UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	)	
	)	**Docket No. 30-31373-CivP**
CONAM INSPECTION, INC.	)	
	)	
(Order Imposing Civil Monetary Penalty)	)	**ASLBP No. 98-735-01-CivP**

CONAM'S MOTION TO AUTHORIZE WEIGHTED DOSE CALCULATION

Conam Inspection, Inc. ("Conam"), by its attorneys, moves the hearing panel of the Atomic Safety and Licensing Board to either approve, or to hold a hearing on the approval of, the external dose weighting factors specified in ICRP 26 and ANSI N113.41 in this case. In support thereof, Conam states as follows:

Introduction

1. Conam employee William Chastain ("Chastain") received a non-uniform dose of radiation while performing radiography on February 27, 1996. The U.S. Nuclear Regulatory Commission Office of Enforcement ("NRC Enforcement") contends that the February 27, 1996 dose to Chastain was a total effective dose equivalent ("TEDE") above 5 rems in violation of 10 CFR §1201(a)(1)(i).

2. The parties have competing dose calculations. NRC Enforcement has calculated a range of doses to Chastain's left thigh from 6.6 to 86 rems, with 34 rems being its "best estimate," and has assigned the 6.6 rems left thigh dose as the "whole

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body" TEDE. NRC Enforcement has done so even though Chastain's whole body did not incur that dose. Conam, on the other hand, has submitted to NRC Enforcement its expert's dose calculations that employ external dose weighting factors set forth in ICRP 26 and ANSI N13.41. Conam's expert calculations show TEDEs for Chastain of either 2.3 or 2.9 rems, depending upon the scenario.

3. NRC acknowledges that basing a TEDE on the dose to the "radiographer's thigh may not be an appropriate indicator of biological effects." Nonetheless, NRC Enforcement recently took the position that this panel cannot under any circumstances consider the use of the dose calculation methods employed by Conam's expert, which is a superior indicator of likely stochastic effects on Chastain.

4. Conam does not wish to proceed with the upcoming hearing without having the panel first decide whether Conam will be permitted to introduce, and whether the panel will consider, the external dose weighting factors utilized by in Conam's expert in determining the TEDE received by Chastain. Deciding this issue before conducting the hearing will shorten the hearing (a) by obviating the need for Conam to present alternate damages theories, and (b) by focusing the parties on the evidence relevant to those dose calculations that the panel will consider. Obviously, if the panel rules that the dose calculation methodology employed by Conam's expert is a superior, more scientifically defensible, and admissible, calculation, NRC Enforcement *may* elect not to proceed with the charge.

The Alleged Dose Violation

5. On June 9, 1997, NRC Enforcement issued a Notice of Violation and Proposed Imposition of Civil Penalty. A hearing before this panel on the disputed matters relating to that Notice of Violation is presently set for June 23 to 25, 1998.

6. NRC Enforcement asserts that, on February 27, 1996, Chastain, a radiographer employed by Conam, received a TEDE of 6.6 rems. On that date, Chastain was using a ladder in order to perform radiography on welds on overhead pipes. It appears that, on one occasion, Chastain failed to fully withdraw the radiation source into the shielded and locked position before entering the room to change the position of his film and the collimator on his "camera." NRC Enforcement asserts that the 6.6 rems dose to Chastain's left thigh violates 10 CFR 20.1201(a)(1)(i), which requires Conam as a licensee to control the occupational dose to individual adults to a total annual TEDE limit of 5 rems (0.05 Sv).

7. Conam and the NRC agree that Chastain most likely received a non-uniform external radiation exposure, and that the correct calculation of the TEDE is the central issue to be decided in the proceeding. Exactly which portions of Chastain's body were exposed, and whether his dosimetry was at all times closer to the exposed source than his "whole body" are matters on which the facts are unclear[1]. Chastain's film badge for

[1] Mr. Chastain reported to RSO Robert Slack on the day after the incident that he did his work in such a way that his dosimetry, carried in a "fanny pack" in front of him, was always closer to the source than any part of his body. On that basis, Mr. Slack viewed Chastain's film badge reading of 4.6 rems as indicative of the maximum possible whole body dose. On April 11, 1996, Chastain recreated the incident for the NRC and reported that, while his dosimetry remained in his fanny pack in front of him, he turned his back to the source during part of his work. During his deposition on May 12, 1998, Chastain said that he performed all of his work with his back to the source, but with his dosimetry in his fanny pack behind him, closest to the source at all times.

February read 4.6 rems after the February 27, 1996 incident. He had received .15 rems during January, 1996. Therefore, if Chastain's film badge were at all times, or nearly all times, closest to the source, there would be no violation.

The Regulations Relevant To This Motion

8. NRC Enforcement's position apparently is that whatever part of the body received the highest dose must be viewed as the "whole body" dose in determining whether there has been a violation of the 5 rems annual dose limit specified in 10 CFR §20.1201(a)(1)(i). This is contrary to the definition of "TEDE" in 10 CFR §20.1003, but is based upon the definition of "weighting factor" found in 10 CFR §20.1003.

> W_T, for an organ or tissue (T) is the proportion of the risk of stochastic effects resulting from irradiation of that organ or tissue to the total risk of stochastic effects when the whole body is irradiated uniformly. For calculating the effective dose equivalent, the values of W_T are:

ORGAN DOSE WEIGHTING FACTORS

Organ or Tissue	W_T
Gonads	0.25
Breast	0.15
Red bone marrow	0.12
Lung	0.12
Thyroid	0.03
Bone surfaces	0.03
Remainder	0.30
Whole Body	1.00

9. There is a footnote to the 1.00 weighting factor for exposure of the "whole body." It provides,

> For the purpose of weighting the external whole body dose (for adding it to the internal dose), a single weighting factor, W_T=1.0 has been specified. The use of other weighting factors for external exposure will be approved on a case-by-case basis until such time as specific guidance is issued.

The above definition of "weighting factor," including this footnote, are the root of the dispute Conam brings before the panel with this Motion.

Chastain did not receive a uniform whole body exposure. Therefore not all of the organs listed in the above chart were irradiated. In fact, only a small portion of his red bone marrow and bone surfaces were irradiated. Therefore, the use of the "whole body" weighting factor is incorrect.

NRC Enforcement's Dose Calculation

10. The NRC has performed calculations indicating the doses received by various parts of Chastain's "whole body[2], and based on those calculations state that their "best estimate" was that Chastain's left leg received a dose of 34.07 rems. NRC Enforcement's dose calculations cover a range, however, of 6.6 to 86.05 rems. The NRC's calculations are attached as Exhibit A to this Motion. In its Inspection Report (attached as Exhibit B), however, the NRC assigns a left thigh dose of 6.6 rems (Exhibit B, p. 12).

[2] "*Whole body* means, for purposes of external exposure, head, trunk (including male gonads), arms above the elbow, or legs above the knee." 10 CFR §20.1003.

11. The regulations distinguish between a uniform and a non-uniform external exposure to the "whole body" by permitting use of "other" weighting factors on a "case by case basis." Obviously, where there is a uniform exposure, W_T=1.0 will be indicative "of stochastic effects resulting from irradiation of that organ or tissue." Where there is a *non*-uniform exposure of the organs and tissues specified in the definition of "weighting factor," however, the regulations reflect the need to "weight" the exposure to various organs and tissues in order to derive a TEDE that is rationally predictive of "stochastic effects resulting from irradiation." Thus, hypothetically, if worker's breast received a dose of 10 rems, but the rest of the body no exposure, the TEDE would be 1.5 rems.

12. Specific external dose weighting factors are not specified in the regulations for parts of the "whole body," however. On that basis, NRC Enforcement made its dose calculation by assigning an external dose weighting factor of 1.0 to whatever part of Mr. Chastain's "whole body" received the highest exposure. Because it determined that his left thigh received the highest dose, which it assumed to be "at least" 6.6 rems, it assigned that figure as the "whole body" dose for the purposes of the limit set forth in 10 CFR 20.1201(a)(1)(i). This technically unsound decision is the basis for the violation alleged.

Conam's Expert's Dose Calculations

13. Because the footnote to the definition of "weighting factor" provides that the use of weighting factors other than 1.0 "will be approved on a case-by-case basis," Conam retained an expert to calculate the TEDE received by Chastain. The expert retained was Carol D. Berger, C.H.P., of Integrated Environmental Management, Inc.

14. In her calculations, Ms. Berger used consensus-standard weighting factors. Those factors are based upon a dose determination rationale developed by the International Commission on Radiological Protection ("ICRP") and translated into specific external dose weighting factors by the American National Standards Institute ("ANSI"). Specifically, the external dose weighting factors used by Ms. Berger were the same ICRP 26 stochastic risk weighing factors that appear in 10 CFR §20.1003, as modified by the compartmental structure set forth in ANSI N13.41. Ms. Berger's methodology is set forth in detail in a letter to Robert Slack dated December 10, 1996, with appendices. A copy of Ms. Berger's report is attached hereto as Exhibit C.

15. As shown in Exhibit C, Ms. Berger used a computer model to perform two sets of calculations, one based on the time and motion explanation given by Mr. Chastain to Conam's RSO on the day following the incident, the other based on NRC Enforcement's time and motion study which was conducted a month and a half later. These calculations yielded TEDEs of 2.347 rems and 2.906 rems respectively, both well under the 5 rems per year annual limitation.

The Dispute About Weighting Factors

16. Ms. Berger's report (Exhibit C), with its use of external dose weighting factors, was submitted to NRC Enforcement on December 13, 1996, during the Predecisional Enforcement Conference. It was submitted for the purposes of showing that there was no violation of 10 CFR §20.1201(a)(1)(i). In so doing, Conam believed

that it was submitting Ms. Berger's weighting factors for "approval" pursuant to footnote 2 to the "weighting factor" definition in 10 CFR §20.1003.

17. NRC Enforcement made essentially no response to the submission of Ms. Berger's report on December 13, 1996. A copy of pages 38-41 of the transcript of the Predecisional Enforcement Conference, dealing with Ms. Berger's report, are attached hereto as Exhibit D.

18. In fact, it was not until eleven months later, on November 5, 1997, when NRC Enforcement issued its Order Imposing Civil Monetary Penalty, that Conam learned that NRC Enforcement had apparently declined to consider Ms. Berger's report on two grounds: (a) NRC Enforcement had not given its *prior* approval to the use of these particular weighting factors, and (b) the ANSI N13.41 standard is applicable to "routine occupational activities," and not to "sudden or unexpected changes in the radiation environment as might occur during accidents. . .." See, Order Imposing Civil Monetary Penalty, Appendix A, p. 4, attached as Exhibit E.

19. On April 9, 1998, Conam again submitted to NRC Enforcement in response to a demand for information detailed data and information regarding Conam's proposed use of external dose weighting factors drawn from ICRP 26 and ANSI N13.41. NRC Enforcement made no response.

20. Therefore, Conam assumed that it could submit for approval by this panel at a hearing, Ms. Berger's report and weighting factor dose-assessment methodology.

Nothing in the "weighting factor" footnote indicates to whom at the NRC a weighting factor methodology must be submitted for approval, or when it must be submitted.

21. During depositions on May 12-14, 1998, however, NRC Enforcement took a remarkable new position: not only must any use of external dose weighting factors be submitted for *prior* approval before being used, but (a) no approval could be used as to an incident occurring prior to the approval, and (b) approval requires an amendment to Conam's license, and would have to go through that process. Thus, NRC Enforcement's new position is that this panel *cannot* approve, and cannot consider, the weighting factors underlying Ms. Berger's report and calculations.

22. NRC Enforcement's new position makes it nearly impossible for Conam to adequately prepare for the upcoming hearing in this matter. Conam does not know whether to prepare to submit to the panel Ms. Berger's calculations, which use the ICRP 26 and ANSI N13.41 weighting factors, or other calculations, or whether various other calculations and assumptions must be submitted in the alternative. If the external dose weighting factors will not be considered by the panel, then Conam may conduct additional time and motion studies in an attempt to clarify the significant factual disparities in this case, and the resulting disparity in the experts' dose calculations. There is no doubt that uncertainty over whether the panel will consider Ms. Berger's dose assessment protocol will require both parties to introduce a substantially broader range of evidence at the hearing, thus prolonging the hearing.

Issues To Be Decided

23. By this Motion, Conam asks that this panel decide two issues before proceeding with a hearing. Those issues are: (a) does this panel have the authority to approve, or to direct approval of, the external dose weighting factors contained in Ms. Berger's report; and (b) if so, should use of those external dose weighting factors for dose assessment purposes be approved in this case?

Power of the Panel

24. The regulatory footnote controlling the question before the panel provides that "The use of other weighting factors for external exposure will be approved on a case-by-case basis. . .." The regulations do not provide any particular time frame, methodology, or procedure for such approval. There is nothing to suggest that "case-by-case basis" precludes approval by panels convened by the Atomic Safety and Licensing Board in the context of "cases" pending before those panels. On that basis, this panel is the proper authority to determine whether the Conam's proposed set of weighting factors should be approved for use in this particular case.

25. NRC Enforcement has suggested to Conam three related reasons why this panel cannot consider whether to authorize use of external dose weighting factors: (a) *prior* approval is required, (b) approval cannot relate back to an incident prior to the approval, and (c) weighting factors are a matter of license amendment. There is absolutely no support in the regulations for any of these propositions.

26. First, the NRC is fully capable of specifying that approval must be *prior,* if that is what it intends. *See,* 10 CFR §20.1204(c)(2) ("the licensee may upon *prior approval of the Commission* adjust the DAC. . .."); 10 CFR §20.1901(d) ("licensee shall notify, in writing, the Regional administrator. . . *at least 30 days before the date* that respiratory protection equipment is first used. . .." (emphasis added). It is significant that the regulatory footnote at issue does not specify *prior* approval as to the use of external dose weighting factors.

27. Second, there nothing in any regulation to suggest that external dose weighting factors, once approved, cannot be used for incidents occurring prior to their approval. Moreover, such a result would be contrary to the requirement of approval on a "case-by-case basis." That requirement means that weighting factors must be approved when the particular circumstances of the case at hand on a scientific basis merit the use of such factors. If approval could never "relate back" to prior incidents, then examination on a "case-by-case basis" would be impossible. Good science is not for prospective application only.

28. Finally, there is nothing in the regulations to suggest that the use of weighting factors is or should be a licensing issue. Requiring such a procedure would be contrary to the regulations' requirement that other weighting factors be approved on a "case-by-case basis."

29. For these reasons, this panel has, and should exercise, the power to determine whether the particular external dose weighting factors which underlie Conam's expert's

dose calculations are appropriate for use and consideration in the specific case of Chastain's radiation exposure.

The Use Of Conam's Weighting Factors Is Reasonable and Reliable

30. Ms. Berger is highly qualified to analyze the particular facts relating to Chastain's exposure and to determine and apply appropriate external dose weighting factors in order to calculate a TEDE in these particular circumstances. She is the one of the leading practitioners and writers in this developing area of dosimetry. Ms. Berger's resume and bibliography are attached hereto as Exhibit G.

31. The particular methodology employed by Ms. Berger, and the specific weighting factors used, are identified in her report (Exhibit C). The underlying scholarship supporting the particular weighting factors employed by Ms. Berger are referenced in her report. Without reviewing that scholarship in detail here, the report demonstrates that the external dose weighting factors employed by Ms. Berger provide the most accurate possible predictor of the risk of stochastic effects resulting from particular external non-uniform radiation exposures. That risk is stated in terms of a "whole body" TEDE.

32. NRC Enforcement, on the other hand, has been forthright in acknowledging that the W_T=1.0 weighting methodology that it felt compelled to employ is not a reliable indicator of the total risk of stochastic effects. In its Order Imposing Civil Penalty (Exhibit E, Appendix A, p. 4), NRC Enforcement stated that, "The NRC . . .

acknowledges that the radiographer's thigh may not be an appropriate predictor of biological effects."

33. Further, during the deposition of Monte Phillips, who was Chief of the Materials Inspection Branch 2 during the inspection, Mr. Phillips testified that there is a substantial difference between actual whole body effects of radiation, as measured by blood tests, and the calculations upon which NRC Enforcement bases its "whole body" TEDE. Mr. Phillips sought to explain why NRC Enforcement's calculations showed a range of whole body TEDEs of 6.6 to 86 rems, when tests of Chastain's blood showed that the whole body exposure *necessarily* was less than 20 rems.

> Q. [by Conam's counsel] Well, let me ask you this, how do you reconcile the fact that most of the calculations in the [NRC's] dose reconstruction yield figures above 20 REM, when the blood work shows a result of less than 20 REM.
>
> A. Again, the calculations that you're looking at here are for the part of the body that's closest to the camera. Whereas, the blood results would be looking at as if the entire body received that number, 20 REM.
>
> Q. But aren't you calling the result that you're calculating for the thigh a whole body result?
>
> A. I'm calling that a legal whole body value.
>
> * * *

Q. So there's a discrepancy between the legal definition of whole body dose and the whole body dose --

A. What part of the body would actually get.

Q. Is that correct?

A. Yes, ...

Deposition of Monte Phillips, May 14, 1998, pp. 132-136 (attached as Exhibit F).

34. Thus, NRC Enforcement's position is that this panel *must* employ what is, *as to this particular case,* acknowledged to be an inferior, inapplicable and unreliable weighting factor (W_T=1.0), and that the panel *may not* consider the superior and technically and biologically more reliable set of external dose weighting factors employed by Ms. Berger.

Suggested Procedure For Addressing This Motion

35. It may be that the panel can decide the issues raised by this Motion on simple briefing. If it would be of assistance to the panel, Conam suggests that the panel solicit detailed reports from the parties' respective experts on the appropriateness of the use of the weighting factors employed in Ms. Berger's report. After those reports are submitted, the panel can determine whether any additional live testimony on this central issue would be of benefit. Conam respectfully requests that the panel postpone the hearing presently set for June 23-25, pending resolution of this issue. Conam is filing a separate motion to postpone that hearing, due to an injury to its lead counsel.

WHEREFORE, Conam respectfully requests that the Board grant Conam's Motion, ordering that (a) it has the authority to approve weighting factors appropriate to this particular case, (b) approving the particular weighting factors employed by Ms. Berger in her report, and (c) postponing the hearing in this matter until these issues related to dose calculation can be resolved.

Respectfully submitted,

CONAM INSPECTION, INC.

Clifton A. Lake, Esq.
Malcolm H. Brooks, Esq.
Counsel for Conam Inspection, Inc.

Dated at Chicago, Illinois
this 29th day of May, 1998.

Clifton A. Lake, Esq.
Malcolm H. Brooks, Esq.
McBride Baker & Coles
500 West Madison, 40th Fl.
Chicago, IL 60661-2511
(312) 715-5700

EXHIBITS

A	NRC Dose Calculations.
B	NRC Inspection Report 11-18-97.
C	Carol D. Berger 12-10-96 Letter and Report Of Dose Calculations.
D	Predecisional Enforcement Conference transcript, p. 38-41. 12-13-96.
E	Order Imposing Civil Monetary Penalty. 11-5-97.
F	Deposition of Monte Phillips, 5-14-98, pp. 132-136.
G	Carol D. Berger Resume and Bibliography.

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Conam Dose Reconstruction

Tom Young/Geoff West

Scenario:

The exposed individual, in the process of performing industrial radiography, left the camera source (camera model Amersham 660B with Ir-192 source of 94 Ci) in an unshielded position while changing film near the camera between "shots". The individual realized, after approximately 4 minutes near the source, that the source locking mechanism had not been engaged during this time and promptly left the area. His pocket chamber was off-scale and his film badge, located near his ventral groin area, was subsequently developed and revealed a dose equivalent of 4.6 rem. The relationship of the individual to the likely vicinity of the source during this exposure (the exit port of the camera) is described in Attachment A. Two orientations, A & B, are described based on evidence collected during a subsequent scenario reenactment. Orientation A corresponds to the individual's approximate position during "tear-down" of the previously-exposed film. Orientation B corresponds to the individual's approximate position during "set-up" of new film. The amount of time spent in each orientation is estimated at 1 minute and 3 minutes for Orientations A & B, respectively. It is not known to what degree the source was shielded by the camera exit port assembly.

The individual received a total of 10mR to his pocket chamber during the month of exposure, up until the day of this exposure. In addition, the film badge analysis indicated exposure from multiple directions, though the orientations are unable to be determined from the badge.

Dose Calculation Methodology:

The dose calculation methodology is as follows. Since the exact source location with respect to the camera exit port is not known, each dose calculation will consist of two parts. The first part will be the determination, based on scenario, of the "adjusted" source activity, that is the apparent source activity with respect to the individual. This activity value will reflect shielding of the source element by the camera exit port assembly. This methodology is justified based on the lack of any beam hardening effect at the gamma energies in question by the exit port assembly material. The adjusted source activity will be calculated using values of times in each orientation, badge exposure, various reference shielding values, and the measurements shown in Attachment A. Once an adjusted source activity is found, a simple dose calculation is performed to get a whole-body dose. Since a different leg is nearest to the source location in each orientation, they are treated separately and the whole-body dose is designated as the greater of the two. This method is conservative, since it assumes that each leg is only receiving exposure during the time period of the orientation in which it is closest to the source. This will thus tend to underestimate the actual exposure.

Since the exact distribution of times spent in each orientation is unknown, as is the true tissue dose buildup factor for shielding purposes, these uncertainties generate an associated uncertainty in derived dose. Because of this, a spreadsheet has been used to look at multiple possible scenarios and generate likely bounding dose estimates. This data and the associated dose

estimates are shown in Attachment C. This attachment shows the results of all calculations. It includes five dose estimates: 1) an extreme low dose, 2) a probable low dose, 3) a best estimate, 4) a probable high dose, and 5) an extreme high dose. The extreme doses represent scenarios that are viewed as being extremely unlikely and represent the absolute physical limits of absorbed dose equivalent within the bounds of the problem. The probable doses represent a range within which the true dose should lie, with a high degree of confidence. These estimates reflect possible scenarios which include allowances for measurement uncertainty, both geometric and temporal. Additionally, they do not include the 0.1 rem allowance to the film badge absorbed dose equivalent given for the extreme low dose, since the evidence indicates that the previously absorbed dose on the film badge before the event was only .01 rem. The best estimate case is a dose calculation based on the best estimates of the individual involved regarding the specifics of the event. It is considered the most likely absorbed dose equivalent to the individual based on all available evidence.

The following quantities and physical assumptions have been made for all calculations: The measurements in Attachment A and the results in Attachment B are included as an addendum.

Given: 94 Ci Ir-192 source
measurements of individual (Attachment A)
4 minute total exposure period
film badge exposure - (4.6 rem - ~ 10 mR)
approximate orientations and respective times

Assumptions: no beam hardening due to partial exit port shielding
air shielding is negligible
β^- contribution is negligible
energy - dependent body shielding (filtering) is negligible
mass attenuation coefficient of body ^{w}/respect to Ir-192
is equal to that for muscle (0.110 cm^2/g)

Constants: density of the body is 1.07 g/cm^3
Γ(Ir-192) = .48 $(R \cdot m^2)/(Ci \cdot hr)$
for muscle (body) tissue, 1 R ≈ .95 rad = .95 rem (gamma)

An example calculation, shown for the best estimate case, is shown below to illustrate the reconstruction methodology used for all generated dose values.

Attachment A: Exposure Geometry

Orientation A: "tear-down"

In Orientation A, the subject is located on the second rung down from the top of the ladder with his body twisted approximately 90° to his right. The subject was working on an overhead pipe. An illustration of the ladder/source/pipe geometry is located on the next page. Also, an illustration of Orientation A is located after that. In this position, the nearest whole-body location is the upper right leg. The following distances were measured for this orientation:

$\overrightarrow{SB}$ ≈ 10.0 inches (source to whole-body distance)

$\overrightarrow{SF}$ ≈ 13.25 inches (source to film badge distance)

Orientation B: "set-up"

Orientation B is identical to Orientation A except that the subject has turned completely around (180°) on the ladder to better access his work. This puts part of his body between the likely location of the source and the film badge. In this position, the nearest whole-body location is the upper left leg. The following distances were measured for this orientation:

$\overrightarrow{SB}$ ≈ 5.875 inches (source to whole-body distance)

$\overrightarrow{SF}$ ≈ 15.5 inches (source to film badge distance)

Body Thickness along $\overrightarrow{SF}$ ≈ 8.75 inches

Attachment B: Reference Data and Calculations

Data for Iridium-192:

β^- of 0.67 MeV (max) $\therefore$ $\bar{E}_\beta \approx (.35)E_{max} = 234.5$ keV

e^-: 0.217, 0.230, 0.239, 0.390 MeV (NA)

γ: 0.317 MeV (81%)
0.468 MeV (49%)
0.308 MeV (30%)
0.296 MeV (29%)
0.604 MeV (9%)
0.612 MeV (6%)
0.589 MeV (4%)

} $\overline{E}_\gamma \approx 374.5$ keV

β^- range ~ 19 inches in air, 0.25 inches in water
skin thickness = 1 cm ≈ .4 in. $\therefore$ no deep dose

mass attenuation coefficients: exponential decline. log plot
coefficient ≈ .1087 cm^2/g @ 374.5 heV

avg coefficient (weighted) = .110 cm^2/g (weighted $\bar{E}_\gamma$ = 363.5 keV) μ/ρ

ρ = 10.07 cm^2/g^3 $\therefore$ **μ = .1177 cm^{-1}**

Dose Buildup Factor:

For 8.75 inches of tissue, use RHHB pg. 145 and best-fit interpolation...power fit.

With E = 374.5 keV and μx = 2.616, our buildup value, using a four-point power fit to the table, is approximately **10.18**

This value assumes an infinite plane of designated thickness. The actual buildup should be somewhat lower given our probable orientation geometry, approximately on the order of 60-90% of the above value. $\therefore$ range ~ [6-9] for B

$K=(8.75)(2.54\ \frac{cm}{in})$

$\mu = (.1177\ cm^{-1}) =$

$\mu x = 10.18$

$(\mu)(\rho) = (.110)(1.07)$ $(cm^2/g)(g/cm^3)$

$= .1177\ cm^{-1}$

$\frac{8.75}{15.5} \frac{\text{Body Thick}}{SF} = .56$

Analysis Example:
Best Estimate

Assumptions (additional): individual was in Orientation A for 1 minutes and Orientation B for 3 minutes
adjusted (65%) tissue buildup factor of 6.62

Using Orientation A & B measurements from Attachment A.
Prior month's badge exposure is negligible.

Solution:

Sum Orientation A & B values for badge exposure to work back to an adjusted apparent source activity due to exit port shielding.

$$\therefore 4.6 \text{ rem} = [(.95 \text{ rem/R})\cdot(.48 \text{ (R}\cdot\text{m}^2\text{)/(Ci}\cdot\text{hr))}\cdot(1 \text{ hr/60 min})\cdot(\text{X Ci})] \cdot [(1 \text{ min}/((13.25 \text{ in}) \cdot (.0254 \text{ m/in}))^2) + ((3 \text{ min})\cdot(6.62)\cdot(e^{-(.1177 \text{ 1/cm})\cdot(8.75 \text{ in})\cdot(2.54 \text{ cm/in})})/((15.5 \text{ in}) \cdot (.0254 \text{ m/in}))^2)]$$

$\therefore X = \underline{33.27 \text{ Ci}}$

Now, the left leg dose resulting from the shielded source would be:

$$H_d \text{ (left leg)} = [(.95 \text{ rem/R})\cdot(.48 \text{ (R}\cdot\text{m}^2\text{)/(Ci}\cdot\text{hr))}\cdot(1 \text{ hr/60 min})\cdot(33.272 \text{ Ci})] \cdot [(3 \text{ min})/((5.875 \text{ in})\cdot(.0254 \text{ m/in}))^2]$$

$$= 34.07 \text{ rem}$$

The right leg dose resulting from the shielded source would be:

$$H_d \text{ (right leg)} = [(.95 \text{ rem/R})\cdot(.48 \text{ (R}\cdot\text{m}^2\text{)/(Ci}\cdot\text{hr))}\cdot(1 \text{ hr/60 min})\cdot(33.272 \text{ Ci})] \cdot [(1 \text{ min})/((10.0 \text{ in})\cdot(.0254 \text{ m/in}))^2]$$

$$= 3.92 \text{ rem}$$

Thus, the whole-body dose, being the greater of the two upper leg doses, is

H_d (whole-body) = **34.07 rem**

See Attachment C for a summary of this dose calculation.

