Comparison of Two Pu-238 Lung-Set Standards

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ABSTRACT

While performing a hand verification of ABACOS 2K calculations we noticed what appeared to be a significant difference in the counting efficiencies calculated with two different Pu-238 lung-set standards. One standard was from the DOE Phantom Library and one was fabricated by the University of Cincinnati. The lung-sets were counted in a wound counter jig armed with a Canberra ACT-II Ge detector array. Each lung-set was counted for 5400 seconds five times. The lungs were removed from the jig and replaced before each count. The counting efficiencies were calculated with Mathcad using the 17 keV x-ray line. In this talk I will review the results of this comparison, which suggest that there is a significant systematic difference between the two standards.

Wound Counter

Comparison of Lung Sets

Comparison of 5400 second counts of the DOE Library lung set and the UC lung set on the wound counting system. The 17 keV x-ray group was analyzed. Written in Mathcad 2001i.

$ORIGIN \equiv 1$ $\quad DOE \equiv 1$ $\quad UC \equiv 2$

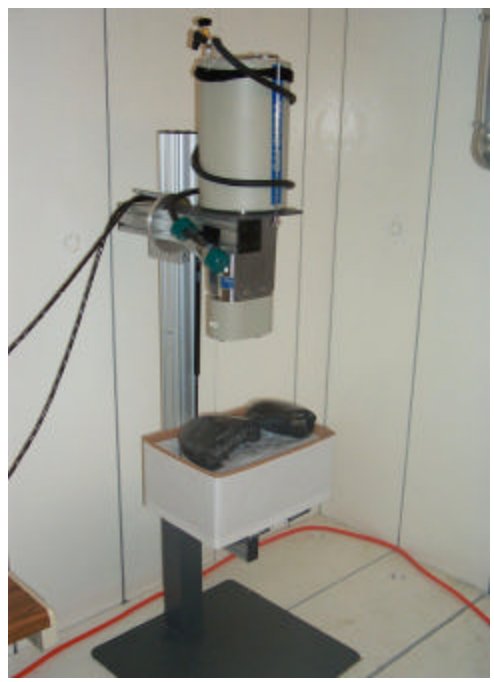
DOE Library Lung Set

Five 5400-second counts of the DOE lung set and the theoretical standard deviations for each count are presented below. The lungs were removed from the counter after each count and replaced for the next count.

$$x := \begin{pmatrix} 3424 \\ 3442 \\ 3393 \\ 3146 \\ 3355 \end{pmatrix} \qquad s_{th} := \begin{pmatrix} 76 \\ 96 \\ 111 \\ 103 \\ 106 \end{pmatrix}$$

$s_{DOE} := stdev(x)$ $\qquad s_{DOE} = 107.154$

$X_{DOE} := mean(x)$ $\qquad X_{DOE} = 3.352 \times 10^3$



The chi-squared test shows that the experimental and theoretical standard deviations are not significantly different, i.e., there is no significant placement error.

$$\chi := \sum_{i=1}^{5} \left(\frac{x_i - X_{DOE}}{s_{th_i}} \right)^2 \qquad \nu := 5 - 1$$

$\chi = 5.914$

$pchisq(\chi, \nu) = 0.794$

UC Lung Set

Five 5400-second counts of the UC lung set and the theoretical standard deviations for each count are presented below. The lungs were removed from the counter after each count and replaced for the next count.

$$x := \begin{pmatrix} 1.511\cdot 10^4 \\ 1.520\cdot 10^4 \\ 1.492\cdot 10^4 \\ 1.488\cdot 10^4 \\ 1.477\cdot 10^4 \end{pmatrix} \qquad s_{th} := \begin{pmatrix} 158 \\ 122 \\ 156 \\ 151 \\ 180 \end{pmatrix}$$

$$s_{UC} := \mathrm{stdev}(x) \qquad s_{UC} = 156.793$$

$$X_{UC} := \mathrm{mean}(x) \qquad X_{UC} = 1.498\times 10^4$$

The chi-squared test shows that the experimental and theoretical standard deviations are not significantly different, i.e., there is no significant placement error.

$$\chi := \sum_{i=1}^{5} \left(\frac{x_i - X_{UC}}{s_{th_i}} \right)^2 \qquad \nu := 5 - 1$$

$$\chi = 5.933$$

$$\mathrm{pchisq}(\chi, \nu) = 0.796$$

Activity in Lung Sets

$$nCi \equiv 37\cdot Bq$$

$$\mathrm{Activity}_{UC} := 1278.2\cdot \exp\left(\frac{-\ln(2)}{87.7\cdot 365}\cdot 966 \right)\cdot nCi \qquad \mathrm{Activity}_{UC} = 1.252\times 10^3\, nCi$$

$$\mathrm{Activity}_{DOE} := 373\cdot \exp\left(\frac{-\ln(2)}{87.7\cdot 365}\cdot 5762 \right)\cdot nCi \qquad \mathrm{Activity}_{DOE} = 3.292\times 10^2\, nCi$$

The uncertainty (1σ) in activity is quoted at 1.7% for the DOE lung set and 0.54% for the UC lung set.

