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Special External Dose Reconstruction Considerations for Mallinckrodt Workers	
Approval: Signature on File Date: 10/26/2005 J.W. Neton, Associate Director for Science	Supersedes: Revision 0

RECORD OF ISSUE/REVISIONS

ISSUE AUTHORIZATION DATE	EFFECTIVE DATE	REV. NO.	DESCRIPTION
10/26/2005	10/26/2005	0	Document initiated to provide guidance on the application of geometry-based dose correction factors to external dosimetry badge data for Mallinckrodt workers in particular job classifications

1.0 Purpose

The purpose of this technical information bulletin (TIB) is to provide guidance on the application of geometry-based dose correction factors to external dosimetry badge data for Mallinckrodt workers in particular job classifications. The factors are to be used for the periods of time where the individual's work history places him/her in that job. Job classifications will be discussed in section 3.0.

2.0 Special Exposure Considerations

Consideration must be given to the role that geometry plays in dose reconstruction in general and for Mallinckrodt workers in particular. Jobs at the facility ranged from those that required continuous hand or near-hand contact during a work day to those jobs where contact was only at a distance and of short duration. The distance and time factors could result in an underestimation of the reconstructed dosimeter and missed dose to organs located in the lower torso region of the body (stomach, liver, bladder, prostate, ovaries, testes, etc…) for high contact jobs. The degree of underestimation, or in some cases overestimation, is also dependent upon the shielding between the worker and source of radiation.

2.1 Exposure Geometries

Exposure geometry is a special consideration in dose reconstruction of energy employees who worked with uranium metal, powders and residues. An underestimation of the dose could occur if the energy employee wore his/her dosimeter on the lapel and not the center area of the chest or on the waist. This underestimation could result due to the difference in relative distance between the external radiation source, the organ of interest, and the dosimeter. Organs in the lower torso are affected most. The dose to lung is considered to have been reasonably approximated by the dosimeter at least to within the dosimeter uncertainty and the dose to the face and head would have been lower than the dose measured by the dosimeter worn on the lapel.

2.2 ATTILA Radiation Transport Software

Attila is a deterministic radiation transport environment that can directly use CAD data and model complex geometry efficiently and accurately to solve large 3-D problems.

Attila can solve for neutron, gamma, charged particle and infra-red transport and accounts for the same transport effects as Monte Carlo but is faster and no variance reduction is required. Attila directly solves the differential form of the Boltzmann transport equation. For charged particles, the Boltzmann-Fokker-Planck transport equation is solved. It discretizes in space, angle and energy to solve for flux as a function of angle, energy and particle type, at every location in the computational domain.

3.0 Methodology

3.1 ATTILA Model Development

A review of table 18, Job titles and classifications with geometry factor, from the **Basis for Development of an Exposure Matrix for the Mallinckrodt Chemical Company St.**

Louis Downtown Site and the St Louis Airport Site, St. Louis, Missouri, Period of Operation: 1942–1958 was made to determine the type of scenario/s for which ATTILA could be used to develop general correction factors for the lower torso of an energy worker. The lower torso is defined as those organs below line A in figure 1.

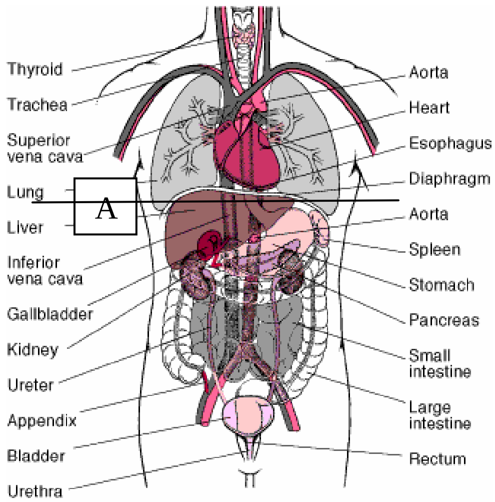

Figure 1 Diagram of Human Torso [4]

Three uranium job exposure scenarios were evaluated that exemplified the range of body/source orientations for which badge correction factors could be determined. These were pitchblende/cleanup activities, ingot/machining activities and de-nitration pot activities. Only the photon contribution was analyzed. This is not a misrepresentation as we are interested in relative values between body locations and the photon components will reflect the beta problem. The human figure was divided into head, upper torso, badge, lower torso and hands. Dose factors were developed based on flux/dose at the badge relative to the other body locations.