Conclusions:

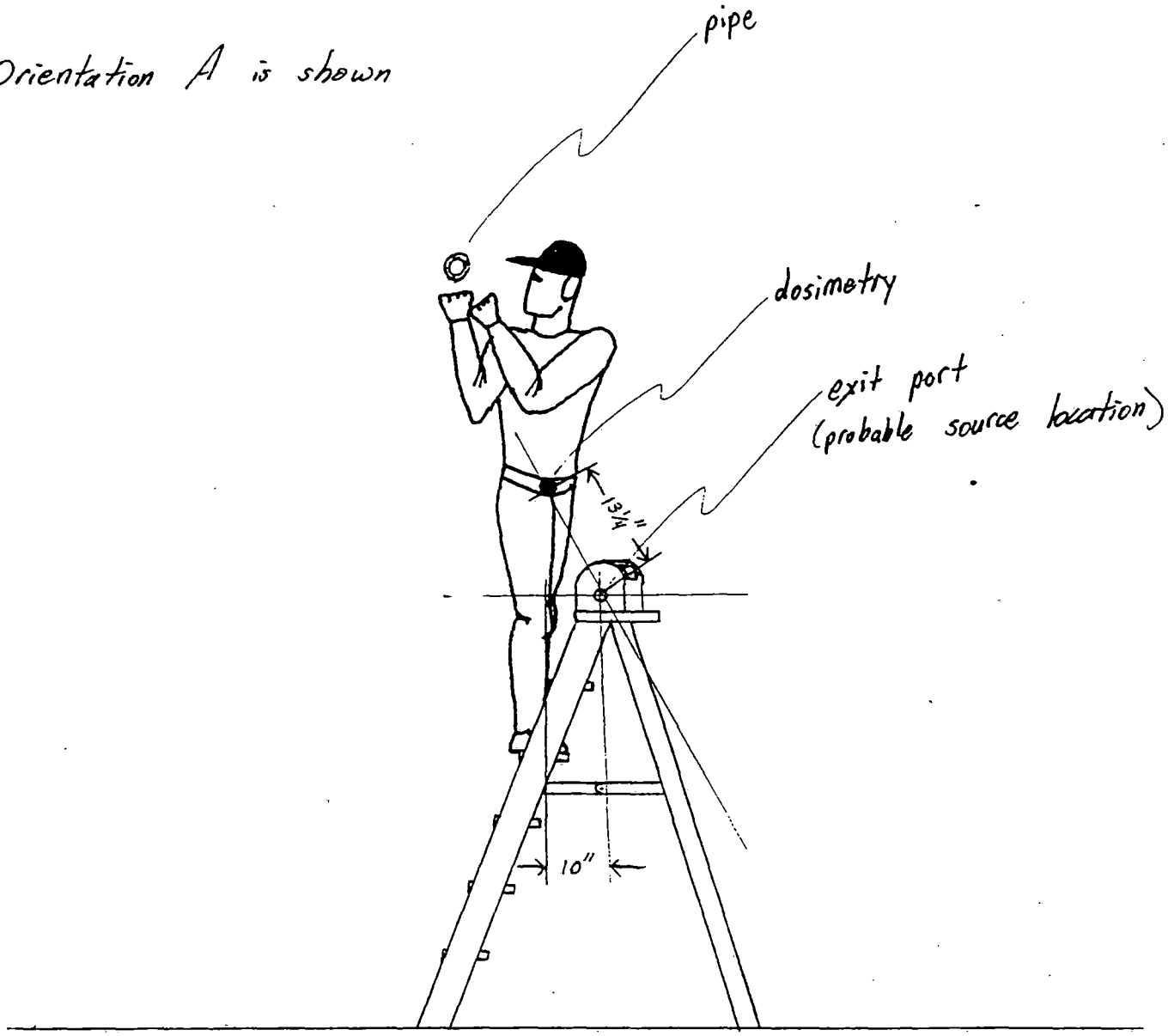
The results of the dose calculations for the five cases mentioned above are as follows:

1.	Extreme Low Case:	6.65 rem
2.	Probable Low Bound:	15.16 rem
3.	Best Estimate:	**34.07 rem**
4.	Probable High Bound:	56.41 rem
5.	Extreme High Case:	86.05 rem

Exposure Orientation

Side View

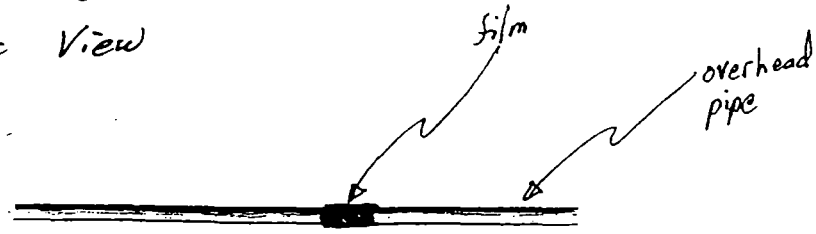
Orientation A is shown

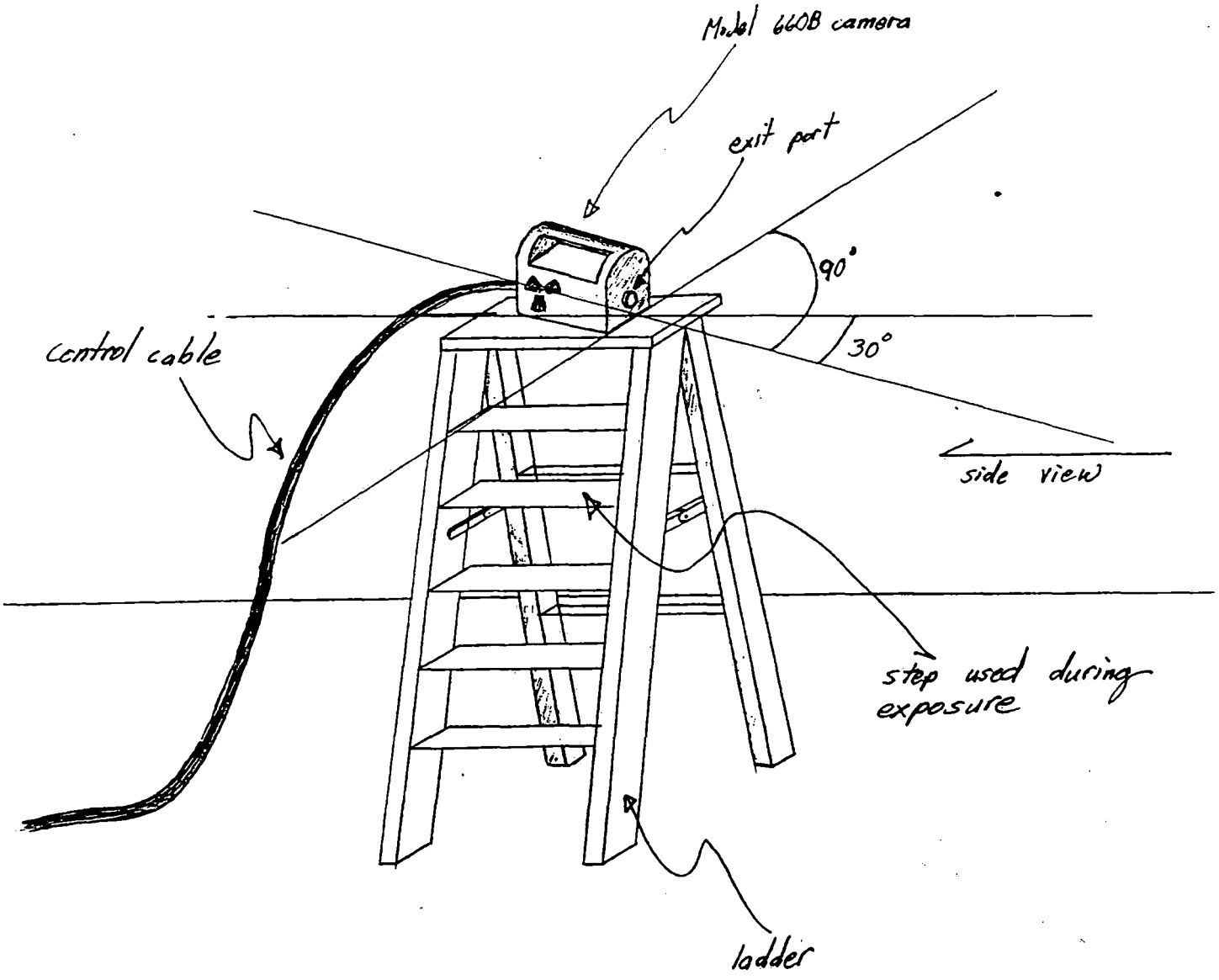


control cable and guide tube not shown for clarity

Equipment orientation

Isometric View





guide tube not shown for clarity.

Attachment C: Dose Calculation Worksheets

Extreme Low Case

Given:	Gamma:	0.48	(R*m^2)/(Ci*hr)
	rem/R:	0.95	rem/R
	Total time:	4	minutes
Orientation A:	Source-Body Distance:	10	inches
	Source-Film Distance	13.25	inches
Orientation B:	Source-Body Distance:	5.875	inches
	Source-Film Distance:	15.5	inches
	Body Shielding Thickness:	8.75	inches
Variables:	Time in Orientation A (a):	2.974	minutes
	Badge Dose:	4.5	rem
	Percent tissue buildup factor:	100	percent
Work:	Effective Source Activity:	18.988	Ci
Solution:	Left Leg:	6.649	rem
	Right Leg:	6.652	rem
	Whole Body:	**6.652**	**rem**
	Dose/5 rem	1.33	

Probable Low Bound

Given:	Gamma:	0.48	(R*m^2)/(Ci*hr)
	rem/R:	0.95	rem/R
	Total time:	4	minutes
Orientation A:	Source-Body Distance:	10	inches
	Source-Film Distance	13.25	inches
Orientation B:	Source-Body Distance:	5.875	inches
	Source-Film Distance:	15.5	inches
	Body Shielding Thickness:	8.75	inches
Variables:	Time in Orientation A (a):	2	minutes
	Badge Dose:	4.6	rem
	Percent tissue buildup factor:	100	percent
Work:	Effective Source Activity:	22.203	Ci
Solution:	Left Leg:	15.16	rem
	Right Leg:	5.231	rem
	Whole Body:	**15.16**	**rem**
	Dose/5 rem	3.031	

Best Estimate

Given:	Gamma:	0.48	(R*m^2)/(Ci*hr)
	rem/R:	0.95	rem/R
	Total time:	4	minutes
Orientation A:	Source-Body Distance:	10	inches
	Source-Film Distance	13.25	inches
Orientation B:	Source-Body Distance:	5.875	inches
	Source-Film Distance:	15.5	inches
	Body Shielding Thickness:	8.75	inches
Variables:	Time in Orientation A (a):	1	minutes
	Badge Dose:	4.6	rem
	Percent tissue buildup factor:	65	percent
Work:	Effective Source Activity:	33.272	Ci
Solution:	Left Leg:	34.07	rem
	Right Leg:	3.919	rem
	Whole Body:	**34.07**	**rem**
	Dose/5 rem	6.813	

Probable High Bound

Given:	Gamma:	0.48	(R*m^2)/(Ci*hr)
	rem/R:	0.95	rem/R
	Total time:	4	minutes
Orientation A:	Source-Body Distance:	10	inches
	Source-Film Distance	13.25	inches
Orientation B:	Source-Body Distance:	5.875	inches
	Source-Film Distance:	15.5	inches
	Body Shielding Thickness:	8.75	inches
Variables:	Time in Orientation A (a):	0.5	minutes
	Badge Dose:	4.6	rem
	Percent tissue buildup factor:	50	percent
Work:	Effective Source Activity:	47.225	Ci
Solution:	Left Leg:	56.41	rem
	Right Leg:	2.782	rem
	Whole Body:	**56.41**	**rem**
	Dose/5 rem	11.28	

Extreme High Case

Given:	Gamma:	0.48	(R*m^2)/(Ci*hr)
	rem/R:	0.95	rem/R
	Total time:	4	minutes
Orientation A:	Source-Body Distance:	10	inches
	Source-Film Distance	13.25	inches
Orientation B:	Source-Body Distance:	5.875	inches
	Source-Film Distance:	15.5	inches
	Body Shielding Thickness:	8.75	inches
Variables:	Time in Orientation A (a):	0	minutes
	Badge Dose:	4.6	rem
	Percent tissue buildup factor:	50	percent
Work:	Effective Source Activity:	63.032	Ci
Solution:	Left Leg:	86.05	rem
	Right Leg:	0	rem
	Whole Body:	**86.05**	**rem**
	Dose/5 rem	17.21	

Dose Calculation Matrix:

Badge Dose: 4.5 rem

Whole Body Buildup %

a	50	55	60	65	70	75	80	85	90	95	100
0	84.18	76.53	70.15	64.75	60.13	56.12	52.61	49.52	46.77	44.30	42.09
0.25	67.60	62.58	58.25	54.48	51.17	48.24	45.62	43.28	41.16	39.24	37.49
0.5	55.19	51.79	48.79	46.12	43.72	41.56	39.61	37.83	36.20	34.71	33.33
0.75	45.53	43.20	41.09	39.18	37.43	35.84	34.38	33.03	31.78	30.63	29.55
1	37.82	36.19	34.70	33.33	32.06	30.88	29.79	28.77	27.82	26.93	26.09
1.25	31.51	30.37	29.31	28.33	27.40	26.54	25.73	24.97	24.25	23.57	22.93
1.5	26.25	25.46	24.71	24.01	23.34	22.71	22.11	21.55	21.01	20.50	20.01
1.75	21.81	21.26	20.73	20.23	19.76	19.31	18.87	18.46	18.06	17.68	17.32
2	18.00	17.62	17.26	16.91	16.58	16.26	15.95	15.65	15.37	15.09	14.83
2.25	14.69	14.44	14.20	13.96	13.74	13.52	13.30	13.09	12.89	12.70	12.51
2.5	11.81	11.64	11.48	11.33	11.18	11.03	10.89	10.75	10.62	10.48	10.35
2.75	9.26	9.16	9.06	8.96	8.87	8.78	8.69	8.60	8.51	8.43	8.34
3	7.24	7.18	7.13	7.07	7.01	6.95	6.90	6.85	6.79	6.74	6.69
3.25	7.43	7.39	7.35	7.30	7.26	7.22	7.18	7.14	7.10	7.06	7.02
3.5	7.60	7.58	7.55	7.52	7.49	7.47	7.44	7.41	7.38	7.36	7.33
3.75	7.76	7.75	7.73	7.72	7.70	7.69	7.68	7.66	7.65	7.64	7.62
4	7.90	7.90	7.90	7.90	7.90	7.90	7.90	7.90	7.90	7.90	7.90

Left Leg Buildup %

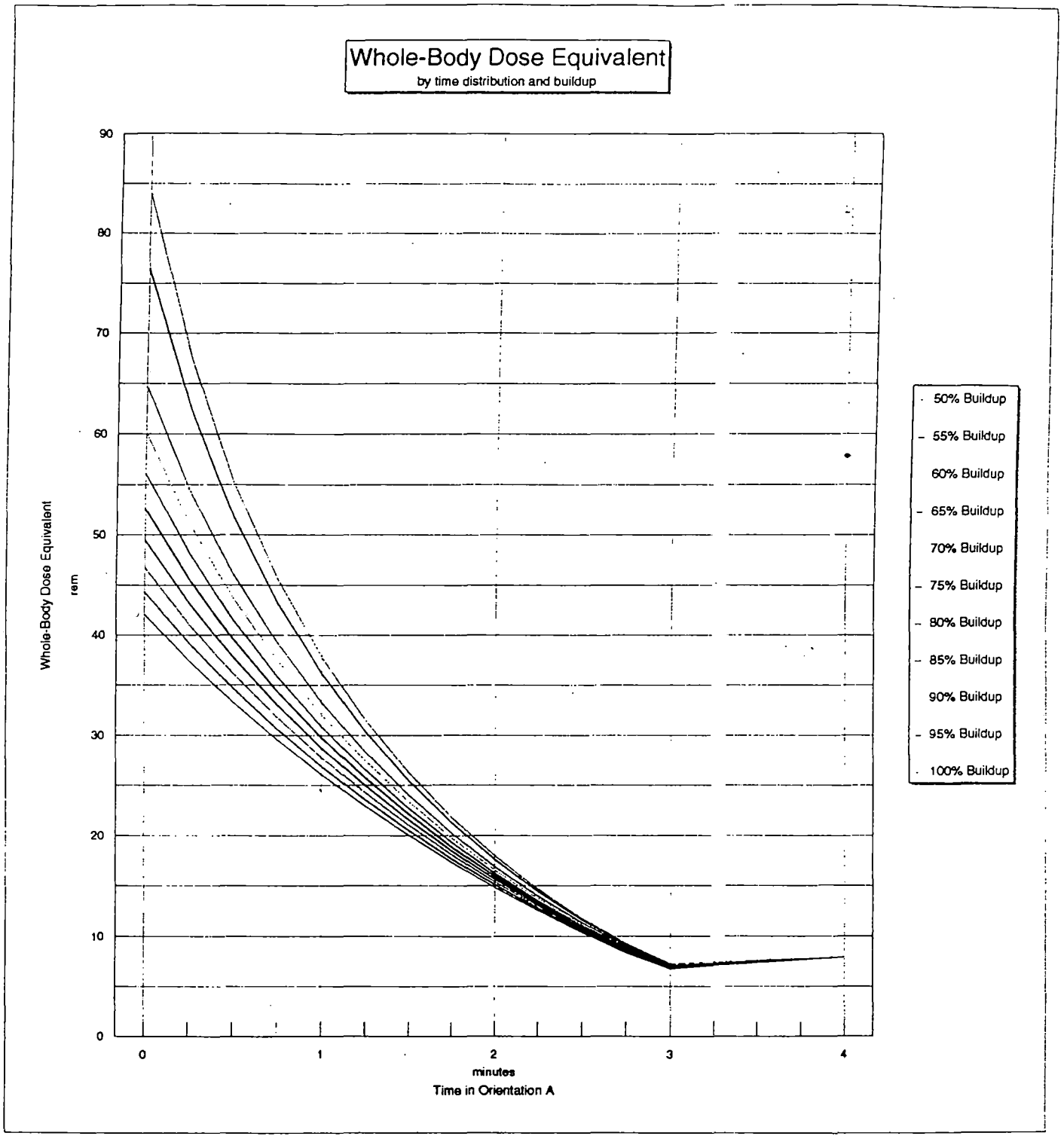
a	50	55	60	65	70	75	80	85	90	95	100
0	84.18	76.53	70.15	64.75	60.13	56.12	52.61	49.52	46.77	44.30	42.09
0.25	67.60	62.58	58.25	54.48	51.17	48.24	45.62	43.28	41.16	39.24	37.49
0.5	55.19	51.79	48.79	46.12	43.72	41.56	39.61	37.83	36.20	34.71	33.33
0.75	45.53	43.20	41.09	39.18	37.43	35.84	34.38	33.03	31.78	30.63	29.55
1	37.82	36.19	34.70	33.33	32.06	30.88	29.79	28.77	27.82	26.93	26.09
1.25	31.51	30.37	29.31	28.33	27.40	26.54	25.73	24.97	24.25	23.57	22.93
1.5	26.25	25.46	24.71	24.01	23.34	22.71	22.11	21.55	21.01	20.50	20.01
1.75	21.81	21.26	20.73	20.23	19.76	19.31	18.87	18.46	18.06	17.68	17.32
2	18.00	17.62	17.26	16.91	16.58	16.26	15.95	15.65	15.37	15.09	14.83
2.25	14.69	14.44	14.20	13.96	13.74	13.52	13.30	13.09	12.89	12.70	12.51
2.5	11.81	11.64	11.48	11.33	11.18	11.03	10.89	10.75	10.62	10.48	10.35
2.75	9.26	9.16	9.06	8.96	8.87	8.78	8.69	8.60	8.51	8.43	8.34
3	7.00	6.94	6.88	6.83	6.77	6.72	6.66	6.61	6.56	6.51	6.46
3.25	4.97	4.94	4.91	4.88	4.86	4.83	4.80	4.77	4.75	4.72	4.69
3.5	3.15	3.14	3.12	3.11	3.10	3.09	3.08	3.07	3.06	3.05	3.03
3.75	1.50	1.50	1.49	1.49	1.49	1.49	1.48	1.48	1.48	1.48	1.47
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Right Leg Buildup %

a	50	55	60	65	70	75	80	85	90	95	100
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.25	1.56	1.44	1.34	1.25	1.18	1.11	1.05	1.00	0.95	0.90	0.86
0.5	2.72	2.55	2.41	2.27	2.16	2.05	1.95	1.87	1.78	1.71	1.64
0.75	3.63	3.44	3.27	3.12	2.98	2.85	2.74	2.63	2.53	2.44	2.35
1	4.35	4.16	3.99	3.83	3.69	3.55	3.43	3.31	3.20	3.10	3.00
1.25	4.94	4.76	4.60	4.44	4.30	4.16	4.04	3.92	3.80	3.70	3.60
1.5	5.44	5.27	5.12	4.97	4.83	4.70	4.58	4.46	4.35	4.25	4.14
1.75	5.85	5.71	5.57	5.43	5.30	5.18	5.07	4.96	4.85	4.75	4.65
2	6.21	6.08	5.96	5.84	5.72	5.61	5.51	5.40	5.30	5.21	5.12
2.25	6.52	6.41	6.30	6.20	6.10	6.00	5.90	5.81	5.72	5.64	5.55
2.5	6.79	6.70	6.61	6.52	6.43	6.35	6.26	6.18	6.11	6.03	5.96
2.75	7.03	6.95	6.88	6.81	6.73	6.66	6.60	6.53	6.46	6.40	6.33
3	7.24	7.18	7.13	7.07	7.01	6.95	6.90	6.85	6.79	6.74	6.69
3.25	7.43	7.39	7.35	7.30	7.26	7.22	7.18	7.14	7.10	7.06	7.02
3.5	7.60	7.58	7.55	7.52	7.49	7.47	7.44	7.41	7.38	7.36	7.33
3.75	7.76	7.75	7.73	7.72	7.70	7.69	7.68	7.66	7.65	7.64	7.62
4	7.90	7.90	7.90	7.90	7.90	7.90	7.90	7.90	7.90	7.90	7.90

Effective Source Activity

a	Building % 50	55	60	65	70	75	80	85	90	95	100
0	61.66	56.06	51.38	47.43	44.04	41.11	38.54	36.27	34.26	32.45	30 83
0.25	52.82	48.89	45.51	42.57	39.98	37.69	35.65	33.81	32.16	30.66	29.29
0.5	46.20	43.36	40.84	38.61	36.60	34.79	33.16	31.67	30.30	29.06	27 90
0.75	41.05	38.94	37.04	35.32	33.75	32.31	30.99	29.78	28.65	27.61	26.64
1	36.94	35.35	33.89	32.55	31.31	30.16	29.09	28.10	27.17	26.30	25.49
1.25	33.57	32.36	31.23	30.18	29.20	28.28	27.41	26.60	25.83	25.11	24.43
1.5	30.77	29.84	28.96	28.13	27.35	26.62	25.92	25.25	24.62	24.02	23.45
1.75	28.40	27.68	27.00	26.35	25.73	25.14	24.58	24.04	23.52	23.03	22.55
2	26.36	25.81	25.28	24.78	24.29	23.82	23.37	22.93	22.51	22.11	21.72
2.25	24.60	24.18	23.77	23.38	23.00	22.63	22.27	21.92	21.59	21.26	20.95
2.5	23.06	22.74	22.43	22.13	21.84	21.55	21.27	21.00	20.74	20.48	20.23
2.75	21.70	21.47	21.24	21.01	20.79	20.57	20.36	20.15	19.95	19.75	19.55
3	20.50	20.33	20.16	20.00	19.84	19.68	19.52	19.37	19.22	19.07	18.92
3.25	19.42	19.30	19.19	19.08	18.97	18.86	18.75	18.65	18.54	18.44	18.33
3.5	18.45	18.38	18.31	18.24	18.17	18.11	18.04	17.97	17.91	17.84	17.78
3.75	17.57	17.53	17.50	17.47	17.44	17.41	17.38	17.35	17.32	17.29	17.26
4	16.77	16.77	16.77	16.77	16.77	16.77	16.77	16.77	16.77	16.77	16.77


Whole-Body Dose Equivalent
by time distribution and buildup
Whole-Body Dose Equivalent
rem
90
80
70
60
50
40
30
20
10
0
0
1
2
3
4
minutes
Time in Orientation A
50% Buildup
55% Buildup
60% Buildup
65% Buildup
70% Buildup
75% Buildup
80% Buildup
85% Buildup
90% Buildup
95% Buildup
100% Buildup

Dose Calculation Matrix:

Badge Dose: 4.6 rem

Whole Body Buildup %

a	50	55	60	65	70	75	80	85	90	95	100
0	86.05	78.23	71.71	66.19	61.46	57.37	53.78	50.62	47.81	45.29	43.03
0.25	69.11	63.97	59.54	55.69	52.30	49.31	46.64	44.24	42.07	40.11	38.33
0.5	56.41	52.94	49.87	47.14	44.69	42.49	40.49	38.67	37.00	35.48	34.07
0.75	46.55	44.16	42.00	40.05	38.27	36.64	35.14	33.76	32.49	31.31	30.21
1	38.66	37.00	35.47	34.07	32.77	31.57	30.45	29.41	28.44	27.53	26.67
1.25	32.21	31.05	29.96	28.96	28.01	27.13	26.30	25.52	24.79	24.09	23.44
1.5	26.84	26.02	25.26	24.54	23.86	23.22	22.61	22.03	21.48	20.95	20.46
1.75	22.29	21.73	21.19	20.68	20.20	19.73	19.29	18.87	18.46	18.08	17.70
2	18.40	18.01	17.64	17.29	16.95	16.62	16.30	16.00	15.71	15.43	15.16
2.25	15.02	14.76	14.51	14.27	14.04	13.82	13.60	13.39	13.18	12.98	12.79
2.5	12.07	11.90	11.74	11.58	11.43	11.28	11.13	10.99	10.85	10.72	10.58
2.75	9.47	9.36	9.26	9.16	9.07	8.97	8.88	8.79	8.70	8.61	8.53
3	7.40	7.34	7.28	7.22	7.17	7.11	7.05	7.00	6.94	6.89	6.84
3.25	7.60	7.55	7.51	7.47	7.42	7.38	7.34	7.30	7.26	7.22	7.18
3.5	7.77	7.74	7.72	7.69	7.66	7.63	7.60	7.58	7.55	7.52	7.49
3.75	7.93	7.92	7.90	7.89	7.88	7.86	7.85	7.83	7.82	7.81	7.79
4	8.08	8.08	8.08	8.08	8.08	8.08	8.08	8.08	8.08	8.08	8.08

Left Leg Buildup %

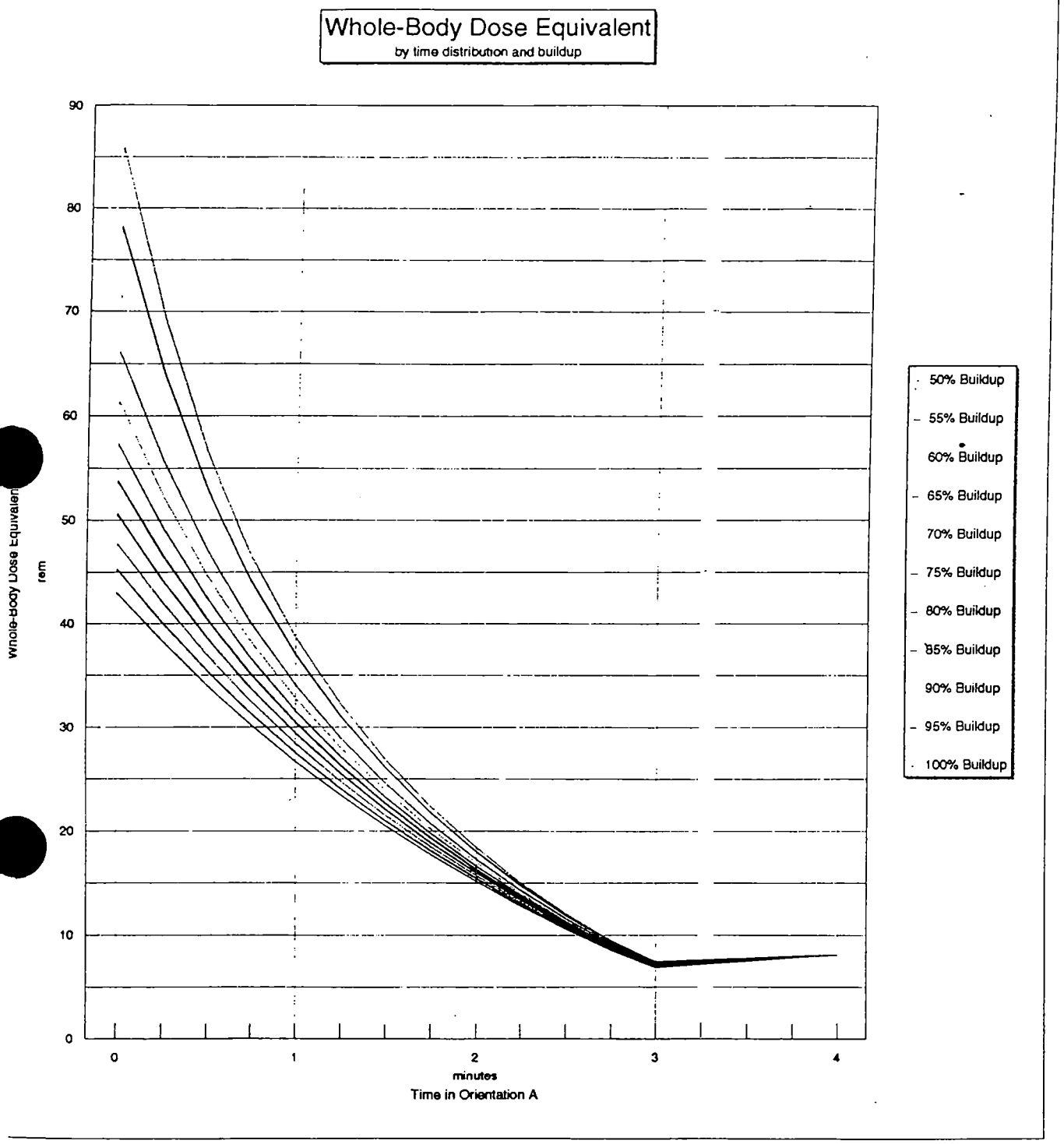
a	50	55	60	65	70	75	80	85	90	95	100
0	86.05	78.23	71.71	66.19	61.46	57.37	53.78	50.62	47.81	45.29	43.03
0.25	69.11	63.97	59.54	55.69	52.30	49.31	46.64	44.24	42.07	40.11	38.33
0.5	56.41	52.94	49.87	47.14	44.69	42.49	40.49	38.67	37.00	35.48	34.07
0.75	46.55	44.16	42.00	40.05	38.27	36.64	35.14	33.76	32.49	31.31	30.21
1	38.66	37.00	35.47	34.07	32.77	31.57	30.45	29.41	28.44	27.53	26.67
1.25	32.21	31.05	29.96	28.96	28.01	27.13	26.30	25.52	24.79	24.09	23.44
1.5	26.84	26.02	25.26	24.54	23.86	23.22	22.61	22.03	21.48	20.95	20.46
1.75	22.29	21.73	21.19	20.68	20.20	19.73	19.29	18.87	18.46	18.08	17.70
2	18.40	18.01	17.64	17.29	16.95	16.62	16.30	16.00	15.71	15.43	15.16
2.25	15.02	14.76	14.51	14.27	14.04	13.82	13.60	13.39	13.18	12.98	12.79
2.5	12.07	11.90	11.74	11.58	11.43	11.28	11.13	10.99	10.85	10.72	10.58
2.75	9.47	9.36	9.26	9.16	9.07	8.97	8.88	8.79	8.70	8.61	8.53
3	7.15	7.09	7.03	6.98	6.92	6.87	6.81	6.76	6.71	6.65	6.60
3.25	5.08	5.05	5.02	4.99	4.96	4.93	4.91	4.88	4.85	4.82	4.80
3.5	3.22	3.21	3.19	3.18	3.17	3.16	3.15	3.14	3.12	3.11	3.10
3.75	1.53	1.53	1.53	1.52	1.52	1.52	1.52	1.51	1.51	1.51	1.51
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Right Leg Buildup %

a	50	55	60	65	70	75	80	85	90	95	100
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.25	1.59	1.47	1.37	1.28	1.20	1.13	1.07	1.02	0.97	0.92	0.88
0.5	2.78	2.61	2.46	2.32	2.20	2.09	2.00	1.91	1.82	1.75	1.68
0.75	3.71	3.52	3.35	3.19	3.05	2.92	2.80	2.69	2.59	2.49	2.41
1	4.45	4.26	4.08	3.92	3.77	3.63	3.50	3.38	3.27	3.17	3.07
1.25	5.05	4.87	4.70	4.54	4.40	4.26	4.13	4.00	3.89	3.78	3.68
1.5	5.56	5.39	5.23	5.08	4.94	4.81	4.68	4.56	4.45	4.34	4.24
1.75	5.98	5.83	5.69	5.55	5.42	5.30	5.18	5.07	4.96	4.85	4.75
2	6.35	6.22	6.09	5.97	5.85	5.74	5.63	5.52	5.42	5.32	5.23
2.25	6.67	6.55	6.44	6.33	6.23	6.13	6.03	5.94	5.85	5.76	5.68
2.5	6.94	6.85	6.75	6.66	6.57	6.49	6.40	6.32	6.24	6.16	6.09
2.75	7.19	7.11	7.03	6.96	6.88	6.81	6.74	6.67	6.61	6.54	6.48
3	7.40	7.34	7.28	7.22	7.17	7.11	7.05	7.00	6.94	6.89	6.84
3.25	7.60	7.55	7.51	7.47	7.42	7.38	7.34	7.30	7.26	7.22	7.18
3.5	7.77	7.74	7.72	7.69	7.66	7.63	7.60	7.58	7.55	7.52	7.49
3.75	7.93	7.92	7.90	7.89	7.88	7.86	7.85	7.83	7.82	7.81	7.79
4	8.08	8.08	8.08	8.08	8.08	8.08	8.08	8.08	8.08	8.08	8.08

