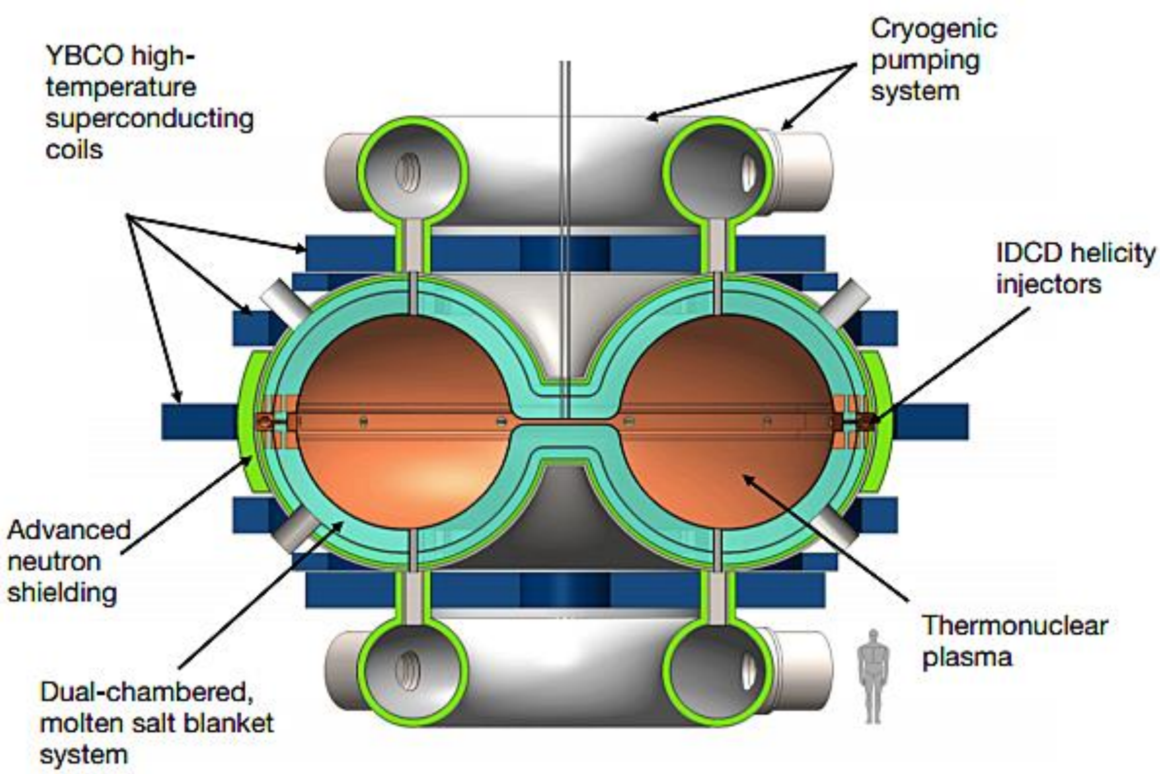
The Fork in the Road to Electric Power From Fusion

CTFusion

Peter Lobner, 1 February 2021

CTFusion was founded in 2015 by Derek Sutherland and Thomas Jarboe as a spin out from the University of Washington's (UW) HIT-SI (Helicity Injected Torus with Steady Inductive drive) research group. The spin out was aided by a $50,000 grant from the UW Innovation Fund in June 2015. Several UW fusion patents are licensed exclusively to CTFusion. Their website is here: https://ctfusion.net

CTFusion is commercializing UW's Dynomak advanced spherical reactor design concept for use in a D-T burning, steady state fusion power plant. A Dynomak imposes s dynamo current drive on a spheromak plasma. The general arrangement of a power plant scale Dynomak is shown in the following diagram.



Dynomak reactor cross-section. Source: CTFusion

You'll find details on this particular design in Patent US9754686B2.

