Development of a lightweight, man-portable, heavy-fuel Generator

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Customer Need

No heavy-fuel small gen set available (0.4-2kw)

Existing Solution = 2 Kw gen set

- "4-man portable"
- ~160 pounds
- Noisy
- Developed for "stationary" power

Need = Small, lightweight, portable, quiet

Competitive - $ per KW

Driving Forces – Small Gen Set

Single Fuel Forward –
- JP8 preferred
- Strong desire to use “scavenged fuel” in theater

Electronic Army –
- Battery charging a big issue

Fast and light –
- Single man portable

“Buy cheap” directive -
- Must be competitive on cost ($/KW)

Customers & funding emerging
- MEP (Mobile Electric Power)
- Nett Warrior
- USASOC

The Problem

1. Heavy fuels need “diesel process” to ignite
   - High compression ratios => high stresses
   - Units are heavy, and expensive – by definition
2. Spark Ignited heavy fuel – has been a “Holy Grail” for a long time
   - If possible – could adapt gasoline engines
   - Light, cheap, ubiquitous
   - Lots of experimenting – same problems keep arising
3. Heavy Fuels can be spark-ignited, if “hot enough”
   - Cold start not possible
   - Operation in cold conditions problematic
   - Some success – start on gasoline, switch after warm-up

Sponsorship

Mobile Electric Power (MEP) = Program to support development of spark-ignited heavy fuel technology

1. Initial work at QinetiQ – development of a “fog carburetor”
   - Developed for the Honda 1kw gen set
   - Voice of the customer on feature set and specifications

2. Additional work at Sonex – development of a “vaporizer”
   - Further development of a cold starting solution
   - Based on work for UAV 2-stroke heavy-fuel engines

3. **During development, QinetiQ and Sonex agreed on a Partnership, and work together to find an optimum solution !**
   - MEP supported the collaboration
   - QinetiQ contributed critical investment funds to keep the program going

Start with COTS

Honda 1 Kw gasoline gen set

- Quality
- Reliable
- High volume production
- Inexpensive

The Competing Solutions

1. First, solve the starting problem
   - Heat the fuel into a vapor electrically (from a battery)
   - Supply the hot vapor and air to the ignition chamber
   - Starts just fine

2. Switch away from electric power after starting
   - QinetiQ Fog Carburetor
     - Heats fuel/air mixture before ingestion into cylinder
     - Uses exhaust gas in the fog chamber

   - Sonex HFE –
     - Vaporizes “fuel droplets” in the combustion cylinder
     - Uses the “residual heat” in cylinder from previous combustion