Effective Source Activity

a \ Building %	50	55	60	65	70	75	80	85	90	95	100
0	63.03	57.30	52.53	48.49	45.02	42.02	39.39	37.08	35.02	33.17	31.52
0.25	54.00	49.98	46.52	43.51	40.87	38.53	36.44	34.56	32.87	31.34	29.95
0.5	47.23	44.32	41.75	39.46	37.41	35.57	33.89	32.37	30.98	29.70	28.52
0.75	41.96	39.81	37.87	36.10	34.50	33.03	31.68	30.44	29.29	28.22	27.23
1	37.76	36.13	34.64	33.27	32.01	30.83	29.74	28.72	27.77	26.89	26.05
1.25	34.32	33.08	31.93	30.85	29.85	28.91	28.02	27.19	26.41	25.67	24.97
1.5	31.45	30.50	29.60	28.76	27.96	27.21	26.49	25.82	25.17	24.56	23.97
1.75	29.03	28.29	27.60	26.93	26.30	25.70	25.12	24.57	24.04	23.54	23.05
2	26.95	26.39	25.84	25.33	24.83	24.35	23.89	23.44	23.01	22.60	22.20
2.25	25.15	24.72	24 30	23.90	23.51	23.13	22.77	22.41	22.07	21.74	21.41
2.5	23.58	23.25	22.93	22.62	22.32	22.03	21.75	21.47	21.20	20.93	20.68
2.75	22.19	21.95	21.71	21.48	21.25	21.03	20.81	20.60	20.39	20.19	19.99
3	20.95	20.78	20.61	20.44	20.28	20.12	19.96	19.80	19.65	19.49	19.35
3.25	19.85	19.73	19.62	19.50	19.39	19.28	19.17	19.06	18.95	18.85	18.74
3.5	18.85	18.78	18.71	18.65	18.58	18.51	18.44	18.37	18.31	18.24	18.18
3.75	17.96	17.92	17.89	17.86	17.83	17.80	17.77	17.73	17.70	17.67	17.64
4	17.14	17.14	17.14	17.14	17.14	17.14	17.14	17.14	17.14	17.14	17.14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November 18, 1996

EA 96-441

Michael Creech
Senior Vice Prescient
Conam Inspection
1245 W. Norwood
Itasca, IL 60143

SUBJECT: NRC INSPECTION REPORT NO. 030-31373/96002(DNMS) AND INVESTIGATION REPORT NO. 3-96-014

Dear Mr. Creech:

This refers to the routine, unannounced inspection conducted on site in Gary, Indiana, on March 28 through April 11, 1996, and the exit meeting conducted by telephone on November 12, 1996. The purpose of the inspection was to determine whether activities authorized by the license were conducted safely and in accordance with NRC requirements. At the conclusion of the inspection, the findings were discussed with you and those members of your staff identified in the enclosed report.

Areas examined during the inspection are identified in the report. Within these areas, the inspection consisted of selective examinations of procedures and representative records, interviews with personnel, and observation of activities in progress.

This also refers to an investigation conducted by the NRC Office of Investigations (OI) to determine if your radiography personnel deliberately violated NRC requirements pertaining to calibration of survey instruments, wearing of film badges, management attention to employee concerns about safety, proper use of an exposure device that resulted in personal radiation exposure, proper use of exposure devices in general, and accuracy of records. A synopsis of the results of the investigation is enclosed.

Based on the results of the inspection and investigation, six apparent violations were identified and are being considered for escalated enforcement action in accordance with the "General Statement of Policy and Procedure for NRC Enforcement Actions" (Enforcement Policy), NUREG-1600 (60 FR 34381; June 30, 1995). These apparent violations pertain to the failure to properly secure the source assembly in the exposure device; failure to complete a survey of the entire circumference of the exposure device after each exposure; failure to control radiation exposure of a worker to less than 5 rems (0.05 Sv), total effective dose equivalent (TEDE); failure to immediately report to NRC an event that may have caused or threatened to cause a worker to receive a radiation dose of 25 rems (0.25 Sv), TEDE, or more; failure to conduct an adequate evaluation of potential personnel exposures to demonstrate compliance with 10 CFR 20.1201(c); and failure to provide a film badge to an individual

who calibrated survey instruments. These apparent violations are of significant concern because the failure to properly secure the source assembly in the exposure device appeared to be willful in nature. This was because the radiographers were knowledgeable of your Operating and Emergency Procedures Manual requirements for operation of the exposure device, which specifies the steps to secure the source assembly in the exposure device after each exposure, but chose to ignore them. This apparent violation was not only associated with the event that caused the apparent overexposure, but also was found to be standard practice by several of your radiographers. Additionally, these violations are significant in that they led to an apparent overexposure.

The apparent violations are described in the enclosed report and will be discussed with your staff in a transcribed predecisional enforcement conference. Consequently, a Notice of Violation is not presently being issued for these inspection findings. The number and characterization of the apparent violations may change as a result of further NRC review.

The transcribed predecisional enforcement conference has been scheduled for Monday, December 2, 1996, at 10:00 a.m. (CST) in the Region III office, 801 Warrenville Road, Lisle, Illinois. The decision to hold an enforcement conference does not mean that the NRC has determined that a violation has occurred or that enforcement action will be taken. The purposes of this conference are to discuss the apparent violations, their causes and safety significance; to provide you the opportunity to point out any errors in our inspection report; and to provide an opportunity for your staff to present your proposed corrective actions. In particular, we expect you to be prepared to discuss: (1) your previously stated position that no overexposure occurred, (2) why the NRC should conclude that management is not placing production pressures on employees to the detriment of safety and compliance, and (3) the adequacy of your corporate-wide training program. In addition, this is an opportunity for you to provide any information concerning your perspectives on: (1) the severity of the violations, (2) the application of the factors that the NRC considers when it determines the amount of a civil penalty that may be assessed in accordance with Section VI.B.2 of the Enforcement Policy, and (3) any other application of the Enforcement Policy to this case, including the exercise of discretion in accordance with Section VII. You will be advised by separate correspondence of the results of our deliberations on this matter. No response regarding these apparent violations is required at this time.

To assist you in preparing for the predecisional enforcement conference, we are enclosing a copy of the NRC Enforcement Policy and an Information Notice which provides guidance on the development and implementation of corrective actions.

Please contact Mr. Monte P. Phillips or Mr. Thomas F. Young at telephone number (630) 829-9806 or (630) 829-9835, respectively, if you have any questions.

In accordance with 10 CFR 2.790 of the NRC's "Rules of Practice," a copy of this letter and enclosures 1 and 2 will be placed in the NRC Public Document Room.

Sincerely,

Original Signed by

Cynthia D. Pederson, Director
Division of Nuclear Materials Safety

License No. 12-16779-01
Docket No. 030-31373

Enclosures: 1. Inspection Report
No. 030-31373/96002(DNMS)
2. OI Synopsis
3. Information Notice 96-28
4. Enforcement Policy (NUREG-1600)

bcc w/encls 1 and 2: J. Goldberg, OGC
D. Cool, NMSS
B. Burgess, EICS
Office of Enforcement
PUBLIC IE07

U.S. NUCLEAR REGULATORY COMMISSION

REGION III

Docket No.:	030-31373
License No.:	12-16779-01
Report No.:	030-31373/96002(DNMS)
Licensee:	Conam Inspection
Facilities:	1. Conam Inspection Corporate Office 2. Conam Inspection Gary Field Office
Location:	1. 1245 W. Norwood, Itasca, IL 60143 2. 2090 East 15th Avenue, Gary, IN
Dates:	March 28 through April 11, 1996 (On site at the Gary Field Office) November 12, 1996 (Exit Meeting by Telephone)
Inspectors:	T. F. Young, Radiation Specialist G. W. West, Radiation Specialist
Approved By:	M. P. Phillips, Chief Nuclear Materials Inspection Branch 2

EXECUTIVE SUMMARY

CONAM INSPECTION
NRC INSPECTION REPORT NO. 030-31373/96002(DNMS)

This was a routine, unannounced safety inspection to evaluate the licensee's oversight of radiation safety controls for its facilities, equipment, personnel, and procedures for the conduct of radiographic operations at the Gary field office. The NRC inspectors determined that the licensee's oversight of its facilities and equipment were generally adequate. However, in reviewing the February 1996 personnel radiation dosimetry report, the inspectors identified an event that occurred on February 27, 1996, involving a high exposure to one of the licensee's radiographers. Subsequent investigation into this event identified the following apparent violations:

1. Failure to properly secure the source assembly in the exposure device after each exposure as required by 10 CFR 34.22(a) and License Condition 26.

2. Failure to complete a survey of the entire circumference of the exposure device after each exposure as required by 10 CFR 34.43(b).

3. Failure to control radiation exposure of a worker to less than 5 rems (0.05 Sv), total effective dose equivalent (TEDE) as required by 10 CFR 20.1201(a).

4. Failure to immediately report to NRC an event that may have caused or threatens to cause an individual to receive a radiation dose of 25 rems (0.25 Sv), TEDE, or more as required by 10 CFR 20.2202(a).

5. Failure to conduct an adequate evaluation of personnel exposures to radiation in order to demonstrate compliance with 10 CFR 20.1201(c) as required by 10 CFR 20.1501(a)(2).

The root cause of the event appeared to be human error, with contributing factors including: (1) time constraints placed on the radiographer at the job site, (2) failure of the radiographer to follow the licensee's Operating and Emergency Procedure Manual (O&E) to properly secure the source assembly in the exposure device after each exposure, (3) weaknesses in the licensee's internal audit program, and (4) weaknesses in the written exam and field exam that were included in the licensee's training program for radiographic testing (RT) personnel.

As corrective actions following the event, the radiographer was restricted from further involvement with the licensee's radiation sources for the remainder of 1996; and the RSO issued a memo to all Radiation Safety administrative personnel about the event and the proper procedure to survey and secure exposure devices after each exposure and requested them to instruct all RT personnel about the event and the procedures to prevent recurrence.

An additional apparent violation was also identified during the inspection unrelated to the event for failure to provide a film badge to an individual who calibrated survey meters as required by License Condition 26.

Two areas of concern were also identified regarding weaknesses in the licensee's programs for internal audits and training of RT personnel in the proper procedure to secure the source assembly in the exposure device after each exposure when multiple exposures are completed from a single RT set up.

INSPECTION DETAILS

1. Program Summary and Inspection History

1.1. Inspection Scope

The inspectors reviewed the current license and licensee commitments contained in letters and applications and the licensee's corrective actions for violations identified during the previous two years.

1.2. Observations and Findings

On February 2, 1995, Amendment No. 6 of License No. 12-16559-01 was issued. The license authorized possession and use at temporary job sites for various sealed sources and devices, for conduct of: radiographic testing (RT), moisture/density measurements, X-ray fluorescence testing, and survey instrument calibration. There were no special license conditions or exemptions from NRC requirements noted in the license.

During the period of November 17, 1994, through February 26, 1996, the NRC completed seven routine, unannounced inspections at the licensee's permanent field offices located in Reading and Sharon Hills, PA; Natick, Auburn, and Springfield, MA; and Columbus, OH. These inspections included one temporary job site in Lima, OH. No violations were identified during these inspections.

The last inspection of the Gary field office was completed on September 10-24, 1993. One violation was identified for failure to carry emergency instructions while transporting licensed material.

2. Licensee Organization and Management Controls

2.1. Inspection Scope

The inspectors reviewed the licensee's current chain of command for control of licensed material and compared the names and qualifications of the incumbents with the names and qualifications of those individuals described in the licensee's commitments.

2.2. Observations and Findings

The licensee's corporate officers who were responsible for the radiation safety program continued to include Boyd Creech, President; Michael Creech, Senior Vice President; and Robert Slack, Radiation Safety Officer (RSO). The management at the Gary field office, included Randy Sweet, General Manager (GM); and Steve Fay, Radiation Safety Supervisor (RSS). These individuals were recently appointed in March 1996 to replace Bill Hiestand and Keith Tucker, respectively, who were no longer employed by the licensee. Also, there were changes for administrative personnel responsible for the Radiation Safety Program at the other field offices.

Although the names and titles of personnel differed from the names and titles submitted with the licensee's application dated March 29, 1993, which is referenced in License Condition 26, the current individuals met the qualifications for administrative personnel described in Section 5.1 of the licensee's Radiation Safety Administrative Procedures Manual (RSAM). According to the RSO, these individuals were qualified radiographers with at least three years of RT experience and had successfully completed the licensee's 125 question written exam. Also, the RSO had revised RSAM Section 1 so that when changes in administrative personnel assignments occurred, the appendices would be updated. The inspectors conferred with Region III license reviewers who indicated this was an acceptable practice. No problem was identified by the inspectors.

The GM and RSS were in the process of completing an audit of the entire radiation safety program at the Gary field office. There were 12 RT personnel assigned to this field office. RT equipment assigned to this field office included 11 exposure devices containing iridium-192 sealed sources, one exposure device containing a cobalt-60 sealed source, and one survey instrument calibrator containing a cesium-137 sealed source. As of March 24, 1996, RT equipment was located at temporary job sites in Region III and in Region I.

2.3. Conclusions

No apparent violations of NRC requirements were identified. Although the updated list of the licensee's radiation safety personnel was different from that originally submitted to NRC, the individuals were apparently qualified radiographers. The licensee is permitted to make administrative personnel changes providing the individuals meet the licensed qualification requirements, as was the case here.

3. Review of February 27, 1996, Event

3.1. Background

3.1.1. Inspection Scope

On March 28, 1996, during a routine unannounced inspection of the licensee's radiographic operations at the Gary field office, the inspectors reviewed the February 1996 personnel radiation dosimetry report that indicated a whole body radiation dose value of 4750 millirems (47.5 mSv) to one individual. The inspectors investigated the details of the radiation dose.

The inspectors interviewed individuals at the Gary field office, including: the radiographer, GM, and RSS.

3.1.2. Observations and Findings

The radiographer described the event to the inspectors during three separate interviews as follows.

On February 27, 1996, the radiographer and a second radiographer were completing radiographic testing of welds for a company located in Indianapolis, IN. These individuals were working the 10 hour evening shift. The radiographer was completing the exposures of the welds and running film to and from the dark room that was located on a licensee vehicle parked outside the building. The second radiographer was working in the dark room loading and unloading film cassettes and developing and interpreting the films. The radiographer was using an Amersham Model 660B exposure device containing 94 curies of iridium-192 in a sealed source assembly.

At about 6:30 p.m., the radiographer was completing RT of welds on two inch pipe in a vacuum pump room on the second floor of the building. After about 15 exposures of several welds, the radiographer retracted the source in the usual manner at the end of an exposure. The drive cable control unit was located outside the vacuum pump room, about 20 feet from the exposure device. The radiographer opened the door and entered the vacuum pump room with a survey instrument and loaded film cassette. The radiographer approached the rear of the exposure device that was mounted on the top platform of a six foot step ladder. The guide tube and collimator were attached to a weld in the ceiling area about three feet above and three feet to the right of the exposure device. The radiographer used the survey instrument to check the radiation levels at the rear and sides of the exposure device and the collimator and guide tube. The radiographer observed no excessive radiation levels and noted the typical reference level, 20 millirems per hour (0.2 mSv per hour), at the right side of the exposure device. The radiographer did not survey the front (exit port) of the exposure device.

10 CFR 34.43(b) requires, in part, the licensee to ensure that a survey with a calibrated and operable radiation survey instrument is made after each radiographic exposure to determine that the sealed source has been returned to its shielded position. The survey must include the entire circumference of the radiographic exposure device and any source guide tube. Failure of the radiographer to complete a radiation survey of the entire circumference of the exposure device after the radiographic exposure was an apparent violation 10 CFR 34.43(b).

The radiographer indicated that he was careless and did not survey the entire circumference of the exposure device after the exposure as required.

The radiographer then set the survey instrument aside and climbed the ladder to the second step from the top to exchange the film cassette for the second exposure of the weld. As the radiographer was facing the exposure device, he reached upward and to the right and removed the collimator and guide tube and unstrapped the first cassette and laid it near the survey instrument on an equipment cart below the ladder.

The radiographer was wearing his dosimetry equipment in a pouch that was worn in front of his waist near the midline of the body. The Direct Reading Dosimeter (DRD), Alarming Ratemeter (AR), and film badge were randomly positioned within the waist pouch along with the radiographer's other personal items. In this position, the dosimetry equipment was closer to the exposure device than the whole body. The radiographer estimated that he was in this position for about one minute.

When the radiographer was ready to strap the second film cassette onto the weld, he reversed his position on the ladder so that he was no longer facing the exposure device and the left side of his upper leg was closest to the exposure device. In this position, the dosimetry equipment was displaced so that it was further from the exposure device than the upper left leg and the film badge was shielded from the exposure device by the radiographer's body. The radiographer estimated that he was in this position for about three minutes while he strapped the second film cassette to the weld and repositioned the collimator for the second exposure of the weld. As the radiographer climbed down the ladder, he picked up the first cassette and survey instrument and reached for the rear of the exposure device to reset the automatic locking mechanism for the second exposure. The radiographer discovered that the automatic locking mechanism was not in the correct position to secure the source in the exposure device.

10 CFR 34.22(a) requires, in part, that, during radiographic operations, the sealed source assembly be secured in the shielded position each time the source is returned to that position. In addition, License Condition 26 requires the radiographer to follow the procedures contained in the licensee's Operating and Emergency Procedures Manual (O&E) that was included in the licensee's application dated March 29, 1993. O&E Item 10.3.3(c)15 requires that for the Amersham Model 660B exposure device, the radiographer turn the selector ring from operate to lock and secure with the projector lock.

On February 27, 1996, the radiographer did not realize that the automatic locking mechanism was not engaged, did not rotate the selector ring from operate to lock, and did not secure the projector lock. These steps to properly secure the source in the exposure device should have been completed after the radiographer surveyed the exposure device and before the radiographer replaced the film cassette on the weld and repositioned the collimator for the second exposure. If the radiographer had completed any of these three redundant steps to properly secure the source assembly in the exposure device, the radiographer would have discovered the unsecured source before continuing to replace the film on the weld. The radiographer indicated

that he was aware of the O&E requirement, but it was not his practice to rotate the selector ring from operate to lock or to secure the projector lock after each exposure. It was the radiographer's routine practice to rely solely on the automatic locking mechanism. Failure of the licensee's radiographer to secure the source in the exposure device is an apparent violation of 10 CFR 34.22(a) and License Condition 26.

Upon realizing that the source was not secured, the radiographer returned to the drive cable control that was positioned just outside the vacuum pump room. The radiographer rotated the control crank about 1/3 to 1/2 turn to fully retract the source assembly into the exposure device so that the automatic locking mechanism was engaged. He applied pressure on the crank in the forward direction and felt resistance that indicated the automatic locking mechanism had engaged. The radiographer checked his DRD and noted that it read "off scale" i.e. > 200 millirems (2 mSv).

The radiographer stated that he checked the AR and noted that it was in the "on" position, and that he checked the alarm test and the AR produced a sustained audible alarm signal. The radiographer, RSO, and inspectors found the alarm signal to be functional and properly respond in tests performed on the AR subsequent to the event. The AR threshold was calibrated in December 1995 to alarm at 500 millirems per hour (5 mSv per hour). The event produced a film badge result of 4600 millirems (46 mSv) in 4 minutes, e.g. 70000 millirems per hour (700 mSv per hour) e.g. 140 times the alarm threshold of the AR. The radiographer insisted that the AR was "on" when he removed it from the waist pouch, however, he did not hear an alarm signal during the event.

The radiographer re-entered the vacuum pump room with the survey instrument and completed a thorough radiation survey of the exposure device and surrounding area, properly secured the source assembly in the exposure device, and removed the key from the projector lock. He went to the dark room and notified the second radiographer about the event. He telephoned the Gary RSS, who instructed him to stop RT until further notice from the RSO. Later the Gary RSS instructed the radiographer to cease all RT operations and report to the Gary field office on the next day, February 28, 1996, so that the RSS and the RSO could review the event. No one from the Gary field office went to the site of the event to observe the scene of the event. Although photographs were taken of the camera location and the ladder in relation to the room, no photographs were taken with the radiographer in either of the two positions referred to above when the event occurred.

3.1.3. Conclusions

Two apparent violations of NRC requirements were identified for failure to properly secure the source assembly in the exposure device after each exposure and for failure to complete a radiation survey of the entire circumference of the exposure device after each exposure. There was no plausible explanation for the failure of the AR to alert the radiographer.

3.2 Results of Licensee Investigation

3.2.1. Inspection Scope

The inspectors evaluated the RSO Incident Report dated February 28, 1996, and the RSO memo dated February 29, 1996, that was sent to all Radiation Safety administrative personnel describing the event and instructing all RT personnel about the procedures to properly secure the source assembly in the exposure device after each exposure. The inspectors interviewed the RSO and the radiographer about these items and about the condition of the RT equipment that was involved in the event.

3.2.2. Observations and Findings

On February 28, 1996 the RSO and radiographer met to discuss the event and determine the radiographer's radiation dose. The RSO tested the radiographer's dosimetry equipment and found the DRD and AR to be operable and reliable. The RSO interviewed the radiographer without props and concluded that the radiographer was not more than waist high on the ladder and was facing the exposure device for the entire period that he was replacing the film on the weld, the dosimetry equipment was worn in a waist pouch at the front of the radiographer, and therefore he concluded that the film badge was closer to the exposure device than the whole body so that the film badge would indicate the maximum radiation dose. Based on the distance the radiographer was away from the exposure device, the RSO calculated the radiation dose to be somewhere between 9 rems to 36 rems (0.09 Sv to 0.36 Sv). The estimate was based on the worst case scenario where the whole body was exposed to an unshielded source of 94 curies of iridium-192 for a period of four minutes at distances of one foot and two feet.

10 CFR 20.2202(a)(1)(i) requires, in part, that the licensee shall immediately report any event involving licensed material that may have caused or threatens to cause an individual to receive a total effective dose equivalent of 25 rems (0.25 Sv) or more. On February 28, 1996, the RSO's calculation included a result that was greater than 25 rems (0.25 Sv), but the licensee did not report the event to NRC as required. Failure of the licensee to immediately report the event is an apparent violation of 10 CFR 20.2202(a).

The RSS sent the film badge to the vendor for immediate processing. The RSO removed the radiographer from RT operations until further notice and waited for a reply from the film badge vendor. On February 29, 1996, the vendor reported to the RSO that the film badge indicated a radiation dose of 4.6 rems (0.046 Sv). Based on the film badge report and his understanding that the film badge location was closer to the exposure device than the whole body, the RSO assigned the 4.6 rems (0.046 Sv) value to the radiographer's personal radiation exposure record and suspended the radiographer from any further involvement with the licensee's radiation sources for the remainder of 1996. Later, the GM implemented disciplinary actions against the radiographer and directed him to prepare a lessons learned training session to be conducted for other licensee RT personnel.

10 CFR 20.1501 requires that each licensee make or cause to be made surveys that may be necessary for the licensee to comply with the regulations in Part 20 and that are reasonable under the circumstances to evaluate the extent of radiation levels, concentrations or quantities of radioactive materials, and the potential radiological hazards that could be present. 10 CFR 20.1003 defines the term *survey* to mean an evaluation of the radiological conditions and potential hazards incident to the production, use, transfer, release, disposal, or presence of radioactive material or other sources of radiation. 10 CFR 20.1201(c) requires, in part, that the assigned deep-dose equivalent must be for the part of the body receiving the highest radiation exposure. The deep-dose equivalent may be assessed from surveys or other radiation measurements for the purpose of demonstrating compliance with the occupational dose limits, if the individual monitoring device was not in the region of highest potential exposure. The licensee's RSO and radiographer did not complete an exact time/motion study at the scene of the event to determine the locations of the whole body, film badge, and exposure device exit port while the radiographer was positioned on the ladder to simulate the event. Also, photographs of the scene that were obtained later did not include the position of the radiographer, so that there was no preservation of the information concerning relative locations of the radiographer, film badge, and exposure device. The RSO relied solely on the radiographer's explanation of the event and the photographs that were obtained later. The RSO assumed that the calculated range of radiation dose, 9 rems to 36 rems (0.09 Sv to 0.36 Sv), was the worst case scenario and most likely over estimated the actual radiation dose. Failure of the license to complete surveys that were reasonable under the circumstances to evaluate the radiation levels and to assess the radiation dose to the part of the body that received the highest potential radiation exposure when the film badge was not worn in the region of highest radiation exposure is an apparent violation of 10 CFR 20.1501(a)(2) and 10 CFR 20.1201(c).

In addition, on February 27, 1996, prior to continuing RT operations after the event, the second radiographer inspected the involved RT equipment and found no defects or mechanical problems with the drive

cable control unit or drive cable connection to the source assembly, the exposure device automatic locking mechanism, selector ring operation, projector lock, guide tube or collimator. Also, the radiation detection survey instrument was operating and reliable.

3.2.3. Conclusions

Two apparent violations of NRC requirements were identified for failure to immediately report the event to the NRC once it was known that the dose could potentially exceed 25 rems (0.25 Sv) TEDE and for failure to complete surveys that were reasonable under the circumstances to evaluate the radiation dose to the part of the body that received the highest potential radiation exposure when the film badge was not worn in the region of highest potential radiation exposure. The RSO's investigation was weakened because an exact time/motion study was not completed at the scene and photographs of the scene did not include the position of the radiographer. The RSO relied solely on the radiographer's explanation of the event and photographs of the event scene that were obtained later. The RSO assumed that the calculated range of radiation dose, 9 rems to 36 rems (0.09 Sv to 0.36 Sv), was the worst case scenario and most likely over estimated the actual radiation dose. As such, the licensee's assessment of the radiation dose was inadequate.

3.3 Results of NRC Inspection

3.3.1. Inspection Scope

The inspectors evaluated the equipment that had been used by the radiographer on February 27, 1996, including the DRD, AR, the survey instrument, and the exposure device. Region III management initiated a telephone conference with the licensee's Senior Vice President and the RSO to discuss the event and subsequently issued a Confirmatory Action Letter (CAL) to the licensee on April 5, 1996. The CAL included a provision to conduct a re-enactment of the circumstances surrounding the event at the licensee's Gary facility. The inspectors participated with the RSO and the radiographer in the re-enactment of the event using a ladder and a dummy exposure device at a location in the licensee's facility that would simulate the location of the overhead pipes the radiographer was working on at the time of the event. The inspectors performed an independent dose assessment for the event based on the measurements obtained during the re-enactment. In addition, based on the exposure results, arrangements were made with the licensee to have a cytogenetic analysis performed on the radiographer by the Oak Ridge Institute for Science and Education (ORISE).

3.3.2. Observations and Findings

On April 2, 1996, the inspectors observed a licensee radiographer that had not been involved with the event set up the exposure device that had been involved with the event and perform about 10 exposures. After each exposure, the radiographer properly secured the source assembly in the

exposure device. No mechanical problem or defect in the operation of the exposure device was apparent. In particular, no malfunction of the automatic locking mechanism occurred. The inspectors also confirmed that the DRD and AR were operational and reliable.

