul Ziemer and Lewis Wade, dated March 22, 2005, *TBD for the Atomic Energy Operations at the Iowa Army Ammunitions Plant (IAAP)*

Dear Dr. Wade:

At the Advisory Board's request, SC&A, Inc. has been conducting an independent review of the Technical Basis Document (TBD) for the Iowa Army Ammunition Plant (IAAP). During the course of this review, we have identified the need for documentation that may be in the possession of either NIOSH or the Department of Energy (DOE). Some of it may be classified, so it is possible that all or portions of this documentation may prove to be available at the April 12, 2005 classified review to be conducted in conjunction with the Advisory Board at the DOE Germantown facilities (while we are in receipt of an agenda for the review, we have not seen an inventory of documents to be made available).

In our March 22, 2005 correspondence, we requested documentation (as a supplement to the questions submitted by SC&A) that NIOSH likely possesses. This documentation, which has not yet been forwarded, includes the following:

- "TOP Hat" Database to review recorded interviews conducted by NIOSH of IAAP workers
- Access to the number of workers monitored to match the numbers of dosimeters referenced in Table 6.4, Revision 1
- Copies of documentation reporting the 15 incidents that involved radioactive materials cited in Appendix E

SC&A also requires access to additional data other than that currently available through the NIOSH site profile research database. This information, which may or may not be classified, and may or may not be available for our review on April 12, 2005, is necessary to properly evaluate likely historical exposure conditions and the appropriateness of theoretical models. We request available documentation related to the following topics:

- Radionuclide constituents of the pits handled
- Size and shape of pits handled
- Radiological survey data (contamination and radiation surveys)
- Historic practices (e.g., number, configuration, number of support personnel) for storage of nuclear weapons or nuclear weapons components
- Release or spread of radioactive contamination to the environment
- Landauer film badge design and calibration procedures.

Pursuant to the existing HHS/DOE memorandum of understanding on site records access, we are requesting the following IAAP documents which, based on site expert interviews, we believe may be available from DOE:

- Health and Safety Procedures
- Radiological survey, air sampling, and internal monitoring data
- Documentation on early Landauer film badges (Landauer indicated this information was provided to NIOSH)
- Production Procedures
- Pantex Box #291 (contains receipt logs for Oy and Pu, tear down logs for Oy and Pu, personnel shielding information, radiation safety correspondence)
- Pantex Box #366 (contains radiation safety correspondence, effluent and environmental monitoring data, nuclide inventory data)
- Pantex Box #186 (contains information on atomic weapon nuclear safety studies and surveys, storage and transportation requirements, handling of raw materials and containers)
- Pantex Box #389 (contains information on AEC accident experience, radiation safety correspondence, and supervisor reports of accidents)
- Pantex Box #367 (contains information on the Hydroshot and Firing Site operations and decontamination)
- Pantex Document #318012, *Landauer and Tracelab Radiation Dosage Reports - Film Badges on Burlington Plant Employees 1956-1962.*
- Inventory of all IAAP records stored at Pantex
- Information on Burning Field and Firing Site operations, including destruction of documentation
- Access to the document repository of IAAP-related records referred to in the *Work Plan for Supplemental Remedial Investigation of Line I (Including Historical Site Assessment) Iowa Army Ammunition Plant Middletown, Iowa* prepared by TN & Associates, Inc.
- Transcripts or notes from the July 29, 2004 worker outreach meeting in Burlington, Iowa
- Supporting records provided by Special Exposure Cohort petitioners

SC&A understands that some of these documents may be classified and require secured access under the MOU.

These records are needed to allow us to effectively evaluate the site profile. Any assistance you can provide would be appreciated. Feel free to contact me at (732) 530-0104, Joe Fitzgerald at (240)-422-9115, or Kathryn Robertson-DeMers at (509)-460-9005 if there are questions or concerns with regard to this request.

Sincerely,

John Mauro
Project Manager

cc: Paul Ziemer, Chairman, ABRWH
Board Members, ABRWH
Joseph Fitzgerald, SC&A
Kathryn Robertson-DeMers, SC&A
Project File: ANIOS/001/09

# ATTACHMENT 3:  CONFERENCE CALL WITH NIOSH AND SC&A

Attachment 3 is not provided at this time, because the transcripts of the conference call have not yet been issued by NIOSH.

# ATTACHMENT 4: IAAP FACILITY SITE EXPERT INTERVIEWS

Over the course of the audit on the Iowa Army Ammunition Plant (IAAP), Kathryn Robertson-DeMers and Joseph Fitzgerald have had an opportunity to interview a number of site experts. Site experts included individuals involved in production, inspection, security, and safety and health. Also interviewed were members of the Burlington Atomic Energy Commission Plant—Former Worker Program at the University of Iowa.

The information the site experts provided has been invaluable in providing us with a working knowledge of operations occurring at the IAAP. Site experts provided a baseline understanding of working conditions and the extent of the safety program through time. This information was utilized to further identify critical vertical issues. The information provided in these interviews helped SC&A obtain a comprehensive understanding of the radiological risk at the facility.

Information regarding the security and production operations at IAAP is provided in Part 1. An interview summary related to the safety program is included in Part 2. These interviews were conducted via teleconference from March 21 to April 14, 2005. The information provided is not a verbatim transcript, but a summary of information collected from all interviewed experts. Individuals have provided this information based on their personal experience. It is recognized that these recollections and statements need to be further substantiated before being adopted in the Technical Basis Document (TBD) (ORAU 2005). However, they stand as critical operational feedback where records and other documentation are lacking or unavailable. This interview summary is provided in that context; site expert input is similarly reflected in our discussion and, with the preceding qualifications in mind, has contributed to our issues.

## Part 1: Security and Production Operations

Many of the operations and processes at the IAAP are deemed classified, therefore limiting the content of the interviews. Workers were told when they began work at IAAP that they were not to discuss their work outside the immediate work areas; otherwise criminal charges would be brought against them. Many of the site experts were concerned about classification issues and company retribution, further limiting the interviews. Topics that could not be discussed during site expert interviews included the following:

- Size, weight and shape of weapons components
- Type of special nuclear material shipped to IAAP
- Radionuclide and chemical constituents of weapons components
- Details of the assembly, disassembly, and retrofit processes
- Details of tritium shipments, including the containers it was shipped in
- Storage of weapons and/or weapons components
- Number of weapons and/or weapons components stored in an area
- Classified documents

### *Facility Description*

IAAP involved two distinct operations from 1947–1975. Division A was run by the Army and was involved in the production of various conventional weapons (i.e., shells, detonators, mines, etc.). Division B was run by the Atomic Energy Commission (AEC) and was involved in the assembly, disassembly, repair, and retrofit of nuclear weapons. AEC took control of Line I, the burning fields, and test firing in 1947. They started modifications to Line I. AEC had the ultimate authority over operations on Line I and used on-site supervisors, inspectors, and plant managers to monitor work performed. Operations began in 1947 and continued to mid-1975. The Army eventually took control of this portion of the plant after AEC left.

The plant has been known by a number of names, including the Iowa Ordnance Plant (IOP), the Burlington Atomic Energy Commission Plant (BAECP), the Iowa Army Ammunition Plant (IAAP or IAAAP), and the American Ordnance Plant. The IAAP mission was to fabricate high explosive (HE) components for nuclear weapons and to assemble, disassemble, and repair nuclear weapons. Division A produced ordinance munitions. Site experts did not know the exact date fissile material arrived onsite.

The plant included buildings dedicated to various functions involved in assembling and disassembling weapons. The buildings were numbered, based on which division the operation supported. Buildings with the leading number of 1 indicate that the building was associated with Line I operations. Table 1 lists some of the buildings associated with Division B work and the general activities that occurred in those buildings.

Several buildings were involved in the handling and storage of radioactive materials including 1-11, 1-12S, 1-13, 1-61 series, 1-63 series, 1-77, C Yard, and the Firing Site. Building 1-100 housed the x-ray units and sources used in radiography. There were several areas on Line I that did not handle radioactive material. These areas included the tool and dye shop, the machine shop, the wet chemistry lab, HE processing, and the melt process.

Several programs were occurring at the facility at a given time. As a result, the process of weapons assembly and disassembly occurred in different locations on Line I. In general, different weapons were assembled in different areas. Assembly operations started in Building 1-13. In later years, retrofit and repair were added to the list of operations in Building 1-13. Once additional assembly buildings were completed, the operation was moved to these buildings. Building 1-12S, series 1-61 buildings, and series 1-63 buildings were involved in assembly and disassembly work. The explosive powder was removed from the weapon in Building 1-12S. Buildings 1-12N and 1-40 were the machining areas.

Assembly occurred early in the operations of Line I, whereas disassembly operations started at a later date. Site experts could not identify a change in operations that would distinguish the pre-1962 period from the post-1962 period. Production was fairly steady until the 1970s.

“The Melt” (Buildings 105-1 and 105-2) manufactured HEs. Raw materials were melted down and poured into molds. The finished mold was then machined to the appropriate tolerance.

## Table 1: Buildings and Areas Associated with AEC Operations at IAAP

| Building | Description of Operations |
|---|---|
| 1-01 | A production office before 1-52 was built. Locksmith and trades were there in later years. |
| 1-04 | Production offices, Safety offices, Maintenance and Administrative services, Chem Lab, and sciences |
| 1-10 | Storage area |
| 1-11 | Tritium reservoir and pit storage. Offloading of RR cars with raw materials. |
| 1-12 (main) | Machining and pressing of HE into balls; 2 MeV X-ray Unit |
| 1-12N | Machining and pressing of HE |
| 1-12S | Disassembly area for pits and HE |
| 1-13 | Assembly area; Retrofit; Disassembly. Major disassembly use: broken HE balls, vacuum pump pinch off tubes. |
| 1-18 | Research and Development |
| 1-19 | General storage area |
| 1-40 | Underground; machining operations |
| 1-50 | Storage of raw material for “The Melt”; movement between conveyor belts to 105-1 or 105-2 |
| 1-51 | Assembly of packages in weapons. Electronics and Non nuclear. Controlled temp and humidity. |
| 1-52 | Production offices and maintenance |
| 1-55 | Production offices in 1960’s. Large vaults for codes and papers. Main Guard access for trucks and vehicles in/out line. |
| 1-61 | Assembly of different programs, including spheres and HE; MOCA was used here. |
| 1-63 Series | Underground Gravel Gertie containing assembly areas with operating bays. 1-63-5 contained a touch up bay. 1-63-7 was used for storage of completed weapons. |
| 1-65-6 | Out-loading of weapons. |
| 1-73 | Inspection, weighing, and swiping of pits |
| 1-77 | Inspection, weighing, and swiping of pits; storage area (built in later years); tritium-related production. |
| 1-80 | |
| 1-85-2 | Believe to be used as load out of weapons. |
| 1-100 Series | These buildings were built for x-ray use. There were x-ray units (2 MeV) and a small HE machining operation. |
| 1-105-1 | Melt Facility |
| 1-105-2 | Melt Facility |
| 1-106-1 | Formulation of material for “The Melt”; put boxes of HE on conveyor for transport to 108-1 |
| 1-106-2 | Formulation of material for “The Melt” |
| 1-107 | Underground; storage area for HE |
| 1-108-1 | Screened for foreign material that could cause sparking. |
| 1-148 or 1-160 | Tool and Die machine shop, built in mid 1960’s |
| Area between 1-11 and 1-77 | Venting of tritium reservoirs |
| 1-137-4 | Line I Cafeteria. Open to entire plant, AEC and the Army. |
| Yard B | a.k.a. Burning field “B,” east of Line I, north of Yard “C”<br>Open burning of explosives, parts and pieces, papers relating to old weapons. Defective HE and scrap. |
| Yard C | Finished products and pit storage for disassembled weapons (Igloos); loading and unloading of completed weapons. |
| Yard L | Shipping and receiving of components; non-nuclear components storage. |

There were also electronics and machine shops, support laboratories, and an administrative area. Building 101 housed the Maintenance Department. This included a machine shop, electric shop, and pipe shop. The machine shops were responsible for machining HEs.

