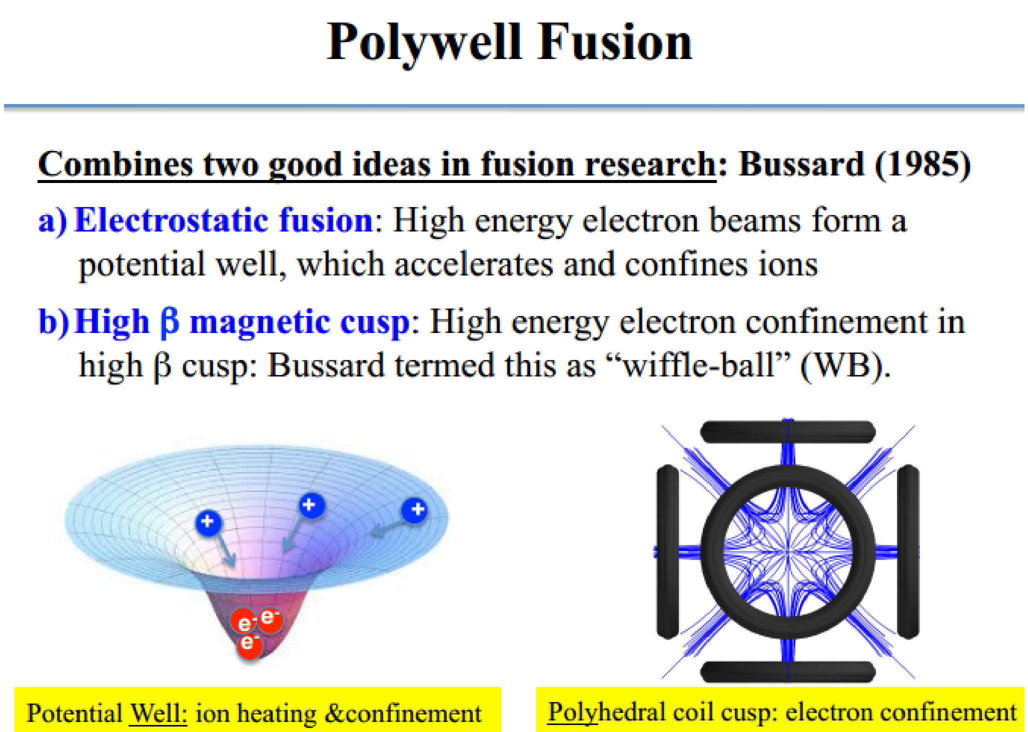
Energy Matter Conversion Corporation (EMC2)

Peter Lobner, 1 February 2021

Energy Matter Conversion Corporation (EMC2) was founded in 1985 by the late Dr. Robert Bussard to develop "Polywell" electrostatic confinement fusion power technology. Dr. Bussard passed away on October 6, 2007 and research at EMC2 continued under the leadership of Dr. Jaeyoung Park. After almost 20 years of fusion research funded by the US Navy, this funding source ended in 2014. EMC2 continued work on Polywell fusion until about 2019 when it appears that the company closed due to lack of funding. Nonetheless, their work was developing an intriguing design concept for a small fusion power reactor. This article provides an overview of that work.

Polywell fusion is based on fusion fuel heating with electron beams combined with a proprietary, quasi-spherical magnetic cusp plasma confinement scheme called the "Wiffle-Ball," shown below.