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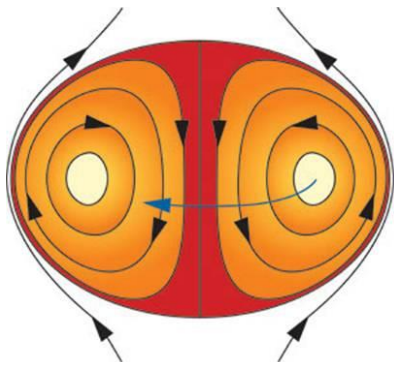
Key design features of a Dynomak commercial power plant are:

- **Spheromak:** A spheromak is a compact, toroidal magnetized plasma contained in a simply connected confinement volume. This means no coils link the plasma through the central axis (as it does in a tokamak). Spheromak magnetic fields are primarily generated by currents driven through the plasma. Therefore, equilibrium is achieved without the use of external coils linking the plasma. This enables a smaller reactor than a tokamak with equivalent power.



A typical spheromak at equilibrium. Toroidal flux is blue. Source: UW

- **Imposed-Dynamo Current Drive (IDCD):** This is a method for forming and sustaining compact magnetically confined fusion plasmas. IDCD involves injecting magnetic helicity into the plasma using toroidal injectors rather than electrodes. This approach reduces plasma wall reactions and improves plasma profile control. IDCD is expected to enable steady-state operation at a much lower energy cost.

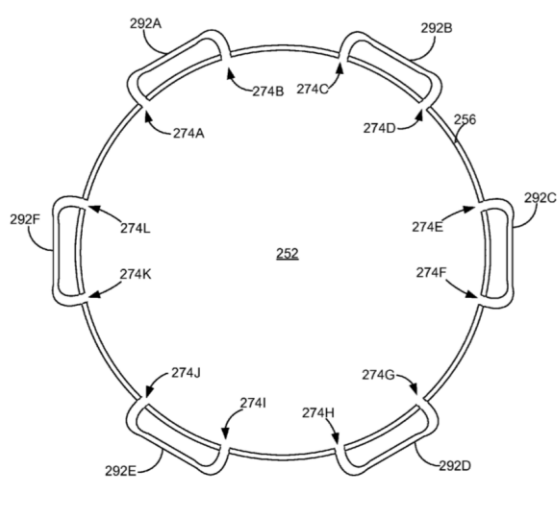


FIG. 2B

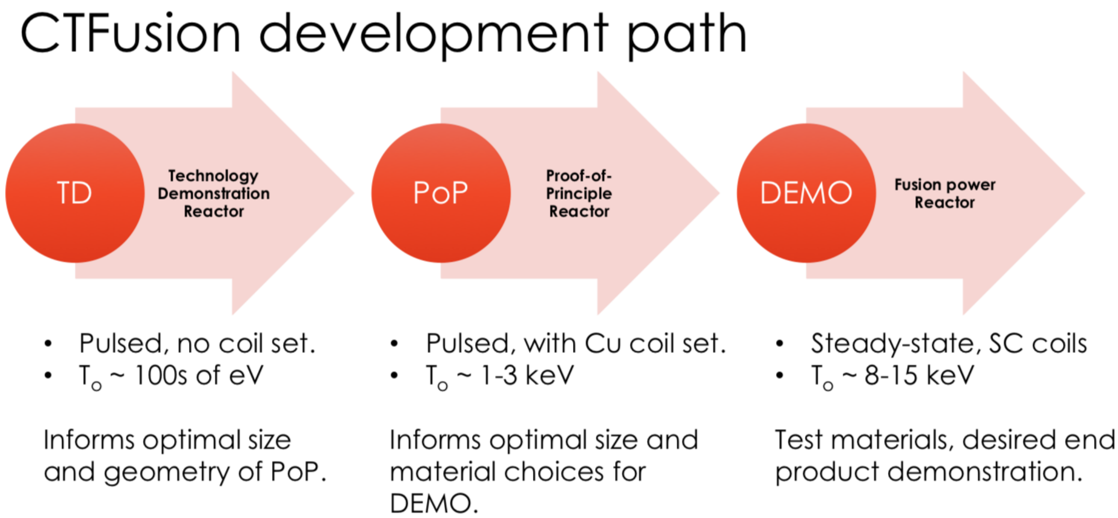
Plasma confinement chamber (252) with helicity injectors (274, 292) placed symmetrically around the outer edge. Source: US9754686B2

- **High Temperature Superconducting (HTS) magnets:** Rare-earth (yttrium)-barium-copper oxide (ReBCO or YBCO) magnets will be fabricated from superconducting tape that can operate at 90 °K (-297 °F), which is above the temperature of liquid nitrogen (77 °K; −320 °F). These magnets enable stronger magnetic confinement fields in a more compact fusion machine.
- **Molten salt blanket:** The blanket serves as the primary heat transfer medium for cooling the first wall of the Dynomak and the tritium-breeding medium. It also functions as a neutron moderator. The particular salt to be used is FLiBE, which is a mixture of lithium fluoride (LiF) and beryllium fluoride (BeF_2).
- **Brayton cycle power conversion system:** The advanced supercritical carbon dioxide Brayton power cycle provides high thermal efficiency (about 40%) and improved plant economics.