There were three laboratories associated with Line I operations, including a main laboratory, an electronics laboratory, and a chemistry laboratory. Laboratories on Line I produced necessary mixtures for production processes, provided analytical support, and performed work on weapons and/or weapons components. Some were involved in Research and Development (R&D) operations, including development of improved methods for initiation.

### *Workforce*

In general, individuals worked for either Division A, which was responsible for conventional explosives, or Division B, which was involved in AEC work. Although Army and AEC personnel worked at the same facility, the production and support workforce was not interchangeable between the two operations. The workforce at IAAP was allowed to move between Division A and B if appropriate clearances were in place and there was a position available. This required changing employers. Security was responsibly for overseeing operations in both Division A and Division B, and could be rotated between the two divisions based on their assigned duty station. Thousands of workers (5,000–10,000) worked at the IAAP facility for either the AEC or the Army.

Sections of the work force on the IAAP site were mobile, while others were static. Individuals would bid on different jobs. At times individuals were assigned to other jobs. There was also movement between shifts.

Typical work shifts were 8 hours per day. IAAP operated 24 hours per day, 7 days per week. A typical workweek was 40-50 hours. Depending on the particular job, there were one to three shifts. The company had what was referred to as “Peg Points.” A Peg Point was a production goal that had to be met on a periodic basis. As the time to meet these goals approached, there was an increase in production. Workdays were extended to 10–12 hours per day up to 7 days per week. One site expert estimated that over the course of a year, there was an average of 10–20% overtime for the production workers. Specific workers were also called in during emergencies, due to their skills. Safety personnel periodically had to work overtime to receive a shipment. During one period of time, production workers went out on strike. As a result, supervisors were asked to perform assembly and disassembly to allow the company to meet its goals.

Upon closure of the AEC operation at IAAP, numerous (>100) employees (e.g., engineers, managers, and supervisors) transferred to the Pantex Plant. Site experts do not recall individuals transferring to Mound.

### *Security*

The contractor (Mason & Hanger) maintained Physical Security for both the Army side and the AEC side. Over 200 persons were used 24 hours per day, 7 days per week on three shifts to supply security. Security’s responsibilities were similar to that of city law enforcement. In addition to general law enforcement duties, security was responsible for traffic control, fire patrols, and physical security of the yards, production lines, and other buildings. They were also trained as Emergency Medical Technicians (EMTs) for the purposes of emergency response. The guard headquarters ran the ambulance service for Division A and Division B. Security had to deal with everything from family fights to drunks to explosions to injuries. Then there was the radiation.

Access to the facility was controlled with the use of an identification badge. The ID badge was constructed in the standard dimensions with a photo of the wearer in the center. Numeric values (i.e., 1–6) were listed on the badge. These numbers corresponded to specific areas in Line I, C yard and L yard. Individuals were allowed to enter only those areas corresponding to the numbers on their badge. The ID badges were also color coded to illustrate whether individuals were from the Army or AEC portion of the plant (i.e., blue and green were used for the Army and AEC, respectively). Additional colors were used to indicate government or contractor status. Guards would verify the level of clearance an individual had prior to entry into an area. Personnel dosimeters were not integrated into the identification badge; however, criticality accident dosimetry (i.e., indium foil) was added in later years. The security badge exchange posts maintained a record of individuals entering and exiting the areas.

The operations were compartmentalized such that the workers had only knowledge of the particular job they were involved in. Workers were directed not to discuss their work outside their immediate work area.

Security guards would report to guard headquarters on their assigned shift for inspection and assignment of firearms. Shift hours were 7 a.m.–3 p.m., 3 p.m.–11 p.m., and 11 p.m.–7 a.m., 7 days per week. There was a formal turnover between shifts. Duty stations were assigned that could include work in either Division A or Division B. Security personnel were allowed to “bid” for or trade duty stations. Individuals who did not have a clearance were required to work on the Division A side. Some of those with Q-clearances did not like to work in Division B because of the health concerns related with the work.

Guards had regular tour assignments to verify materials were in the appropriate locations and there were no unauthorized entries into areas. Specific duty stations included the following:

- Manning badge exchanges
- Working in two-man teams among weapons and storage areas
- Mounted patrols roaming the local area
- Walking tours of Line I
- Driving tours of the facility boundary

A Detex clock was used to verify that the guards assigned to tours performed all checks required of the duty station. Security verified seals on doors and windows, and inspected general areas. For AEC, there was a mounted patrol both inside and outside the interior fences around Line I and associated storage areas. Foot patrols were used from the time day shift production workers exited until they returned to the line. Security personnel were rotated through various tours. There were over 200 guards assigned to security between the AEC and Army operations onsite. About 25 security personnel were assigned to work supporting AEC operations. During the day shift, more than 40 guards were assigned to AEC operations.

Some duty posts involved touring multiple buildings, while others required surveillance of specific areas. The interior and exterior of the buildings, rooms within buildings, and materials had to be inspected periodically (e.g., every 30 minutes for some areas). Guards had to verify that material was present and that no authorized entries had been made into the area. They walked around the weapons and/or weapons components to ensure everything was in its place. The distance between the guard and the contained nuclear material ranged from direct contact to several yards.

Security was responsible for guarding special nuclear material and weapons. Access to both coded vaults and vaults containing actual weapons or parts was controlled. If individuals were guarding access to vaults that contained weapons, the job required the use of the buddy system. There were high-security combination locks on the data and code vaults. In addition, there was key control over these areas. Each individual of the two-man team had a key. Both keys were necessary to access these areas. One guard would lock the other guard into the area. There were seals placed across the door that had to be removed and logged with each entry. Upon leaving the area, a new security seal was placed across the door. The tours required guards to work among the weapons for a full shift. Guards were assigned to these areas for variable periods of time ranging up to 40 hours per week in some cases. There were also periods of time when there was substantial overtime. At times the guards were required to stand immediately adjacent to the material. Some guards reported feeling weak during and after these types of job assignments. Security guards reported that on these tours, the hair on their arms stood on end. When this occurred, the guard gave the weapons a lot of space to prevent this from recurring.

The reference to a vault must be clearly defined when discussing Security guarding weapons and weapons components. These vaults were similar to bank vaults. This does not refer to the Igloos. The guards' job was to stand watch and make sure materials did not leave the vault. The weapons and weapons components had to remain inside.

There were no signs posted on containers that identified the contents. Guards did not have a need to know what they were guarding.

Logs were kept to document any security infractions. If a guard identified problems, such as something being out of place or a security infraction, they were to notify guard headquarters immediately. Headquarters would determine follow-up actions related to the incident. An incident report was generated for each occurrence and reviewed by a lieutenant. How effective this process was is questionable. They were reviewed and most ended up being discarded in the trash rather than provided to higher-ups. Some security guards remember seeing these reports in the trash. Some workers have postulated that unless the incident was serious, it was not formally documented. There is a concern that security incident reports were hushed due to the reduction in awards fees and bonuses associated with security infractions. In addition, some security employees felt individuals making waves were assigned to less desirable duty posts. In some cases, guards maintained personal notes, which were later confiscated and burned.

### *Material Shipping and Receiving*

Security held the joint responsibility with AEC couriers for the procurement of components used in the assembly of weapons. The details of these transactions are classified and could not be discussed. Weapons components were shipped in and out via railway, truck, and airplane. Weapons components were shipped in and out of the plant on a continuous basis. Enough components were maintained onsite to keep production going. An AEC courier accompanied material shipped onto the site. This was to assure everything was proper and accounted for prior to receiving (sometimes referred to as buying) the material. A mass balance inventory of received and shipped nuclear components was maintained. Components were received from the Y-12 Plant, the Savannah River Site, and the Rocky Flats Plant. Los Alamos National Laboratory (LANL) and Sandia provided engineering support to the facility.

Security commanders had the responsibility of meeting, inspecting, and receiving shipments of material from couriers. They were the first to enter the transport vehicle just inside the perimeter fences. Pits were received in white barrels like 55-gallon drums, each placed on a wooded skid. Tritium was inside JP containers (i.e., pressurized containers). Security performed a physical search of each barrel or container and compared the serial number of each to the manifest. This required the commander to climb on and around the containers on the transport vehicle. This process took from 30 minutes to an hour. Once completed, the commander accompanied the shipment to Building 1-11 or 1-77. At this point, the material was in a secured area. Security was not required to escort the nuclear material within the secured area.

Safety personnel would perform contamination and radiation surveys in and around the transport vehicle. Swipes were taken on the packaging of material shipped. Safety personnel wore coveralls and booties upon entry into the transport vehicle. Security personnel were not provided with personnel protective equipment to perform the initial inventory check. When the surveys were completed, production control or stores operators would move the shipment to the storage facility. Some commanders were upset by the fact that they were required to enter the railcars or trucks prior to survey by the Safety Department.

Company inspectors were required to perform “weight” checks of the pits upon receipt at IAAP in Building 1-73 or 1-77. This inspection of the pits involved weighing them and recording the results. Production control would remove up to 10 pit container lids in the storage area at one time. Safety would perform contamination surveys on a subset of all the pits inspected per day. Two containers were taken to the inspection area. Inspectors would remove the pit manually from the container and place it on a scale, where it was weighed. The scale had a see-through sliding glass door, which was closed after the pit was placed on the scale. The pit was removed and put back into the container and the next pit removed for weighing. The two containers were opened, exposing the pits at the same time in the inspection area (i.e., approximately 15 ft x 15 ft); however, only one pit was out of its container at a time. This process was repeated for the entire shift. Reservoirs were also weighed.

