D. New concepts and Brainstorming

Fusion Internal Combustion Engine (Fusion-ICE)

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The adiabatic compression of hydrocarbon fuels to ignition has worked very well for the internal combustion engine, powering systems on scales ranging from model aircraft through to ocean liners. However, there is currently a desire to switch to non-CO_2 producing fuels for purposes of energy independence and climate change mitigation. We therefore propose a new device for compressing deuterium and tritium plasmas to ignition: the Fusion Internal Combustion Engine [1]. In this engine, a mechanical piston is used to adiabatically compress a plasma ring, isolating it from the walls of the combustion chamber by use of magnetic fields. The plasma remains compressed for most of the cycle, with a short decompression for refueling and refluxing. Heat released in the chamber (in the form of neutrons and hot particles) is captured to drive a steam cycle and turbine. No CO_2 is produced, and fuel is bred in the device.

Technologically, there exist engines of the scale that we propose: the world's largest diesel engine [2] has a bore of 96cm, 300 ton crankshaft, and generates ~10MW per cylinder with up to 14 cylinders per engine. One incarnation of our proposed technology is similar, resulting in 50MWe cylinders that can be ganged together on a single cam to deliver up to 250MWe. As such this technology would have a higher power density than existing hydrocarbon engines, and is scalable so costs and time-lines would be compatible with private sector development. An ultra compact configuration such as this would be simple, highly modular, and would have no interconnected coils thus allowing for easier maintenance and repair. First wall components are chosen to withstand continuous neutron fluxes of ~5MW/m^2, giving mass power densities similar to conventional reactors.

In terms of the physics, the plasma ring of choice is a compact torus with poloidal and toroidal magnetic fields otherwise known as the Spheromak [3]. Spheromak research during the last 20 years has culminated in confinement approaching that of the tokamak L-mode and various means for forming and sustaining the plasma have been demonstrated. Stability to dominant macroscopic modes has also been demonstrated. Adiabatic compression has been examined quite extensively though mostly as pulsed systems in which the peak compression and burn only occurs for short periods, and with targets that are quite small. Here we start with a 3m diameter plasma and compress with a volumetric compression ratio of ~10 on a time-scale short compared with the energy confinement time to obtain fusion conditions during a decay time (many seconds), during which the current profile does not evolve appreciably [4].

There remain several technical hurdles on the path to the realization of this concept, so a technical roadmap will be presented for addressing those issues. Not unsurprisingly they are not dissimilar to the issues already outlined in the DOE Renew report [5].

[1] S. Woodruff ‘Fusion Internal Combustion Engine’ *Patent Pending*
[2] Wartsila-Sulzer RT96-C see e.g. http://www.youtube.com/watch?v=jXHvY-zY9hA
[3] S. Woodruff Opportunities for the Compact Torus http://www.pppl.gov/conferences/ReNeW/T5Workshop/Tues_pres/CTO_Woodruff.pdf
[4] N. Mattor, S. Woodruff Confinement Scaling for the Adiabatic Compression of a Spheromak ICC 2010
[5] ReNeW report R. Hazeltine (Chair). D. N. Hill (Vice Chair) http://burningplasma.org/web/renew.html

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