Z PINCH FUSION SYSTEMS – Who will be the first to achieve breakeven and beyond?

Many Players in Fusion Large and Small

A few months ago, an article in the Economist highlighted six key players in the private fusion landscape. If you're familiar with the space, you won't be surprised to see **General Fusion**, **Tokamak Energy**, **First Light Fusion**, **Commonwealth Fusion Systems, Helion Energy** and **TAE Technologies** mentioned. These players were noted as the heavy hitters in the field, but there are 36 other firms also looking to advance fusion technologies that were written off as "tiddlers." While there is no doubt the previously mentioned companies have achieved impressive milestones and have raised substantial capital, other players looking to commercialize fusion power should not be overlooked.

Z Pinch systems, which companies like **Magneto-Inertial Fusion Technologies, Inc. (MIFTI)** and **Zap Energy** are accelerating, and modular fusion technologies, like those presented by **Avalanche Energy**, **Electric Fusion Systems** and **Compact Fusion Systems**, offer innovative designs that may provide a faster pathway to net energy gain, given their smaller, lower cost, fusion-based reactor construct.

Achieving Breakeven:

Although there is no doubt of the importance that larger companies will play in connecting nuclear fusion systems to the grid and in the overall journey towards commercialization. Some of these smaller players may also play a sizable role as potentially the first to achieve "breakeven" and ultimately "ignition," commonly known as net energy gain, or an exponentially higher energy output in relation to the energy required to produce the effect. This is the key milestone that private companies are looking to achieve.

So far, Lawrence Livermore National Laboratory (LLNL) is the only entity to achieve a significant advancement in fusion energy gain using Inertial Confinement Fusion (ICF) systems that require a costly and complex assembly of high-powered lasers. The LLNL scientists have twice successfully applied almost 400 MJ of energy producing 2MJ of laser energy that was then absorbed in a target to produce 3MJ of fusion energy, thus achieving what is termed "scientific breakeven." In this case, the fusion energy produced was more than the energy absorbed by the target.

However, although ICF systems were the first to prove controlled nuclear fusion breakeven was possible, there is still a long pathway forward for these types of technologies to be scalable and repeatable on a commercial level. On the other hand, magnetic confinement fusion (MCF) systems, which use high powered magnets, and include system configurations like tokamaks and stellarators, are looking to overcome challenges related to plasma stability and engineering of highly complex systems.

Z Pinch Fusion Configurations

Z Pinch fusion systems, like those pioneered by MIFTI and Zap Energy, do not face many of these challenges. Z Pinch works by using the same deuterium and, sometimes, tritium isotopes of hydrogen for fuel. However, in this case a large current is passed through the plasma, compressing and pinching the plasma into a column thus stabilizing it. This system does not require expensive magnets or lasers, and allows the ions to collide whereby fusion reactions take place and generate a neutron yield. These fusion-propagated neutrons are "captured" in sufficient quantity to generate heat and thus produce power for electricity. Both MIFTI and Zap have made significant strides in this field.

MIFTI was founded in 2008 by scientists working at the University of California, Irvine (UCI) and successful, California-based entrepreneurs. The MIFTI team is developing their Staged Z-pinch (SZP) system; a multi-layered pinch whereby cylindrical, fusible target plasma is surrounded by concentric shell liner plasma made of high-Z radiative plasma. A fast-rising current pulse compresses this cylindrical load of multi-layered plasma that allows for shock heating and then compressional heating of the fusible plasma target to an extremely high density and temperature greater than 10KeV.

Since MIFTI's SZP reaction produces a stable, very high density, high temperature plasma, it leads to a much higher fusion energy yield as compared to the other concepts. State of the art computer modelling for scale-up predicts that SZP technology, using a current of more than 10 MA, can produce a net gain in fusion energy.

MIFTI's President and Chief Scientist, Dr. Hafiz Rahman, reports that recent test results on the L3 Harris 4 MA machine in San Leandro, California, set at a current level of 3 MA, produced remarkably stable results that met all advanced computer code predictions. Dr. Rahman further elaborated that MIFTI's recent experiments at L3 Harris produced a neutron yield of 10 to the 11^{th}; the highest level ever achieved by any private company in the world. MIFTI has accomplished this significant success on an overall budget of $12 million, including a $5.1 million Department of Energy Advanced Research Projects Agency - Energy (DOE/ARPA-E) grant.

Zap Energy has raised substantial funding from investors in the amount of $160M in 2022, quickly accelerating the development of their sheared flow Z pinch system. Zap's sheared flow motion fusion technology results from the geometry of a nose cone that makes parts of the plasma ring move at different speeds which produces a stabilizing effect. Zap has also received a $5 million grant from the Milestone Based Fusion Development Program earlier this year.

Looking Ahead:

While MIFTI and Zap may not be the first companies that come to mind when we think of leaders in the nuclear fusion race, their rapidly developing technologies should not be overlooked. Creating commercial fusion systems will require a wide variety of technology types and the build out of different supply chains. The climate crisis will require various solutions to provide a safe and sustainable alternative to fossil fuels, and nuclear fusion and Z pinch fusion systems may be closer on the horizon than we think.