There were one or two shipments received from Oak Ridge that had some contamination on them. The Safety Manager was sent to Oak Ridge to resolve this situation, as they were concerned the material would have to be returned to Oak Ridge. Contamination was believed to be depleted uranium.

Following survey and receipt of shipments, units were either put into storage or shipped directly to the production line. Site experts do not recollect receiving “special shipments.”

Couriers were cognizant of containers that posed some type of problem (e.g., damaged units, high dose rates, leaks, etc.). They would inform Security which units were causing a problem. Damaged material was separated and sent directly to Building 1-13. Some of these units came from Pantex to IAAP for rework. Ultimately they were sent back to Pantex.

Assembled weapons were shipped to other AEC facilities. The reverse process was performed when items were shipped out. When weapons or components were shipped by airplane, Security had to escort the material to the airport and remain there until the airplane took off.

### ***Storage of Weapons and Weapons Components***

Pits were shipped to IAAP as individual units. They remained in storage until they were needed for assembly. The length of time the finished units were stored at the facility varied based on the availability of transportation. Some units stayed in the storage area for an extended period of time, while others were shipped right out. Capsules and pits were stored in Buildings 1-11 and 1-77, and later 1-73. Finished weapons were stored in the Igloos in Yard C. Some site experts indicated that completed weapons were stored outside under tarps prior to placement in the Igloos.

When the weapons or components were worked on, they were moved to Line I. There were several storage areas on the production line. Units could be stored in the bays for 24–48 hours, making them immediately available. The quantity of HE allowed in the area at one time was restricted. This limit was posted in the immediate area as a reference for workers.

Storage areas were designed to prevent criticalities. There were boxes painted on the floor in Buildings 1-11 and 1-77, which were designated for storage of materials. The metal boxes in which the pits were stored ensured proper spacing during storage. The storage configuration varied with the storage facility. Criticality prevention specifications (i.e., spacing, inventory) were not consistently applied across the various operations and throughout the period of AEC operation at IAAP.

### ***Weapons Production***

IAAP was the first plant of its kind involved in the final assembly of nuclear weapons following the on-site manufacture of explosive components for each weapon. Numerous types of weapons were assembled and disassembled at the site over time. The exact contents of the subassemblies were dependent on the type of weapon. There was a notable difference between the assembled and disassembled pits. Weapons produced at the site supported military involvement in Korea, Vietnam, and the cold war. Site experts identified Mark 6, Mark 28, and Poseidon missiles as some of the units worked on. If the worker did not have a need to know, the worker was not told the details relating to the material handled. Even the radionuclide constituents of the particular pits were not communicated to the workers. Workers noted that smaller units generated more heat.

There were multiple programs occurring at the same time during operation.  The weapons size and components varied over time.  The time it took to assemble a weapon varied based on the type of weapon.

Standard Operating Procedures (SOPs) were used to guide the assembly and disassembly process.  There were different procedures for different weapons.  The specific SOPs contained details processes associated with a specific weapon type.  Although there was no formal criticality safety program, specifications for storage and inventory limits were included in SOPs.

The number of individuals working in a particular job assignment at a particular time depended on the operation and the shift.  During the day shift, approximately seven to eight individuals were assigned to each cell during assembly.  This group of individuals included AEC personnel, inspectors, operators, and production control.  Assembly and disassembly areas housed numerous bays, depending on the building.  Some operations were not performed during swing and graveyard shifts, so a smaller population of workers was at the facility during this time.

IAAP manufactured HEs for use in weapons.  This involved melting, pressing, and machining of HEs.  Raw materials for HEs were melted in a kettle and mixed with chemicals.  The “melt” was poured into molds to shape the HE shells.  Various explosives (e.g. HMX, RDX, PETN, and other exotics) were used in the development of initiating systems.  Once formed, the HE shells were machined.  The beryllium shells within the HE hemispheres were also machined.

Assembly operations were performed in Gravel Gerties, which were covered with about 40 ft of dirt.  These were designed to implode if an explosion occurred.  Groups of workers were assigned to an assembly area.  Two or more individuals (i.e., more individuals required for disassembly) worked on one or more units within the same assembly area (i.e., Gravel Gertie).  In other cases, there was more than one team in the same assembly area working on separate weapons.  Weapons were assembled in stages.  Each stage had to be inspected by an AEC and a company inspector.  These assembly inspections took variable amounts of time, depending on the particular stages and the availability of inspectors.  Each individual was responsible for making sure each stage was completed correctly prior to the inspection process.

The nuclear package consisted of a pit, a HE hemisphere, and a beryllium shell, which fit between the pit and the HE.  The HE hemispheres were manufactured at the Burlington Plant.  The pits arrived at the facility already machined.  The radioactive constituents of the pit were enclosed in a sheath.  Beryllium shells were glued into the HE hemisphere.  The pit was positioned in the bottom hemisphere of the HE.  It was manipulated manually or with the use of an air-operated hoist and clamping device.  The pit had to be carefully lined up in the hemisphere.  Adhesive was placed on the hemisphere and the pit, and the top hemisphere was sealed to the bottom hemisphere.  Some production workers would also add adhesive to the lower hemisphere to ensure the unit stayed intact.

There were various phases of weapons assembly and disassembly that required direct contact with radioactive material.  Workers had to bend over the pit in the bottom part of the hemisphere to pick the top of the sphere off the floor.  This resulted in exposure of the face and pelvic area to the radiation field.  Sometimes they had to hold the hemisphere against their body.  Other times the materials were handled within the spherical casing.  Workers were provided with cotton gloves, as they were not allowed to get body oil on the pit.

The time workers were in the immediate proximity of the pit (i.e., within 1 m) varied by the program, the skill of the particular workers, the quality assurance process, the number of units processed per day, and the number of units in the immediate area. Based on this site expert feedback, the implication of the work factor derived by the National Institute of Occupational Safety and Health (NIOSH)─that individuals were within 1 m of the pit for about 1 hour per day─is apparently not consistent with the actual operations at IAAP, as directly experienced by some production workers.

The production control group was responsible for transportation of components and finished weapons. Forklifts were used to move material between the production line and storage. Cranes were used for numerous operations, including movement of weapons components, placing items into the weapon, and loading railcars. Other production control duties involved performing inventories on nuclear items. These inventories were performed monthly. Two-man teams were responsible for comparing numbers on the containers to serial numbers on a master list. During these duties, they were among the nuclear components.

Disassembly, repair, and retrofitting were also performed at IAAP. The purpose of the disassembly of weapons (sometimes referred to as teardown) was to salvage portions of the weapon that could be reused and to destroy the remainder of the weapon. The pit was one portion of the weapon that was recovered and eventually shipped to other AEC facilities. Disassembly was the reverse of the assembly process. High explosive hemispheres and any inner beryllium shells had to be removed from the pits. Following the initial attempt to remove the hemisphere and associated shells from the pit, residual adhesive and HE was left on the pit. Pits had to be returned free of adhesive. The pits were soaked in a bath of acetone and the residual material was scraped off the pit. At times the liner would separate from the HE, but remain fixed to the pit. This made it more difficult to remove. When the use of dry ice began, the disassembly process became easier. The clean pit was shipped off site for storage. The remainder of the unit was sent to the burning field. Weapons disassembled at IAAP included weapons assembled at the Pantex Plant.

Retrofit involved rework on units already assembled. This was a limited operation. Some of the units requiring retrofit were sent from Pantex. Repair activities included removing chips produced by machining in the HE. Weapons repair in the HE section was completed by Weapons Repair men. They used melted HE material to repair nicks in the HE hemisphere. A Weapons Specialist was available to assist during assembly when things were not working quite right.

Appendix B of the TBD outlines the assembly and disassembly dates for various weapon types at IAAP. This list appears to accurately reflect the operations at IAAP.

### *Other Operations*

Radiography sources included a Co-60, flash x-ray units, and other x-ray units. Laboratory staff was involved in developing improved methods for initiation. The laboratory analyzed various explosive materials and metals. Staff worked with flash x-ray units, open x-ray diffraction units, and radioactive sources. These sources were used as a replacement for the x-ray machines.

Radiography was primarily performed on HEs; however, warheads were also examined on occasion. The x-ray units were used to examine HEs for cavities and cracks. Cobalt-60 was used occasionally to radiograph completed weapons. The Co-60 source was maintained in a huge lead pit. Radiography operations were conducted in the x-ray vaults, which had a double interlock system.

X-ray unit inspections were periodically performed by equipment operators. Periodically, Safety conducted surveys on radiography systems, including checking the interlock systems. Shielding was provided around the x-ray machines to reduce exposure. When using the flash x-ray unit, personnel were 50 yards away in an underground area behind 3–4 ft of concrete.

The flash x-ray units were used during hydroshots to perform high-speed diagnostic surveys of HEs at the moment of detonation. Flash x-rays had to travel through steel and/or explosives requiring energetic photons. Explosives were used to drive a conductor through a magnetic field, creating high energy x-rays necessary to penetrate the material.

Although much of the weapons design work was done at Sandia, LANL, and Lawrence Livermore National Laboratory (LLNL), IAAP personnel were directly involved in resolving issues related to designs. Some engineers traveled to these sites to consult with weapons design staff. R&D was conducted on HEs materials and components. They were attempting to make smaller weapons. This work did not involve use of radioactive material containing Pu-239. Personnel designed improved equipment for use in the manufacturing and assembly process. As a result of these activities, visiting engineers came from other facilities to oversee design work, and to observe the use of newly designed equipment.

### *Burning Fields*

The burning field was located east/northeast of Line I and approximately 2 miles from the plant boundary. Materials (e.g., tools, pipes, tile, etc.) coming out of Line I that were not shipped off site were taken to the burning field. For example, if a weapon was taken out of service, the weapon was broken up, and the pit and other valuable material (e.g., gold and silver) was removed. The remaining components were taken to the burning field. That included even the papers and documents that referred to that specific weapon. Guards recalled having to escort documents to the Burning Field for destruction. They were required to stay with the documents until the process was completed. Materials were crushed if necessary, flash-burnt, and buried. Burning field operations involved open burning. Fires were lit remotely, after which individuals would go to an area about 0.5 mile away.

### *Test Firing (Hydroshots)*

Test firing of units with depleted uranium was performed from 1965–1974. There were a total of 701 hydroshots. A total of 8,500 lb of depleted uranium was destroyed in hydroshots. In addition, regular HE detonations were performed during this period.

Material to be tested was compiled in FS-5 or what is referred to as the Make Up Bay. Pin bugs, used to monitor parameters of the detonation, were glued into the hemisphere. The unit was taken to the firing site for set-up. Cables were lowered down into the FS-12 tunnel and plugged into the detonator lead. The set-up crew would go to a safe area (approximately 2 city blocks away). A siren would sound warning individuals test firing was occurring. The hemisphere was then detonated. A camera filmed the detonation. There were a couple of “special shots” per month that used flash x-ray. The force of the explosion drove the molten metal 0.5 inch into the neighboring steel-plated building. Occasionally, the detonation would cause fires in nearby timbers outside the fire break areas. Some site experts reported seeing a glow on the lake following hydroshots.

