9. Design of Helium Separator

In order to produce kilowatts of energy, cold fusion generators must be able to sustain more than 10^{16} nuclear reactions per second. Reactant product helium gas molecules can be anticipated to be produced at approximately this rate, and will need to be removed from the system so that additional hydrogen and/or deuterium gas can be added, thus enabling the generator to operate for long periods of time. A year of continuous operation at 10^{16} nuclear reactions per second can produce 3 x 10^{23} helium molecules (0.5 mole) that occupy about 11 liters.

Benefits of Helium Separation

Removal of helium can, therefore, be crucial for spacecraft power applications and in unattended power applications in remote areas where sustained operations are required for long periods of time. A capability to remove incremental and pre-determined quantities of helium, with the addition of hydrogen and/or deuterium to the reactor, can also be used to help balance pressure-related, variable operating conditions within the reactor and to support maintenance of consistent pressure and temperature operating conditions. Additionally, government directives for controlling helium usage have stimulated incentives for saving and re-use of helium as an irreplaceable natural resource of limited extent. Supplies of helium-3 are particularly limited and of high cost. Collection and storage of helium reactant product gas can result in a profitable resource due to its commercial uses.

Separation Methods

Many methods of helium separation have been investigated. These include: diffusion, adsorption, cryogenics, fractional distillation, Becker nozzles, and centrifuges. Diffusion relying upon the permeability of helium through materials has been the most studied and applied in practical systems to separate helium from other gases, e.g., for the gas industry. Sufficiently high helium diffusion rates are possible due to helium's small, monoatomic molecule diameter compared, e.g., with hydrogen's larger diatomic molecule diameter. Helium diffusion rate through materials and seals has also been extensively studied by others in relation to leak testing methods, such as those used to ensure mechanical integrity of piping. Helium can be separated by diffusion without the use of “purifiers”/“purification” where the other gases would be required to be adsorbed or otherwise removed from the gas mixture, i.e., by a getter or absorber, and without additional valves or pumps that may be required by some other methods of separation.

An article on “The Diffusion of Hydrogen and Helium through Silica Glass and other Glasses,” by G. A. Williams and J. B. Ferguson in 1922 demonstrated that permeability of silica glass both to helium and hydrogen is proportional to gas pressure and to an exponential function of temperature. Permeability to helium is much larger than permeability to hydrogen. Permeability of helium through fused quartz (est. 10^{13} atoms per second per cm^2 for 1 mm thick samples at 300^oC and pressure difference of 1 atmosphere) compared with hydrogen and deuterium was discussed in “Diffusion Coefficients of Helium in Fused Quartz,” by D. E. Swets et al., in 1961 and in “Diffusion of Hydrogen and Deuterium in Fused Quartz,” by R. W. Lee et al. in 1962. Values were obtained through a series of steady state measurements with different, but constant temperatures and pressures.

Permeable Element Materials

Materials for construction of helium permeable elements for cold fusion generators can be determined from a list of materials able to withstand high temperature and known from the technical literature to be effective in separating helium from other gases. Zirconia, fused silica and silica glass are considered to be the best materials to use for the permeable elements (see photograph). Polyethylene was discussed in “Permeability of Solids to Gases,” by A.P. Brady et al. in 1963, but is not considered to be useful due to its relatively low melting temperature. The use of zirconia (permeability to helium est. 10^{15} atoms per second per square centimeter for a 1 mm. thick element and pressure difference of about 1 atmosphere) was discussed in 1969 by W.R. Seetoo and J. W. McGrew in NASA CR-72603 as a means of removing helium from nuclear reactor containment vessels. Permeability of zirconia to helium was shown to be much larger than permeability to hydrogen. As discussed in “Permeation in Fused Silica,” by J. S. Masaryk and R. M. Fulrath in 1971, fused silica is also considered as a promising construction material for helium permeable elements because of its permeability to helium (est. about 10^{13} atoms per second per square centimeter across 1 mm at 300°C with a pressure difference of 1 atmosphere).