Source: EMC2

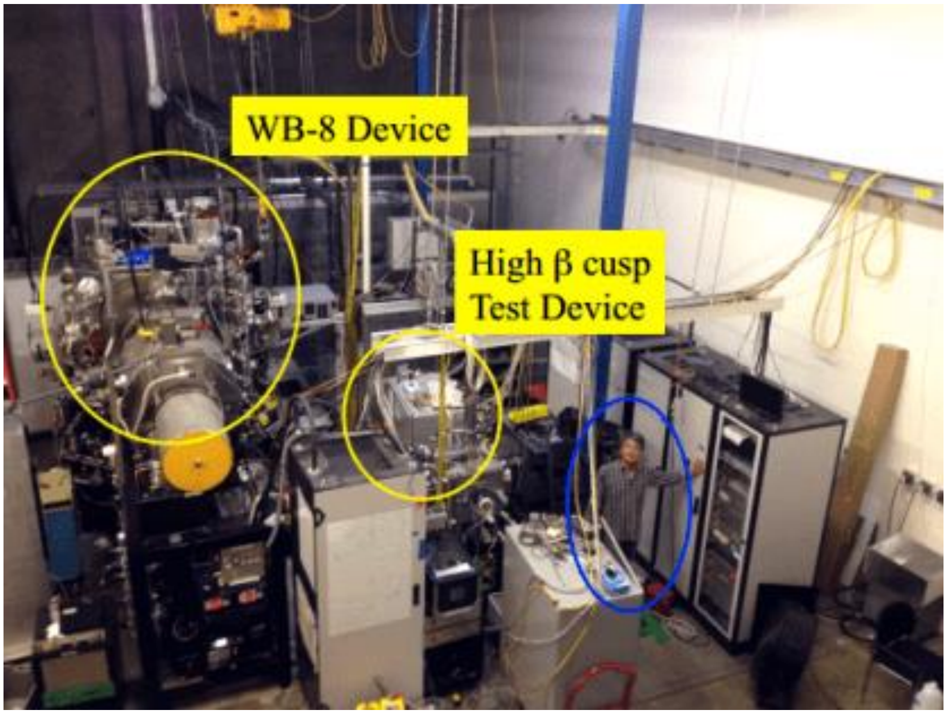
The Fork in the Road to Electric Power From Fusion

In a 2015 paper, Jaeyoung Park explained the operation of their Polywell fusion reactor:

> “In the Polywell reactor, electrons are confined magnetically by a cusp field while ions are confined by an electrostatic potential well produced by electron beam injection. The use of an electron beam provides two critical advantages for the Polywell reactor over other magnetic cusp devices. First, the excess electrons from the beam form an electrostatic potential well. By utilizing an electrostatic potential well, the Polywell reactor employs a highly efficient method to accelerate ions to high energies for fusion. Second, the potential well, rather than the magnetic field, confines ions. In a Polywell reactor, the main issues of high-temperature plasma containment and plasma heating are thus reduced to the confinement property of the injected electron beam.”

The EMC2 Polywell WB6 electron confinement device.
Source: medium.com, 2019

The first experimental evidence that this approach to fusion might work was reported by Jaeyoung Park in 2015. The experiments demonstrated that a fusion power reactor based on cusp confinement will require a high β (beta, the ratio of plasma pressure to magnetic field pressure), on the of order unity (1.0). In contrast, tokamaks like ITER operate at low β, on the order of 0.05 (5%). In March 2015, EMC2 filed patent application US2015/0380114A1 describing the use of high β cusp confinement in a Polywell reactor.



