DuPont Deepwater Works
NIOSH's Response to Findings in SC&A's Review, Dated August 12, 2011

James W. Neton, Ph.D., CHP
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During the September 2012 meeting of the Uranium Refining Atomic Weapon's Employer (AWE) working group, NIOSH indicated that responses to the SC&A review of the DuPont Deepwater Works site profile would be difficult to summarize in a matrix. NIOSH's suggestion that a white paper response be prepared was agreed to by the group. This white paper contains those responses.

Finding 1: The site profile should discuss the degree to which the air sampling data, which were collected in 1944 and 1945, can be used to reasonably bound doses in the earlier years of operation (e.g., 1942–1943).

The work at DuPont was initiated by a series of letter contracts, with the first contract issued in late 1942. In all, there were seven contracts written (three of which were for the production of non-radioactive materials). All of them contained a construction phase. Table 1 below provides the list of Manhattan Engineer District (MED) projects that were completed under letter contract. The information in Table 1 was compiled from *History, Chambers Works Special Construction* (SRDB #16272) and *Design and Procurement History of Chambers Works Special Projects* (SRDB #89139).The "Project" number was designated by DuPont while the "Contract" number was that issued by MED. Materials in the contracts were listed by codes names in SRDB #16272, but the common name of the coded material can be identified from the table included on PDF page 16 of SRDB #89239.

Table 1

Project	Contract	Product Name	Common Name	Comment 1	Comment 2
9595	W-7412 Eng 2	Make C716	Non-radiological material		

9634 Stage 1	W-7412 Eng 3	Make C-103 from C-100&C-101	Peruranic acid to UO2	Turned over to Ops 6/5/43	"Advice of physical completion" 1/15/1944
9634 Stage 2	W-7412 Eng 3	Convert to C-103 to C-104.	UO2 to UF4	Start 2/13/43	
9634 Stage 3	W-7412 Eng 3	Convert to C-104 to C-105.	UF4 to U metal	Start 4/28/43	
9757	W-7412 Eng 6	Make C-816	Non-radiological material		
9233	W-7412 Eng 8	Distill HF	Non-radiological material		
9803	W-7412 Eng 22	Convert various scrap to C-103	Convert scrap to UO2	Section 100 start 8/16/43 200 section 10/1/43	"Advice of physical completion" 4/15/1944

The "start date" listed in the documents appears to be the initial date that testing began. For example, project 9634 Stage 1 was turned over to operations on 6/5/1943. After that, a "small daily force" was used to make changes to the equipment until 1/1/1944. Soon after that date, on 1/15/1944, an "advice of physical completion" documentation was given to operating management. A similar time frame for project 9803 can be seen where one section was started on 8/16/943 and the other on 10/1/1943, but the "advice of physical completion" was not issued until 4/15/1944.

From this information, it is likely that full-scale production on the contracts did not commence until several months after the "start date". Therefore, full scale production for any of the projects would not have started until late in 1943 or early 1944. The first air samples taken in April 1944 were collected near the beginning of full scale operation, but not in the startup and testing phase where production rates, and associated airborne levels, were lower.

Finding 2: We would request that the site profile discuss the levels of surface contamination at the facility and explain that, at these levels, the default ingestion rate of 0.5 mg/day, which is inherent to TIB-009, applies to this facility. NIOSH should also describe how the ingestion intake in Table 1 was calculated.

This finding pertains to the quantification of ingestion intakes which was transferred to the Procedures Subcommittee. The subcommittee appears to have completed its work and has concluded that no changes are necessary to TIB-009. However, NIOSH's implementation of TIB-009 in the residual period has been misinterpreted in the DuPont Deepwater works TBD. These values will be revised in keeping with the discussions held in the Procedures Subcommittee.

Finding 3: It appears that uranium metal was produced at the site using the UF_4 to U magnesium bomb reduction process, which, because of the Putzier effect, could have produced uranium ingots that were associated with external beta radiation fields that were 10 to 20 times greater than those adopted in the site profile.

This issue was studied by the TBD-6000 working group resulting in a revision to Battelle-TBD-6000 that discussed this effect. The discussion, which can be found in section 3.3.1 of TBD-6000, indicates that this effect does not appear to occur during the metal reduction process. Rather, it is the uranium recasting process where the phenomenon has been observed. While DuPont did perform metal reduction, there is no indication that they performed metal recasting.

Finding 4: There seems to be a substantial disparity between the explanation of how the annual photon doses to operators were derived and the actual values employed in the site profile.

The SC&A review calculated an annual photon dose of 1,920 mR/yr, while the TBD provided an annual dose of 519 mR/yr. The SC&A review assumed values of 2400 hours worked per year and further assumed that for 50% of the time the operator was within 1 foot of the material and the other 50% was spent at 1 meter from the material. This is consistent with the DuPont TBD.

The SC&A review, however, used values of 1.3 mR/hr and 0.3 mR/hr for the 1 foot and 1 meter dose rates from Table 6 of the TBD. On page 11 of the TBD, however, it is explained that the dose rates indicated were considered to be average dose rates and the default GSD of 5 was used. The TBD goes on to calculate the geometric mean of the dose rate in Table 7. When multiplied by 2400 hour work year, the geometric mean results in the annual dose of 519 mR. The full distribution is assigned to operators and the average of that distribution results in the 1,920 mR annual dose calculated in the review.

During the work group call on September 7, 2012, a discussion about favorability of assigning the average value as a constant versus assigning the full distribution took place. The use of the full distribution was questioned because a geometric standard deviation of five produced an average value almost four times that of the geometric mean. NIOSH performed a few example calculations to demonstrate this effect. The example calculations are provided in Attachment 1.