QinetiQ Fog Carburetor

Combustion Solution - QinetiQ Fog Carburetor

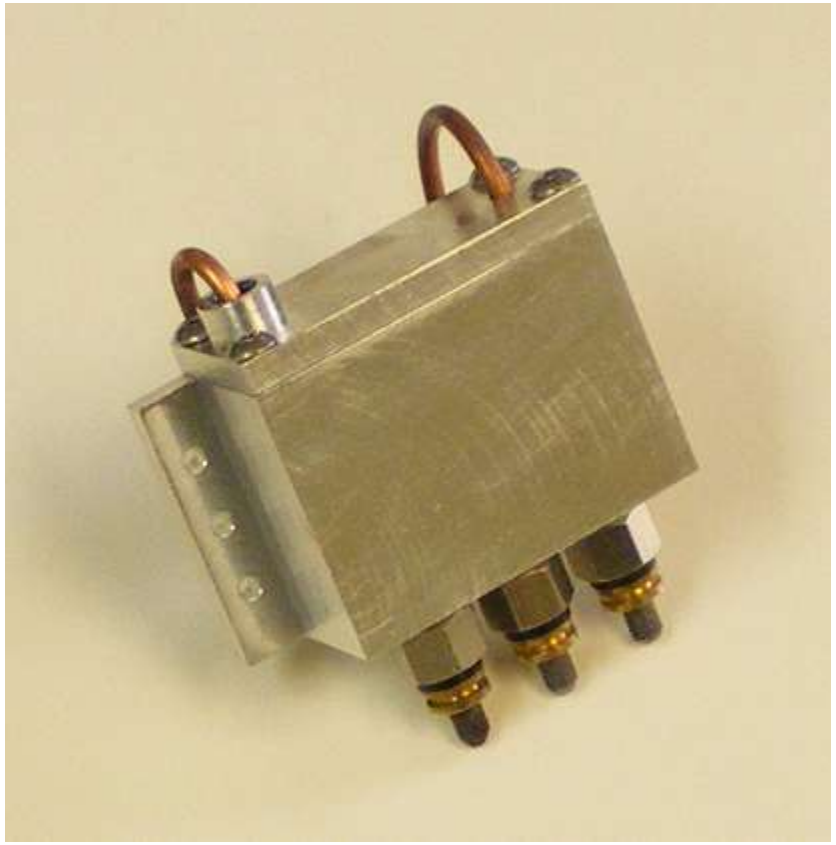
Characteristics of operation

- Fuel enters a separate heated chamber – vaporized to a fog – ingested into cylinder as air/vapor mix
- Chamber heated with electricity to start, switches to hot exhaust gas after starting (T>400 deg F)
- Electricity to “trim” the temperature for control

Works “fairly well” –

- “Proof-of-Concept” units for early customer feedback
- Needs a lower compression ratio to avoid knocking
  (an “issue” with Honda)
- A bit “fussy” to control (elevation and temperature)
- At “low temperatures” – fuel-in-oil becomes an issue.
  Fog condenses in cold engine cylinder

Sonex Cold Start Vaporizer (CSV)



Sonex vaporizer as installed in Honda Gen Set

Sonex Vaporizer

Characteristics of operation

- Fuel enters an electrically heated coil – vaporized for starting
- Switches to normal carburetion when the cylinder is “hot”
- Maintains cylinder head temperature for combustion

Works “quite well”

- Can run with COTS compression ratio – no steady-state knocking problem
- Can achieve COTS carburetor performance when hot
- Developed for Scan Eagle UAV – validated for 2-stroke engines
- (Has the same “fuel-in-oil issue” at cold temperatures)

Interesting Mechanics

- Unburned fuel collects on top of piston
- Is “thrown” up against the hot cylinder head and valves
- Vaporizes – (like spitting on a hot iron) - Spark ignites
- Stratifies the charge – no compression heating and pre-ignition

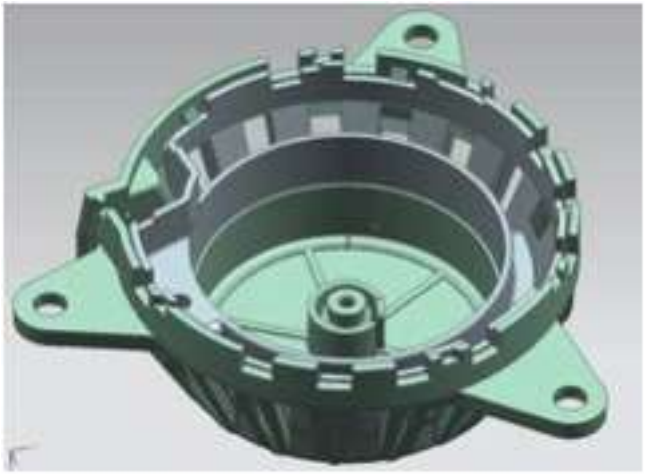
Collaboration

Key achievements from QinetiQ/ Sonex collaboration:

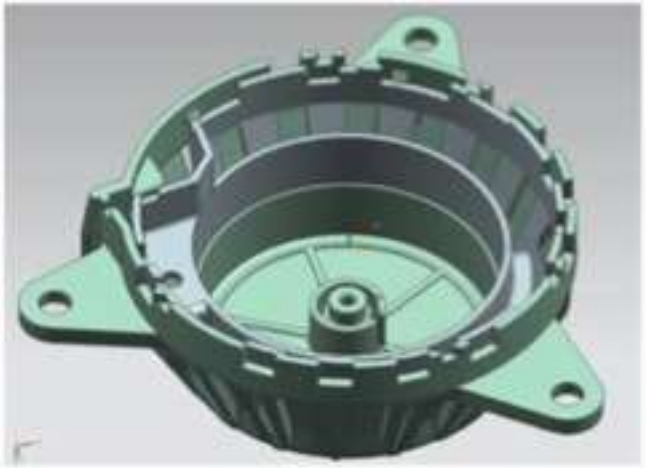
- Recognition that if cylinder temp is kept at ~400 deg F
  - The cylinder acts like the QinetiQ fog chamber !
- If temperature is controlled, fuel-in-oil issue is resolved !
  - All the fuel is burned
- Demonstration that active control of cooling airflow actually works.
  - Cold start – handoff to carburetor
  - Cold operation – maintain cylinder temp
  - Hot operation – equal to COTS cooling