CTFusion is developing the IDCD plasma sustainment technology on UW's Steady Inductive Helicity Injected Torus (HIT-SI3 and HIT-SIU) machines, which are about one-tenth the scale of a power-producing Dynomak.

Under DOE's ARPA-E OPEN 2018 program, CTFusion was awarded $3.46 million for a period of performance from 2019 to 2021 for its HIT-TD Technology Demonstration (TD). With this funding, CTFusion will conduct an integrated demonstration of IDCD and confirm the scalability of spheromaks sustained with IDCD toward eventual power plant conditions.

After TD, CTFusion plans to develop its Containment Demonstrator [aka Proof-of-Principle (PoP) reactor], which will help refine the technology for plasma confinement. Plasma profile control and helicity injection will be part of the CD tests. After the TD and CD tests have been completed, CTFusion plant to build their first Dynomak demonstration plant, which will be designed to achieve a net gain ($Q > 1.0$).



Source: CTFusion (2017)

CTFusion's Dynomak design target (in 2014 and 2017) was for a 2,486 MWt / 1,000 MWe commercial power plant with an overnight capital cost of $2.8/W and a total cost of $2.8 billion in 2016 dollars. DOE's ARPA-E has recommended the following cost targets for a commercial fusion power plant: Overnight capital cost of < US $2 billion and < $5/W. On a cost per Watt basis, the CTFusion Dynomak is well within the ARPA-E guidelines. A smaller plant (< 714 MWe) easily could meet the $2 billion target.

Funding

CTFusion received seed funding from the UW Innovation Fund in June 2015 ($50,000) and a US Small Business Innovation Research Grant in June 2018 ($150,000).

As described above CTFusion also received $3.46 million under the DOE's ARPA-E OPEN 2018 program.

Under the DOE ARPA-E BETHE program, UW received $1.5 million for improving IDCD plasma control, which is applicable to UW's collaborative work with CTFusion on the Dynomak fusion reactor concept.

For more information

- "Spheromaks - What is a spheromak?" University of Washington: https://www.aa.washington.edu/research/HITsi/research/spheromak
- D. A. Sutherland, et al., "The dynomak: An advanced spheromak reactor concept with imposed-dynamo current drive and next-generation nuclear power technologies," Fusion Engineering and Design, Vol. 89, Issue 4, pp. 412 – 425, April 2014: https://www.sciencedirect.com/science/article/abs/pii/S0920379614002518
- Brian Wang, "Dynomak nuclear fusion roadmap and technical details," NextBigFuture, 11 October 2014: http://nextbigfuture.com/2014/10/dynomak-nuclear-fusion-roadmap-and.html
- Derek Sutherland, "Steady-state spheromaks for the pursuit of economical fusion power," CTFusion, 30 August 2017: https://arpa-e.energy.gov/sites/default/files/6_SUTHERLAND.pdf
- "HIT-TD: Plasma Driver Technology Demonstration for Economical Fusion Power Plants," ARPA-E OPEN 2018 program: https://arpa-e.energy.gov/technologies/projects/hit-td-plasma-driver-technology-demonstration-economical-fusion-power-plants
- D.A. Sutherland, "R&D activities for the sustained spheromak approach to magnetic fusion energy," CTFusion presentation, 16 December 2020: http://www.firefusionpower.org/FPA_20_Sutherland_CTFusion.pdf

Patents

- Patent US2014/0321587A1, "Magnetically Contained Energized Plasma," filed 14 November 2012, published 30 October 2014, assigned to US DOE (2020): https://patents.google.com/patent/US20140321587A1/en?oq=US20140321587A1

- Patent US9754686B2, “Plasma confinement system and methods for use,” filed 18 August 2014 by UW Center for Commercialization, granted 5 September 2017: https://patents.google.com/patent/US9754686?oq=Thomas+R.+Jarboe