Finding 5: There seems to be a substantial disparity between the explanation of how the annual contact doses to operators were derived and the actual values employed in the site profile. In addition, justification should be provided as to why TBD-6000 default values should not be used at DuPont, since no site data are available for external exposure during the operating period.

This finding has the same explanation as finding 4. The geometric mean of the extremity dose rates is listed in Table 7 of the TBD.

Finding 6: Assuming 50% of the beta/gamma dose rate measured at 3 feet from a surface is 50% from gamma and 50% from beta does not appear to be appropriate. In addition, beta dose cannot contribute significantly to whole body dose.

This finding indicates the one to one beta to gamma ratio used in the TBD is not appropriate and not favorable. The text of the review notes that the photon exposure rate from contamination is a factor of 100 lower than the beta dose rate according to conversion factors in TBD-6000.

Conversion factors in TBD-6000 were based on a thin layer of contamination. As the thickness of the source of radiation increase, more betas are shielded than gammas and the value of the ratio decreases. At DuPont, the contamination apparently leached into the concrete to the point that 0.04 inches of concrete was removed by sandblasting to reduce the contamination levels. This indicates the remaining contamination is intermixed with the concrete and the beta to photon ratio obtained from an infinitely thin source would not be appropriate.

The DuPont TBD used a ratio of one to one since this would produce the largest photon dose. The photon dose is used for most organs with the most notable exception being the skin. For skin dose, both photon and beta dose are used. Thus for an 80 mR/yr total exposure, the 1 to 1 ratio would estimate a skin dose of 40 mR photon and 40 mrad beta. Conversely, a ratio of 100 would estimate a skin dose of approximately 79.2 mrad beta and 0.8 mR photon dose. The only difference produced by the ratio would be to reduce the photon dose which is the only dose to most organs.

However, NIOSH agrees that the use of a one to beta to gamma one ratio is likely inappropriate. A 10 to 1 ratio is used in TBD-6000 and during discussions in the TBD-6000 work group; it was shown that this ratio appears to be favorable for volume sources (uranium metal, uranium products in tanks, etc.). NIOSH recommends changing this assumption to a 10 to 1 ratio.

Finding 7: The development of the photon dose is convoluted and not scientifically sound. A simpler approach would be to assume that the deep dose rate was 0.05 mrad/hr based on measurements at 3 feet from contaminated surfaces, and pro-rate this dose rate between beta and gamma based on Table 3.10 of TBD-6000.

The highest reading during the residual period was 0.05 mrep/hr in building 708, which was demolished in 1953. Early work was developmental and performed in Bldg J-16 which was a laboratory. Building J-16 was demolished sometime between 1943 and 1945 during the covered period. Building 845 was the only building remaining after 1953 that handled uranium. The highest applicable reading in bldg. 845 was 0.03 mrep/hr.

A reading of 0.04 mrep/hr appears to be above the average reading of the applicable readings in building 708 making it a reasonable value to use for the residual period dose. Alternatively, it is reasonable to believe workers divided their time between 708 and 845 (and other buildings) so an average of the highest in both buildings may be considered reasonable. The average would be 0.04 mrep/hr. Lastly, even if the max reading of 0.05 mrep/hr were used, it would only be applicable until 1953. After that, a value of 0.03 would be used which is the max in the remaining building (bldg. 845).

Attachment 1

Evaluation of Use of the Full distribution Versus the Average Value

In findings 4 and 5, SC&A calculated the average value of a lognormal distribution and pointed out that it was higher than the geometric mean. During a meeting of the work group, they pointed out that for finding 4, the average was almost four times higher than the geometric mean and questioned whether it would be more favorable to assign the average as a constant rather than the distribution.

NIOSH developed a simple example in an attempt to explore this effect. Although this analysis is not intended to be all encompassing or provide a mathematical proof, it is clear that the use of the full distribution is this example provides a slightly more claimant favorable result than using the average value as constant.

For this comparison a hypothetical scenario for a dose reconstruction was chosen that had the following characteristics:

- Male born in 1940;
- Exposure started 1965;
- Exposure ended in 1974;
- Liver cancer diagnosed in 2000; and,
- Exposure to mid energy photons at a chronic exposure rate.

Next, a geometric mean (GM) exposure of 1 rem was assumed for each year and the geometric standard deviation (GSD) varied for several different examples. From the GM, the average of the distribution was calculated as follows:

$$Average = GM\ x\ e^{\left(\frac{1}{2}\sigma^2\right)};$$

where σ = the natural log of the GSD.

Lastly, IREP was used to calculate the probability of causation (at the 99 percent upper credibility limit) using the full lognormal distribution and again using the average as a constant for each example. The table below provides the results of these calculations.

GM	GSD	Average	POC full distribution	POC average as a constant
1	1	1.00	N/A	53.24%
1	2	1.27	63.06%	59.15%
1	3	1.83	72.84%	67.55%
1	4	2.61	79.75%	74.85%
1	5	3.65	84.49%	80.61%
1	10	14.17	96.77%	94.16%
1	100	40,287	100.00%	100.00%

A lognormal distribution with a GSD of one is a constant. IREP recognizes that condition as an error, so no POC value was provided for that case. From the table it can be clearly seen that the claimant favorability of using a GM with a distribution to a constant value must consider the effect of the GSD on POC result. For findings 4 and 5, a default GSD of 5 was used, resulting in an average value almost 4 times the GM but the POC in this scenario results in higher POCs when the full distribution is used as the input term.