On April 11, 1996, the radiographer re-enacted the event for the inspectors and RSO. The radiographer climbed the ladder and assumed the positions that were necessary to remove the collimator and guide tube from the pipe and to exchange the film on the weld. The distances from the exit port of the exposure device to the film badge and various parts of the whole body were measured. Also, thicknesses of the radiographer's upper left leg and torso were measured. These measurements were taken at appropriate angles to indicate direct exposure of the whole body and the film badge. A copy of the record of the measurements was provided to the RSO. The RSO concluded that the radiographer's position on the ladder differed from his previous understanding of the event because the radiographer's demonstration did not match the RSO's understanding of the information provided to the RSO during his interview of the radiographer on February 28, 1996.

The licensee also provided the results of the film badge evaluation. The film badge vendor reported that the film appeared to be typical of occupational exposure. However, the film also appeared to be partially shielded as evidenced by a lighter exposure on the left side of the film. The nonuniform exposure of the film did not interfere with determination of the reported radiation dose of 4.6 rems (0.046 Sv). The position of the film badge on the body could not be discerned.

Based on the physical measurements of time, distance, and the film badge dose (4.6 rems) (0.046 Sv), the inspectors calculated the apparent activity of the source that was partially shielded in the exposure device. The dose assessment completed by the inspectors assumed the physical constants associated with iridium-192, the distances re-enacted by the radiographer, and the film badge dose (4.6 rems) (0.046 Sv). The variables associated with the dose assessment included the durations of the radiographer's two positions that were associated with exchanging the film on the weld. The apparent activity was used to assess the range of possible radiation doses to various aspects of the whole body. The upper left leg was closest to the exit port of the exposure device.

The lower limit of the range of doses the NRC calculated to the upper left leg was 6.6 rems (0.066 Sv), which is a conservative value in that it assumes the most shielding afforded to the source by the exposure device, and it assumes the radiographer was facing the exposure device for <u>three minutes</u> while he was removing the collimator, guide tube, and film from the weld. It also assumes a <u>one minute</u> duration for the radiographer to replace the second film on the weld and reposition the collimator and guide tube before exiting the vacuum pump room. However, during the interviews, the radiographer indicated times of one minute and three minutes, respectively, for the two positions.

If the times were reversed (one minute for removal activities and three minutes for replacement activities), the dose calculated to this location ranges from 15 rems (0.15 Sv) to a maximum of 86.0 rems (0.86 Sv), with a best estimate of 34 rems (0.34 Sv).

Because the upper range of the calculated dose was above 25 rems (0.25 Sv), NRC arranged for ORISE to complete a cytogenetic analysis of the radiographer. ORISE reported the results as less than 20 rems (0.2 Sv). This value was considered to be the upper limit of the radiation dose, in that it assumes the cytogenetic study results effectively set the upper limit because of the conspicuous absence of chromosomal anomalies in the radiographer's blood sample.

10 CFR 20.1201(a)(1)(i) requires, in part, that the licensee control the occupational dose to individual adults to an annual dose limit of 5 rems (0.05 Sv) total effective dose equivalent. Failure of the licensee to control the occupational dose of the radiographer to an annual dose limit of 5 rems (0.05 Sv) total effective dose equivalent is an apparent violation of 10 CFR 20.1201(a)(1)(i).

3.3.3 Conclusions

One apparent violation of NRC requirements was identified for failure of the licensee to control the annual dose of the radiographer to less than 5 rems (0.05 Sv), TEDE. The NRC estimated that the radiographer received a radiation dose in the range of 6 rems (0.06 Sv) to 20 rems (0.2 Sv), total effective dose equivalent, during the event on February 27, 1996.

3.4 NRC Identified Root Causes and Contributing Factors

3.4.1. Inspection Scope

The inspectors interviewed the radiographer and RSO about time constraints on the job and the licensee's internal audit program. The inspectors reviewed the licensee's training program materials and required examinations for RT personnel with respect to the O&E procedures for properly securing the source assembly in the exposure device after each exposure.

3.4.2. Observations and Findings

The radiographer indicated that the client had recently complained about the lack of RT productivity. The licensee extended the 8-hour shifts to 10 or 12 hour shifts to accommodate the client's request. The radiographer stated that he felt he was constrained by time to complete RT of the assigned welds during his shift. The radiographer indicated that he felt rushed at the time of the event.

According to the RSO and radiographer, the licensee's internal audit program did not specifically evaluate RT personnel performance of the O&E procedure to properly secure the source assembly in the exposure

device after each exposure when multiple exposures were completed from a single RT set up. Typically, the auditor would observe the RT personnel complete a single radiographic exposure so that the individual would properly secure the source assembly in the exposure device just prior to disconnecting the drive cable from the source assembly. However, in the case of the event that occurred on February 27, 1996, the radiographer was completing multiple exposures from the same RT set up and was not properly securing the source assembly in the exposure device after each exposure.

An area of concern was identified regarding the inability of the licensee's internal audit program to evaluate RT personnel securing of the source assembly in the exposure device after each exposure when multiple exposures were completed from a single RT set up.

The inspectors reviewed the licensee's program for training RT personnel. The list of topics included the use of exposure devices and the licensee's O&E procedures for the Amersham 660B exposure device. However, the written examination that was based on the training program did not address the procedure to properly secure the source assembly in the exposure device after each exposure when multiple exposures were completed from a single RT set up. As noted above in the discussion of the audit program, the field examination that was given to evaluate the trainee's understanding of the licensee's O&E procedure to properly secure the source assembly in the exposure device after each exposure was based on a single exposure RT set up.

An additional area of concern was identified regarding the weaknesses in the licensee's training program given that it did not test the trainee's understanding of the proper procedure to secure the source assembly in the exposure device after each exposure in the written examination or in the field examination.

3.4.3. Conclusions

The root cause of the event appears to be human error, with contributing factors including: (1) the time constraints placed on the radiographer to complete RT of a specific number of welds during that shift, (2) failure of the radiographer to follow the licensee's written operating procedure to secure the source assembly in the exposure device after each exposure, (3) weaknesses in the licensee's internal audit program to observe the radiographer when multiple exposures were completed at a single set up location and ensure proper securing of the source assembly, and (4) weaknesses in the licensee's training program for RT personnel in that the written test of the licensee's operating procedures did not address the proper procedure to secure the source assembly in the exposure device after each exposure and the field exam did not require the radiographer to demonstrate a proper understanding of the procedure to secure the source assembly in the exposure device after each exposure.

3.5 Licensee Corrective Actions

3.5.1. Inspection Scope

The inspectors interviewed the RSO and radiographer about the radiographer's current involvement in the use of licensed material. The inspectors evaluated the RSO memo dated February 29, 1996, that described the event to the Radiation Safety Personnel. The inspectors interviewed other radiographers about their understanding of the RSO's instructions.

3.5.2. Observations and Findings

The RSO and radiographer confirmed that since February 27, 1996, the radiographer had not been assigned to any use of licensed material and will remain uninvolved for the remainder of 1996.

The RSO's memo dated February 29, 1996, to Radiation Safety administrative personnel instructed all RT personnel to properly secure the source assembly in the exposure device after each exposure. In response to the CAL, the licensee directly notified all RT personnel of same. Other of the licensee's radiographers indicated that their understanding was clarified by the licensee so that they now routinely secure the source assembly in the exposure device after each exposure by rotating the selector ring and depressing the projector lock after each exposure.

3.5.3. Conclusions

No violation of NRC requirements was identified. It appears that the licensee's instructions to Radiation Safety administrative personnel and RT personnel effectively clarified the licensee's procedure so that all personnel understood the requirement.

4. Other Areas Inspected

4.1. Inspection Scope

Other program areas inspected included: training, internal audits of personnel, inspection and maintenance of RT equipment, facilities, materials, instrumentation, radiation surveys, radiation protection, receipt and transfer of material, independent measurements, audible and visible alarms, posting, and labeling. The inspectors reviewed records located at the Gary field office from the period of September 1993 to March 1996. The inspectors observed a radiographer complete exposures in the Gary permanent radiographic facility.

4.2. Observations and Findings

The inspectors reviewed the training and experience qualifications of the two radiographers that performed work at the company in Indianapolis, IN, on February 27, 1996. Both individuals were

previously employed as radiographers by other licensees and were requalified by the licensee in accordance with RSAM 5.0. The radiographers were audited at three month intervals, and the audit records were unremarkable with regard to the radiographers' practices. Records of quarterly inspection and maintenance of exposure devices indicated no major equipment problems occurred. Records of receipt and transfer of radiographic sources and devices indicated no excessive radiation levels and no unauthorized devices for transfer and storage of sealed sources. A review of the sealed sources and devices on the premises indicated no unauthorized material was present. Except for the event that occurred on February 27, 1996, the records of personnel radiation dosimetry indicated that no individual received an annual radiation dose in excess of 2.23 rems (0.0223 Sv), TEDE. Audible and visible alarms were operating properly during radiographic exposures completed in the Gary permanent radiographic facility. The inspectors also completed radiation exposure surveys near the facility during radiographic exposures. The radiation exposure rates were less than 0.5 millirem per hour (0.005 mSv per hour). The facility was posted with NRC Form NRC-3, Caution Radioactive Materials, Caution Radiation Area, and Caution High Radiation Area.

The Gary RSS described the procedure for the calibration of survey instruments. The calibration labels that were applied to four survey instruments, calibrated on March 14, 1996, were signed by an individual who was not authorized to use the instrument calibration source. The RSS indicated that he completed a training session with the individual who actually used the instrument calibration source under his supervision. Later, the RSS recalibrated the survey instruments himself. During the repeat calibrations, no adjustments were necessary because the survey instruments had been properly calibrated earlier. The RSS relabeled the survey instruments with calibration labels that were signed by the RSS. The RSS also indicated that during the training session, the trainee was not wearing a film badge or DRD. License Condition 26 requires that the licensee shall follow the procedures contained in the O&E that was included with the licensee's application dated March 29, 1993. O&E Item 5.1 requires, in part, that trainees wear a film badge and a DRD at all times when working with ionizing radiation. Failure of the licensee's trainee to wear a film badge and DRD while calibrating survey instruments with a sealed source of licensed material is an apparent violation of License Condition 26.

4.3. Conclusions

One apparent violation of NRC requirements was identified for failure of a trainee to wear a film badge and DRD while calibrating survey instruments with a calibration source of licensed material. Other records for the period of September 1993 to March 1996 appeared to be adequate. The licensee's facilities and equipment at the Gary office appeared to be adequate.

5. Exit Summary

On November 12, 1996, the inspectors held a telephone conference with the licensee to explain the apparent violations. Licensee participants included Michael Creech, Senior Vice President; Randy Sweet, GM; Robert Slack, RSO; and Ron Wilson, Assistant RSO. The inspectors summarized the scope and findings of the inspection, including the apparent violations identified. The inspectors also discussed the two areas of concern. The licensee did not identify any information contained in the report as proprietary.

PERSONNEL CONTACTED

Michael Creech, Senior Vice President

Robert Slack, Radiation Safety Officer

Randy Sweet, General Manager, Gary Office

Steve Fay, Radiation Safety Supervisor, Gary Office

Larry Hiestand, Lab. Foreman, Gary Office

William Chastain, Radiographer, Gary Office

LIST OF ACRONYMS

AR	Alarming Ratemeter
DNMS	NRC, Region III, Division of Nuclear Material Safety
CAL	Confirmatory Action Letter, dated April 5, 1996
CFR	Code of Federal Regulations
DRD	Direct Reading Dosimeter
GM	General Manager
O&E	Operating and Emergency Procedure Manual that was submitted with the licensee's application dated March 29, 1993
ORISE	Oak Ridge Institute for Science and Education
RSAM	Radiation Safety Administrative Procedures Manual that was submitted with the licensee's application dated March 29, 1993
RSO	Corporate Radiation Safety Officer
RSS	Radiation Safety Supervisor
RT	Radiographic Testing
TEDE	Total Effective Dose Equivalent

SYNOPSIS

On April 8, 1996, an investigation was initiated by the U.S. Nuclear Regulatory Commission (NRC), Office of Investigations (OI), Region III (RIII), to determine if an untrained, Conam Inspection, Inc. (Conam), employee at the Gary, Indiana, office, deliberately calibrated a survey meter; to determine if a Conam employee deliberately failed to wear a film badge while calibrating survey instruments with a radiation source; to determine if Conam management deliberately failed to take appropriate action when a safety concern was brought to their attention; to determine if a Conam radiographer deliberately failed to follow the licensee's procedure in the operation of an exposure device, which resulted in an overexposure to himself; to determine if Conam radiographers deliberately failed to follow the licensee's procedure in the operation of exposure devices; and to determine if a Conam supervisor deliberately falsified a 90-day inspection report regarding an exposure device.

Based upon the evidence developed during the OI investigation, it is concluded that there was no substantiation to the allegation that an untrained Conam employee deliberately calibrated survey instruments; that there was no substantiation to the allegation that a Conam employee deliberately failed to wear a film badge while calibrating a survey meter with a radiation source; that there was no substantiation to the allegation that Conam management deliberately failed to take appropriate action when a safety concern was brought to their attention; that there was substantiation to the allegation that a Conam radiographer wilfully failed to follow the licensee's procedure in the operation of an exposure device, which resulted in an overexposure to himself; that there was substantiation to the allegation that Conam radiographers wilfully failed to follow the licensee's procedure in the operation of exposure devices; and it was not substantiated that a Conam supervisor deliberately falsified a 90-day inspection report regarding an exposure device.

IEM
Integrated Environmental Management, Inc.

9040 Executive Park Drive, Suite 205
Knoxville, TN 37923
Phone: (423) 531-9140
Fax: (423) 531-9130

1680 East Gude Drive, Suite 305
Rockville, MD 20850
Phone: (301) 762-0502
Fax: (301) 762-0638

December 10, 1996

Mr. Robert Slack, R.S.O.
Conam Inspection Inc.
1245 West Norwood
Itasca, Illinois 60143

Dear Mr. Slack:

Pursuant to your written request of November 22, 1996, I have completed an assessment of the effective dose equivalent incurred by Conam Inspection Inc. (Conam) employee Mr. W. Chastain. This individual was the subject in an external radiation exposure incident that took place on February 27, 1996.

For this assessment, I relied upon the information contained in a number of documents that were provided to me by Conam. The following is a listing of those documents:

- Letter to Michael Creech, Conam Inspection, from Cynthia D. Pederson, USNRC, "NRC Inspection Report No. 030-31373/96002 (DNMS) and Investigation Report No. 3-96-014", November 18, 1996.
- Memo to Distribution from R. J. Slack, "Radiation Incident", February 29, 1996.
- "Conam Inspection Inc. Dose Reconstruction Data", Author Unknown (USNRC?), facsimile date of April 19, 1996.
- Letter to Thomas Young , USNRC from Robert J. Slack, Conam Inspection Inc., "Confirmatory Action Letter/April 5, 1996", April 17, 1996.
- Dosimetry Report, Radiation Detection Company, March 22, 1996.
- Letter to Robert Slack, Conam Inspection, from Steven Souza, Radiation Detection Company, "Film Dosimeter Report for W. Chastain, IBM #3723, dated 2-1-96, Account 48, Group 12", April 4, 1996.
- Letter to Michael B. Creech, Conam Inspection, from Cynthia Pederson, USNRC, "Satisfaction of Confirmatory Action Letter Dated April 5, 1996", May 14, 1996.
- Cumulative Occupational Exposure History (Form 4) for William J. Chastain, November 13, 1996.

- Letter to Michael Creech, Conam Inspection, from Cynthia Pederson, USNRC, "Confirmatory Action Letter", April 5, 1996.
- Letter to William Chastain from Ronald Goans, ORISE, June 11, 1996.[1]
- Facsimile Report to Bob Slack, Conam Inspection, from Steven Souza, Radiation Detection Company, "Dosimetry Results", March 8, 1996.
- William Chastain, Written Description of Events, February 28, 1996.
- Facsimile Report to Bob Slack, Conam Inspection, from Kate Roughan, Amersham Corporation, "Drawing for the Mod. No. 660A Camera", November 26, 1996.
- Amersham Corporation, Source Certificate, Source Serial No. A7462.
- Written Communication to Carol Berger, IEM, from Robert Slack, Conam Inspection, "Mock Up Exposure" (date unknown).
- Facsimile to Carol Berger, IEM, from Robert Slack, Conam Inspection, "Time and Motion Information and Device Specifications", December 4, 1996.

Because the source of Mr. Chastain's exposure was a highly-collimated beam of penetrating radiation rather than a uniform irradiation of the "whole body", I performed the exposure assessment in two phases. In the first phase, I calculated the dose to the various regions of his body (e.g., the compartmental doses). In the second phase, I calculated the effective dose equivalent using compartmental doses that were weighted to account for the risk incurred by the organs and tissues in those compartments relative to the whole body.

To assess the compartmental doses, the processing results from the film badge worn by Mr. Chastain and exposure rates generated using the MicroShield computer code were used, along with time and motion information provided by Mr. Chastain. However, during the investigation of this incident, Mr. Chastain relayed two (2) different versions of his time-and-motion, the substance of which differed significantly. Therefore, compartmental doses were determined for both of his scenarios, even though only one of them is consistent his personnel dosimetry (film badge) results.

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[1] This document contains the results of cytogenetic studies that were preformed on the blood of the subject. Although these data were reviewed as part of this assessment process, they were disregarded. The reasons for this are because the "detection limit" for this methodology is relatively high (e.g., between 10,000 and 20,000 millirem), and because the methodology is of limited usefulness in cases of non-uniform irradiation of the body (Littlefield, et al,, "Current Status of Cytogenetic Studies to Detect and Quantify Previous Exposures to Radioactive Materials", Report to the National Cancer Institute, ORAU-285, Oak Ridge Associated Universities, Oak Ridge, Tennessee, August, 1987).

Appendix A contains a description of the methodology that was used for assessing the effective dose equivalent for non-uniform exposures of the whole body, Appendices B and C contain the compartmental dose calculations for the two (2) time-and-motion scenarios, and Appendix D contains the effective dose equivalent calculations. In my opinion, the *most likely* effective dose equivalent incurred by Mr. Chastain as a result of the February 27, 1996 incident is 2,347 millirem. The *maximum likely* effective dose equivalent, based upon more conservative assumptions, is 2,906 millirem. Both of these values are well-below the USNRC's primary dose limit of 5,000 millirem Total Effective Dose Equivalent.[2]

There is one unusual aspect to this case that I cannot readily explain. The subject's alarming dosimeter, worn in the immediate proximity of his film badge during the exposure event, did not activate. This was in spite of the fact that the device was confirmed to be "on", that it was confirmed to alarm at dose rates in excess of 500 mR per hour, and that the dose rate at the location of his film badge was between 69,000 and 276,000 mR per hour, depending upon the exposure duration. Without an explanation for this disturbing occurrence, I cannot reconcile the alarming dosimeter response with the findings of this letter report.

If you have any questions or if I can provide you with additional information, please do not hesitate to call me at (301) 762-0502. Thank you for the opportunity of assisting you in this interesting and important dose assessment.

Sincerely,

Carol D. Berger, C.H.P.

File 96004

[2] Since the Total Effective Dose Equivalent in Title 10, Code of Federal Regulations, Part 20, "Standards for Protection Against Radiation", is defined as the sum of the deep dose equivalent from external sources and the committed effective dose equivalent from internal sources, this conclusion assumes that Mr. Chastain incurred no internal exposures of significance during calendar year 1996. (Title 10 CFR 20 defines the "deep dose equivalent" as external exposure of the whole body at a tissue depth of one centimeter.)

APPENDIX A
Basis and Methodology for Determining Effective Dose Equivalent from Non-Uniform Irradiation of the Whole Body

Background

In Publication 26, the International Commission on Radiological Protection (ICRP) discusses the issue of dosimetric assumptions. Included in the discussion is the following statement:

> "A practical radiation protection system needs to be based on certain simplifying assumptions if it is to be applied effectively. The assumptions already made about the proportionality between dose and effect over the range of doses of concern in radiation protection imply certain principles that can be applied to important practical problems such as those relating to significant volumes and areas and the rate at which doses may be accumulated".[3]

The use of compartments and corresponding weighting factors for interpreting personnel dosimeter data is one such simplification in regard to significantly different doses occurring in various volumes of the body.

Little guidance is offered by national or international authorities on estimating mean organ or tissue doses from personnel monitoring devices. Instead, there are recommendations that pertain to quantities such as the "dose equivalent index" or "individual dose equivalent, penetrating or superficial".[4] Under idealized exposure conditions, these operational quantities have been shown to be adequate estimators of the basic quantities ("effective dose equivalent" as described in ICRP Publication 26) for which regulatory limits have been established.

Various tables and figures of conversion factors have been published which show the relationship between the operational and the basic quantities for selected ideal irradiation conditions and phantom configurations. Implicit in these data are the assumptions that the dose measured at a single point is an adequate predictor of doses at other locations in the phantom and that the relationship is constant during the assessment period. This is why only a single personnel dosimeter is typically used for monitoring workers.

There are, however, situations wherein these assumptions may not be inappropriate. In Publication 51, the ICRP introduces factors which limit the application of data obtained under

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[3] International Commission on Radiological Protection, ICRP Publication 26, "Recommendations of the International Commission on Radiological Protection", Pergamon Press, January, 1977.

[4] International Commission on Radiation Units and Measurements, ICRU Publication 43, "Determination of dose Equivalents from External Radiation Sources -- Part 2", 1988.

ideal conditions to non-ideal situations.[5] During periods when non-uniform irradiation of the body occurs, the dose measured at one location cannot be extended to all other areas of concern. More information is necessary in order to estimate the actual distribution of dose equivalents in the body. This information may be obtained from mathematical modeling or from the placement of extra dosimeters on the body.

Methodology

The fundamental concepts underlying the quantity "effective dose equivalent" offer an appropriate foundation for combining dosimetry information from various points on the body into a single dose value which can then be compared to regulatory or operational dose limits. To derive such a value requires that estimates of organ dose equivalents be made, and that these estimates be summed using appropriate weighting factors.

A methodology for determining effective dose equivalent from non-uniform exposures of the body is described in a report by Berger et al, and in (draft) ANSI N13.41.[6,7] In these documents, it is recommended that the personal dose equivalent, or $H_p(10)$, be determined for each compartment from a measurement result (e.g., dosimeter result or mathematical model) for that compartment.[8] After the personal dose equivalent has been determined for each compartment area, it is then multiplied by an appropriate compartment factor. The following table contains the Compartment Weighting Factors from (draft) ANSI N13.41:

Compartment Name	Associated Organs and Tissues	ICRP 26 Stochastic Risk Weighting Factor, W_T	Fraction of W_T Assigned to Compartment	Resulting W_T for Compartment
Head/Neck	Thyroid	0.03	1.0	0.03
	Bone Surfaces	0.03	0.33	0.01
	Red Bone Marrow	0.12	0.165	0.02
	Remainder; esophagus	0.06	0.6	0.04
		TOTAL FOR COMPARTMENT		0.10

[5] International Commission on Radiological Protection, ICRP Publication 51, "Data for Use in Protection Against External Radiation", Pergamon Press, March, 1987.

[6] Berger, C. D., V. P. Gupta, C. Glenn Hudson, K. H. Pryor, D. A. Stevenson, and R. C. Yoder, "Criteria for Performing Multiple Dosimetry", *Health Physics*, Vol. 69, No. 4, pg. 570-476, October, 1995.

[7] American National Standards Institute, "Criteria for Performing Multiple Dosimetry", (draft) HPS N13.41-1997.

[8] The documents also recommend that if no dosimeter is placed in a particular compartment area, the personal dose equivalent determined from nearby areas where exposures are judged to be similar should be used. Also, if there are multiple personal dose equivalent results for a single compartment area, the highest of these values is used to represent the personal dose equivalent for that compartment.

Compartment Name	Associated Organs and Tissues	ICRP 26 Stochastic Risk Weighting Factor, W_T	Fraction of W_T Assigned to Compartment	Resulting W_T for Compartment
Thorax	Breast	0.15	1.0	0.15
	Lung	0.12	1.0	0.12
	Red Bone Marrow	0.12	0.33	0.04
	Bone Surfaces	0.03	0.33	0.01
	Remainder;			
	Esophagus	0.06	0.4	0.02
	Stomach	0.06	0.4	0.02
	Liver	0.06	0.4	0.02
		TOTAL FOR COMPARTMENT		0.38
Abdomen	Gonads	0.25	1.0	0.25
	Red Bone Marrow	0.12	0.33	0.04
	Bone Surfaces	0.03	0.33	0.01
	Remainder;			
	Liver	0.06	0.6	0.04
	Stomach	0.06	0.6	0.04
	Other GI Tissues	0.12	1.0	0.12
		TOTAL FOR COMPARTMENT		0.50
Proximal Extremity (each)	Red Bone Marrow	0.12	0.04	0.005

The resulting products for each of the compartments are then summed to produce the effective dose equivalent. It is this value that is then compared to primary dose limits given in units of "effective dose equivalent".

APPENDIX B
Compartmental Doses from the Subject's Initial Time-and-Motion Scenario

Time and Motion

On February 27, 1996, the subject of this incident failed to positively determine that a 94 Curie source of ^{192}Ir was fully retracted into an Amersham Model 660B radiography camera prior to positioning himself directly in front of the camera's exit port.[9] When debriefed by the Conam Radiation Safety Officer (RSO) shortly after the incident occurred, the subject indicated that the camera was positioned on the top step of a ladder.[10,11] During the incident in question, the subject proceeded up a ladder to set up the next radiography event and, after surveying *all* sides of the camera, reached to the back of the camera to unlock the source. It was at this time that he discovered that the source was already unlocked. His survey results revealed a maximum exposure rate of 20 millirems per hour somewhere within the immediate vicinity of the device.

While on the ladder, the subject indicated that the front of his body was facing the ladder and the camera. He informed the RSO that he remained in that position, with the exit port of the camera a distance of one (1) to three (3) feet away from his abdomen, for three (3) to four (4) minutes.[12]

Measurement Information

The subject indicated that his lower right thigh was as close as 30.48 cm and as far as 91.44 cm from the exit port of the camera. Biometric measurements of the subject made at a later date revealed that his lateral abdomen width is 34.29 cm, and his anterior-posterior (AP) width is 24.77 cm.[13] They also revealed that his lateral lower right thigh width is 18.03 cm, with an AP width of 24.13 cm.[14]

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[9] Letter to Michael Creech, Conam Inspection, from Cynthia D. Pederson, USNRC, "NRC Inspection Report No. 030-31373/96002 (DNMS) and Investigation Report No. 3-96-014", November.18, 1996.

[10] William Chastain, Written Description of Events, February 28, 1996.

[11] Facsimile to Carol Berger, IEM, from Robert Slack, Conam Inspection, "Time and Motion Information and Device Specifications", December 4, 1996.

[12] Facsimile to Carol Berger, IEM, from Robert Slack, Conam Inspection, "Time and Motion Information and Device Specifications", December 4, 1996.

[13] In the Dose Reconstruction Data that resulted from the re-enactment, these dimensions were reported as "torso" dimensions. Because their magnitudes are smaller than typical torso dimensions for standard-sized adult males, and because the body compartment of interest in this case is the abdomen, it is assumed that the Data were actually referring to the abdomen.

[14] "Conam Inspection Inc. Dose Reconstruction Data", Author Unknown (USNRC?), facsimile date of April 19, 1996.

Dosimetry Information

During these activities, the subject's alarming dosimeter remained silent, even though it was later confirmed to be "on" and functional.[15] Immediately after descending from the ladder, the subject noted that his 0 to 200 mR self-reading dosimeter was off-scale. After processing, his film badge reflected a deep dose equivalent of 4,600 millirem, with no evidence of directional exposure.[16,17]

Device Description

The Model 660B radiography camera in use at the time contained a sealed source of ^{192}Ir, with a source activity of 121 curies on January 31, 1996.[18] On the day of the incident, the source activity was:

$$Activity\ on\ day\ 27 = 121\ e^{\frac{-0.693 \times 27\ days}{74.02\ days}} = 94\ Ci$$

In its fully-retracted position, the source is located within a depleted uranium shield at a distance of 13.34 cm from the exit port of the camera.[19] The shield extends to within 1.27 cm of the exit port.

When the subject discovered that the source was not secured, he rotated the control crank "1/3 to 1/2 turn" to fully retract the source and engage the automatic locking mechanism.[20] At the "1/3 turn" position, the source is 6.99 cm from the exit port and 5.72 cm from the end of the depleted uranium shield. At "1/2 turn", the source is 2.54 cm from the exit port and 1.27 cm from the end of the shield.

Computer Simulation of the Exposure Scenario

Since the personnel dosimeter worn by the subject was positioned below his waist and in front of his body surface, the processing results can be attributed to the subject's scenario of a four (4)

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[15] Since this device was calibrated to alarm at a dose rate of 500 millirem per hour, it is not clear why it did not signal an elevated exposure rate during the incident.

[16] The film badge was issued to the subject at the beginning of the month, and thus contained accumulated dose from other activities performed during this time. However, it is not likely that the accumulated dose was significantly different from 100 millirem. Therefore, the accumulated dose is disregarded for this assessment, and the results of film badge processing are attributed, solely, to the incident.

[17] Letter to Robert Slack, Conam Inspection, from Steven Souza, Radiation Detection Company, "Film Dosimeter Report for W. Chastain, IBM #3723, dated 2-1-96, Account 48, Group 12", April 4, 1996.

[18] Amersham Corporation, Source Certificate, Source Serial No. A7462.

[19] Facsimile Report to Bob Slack, Conam Inspection, from Kate Roughan, Amersham Corporation, "Drawing for the Mod. No. 660A Camera", November 26, 1996.