Following the hydroshots, a crew of men was required to retrieve large chunks of metal. Both large remnants and fine particles resulted from the explosion. Large pieces were retrieved using either bare hands or cotton gloves. Geiger counters were used in some cases to help locate these large pieces. This material was marked as radioactive material and forwarded for disposal. Personnel were required to access the FS-12 tunnel to set up detonations and recover materials from previous detonations.

During the remediation of the site, 35 lb of depleted uranium was found in the soil. This area was cordoned off and personnel, even the mowing crew, are not allowed into the area without authorization. This prevented disturbance of the depleted uranium, which may still be present at the site.

### *Production Records*

All records related to AEC activities were shipped to Pantex when the operations at IAAP ceased. Mason & Hanger was sold and no longer exists. No records are known to be stored at the corporate headquarters in Lexington, Kentucky. Some of the contents of the records available at Pantex include air monitoring data, area dosimeter readings, beryllium air monitoring data, accident investigations, and administrative procedures.

One site expert was formerly employed at Pantex and had the opportunity to review records at Pantex relating to the Burlington operations. The review of these records was required, due to requests submitted for worker records and incident investigations. Epidemiology groups also have requested records, including personnel monitoring records, air monitoring, and radiation survey data. There are a few hundred boxes of records relating to the Burlington plant located at Pantex. Many of the records are classified. The records were shipped from Burlington and automatically put into a Q-cleared storage area. The records have not undergone formal classification review.

### *Comparison of IAAP and Pantex*

Pantex and IAAP received two different weapons designs. Pantex worked primarily on weapons designed by LLNL. IAAP worked primarily on weapons designed by LANL. This indicates that the source term for the two facilities was not identical. Pantex had a similar mission to IAAP; the two were considered sister plants. The facilities were also similar in design. When both facilities were in operation, some weapons and/or components were passed back and forth between the plants. Items received from Pantex primarily required retrofitting due to what site experts refer to as poor craftsmanship. Pantex eventually took over the work performed by IAAP.

The processes implemented at IAAP varied from those implemented at Pantex. Each plant had its own interpretation of instructions and best practices. In general, the types of radiation hazards associated with the two facilities were the same from 1951–1975. Operations at both plants were primarily manual.

Chief engineers and scientists had the opportunity to visit Pantex, LANL, and LLNL (known at the time as Lawrence Radiation Laboratory) on a regular basis. During their visits to Pantex, it was observed that the facility had a better safety program than IAAP. For example, Pantex issued dosimeter badges to all individuals entering radiation areas. It was also noted that there was tighter control over the dosimeters. At Pantex, workers were provided with lead aprons; whereas at IAAP they were not. Worker proximity to the radioactive material also differed at IAAP and Pantex.

NIOSH used the Pantex film badge data from 1993–2003 to determine the neutron-to-photon ratios for IAAP. There is considerable concern among site experts, including safety personnel, regarding the use of these data as a surrogate for IAAP. One former worker of both facilities stated that comparing neutron exposure during the 1950s, 1960s, and 1970s at IAAP with that from Pantex in the 1990s is not valid. There were two reasons stated:

1. Weapon systems were very different
2. Processes were different, i.e., shielding process times were shorter at Pantex in the 1990s due to weapon design; therefore exposure was different

### *Army Plant Operations and Incidents*

Many individuals were killed in accidents at the plant in Division A. Incidents primarily involved explosions and exposure to chemicals. Guards at times had to remove corpses or portions of bodies from accident areas. Some of the specific incidents that occurred at the plant included the following:

- An explosion in a powder room, which killed a woman
- Explosions resulting in loss of hands or portions of hands
- An explosion of a detonator, which resulting in shrapnel being propelled into a woman’s leg
- Loss of consciousness from chemical exposure

Tetryl, a yellow powder, was used on Line 5B. People that worked with tetryl had their skin, hair, and the whites of their eyes turn a yellowish-orange tinge.

## Part 2: Health and Safety Program

As previously mentioned, interviews were conducted with a number of site experts, including former workers in production, inspection, test fire, security, and safety and health. Also interviewed were members of the Burlington Atomic Energy Commission Plant—Former Worker Program at the University of Iowa. The information provided is not a verbatim discussion, but is a summary of information collected from all experts interviewed.

Although many of the details of the operations and processes at the IAAP are deemed classified, it is evident that health and safety program information is not. This information is summarized separately in an effort to keep worker input intact.

### *General Information*

Mason & Hanger were responsible for the safety program. The safety department was responsible for providing industrial safety, industrial hygiene, radiation protection and environmental monitoring support to Line I operations. Initially the safety department was relatively small, with seven to eight individuals supporting Division B operations. Eventually this number grew to 10–15 individuals. This included safety inspectors, area safety engineers (responsible for a particular area), safety engineers (responsible for multiple areas), and safety management. Rarely, the safety personnel were sent to Division A to support operations or for training. Safety was also involved with criticality safety. The AEC conducted semi-annual audits of the safety program, including criticality safety and radiation protection. Inspectors were sent from the AEC office in Albuquerque.

The safety department at the facility was privy to the types of weapons assembled, disassembled, and retrofitted. They had a general knowledge of the radionuclide constituents of the subassembly.

### *Radiation Safety Training*

There was no formal radiation protection, criticality safety, and fissile material handling training onsite. The level of training depended on the position the employee held. Safety personnel received radiation protection training from the AEC, including training courses taught offsite (e.g., DESA Base, Nevada Test Site). Courses included training in radiation protection, explosive handling, industrial safety, and fissile material handling. Some individuals (e.g., safety, process engineering, and chemistry) were sent to LANL, Sandia, and Pantex for training. These classes covered fissile material handling, criticality safety, and emergency response. Personnel involved in radiography were provided training when they first started at the plant. There was facility safety training associated with work on Line I, but it was not extensive.

Periodic radiation safety training sessions were conducted onsite. The contents of these meetings included all aspects of safety. During these meetings, they would discuss problems encountered in operations and the safety related to various operations. These meetings did not exclusively focus on radiation safety, but included dangers related to handling and processing explosives and the requirements for cleanliness in the work areas. Cleanliness was critical, as dust could be an explosive hazard. Some sessions included a discussion of the dangers of radiation and how to minimize exposure (e.g., time, distance, and shielding). Annual safety meetings were also held at the plant. Individuals received on-the-job training related to their particular job. Safety performed walkthroughs of the area, providing input on safe handling of radioactive material during these tours.

Although the security force was frequently near the weapons and materials, they did not receive radiation safety training. The shift commanders of Physical Security Guards had the responsibility for providing first response for injuries. They were provided with no training related to this responsibility. The limited amount of information they were able to ascertain on safety was learned from documents left out by mistake. There was no formal safety training.

Worker awareness of the presence of radioactive material in the facility seemed to vary. Some were cognizant they were handling this material, while others were blind to this fact. Safety and supervision tried to made individuals aware that they were handling radioactive material. The workers did gain a general awareness of what they were doing from the news media. Supervisors who were questioned told workers “Don’t worry, it’s clean enough to eat off of.” Workers were repeatedly reassured there was no radiation leakage from the pits. Some workers were aware of the potential hazards of select chemicals. Production workers could feel heat emanating from radioactive material. Hair on their arms would stand up and their legs felt prickly. Many workers were also aware that they were working with hazardous chemicals.

As a group, workers were concerned about their safety and the safety of their coworkers. As workers become more aware of the hazards over time, they began to become more safety conscious. In general, site experts felt the radiation safety program at IAAP was lax. The corporate policy towards safety was to provide the worker with the best possible safe working conditions using the latest technology available at the time. This was a consistent policy over time. Although some workers believe the company would not put them in harm’s way, others indicated the hierarchy of priorities at the facility was production, security, and safety, in that order.

The company maintained a record of safe workdays. Demonstrating good safety statistics was important to management. As a result, injured workers were strongly encouraged to return to work, even if they could only sit there for the remainder of the shift.

When the AEC started to ship the pits and other material back to Pantex, the situation worsened. There were a couple of occurrences where pits and the beryllium shells were found lying on the floor. The AEC supervisors at the facility were not strictly enforcing safety requirements associated with the proper storage of weapons components.

### *External Exposure*

The level of contact with radioactive components during weapons assembly was dependent on the phase of the process in which the individual was involved. Some jobs did not require handling the material at all, while others did. In some cases, this direct contact with pits was a routine part of a worker’s job. There was no contact with neutron generators, to the best of site experts’ knowledge. The highest exposure potential was associated with the assembly and disassembly process. The radiation exposure was reportedly worse in 1-11, 1-63, 1-61, and 1-13. Situations where radiological conditions were unknown, such as when the commander initially entered the transport vehicle, may have posed radiation exposure risks.

TracerLab and later Landauer provided external dosimetry services to the site. Whole-body dose was monitored via beta-gamma film badges to some extent throughout IAAP AEC operations. Thermoluminescent dosimeters (TLDs) were not used for the measurement of whole-body dose during AEC operations. The monitoring policy was to assign film badges to workers who performed hands-on work with radioactive material and to radiographers. X-ray technicians and radiographers were among those routinely monitored. Those individuals who had intermittent exposure, such as those walking through an area, were not assigned dosimeters (e.g., some production workers). Prior to 1962, film badge monitoring was intermittent, even for those who were assigned dosimeters.

Workers were pulled from the area when they had exceeded their limits; the film badge data does not reflect this. Also, there are a number of individuals who entered areas where radiological hazards existed (e.g., the bays) who were not badged. In addition, the security force was responsible for shipping and receiving of materials as well as guarding stored materials. They were not routinely badged. The monitoring policy for workers was not standardized. For example, supervisors were badged rather than production workers. Dosimeter usage was not strictly enforced, so at times the workers did not wear their dosimeters while working with radioactive material. Although there was direct contact with radioactive material, not all workers assigned to a particular task were monitored with film badges. Many sites experts involved in production say they were not monitored with pocket ionization chambers or extremity badges.

Dosimeters were provided to laboratory staff. The badges were worn during the operation of machines generating radiation or containing radioactive material. Workers did not wear their dosimeter when the units were not in operation. During staff shortages, the laboratory was provided with temporary support from other areas. These individuals were not provided dosimeters during their assignment to this area.

Extremity dosimetry (i.e., ring and wrist dosimeters) was initially used intermittently due to the poor design of the dosimeters. When Landauer started producing extremity TLDs, there was an increase in use of extremity dosimeters. Extremity dosimetry was not assigned to many production workers, including those with direct access to pits. Pocket ionization chambers were used at times in the x-ray vaults. Safety staff did not find them very reliable. Timekeeping was not used at the facility to track worker dose.