The pictorial results for pitchblende/cleanup activities, ingot/machining activities and de-nitration pot activities are seen for in figures 2, 3 and 4 respectively. Each factor is relative to the dosimeter/badge worn on the upper chest. The factors, as calculated, are in table 1.

Table1

	INGOT	PITCHBLENDE	DENITRATION POT
HEAD	0.4	0.409448819	0.571428571
BADGE	1	1	1
LOWER TORSO	2.125	2.11023622	0.033333333
HANDS	3.65	1.204724409	1.666666667

It should be noted that there is a significant reduction in dose to the head for all scenarios and the lower torso of the de-nitration pot. In assigning the badge dose to these body locations we are being claimant favorable.

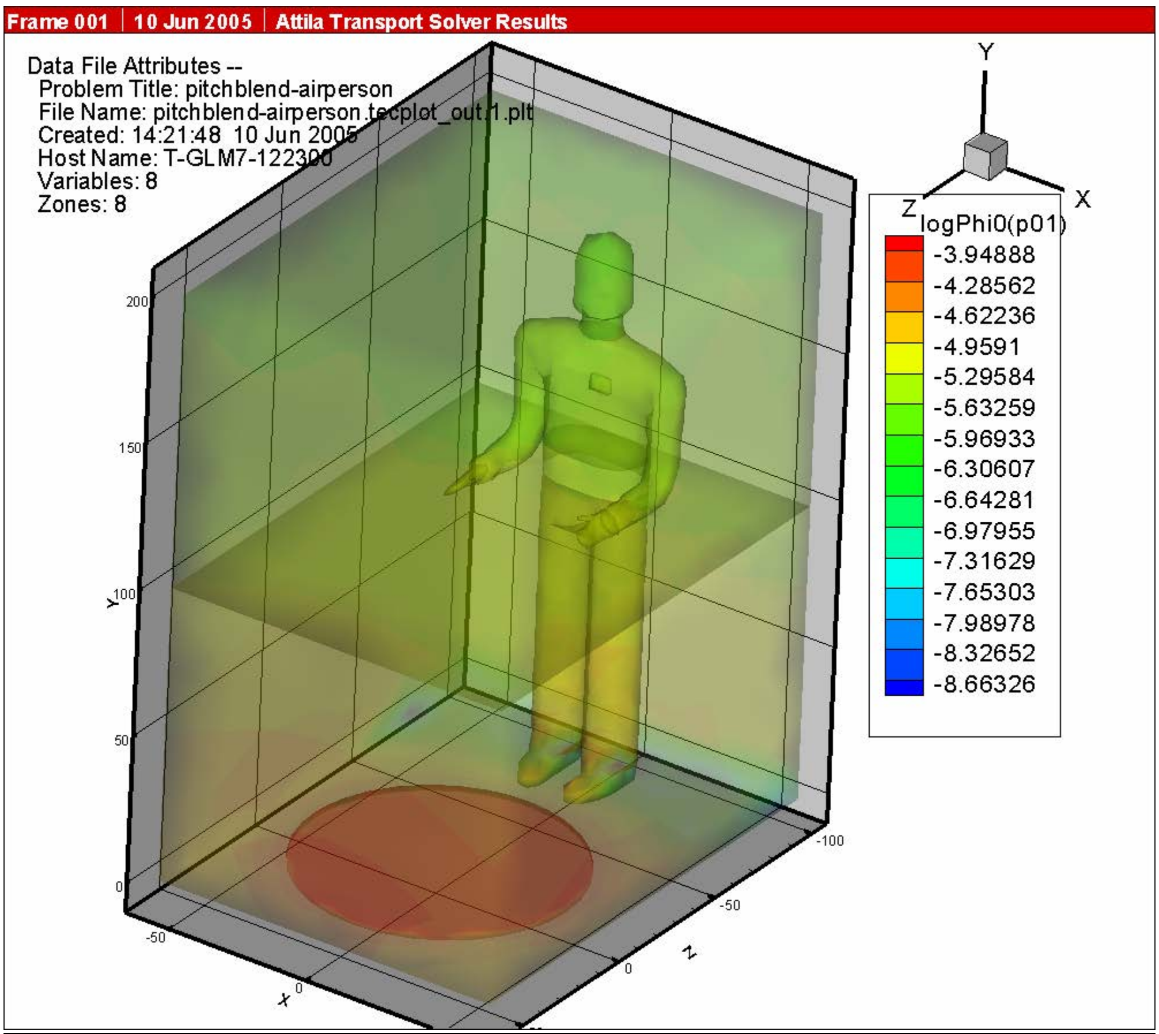

Figure 2 Pitchblende/Cleanup

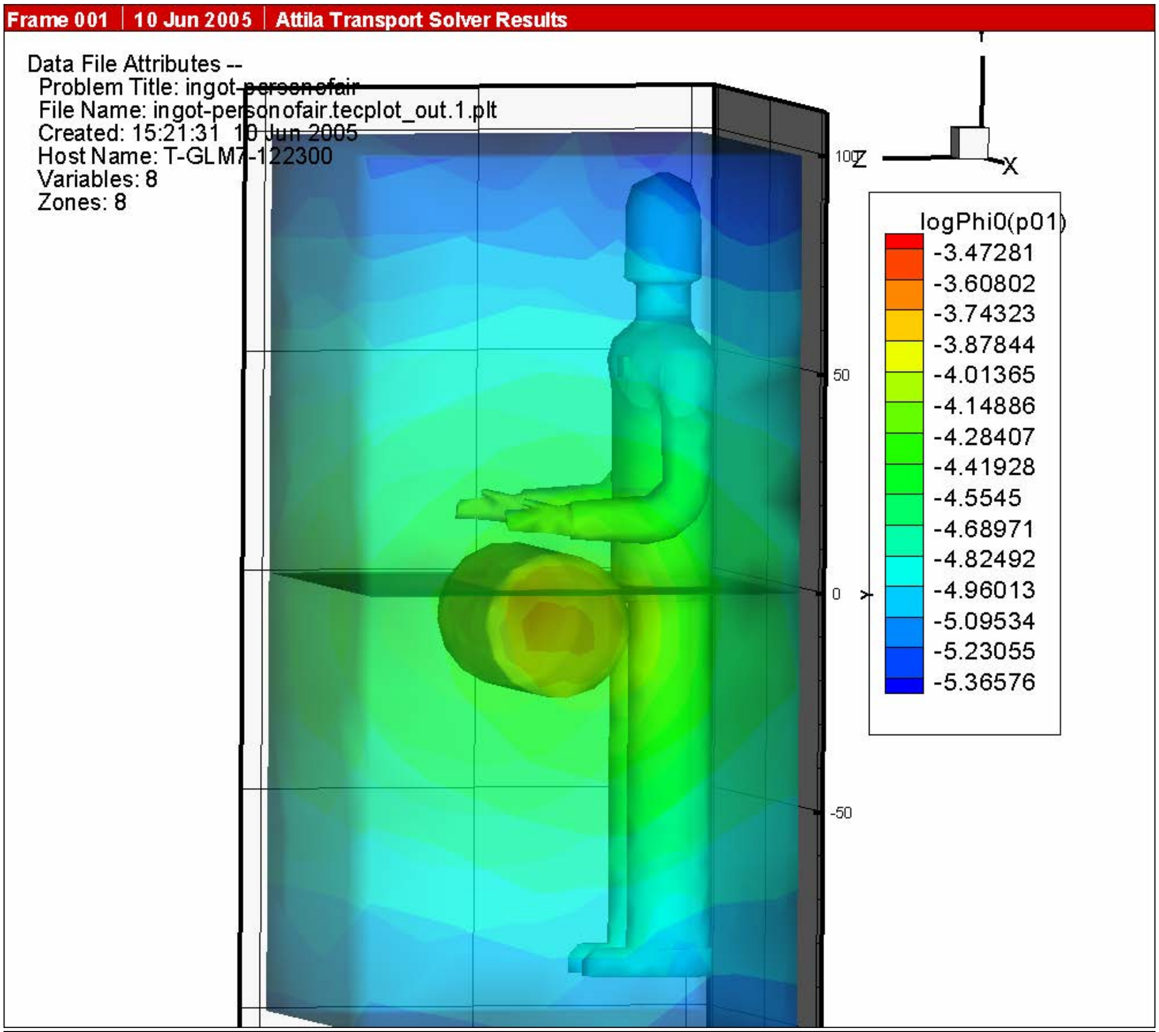

Figure 3 Ingot/Machining

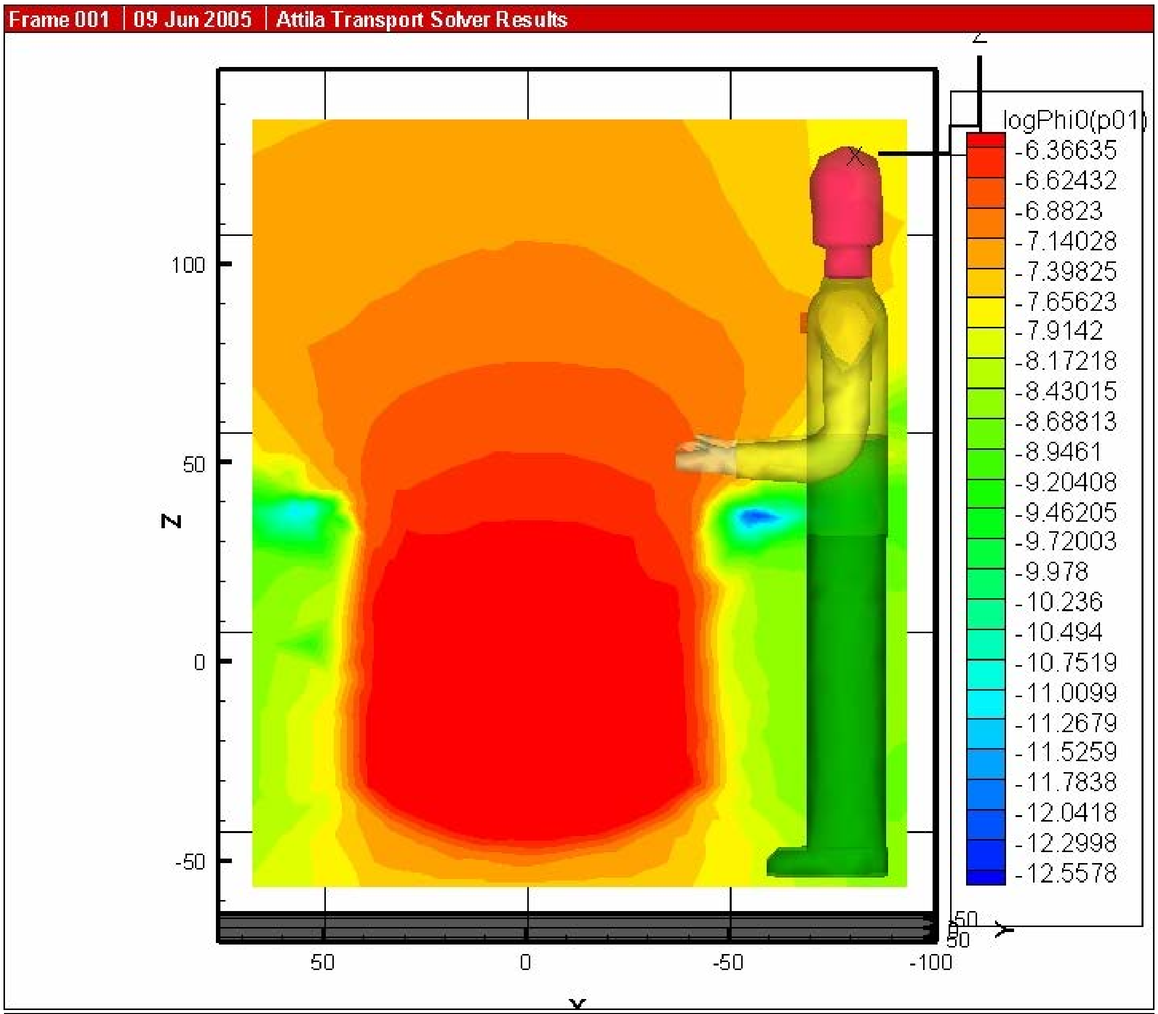

Figure 4 De-nitration Pot

3.2 Application of Geometry Correction Factor