[20] Letter to Michael Creech, Conam Inspection, from Cynthia D. Pederson, USNRC, "NRC Inspection Report No. 030-31373/96002 (DNMS) and Investigation Report No. 3-96-014", November 18, 1996.

minute exposure from the front of the dosimeter. The computer code MicroShield was used to re-construct these exposure conditions.[21] For this assessment, the following were assumed:

- The source activity was 94 Ci of ^{192}Ir.
- The source-to-dosimeter distance is 37.64 cm, which is the most conservative value relayed to the RSO by the subject.
- The exposure duration is four (4) minutes, which is the most conservative value relayed to the RSO by the subject.
- The source capsule was at the "1/2 turn" position throughout the exposure period which is the most conservative value relayed to the RSO by the subject.
- The beam of ionizing radiation from the sealed source in the camera traverses 1.23 cm of air within the source tube, 0.87 cm of titanium, 1.38 cm of foam, 0.56 cm of steel, and 33.60 cm of air prior to reaching the front of the subject's dosimeter.
- A MicroShield "point source" geometry is a reasonable simulation, with x = 37.64 cm, y = 0 cm, and z = 0 cm.

Attachment 1 contains the MicroShield summary report for this exposure model using the aforementioned input parameters. When interpreted, these results show that the predicted dose at the location of the subject's dosimeter should have been 17,040 millirem, which is 3.7 times higher than the 4,600 millirem dose measured by the dosimeter.[22,23] Therefore, it is possible that the exposure duration was actually shorter than four (4) minutes, or the source-to-body distance was actually greater than 30.48 cm (or some combination of these two variables).

If the analysis is repeated with the source-to-body distance increased to 91.44, which is the farthest distance relayed to the RSO by the subject, the total dose at the location of the film badge would be 2,606 millirem - a factor of 1.8 lower than the 4,600 millirem measurement. If the source-to-body distance remains at 30.48 cm, but the exposure duration is reduced to one (1) minute, which

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[21] MicroShield, Version 4.21, Grove Engineering.

[22] The deep dose equivalent rate predicted by MicroShield is 2.556E5 millirem per hour. For a four (4) minute exposure time, the total dose is 17,040 millirem. The ratio of "measured-to-calculated" for this exposure scenario is thus 0.27.

[23] The MicroShield analysis was repeated assuming the source capsule was at the "1/3 turn" position throughout the exposure period. For this scenario, the beam of ionizing radiation from the sealed source in the camera traverses 1.23 cm of air within the source tube, 0.87 cm of titanium, 2.97 cm of depleted uranium, 1.38 cm of foam, 0.56 cm of steel, and 30.61 cm of air prior to reaching the front of the subject's dosimeter. Thus x = 37.62 cm for the MicroShield "point source" geometry. The results from this model show that the predicted dose at the location of the subject's dosimeter is 197.67 millirem, which is 23 times lower than the 4,600 millirem dose measured by the dosimeter. Thus it does not appear that the source capsule was at the "1/3 turn" position for this incident.

is the shortest duration relayed to the RSO by the subject, the total dose at the location of the film badge would be 4,260 millirem. This value is reasonably consistent with (e.g., 93 percent of) the personnel dosimeter results. Therefore, for the following compartmental dose assessments, the time-and-motion scenario relayed to the RSO by the subject is assumed to be correct, the exposure duration is assumed to be one (1) minute, and the results generated by MicroShield are assumed to under-estimate the true dose by a factor of 1.08.

Maximum Possible Dose to the Abdomen Compartment

Since the personnel dosimeter worn by the subject was positioned below his waist and in front of his body surface (e.g., closer to the source than the body surface), the dose to the abdomen compartment is conservatively assumed to be the dose reflected by the personnel dosimeter (e.g., 4,600 millirem).

Maximum Possible Dose to the Right Thigh Compartment

If it is assumed that the dose reflected by the subject's personnel dosimeter is valid, the MicroShield computer code can be used to calculate the dose to the right thigh compartment for this exposure scenario. The following are the parameters used as input to the code:

- The source activity was 94 Ci of ^{192}Ir.
- The source-to-right thigh distance is 30.48 cm, which is the most conservative of the values relayed by the subject to the RSO.
- The source capsule was at the "1/2 turn" position throughout the exposure period, which is the most conservative of the values relayed by the subject to the RSO.
- The exposure duration is one (1) minute.
- The beam of ionizing radiation from the sealed source in the camera traverses 30.48 cm of air prior to reaching the front of the right thigh.
- A MicroShield "point source" geometry is a reasonable simulation, with x = 30.48 cm, y = 0 cm, and z = 0 cm.
- The dose rates predicted by MicroShield are a factor of 1.08 below the true dose rates.

Attachment 2 contains the MicroShield summary report from this analysis. From the corrected dose rates (e.g., 5.205E5 x 1.08 = 5.621E5 millirem per hour), the dose to the right thigh compartment from the one (1) minute exposure is 9,369 millirem.

Dose to the Remaining Compartments

Because the ^{192}Ir source remained within the depleted uranium shield of the Model 660B camera, it is unlikely that the remaining compartments of the body incurred a significant dose. However,

to ensure an element of conservatism in this analysis, the 20 millirem per hour survey measurement made in the vicinity of the sides of the camera is taken to be the dose rate to all remaining compartments. Therefore, the dose to each of the head and neck, thorax, right upper arm, left upper arm, and left upper leg compartments was 0.33 millirem over the one (1) minute exposure duration.

ATTACHMENT 1

MicroShield 4.21 - Serial #4.21-00996
Integrated Environmental Management, Inc.

Page : 1
DOS File: CONFF121.MS4
Run Date: December 5, 1996
Run Time: 3:32 p.m. Thursday
Duration: 0:00:02

File Ref: 96004.01
Date: __/__/__
By: _____
Checked: _____

Case Title: Conam Dose Est. - Frontal Exp. of Film Badge (D=12, S=1.0)

GEOMETRY 1 - Point

	centimeters	feet	and inches
Dose point coordinate X:	37.6428	1.0	2.8
Dose point coordinate Y:	0.0	0.0	.0
Dose point coordinate Z:	0.0	0.0	.0
Shield 1:	1.22936	0.0	.5
Shield 2:	0.87122	0.0	.3
Shield 3:	1.3843	0.0	.5
Shield 4:	0.5588	0.0	.2
Shield 5:	33.5788	1.0	1.2
Air Gap:	2.032e-002	0.0	.0

MATERIAL DENSITIES (g/cm^3)

Material	Shield 1 Slab	Shield 2 Slab	Shield 3 Slab	Shield 4 Slab	Shield 5 Slab
Air	0.00122				0.00122
Iron		4.5		7.86	
Water			0.802		

Material	Air Gap
Air	0.00122

BUILDUP
Method: Buildup Factor Tables
The material reference is Shield 2

INTEGRATION PARAMETERS
Case solved analytically.

SOURCE NUCLIDES

Nuclide	
Ir-192	9.4000e+001

DOS File: CONFF121.MS4
Run Date: December 5, 1996
Run Time: 3:32 p.m. Thursday
Title : Conam Dose Est. - Frontal Exp. of Film Badge (D=12, S=1.0)

RESULTS

Energy (MeV)	Activity (photons/sec)	Energy Fluence Rate (MeV/sq cm/sec)		Exposure Rate In Air (mR/hr)	
		No Buildup	With Buildup	No Buildup	With Buildup
0.0615	3.938e+010	1.615e+001	2.314e+001	3.113e-002	4.460e-002
0.063	6.801e+010	4.931e+001	7.159e+001	9.246e-002	1.342e-001
0.0651	9.165e+010	1.359e+002	2.007e+002	2.463e-001	3.637e-001
0.0668	1.572e+011	3.904e+002	5.831e+002	6.906e-001	1.031e+000
0.0714	2.921e+010	2.309e+002	3.542e+002	3.878e-001	5.949e-001
0.0757	6.843e+010	1.280e+003	2.026e+003	2.076e+000	3.286e+000
0.1363	6.282e+009	7.256e+003	1.430e+004	1.167e+001	2.298e+001
0.2013	1.625e+010	5.010e+004	1.050e+005	8.855e+001	1.855e+002
0.2058	1.143e+011	3.678e+005	7.707e+005	6.532e+002	1.369e+003
0.2833	9.095e+009	5.055e+004	1.026e+005	9.514e+001	1.932e+002
0.296	1.009e+012	6.003e+006	1.210e+007	1.137e+004	2.291e+004
0.3085	1.032e+012	6.540e+006	1.308e+007	1.245e+004	2.490e+004
0.3165	2.882e+012	1.898e+007	3.778e+007	3.624e+004	7.213e+004
0.3745	2.526e+010	2.129e+005	4.085e+005	4.130e+002	7.924e+002
0.4165	2.311e+010	2.265e+005	4.230e+005	4.423e+002	8.260e+002
0.4231	2.772e+009	2.777e+004	5.164e+004	5.428e+001	1.009e+002
0.4681	1.671e+012	1.927e+007	3.485e+007	3.780e+004	6.836e+004
0.4846	1.100e+011	1.330e+006	2.382e+006	2.611e+003	4.675e+003
0.4891	1.386e+010	1.697e+005	3.031e+005	3.331e+002	5.950e+002
0.5886	1.591e+011	2.504e+006	4.239e+006	4.892e+003	8.284e+003
0.6044	2.853e+011	4.653e+006	7.819e+006	9.078e+003	1.525e+004
0.6125	1.856e+011	3.081e+006	5.157e+006	6.006e+003	1.005e+004
0.8717	3.429e+009	9.063e+004	1.378e+005	1.705e+002	2.594e+002
0.8845	1.049e+010	2.825e+005	4.281e+005	5.306e+002	8.041e+002
TOTAL:	8.013e+012	6.385e+007	1.202e+008	1.232e+005	2.317e+005

MicroShield 4.21 - Serial #4.21-00996
Licensed to Integrated Environmental Management, Inc.
CONVERSION OF CALCULATED EXPOSURE IN AIR TO DOSE
FILE: CONFF121.MS4
Case Title: Conam Dose Est. - Frontal Exp. of Film Badge (D=12, S=1.0)
This case was run on Thursday, December 5, 1996 at 3:32 p.m.

Results (Summed over energies)	Units	Without Buildup	With Buildup
Photon Fluence Rate (flux)	Photons/cm²/sec	1.666e+008	3.188e+008
Photon Energy Fluence Rate	MeV/cm²/sec	6.385e+007	1.202e+008
Exposure Rate in Air	mR/hr	1.232e+005	2.317e+005
Absorbed Dose Rate in Air	mGy/hr	1.076e+003	2.023e+003
"	mrad/hr	1.076e+005	2.023e+005
Deep Dose Equivalent Rate (ICRP 51 - 1987)			
o Parallel Geometry	mSv/hr	1.356e+003	2.556e+003
o Opposed "	"	1.001e+003	1.880e+003
o Rotational "	"	1.001e+003	1.880e+003
o Isotropic "	"	8.906e+002	1.674e+003
Shallow Dose Equivalent Rate (ICRP 51 - 1987)			
o Parallel Geometry	mSv/hr	1.406e+003	2.647e+003
o Opposed "	"	1.319e+003	2.482e+003
o Rotational "	"	1.319e+003	2.482e+003
o Isotropic "	"	9.518e+002	1.789e+003
Effective Dose Equivalent Rate (ICRP 51 - 1987)			
o Anterior/Posterior Geometry	mSv/hr	1.179e+003	2.221e+003
o Posterior/Anterior "	"	1.004e+003	1.888e+003
o Lateral "	"	7.066e+002	1.327e+003
o Rotational "	"	8.866e+002	1.667e+003
o Isotropic "	"	7.419e+002	1.394e+003

ATTACHMENT 2

MicroShield 4.21 - Serial #4.21-00996
Integrated Environmental Management, Inc.

Page : 1
DOS File: CONAMFT1.MS4
Run Date: December 5, 1996
Run Time: 3:35 p.m. Thursday
Duration: 0:00:01

File Ref: 9600A.01
Date: __/__/__
By: _____
Checked: _____

Case Title: Conam Dose Estimate - Exposure of Thigh from Front (D=12.0)

GEOMETRY 1 - Point

	centimeters	feet and inches	
Dose point coordinate X:	30.48	1.0	.0
Dose point coordinate Y:	0.0	0.0	.0
Dose point coordinate Z:	0.0	0.0	.0
Air Gap:	30.48	1.0	.0

MATERIAL DENSITIES (g/cm^3)

Material	Air Gap
Air	0.00122

BUILDUP
Method: Buildup Factor Tables
The material reference is Air Gap

INTEGRATION PARAMETERS
Case solved analytically.

SOURCE NUCLIDES

Nuclide	
Ir-192	9.4000e+001

DOS File: CONAMFT1.MS4
Run Date: December 5, 1996
Run Time: 3:35 p.m. Thursday
Title : Conam Dose Estimate - Exposure of Thigh from Front (D=12.0)

RESULTS

Energy (MeV)	Activity (photons/sec)	Energy Fluence Rate (MeV/sq cm/sec)		Exposure Rate In Air (mR/hr)	
		No Buildup	With Buildup	No Buildup	With Buildup
0.0615	3.938e+010	2.060e+005	2.086e+005	3.972e+002	4.022e+002
0.063	6.801e+010	3.646e+005	3.692e+005	6.837e+002	6.922e+002
0.0651	9.165e+010	5.079e+005	5.142e+005	9.203e+002	9.317e+002
0.0668	1.572e+011	8.942e+005	9.051e+005	1.581e+003	1.601e+003
0.0714	2.921e+010	1.775e+005	1.796e+005	2.982e+002	3.017e+002
0.0757	6.843e+010	4.410e+005	4.461e+005	7.152e+002	7.234e+002
0.1363	6.282e+009	7.299e+004	7.359e+004	1.173e+002	1.183e+002
0.2013	1.625e+010	2.790e+005	2.806e+005	4.932e+002	4.960e+002
0.2058	1.143e+011	2.006e+006	2.018e+006	3.563e+003	3.584e+003
0.2833	9.095e+009	2.198e+005	2.208e+005	4.136e+002	4.155e+002
0.296	1.009e+012	2.548e+007	2.560e+007	4.825e+004	4.847e+004
0.3085	1.032e+012	2.717e+007	2.728e+007	5.171e+004	5.194e+004
0.3165	2.882e+012	7.782e+007	7.816e+007	1.486e+005	1.492e+005
0.3745	2.526e+010	8.074e+005	8.105e+005	1.566e+003	1.572e+003
0.4165	2.311e+010	8.215e+005	8.244e+005	1.604e+003	1.610e+003
0.4231	2.772e+009	1.001e+005	1.004e+005	1.956e+002	1.963e+002
0.4681	1.671e+012	6.679e+007	6.700e+007	1.310e+005	1.314e+005
0.4846	1.100e+011	4.551e+006	4.565e+006	8.932e+003	8.960e+003
0.4891	1.386e+010	5.787e+005	5.804e+005	1.136e+003	1.139e+003
0.5886	1.591e+011	7.995e+006	8.017e+006	1.562e+004	1.566e+004
0.6044	2.853e+011	1.473e+007	1.476e+007	2.873e+004	2.881e+004
0.6125	1.856e+011	9.707e+006	9.732e+006	1.892e+004	1.897e+004
0.8717	3.429e+009	2.554e+005	2.559e+005	4.806e+002	4.816e+002
0.8845	1.049e+010	7.927e+005	7.943e+005	1.489e+003	1.492e+003
TOTAL:	8.013e+012	2.428e+008	2.437e+008	4.674e+005	4.692e+005

MicroShield 4.21 - Serial #4.21-00996
Licensed to Integrated Environmental Management, Inc.
CONVERSION OF CALCULATED EXPOSURE IN AIR TO DOSE
FILE: CONAMFT1.MS4
Case Title: Conam Dose Estimate - Exposure of Thigh from Front (D=12.0)
This case was run on Thursday, December 5, 1996 at 3:35 p.m.

Results (Summed over energies)	Units	Without Buildup	With Buildup
Photon Fluence Rate (flux)	Photons/cm²/sec	6.837e+008	6.867e+008
Photon Energy Fluence Rate	MeV/cm²/sec	2.428e+008	2.437e+008
Exposure Rate in Air	mR/hr	4.674e+005	4.692e+005
Absorbed Dose Rate in Air	mGy/hr	4.081e+003	4.096e+003
"	mrad/hr	4.081e+005	4.096e+005
Deep Dose Equivalent Rate (ICRP 51 - 1987)			
o Parallel Geometry	mSv/hr	5.185e+003	5.205e+003
o Opposed "	"	3.791e+003	3.806e+003
o Rotational "	"	3.790e+003	3.804e+003
o Isotropic "	"	3.379e+003	3.392e+003
Shallow Dose Equivalent Rate (ICRP 51 - 1987)			
o Parallel Geometry	mSv/hr	5.364e+003	5.385e+003
o Opposed "	"	5.011e+003	5.030e+003
o Rotational "	"	5.011e+003	5.030e+003
o Isotropic "	"	3.611e+003	3.625e+003
Effective Dose Equivalent Rate (ICRP 51 - 1987)			
o Anterior/Posterior Geometry	mSv/hr	4.500e+003	4.517e+003
o Posterior/Anterior "	"	3.815e+003	3.830e+003
o Lateral "	"	2.674e+003	2.684e+003
o Rotational "	"	3.366e+003	3.379e+003
o Isotropic "	"	2.814e+003	2.825e+003

APPENDIX C
Compartmental Doses from the Subject's Second Time-and-Motion Scenario

Time and Motion

On February 27, 1996, the subject of this incident failed to positively determine that a 94 Curie source of ^{192}Ir was fully retracted into an Amersham Model 660B radiography camera prior to positioning himself directly in front of the camera's exit port.[24] When debriefed by the USNRC on April 11, 1996, the subject indicated that he did not realize that the automatic locking mechanism was disengaged since his previous surveys of the camera indicated a maximum exposure rate of 20 millirems in the vicinity of the surfaces of the device. However, a survey of the exit port of the camera was not performed at that time.

During the April 11, 1996 debriefing, the subject participated in a re-creation of the incident. While on the ladder, the subject demonstrated that, initially, the front of his body was facing the ladder and the camera. He stated that he remained in that position, with the exit port of the camera facing his abdomen for a total of one (1) minute (Position A). He then reversed his position on the ladder so that he was facing away from the device (Position B), and remained there for a total of three (3) minutes.

Measurement Information

When in Position A, the subject's personnel dosimeter (film badge), self-reading dosimeter, and alarming dosimeter were measured to be 33.66 cm from the exit port of the camera.[25,26] It was also determined that the subject's lower right thigh, located 25.40 cm from the exit port, was the part of the body that was closest to the exit port. When in Position B, the subject's dosimeters were located 39.37 cm from the exit port, and the back of the subject's lower left thigh, located 14.92 cm from the exit port, was the part of the body closest to the exit port. Biometric measurements of the subject revealed that his lateral abdomen width is 34.29 cm, and his AP width is 24.77 cm.[27] They also revealed that his lateral lower right and left thigh widths are 18.03 cm, with AP widths of 24.13 cm.

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[24] Letter to Michael Creech, Conam Inspection, from Cynthia D. Pederson, USNRC, "NRC Inspection Report No. 030-31373/96002 (DNMS) and Investigation Report No. 3-96-014", November 18, 1996.

[25] "Conam Inspection Inc. Dose Reconstruction Data", Author Unknown (USNRC?), facsimile date of April 19, 1996.

[26] In order for the measurements made during the April 11th re-construction to be consistent with one another, the dosimeter must have been located on the left side of the subject's abdomen while he was in Position B.

[27] In the Dose Reconstruction Data that resulted from the re-enactment, these dimensions were reported as "torso" dimensions. Because their magnitudes are smaller than typical torso dimensions for standard-sized adult males, and because the body compartment of interest in this case is the abdomen, it is assumed that the Data were actually referring to the abdomen.

Dosimetry Information

While on the ladder, the subject's alarming dosimeter remained silent, even though it was confirmed to be turned on and functional.[28] After descending from the ladder, the subject noted that his 0-to-200 mR self-reading dosimeter was off-scale. After processing, the film badge reflected a deep dose equivalent of 4,600 millirem, and exhibited no evidence of directional exposure.[29,30]

Device Description

The Model 660B radiography camera in use at the time contained a sealed source of ^{192}Ir, with a source activity of 121 curies on January 31, 1996.[31] On the day of the incident, the source activity was approximately 94 curies, determined as follows:

$$Activity\ on\ day\ 27 = 121\ e^{\frac{-0.693 \times 27\ days}{74.02\ days}} = 94\ Ci$$

In its fully-retracted position, the source is located within a depleted uranium shield at a distance of 13.34 cm from the exit port of the camera.[32] The shield extends to within 1.27 cm of the exit port.

When the subject discovered that the source was not secured, he rotated the control crank "1/3 to 1/2 turn" to fully retract the source and engage the automatic locking mechanism.[33] At the "1/3 turn" position, the source is 6.99 cm from the exit port and 5.72 cm from the end of the depleted uranium shield. At "1/2 turn", the source is 2.54 cm from the exit port and 1.27 cm from the end of the shield.

Computer Simulation of the Exposure Scenario

Since the personnel dosimeter worn by the subject was positioned below his waist and in front of his body surface, the processing results can be attributed to a one (1) minute exposure from the front of the dosimeter, and a three (3) minute exposure from the back of the dosimeter. The

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[28] Since this device was calibrated to alarm at a dose rate of 500 millirem per hour, it is not clear why it did not signal an elevated dose rate during the incident.

[29] Letter to Robert Slack, Conam Inspection, from Steven Souza, Radiation Detection Company, "Film Dosimeter Report for W. Chastain, IBM #3723, dated 2-1-96, Account 48, Group 12", April 4, 1996.

[30] The film badge was issued to the subject at the beginning of the month, and thus contained accumulated dose from other activities performed during this time. However, it is not likely that the accumulated dose was significantly different from 100 millirem. Therefore, the accumulated dose is disregarded for this assessment, and the results of film badge processing are attributed, solely, to the incident.

[31] Amersham Corporation, Source Certificate, Source Serial No. A7462.

[32] Facsimile Report to Bob Slack, Conam Inspection, from Kate Roughan, Amersham Corporation, "Drawing for the Mod. No. 660A Camera", November 26, 1996.

[33] Letter to Michael Creech, Conam Inspection, from Cynthia D. Pederson, USNRC, "NRC Inspection Report No. 030-31373/96002 (DNMS) and Investigation Report No. 3-96-014", November 18, 1996.

computer code MicroShield was used to re-construct these exposure conditions.[34] For this assessment, the following was assumed:

- The source activity was 94 Ci of ^{192}Ir.
- The source-to-dosimeter distance for the front irradiation is 33.66 cm, as measured during the April 11th re-creation.
- The source-to-dosimeter distance for the back irradiation is 39.37 cm, as measured during the April 11th re-creation.
- The source capsule was at the "1/2 turn" position throughout the exposure period which is the most conservative of the values relayed by the subject during the April 11th re-creation.
- The beam of ionizing radiation from the sealed source in the camera traverses 1.10 cm of air within the source tube, 0.95 cm of titanium, 3.23 cm of foam, 0.34 cm of steel, and 28.04 cm of air prior to reaching the front of the subject's dosimeter.
- The beam traverses 1.47 cm of air within the source tube, 1.27 cm of titanium, 0.32 cm of steel, 12.98 cm of air, and 23.32 cm of tissue prior to reaching the back of the dosimeter.
- A MicroShield "point source" geometry is a reasonable simulation, with x = 33.66 cm, y = 0 cm, and z = 0 cm for the front irradiation. For the back irradiation, x = 39.37 cm.

Attachment 1 contains the MicroShield summary reports for the front and back exposure models using the aforementioned input parameters. When interpreted, these results show that the predicted dose at the location of the subject's dosimeter should have been 11,848 millirem, which is 2.58 times higher than the 4,600 millirem dose measured by the dosimeter.[35] Unless the April 11th re-creation significantly over-estimated the exposure durations, significantly under-estimated the source-to-dosimeter distances, or mis-construed the various subject-source-dosimeter geometries, the only other explanation for the discrepancy is that the film badge was mis-read.

In light of the apparent discrepancy between the dose evaluation based upon this time-and-motion information and the personnel dosimeter result, there is insufficient evidence to conclude that an "over-exposure" occurred. However, in spite of the fact that the dosimeter results cannot be

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[34] MicroShield, Version 4.21, Grove Engineering.

[35] The deep dose equivalent rate predicted by MicroShield is 3.155E5 millirem per hour for a one (1) minute exposure time, and 1.318E5 millirem per hour for a three (3) minute exposure time. When summed, the total is 11,848 millirem. The ratio of "measured-to-calculated" for this exposure scenario is thus 0.388.

duplicated, the MicroShield computer code was nonetheless used to estimate the doses incurred by the various body compartments, as long as all results are normalized to the results reflected by the dosimeter (e.g., decreased by a factor of 2.58).

Maximum Possible Dose to Abdomen Compartment

Since the personnel dosimeter worn by the subject was positioned below his waist and in front of his body surface (e.g., closer to the source than the body surface), the dose to the abdomen compartment is conservatively assumed to be the dose reflected by the personnel dosimeter (e.g., 4,600 millirem).

Maximum Possible Dose to the Right Thigh

If it is again assumed that the dose reflected by the subject's personnel dosimeter is valid, the MicroShield computer code can be used to calculate the dose to the right thigh compartment for this exposure scenario. The following are the parameters used as input to the code:

- The source activity was 94 Ci of ^{192}Ir.
- The source-to-right thigh distance for the front irradiation is 25.40 cm, as measured during the April 11th re-creation.
- During the back irradiation, the right thigh is sufficiently far from the beam that a dose of significance is not likely. However, to ensure an element of conservatism in this analysis, the 20 millirem per hour survey measurement made in the vicinity of the sides of the camera is taken to be the dose rate to this compartment during the back irradiation.
- The source capsule was at the "1/2 turn" position throughout the exposure period which is the most conservative of the values relayed by the subject during the April 11th re-creation.
- The beam of ionizing radiation from the sealed source in the camera traverses 25.40 cm of air prior to reaching the front of the right thigh.
- A MicroShield "point source" geometry is a reasonable simulation, with x = 25.40 cm, y = 0 cm, and z = 0 cm.
- The dose rates predicted by MicroShield are a factor of 2.58 above the true dose rates.

Attachment 3 contains the MicroShield summary report from this analysis. From the corrected dose rates (e.g., 2.905E5 millirem per hour), the dose to the right thigh from the one (1) minute front exposure is 4,842 millirem, and one (1) millirem from the three (3) minute back exposure, for a total compartment dose of 4,843 millirem.

Maximum Dose to the Left Thigh Compartment

If it is again assumed that the dose reflected by the subject's personnel dosimeter is valid, the MicroShield computer code can be used to calculate the dose to the left thigh compartment based upon the April 11th time-and-motion scenario. The following are the parameters used as input to the code:

- The source activity was 94 Ci of ^{192}Ir.
- The source-to-left thigh distance for the back irradiation is 14.92 cm, as measured during the April 11th re-creation.
- During the front irradiation, the left thigh is sufficiently far from the beam that a dose of significance is not likely. However, to ensure an element of conservatism in this analysis, the 20 millirem per hour survey measurement made in the vicinity of the sides of the camera is taken to be the dose rate to this compartment during the front irradiation.
- The source capsule was at the "1/2 turn" position throughout the exposure period which is the most conservative of the values relayed by the subject during the April 11th re-creation.
- The beam of ionizing radiation from the sealed source in the camera traverses 14.92 cm of air prior to reaching the left thigh.
- A MicroShield "point source" geometry is a reasonable simulation, with x = 14.92 cm, y = 0 cm, and z = 0 cm.
- The dose rates predicted by MicroShield are a factor of 2.58 above the true dose rates.

Attachment 4 contains the MicroShield summary report from this analysis. From the corrected dose rates, the dose to the left thigh from the one (1) minute front exposure is 0.33 millirem, and 41,075 millirem from the three (3) minute back exposure, for a total compartment dose of 42,075 millirem.

Dose to the Remaining Compartments

Because the ^{192}Ir source remained within the depleted uranium shield of the Model 660B camera during this scenario, it is not likely that the remaining compartments of the body incurred a significant dose. However, to ensure an element of conservatism in this analysis, the 20 millirem per hour survey measurement made in the vicinity of the sides of the camera is taken to be the dose rate to all remaining compartments. Thus the dose to the head and neck, thorax, right upper arm, and left upper arm compartments was 1.33 millirem for the four (4) minute exposure duration.

ATTACHMENT 1

MicroShield 4.21 - Serial #4.21-00996
Integrated Environmental Management, Inc.

Page : 1
DOS File: CONAMFF1.MS4
Run Date: December 5, 1996
Run Time: 1:29 p.m. Thursday
Duration: 0:00:02

File Ref: 96004.01
Date: __/__/__
By: _____
Checked: _____

Case Title: Conam Dose Est. - Exp. of Film Badge from the Front (S=1.0)

GEOMETRY 1 - Point

	centimeters	feet	and inches
Dose point coordinate X:	33.655	1.0	1.3
Dose point coordinate Y:	0.0	0.0	.0
Dose point coordinate Z:	0.0	0.0	.0
Shield 1:	1.09982	0.0	.4
Shield 2:	0.94996	0.0	.4
Shield 3:	3.2258	0.0	1.3
Shield 4:	0.34036	0.0	.1
Shield 5:	28.0162	0.0	11.0
Air Gap:	2.286e-002	0.0	.0

MATERIAL DENSITIES (g/cm^3)

Material	Shield 1 Slab	Shield 2 Slab	Shield 3 Slab	Shield 4 Slab	Shield 5 Slab
Air	0.00122				0.00122
Iron		4.5		7.86	
Water			0.802		

Material	Air Gap
Air	0.00122

BUILDUP
Method: Buildup Factor Tables
The material reference is Shield 2

INTEGRATION PARAMETERS
Case solved analytically.