Few details on the design of the film dosimeter were obtained from site experts. They did remember that the dosimeters were green and rectangular in shape. Film badges were stored on racks at the AX-1 security post. There may have also been a storage rack in Building 1-100. Badges were exchanged periodically. Some film badges had individual names, while others did not. Control badges accompanied each shipment of dosimeters from Landauer. These were stored in the safety office. Site experts typically reported that when monitored, they wore their dosimeters on the collar of their coveralls. Other employees wore their dosimeter at their chest level. The radioactive source was typically at waist level or higher. Only a fraction of the individuals who worked in Division B were monitored. The used dosimeters were put into a box and new dosimeters were put in their place. Some type of inventory or processing apparently occurred at the laboratory on site.

Workers were not sure their dosimeters were actually being processed, so they marked a couple of the dosimeters and followed their movement to the lab. These dosimeters were later found in the trash.

Personnel wore wedding rings and watches into the production areas. Jewelry, belt buckles or other metals were never confiscated by safety as a result of neutron activation.

Workers were not cognizant of the biological risks associated with the exposure to radioactive material. No shielding, such as lead aprons, was used during production operations. Production workers came in direct contact with the pits. Workers could feel the heat generated from the hemisphere. Due to the orientation of the units, heat could be felt from the knees to the mid-trunk. The smaller the unit, the hotter it was. Workers had to prevent body oil and dust from getting on the surface of the pits, so they used cotton gloves or Kimwipes to handle them.

### *Internal Exposure*

Tritium reservoirs were received in small canisters. Alarming monitors detected airborne tritium releases during the decanting process. There may have been significant exposures related to work with tritium. Tritium leaks were a common occurrence at IAAP. Contamination surveys of the lifts and other areas indicated beta contamination from tritium. No flaking or loss material was observed on the pits. Other potentials for internal exposure were present at the burning fields and test areas.

With respect to internal dose hazards, it should be noted that the average radon concentrations in the Iowa area are the highest in the nation, whereas radon concentrations in Texas are quite low. This invalidates the use of the Pantex indoor radon values in the TBD. A better method of radon exposure reconstruction would be the use of glass-based reconstruction detectors (Steck et al. 2002). Workers often spent significant time in underground structures at IAAP. The potential for radon exposure is significant when one considers that that a yearly average radon concentration of 150 Bq/m$^3$ (4 pCi/L) imparts an estimated average annual dose of 200 mSv (20,000 mrem) to the target cells in the bronchial epithelium (Field 2005b).

A limited bioassay program existed at the facility. Urine bioassay samples were collected from some workers several times per year, while others were not required to submit a single bioassay sample during the course of their employment on Line I. Some of the bioassay samples were analyzed onsite, while others were shipped offsite, according to site experts. In-vivo counting was not used to monitor internal exposure at the facility. Site experts were not familiar with the term “bioassay,” making it difficult to distinguish between medical and drug-testing urinalysis and that done for the purpose of radiation protection.

Personnel protective equipment (PPE) included coveralls, safety shoes, safety glasses, gloves (occasionally), and face shields (occasionally). Site experts indicated that general job assignments were indicated by the color of coveralls worn. Management and Safety wore white coveralls. Those involved with HEs wore brown coveralls. Assembly workers wore green coveralls. Civilian clothing was worn under the coveralls. The plant provided conductor safety shoes, which were worn home. Cotton gloves were provided for some operations (e.g., handling pits). Work clothes and safety shoes would accumulate dust and chemicals over the course of the shift. Occasionally, they took their work clothes or parts of their work clothes home for laundering and families would come in contact with the material deposited on these clothes. Security personnel work uniforms.

Shower facilities and change rooms were available at the plant. Some individuals took showers and changed, and some did not. Individuals from the HE, disassembly, and melts took more showers than others. Workers were not required to frisk when leaving the area. At times workers would run the Geiger counter over the body for fun. They did not detect radiation above background. Production's work clothes were laundered on site. Security staff did not have access to showers or changing facilities and wore their uniforms home.

Specific workers had additional or alternate personnel protective clothing. Painter's masks were used in the HEs area. Personnel in the labs or involved with radiography were provided with lead aprons, face shields, gauntlets, safety glasses, and/or safety shoes, as needed. The production workers' coveralls were laundered in the plant laundry. The guards' were sent to Sickels Laundry in Burlington. The workforce did not use lead aprons when working around radioactive material. Contaminated laundry was reportedly shipped to Pantex for disposal. As a result of the shipment of laundry off site, there has been some concern with regard to contamination of public areas.

Eating, drinking, smoking, or applying makeup in the immediate area of radioactive material was not allowed in general. For some security posts (e.g., buddy system posts) guards were not allowed to leave the area and therefore had to eat their meals at their duty station. Drinking water was available in the ramps, which were separated from the production area by a door. The ramps were enclosed covered walkways between bays and buildings. There were a few smoking areas in the ramps.

There was ventilation within the production areas, due to the chemicals handled. Fume hoods were used for a few operations (i.e., venting tritium containers). One building housed a booth for sandblasting. Ventilation in the production areas varied based upon location. Buildings 1-61, 1-63, 1-13, and 1-40 were sealed tight with a limited air exchange. There were many air leaks in walkways and some buildings. Other buildings, such as 1-63, 1-77, 1-73, 1-13, and 1-61, were climate controlled at 73.4 degrees and less than 15% humidity. When there was a failure in temperature and humidity controls, weapons had to be moved to other areas. Ramps were enclosed and heated. Buildings were air-conditioned.

The assembly and disassembly processes occurred on tables in the middle of the room. Inspections also took place in an open area. In the case of an explosion, the Gerties (i.e., assembly and disassembly areas) were designed to seal themselves. Production workers did not use lead aprons.

### *Field Radiological Control*

Special Work Permits or Radiation Work Permits were not used at IAAP. Safety Department Work Permits were issued when maintenance work was performed at the facility. Safety activities were directed by procedures, which were maintained by the Safety group. Emergency response (red bordered) procedures were placed at the entrance to each operating building. Specific safety instructions were written into operating procedures.

Radiation postings were at the entrance to areas involved in processing of radioactive material. These areas included 1-11, 1-12, 1-13, 1-61, 1-63, 1-73, 1-77, 1-100, the lab, and C Yard. Site experts remember seeing radiation labels on some units or containers. Postings and labels were the standard yellow and magenta postings with the trefoil. Following an OSHA visit in 1974, there was a marked increase in radiological posting at the plant. Hazardous material postings (i.e., chemical and cancer-causing) also increased during this period of time.

The radiation survey instruments used at the IAAP included Victoreen 440 ionization chambers, Eberline PAC-3Gs, Geiger-Mueller counters (Geiger counters), scintillation detectors, T-289 fixed tritium monitors, and T-290 portable tritium monitors. The Victoreen 440 was primarily used to perform surveys on x-ray units and radiography sources. It was also used for general area surveys. Both the T-289 and the T-290 were flow-through ionization chambers used to monitor for airborne tritium.

The first individual entering the assembly/disassembly area each morning was required to response-check an area Geiger counter. If it didn’t respond correctly, no one was allowed in the building until a functional meter was obtained. When a replacement Geiger counter had to be obtained, Security was required to escort the individual and the replacement meter into the area.

Direct contamination was measured with a Geiger counter. These surveys were conducted on a monthly basis. Swipes were taken to evaluate removable contamination in the production areas and on material shipped and received at the site. A fraction of the pits opened per day for weighing and inspection were swiped. The swipes were analyzed for contamination on a scintillation detector. Little or no wet chemistry was done on the swipes.

Dose rate measurements were taken in some areas along Line I. There were radiation readings observed periodically in the Igloos and other operating areas; however, they were not high enough to cause any safety concern. The configuration and number of items allowed in a particular area limited the external exposure in those areas.

Regular neutron surveys were *not* conducted at the facility. IAAP did have a neutron monitor onsite in case of an incident. At one time visitors from Battelle in Washington State performed an analysis of neutron exposures on a unit at the facility.

Air sampling and external radiation measurements were performed in the control room during the hydroshots. The air filters were tested for alpha contamination. Hydroshots dispersed large and small pieces of uranium oxide. The larger pieces were driven into the ground. Smaller pieces may have been found on the surface. As previously mentioned, larger pieces were retrieved. This work required heavy leather gloves to protect the hands. There was an established waiting period prior to re-entry into the site.

There was an extensive area dosimetry monitoring program for gamma exposure. Area dosimeters were placed in production areas and storage areas. Area dosimeters were hung on the walls in storage and production areas. They were similar to the personnel dosimeters. Film badges were placed at or above the individual’s head. In general, workers were closer to the source term than was the area dosimeter. For example, the worker may be in contact with the radioactive material, but the area film badge was located several feet away. Although little information is available on the storage of pits and other radioactive weapons components, area monitors were placed in these areas. There were storage yards with annual radiation exposures exceeding 8 rem per year. The levels are reflected in a letter to the Board from Dr. William Field (Field 2005a).

T-289 monitors were wall-mounted radiation monitors with alarm capabilities and lights (i.e., green, red and yellow). These were used in the tritium storage buildings and some production areas, such as Buildings 1-11, 1-13, 1-61, and 1-63. T-290 tritium monitors were portable and resembled a suitcase. The monitors were often put on onsite transport vehicles, or were put in areas where tritium monitoring was needed. Both tritium monitors were very sensitive. When the tritium shipping container was opened, the T-289 would occasionally measure some airborne tritium.

Limited information is available on waste management practices at IAAP. There were special containers for the disposal of swipes and Kimwipes. These were periodically removed from the area. Radioactive waste was generated as a part of the disassembly process. Radioactive waste shipments were sent to Pantex in the 1970s. Contaminated clothing was included in these shipments. Records also indicate that Cs-137 was sent to Pantex from Burlington. The source of the Cs-137 is unknown. When Line I was cleaned, the area was hosed down, mopped, and the water swept out the door. The contents of this waste were not always known.

### *Environmental Monitoring*

For a period of time, there was some perimeter monitoring for radiation. Each cell had an individual filter system that ventilated to the outside. The tritium can was vented in an open-faced fume hood. Some of the tritium was released through the stack. There was environmental monitoring related to explosive contamination, solvents, adhesives, and other chemicals. Site experts were not certain whether stack monitoring data was available.

Tests related to the nuclear weapons program were performed at the firing site several times per week. Newspapers reported the release of radioactivity to the environment from these blasts. Smoke blew all over, including offsite. When the air currents were right, contamination from the burning fields and firing sites was spread to Middletown, Burlington, or West Burlington. The kids of Middletown reportedly liked to play in what they referred to as “the clouds.”