EMC2 WB-8 Lab in San Diego, CA, circa 2014. Source: EMC2

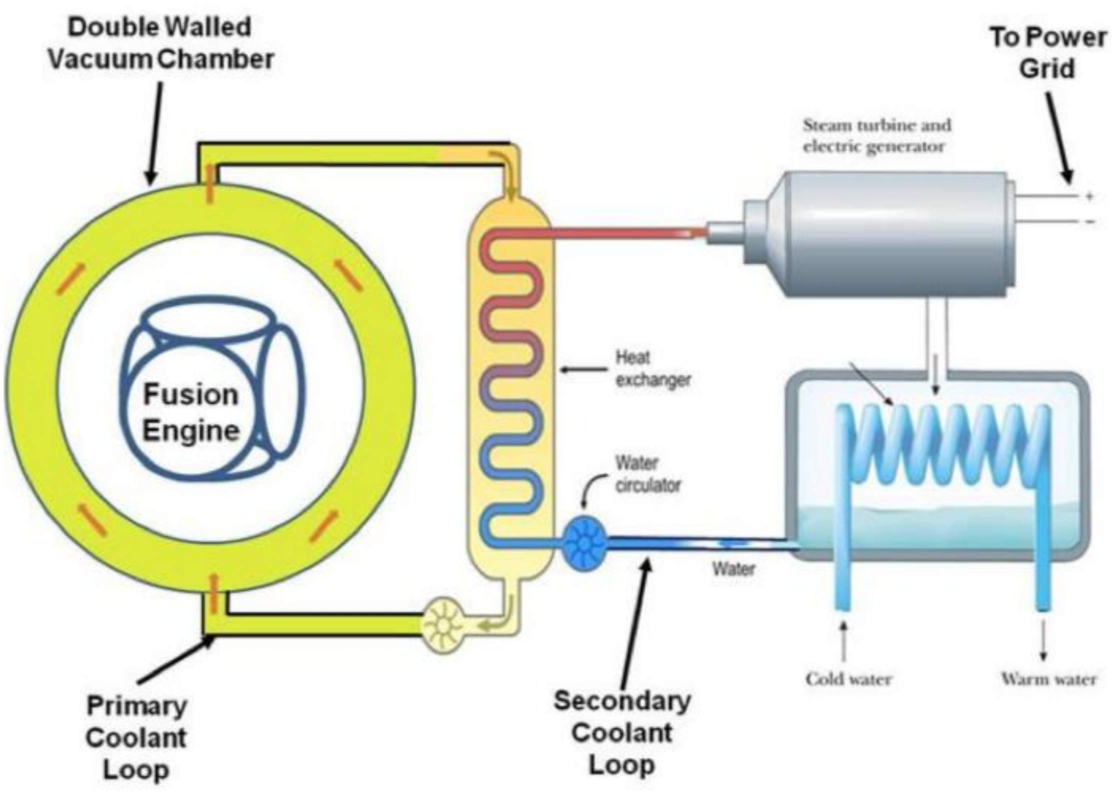
EMC2 claims that the Polywell reactor concept is scalable and can be configured for use with any fusionable ions: deuterium-deuterium (D-D), deuterium-tritium (D-T), D-helium-3 (D-^{3}He), and hydrogen-boron-11 (p-B^{11}).

A particularly desirable variant for the Polywell reactor is one that would operate with aneutronic hydrogen (proton) / boron-11 (p-B11) fusion, which can be triggered at an extremely high temperature of about 3 billion °C by the following reaction:

$$^{1}p + {}^{11}B \rightarrow 3\,{}^{4}He + 8.7\text{ MeV}$$

This fusion reaction does not generate neutrons. Energy generated by fusion is carried off by three positively charged alpha particles, which creates an opportunity for direct conversion into electricity, without the need for a thermal cycle power conversion system. The alpha particles will escape from the center of the Polywell reactor. After the alpha particles are slowed down, direct energy conversion could be accomplished with an efficiency of about 80%.

A Polywell reactor operating with D-T fusion version generates copious amounts of neutrons and would require a heat transfer system to cool the reactor vacuum vessel and transfer heat to a secondary heat transfer loop with a power conversion system. One possible configuration is shown in the following diagram. Helium would be used as the primary coolant, operating at 725°C and removing heat from the Polywell reactor vacuum vessel. Overall thermal efficiency would be about 40%. The high neutron fluence from D-T fusion requires routine replacement of the Polywell fusion core.



Polywell fusion power plant concept. Source: EMC2 (2018)

Patent WO 2018/208953 describes a Polywell reactor operating with a D-T fusion cycle for applications other than electric power production (i.e., medical isotope production, neutron radiography, transmutation of radioactive waste).

Patent Figure 21 shows one embodiment of a Polywell reactor having vacuum enclosure (201, the reactor chamber), six coils generating cusp magnetic fields (202), two plasma initiators (203) to form the high β plasma (204) during the startup, one ion beam injector (205) to produce fusion reactions and to provide heating to the target plasma to sustain high β plasma, one low energy electron beam injectors (721) to form a potential well to reduce the ion loss of the target plasma, and one fusion fuel injector (206) to replenish ions and electrons in the target plasma. The vacuum conditions in the vessel are maintained by a pumping system (207, 208, 209).