SOURCE NUCLIDES

Nuclide	
Ir-192	9.4000e+001

DOS File: CONAMFF1.MS4
Run Date: December 5, 1996
Run Time: 1:29 p.m. Thursday
Title : Conam Dose Est. - Exp. of Film Badge from the Front (S=1.0)

RESULTS

Energy (MeV)	Activity (photons/sec)	Energy Fluence Rate (MeV/sq cm/sec)		Exposure Rate In Air (mR/hr)	
		No Buildup	With Buildup	No Buildup	With Buildup
0.0615	3.938e+010	6.429e+001	9.086e+001	1.239e-001	1.751e-001
0.063	6.801e+010	1.801e+002	2.574e+002	3.376e-001	4.826e-001
0.0651	9.165e+010	4.455e+002	6.447e+002	8.072e-001	1.168e+000
0.0668	1.572e+011	1.184e+003	1.729e+003	2.095e+000	3.058e+000
0.0714	2.921e+010	5.899e+002	8.896e+002	9.907e-001	1.494e+000
0.0757	6.843e+010	2.883e+003	4.476e+003	4.676e+000	7.259e+000
0.1363	6.282e+009	9.599e+003	1.872e+004	1.543e+001	3.009e+001
0.2013	1.625e+010	6.191e+004	1.303e+005	1.094e+002	2.303e+002
0.2058	1.143e+011	4.537e+005	9.556e+005	8.057e+002	1.697e+003
0.2833	9.095e+009	6.149e+004	1.266e+005	1.157e+002	2.382e+002
0.296	1.009e+012	7.297e+006	1.492e+007	1.382e+004	2.825e+004
0.3085	1.032e+012	7.945e+006	1.613e+007	1.512e+004	3.070e+004
0.3165	2.882e+012	2.305e+007	4.658e+007	4.401e+004	8.894e+004
0.3745	2.526e+010	2.584e+005	5.041e+005	5.012e+002	9.778e+002
0.4165	2.311e+010	2.749e+005	5.223e+005	5.369e+002	1.020e+003
0.4231	2.772e+009	3.371e+004	6.378e+004	6.588e+001	1.247e+002
0.4681	1.671e+012	2.340e+007	4.306e+007	4.591e+004	8.447e+004
0.4846	1.100e+011	1.616e+006	2.944e+006	3.171e+003	5.778e+003
0.4891	1.386e+010	2.062e+005	3.746e+005	4.047e+002	7.353e+002
0.5886	1.591e+011	3.046e+006	5.244e+006	5.951e+003	1.025e+004
0.6044	2.853e+011	5.662e+006	9.672e+006	1.105e+004	1.887e+004
0.6125	1.856e+011	3.749e+006	6.380e+006	7.309e+003	1.244e+004
0.8717	3.429e+009	1.107e+005	1.707e+005	2.083e+002	3.212e+002
0.8845	1.049e+010	3.450e+005	5.301e+005	6.480e+002	9.957e+002
TOTAL:	8.013e+012	7.759e+007	1.483e+008	1.498e+005	2.861e+005

MicroShield 4.21 - Serial #4.21-00996
Licensed to Integrated Environmental Management, Inc.
CONVERSION OF CALCULATED EXPOSURE IN AIR TO DOSE
FILE: CONAMFF1.MS4
Case Title: Conam Dose Est. - Exp. of Film Badge from the Front (S=1.0)
This case was run on Thursday, December 5, 1996 at 1:29 p.m.

Results (Summed over energies)	Units	Without Buildup	With Buildup
Photon Fluence Rate (flux)	Photons/cm²/sec	2.025e+008	3.936e+008
Photon Energy Fluence Rate	MeV/cm²/sec	7.759e+007	1.483e+008
Exposure Rate in Air	mR/hr	1.498e+005	2.861e+005
Absorbed Dose Rate in Air	mGy/hr	1.307e+003	2.497e+003
"	mrad/hr	1.307e+005	2.497e+005
Deep Dose Equivalent Rate (ICRP 51 - 1987)			
o Parallel Geometry	mSv/hr	1.648e+003	3.155e+003
o Opposed "	"	1.216e+003	2.321e+003
o Rotational "	"	1.216e+003	2.321e+003
o Isotropic "	"	1.082e+003	2.067e+003
Shallow Dose Equivalent Rate (ICRP 51 - 1987)			
o Parallel Geometry	mSv/hr	1.708e+003	3.268e+003
o Opposed "	"	1.602e+003	3.064e+003
o Rotational "	"	1.602e+003	3.064e+003
o Isotropic "	"	1.157e+003	2.209e+003
Effective Dose Equivalent Rate (ICRP 51 - 1987)			
o Anterior/Posterior Geometry	mSv/hr	1.433e+003	2.742e+003
o Posterior/Anterior "	"	1.220e+003	2.331e+003
o Lateral "	"	8.586e+002	1.638e+003
o Rotational "	"	1.077e+003	2.058e+003
o Isotropic "	"	9.015e+002	1.722e+003

C.1

MicroShield 4.21 - Serial #4.21-00996
Integrated Environmental Management, Inc.

Page : 1
DOS File: CONAMFR1.MS4
Run Date: December 5, 1996
Run Time: 1:25 p.m. Thursday
Duration: 0:00:02

File Ref: 96004.01
Date: __/__/__
By: _____
Checked: _____

Case Title: Conam Dose Est. - Exp. of Film Badge from the Rear (S=1.0)

GEOMETRY 1 - Point

	centimeters	feet	and inches
Dose point coordinate X:	39.37	1.0	3.5
Dose point coordinate Y:	0.0	0.0	.0
Dose point coordinate Z:	0.0	0.0	.0
Shield 1:	1.4732	0.0	.6
Shield 2:	1.27254	0.0	.5
Shield 3:	0.32258	0.0	.1
Shield 4:	12.9794	0.0	5.1
Shield 5:	23.3172	0.0	9.2
Air Gap:	5.08e-003	0.0	.0

MATERIAL DENSITIES (g/cm^3)

Material	Shield 1 Slab	Shield 2 Slab	Shield 3 Slab	Shield 4 Slab	Shield 5 Slab
Air	0.00122			0.00122	
Iron		4.5	7.86		
Water					1.0

Material	Air Gap
Air	0.00122

BUILDUP
Method: Buildup Factor Tables
The material reference is Shield 5

INTEGRATION PARAMETERS
Case solved analytically.

SOURCE NUCLIDES

Nuclide	
Ir-192	9.4000e+001

DOS File: CONAMFR1.MS4
Run Date: December 5, 1996
Run Time: 1:25 p.m. Thursday
Title : Conam Dose Est. - Exp. of Film Badge from the Rear (S=1.0)

RESULTS

Energy (MeV)	Activity (photons/sec)	Energy Fluence Rate (MeV/sq cm/sec)		Exposure Rate In Air (mR/hr)	
		No Buildup	With Buildup	No Buildup	With Buildup
0.0615	3.938e+010	2.043e-001	6.576e+001	3.937e-004	1.268e-001
0.063	6.801e+010	6.474e-001	2.028e+002	1.214e-003	3.802e-001
0.0651	9.165e+010	1.873e+000	5.614e+002	3.394e-003	1.017e+000
0.0668	1.572e+011	5.581e+000	1.608e+003	9.871e-003	2.844e+000
0.0714	2.921e+010	3.603e+000	9.264e+002	6.051e-003	1.556e+000
0.0757	6.843e+010	2.146e+001	4.932e+003	3.481e-002	7.998e+000
0.1363	6.282e+009	2.237e+002	1.439e+004	3.596e-001	2.314e+001
0.2013	1.625e+010	2.267e+003	7.024e+004	4.007e+000	1.242e+002
0.2058	1.143e+011	1.700e+004	5.076e+005	3.020e+001	9.015e+002
0.2833	9.095e+009	3.186e+003	5.669e+004	5.997e+000	1.067e+002
0.296	1.009e+012	3.947e+005	6.564e+006	7.474e+002	1.243e+004
0.3085	1.032e+012	4.475e+005	6.991e+006	8.518e+002	1.331e+004
0.3165	2.882e+012	1.331e+006	2.002e+007	2.542e+003	3.822e+004
0.3745	2.526e+010	1.754e+004	2.078e+005	3.402e+001	4.031e+002
0.4165	2.311e+010	2.061e+004	2.117e+005	4.025e+001	4.134e+002
0.4231	2.772e+009	2.564e+003	2.579e+004	5.012e+000	5.041e+001
0.4681	1.671e+012	1.952e+006	1.722e+007	3.830e+003	3.377e+004
0.4846	1.100e+011	1.391e+005	1.174e+006	2.729e+002	2.303e+003
0.4891	1.386e+010	1.789e+004	1.492e+005	3.511e+001	2.929e+002
0.5886	1.591e+011	3.108e+005	2.071e+006	6.073e+002	4.047e+003
0.6044	2.853e+011	5.910e+005	3.819e+006	1.153e+003	7.452e+003
0.6125	1.856e+011	3.958e+005	2.519e+006	7.715e+002	4.911e+003
0.8717	3.429e+009	1.559e+004	6.846e+004	2.933e+001	1.288e+002
0.8845	1.049e+010	4.915e+004	2.129e+005	9.231e+001	3.998e+002
TOTAL:	8.013e+012	5.709e+006	6.191e+007	1.105e+004	1.193e+005

MicroShield 4.21 - Serial #4.21-00996
Licensed to Integrated Environmental Management, Inc.
CONVERSION OF CALCULATED EXPOSURE IN AIR TO DOSE
FILE: CONAMFR1.MS4
Case Title: Conam Dose Est. - Exp. of Film Badge from the Rear (S=1.0)
This case was run on Thursday, December 5, 1996 at 1:25 p.m.

Results (Summed over energies)	Units	Without Buildup	With Buildup
Photon Fluence Rate (flux)	Photons/cm²/sec	1.392e+007	1.662e+008
Photon Energy Fluence Rate	MeV/cm²/sec	5.709e+006	6.191e+007
Exposure Rate in Air	mR/hr	1.105e+004	1.193e+005
Absorbed Dose Rate in Air	mGy/hr	9.649e+001	1.042e+003
"	mrad/hr	9.649e+003	1.042e+005
Deep Dose Equivalent Rate (ICRP 51 - 1987)			
o Parallel Geometry	mSv/hr	1.204e+002	1.318e+003
o Opposed "	"	8.997e+001	9.677e+002
o Rotational "	"	8.997e+001	9.677e+002
o Isotropic "	"	7.994e+001	8.619e+002
Shallow Dose Equivalent Rate (ICRP 51 - 1987)			
o Parallel Geometry	mSv/hr	1.253e+002	1.364e+003
o Opposed "	"	1.178e+002	1.279e+003
o Rotational "	"	1.178e+002	1.279e+003
o Isotropic "	"	8.541e+001	9.213e+002
Effective Dose Equivalent Rate (ICRP 51 - 1987)			
o Anterior/Posterior Geometry	mSv/hr	1.050e+002	1.145e+003
o Posterior/Anterior "	"	8.981e+001	9.725e+002
o Lateral "	"	6.366e+001	6.828e+002
o Rotational "	"	7.950e+001	8.585e+002
o Isotropic "	"	6.661e+001	7.179e+002

ATTACHMENT 2

C.2

MicroShield 4.21 - Serial #4.21-00996
Integrated Environmental Management, Inc.

Page : 1
DOS File: CONAMFF1.MS4
Run Date: December 5, 1996
Run Time: 1:29 p.m. Thursday
Duration: 0:00:02

File Ref: 96004.01
Date: __/__/__
By: _____
Checked: _____

Case Title: Conam Dose Est. - Exp. of Film Badge from the Front (S=1.0)

GEOMETRY 1 - Point

	centimeters	feet and inches	
Dose point coordinate X:	33.655	1.0	1.3
Dose point coordinate Y:	0.0	0.0	.0
Dose point coordinate Z:	0.0	0.0	.0
Shield 1:	1.09982	0.0	.4
Shield 2:	0.94996	0.0	.4
Shield 3:	3.2258	0.0	1.3
Shield 4:	0.34036	0.0	.1
Shield 5:	28.0162	0.0	11.0
Air Gap:	2.286e-002	0.0	.0

MATERIAL DENSITIES (g/cm^3)

Material	Shield 1 Slab	Shield 2 Slab	Shield 3 Slab	Shield 4 Slab	Shield 5 Slab
Air	0.00122				0.00122
Iron		4.5		7.86	
Water			0.802		

Material	Air Gap
Air	0.00122

BUILDUP
Method: Buildup Factor Tables
The material reference is Shield 2

INTEGRATION PARAMETERS
Case solved analytically.

SOURCE NUCLIDES

Nuclide	
Ir-192	9.4000e+001

DOS File: CONAMFF1.MS4
Run Date: December 5, 1996
Run Time: 1:29 p.m. Thursday
Title : Conam Dose Est. - Exp. of Film Badge from the Front (S=1.0)

RESULTS

Energy (MeV)	Activity (photons/sec)	Energy Fluence Rate (MeV/sq cm/sec)		Exposure Rate In Air (mR/hr)	
		No Buildup	With Buildup	No Buildup	With Buildup
0.0615	3.938e+010	6.429e+001	9.086e+001	1.239e-001	1.751e-001
0.063	6.801e+010	1.801e+002	2.574e+002	3.376e-001	4.826e-001
0.0651	9.165e+010	4.455e+002	6.447e+002	8.072e-001	1.168e+000
0.0668	1.572e+011	1.184e+003	1.729e+003	2.095e+000	3.058e+000
0.0714	2.921e+010	5.899e+002	8.896e+002	9.907e-001	1.494e+000
0.0757	6.843e+010	2.883e+003	4.476e+003	4.676e+000	7.259e+000
0.1363	6.282e+009	9.599e+003	1.872e+004	1.543e+001	3.009e+001
0.2013	1.625e+010	6.191e+004	1.303e+005	1.094e+002	2.303e+002
0.2058	1.143e+011	4.537e+005	9.556e+005	8.057e+002	1.697e+003
0.2833	9.095e+009	6.149e+004	1.266e+005	1.157e+002	2.382e+002
0.296	1.009e+012	7.297e+006	1.492e+007	1.382e+004	2.825e+004
0.3085	1.032e+012	7.945e+006	1.613e+007	1.512e+004	3.070e+004
0.3165	2.882e+012	2.305e+007	4.658e+007	4.401e+004	8.894e+004
0.3745	2.526e+010	2.584e+005	5.041e+005	5.012e+002	9.778e+002
0.4165	2.311e+010	2.749e+005	5.223e+005	5.369e+002	1.020e+003
0.4231	2.772e+009	3.371e+004	6.378e+004	6.588e+001	1.247e+002
0.4681	1.671e+012	2.340e+007	4.306e+007	4.591e+004	8.447e+004
0.4846	1.100e+011	1.616e+006	2.944e+006	3.171e+003	5.778e+003
0.4891	1.386e+010	2.062e+005	3.746e+005	4.047e+002	7.353e+002
0.5886	1.591e+011	3.046e+006	5.244e+006	5.951e+003	1.025e+004
0.6044	2.853e+011	5.662e+006	9.672e+006	1.105e+004	1.887e+004
0.6125	1.856e+011	3.749e+006	6.380e+006	7.309e+003	1.244e+004
0.8717	3.429e+009	1.107e+005	1.707e+005	2.083e+002	3.212e+002
0.8845	1.049e+010	3.450e+005	5.301e+005	6.480e+002	9.957e+002
TOTAL:	8.013e+012	7.759e+007	1.483e+008	1.498e+005	2.861e+005

MicroShield 4.21 - Serial #4.21-00996
Licensed to Integrated Environmental Management, Inc.
CONVERSION OF CALCULATED EXPOSURE IN AIR TO DOSE
FILE: CONAMFF1.MS4
Case Title: Conam Dose Est. - Exp. of Film Badge from the Front (S=1.0)
This case was run on Thursday, December 5, 1996 at 1:29 p.m.

Results (Summed over energies)	Units	Without Buildup	With Buildup
Photon Fluence Rate (flux)	Photons/cm²/sec	2.025e+008	3.936e+008
Photon Energy Fluence Rate	MeV/cm²/sec	7.759e+007	1.483e+008
Exposure Rate in Air	mR/hr	1.498e+005	2.861e+005
Absorbed Dose Rate in Air	mGy/hr	1.307e+003	2.497e+003
"	mrad/hr	1.307e+005	2.497e+005
Deep Dose Equivalent Rate (ICRP 51 - 1987)			
o Parallel Geometry	mSv/hr	1.648e+003	3.155e+003
o Opposed "	"	1.216e+003	2.321e+003
o Rotational "	"	1.216e+003	2.321e+003
o Isotropic "	"	1.082e+003	2.067e+003
Shallow Dose Equivalent Rate (ICRP 51 - 1987)			
o Parallel Geometry	mSv/hr	1.708e+003	3.268e+003
o Opposed "	"	1.602e+003	3.064e+003
o Rotational "	"	1.602e+003	3.064e+003
o Isotropic "	"	1.157e+003	2.209e+003
Effective Dose Equivalent Rate (ICRP 51 - 1987)			
o Anterior/Posterior Geometry	mSv/hr	1.433e+003	2.742e+003
o Posterior/Anterior "	"	1.220e+003	2.331e+003
o Lateral "	"	8.586e+002	1.638e+003
o Rotational "	"	1.077e+003	2.058e+003
o Isotropic "	"	9.015e+002	1.722e+003

ATTACHMENT 3

MicroShield 4.21 - Serial #4.21-00996
Integrated Environmental Management, Inc.

Page : 1
DOS File: CONAMTF.MS4
Run Date: December 5, 1996
Run Time: 8:17 a.m. Thursday
Duration: 0:00:02

File Ref: 96004.01
Date: __/__/__
By: _____
Checked: _____

Case Title: Conam Dose Estimate - Exposure of Thigh from Front

GEOMETRY 1 - Point

	centimeters	feet and inches	
Dose point coordinate X:	25.4	0.0	10.0
Dose point coordinate Y:	0.0	0.0	.0
Dose point coordinate Z:	0.0	0.0	.0
Air Gap:	25.4	0.0	10.0

MATERIAL DENSITIES (g/cm^3)

Material	Air Gap
Air	0.00122

BUILDUP
Method: Buildup Factor Tables
The material reference is Air Gap

INTEGRATION PARAMETERS
Case solved analytically.

SOURCE NUCLIDES

Nuclide	
Ir-192	9.4000e+001

DOS File: CONAMTF.MS4
Run Date: December 5, 1996
Run Time: 8:17 a.m. Thursday
Title : Conam Dose Estimate - Exposure of Thigh from Front

RESULTS

Energy (MeV)	Activity (photons/sec)	Energy Fluence Rate (MeV/sq cm/sec)		Exposure Rate In Air (mR/hr)	
		No Buildup	With Buildup	No Buildup	With Buildup
0.0615	3.938e+010	2.970e+005	3.002e+005	5.725e+002	5.785e+002
0.063	6.801e+010	5.256e+005	5.311e+005	9.856e+002	9.958e+002
0.0651	9.165e+010	7.322e+005	7.397e+005	1.327e+003	1.340e+003
0.0668	1.572e+011	1.289e+006	1.302e+006	2.280e+003	2.303e+003
0.0714	2.921e+010	2.559e+005	2.585e+005	4.298e+002	4.340e+002
0.0757	6.843e+010	6.357e+005	6.418e+005	1.031e+003	1.041e+003
0.1363	6.282e+009	1.052e+005	1.059e+005	1.691e+002	1.703e+002
0.2013	1.625e+010	4.021e+005	4.040e+005	7.107e+002	7.141e+002
0.2058	1.143e+011	2.891e+006	2.905e+006	5.135e+003	5.160e+003
0.2833	9.095e+009	3.167e+005	3.179e+005	5.960e+002	5.983e+002
0.296	1.009e+012	3.672e+007	3.685e+007	6.953e+004	6.979e+004
0.3085	1.032e+012	3.914e+007	3.929e+007	7.451e+004	7.478e+004
0.3165	2.882e+012	1.121e+008	1.125e+008	2.141e+005	2.149e+005
0.3745	2.526e+010	1.163e+006	1.167e+006	2.257e+003	2.264e+003
0.4165	2.311e+010	1.184e+006	1.187e+006	2.312e+003	2.318e+003
0.4231	2.772e+009	1.442e+005	1.446e+005	2.819e+002	2.827e+002
0.4681	1.671e+012	9.623e+007	9.648e+007	1.888e+005	1.893e+005
0.4846	1.100e+011	6.557e+006	6.574e+006	1.287e+004	1.290e+004
0.4891	1.386e+010	8.337e+005	8.359e+005	1.636e+003	1.641e+003
0.5886	1.591e+011	1.152e+007	1.154e+007	2.251e+004	2.256e+004
0.6044	2.853e+011	2.122e+007	2.126e+007	4.139e+004	4.148e+004
0.6125	1.856e+011	1.398e+007	1.402e+007	2.726e+004	2.732e+004
0.8717	3.429e+009	3.679e+005	3.686e+005	6.924e+002	6.935e+002
0.8845	1.049e+010	1.142e+006	1.144e+006	2.145e+003	2.148e+003
TOTAL:	8.013e+012	3.498e+008	3.509e+008	6.735e+005	6.756e+005

MicroShield 4.21 - Serial #4.21-00996
Licensed to Integrated Environmental Management, Inc.
CONVERSION OF CALCULATED EXPOSURE IN AIR TO DOSE
FILE: CONAMTF.MS4
Case Title: Conam Dose Estimate - Exposure of Thigh from Front
This case was run on Thursday, December 5, 1996 at 8:17 a.m.

Results (Summed over energies)	Units	Without Buildup	With Buildup
Photon Fluence Rate (flux)	Photons/cm²/sec	9.852e+008	9.888e+008
Photon Energy Fluence Rate	MeV/cm²/sec	3.498e+008	3.509e+008
Exposure Rate in Air	mR/hr	6.735e+005	6.756e+005
Absorbed Dose Rate in Air	mGy/hr	5.880e+003	5.898e+003
"	mrad/hr	5.880e+005	5.898e+005
Deep Dose Equivalent Rate (ICRP 51 - 1987)			
o Parallel Geometry	mSv/hr	7.471e+003	7.495e+003
o Opposed "	"	5.463e+003	5.480e+003
o Rotational "	"	5.460e+003	5.478e+003
o Isotropic "	"	4.869e+003	4.884e+003
Shallow Dose Equivalent Rate (ICRP 51 - 1987)			
o Parallel Geometry	mSv/hr	7.728e+003	7.753e+003
o Opposed "	"	7.220e+003	7.244e+003
o Rotational "	"	7.220e+003	7.244e+003
o Isotropic "	"	5.203e+003	5.219e+003
Effective Dose Equivalent Rate (ICRP 51 - 1987)			
o Anterior/Posterior Geometry	mSv/hr	6.484e+003	6.505e+003
o Posterior/Anterior "	"	5.497e+003	5.515e+003
o Lateral "	"	3.853e+003	3.865e+003
o Rotational "	"	4.850e+003	4.866e+003
o Isotropic "	"	4.055e+003	4.068e+003

ATTACHMENT 4

C.4

MicroShield 4.21 - Serial #4.21-00996
Integrated Environmental Management, Inc.

Page : 1
DOS File: CONAMTR.MS4
Run Date: December 5, 1996
Run Time: 8:16 a.m. Thursday
Duration: 0:00:01

File Ref: 96004.01
Date: __/__/__
By: _____
Checked: _____

Case Title: Conam Dose Estimate - Exposure of Thigh from Rear

GEOMETRY 1 - Point

	centimeters	feet and inches	
Dose point coordinate X:	14.9225	0.0	5.9
Dose point coordinate Y:	0.0	0.0	.0
Dose point coordinate Z:	0.0	0.0	.0
Air Gap:	14.9225	0.0	5.9

MATERIAL DENSITIES (g/cm^3)

Material	Air Gap
Air	0.00122

BUILDUP
Method: Buildup Factor Tables
The material reference is Air Gap

INTEGRATION PARAMETERS
Case solved analytically.

SOURCE NUCLIDES

Nuclide	
Ir-192	9.4000e+001

DOS File: CONAMTR.MS4
Run Date: December 5, 1996
Run Time: 8:16 a.m. Thursday
Title : Conam Dose Estimate - Exposure of Thigh from Rear

RESULTS

Energy (MeV)	Activity (photons/sec)	Energy Fluence Rate (MeV/sq cm/sec)		Exposure Rate In Air (mR/hr)	
		No Buildup	With Buildup	No Buildup	With Buildup
0.0615	3.938e+010	8.625e+005	8.678e+005	1.663e+003	1.673e+003
0.063	6.801e+010	1.526e+006	1.536e+006	2.862e+003	2.879e+003
0.0651	9.165e+010	2.126e+006	2.139e+006	3.852e+003	3.875e+003
0.0668	1.572e+011	3.743e+006	3.765e+006	6.619e+003	6.659e+003
0.0714	2.921e+010	7.431e+005	7.474e+005	1.248e+003	1.255e+003
0.0757	6.843e+010	1.846e+006	1.856e+006	2.993e+003	3.010e+003
0.1363	6.282e+009	3.053e+005	3.066e+005	4.908e+002	4.928e+002
0.2013	1.625e+010	1.167e+006	1.170e+006	2.062e+003	2.068e+003
0.2058	1.143e+011	8.390e+006	8.413e+006	1.490e+004	1.494e+004
0.2833	9.095e+009	9.188e+005	9.209e+005	1.729e+003	1.733e+003
0.296	1.009e+012	1.065e+008	1.068e+008	2.017e+005	2.021e+005
0.3085	1.032e+012	1.136e+008	1.138e+008	2.162e+005	2.166e+005
0.3165	2.882e+012	3.253e+008	3.260e+008	6.211e+005	6.224e+005
0.3745	2.526e+010	3.375e+006	3.381e+006	6.546e+003	6.558e+003
0.4165	2.311e+010	3.434e+006	3.439e+006	6.706e+003	6.717e+003
0.4231	2.772e+009	4.183e+005	4.190e+005	8.176e+002	8.190e+002
0.4681	1.671e+012	2.791e+008	2.795e+008	5.475e+005	5.483e+005
0.4846	1.100e+011	1.902e+007	1.905e+007	3.733e+004	3.738e+004
0.4891	1.386e+010	2.418e+006	2.422e+006	4.746e+003	4.753e+003
0.5886	1.591e+011	3.341e+007	3.345e+007	6.528e+004	6.536e+004
0.6044	2.853e+011	6.153e+007	6.161e+007	1.200e+005	1.202e+005
0.6125	1.856e+011	4.056e+007	4.061e+007	7.907e+004	7.917e+004
0.8717	3.429e+009	1.067e+006	1.068e+006	2.008e+003	2.010e+003
0.8845	1.049e+010	3.311e+006	3.315e+006	6.219e+003	6.225e+003
TOTAL:	8.013e+012	1.015e+009	1.017e+009	1.954e+006	1.957e+006

MicroShield 4.21 - Serial #4.21-00996
Licensed to Integrated Environmental Management, Inc.
CONVERSION OF CALCULATED EXPOSURE IN AIR TO DOSE
FILE: CONAMTR.MS4
Case Title: Conam Dose Estimate - Exposure of Thigh from Rear
This case was run on Thursday, December 5, 1996 at 8:16 a.m.

Results (Summed over energies)	Units	Without Buildup	With Buildup
Photon Fluence Rate (flux)	Photons/cm²/sec	2.858e+009	2.864e+009
Photon Energy Fluence Rate	MeV/cm²/sec	1.015e+009	1.017e+009
Exposure Rate in Air	mR/hr	1.954e+006	1.957e+006
Absorbed Dose Rate in Air	mGy/hr	1.706e+004	1.709e+004
"	mrad/hr	1.706e+006	1.709e+006
Deep Dose Equivalent Rate (ICRP 51 - 1987)			
o Parallel Geometry	mSv/hr	2.167e+004	2.171e+004
o Opposed "	"	1.585e+004	1.588e+004
o Rotational "	"	1.584e+004	1.587e+004
o Isotropic "	"	1.412e+004	1.415e+004
Shallow Dose Equivalent Rate (ICRP 51 - 1987)			
o Parallel Geometry	mSv/hr	2.242e+004	2.246e+004
o Opposed "	"	2.095e+004	2.098e+004
o Rotational "	"	2.095e+004	2.098e+004
o Isotropic "	"	1.509e+004	1.512e+004
Effective Dose Equivalent Rate (ICRP 51 - 1987)			
o Anterior/Posterior Geometry	mSv/hr	1.881e+004	1.884e+004
o Posterior/Anterior "	"	1.595e+004	1.598e+004
o Lateral "	"	1.118e+004	1.120e+004
o Rotational "	"	1.407e+004	1.410e+004
o Isotropic "	"	1.176e+004	1.178e+004

APPENDIX D
Effective Dose Equivalent Assessment

The radiation dose incurred by a small area of the body does not subject the exposed individual to the same risk as if that dose were distributed over the entire body. Consequently, the compartmental doses calculated for the subject involved in the February 27, 1996 exposure incident cannot be compared to the effective dose equivalent limits contained in Title 10, Code of Federal Regulations, Part 20, "Standards for Protection Against Radiation".

Using the methodology described in an applicable (draft) ANSI standard, an estimate of the effective dose equivalent incurred by this subject based upon his initial representation of his time and motion during the incident, is 2,347 millirem (see Attachment 1 for the calculation summary).[36] This estimate assumes the duration of the exposure was one (1) minute.

On April 11, 1996, the subject presented a second time-and-motion scenario that differed from the initial representation. At that time, a re-enactment of the circumstances surrounding the incident also took place, and specific measurements of subject-source-dosimeter geometries were made. Although the results obtained when the subject's personnel dosimeter was processed cannot be reconciled with the April 11th time-and-motion scenario, an effective dose equivalent estimate can still be made.

