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Letter to the Editor

Comment on Comparison Between Historic Nuclear Explosion Yield Formulas

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Nuclear Technology is to be commended for publishing the superb series of papers celebrating the 75th anniversary of the Manhattan Project as a supplement to Vol. 207 in late 2021. These papers will be a trove of information for scientists and historians interested in the Project.

My attention was particularly caught by Lestone et al.'s comparison of the bare-core nuclear explosion yield formulae of Compton, Serber, Frisch and Peierls, Feynman and Bethe, and Dirac and Pryce.[1] That different researchers working in different places at different times came up with such similar expressions hints that the same underlying physics was involved, and I offer here a few remarks on the provenance of these formulae.

The underlying physics in the case of the Compton report and Serber's *Los Alamos Primer* is the work-energy theorem in its thermodynamic *PdV* formulation. In brief, the idea is to equate the work produced by the pressure created by energy released in fissions to the change in kinetic energy of the expanding core, integrating until second criticality is reached. There are nuances to be considered, such as whether gas or radiation pressure is invoked and how to deal with the changing density of the core and the time evolution of the neutron growth factor α, but these can largely be subsumed into the scaling factors Lestone et al. describe. Compton took this approach in his November 1941 report to the National Academy of Sciences, as did Serber in the *Los Alamos Primer*, albeit a little more circuitously. Detailed derivations can be found in various publications by this writer; neither of those documents were intended to be tutorial works.[2–4] That the Compton/Serber formula can be transformed into that offered by Frisch and Peierls hints that they must have taken a very similar approach.[a] Further information on the physics backgrounding the Frisch-Peierls memorandum can be found in a paper by Jeremy Bernstein.[5] I do not have copies of the Feynman-Bethe or Dirac-Pryce documents, but it seems reasonable to speculate that they might have followed similar paths.

There is an educational lesson here: Our students see the work-energy theorem in basic mechanics classes and then again in advanced dynamics and thermodynamics classes. I always take the opportunity to point out to them that this very classical theory plays an important role in understanding the functioning of devices that otherwise seem the purview of a remote priesthood. Much of the design and performance of the bombs produced in the Manhattan Project can be understood with undergraduate physics and mathematics.

Disclosure Statement

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References

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[a] See Lestone et al.'s Eq. (6); see also Sec. 2.5 of Ref. 4.