Counting Efficiency

The counting efficiencies ε for the wound counter in counts per disintegration (unitless) are calculated with each source.

$$\varepsilon_{DOE} := \frac{\frac{X_{DOE}}{5400 \cdot s}}{Activity_{DOE}} \qquad \varepsilon_{UC} := \frac{\frac{X_{UC}}{5400 \cdot s}}{Activity_{UC}}$$

$$\varepsilon_{DOE} = 5.095 \times 10^{-5} \qquad \varepsilon_{UC} = 5.988 \times 10^{-5}$$

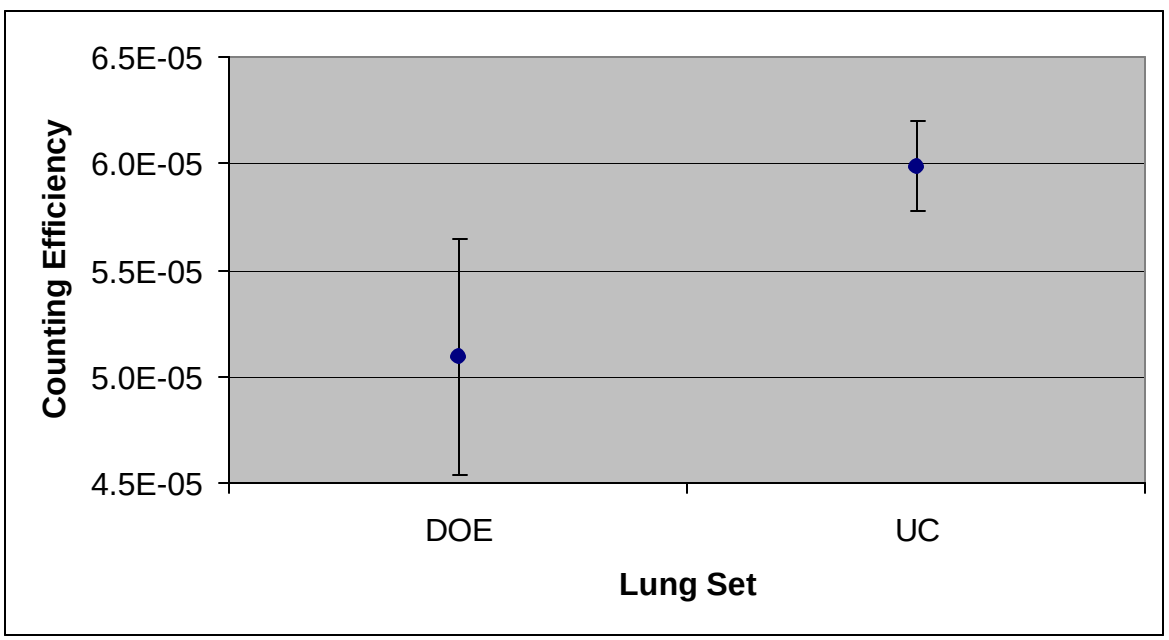
The total propagated uncertainty is calculated for each efficiency.

$$\sigma_{DOE} := \varepsilon_{DOE} \cdot \sqrt{\left(\frac{s_{DOE}}{X_{DOE}}\right)^2 + 0.017^2} \qquad \sigma_{UC} := \varepsilon_{UC} \cdot \sqrt{\left(\frac{s_{UC}}{X_{UC}}\right)^2 + 0.0054^2}$$

$$\sigma_{DOE} = 1.845 \times 10^{-6} \qquad \sigma_{UC} = 7.054 \times 10^{-7}$$

(5.10 ± 0.18) x 10^{-5} **(5.988 ± 0.071) x 10^{-5}**

Plot of efficiencies and 3σ uncertainties for both lung sets.



$(\varepsilon \quad \sigma)$

t Test

Even without the t-test, the counting efficiency calculated with DOE lung set is obviously different than the counting efficiency calculated with the UC lung set, i.e., the activity quoted for one or both sources is in error.

$$n := 5 \qquad df := n + n - 2$$

$$t := \frac{\varepsilon_{UC} - \varepsilon_{DOE}}{\sqrt{\frac{(n-1)\cdot(\sigma_{UC})^2 + (n-1)\cdot(\sigma_{DOE})^2}{n+n-2}}\cdot\sqrt{\frac{1}{n}+\frac{1}{n}}}$$

$$t = 10.105$$

The cumulative probability for this value of t is

$$pt(t, df) = 1.0000$$

which means that it is most unlikely that these two sources have produced the same counting efficiency.