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ON THE DANGER OF RADIOACTIVE C^{14} NEAR THE PILE

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ABSTRACT

The danger to personnel due to the formation of radioactive C^{14} near a 10^5 kw pile operated in ordinary air is estimated. If the pile air is changed once a day, and if the C^{14} is assumed to remain in the body indefinitely, sufficient C^{14} to give .23R every day will be inspired in one 24 hour day near the pile. If the pile air is changed once a day and the C^{14} is assumed to remain only 2 hours in the blood, but the effect of concentration of CO in the blood cells is taken into account, enough C^{14} to produce 4.8 R every day the C^{14} remaining in the body is absorbed during a 2 hour period of breathing contaminated air.

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The present note is a record of a discussion (Friedman, Teller, Weinberg, Williamson, Wollan, Young) concerning the possible danger to personnel which might arise from breathing air contaminated with radioactive C^{14}. The C^{14} is produced by the absorption of slow neutrons by nitrogen; the present considerations are therefore of interest in connection with a recent proposal by Zinn that the power plant be operated in an atmosphere of ordinary air. The computation will be done in two steps: first the tolerable amount of C^{14} in the body will be estimated and expressed in terms of the corresponding safe concentration of atmospheric C^{14} (assuming an individual to breath contaminated air continuously for n days); second, the maximum contamination of air to be expected if the air is changed once a day and all the leakage neutrons from the pile have a chance of forming C^{14} will be computed. If the degree of contamination is less than the safe amount, the C^{14} problem may be ignored; otherwise measures may have to be taken to get rid of the contaminated air.

The safe dose per day of general body radiation is 0.1R: this corresponds to 2×10^8 ion pairs/c.c. in air or 1.4×10^{11} ion pairs/c.c. in tissue (which has a density 700 x air). The average total volume of tissue in a human (70 kg) is 7×10^4 c.c; hence the total safe number of ion pairs/day is 1.0×10^{16}. The half life of C^{14} is 7×10^6 days, and its β rays have sufficient energy (10^5 eV maximum according to Kamen and Rubin) to produce 1000 ion pairs per β ray. Hence each C^{14} produces 1.42×10^{-4} ion pairs/day; consequently the tolerable number of C^{14} atoms in the body is $\frac{1.0 \times 10^{16}}{1.42 \times 10^{-4}}$ $= 7.0 \times 10^{19}$ atoms or 1600 micrograms. This corresponds to 23 μgm of C^{14} per kg. of body weight. A similar calculation for Ra gives, according to Wollan, 3.5 μgm as a safe dose. Actually 0.1 μgm is already very close to the danger-limit. The factor of 35 between these two figures can be accounted for by the concentration of Ra in the bone marrow. Other contributing factors may be the greater sensitivity of the bone marrow to radiation and possibly a greater specific effect of the α rays which give rise to more dense ionization than the β and γ rays.

On the average 10 liters of air are breathed per minute, or 1.5×10^7 c.c/day. In n days 1.5×10^7 n c.c. are taken in; if all the C^{14} contained in the respired air is accumulated by the body during this time, the safe average concentration of C^{14} in the air is