6. Heat from Cold Fusion Generators

Hydrogen (proton) – deuterium (deuteron) fusion reactions need to be considered when developing cold fusion generators. The main reason for this emphasis is that proton-deuteron fusion reactions should occur more easily in a cold fusion physical environment than deuteron-deuteron reactions. This is discussed in a paper on the web by Setauo Ichimaru, "Radiative Proton-Capture Nuclear Processes in Metallic Hydrogen," that was published in Physics of Plasmas in October 2001 (Vol. 8 (#10), pages 4284-4291). A second reason is that facilitating proton-deuteron reactions, e.g., over deuteron-deuteron reactions, would help to control the amount of local heating in each microscopic-sized, very small reaction site within cold fusion generator cathodes. Deuteron-deuteron reactions produce protons and other nuclear particles that would likely damage the reaction sites. Fusion of deuterium and hydrogen produces gamma radiation that is not able to be absorbed significantly within the small reaction sites. The heat produced would be distributed through the whole of the generator and would not be able to melt local cathode material at the reaction sites. Cold fusion generators should be able to operate for much longer periods if the reaction sites are not degraded.

**Process of Converting Gamma Energy to Heat**

The energy produced as gamma radiation [highlight "gamma radiation" and provide click on for www.youtube.com/watch?v=PPlrtgilgK8 ] from each proton-deuteron (p-d) reaction is sufficient to ionize thousands of atoms and molecules in the cathode and other parts of the generator, and this is part of the process of producing heat. Only 10 to 1000 eV are needed for each ionization. The relation between energy and frequency of the radiation is described by the formula

$$E = h f \quad ,$$

where E is energy in joules, h is Plank's constant ($6.63 \times 10^{-34}$ joule-seconds), and f is frequency of the radiation in Hertz. Thus, 5.5 MeV gamma radiation photons will have a frequency of $1.3 \times 10^{21}$ Hertz. Note that here we are speaking about "photons" or electromagnetic radiation, not "phonons". Wavelength ( $\lambda$ ) of the radiation can be determined from the formula $\lambda = c/f$, where c is a constant equal to the speed of light ($3 \times 10^{8}$ meters per second). The 5.5 MeV gamma radiation will have a wavelength of $2.3 \times 10^{-3}$ Angstroms. This indicates a low probability of interaction between the photon and any single atom or molecule in the cathode and other parts of the generator. But, the generator is composed of a great many atoms of material with which to interact. Higher energy gamma ray photons, such as 23.8 MeV from d-d fusion would have much less probability of interacting with the material.

Gamma radiation is attenuated by the photoelectric effect (most important for gamma energy below several hundred keV), by Compton scattering (most important for gamma energy between several hundred keV and a few MeV), and by pair production (considered for gamma energies above 1.022 MeV). Each of these effects will come into play for 5.5 MeV gamma ray photons produced by p-d fusion reactions. Each of the three gamma ray attenuation processes involves production of electrons. Heat is produced as the electrons slow down by Coulomb interactions with atoms in the absorbing material.

In the photoelectric effect, a gamma ray photon interacts with an atom of absorbing material, resulting in ejection of an electron from the material. The electron receives all the energy of the gamma ray minus the electron's binding energy, and may induce secondary ionization events. The probability of the photoelectric effect is proportional to atomic number (Z) of the absorbing material and is inversely related to gamma ray energy. The photoelectric effect is most important for low energy gamma rays interacting with heavy elements.

Compton scattering also involves interaction of a gamma ray photon with an atom of the material and ejection of an electron from the material. In Compton scattering, however, only a portion of the energy from the higher energy gamma ray is transferred to the electron and the remaining energy is transmitted as gamma rays at lower energy. As with the photoelectric effect, the probability of Compton scattering is proportional to atomic number (Z) of the absorbing material and is inversely related to gamma ray energy. Compton scattering produces a continuum of scattered gamma ray energies from 250 keV below the highest energy of the incident gamma radiation (known as the "Compton gap") down to a minimum value. The minimum energy (in keV) of scattered gammas produced by Compton scattering can be determined from the equation

$$E_{min} = 511\, E_{incident} / (511 + 2\, E_{incident}) \,.$$

In pair production, a gamma ray photon above 1.022 MeV can be converted into an electron-positron pair near the nucleus of an atom of the absorbing material. Any energy of the incident gamma ray photon greater than 1.022 MeV is transferred to the electron and positron as kinetic energy. The electron and positron can produce additional ionization in the absorber material. The positron will eventually be annihilated, producing two 511 keV gamma rays, which can interact further with the material.

**Generator Design**

The whole mass of the cold fusion generator would be able to absorb heat produced by gamma radiation. An additional energy shield made of a high atomic number (Z) material such as tungsten can be used as necessary to absorb any radiation that is not otherwise absorbed. The National Institutes of Standards and Technology (NIST)'s XCOM database [ click to www.nist.gov/pml/xcom-photon-cross-sections-database and highlight "XCOM database" ] may be referenced in determining the amount of gamma ray absorption in various materials. In addition, the specific amount of absorption by the photoelectric effect, Compton scattering and pair production can be determined from one of several x-ray and gamma ray calculators on the web.