Airflow Control

Fan inlet – COTS unit



Damper – open/ closed



Airflow Control

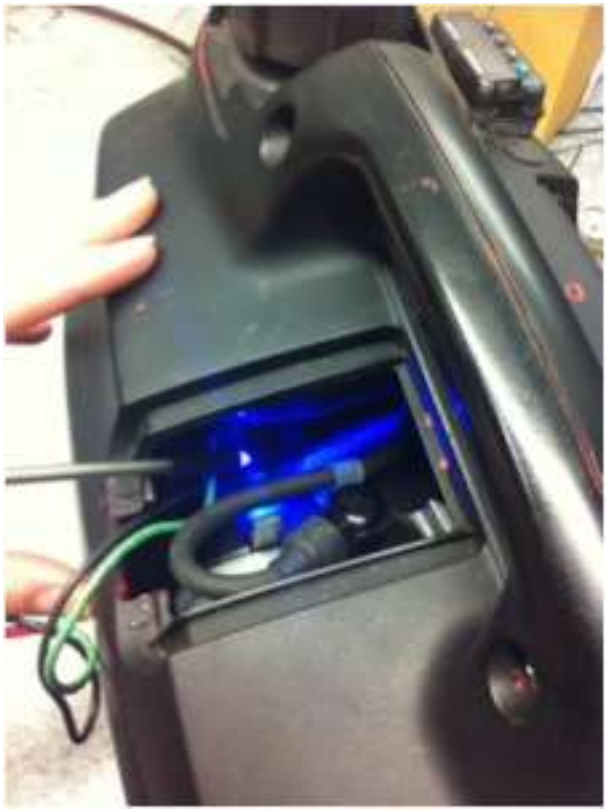
Rise over Ambient deg F	No Load	500w load
COTS Airflow	217˚	278˚
-20% Airflow	256˚	330˚
No Airflow	417˚	Way too hot

<u>Key for operation on Heavy Fuel:</u>
cylinder temperature >354˚ F

Airflow Controller

Cold Temperature “hand-off”

Time to reach 215° F, after starting	10° F	0° F
No load, -20% airflow	~6 min	~10 min
No Load, no airflow	~2.5 min	~3 min
500w AC load, no airflow	~1 min	~1.5 min