At Mallinckrodt there are numerous different work stations for which a geometry correction factor should be applied to accurately estimate the dose to organs in the lower torso from a film badge worn on the lapel. A review of the claimant work history information in conjunction with the job descriptions in Table 18 of the Mallinckrodt site profile indicates that many Production and Chemical Operators worked at various stations some of which require a geometry correction and some do not. Time estimates used in the dust studies could be used to estimate the fraction of time a worker would be in one geometry versus another, however, the external dose cannot be reasonably partitioned based time since the external dose rate changes from location to location. In addition, trades and crafts workers conducted work in and around radioactive materials throughout the facility. As with chemical and production operators, time motion dust study data could be used to estimate the general time they were in a specific area, however, the external dose rates changed such that it is not practical to partition the dose measured on the lapel dosimeter accordingly.

As a result, the claimant favorable assumption is made that the geometry correction factor should be applied to all measured and missed dose for the general occupations listed in Table 2.

Table 2 Job Types for which the geometric correction factor should be applied.

General Category	Specific Job Titles
Operators and Material Handlers	Chemical Operator, Production Operator, Material Handler
Trades and Crafts	Pipefitters, Carpenters, Welders, Sheet Metal Workers, Electricians, Foremen, etc…

4.0 Comparison of Model Estimate to Dosimetry Data

Limited ring badge dosimetry data was used to validate the Attila modeled geometry ratio. In 1949, for a 5 week period, selected workers were issued ring dosimeters in addition to their whole body dosimeter. At the current time, a full comparison of this data is not possible since the detailed dosimetry for most of the study participants has not yet been obtained from DOE. However, for three individuals with a non-zero dose, a comparison of the ring dosimeter to whole dosimeter was possible. Table 3 provides the data comparison and the calculated geometric correction ratio. Figure 5 provides this limited data on a probability plot to indicate the range of values with the three Attila point estimates.

Table 3

Study Subject	Radiation Type	Ring Dose	Whole Body Dose	Geometric Correction Ratio
1	Beta	195	85	2.29
2	Beta	95	30	3.17
1	Gamma	440	150	2.93
3	Gamma	560	275[(a)]	2.04
4	Gamma	460	275[(a)]	1.67
		Attila Estimated Hand Ratio		3.65

(a) Estimated Midpoint – the data indicate whole body dosimeter was between 251 mR and 300 mR.

