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GSE, Inc.'s SIV-350 for DARPA ANCILLARY VTOL Propulsion

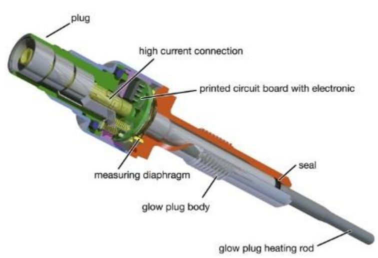
To meet the essential ANICILLARY Program HFE requirements the GSE preferred approach is to use a purpose built SIV-300 350. This HFE approach has all the key elements of a high-speed, multi-fuel injection and combustion system in a naturally aspirated design (Figure 1). The DARPA ANCILLARY propulsion requirements are constrained by a number of important factors, namely:

- Heavy Fuels as supplied by the Defense Logistics Agency Energy Enterprise (JP-5/JP-8/F-24/F-76) (i.e., requires true multi-fuel combustion).
- Prohibition law in Section 848 of the 2020 national Defense Authorization Act (NDAA) restricts COTS component procurement from China, Russia, Iran, and North Korea. This is key in that over 70% of Bosch/CI and Orbital/SI fuel systems are there by restricted by their China-based production.

Figure 1 – GSE SIV-350 HFE

- Wide cut DLA kerosene-based fuels are characterized by having variable viscosity, lubricity, and cetane ratings having adverse performance in ICE/HFE powerplants resulting in difficult cold start and erratic combustion trace/early flame out characteristics and limited life cycle for SI and CI intermittent combustion COTS engines."
- The vertical takeoff power versus the part load range and endurance objectives of the ANCILLARY vehicle dictates the need for a fundamentally new form of engine type that can produce 2~3x power for short VTOL maneuvers with approximately 10% power for extended cruise and time on station with an overall brake thermal efficiency approaching BTE= 40~45%. Depending on the ANCILLARY vehicle conceptual design, some form of efficient and lightweight combined-cycle engine is required.

Figure 2 – Heavy Fuel Ignition Independent of Pressure Ratio



The preferred GSE HFE combine cycle engine technology represents a breakthrough in terms of a robust Catalytic Hot Surface Ignition (CHSI) (Figures 2 & 3) that is timed by a 2~3% pilot injection and resulting flame front (Figure 4) which occurs after the bulk of the fuel is injected into the combustion space. This form of modern multi-fuel M-System combustion results in normalizing the rate of heat release from kerosene-based transport fuels having widely different fuel cetane ratings (Figure 4).

Figure 3 - Heavy Fuel Ignition Independent of Pressure Ratio

While CHSI remains incandescent in the combustion chamber resulting in stable heavy fuel combustion independent of engine scale, compression ratio, and/or ambient conditions.

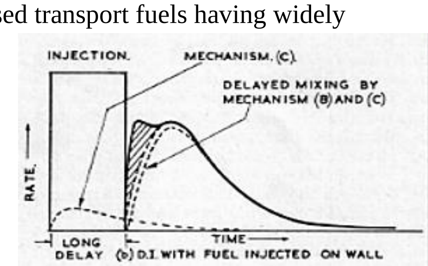
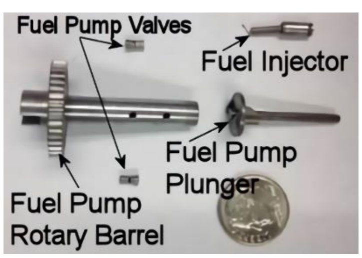
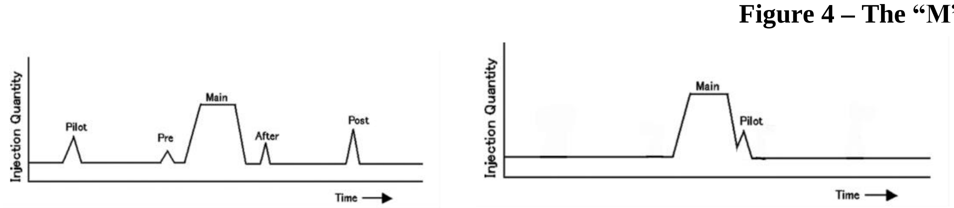


Figure 4 – The "M" System



The result is a smooth combustion process over a greater crank angle time with high air utilization and power output (Figure 5).



DI / Common Rail **GSE Hybrid DI / IDI / M-System**

Figure 5 - Mechanical Micro Fuel System - Impervious to EMP Attacks

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The heterogenous charge direct injection enables lean burn combustion at part load with a broad air/fuel ratio range from 17 to 55:1. The overall in cylinder peak to mean pressure ratio is kept below just 6:1, thereby greatly enhancing the durability of the multi-fuel engine while keeping the specific weight below 1 lb./hp.