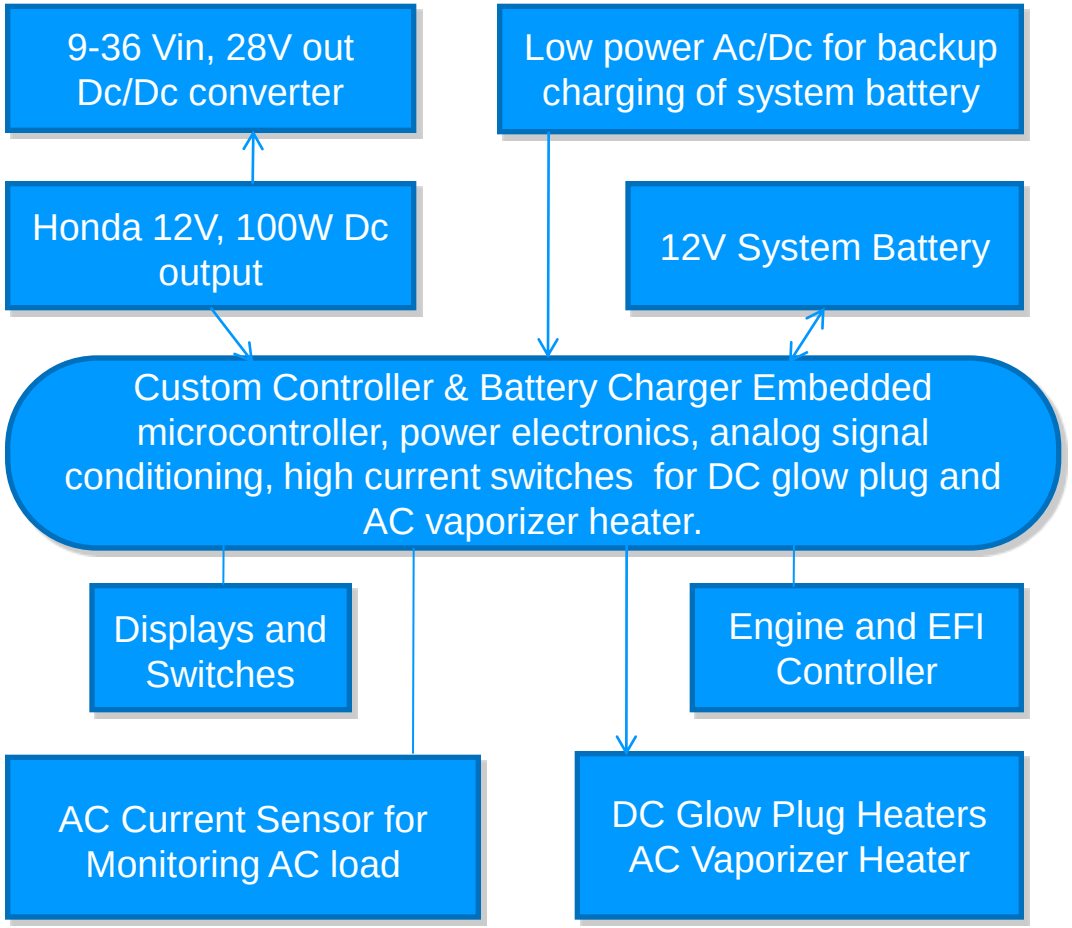


Critical Hand-off temperature:
cylinder temperature >215° F
for operation on carburetor

Target time to hand-off < 1.5 Min

Solution = heat with AC after start

Control and power switching



Product definition

Mod-1:

- Carburetor, near COTS
- JP8 fuel only
- Resolve feature set and specifications
- Voice of the customer
- LRIP units available 2011

Mod-2:

- Fuel Injector, new case
- Multiple fuels - heavy and gasoline (JP8, Jet A, DF2, gas)
- Specific “improvements”
  - Filtering for sand and dust
  - EMI suppression
  - Enhanced performance at altitude and temperature
- LRIP units available 2012

Mod-2: Multi-fuel Feasibility Assessment

Honda Engine
with vaporizer
and fuel injector

Mod-2: Multi-Fuel Solution

Fuel Injection is the ultimate solution

- More robust than Carburetion
- Operate on any fuel – no viscosity or flow problems
- Can control for temperature, altitude better
- Proven technology –
  - Flying on 2-stroke UAV engines
  - In volume production on low cost motorbikes
- Starting and temp control – same as Mod-1
- Same low cost solution

Feature set and specifications

Mobility: Single-Man-Portable (<40 lbs)

Fuel: Mod-1: JP8 only

Mod-2: Multi-fuel (JP8, DF2, Jet A, Gasoline)

Output Power: 110VAC – 1,000 Watts (1Kw)

24 VDC – 100 Watts

Noise: <64dBA @ 7 meters

Weight: (dry/Wet): 36 lbs / 39 lbs

Size: L=19”, W=9.5”, H=16”

Minimum Starting Temp: 10° F **Operating Temp:** -10° F to +125° F

Altitude: 1kW @ MSL, de-rated up to 6000ft

Fuel Capacity: 5 hours @ 80% Load (0.12 gal/hr)

How to get one

MEP is consolidating demand for Mod-1 units

- Call Dick Carroll – 270-719-1273
- **Dick.carroll@qinetiq-na.com**

Some other notes:

- Expected life ~1,000 hrs.
- Unit will alert for replacement
- Scheduled Honda maintenance – available as service

Appendix:

Since Everyone Loves to discuss the Technical Stuff….

See us at the Booth