Using the methodology shown in the (draft) ANSI standard, along with an attempt to reconcile the calculated exposure rates with the personnel dosimetry results, an estimate of the effective dose equivalent incurred by this subject based upon his secondary representation of his time and motion during the incident is 2,535 millirem (see Attachment 2 for the calculation summary). If the discrepancy between the exposure scenario and the film badge results is disregarded (e.g., if no attempt is made to reconcile the calculated exposure rates with the personnel dosimetry results), the estimated effective dose equivalent would be 2,906 millirem.

The effective dose equivalent estimate based upon the subject's original representation of time-and-motion is considered to be the most reliable because:

- The exposure circumstances are based upon information obtained from the subject shortly after the incident occurred (e.g., when the actual conditions were fresh in his mind); and

- The results are supported by the personnel dosimetry results.

Therefore, the most likely effective dose equivalent incurred by the subject as a result of the February 27, 1996 incident is 2,347 millirem.

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[36] American National Standards Institute, "Criteria for Performing Multiple Dosimetry", (draft) HPS N13.41-1997.

ATTACHMENT 1
Effective Dose Equivalent Estimation for the Initial Time-and-Motion Scenario

Area of the Body	Compartmental Dose (millirem)	Compartment Factor	Estimated Effective Dose Equivalent (millirem)
Head and neck	0.33	0.10	0.03
Thorax	0.33	0.38	0.13
Abdomen	4600	0.50	2300.00
Upper right arm	0.33	0.005	0.00
Upper left arm	0.33	0.005	0.00
Right thigh	9369	0.005	46.85
Left thigh	0.33	0.005	0.00
	ESTIMATED EFFECTIVE DOSE EQUIVALENT		**2347.01**

ATTACHMENT 2
Effective Dose Equivalent Estimation for the Second Time-and-Motion Scenario

Area of the Body	Compartmental Dose (millirem)	Compartment Factor	Estimated Effective Dose Equivalent (millirem)
Head and neck	1.33	0.10	0.13
Thorax	1.33	0.38	0.51
Abdomen	4600	0.50	2300.00
Upper right arm	1.33	0.005	0.01
Upper left arm	1.33	0.005	0.01
Right thigh	4843	0.005	24.22
Left thigh	42075	0.005	210.38
	ESTIMATED EFFECTIVE DOSE EQUIVALENT		**2535.24**

BEFORE THE UNITED STATES
NUCLEAR REGULATORY COMMISSION

PREDECISIONAL ENFORCEMENT CONFERENCE	)
IN RE THE MATTER OF:	)
CONAM INSPECTION, INC.	)

December 13, 1996.
10:00 A.M.

REPORT OF PROCEEDINGS had and testimony taken at the hearing of the above-entitled cause, taken at the 801 Warrenville Road, Lisle, Illinois, before MARY N. LEAHY, C.S.R., a Notary Public qualified and commissioned for the State of Illinois.

PRESENT:

MS. CYNTHIA D. PEDERSON, Director, Division of Nuclear Materials Safety;

MR. NADER MAMISH, Office of Enforcement, NRC;

MS. TOYE SIMMONS, Enforcement Specialist, NRC;

MR. MONTE PHILLIPS, Chief of Nuclear Materials Inspection, Branch 2, NRC;

MR. TOM YOUNG, Radiation Specialist, NRC;

MR. BRUCE BERSON, Office of General Counsel, NRC;

MR. JIM SMITH, NMSS Regional Program Coordinator, via telephone;

MICHAEL B. CREECH, President, Conam Inspection, Inc.;

MR. CLIFTON A. LAKE, McBride, Baker, & Coles, Attorney for Conam Inspection, Inc.;

MR. ROBERT J. SLACK, Quality Assurance Director, Conam Inspection, Inc.;

MR. RANDY SWEET, General Manager, Conam Inspection, Inc.;

MR. STEPHEN L. FAY, Lab Manager, Conam Inspection, Inc.

failure to control radiation exposure of the worker to less than 5 REM total effective dose, and that's a requirement of the 10 CFR Part 20, section 20.1201(a).

MR. PHILLIPS: Let me summarize that a little easier because I think I already know what both of our positions are so we'll just go over it quickly.

Based on the information the radiographer provided us during the reenactment that we did in April, it's clear that, by our regulations, an overexposure would have occurred. Simultaneously, based on the information we provided you in February orally, that the film badge was always the closest to the camera, I could see where you would conclude that an overexposure did not occur.

So we're left with the problem of reconciling the two different stories. That's where we are on this, as I see it.

MS. PEDERSON: Is that also how you would see it?

MR. SLACK: Monte said that based on your review, you're looking at something that a dose would

have occurred. That wasn't a consideration at all for us. We didn't feel we needed to consider that.

For as long as I can remember, at least 30 years, a film badge has always been a record, be it a gross record, an indicator of dose; it's always been the record.

There are statements in the regulation that say "don't do this if this or if this doesn't exist." One of these ifs is that if the film badge, if the dosimetry records do not exist. Dosimetry records definitely do exist. They are 4.6 R. So I don't think there is a question on the gross basis.

You folks did some studies, some calculations. We additionally had given the information to an outside agency to do a review. The company is IEM, which is Integrated Environmental Management Company out of -- from Maryland and Tennessee. The author's name is Carol Berger. We gave her the information, gave her all the documents that have come and gone to and from Conam and NRC, and we had discussions; and she did a calculation based on what she does. I have that available for

you.

Primarily what this does is it compartmentalizes dose through various organs, appendices, skin, whole body. The results that have been returned to us are that -- if I may pass these out, if you folks would like a copy -- the results indicate, if you go to the last two pages, page 25 and 26, I believe -- 24 and 25, based on our final assessment of the film badge of the conditions that existed, of the camera itself, of the structure of the camera, the uranium shielding, location of where the source might have been, based on Bill Chastain's statement of either one-third or one-half turn. 24 indicates a 2347 mR, or 2.347 R dose, in the scenario that Bill described to me. In the scenario that Bill described to you folks, with me present, 2535 or 2.5 R.

MR. PHILLIPS: Depending on how you describe whole body. Because I see a 42,075 left thigh, which would be the end point, I would assume, of the left thigh.

MS. PEDERSON: I think we need to speak a little

bit more loudly with the ventilation so we make sure the transcriptionist hears us.

MR. PHILLIPS: Good point.

MR. SLACK: But in my discussions with her, with Carol, her final analysis indicates that for a genuine whole body dose in the two scenarios described, the 2.3 or the 2.5 is consistent with the film badge, even with the Orise (phonetic) report that describes a zero to 20 R dose and 6.6 or 6 REM whole body.

MR. PHILLIPS: I read that as less than 20.

MR. SLACK: I know. That's what you said. And I would rather call it a zero to 20 R.

So we have subsequently had this survey performed, and I believe you folks should give consideration to it in your final decision of the 5 R dose to the whole body.

MS. PEDERSON: Any further discussion on No. 3?

MR. PHILLIPS: No. I think we're done.

MS. PEDERSON: Tom, No. 4?

MR. PHILLIPS: Is there anything in here proprietary in nature?

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

November 5, 1997

EA 97-207

Mr. Michael B. Creech
President
Conam Inspection, Inc.
1245 W. Norwood
Itasca, Illinois 60143

SUBJECT: ORDER IMPOSING CIVIL MONETARY PENALTY - $16,000

Dear Mr. Creech:

This refers to the letter dated July 7, 1997 from Clifton A. Lake, attorney for Conam Inspection, Inc., in response to the NRC Notice of Violation and Proposed Imposition of Civil Penalty (Notice) sent to you on June 9, 1997. Our letter and Notice described three violations (Violations I.A, I.B, and I.C) which were classified in the aggregate as a Severity Level II problem.

A civil penalty of $16,000 was proposed for the violations to emphasize the importance of compliance with NRC requirements, and the need for prompt identification and comprehensive correction of violations. In addition, two other violations (Violations II.A and II.B) were classified at Severity Level IV for which no civil penalty was assessed.

In its response to the Notice, Conam admitted Violations I.A and II.B; denied Violations I.B, I.C, and II.A; and requested remission or full mitigation of the civil penalty.

After consideration of Conam's response, we have concluded, for the reasons given in the Appendices attached to the enclosed Order Imposing Civil Monetary Penalty, the following: (a) Violation II.A is hereby withdrawn; and (b) Conam did not provide an adequate basis for withdrawing Violations I.B and I.C, for mitigating the severity level of Violations I.A, I.B, and I.C in the aggregate, or for mitigating the civil penalty associated with Violations I.A, I.B, and I.C. Accordingly, we hereby serve the enclosed Order on Conam Inspection, Inc., imposing a civil monetary penalty in the amount of $16,000. As provided in Section IV of the enclosed Order, payment should be made within 30 days of the date of this Order, by check, draft, money order, or electronic transfer, payable to the Treasurer of the United States and mailed to James Lieberman, Director, Office of Enforcement, U.S. Nuclear Regulatory Commission, One White Flint North, 11555 Rockville Pike, Rockville, MD 20852-2738. We will review the effectiveness of your corrective actions during a subsequent inspection.

In accordance with 10 CFR 2.790 of the NRC's "Rules of Practice," a copy of this letter and the enclosures will be placed in the NRC's Public Document Room.

Sincerely,

James Lieberman, Director
Office of Enforcement

Docket No. 030-31373
License No. 12-16559-01

Enclosures: As stated (2)

UNITED STATES
NUCLEAR REGULATORY COMMISSION

In the Matter of	)	
	)	Docket No. 030-31373
CONAM INSPECTION, INC.	)	License No. 12-16559-01
Itasca, IL	)	EA 97-207
	)	

ORDER IMPOSING CIVIL MONETARY PENALTY

I

Conam Inspection, Inc. (Conam or Licensee) is the holder of Byproduct Materials License No. 12-16559-01 issued by the Nuclear Regulatory Commission (NRC or Commission) on January 2, 1990. The license authorizes the Licensee to possess and use certain byproduct materials in accordance with the conditions specified therein at the Licensee's facilities in Columbus, Ohio; Gary, Indiana; Reading, Pennsylvania; Gallipolis, Ohio; and at temporary job sites anywhere in the United States where the NRC maintains jurisdiction for regulating the use of licensed material.

II

An inspection and investigation of the Licensee's activities were conducted between March 28, 1996 and November 12, 1996. The results of the inspection and investigation indicated that the Licensee had not conducted its activities in full compliance with NRC requirements. A written Notice of Violation and Proposed Imposition of Civil Penalty (Notice) was served upon the Licensee by letter dated June 9, 1997. The Notice states the nature of the violations, the provisions of the NRC's requirements that the Licensee had violated, and the amount of the civil penalty proposed for three of the violations in the aggregate (Violations I.A, I.B, and I.C).

The Licensee responded to the Notice in a letter dated July 7, 1997. In its response, the Licensee denied Violations I.B and I.C. and requested remission or full mitigation of the civil penalty.

III

After consideration of the Licensee's response and arguments for mitigation contained therein, the NRC staff has determined, as set forth in the Appendix to this Order, that the Licensee did not provide an adequate basis for withdrawing Violations I.B and I.C, or mitigating the severity level of Violations I.A, I.B, and I.C in the aggregate, or mitigating the civil penalty associated with Violations I.A, I.B, and I.C. Therefore, a civil penalty in the amount of $16,000 should be imposed.

IV

In view of the foregoing and pursuant to Section 234 of the Atomic Energy Act of 1954, as amended (Act), 42 U.S.C. 2282, and 10 CFR 2.205, IT IS HEREBY ORDERED THAT:

The Licensee pay a civil penalty in the amount of $16,000 within 30 days of the date of this Order, by check, draft, money order, or electronic transfer, payable to the Treasurer of the United States and mailed to James Lieberman, Director, Office of Enforcement, U.S. Nuclear Regulatory Commission, One White Flint North, 11555 Rockville Pike, Rockville, MD 20852-2738.

V

The Licensee may request a hearing within 30 days of the date of this Order. Where good cause is shown, consideration will be given to extending the time to request a hearing. A request for extension of time must be made in writing to the Director, Office of Enforcement, U.S. Nuclear Regulatory Commission Washington, D.C. 20555, and include a statement of good cause for the extension. A request for a hearing should be clearly marked as a "Request for an Enforcement Hearing" and shall be addressed to the Director, Office of Enforcement, U.S. Nuclear Regulatory Commission Washington, D.C. 20555, with a copy to the Commission's Document Control Desk, Washington, D.C. 20555. Copies also shall be sent to the Assistant General Counsel for Hearings and Enforcement at the same address and to the Regional Administrator, NRC Region III, 801 Warrenville Road, Lisle, IL 60532.

If a hearing is requested, the Commission will issue an Order designating the time and place of the hearing. If the Licensee fails to request a hearing within 30 days of the date of this Order (or if written approval of an extension of time in which to request a hearing has not been granted), the provisions of this Order shall be effective without further proceedings. If payment has not been made by that time, the matter may be referred to the Attorney General for collection.

In the event the Licensee requests a hearing as provided above, the issues to be considered at such hearing shall be:

(a) whether the Licensee was in violation of the Commission's requirements as set forth in Violations I.B and I.C of the Notice referenced in Section II above, and

(b) whether, on the basis of such violations and the additional violations set forth in the Notice of Violation that the Licensee admitted, this Order should be sustained.

FOR THE NUCLEAR REGULATORY COMMISSION

James Lieberman, Director
Office of Enforcement

Dated at Rockville, Maryland
this 5th day of November 1997

APPENDIX A
EVALUATIONS AND CONCLUSION

On June 9, 1997, the NRC issued to Conam Inspection, Inc., (Licensee or Conam) a Notice of Violation and Proposed Imposition of Civil Penalty (Notice) in the amount of $16,000 for violations identified during an NRC inspection and investigation conducted from March 28 through November 12, 1996. The Licensee responded to the Notice by letter dated July 7, 1997. With regard to the violations assessed a civil penalty, the Licensee admitted Violation I.A; denied Violations I.B and I.C; and requested remission or full mitigation of the civil penalty. The NRC's evaluations and conclusion regarding the Licensee's requests are as follows:

Restatement of Violation I.B

I.B 10 CFR 34.43(b) requires, in part, a licensee to ensure that a survey with a calibrated and operable radiation survey instrument is made after each radiographic exposure to determine that the sealed source has been returned to its shielded position. The survey must include the entire circumference of the radiographic exposure device and any source guide tube.

Contrary to the above, on February 27, 1996, at Eli Lilly, Indianapolis, IN, a Licensee radiographer did not perform an adequate survey after each radiographic exposure to determine that the sealed source had been returned to its shielded position, in that the survey did not include the entire circumference of the radiographic exposure device and the source guide tube.

Summary of Licensee's Response to Violation I.B

The Licensee, in its response, denies Violation I.B and states that on February 28, 1996, the day following the incident, the radiographer expressly stated to the Licensee's Radiation Safety Officer (RSO) that he had performed a full 360-degree circumferential survey of the radiographic exposure device.

NRC Evaluation of Licensee's Response to Violation I.B

The specific issue addressed in Violation I.B is whether the radiographer performed the required survey to determine that the source had completely been withdrawn into the radiographic exposure device. This requires, among other things, that the radiographer be aware of the results of the survey, especially the dose rate measured at the exit port (front) of the radiographic exposure device. As noted on page 7 of the Licensee's reply to the Notice, the Licensee states (regarding the radiographer's survey) that: "He then failed to properly read his survey meter when he performed a radiation survey in a 360-degree motion around the camera." The fact that the radiographer improperly read the survey meter means that he failed to properly determine: (1) whether the source had been completely withdrawn into the radiographic exposure device; and (2) the radiological conditions and potential hazards incident to use of radioactive material.

In addition, during the investigation conducted by the NRC's Office of Investigations, the radiographer stated that he surveyed the radiographic exposure device, but only on the sides. He also stated to the investigator that because of the position of the radiographic exposure device, he did not survey the front part. This conflicts with the information provided by the radiographer to the Licensee's RSO, but appears to be more in line with the facts of the case given the elevated exposure result to the radiographer's film badge.

In either case, whether the radiographer improperly read the survey meter or whether the radiographer failed to survey the front part, the NRC concludes that Violation I.B occurred as stated in the Notice.

Restatement of Violation I.C

I.C 10 CFR 20.1201(a)(1)(i) requires, with exceptions not applicable here, that a licensee control the occupational dose to individual adults to an annual dose limit of 5 rems total effective dose equivalent.

Contrary to the above, the Licensee did not limit the annual occupational dose to an adult radiographer to 5 rems, total effective dose equivalent. Specifically, the individual received a radiation dose of a minimum of 6 rems, total effective dose equivalent, during an event on February 27, 1996.

Summary of Licensee's Response to Violation I.C

The Licensee, in its response, denies Violation I.C, states that the NRC's methodology in determining the total effective dose equivalent is flawed, and does not agree with the intent of the regulations. The Licensee contends that using conventional dose assessment models, consensus industry standards, and the NRC's own definitions, the maximum likely Total Effective Dose Equivalent (TEDE) incurred by the radiographer during the event was 2.9 rems, based upon the radiographer's description of time and motion.

As a basis for its argument, the Licensee asserts that while the Licensee's consultant calculated a dose to the right thigh of 9.369 rems, this dose does not constitute the TEDE. The Licensee states that the dose limits are based on the 1976 [1977] recommendations of the International Commission on Radiological Protection (ICRP), which states that there is a predictable relationship between irradiation of the whole body and biological effects. The Licensee argues that the dose to the radiographer's thigh is not an appropriate predictor of biological effects, and thus should not be compared to the primary dose limit in 10 CFR 20.1201.

The Licensee asserts that the ICRP recommendations should take precedence in determining how the TEDE is computed. As such, in calculating the TEDE, the Licensee uses weighting factors for each tissue area which are derived from ICRP Publication 26. The Licensee believes this is an acceptable approach because the Statements of Consideration for the issuance of the revised 10 CFR Part 20 included, as reasons for the revision, the need to incorporate updated scientific information, to reflect changes in the basic philosophy of radiation protection, and to put into practice recommendations from ICRP 26 and subsequent ICRP publications. The Licensee asserts that sections 10 CFR 20.1003, which defines the TEDE,

and 10 CFR 20.1201(a), which specifies exposure limits, conform with ICRP 26 recommendations.

The Licensee maintains that the NRC's guidance on interpretation of 10 CFR 20.1201(c) permits use of external dose weighting factors. However, the Licensee argues that the language in 10 CFR 20.1201(c): (1) conflicts with the definition of deep-dose equivalent provided in 10 CFR 20.1003; (2) is inconsistent with the ICRP recommendations; and (3) deviates from the fundamental principles underlying the dose limits in 10 CFR Part 20.

The Licensee does note that the specific use of weighting factors other than 1.0 for all organs was not approved by 10 CFR Part 20; rather, 10 CFR 20.1003 states that "[f]or the purpose of weighting the external whole-body dose (for adding it to the internal dose), a single weighting factor, Wt = 1.0, has been specified. The use of other weighting factors for external exposures will be approved on a case-by-case basis until such time as specific guidance is issued." The Licensee notes that the NRC has not yet issued specific guidance in interpreting this issue; however, since the American National Standards Institute (ANSI) has issued N13.41, "Criteria for Performing Multiple Dosimetry," the Licensee believes that it should be able to use this methodology in computing its TEDE value. This guidance was utilized and the resulting TEDE was 2.9 rems.

The Licensee asserts that in light of the conflicting regulatory language in 10 CFR Part 20 regarding non-uniform exposure of the whole body, and the fact that 10 CFR 20.1003 allows weighting factors to be considered, the dose determined for the radiographer using ANSI N13.41 protocol was appropriate and consistent with the rationale underlying the occupational dose limits.

NRC Evaluation of Licensee's Response to Violation I.C

The specific issue addressed in Violation I.C is whether the radiographer's total effective dose equivalent as defined in the regulations exceeded the regulatory limits. The Licensee's use of ICRP 26 and ANSI N13.41 (i.e., use of a compartmentalization methodology to sum the effective dose equivalents for various areas of the whole body) was neither approved by the NRC nor in accordance with NRC requirements, for the reasons described below.

1. NRC Basis for Violation I.C: As noted in the Notice, 10 CFR 20.1201(a)(1)(i) requires, in part, that a licensee control the occupational dose to individual adults to an annual dose limit of 5 rems total effective dose equivalent. In addition, 10 CFR 20.1201(c) requires, in part, that the assigned deep-dose equivalent must be for the part of the body receiving the highest exposure and that the deep-dose equivalent may be assessed from surveys or other radiation measurements for the purpose of demonstrating compliance with the occupational dose limits, if the individual monitoring device was not in the region of highest potential exposure. As defined in 10 CFR 20.1003, Whole body means: "for purposes of external exposure, head, trunk (including male gonads), arms above the elbow, or legs above the knee."[1]

[1] The NRC's definition is based, in part, on the fact that these portions of the whole body contain blood-forming organs.

Based on the findings in the NRC inspection report dated November 18, 1996, the NRC concluded, as described in the Notice, that the radiographer received a TEDE of 6 rems. The conclusion was based on: (1) measurements of time and distances as re-enacted by the radiographer and the Licensee's film badge dose; and (2) the dose to the part of the body receiving the highest exposure (i.e., upper left thigh), given that the individual monitoring device was not in the region of highest potential exposure, the dose field from the radiographic exposure device was non-uniform, and the position of the radiographer and his film badge in relationship to the radiographic exposure device.

2. The Licensee's Use of ICRP 26 and ANSI N13.41: The NRC agrees that the dose limits in 10 CFR Part 20 are based on the ICRP 26 recommendations and acknowledges that the radiographer's thigh may not be an appropriate predictor of biological effects. However, the Licensee's use of ICRP 26 and the draft ANSI N13.41 for calculating the radiographer's whole-body dose is inappropriate in this case.

While the ICRP 26 recommendations in principle permit the use of external weighting factors, no specific recommendations were included concerning the use of weighting factors for external dose because there are practical problems with such use. The application of weighting factors also entails calculation of organ doses instead of whole-body doses from external radiation. One component of this calculation is the estimation of radiation attenuation as a function of the depth in the body. Therefore, as noted in the NRC's Statement of Consideration for 10 CFR Part 20 (56 FR 23369), the Commission decided that "application of weighting factors for external exposures will be evaluated on a case-by-case basis until more guidance and additional weighting factors (such as for the head and the extremities) are recommended ... The use of other weighting factors for external exposure may be approved on a case-by-case basis upon request to the NRC." (emphasis added). This means that, if a licensee proposes to use other weighting factors for external use, the licensee needs to develop the basis and technical justification for its request, submit the request to the NRC, and await approval of its request before using any modified weighting factors. To date, the Licensee has not submitted to the Commission such a request for an exemption of 10 CFR 20.1201.

With regard to ANSI N13.41, this is a draft standard that has been neither approved by ANSI, nor reviewed and approved by the Commission for use by NRC licensees. Moreover, ANSI N13.41 is not applicable because this case falls outside of the scope of that standard. This is evident from the standard itself, which states, under Scope, page 9, that "this standard contains criteria applicable to routine occupational activities (emphasis added) for when and how to use multiple dosimeters to monitor the body and extremity of individuals exposed to sources of ionizing radiation." The next paragraph under this section goes on to state, "Sudden or unexpected changes in the radiation environment as might occur during accidents are beyond the scope of this standard" (emphasis added).

The dose calculated by the consultant to the radiographer's right thigh was 9.369 rems. As noted in the Licensee's response, the footnote attached to 10 CFR 20.1003 specifies that a single weighting factor, Wt=1.0, be used for external exposures. However, rather

than using this weighting factor, the Licensee applied the factors provided in ANSI N13.41 (which are less than 1.0) to calculate exposures of portions of the whole body to arrive at the overall dose determination. The Licensee's use of weighting factors (on the basis that the NRC has not issued new weighting factors) without prior NRC approval is contrary to NRC requirements. Given the above, the Licensee's method for calculating the radiographer's exposure is incorrect.

3. Arguments Concerning Deep-Dose Equivalent: 10 CFR 20.1201(c) requires, in part, that the assigned deep-dose equivalent must be for the part of the body receiving the highest exposure. 10 CFR 20.1003 defines deep-dose equivalent as the dose equivalent at a tissue depth of 1 cm (1000 mg/cm^2) [regardless of the part of the whole body that is exposed]. Given that ICRP 26 did not include specific recommendations concerning the use of weighting factors for external dose, and the fact that there are practical problems in using weighting factors to assess external exposure as noted above, the NRC disagrees with the Licensee's argument that 10 CFR 20.1201(c) is inconsistent with the ICRP recommendations and that 10 CFR 20.1201(c) deviates from the fundamental principles underlying the dose limits in 10 CFR Part 20.

4. Use of the Consultant Results and Part 20 Weighting Factors: The NRC bases its enforcement actions on its regulations as codified in Title 10, Code of Federal Regulations. In this case, 10 CFR 20.1003 defines the weighting factor for the whole body as 1.0. As noted in the Licensee's response, the NRC has not approved the use of other weighting factors for external exposures nor has the NRC issued specific guidance on the use of other weighting factors. The regulations do allow for the use of a different methodology, but only after review and prior approval by the NRC. In this case, such approval was not obtained by the Licensee. Because the thigh (right or left) is an area of the body meeting the definition for whole body, the appropriate weighting factor per the regulations is 1.0. Therefore, if the Licensee chooses to use the consultant's results in conjunction with the Part 20 weighting factors, the radiographer's TEDE for the event would be:

Dose to right thigh (9.369 rems) x weighting factor (1.0) = 9.369 rems

The Licensee correctly notes that the limit for whole-body exposure in 10 CFR 20.1201(a)(1)(i) is a TEDE of 5 rems. 10 CFR 20.1003 defines the TEDE as the sum of the deep-dose equivalent (external exposure) and committed effective dose equivalent (internal exposure). In this case, the TEDE can be considered to be equal to the deep-dose equivalent, because there was no internal exposure involved.

The circumstances surrounding the exposure, as described in the inspection report and by the radiographer during the conduct of the NRC's investigation, demonstrated that the radiographer's body was between the radiographic exposure device and the radiographer's film badge. As noted in the radiographer's and RSO's description of the Licensee's time-motion study, no props were used - the event was discussed at a table with the radiographer describing to the RSO what occurred. During this time-motion discussion, it was not clear that the radiographer's film badge was at the point nearest the source. It was clear that the beam from the exit port of the radiographic exposure

device would be very directional and non-uniform. Later, on April 11, 1996, a re-enactment of the event by the radiographer in the presence of the Licensee's RSO and NRC personnel was performed and appropriate props were used. The radiographer was asked to demonstrate his activities at the time the exposure occurred. This re-enactment provided information that the Licensee had not obtained during its verbal time-motion discussion, namely, that the radiographer's leg was significantly closer to the source than was his film badge. For the sake of argument, the NRC has chosen to utilize the Licensee's dose calculation based on its verbal characterization, and the resulting dose obtained to the right thigh. If the Licensee chooses to use the consultant's results (which utilized variables from the NRC's re-enactment) in conjunction with the Part 20 weighting factors, the radiographer's TEDE for the event would be:

Dose to left thigh (42.075 rems) x weighting factor (1.0) = 42.075 rems

10 CFR 20.1201(c) states that "the assigned deep-dose equivalent and shallow-dose equivalent must be for the part of the body receiving the highest exposure. The deep-dose equivalent, eye dose equivalent and shallow-dose equivalent may be assessed from surveys or other radiation measurements for the purpose of demonstrating compliance with the occupational dose limits, if the individual monitoring device was not in the region of highest potential exposure, or the results of individual monitoring are unavailable." In this case, the individual monitoring device was not in the region of highest potential exposure, given the non-uniform nature of the dose field from the radiographic exposure device and the position of the radiographer and his film badge in relationship to the radiographic exposure device. Therefore, per this requirement, the assigned deep-dose equivalent must be for the right thigh (using the Licensee's computation), as it is part of the whole body. This results in an assigned deep-dose equivalent of 9.369 rems. As noted above, the TEDE consists of the sum of the deep-dose equivalent and committed effective dose equivalent. In this case, it is equal to the deep-dose equivalent, 9.369 rems, a value that is in excess of the limit specified in 10 CFR 20.1201(a)(1)(i).

Given the above, the NRC concludes that: (a) the Licensee has not provided a basis to substantiate that the radiographer's TEDE was below 5 rems; and (b) Violation I.C occurred as stated in the Notice.

Summary of Licensee's Request for Remission or Mitigation and Reconsideration of Severity Level

The Licensee offered several arguments in support of its request for remission or mitigation of the proposed penalty. Below is a summary listing of the Licensee's arguments that are related to its request for remission or mitigation, some of which have been consolidated. The NRC's evaluation follows each argument.

1. Licensee's Argument

The Licensee asserts that violations cited in Section I of the Notice should not be considered willful, for the following reasons:

- Based on the Licensee's discussion of the event on February 28, 1996, between the RSO and the radiographer, the Licensee concluded that the radiographer was negligent in failing to rotate the selector ring from the "operate" to the "lock" position and failing to depress the plunger mechanism of the radiographic exposure device.

- This act was not the result of deficiencies in the Licensee's Radiation Safety Program, nor did it follow other incidents of a similar nature. As evidence for its argument, the Licensee notes that seven prior unannounced NRC inspections had not identified any violations of applicable regulations.

- The Licensee disputes the fact that it was a "typical" practice of Conam radiographers to rely upon the automatic locking mechanism of their radiographic exposure devices rather than locking them in the manner required by the Licensee's radiation safety procedures.

- The Licensee believes that "[b]ecause the NRC's conclusion that a 'willful' violation has occurred is influenced by its erroneous conclusion that a violation of the occupational exposure limit occurred, its characterization of the violation as 'willful' is flawed."

NRC Evaluation

In its Notice, the NRC did not conclude that the violations in Section I were willful; rather, the NRC concluded that only Violation I.A was willful. In this regard, Section IV.C of the NRC Enforcement Policy defines willful violations to encompass not merely deliberate acts but acts of careless disregard as well. As part of the NRC's evaluation of this event, an investigation was conducted by the NRC's Office of Investigations (OI). That investigation concluded that the Licensee's radiographer willfully failed to follow the Licensee's procedures while operating the radiographic exposure device. The radiographer, who was knowledgeable of the requirement but failed to perform it due to being "lax," demonstrated careless disregard for NRC requirements, a condition that clearly meets the NRC's definition of a willful violation.