Impound pools were maintained on the backline. Material from operations was allowed to flow in these pools. The water would turn a reddish color, due to the material released into the pool. A pipeline ran between Line I, and Lines 2 and 3, to the plant spillway. Long Creek ran into the plant lake and over the spillway to the Skunk River. Mathis Lake was the only source of drinking water to the plant for years before connecting to the Burlington city water supply. This was also the source of water for residents adjacent to, or on, the plant property. Long Creek passed through the firing site on its way to the Skunk River, then to the Mississippi River. RDX contamination was identified in groundwater around nearby Wever, Iowa. Biological organisms have been used to assist in the cleanup of the contamination in the area (presumably, chemical contamination). Site experts noted that there were occasions when wildlife in the creek died due to contamination from the site.

After the end of the AEC mission, the facility was cleaned and checked. The site was eventually named a Superfund site. When the site was remediated, the burning field was excavated. The plant maintained an onsite disposal site. Plant waste was disposed of in this area. Bags of beryllium and other metals were retrieved from this area. Material was relocated to berms on the west side of the property.

### *Line I Incidents and Unusual Occurrences*

In the case of an incident or unusual occurrence, workers were directed to contact Safety and/or Security. Emergency response procedures were available at the entrance to a particular facility. Personnel were trained on how to respond to tritium monitor alarms or unexpected incidents involving safety.

There were numerous injuries at the plant, including abrasions, cuts, smashed fingers, overexposure to chemicals, etc. These were primarily associated with the production activities. There were a lot of burns observed in the Melt area. When an individual had more significant injuries, they were taken to the site hospital (basically a first-aid station) for treatment. Following this they were returned to work to finish the shift. If injuries were minor, personnel would take care of the situation on their own (e.g., wrap the area with masking tape) to avoid going to the site hospital. Safety reports were filed; however, it is uncertain whether these reports were retained.

According to safety personnel, radiation incidents were few and far between. There was at least one occurrence where a woman was reassigned to another job due to excessive radiation exposure. There were a number of industrial safety incidents. No skin or personnel contamination incidents were recorded at IAAP from 1958–1974. Prior to this, it is unknown, as the safety staff members interviewed started employment in 1958.

Tritium monitors (T-289 monitors) were mounted on the walls in various areas. The unit had an alarm function with red, yellow and green lights. When the T-289 alarm sounded, occupants were directed hold to their breath and to exit the area immediately. Evacuation of some areas was time-consuming, since only one person at a time could exit through the revolving doors. Security personnel fell back to a secondary position. Sometimes they used their vehicles to surround the building after an alarm. The Safety Department was notified of the alarms and entered the area with a meter to determine the radiological conditions. At times the building was declared off limits for the remainder of the shift and at other times personnel were allowed back after Safety had declared it safe. Personnel were not provided with an explanation of why the unit alarmed. The frequency of alarms became more prevalent starting in the late 1960s. The alarms on these monitors would frequently go off and become a nuisance. As a result, these monitors were turned off or the alarm set point was raised. In other cases, the T-289 monitors were found unplugged. Security maintained a log of radiation monitoring alarm occurrences and noted that there appeared to be fewer alarms immediately following calibration of the equipment.

Many of the incidents involved accidents with HEs that were processed on mills, lathes, or other machines. In one instance, an individual was working on a hydraulic press. Hydraulic presses were used to press explosives into a container. Explosives were compressed on a press at 20,000 psi. When the individual went to use the press, the machine plug shot up through the roof and back down to the ground. The press was destroyed as a result of this. No personnel were injured. There were two additional incidents involving presses.

Some workers reported seeing a blue flash in a cell once, which could have been any number of things. Some workers maintain that this was a criticality. Another possible explanation is that the tester was hooked up to the wrong charge, and there was a blue flash. There was no explosion associated with the incident.

There is a story of a couple of men who were burned in some sort of accident in Building 1-63. They were removed from the facility via ambulance. Eventually they were transferred to Iowa City, Iowa, due to massive burns. Both men died within a few days. Not much detail is known relating to this incident and paper evidence is absent. The incident was kept hushed. The workers may have been visitors from another facility. A shift lieutenant and security guard went into a Gravel Gertie and brought them out. The security personnel both suffered health problems.

Two production workers, highly skilled in disassembly of weapons, were approached by their supervisor to assist in the disassembly of a particular weapon (i.e., Mark 25) that had been shipped to IAAP. After much coaxing and a promise that they could leave early, these men agreed to do the disassembly. This weapon had fallen out of the bomber door and skidded down the runway. It was evident that the weapon had been exposed to flames, as there was some blackness on the weapon. The sphere was very difficult to pull apart, so they had to use the press to assist in this task. Facility management and workers were very concerned about a compression incident, so care had to be taken. Site experts indicated that the pit was intact.

Following the completion of this task, the men were not allowed to go home early. As a result, they did not agree to perform anymore of these types of disassemblies. They were asked one other time to perform a special disassembly and declined. The details are not known with regarding this request.

Site experts do not recollect explosions (other than hydroshots) that could have dispersed radioactive material. There were no fires associated with the pits; however, the adhesive would get hot and flame if left sitting too long.

As with many facilities, workers were involved in unauthorized practices. To initiate new guards, senior guards would use a steel brush on the pits to show them the resulting sparking without the knowledge or consent of supervisors. Several site experts have reported occurrences where pits were dropped. One shift commander reported visiting a disassembly site that had the explosive ball frozen and cracked open. The pit was lying on the cement floor with a vacuum pump attached. A couple of the workers wanted to be cute and dropped a 20–30-lb chunk of explosive on the floor to see if security would get excited.

### *Chemical Usage*

Site experts reviewed a chemical inventory associated with weapons production and indicated that the following chemicals were used at IAAP in the weapon production process. Some of these chemicals were used in the HE manufacturing process. This is not a comprehensive list of all chemical used throughout the AEC operation, but lists some of the more frequently used items.

Acetone
Acetylene
Alcohol (methanol, isopropyl, ethyl)
Barium
Boron
Dichlorodifluoromethane
Dry Ice
Glacial Acetic Acid
High Melting Explosive (HMX)
Hydrochloric Acid
Kerosene
Methyl Ethyl Ketone (MEK)
MOCA (adhesive)
Oxygen
Plastic Bonded Explosive (PBX)
Pentaerythritol Tetranitrate (PETN)
Polyester Resin
Cyclotrimethylenetrinitramine (RDX)
Sulfuric Acid
Tetryl
Thinner (enamel, paste stencil)
Trinitrotoluene (TNT)
Toluene
Trichloroethylene

This information is provided so that any interactions between the chemicals and the nuclear components of the weapons can be evaluated.

Beryllium exposure was of significant concern. Beryllium tools were used in operations because they would not spark. These tools had to be sharpened occasionally by the machine shop. There was also beryllium exposure in the machine shops. At times the fork lift drivers would run into walls, causing release of asbestos.

### *Medical Exams*

Individuals received medical exams upon initial hire, periodically thereafter, and at termination. Physical exams occurred as often as once or twice per year. Individuals also had to be evaluated by Medical if they were on sick leave for extended periods of time. Medical exams included urinalysis, blood work, a hearing test, a vision test, and a standard chest x-ray. X-rays were taken in the posterioanterior position with the shoulders against the plate. Security also received a back exam. At one period of time, the plant doctor refused to perform x-rays until a new unit was available, because the existing x-ray machine was too dangerous for use.

### *Safety Records*

Radiation protection support was provided by onsite personnel. The Safety Department maintained a file on each monitored worker. Dosimeter readings were maintained in batches. Some records were copied and place in a worker's medical file. The type of report issued by Landauer was based on the regulations that applied at the time. With respect to IAAP dosimetry results, the DOE reporting regulations should be consulted. There are times in history when a vendor was not required to report both deep and shallow dose.

Personnel radiation exposure records included results of badge reports and cumulative exposure. Badging frequency could also be determined from information in the record. Many workers have never seen the contents of their radiation exposure file. During the period of operation, formal radiation exposure reports were not issued to monitored employees. Some monitored workers were told whether they were within limits or not.

Landauer presently maintains a comprehensive collection of historical records, including all the film submitted for processing since the inception of the company. There is information available on dosimeter design and calibration procedures. This information was previously provided to NIOSH; however, it is uncertain whether the Office of Compensation Analysis and Support or another group received this information.

When AEC discontinued operations at IAAP, they sent the records to Pantex. One former employee of Pantex was involved in a review of IAAP records at the Pantex Plant. This was the result of repeated requests for radiation monitoring data and incident reports. There are a few hundred boxes of records that were presumably shipped to Pantex when IAAP AEC operations discontinued. As these records have never undergone a formal review for classification, all records are stored in a Q-cleared facility. Records include air monitoring, survey, and personnel monitoring records. Also included are beryllium air monitoring records, incident and accident reports, and administrative procedures. Additional records may be available at LANL; however, this has not been verified. There are no publicly available historical records. IAAP Safety personnel interviewed indicated that field survey data and personnel monitoring data were *not* marked as classified data.

Records retrieved by the University of Iowa as a part of the medical surveillance study took a considerable effort to obtain, due to security issues and identification of the location of records. A limited number of records have been identified at the Pantex Plant. There may be additional records in Albuquerque, since this field office oversaw operations at IAAP. When the University made the original inquiry for the records at Pantex, they requested all records relating to operations at Burlington. Pantex provided an inventory of records they had in the "vault," which comprised the contents of six boxes. The inventory list was reviewed by Pantex to insure information provided was not classified. Whether the inventory was sanitized is uncertain.

There is limited data available on individual work histories. The dataset compiled by the University of Iowa includes personnel identifiers, date of termination, job codes, area dosimeter readings, and individual dosimeter readings, where available. The only specific work history is that obtained from the workers themselves. This makes determination of dose by category difficult, if not impossible. Other then self-reported information, there is no way of knowing which buildings an individual may have been assigned to.

Linkage between individual film badge readings and work location are possible based on personal knowledge; however, the available records do not contain specific information to allow for this type of linkage.  Workers periodically changed job assignments, and thus work locations, making this more difficult.

Both field and personnel monitoring at IAAP are incomplete, based on the information reviewed to date and discussions with former IAAP workers.  During the course of the work performed by University of Iowa, the researchers have not been able to locate standard operating procedures for health and safety, and criticality safety.  Nor were they able to locate any bioassay data, including tritium bioassay data, which, they were told, started at the plant in the 1950s.  No calibration procedures for radiation monitoring equipment have been found.  Limited amounts of area monitoring data are available.

### *Site Profile Comments*

NIOSH conducted a worker outreach meeting at the union hall in Burlington on July 29, 2004. NIOSH staff formally documented this meeting, and copies have been recently distributed to the workers involved in the meeting for their comments.  This meeting was held to specifically discuss Revision 0 of the IAAP site profile (ORAU 2004).  Site experts indicated that Revision 0 of the IAAP site profile did not reflect the operations occurring at the plant.  Some worker input has been integrated into the site profile, while other input has not.   There is a general concern regarding the transparency of the dose reconstruction process and the generalities associated with the document.