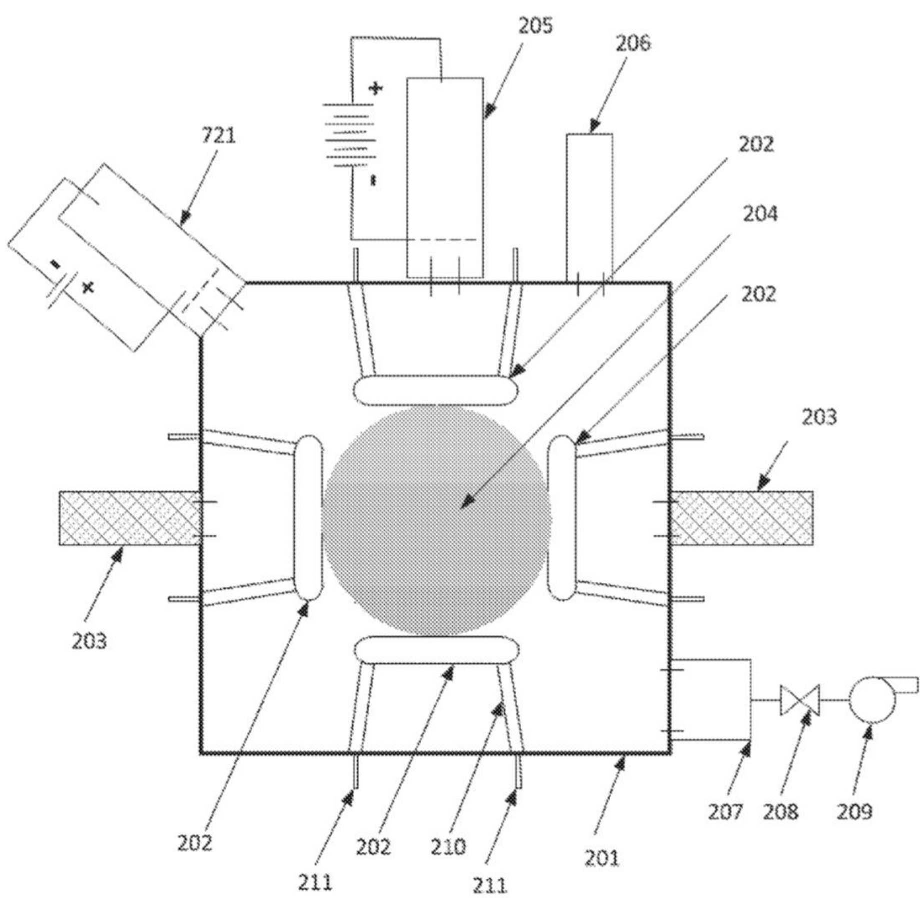


Figure 21

From 1995 to 2014, EMC2 received about $21 million in funding from the US Navy, with $12 million of that between 2008 – 2014. During that time, EMC2 tested 19 different prototypes of their Polywell machine, leading to the performance breakthrough reported in Physical Review in 2015. EMC2 did not receive any DOE funding.

It appears that the firm EMC2 ceased operating in 2019. The website for the commercial firm EMC2 is no longer online. Note that there is an unaffiliated non-profit organization that goes by a very similar name: EMC2 Fusion Development Corp. Their website, which includes links to some Polywell documents and other general fusion references, is here: http://www.emc2fusion.org

For more information:

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- Jaeyoung Park, "Polywell Fusion," EMC2, ENN Fusion Symposium, 20 April 2018: http://luminaryapps.com/temp/Polywell-Fusion-Park.pdf
- Tim Ventura, "Robert Bussard on IEC Fusion Power & The Polywell Reactor," Medium.com, 7 December 2019: https://medium.com/discourse/robert-bussard-on-iec-fusion-power-the-polywell-reactor-be4a59dc7318

Patents

- Patent application US2015/0380114A1, "Method and apparatus of confining high energy charged particles in magnetic cusp configuration," filed by EMC2 11 March 2015, published 31 December 2015, current status: abandoned 2019: https://patents.google.com/patent/US20150380114A1/en?oq=US+2015-0380114+A1
- Patent application WO2018/208953A1, "Generating nuclear fusion reactions with the use of ion beam injection in high pressure magnetic cusp devices," filed by EMC2 9 May 2018, published 15 November 2018: https://patents.google.com/patent/WO2018208953A1/en?oq=WO%2f2018%2f208953