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Overview of TAE Technologies' Fusion Program

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TAE Technologies (TAE; formerly named Tri Alpha Energy) was established in 1998 as a fusion start-up private company, spun off from University of California at Irvine by the late Prof. Norman Rostoker, aiming for the development and steady operation of commercial fusion reactors. It is currently one of the world's largest privately funded fusion research companies. TAE's concept of a magnetically confined fusion reactor is based on utilizing a field-reversed configuration (FRC) as the core plasma and performing plasma heating and current drive for steady operation by neutral beam (NB) injection [1]. TAE's fusion approach is to eventually adopt advanced fuels such as hydrogen-boron (p-^{11}B) with the ultimate aim of a safe and economical fusion reactor that does not generate neutrons in its primary fusion reaction. This approach also has many technological advantages that make it easier to design, construct and operate the reactor because there is little to no concern about neutron induced damage on the reactor.

An FRC is a high-beta compact toroid (CT), solely consisting of poloidal axisymmetric magnetic field inside closed-field lines formed by the toroidal self-current, where its separatrix is surrounded by open-field lines. The volume-averaged beta (ratio of plasma pressure to external magnetic pressure) is near unity, so FRCs can be compact and highly magnetically efficient thus economically attractive as a fusion reactor plasma. Furthermore, because the closed magnetic-field-line structure exists independently of the open magnetic-field lines outside the separatrix, FRCs can be easily translated in the axial direction. A direct energy conversion may also be utilized by using natural divertors at both ends of the device.

TAE's current experimental device, C-2W (a.k.a. "Norman," shown in Fig. 1), is the company's fifth generation FRC device and the world's largest theta-pinch, CT collisional-merging system [2]. It forms high-magnetic-flux, high-temperature, and stable FRC plasmas. High-energy particles inside the FRC are injected/produced by a state-of-the-art tunable energy (15-40 keV variable during a shot) NB injector system. It has made significant progress in FRC performance, producing record breaking, high temperature ($T_e \sim 1$ keV, $T_{tot} > 5$ keV) advanced beam-driven FRC plasmas, dominated by injected fast particles and sustained in steady-state for up to 40 ms (limited only by the energy storage on-site). An active plasma control system has been developed and utilized in C-2W to produce better and consistent FRC performance using magnets, electrodes, gas injection, and tunable-energy NBs. Overall FRC performance is well correlated with NBs and edge-biasing system, where higher total plasma energy is obtained by increasing both NB injection power and applied-voltage on biasing electrodes. Google's machine-learning framework for experimental optimization has been routinely used in C-2W [2,3]. Together with real-time control systems for FRC shape/position control as well as for electrode biasing and particle fueling, C-2W operations have now reached to a matured level where the machine can produce hot, stable, long-lived and repeatable plasmas in a well-controlled manner.

This presentation will review the highlights of recent C-2W experimental campaigns as well as future plans and perspectives of TAE's fusion program. TAE's next fusion device, called Copernicus, is under construction; its program goals and some key design parameters will also be presented.

References

[1] M.W. Binderbauer *et al*., Phys. Plasmas **22**, 056110 (2015).
[2] H. Gota *et al*., Nucl. Fusion **61**, 106039 (2021).
[3] E.A. Baltz *et al*., Sci. Reports **7**, 6425 (2017).

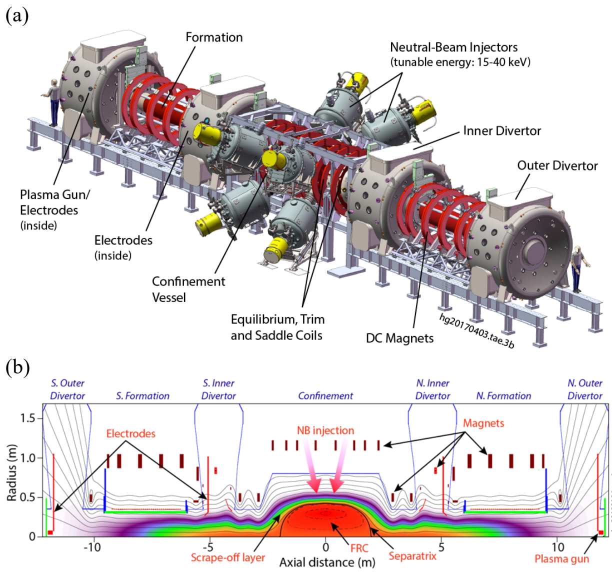

Figure 1. (a) Illustration of the C-2W experimental device, Norman, consisting of the central confinement section surrounded by 2 inner divertors, 2 formation sections, and 2 outer divertors. Eight NB injectors (4 of 15 keV fixed-energy NBs and 4 of 15–40 keV tunable-energy NBs) are installed in the central region of the confinement vessel. (b) Sketch of FRC magnetic topology and density contours, calculated by 2D multifluid force-balanced equilibrium code, where field-line contours are traced and plasma densities are indicated with colors.