## References

Field, R.W., 2005a.  Letter dated April 22, 2005, to Paul Zeimer and other members of the Advisory Board on Radiation and Worker Health.

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ORAU, 2004.  “Technical Basis Document for Atomic Energy Operations at the Iowa Army Ammunition Plant (IAAP),” ORAUT-TKBS-0018, Rev. 00, Oak Ridge, Tennessee.

ORAU, 2005.  “Technical Basis Document for Atomic Energy Operations at the Iowa Army Ammunition Plant (IAAP),” ORAUT-TKBS-0018, Rev. 01, Oak Ridge, Tennessee.

Steck, D.J., M.C. Alavanja, R.W. Field, M.A. Parkhurst, D.J. Bates, and J.A. Mahaffey, 2002. “$^{210}$Po implanted in glass surfaces by long term exposure to indoor radon,” *Health Physics*, 83(2):261–271.

# ATTACHMENT 5: CLASSIFIED REVIEW AGENDA

## Advisory Board on Radiation and Worker Health (ABRWH)
## Classified Briefing on the IAAP Site Profile

Draft Agenda
April 12, 2005

**8:00 – 8:30 Facility Badging**

**8:30- 9:00 Welcome and Introductions**
- History of Site Profile Revision
- DHHS / NIOSH Need-to-Know

**9:00 – 9:15 Classified Records Reviewed**
- Classified - IAAP History Reports (NARA)
- Classified - Health Physics Analysis of Doses Received at the Iowa Ordinance Plant PNNL-ETD-0385 (PNNL)
- Classified - "Bomb Books" (DOE-HQ)

**Other Records Reviewed Incorporated into Revision**
- University of Iowa Records (Dosimetry)
- DOE (EH-8 / Pantex) (Incident Reports)
- Pantex Records Holdings (Tritium and DU air monitoring data)
- ATSDR Health Consultation
- ORNL – Indoor Radiological Survey

**9:30 – 11:30 Overview of Radiation Exposures at IAAP**
- *General Information*
  - Weapons Programs at IAAP
  - Radionuclides associated with IAAP Weapons Programs
- *Internal Dose Reconstruction (Chapter 5)*
  - Encapsulated Fissile Materials
  - Tritium Exposures
  - Depleted Uranium Exposures
  - Other Radionuclide Exposures
- *External Dose Reconstruction (Chapter 6)*
  - Generic Pit
  - Work Factor Methodology (PNNL Report)
  - Neutron Exposures (Pantex data)

**11:30 – 12:30 Lunch**

**12:30 – 4:30 ABRWH and SC&A**
- Questions and Answers?
- Review of Classified Documents?

# ATTACHMENT 6: ASSESSMENT OF DOSE RATES FROM "GENERIC PIT"

Appendix D of the TBD presents a summary of the assessment of the external dose rate from a "generic pit," which is represented as a bounding exposure for the purpose of evaluating worker doses during the 1949–1962 period at IAAP. SC&A has performed its own analysis of this scenario, using the parameters presented in Appendix D. The SC&A analysis utilized the Los Alamos Monte Carlo code MCNP5 (LANL 2003), a revision of the MCNP4C code used by NIOSH.

Various isotopic mixtures of plutonium can be used in nuclear weapons. In order to study the effect of such different compositions, we performed a set of five analyses. Each analysis, in turn, assessed the dose rate from one of the five principal radionuclides found in plutonium weapons: Pu-238, Pu-239, Pu-240, Pu-241, and Am-241.

In addition to plutonium isotopes and highly enriched uranium, U-233 was produced at DOE nuclear defense production plants (DOE 2003). According to Fretwell (2002), a composite U-233/plutonium weapon was reportedly detonated at the Nevada Test Site in 1955. Uranium-233 was processed at the Rocky Flats Plant between 1965 and 1982 (Freiboth and Gibbs 2000). During early production, the material was contaminated with about 50 ppm of U-233. In later years (1974–1977), the U-232 contamination was reduced to 7–8 ppm. In order to evaluate the dose rate from such a weapon, we performed an MCNP analysis of a U-233 pit.

### *Exposure Geometry*

Because of the intimate geometrical relationship between the receptor and the source, the receptor geometry was described by a MIRD phantom. The phantom used in the simulations is a custom version of BodyBuilder, a commercial MIRD phantom computer program from White Rock Science.[1] This program generates an MCNP geometry description for a MIRD-type anthropomorphic phantom of a specified age, from infant through adult. The phantom's sex may be chosen, as well as which organs to include in the model. The models produced by BodyBuilder are based on the descriptions for several ages (newborn, ages 1, 5, 10, and 15 years, adult female, and adult male) by Cristy and Eckerman (1987). A 21-year-old androgynous phantom, with female breasts and both male and female gonads, was used in the present analysis (see Figure 1).

The calculated organ doses were summed to determine effective dose, using the ICRP-60 methodology. Two assumptions were made:

(1) Red bone marrow is distributed over entire skeleton
(2) Red bone marrow and bone surface dose are equal

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[1] P.O. Box 4729, Los Alamos, NM 87544

The plutonium pit was assumed to be a spherical shell, with an outer radius of 15.24 cm, an inner radius of 15.11 cm, and a density of 16 g/cm$^3$, which yield a total mass of 6,019 g of plutonium metal. The U-233 pit was also modeled as a hollow sphere. Because U-233 has a higher critical mass than Pu-239, the sphere was assumed to have a mass of 16 kg. The density of uranium is 19.1 g/cm$^3$; the sphere has an outer radius of 15.24 cm and an inner radius of 14.947 cm, which yield a total mass of 16,022 g of uranium metal.

The source and the receptor were surrounded by moist air above a 30-cm-thick slab of concrete.

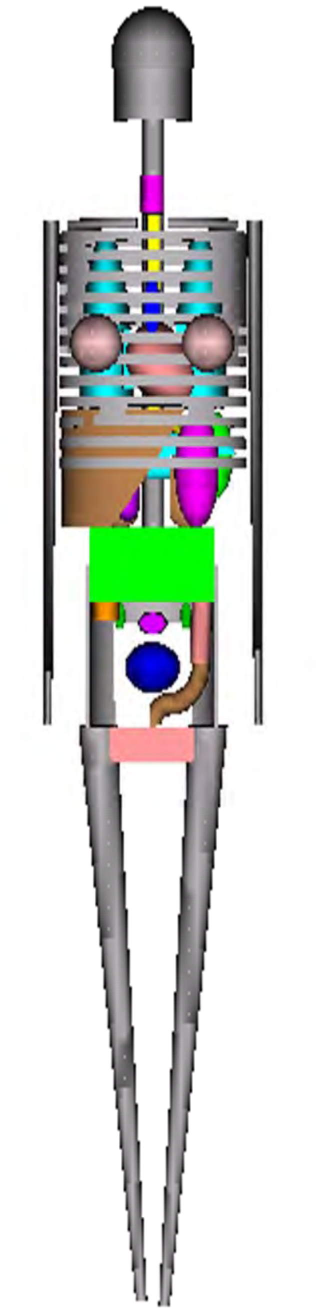

Figure 1. Standing Phantom

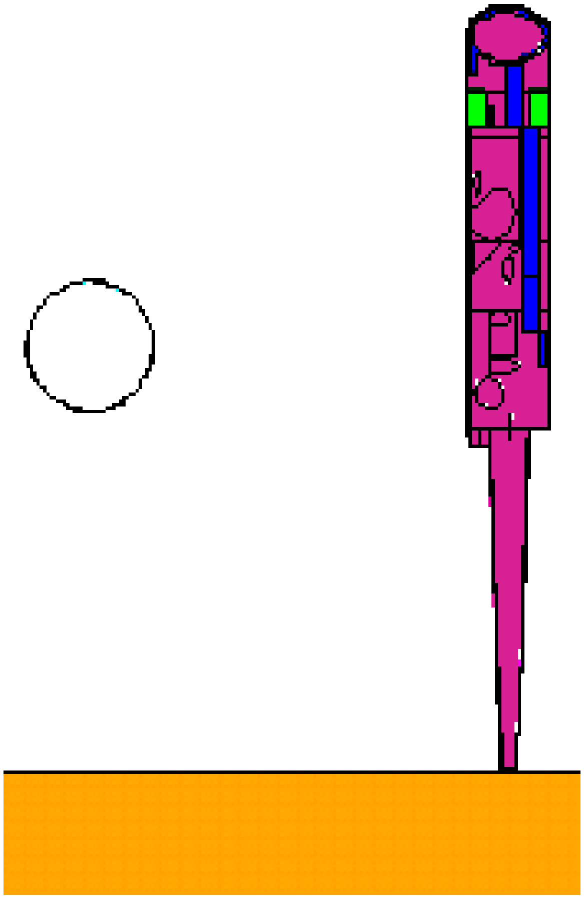

Figure 2. Standing Phantom with Pit

Two exposure geometries were evaluated:

(1) A standing phantom, facing the shell at a distance of 100 cm from the center of the shell to the center of phantom (see Figures 1 and 2). The center of the pit is 100 cm above the floor.

(2) A seated phantom, with the spherical shell in its lap (see Figure 3).

The analysis of the plutonium pit was confined to the principal x-ray and γ-ray emissions from each of the five radionuclides. These photon spectra were based on data compiled by the Tokai Research Establishment, JAERI (2001). Electrons, β rays, bremsstrahlung x-rays, and the photon and neutron spectra from spontaneous fission were not included. These radiations were judged to constitute a small fraction of the total dose.

Before assessing the dose rates from the U-233 pit, we performed scoping analyses to estimate the relative contributions of U-232, which is present as a contaminant. Uranium-232 decays to Th-228, which has a 1.9-year half-life. Thus, 15-year-old U-232 would essentially be in secular equilibrium with Th-228 and its short-lived progeny, which include highly energetic γ emitters, notably Tl-208. We confined our analyses to the principal x-ray and γ-ray emissions from Th-228 and its progeny (U-232 itself produces no significant photon radiation).