Given the results of the OI investigation, the problem with failing to follow procedures was not isolated. As noted both in the November 18, 1996 inspection report and during the subsequent Predecisional Enforcement Conference, the Licensee's policy for performing field audits did not encompass multiple exposures or other situations where the potential existed for a radiographer to fail to properly rotate the selector ring and depress the plunger. A single radiographic shot was often used, where this act would be performed prior to moving the radiographic exposure device. As such, the Licensee was unaware of the problem until it manifested itself in the exposure event that occurred

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on February 27, 1996, although a better field auditing technique may have allowed the Licensee to identify the problem prior to the February event. Therefore, the Licensee's arguments (i.e., lack of deficiencies in its radiation safety program and the lack of NRC findings during prior unannounced NRC inspections) do not alter the NRC's conclusion concerning the willful act of the radiographer.

When questioned by the OI investigator, approximately 25% of the Licensee's radiographers at the Gary, Indiana facility, including the radiographer associated with the event, admitted that on or prior to February 28, 1996, they failed on occasion to rotate the selector ring from the "operate" to the "lock" position and failed to depress the plunger mechanism as required by the Licensee's operating procedures. They stated to the investigator that they had been "lax," but that they were knowledgeable of the requirement. They also stated that after the memo was issued by the RSO discussing the event and the need to follow procedures, they no longer violated this requirement.

In determining whether the radiographer willfully failed to lock the radiographic exposure device, the NRC based its conclusion on interviews with the radiographer as noted above. The Licensee's belief that the NRC's conclusion concerning willfulness was influenced by whether a violation of the occupational exposure limit occurred is simply incorrect.

2. Licensee's Argument

The Licensee asserts that the NRC improperly denied identification and corrective action credit under the terms of the NRC Enforcement Policy, Section VI.B.2.b and c, by ignoring essential facts. The Licensee asserts that while the incident was identified through an event, this fact does not preclude identification credit where the problem arose from a single incident of negligence by a radiographer in violation of well-publicized Conam safety procedures, where the Licensee's quarterly radiation safety compliance audit program was demonstrably adequate, and where there were no prior deficient occurrences to identify the problem.

In addition, the Licensee argues that its corrective actions were also prompt and comprehensive and should result in credit. The Licensee believes that the incident was promptly and comprehensively addressed and corrected by the Licensee's RSO through his analysis of the film badge, his issuance of a February 29, 1996, memorandum reminding all Conam radiographic personnel of the proper procedure for operating radiographic exposure devices, his withdrawal of the radiographer from further radiographic duties, and the suspension of the radiographer without pay for one week.

The Licensee disagrees with the NRC's position, as described in the Notice, that credit should not be given because the Licensee did not confirm that each radiographer had received the February 29, 1996, memorandum from the RSO, nor had the Licensee instituted any monitoring/auditing program to evaluate the effectiveness of the memorandum. The Licensee states that there is no evidence that the radiographers did not receive the memorandum, and that there has been no repetition of the problem since the February event's occurrence. The Licensee believes that the NRC's dismissal

of credit for identification and corrective action ignores the fact that the February event was the only one of its kind against a record of no violations whatsoever during seven prior NRC inspections, and no that subsequent violations since the event have been identified by NRC inspections.

NRC Evaluation

The NRC Enforcement Policy, Section VI.B.2.b, discusses the criteria to be considered when deciding if a licensee should be given credit for actions related to identification. These circumstances include: (i) whether the problem requiring corrective action was NRC-identified, licensee-identified, or revealed through an event; and (ii) for a problem revealed through an event, the ease of discovery, the licensee's self-monitoring effort, the degree of licensee initiative in identifying the problem requiring corrective action, and whether prior opportunities existed to identify the problem (Section VI.B.2.b(2)(ii) of the Enforcement Policy).

The NRC and the Licensee both agree that the problem requiring corrective action was revealed through an event. Therefore, the criteria in Section VI.B.2.b(2)(ii) of the Enforcement Policy are applicable in this case. Regarding the ease of discovery, as well as the Licensee's self-monitoring effort, the radiographer involved in the incident reported the problem to the Licensee's RSO; and the problem was not identified through any self-monitoring action of the Licensee's RSO or management, such as an audit. Regarding the degree of licensee initiative in identifying the problem requiring corrective action, the Licensee's initiative does not deserve credit, as described below. Regarding the existence of prior opportunities to identify the problem, as stated earlier, the OI investigation revealed that approximately 25% of the Licensee's radiographers and assistant radiographers at the Gary, Indiana facility admitted that on or prior to February 28, 1996, they on occasion failed to rotate the selector ring from the "operate" to the "lock" position and failed to depress the plunger mechanism as required by the Licensee's operating procedures. Thus, the problem with failing to follow procedures was not isolated. The Licensee performs quarterly field audits of its radiographers. As noted in the inspection report and during the Predecisional Enforcement Conference, the Licensee's policy for performing field audits did not encompass multiple exposures or other situations where the potential existed for a radiographer to fail to properly rotate the selector ring and depress the plunger. Therefore, numerous prior opportunities existed to identify the problem, yet the problem was not identified prior to the February 27, 1996 incident. Thus, credit for identification is not warranted.

The NRC Enforcement Policy, Section VI.B.2.c, discusses the criteria to be considered when deciding if a licensee should be given credit for prompt and comprehensive corrective actions. These criteria include: (i) the timeliness of the corrective action, (ii) the adequacy of the licensee's root cause analysis for the violation, and (iii) the comprehensiveness of the corrective action. As stated in the inspection report, the NRC acknowledges the Licensee's prompt action in issuing a memorandum to all radiation safety supervisory personnel advising all radiography staff to complete a full and accurate survey of the radiographic exposure device, collimator, guide tube, and connector after each exposure and to secure the source assembly in accordance with

the Licensee's procedures. However, although the issuance of the memorandum was timely, it does not constitute a comprehensive corrective action.

Specifically, after the Licensee received the vendor's report indicating the radiographer's dose, the Licensee did not perform an exact time-motion study at the scene of the event to determine the locations of the whole body, film badge and radiographic exposure device exit port. Photographs of the scene that were obtained later did not include the position of the radiographer. In addition, the Licensee could not confirm that each radiographer had received the memorandum, nor had the Licensee instituted any monitoring/auditing program to evaluate the effectiveness of the memorandum. The Licensee's argument that there is no evidence that the radiographers did not receive the memorandum is not persuasive; a comprehensive corrective action would ensure that each radiographer had received, reviewed, and understood the memorandum, and would monitor the radiographers' understanding of and compliance with the memorandum. Such comprehensive corrective actions were not implemented by the Licensee.

Finally, the fact that no violations had been identified during seven NRC inspections prior to the February 27, 1996 event, although commendable, is not relevant as far as credit for corrective action is concerned. Further, in accordance with Section VI.B.2.c of the NRC Enforcement Policy, the adequacy of a licensee's corrective actions is judged at the time of the enforcement conference, not on the basis of whether subsequent violations following the event have been identified by the NRC. Given the above, the NRC concludes that while the Licensee took some timely actions, on balance, such actions did not address the root cause of the violations and were not comprehensive. Thus, credit for prompt and comprehensive corrective actions is not warranted.

3. Licensee's Argument

The Licensee asserts that the NRC Enforcement Policy should find, at worst, that the February 27,1996 incident involved two non-willful Severity Level III violations which, with appropriate identification and corrective action credit, do not justify any civil penalty. The Licensee asserts that to aggregate the violations cited in Section I of the Notice and assign a Severity Level II "problem" to this collection is not consistent with the NRC's Enforcement Policy published in 60 FR 34381 (June 30, 1995). The Licensee believes that the NRC's Notice compounds that error by determining that the Severity Level II problem was willful, and on that basis justifying a 100% escalation of the $8,000 Severity Level II base penalty.

NRC Evaluation

As described above, the NRC has determined that Violation I.A was willful, that Violations I.A, I.B, and I.C occurred as described in the inspection report, and that credit for identification and corrective action is not warranted. The NRC Enforcement Policy, Section IV.A, states, in part, that the purpose of aggregating violations is to focus the licensee's attention on the fundamental underlying causes for which enforcement action appears warranted and to reflect the fact that several violations with a common cause

may be more significant collectively than individually and may, therefore, warrant a more substantial enforcement action. As noted in the Notice, in consideration of the willfulness involved, the relationship of these violations to a single incident, and the fact that two safety barriers were breached, the violations are of very significant regulatory concern. Therefore, consistent with Section IV.A of the Enforcement Policy, the violations in Section I of the Notice were combined to reflect that, collectively, they are more significant than individually and, therefore, warrant a more substantial enforcement action.

As to the Licensee's argument concerning escalation of the $8,000 base penalty, the NRC did not escalate the civil penalty on the basis of a willful violation. The base amount for a Severity Level II problem is $8,000. Credit was not warranted for the identification and corrective action factors. Therefore, in accordance with the civil penalty assessment process described in Section VI.b.2, the civil penalty for the Severity Level II problem is twice the base amount (i.e., $16,000).

NRC Conclusion

The NRC concludes that the Licensee did not provide an adequate basis for withdrawing Violations I.B and I.C, for mitigating the severity level of Violations I.A, I.B, and I.C in the aggregate, or for mitigating the civil penalty associated with Violations I.A, I.B, and I.C. Therefore, the proposed civil penalty in the amount of $16,000 should be imposed by order.

APPENDIX B
EVALUATION OF VIOLATIONS
NOT ASSESSED A CIVIL PENALTY

Of the violations not assessed a civil penalty, the Licensee admitted violation II.B and denied Violation II.A.

Restatement of Violation II.A

II.A 10 CFR 20.2203(a)(2)(i) requires, in part, that a licensee submit a written report within 30 days after learning of a dose in excess of the occupational dose limits for adults as defined in 10 CFR 20.1201.

Contrary to the above, on April 11, 1996, the Licensee learned of an event that caused an adult radiographer to receive a total effective dose equivalent of more than 5 rems total effective dose equivalent and did not submit a written report within 30 days as required.

Summary of Licensee's Response to Violation II.A

The Licensee, in its response, denies Violation II.A and states that, because the radiographer was not exposed to a dose in excess of 5 rems, total effective dose equivalent, no reporting obligation arose under applicable regulations.

NRC Evaluation of Licensee's Response to Violation II.A

The specific issue raised by Violation II.A was whether the Licensee was required to submit a report to the NRC after learning of a dose in excess of the occupational dose limits for adults as defined in 10 CFR 20.1201. In this case, the Licensee's evaluation of the circumstances did not appear to be adequate in that the Licensee did not complete an exact time/motion study at the scene of the event to determine the locations of the whole body, film badge, and radiography exposure device. As a result, the Licensee did not conclude that an exposure in excess of the dose limits occurred.[2]

By letter dated June 23, 1997, the Licensee did submit the report required by 10 CFR 20.2203(a)(2)(i), but solely on the basis that the NRC's letter transmitting the Notice of Violation and Proposed Imposition of Civil Penalty specifically stated that the Licensee was required to make such a report. As noted above, the Licensee still contends that an exposure in excess of regulatory limits did not occur based on the Licensee's unapproved methodology it used to compute the TEDE.

Given that the Licensee did not learn that the radiographer's exposure was in excess of regulatory limits, and that, after being informed by the NRC of the radiographer's exposure, the Licensee submitted a report per the requirements of 10 CFR 20.2203(a)(2)(i), the NRC concludes that Violation II.A should be withdrawn.

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[2] For details concerning the Licensee's evaluation, see Summary of the Licensee's Response to Violation I.C and the NRC's Evaluation of the Licensee's Response to Violation I.C.

NRC Conclusion

The NRC staff concludes that the Licensee provided an adequate basis for withdrawing Violation II.A. Therefore, Violation II.A should be withdrawn.

range to be unreliable?

THE WITNESS: No.

BY MR. BROOKS:

Q Let me ask you this, you use calculations that show up in Deposition Exhibit 10 have a range of 6.6 to just slightly over 86, correct?

A If I could take a look, yeah, right, right about 86.

Q And of that range you know from the blood test that the upper three-quarters of the range cannot be accurate, is that correct?

A No, that's not necessarily correct.

Q Why?

A Because the blood estimate gives you, as I mentioned earlier, the dose that the entire body would have had to seek, EG, you would have to have 20 REM's for example up at the chest, not just at the lower thigh. The dose calculation would give you 86 REM, for example, I believe the exact location here is the left leg, well the left leg is not going to give you the blood forming organs of the ribs. Actually, those two numbers could, in fact, be compatible. Highly unlikely though that if you were looking at 86 REM's to the thigh you would not also be seeing close to 20 REM's to the whole body, EG, the blood forming organs of the ribs.

Q So what you're saying then is that the calculation of a dose to the thigh does not correlate to the dose to the whole body in reality?

A No, it does not correlate to a problem with blood.

Q Well, let me ask you this, how do you reconcile the fact that most of the calculations in the dose reconstruction yield figures that are above 20 REM, when the blood work shows a result of less than 20 REM.

A Again, the calculations that you're looking at here are for the part of the body that's closest to the camera. Whereas, the blood results would be looking at as if the entire body received that number, 20 REM.

Q But aren't you calling the result that you're calculating for the thigh a whole body result?

A I'm calling that a legal whole body value.

Q What's the difference between a legal whole body value and a real whole body value?

A Ten CFR part 20 defines the whole body. It says any part, any part of the body that consists of and it goes through the body parts lower, the thigh, the chest, the trunk, the arms above the, I believe it's arms above the forearm and it defines all of those areas as being whole body.

Now if any portion of that part of the body receives the dose that per 10 CFR, as you mentioned earlier,

20.1201C, that's the portion that's to be assigned the whole body dose. Does that technically give you a dose that's greater than what you see for example at some other part of the body? Yes, it does. But that is the legal definition of whole body.

Q So there's a discrepancy between the legal definition of whole body dose and the whole body dose --

A What part of the body would actually get.

Q Is that correct?

A Yes, especially for unisotropic fields where you're talking about part of your body can be in the field and part of your body may not be in the field. Obviously, you're going to reach a situation where part of your body is going to receive exposure and part of your body not.

Now what you may end up with, of course, is a tumor that then develops on your left arm, from a health standpoint that doesn't do you a whole lot much more good than if you dispelled leukemia in your entire blood system. Pick one, which would you like to die from? It's not really good.

So that's the reason why the limits are set the way they're set low for any part of that body that could be exposed. Because that's where you have the highest, what's the term used here, body effect is the guess way to term. I mean there is blood forming tissue here, okay, it's not all

of your blood forming tissue but it's some of your blood forming tissue. If you happen to develop leukemia or cancer from that, it doesn't make a whole lot of difference whether it starts here or starts here, or starts everywhere. You got the problem. So that's why the limits are set for all those parts of the body that are defined.

Q In Mr. Chastain's case, the blood results showed no tendency toward forming of any leukemia or any other blood abnormalities, is that correct?

A It showed that he had, I believe, two chromosomal deficiencies and they, therefore, said based on that, they assumed that the dose was about 12, but that their MDA was 20 up. And therefore, as far as I'm concerned, as I mentioned earlier, if they say that their minimum detectable number that they can rehang a hat on is 20, then since they're saying it's less than that, as far as I'm concerned, it's less than 20. If you look at those calculations, you'll note that our actual best estimate calculation was 15, which is also less than 20. That's our probable, probable low bound. The best estimate, I believe came out to the left leg of about 34. Again, even the 86 number to the leg would still give you a value which would not result in chromosomal damages, if that's the only part that got a high value.

Q Would you turn to the fifth page of Conam

Deposition Exhibit 10.

A Best estimate analysis, okay.

Q Does that represent U.S. NRC's best estimate analysis of Mr. Chastain's dose?

A I'm going to make that assumption as the best estimate analysis is based on what we thought were all the orientations where he said he was going to be, correct.

Q And what's the result shown here on page 5 of Deposition Exhibit 10?

A 34 REM.

Q Is that likely to be inaccurate given the blood work?

A No. Again, as I mentioned earlier, the blood work and this number would not necessarily yield the same conclusions.

Q Can you tell given the blood work --

A The blood work as I said earlier is looking at the entire body and this is a calculation, I can read from what it says right here, is the upper leg dose to the left leg only.

Q When we're talking about chromosomal damage indications are those the result of acute or chronic doses of radiation?

A Well, in this case, it would have been acute.

Q And it could also be chronic exposure?

Carol D. Berger

Professional Qualifications

Ms. Berger has over twenty years experience in nuclear and radiological activities with emphasis in strategic planning, radiation dosimetry, instrumentation, and applied health physics. As a co-founder of **IEM**, Inc., Ms. Berger is actively involved in performance of radiological dose assessments, regulatory interactions, site decommissioning, program evaluations, program development, pathway analyses, risk assessments, dosimetry evaluations, assessment and control of sources of non-ionizing radiations, waste management programs, environmental monitoring programs, and detection and quantification of low-levels of radioactivity.

Education

M.S., Health Physics, San Diego State University, San Diego, California; 1979
M.S., Radiation Physics, San Diego State University, San Diego, California; 1977
B.S., Physics/Chemistry, San Diego State University, San Diego, California; 1972

Certifications

Certified Health Physicist (Comprehensive): American Board of Health Physics, 1983
Re-certified: 1987, 1991, 1995

Experience and Background

1994 - Present — *Founder, Integrated Environmental Management, Inc., Rockville, Maryland.*
Provides high-quality strategic environmental management services to commercial and government clients. As a member of the client's response team, works with clients to promote an understanding of what is required to achieve and/or maintain compliance in the eyes of all pertinent regulatory agencies, individually or jointly; develop an overall strategy for achieving compliance and reduce liabilities in a technically-sound, legally-defensible, and fiscally-conservative business manner; recommend specific solutions that are compatible with the client's operating philosophy; and provide insights into future regulatory issues and their impact as input to the client's long-range business planning and cost forecasting process.

1989 - 1994 — *Senior Technical Consultant, IT Corporation/Nuclear Sciences, Washington, D.C.*
Performed health physics consulting for government and commercial facilities in Internal and External Dosimetry; Radiation Monitoring; Environmental Monitoring; Instrumentation; Emergency Response and Preparedness; Site Decommissioning; Radioactive Waste Management; Radiation Risk Assessment; Training; Licensing and Regulatory Negotiations; and Non-ionizing Radiation

1986 - 1989 *Senior Health Physicist, IT Radiological Sciences Laboratory, Knoxville, Tennessee* Performed health physics consulting for government and commercial facilities in Internal and External Dosimetry; Radiation Monitoring; Environmental Monitoring; Applied Health Physics; Instrumentation; Radioactive Waste Management; Training; and Non-ionizing Radiation.

1983 - *1986* *Radiation Dosimetry Group Leader, Oak Ridge National Laboratory, Oak Ridge, Tennessee.* Responsible for internal and external dose assessment and programs for ORNL employees, visitors and contractors. Experience included Internal and External Dose Assessment; Monitoring Program Design and Implementation; Instrumentation Development; Site Characterizations; Personnel Management; and Training.

1978 - *1983* *Internal Dose Group Leader, Oak Ridge National Laboratory, Oak Ridge, Tennessee.* Responsible for development of the ORNL Whole Body Counter Facility for detection and quantification of the actinides in-vivo. Experience included: Internal Dose Assessment; Monitoring Program Design and Implementation; Instrumentation Development; Special Studies; Personnel Management; and Training.

1978 - *1986* *Adjunct Faculty, Oak Ridge Associated Universities, Oak Ridge, Tennessee.* Professional training courses and general classes in the following health physics and radiation protection areas: Internal Dose Assessment; In-vivo Monitoring and Bioassay Methodologies; Instrumentation, and Applied Health Physics.

1979 - *1980* *Health Physics and Dosimetry Task Group Member, President's Commission on the Accident at Three Mile Island, Washington, D.C.* Tasks included: Internal Dose Assessment from Whole Body Counting Results; Estimates of Source Term from in-plant Monitoring Systems; Atmospheric Dispersion Modeling and Population Dose Assessment; and Development of Health Physics Sequence of Events.

Professional Society Membership

American Academy of Health Physics (President, 1995; Executive Committee, 1995-1997; Chair of Strategic Planning Committee, 1997)
Health Physics Society
Baltimore-Washington Chapter - Health Physics Society (Treasurer, 1993-1994)
Sigma Xi - Scientific Research Society
American Bar Association, Section of Natural Resources, Energy, and Environmental Law

Publications

Over 30 professional publications; over 40 oral presentations; over 100 technical reports; more than 15 training courses taught.

Other Appointments/Awards

East Tennessee Chapter - Health Physics Society (President, 1986; President-Elect, 1985; Secretary, 1981-1982)

San Diego Chapter - Health Physics Society (Charter member)

American Board of Health Physics, Comprehensive Panel of Examiners, 1989-1993.

ASTM Task Group E-10.04.27 "Transuranic Wound Analysis"; 1986 to present

ANSI Standards Committee (ANSI N13.41) on Multiple Badging; 1986 to 1996 (Chairman, PlanCo-59 Working Group, 1990 to 1996)

ANSI Standards Committee (ANSI N13.39) on Internal Dosimetry Programs; 1994 to present

NCRP Scientific Committee 46-10, "Assessment of Occupational Exposures from Internal Emitters", 1989 to present.

Member of the Health Sciences Advisory Council for the School of Health Sciences, Purdue University, 1995 to 1998.

DOE/IAEA Whole Body Counter Intercalibration Committee (1980-1986)

Consultant to Knoxville Academy of Medicine, Mass Casualty Simulation (1984-1985)

Consultant to the National Cancer Institute to Evaluate Devices and Techniques to Determine Previous Radiation Exposure under Public Law 98-54 (Award for participation presented by Oak Ridge Associated Universities, April, 1988.)

Steering Committee Member, U. S. Department of Energy Task Group on the Education of Future Health Physicists - 1989 to 1991.

Technical reviewer and referee for *Health Physics*, *Nuclear Technology*, and *Radiation Protection Management*

IT Corporation *Distinguished Technical Associate* - June, 1992.

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Berger, C. D., D. E. Bihl, E. M. Brackett, D. R. Fisher, F. E. Gallagher, J. P. Griffin, R. B. Holtzman, W. S. Loring, K. S. Thind, "Draft ANSI N13.39, American National Standard for Design of Internal Dosimetry Programs - Minimum Acceptable Requirements", presented at the 42nd Annual Meeting of the Health Physics Society, San Antonio, Texas, June 30, 1997.

Training Courses (Classes) Given

"Laboratory Assessment of Body Burden," REAC/TS Training Course for Emergency Medical Personnel, 1978-1983, Oak Ridge Associated Universities.

"Radiation Detection Instrumentation," REAC/TS Training Course for Emergency Medical Personnel, 1978-Present, Oak Ridge Associated Universities.

"Whole Body Counting," Five-Week Training Course for Health Physics Personnel, 1979-1986, Oak Ridge Associated Universities.

"Bioassay," Five-Week Training course for Emergency Medical Personnel, 1979-1983, Oak Ridge Associated Universities.

"Internal Dosimetry," REAC/TS Training Course for Emergency Medical Personnel, 1978-1983, Oak Ridge Associated Universities.

"Special Detectors/Instrumentation for Low-Level Counting," Ten Week Training Course for Health Physics Personnel, 1979-1981, Oak Ridge Associated Universities.

"Basic Radiation Protection," REAC/TS Course for Health Physics Technicians, 1978-1982, Oak Ridge Associated Universities.

"NRRPT Review Course-Bioassay/Whole Body Counting," East Tennessee Chapter Health Physics Society, 1979-1986, Oak Ridge, Tennessee.

"ABHP Review Course - Whole Body/Lung Counting," East Tennessee Chapter Health Physics Society, 1979-1984, Oak Ridge, Tennessee.

"In-Vivo Detection of Internally Deposited Radionuclides," TVA Operator Certification Program, 1982, 1983, Sequoia Training Facility, Chattanooga, Tennessee.

"Radiation Monitoring," ORNL Technician Orientation Course, 1981, 1982, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

"Lung Counting," Five-Week Training Course for Health Physics Personnel, 1980,1983, Oak Ridge Associated Universities.

"NRRPT Review Course - Personnel Dosimetry," 1984-1986, Oak Ridge, Tennessee.

"Principles of Whole Body Counting" - Health Physics Society Professional Enrichment Program, Salt Lake City, Utah, July 5, 1987.

"Practical Internal Dosimetry for Operational Health Physicists", presented to health and safety personnel, Calloway Nuclear Plant, Union Electric Corporation, Columbia, Missouri, January 16, 1989.

"Real-Life Whole Body Counting", (IT Corporation Report No. IT/NS-89-111) Professional Enrichment Program, Annual Meeting, Health Physics Society, June 25, 1989, Albuquerque, New Mexico.

"Safety Light Corporation - General Employee Training in Radiation Protection", developed (including videotape) and presented to Safety Light Corporation and USR Industries employees, Bloomsburg, Pennsylvania, June 30, 1988.

"Radiation Worker Training -- Armed Forces Radiobiology Research Institute", developed and presented (including videotape) to the Safety and Health Department, Armed Forces Radiobiology Research Institute, Bethesda, Maryland.

"General Employee Training in Radiation Protection", presented to GE-Lighting, Cleveland, Ohio (with K. Ladrack).

"Radiation Worker Training for General Electric - Lighting Division", presented to GE-Lighting, Cleveland, Ohio (with S. J. Layendecker).

"Site Specific Internal Dose Assessment and Internal Radiation Monitoring", presented to Union Electric Corporation, Callaway Nuclear Plant, January 20-24, 1992, Fulton, Missouri.

"Skin Dose Assessment", presented to the U. S. Nuclear Regulatory Commission, Region I, October 13-14, 1992, King of Prussia, Pennsylvania.

"Skin Dose Assessment", presented to the U. S. Nuclear Regulatory Commission, Region II, December 10-11, 1992, Atlanta, Georgia.

"Skin Dose Assessment", presented to the U. S. Nuclear Regulatory Commission, Region III, April 5-6, 1993, Glen Ellyn, Illinois.

"Internal Dosimetry", Course H-312, presented to the U. S. Nuclear Regulatory Commission, Technical Training Center, June 28-July 2, 1993, Chattanooga, Tennessee (with S. H. Fong)

"Internal Dosimetry for the Applied Health Physicist", presented to Illinois Power, Clinton Nuclear Station, August 3-5, 1993, Clinton, Illinois.

"Internal Dosimetry", Course H-312, presented to the U. S. Nuclear Regulatory Commission, Technical Training Center, March 7-11, 1994, Chattanooga, Tennessee (with S. H. Fong).

"NORMalizing Radiation Protection Programs", presented at the Edison Walthall Hotel, Jackson, Mississippi, October 21, 1994 (with B. A. Kelly and J. P. Reynolds).

"Interactions of Radiation With Matter", Baltimore-Washington Chapter HPS Basic Radiological Health Course, National Institute of Standards and Technology, October 27, 1994.

"Understanding Radiation Protection Programs - Practical Methods for Demonstrating Compliance with State Regulations", presented at Kay-Ray/Sensall, Inc., Mount Prospect, Illinois, May 1, 1995.

"Managing Radiation Protection Programs - Demonstrating Compliance with U. S. Nuclear Regulatory Commission Regulations", presented at Shieldalloy Metallurgical Corporation, Newfield, New Jersey, May 17, 1996.

"Internal Dosimetry", presented to the Radiation Safety Department, USDOE Pantex Plant, Steptember 9-13, 1996, Amarillo, Texas (with S. H. Fong).

"Not Only Unraveling the Thorium Mystery, but Doing Something About It (Or How to Keep Thorium from Becoming a Thorn in your Side)", Professional Enrichment Program, 42nd Annual Meeting of the Health Physics Society, San Antonio, Texas, June 29, 1997.

"Review of Important Internal Dosimetry Concepts", presented at the Baltimore-Washington Chapter HPS Certification Review Course, USNRC Building 2, February 19, 1998.

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	)	
	)	Docket No. 30-31373-CivP
CONAM INSPECTION, INC.	)	
	)	
(Order Imposing Civil Monetary Penalty)	)	ASLBP No. 98-735-01-CivP

CERTIFICATE OF SERVICE

I hereby certify that copies of **CONAM'S MOTION TO AUTHORIZE WEIGHTED DOSE CALCULATION** in the above-captioned proceeding have been served the following by sending the attached via Federal Express® on the 29th day of May, 1998.

Charles Bechhoefer, Chairman
Administrative Judge
Atomic Safety and Licensing Board
Mail Stop: T-3 F23
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555
Fax: (301) 415-5599

Charles A. Barth
U.S. Nuclear Regulatory Commission
Office of the General Counsel
Washington, D.C. 20555
Fax: (301) 415-3725

Dr. Richard F. Cole
Administrative Judge
Atomic Safety and Licensing Board
Mail Stop: T-3 F23
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555
Fax: (301) 415-5599

Regional Adminstrator
U.S. Nuclear Regulatory Commission
Region III
801 Warrenville Road
Lisle, Illinois 60532

Mr. Charles N. Kelber
Administrative Judge
Atomic Safety and Licensing Board
Mail Stop: T-3 F23
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555
Fax: (301) 415-5599

Office of Commission Appellate Adjudication
Mail Stop: O-16 G15
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Atomic Safety and Licensing Board Panel
Mail Stop: T-3 F23
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Adjudicatory File (2)
Atomic Safety and Licensing Board Panel
Mail Stop: T-3 F23
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Secretary (2)
Attn: Rulemakings and Adjudications Staff
Mail Stop: O-16 G15
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dennis C. Dambly
U.S. Nuclear Regulatory Commission
Office of the General Counsel
Washington, D.C. 20555
Fax: (301) 415-3725

Clifton A. Lake, Esq.
Counsel for Conam Inspection, Inc.

Dated: May 29, 1998