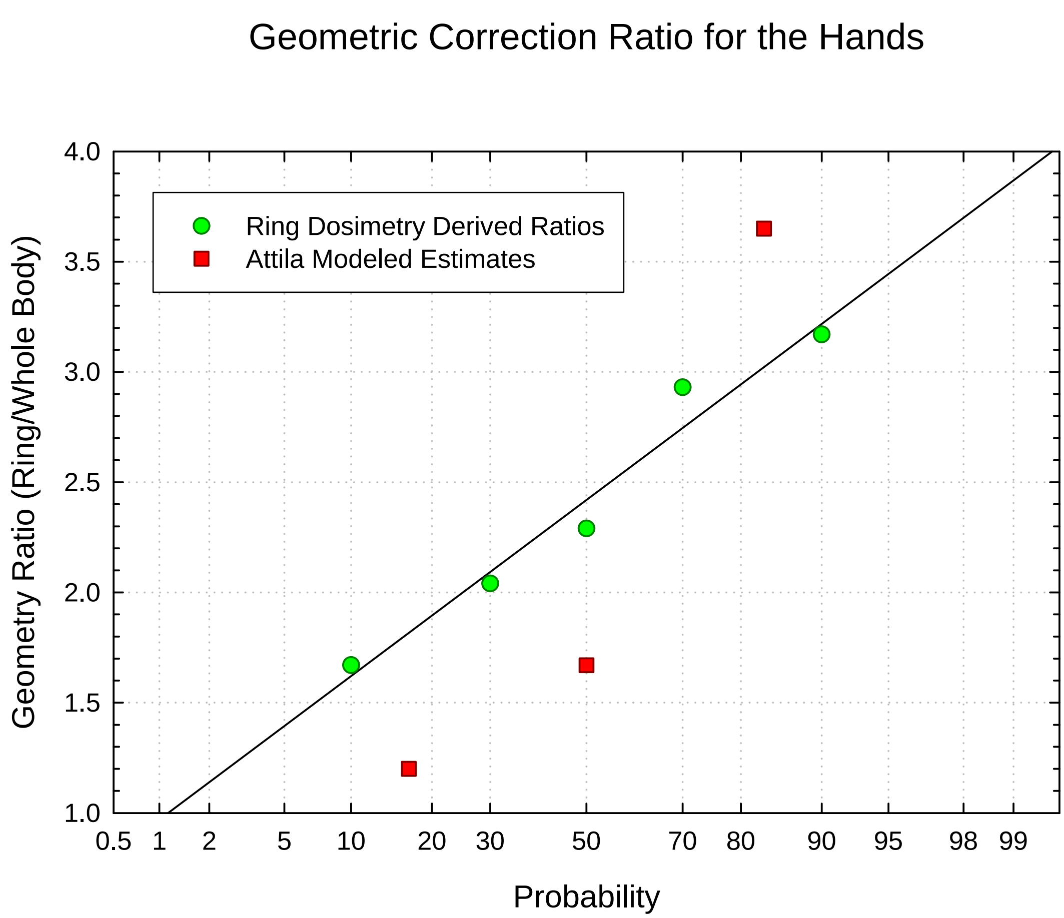

Figure 5: Probability Plot of Attila modeled point estimates and limited ring dosimetry comparison data.

The limited dosimetry data clearly indicate that the model reasonably predicts the geometric correction factor. As a result, the dose reconstruction to organs in the lower torso should multiply the measured and the missed dose by the factor 2.1 as indicated by the Attila model.

3.3 Reasonable Claimant Favorable Assumptions

Listed below are several claimant favorable assumptions used in the development of this methodology that could result in an overestimate of the actual dose.

- Claimant favorable model design
- Assignment of badge results where actual reduction due to geometry occurs
- Assignment of correction factor all jobs within the classification

Obtaining data to precisely evaluate each of these parameters requires extensive time and research on an individual basis and in some instances it is known that the information cannot be obtained (i.e. facility has undergone D&D or other significant modification over time).

4.0 Summary

This Technical Information Bulletin provides guidance for dose reconstruction to organs located in the lower torso. The dose reconstruction to organs in the lower torso should multiply the measured and the missed dose by the factor 2.1 for all members of the general job categories of table 2.

7.0 References

1. 42 CFR 82, *Methods for Radiation Dose Reconstruction Under the Energy Employee Occupational Illness Compensation Program Act of 2000*; Final Rule, Federal Register/Vol.67, No. 85/Thursday, May 2, 2002, p 22314.

2. NIOSH, (2002) External Dose Reconstruction Implementation Guideline, Rev 1, OCAS-IG-001, National Institute for Occupational Safety and Health, Office of Compensation Analysis and Support, Cincinnati, Ohio.