Open combustion chamber clearance volume fitted with the CHSI ignition enables modest compression ratios below CR 9:1 to be employed. This results in the ability to highly supercharge the small engine on demand for the required 2~3x power during VTOL operations.

Parallel hybrid installations with motor/generator can be enhanced by an innovative compound differential transmission (Figure 6).

The advantage of which is related to the automatic power input proportional to propeller pitch and load. Hence, both the motor/generator torque being opposite the propeller results in the torque balance between the two at all times that self-compensates while greatly reducing any torsional vibration issues in the reduction drive system to the overhead rotor.

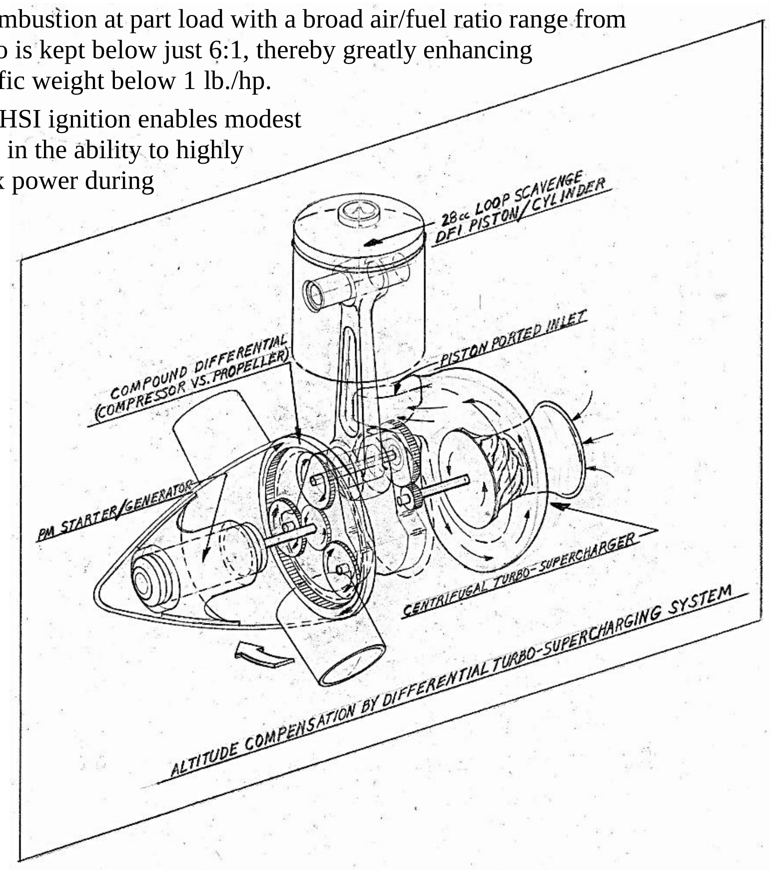

Figure 6 – Altitude Compensation Compound Differential

Multi-Fuel Combustion System

The cycle efficiency of any engine is proportionate to the ultimate expansion ratio, while the combustion efficiency is defined by the peak combustion pressure divided by the mean effective pressure in the cylinder (Figure 7).

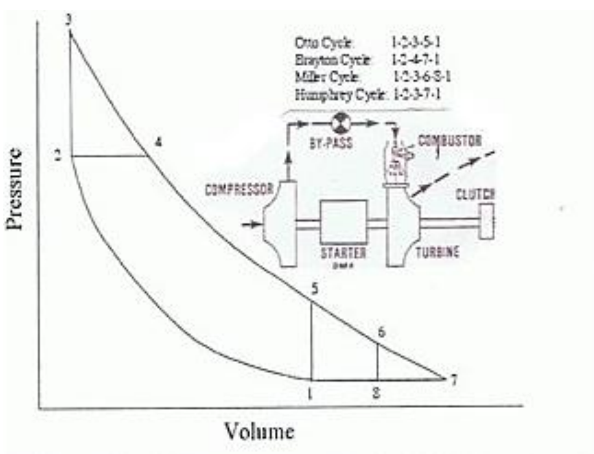

Figure 7 – Four Ideal Thermodynamic Cycles

Small engine displacements must be able to operate at high higher speeds to take advantage of their high volumetric efficiency while recovering heat losses by operating at piston speeds above 2500 ft/min. Hence the inherent advantages of the preferred pneumatic injection technology that has the lowest internal inertia and most rapid response rate that enables direct injection operating speeds up to 8,000 RPM. That is to say, the whole process of fuel **injection, atomization, evaporation**, and **combustion** is conducted within 30 degrees of crank angle time or just 0.4 milli-seconds at rated speed.