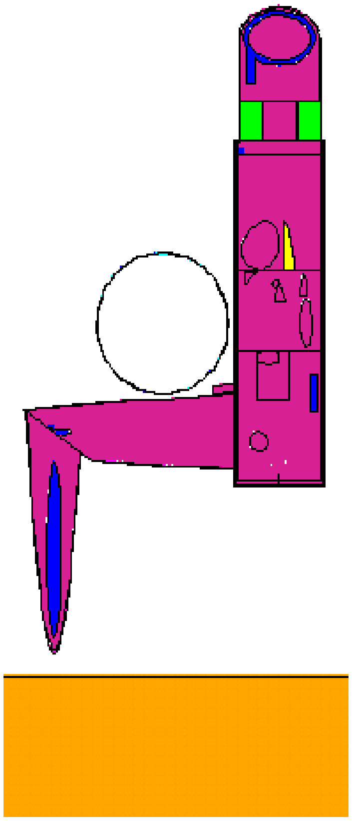

Figure 3. Seated Phantom with Pit

### *Results*

The results of the calculations on the plutonium pit are shown in Table 1. The values in the columns headed "Normalized Dose Rate" are derived from the MCNP calculations for the two exposure geometries described above. These values are normalized to a mass fraction of one for each isotope—i.e., the specific activity of the given isotope is the same as if the pit were composed entirely of that one isotope.

**Table 1. Dose Rates from Generic Plutonium Pit**

| Nuclide | Normalized | | Hanford Weapons Grade | | | Hanford Reactor Grade | | |
|---|---|---|---|---|---|---|---|---|
| | Dose Rate (mrem/h) | | Fraction (g/g) | Dose Rate (mrem/h) | | Fraction (g/g) | Dose Rate (mrem/h) | |
| | Standing | Seated | | Standing | Seated | | Standing | Seated |
| Pu-238 | 676.57 | 1,763.33 | 4.44E-04 | 0.30 | 0.78 | 8.87E-03 | 6.0 | 15.6 |
| Pu-239 | 8.00 | 23.93 | 9.30E-01 | 7.45 | 22.29 | 5.50E-01 | 4.4 | 13.2 |
| Pu-240 | 8.43 | 21.87 | 5.98E-02 | 0.51 | 1.31 | 2.60E-01 | 2.2 | 5.7 |
| Pu-241 | 121.32 | 375.88 | 3.86E-03 | 0.47 | 1.45 | 6.28E-02 | 7.6 | 23.6 |
| Am-241 | 9,563.52 | 26,807.16 | 4.06E-03 | 38.85 | 108.91 | 6.59E-02 | 600.9 | 1,684.4 |
| Total | — | — | 9.98E-01 | 47.59 | 134.75 | 9.47E-01 | 621.1 | 1,742.5 |

There is considerable uncertainty regarding the actual composition of the plutonium pits handled at IAAP. Since no composition data are presented in the IAAP TBD, we used the activity composition of Hanford reference weapons-grade plutonium (ORAU 2004, Table A2.3) to derive the mass fraction of each of the principal nuclides after 15 years of decay and ingrowth. These mass fractions and the corresponding dose rates are listed in Table 1. Furthermore, a test of a nuclear weapon using reactor-grade plutonium was conducted in 1962 (DOE n/d). We therefore calculated the dose rates from a pit composed of reactor-grade plutonium. The mass fractions were derived from the activity composition of Hanford reference fuel-grade plutonium (ORAU 2004, Table A2.4). The results are shown in Table 1.

Table 2 shows the dose rates from a 15-year-old, 16-kg uranium sphere containing varying concentrations of U-232. Except for the more massive, thicker, and denser sphere consisting of uranium metal, the exposure geometries are the same as for the plutonium sphere.

**Table 2. Dose Rates from U-232 Contamination in Uranium Pit**

| Concentration (ppm) | Dose Rate (mrem/h) | |
|---|---|---|
| | Standing | Seated |
| 1 | 3.43E+02 | 1.11E+03 |
| 7.5 | 2.57E+03 | 8.30E+03 |
| 50 | 1.72E+04 | 5.54E+04 |

### *Discussion and Conclusions*

The dose rate of 48 mrem/h from the generic pit of weapons-grade plutonium at a distance of 1 m is consistent with the dose rate of 33 mrem/h calculated by NIOSH, given the variability in the isotopic composition. However, the dose rate from the pit in the lap of the seated phantom, 135 mrem/h, is significantly higher. This scenario was included in our analysis on the basis of information furnished by workers, who said that workers carrying the pits held them against their bodies. Holding the pit in the lap, while at the high end of plausible scenarios, is a scenario that should be addressed in the TBD.

The dose rates from reactor-grade plutonium are more than 1 order of magnitude greater than those from the weapons-grade material. Pu-239 constitutes only 55% of reactor-grade plutonium, compared to about 93% of weapons-grade material. The reactor-grade metal thus has higher fractions of other plutonium isotopes, notably Pu-241, which decays to Am-241, the principal contributor to the dose.

Given the lack of publicly available information to the contrary, we cannot rule out the possibility that weapons contaminated with U-232 might have been processed at IAAP. Were this the case, the dose rates could be up to 3 orders of magnitude greater than those from the generic plutonium pit. This issue needs to be addressed in the TBD.

***References***

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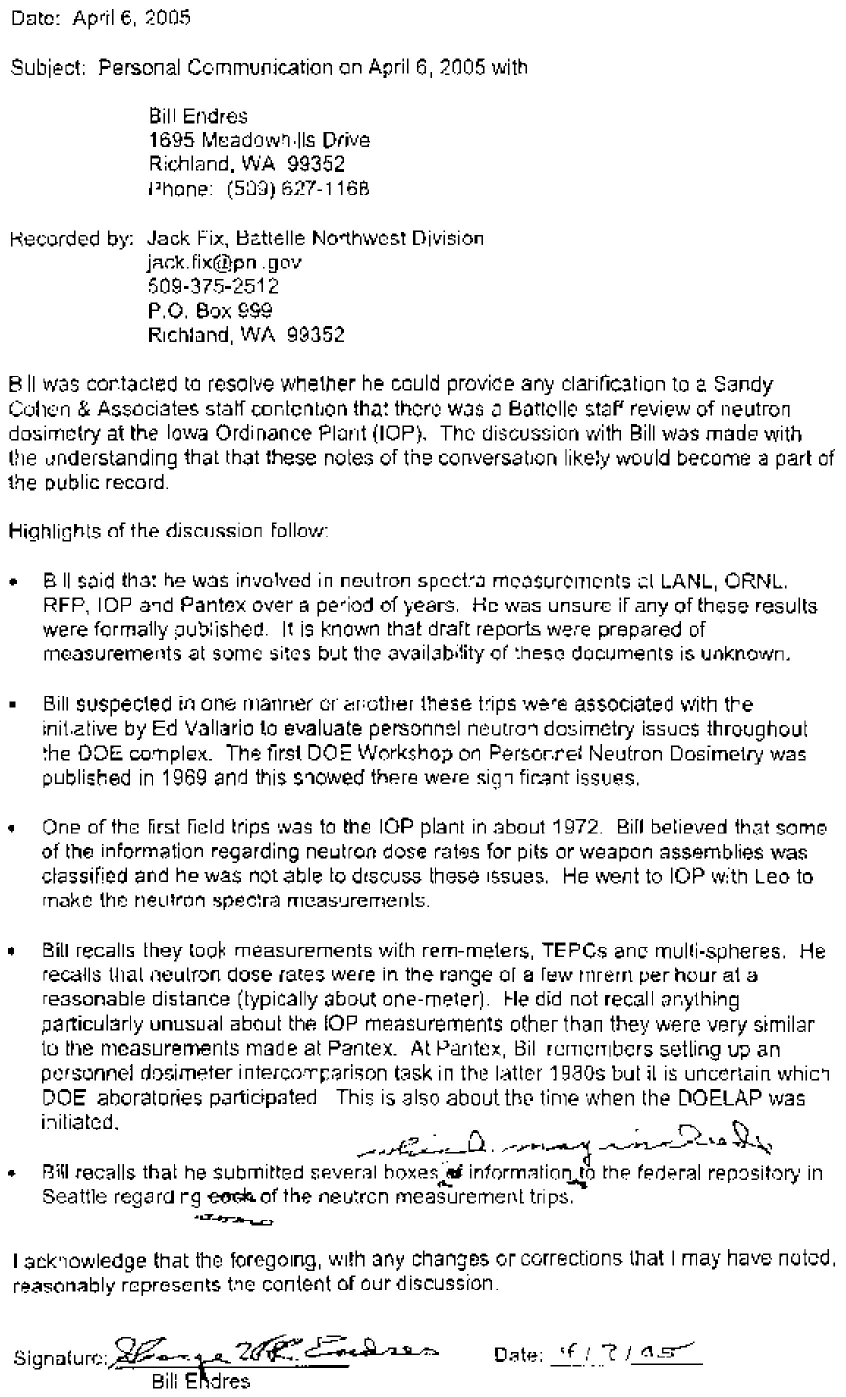
# ATTACHMENT 7: JACK FIX: MEMORANDUM TO FILE

Memorandum to file from Jack Fix, Battelle Northwest Division, "Personal Communication on April 6, 2005 with Bill Endress," April 6, 2005.



Date: April 6, 2005

Subject: Personal Communication on April 6, 2005 with

Bill Endres
1695 Meadowhills Drive
Richland, WA 99352
Phone: (509) 627-1168

Recorded by: Jack Fix, Battelle Northwest Division
jack.fix@pn .gov
509-375-2512
P.O. Box 999
Richland, WA 99352

Bill was contacted to resolve whether he could provide any clarification to a Sandy Cohen & Associates staff contention that there was a Battelle staff review of neutron dosimetry at the Iowa Ordinance Plant (IOP). The discussion with Bill was made with the understanding that that these notes of the conversation likely would become a part of the public record.

Highlights of the discussion follow:

- Bill said that he was involved in neutron spectra measurements at LANL, ORNL, RFP, IOP and Pantex over a period of years. He was unsure if any of these results were formally published. It is known that draft reports were prepared of measurements at some sites but the availability of these documents is unknown.
- Bill suspected in one manner or another these trips were associated with the initiative by Ed Vallario to evaluate personnel neutron dosimetry issues throughout the DOE complex. The first DOE Workshop on Personnel Neutron Dosimetry was published in 1969 and this showed there were significant issues.
- One of the first field trips was to the IOP plant in about 1972. Bill believed that some of the information regarding neutron dose rates for pits or weapon assemblies was classified and he was not able to discuss these issues. He went to IOP with Leo to make the neutron spectra measurements.
- Bill recalls they took measurements with rem-meters, TEPCs and multi-spheres. He recalls that neutron dose rates were in the range of a few mrem per hour at a reasonable distance (typically about one-meter). He did not recall anything particularly unusual about the IOP measurements other than they were very similar to the measurements made at Pantex. At Pantex, Bill remembers setting up an personnel dosimeter intercomparison task in the latter 1980s but it is uncertain which DOE laboratories participated This is also about the time when the DOELAP was initiated.
- [illegible] Bill recalls that he submitted several boxes ~~of~~ information to the federal repository in Seattle regarding ~~each~~ [illegible] of the neutron measurement trips.

I acknowledge that the foregoing, with any changes or corrections that I may have noted, reasonably represents the content of our discussion.

Signature: George W. R. Endres Date: 4 / 7 / 05
Bill Endres