

NOVATIO

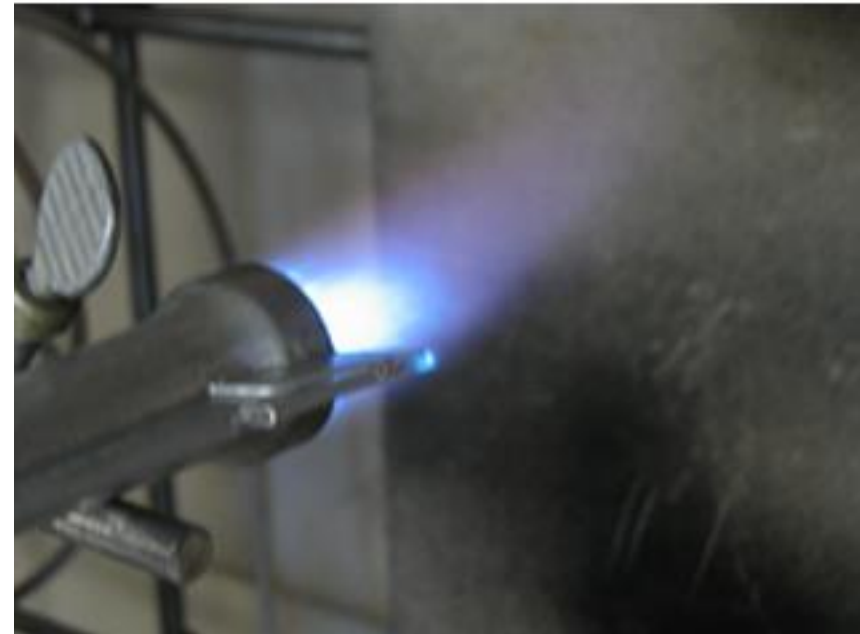
ENGINEERING, INC.

Fuel-Oil powered back-up generators

**NORA Technical Review
& Research Planning Workshop**
4 April 2019

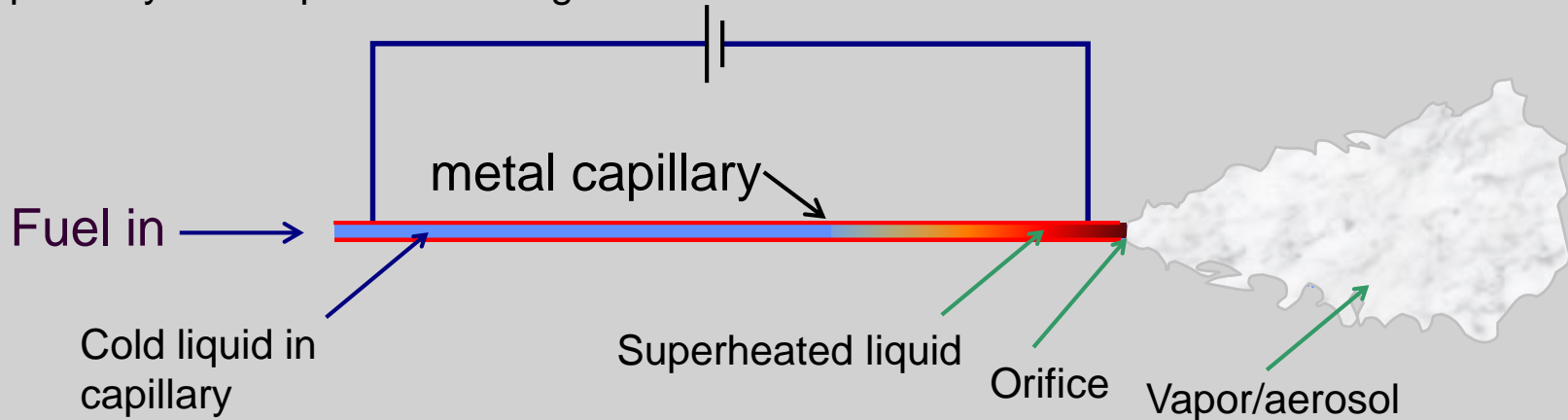
Capillary aerosol generator fuel pre-conditioner

- Capillary heaters use careful control of electric heat to create an aerosol from fuels
- Aerosol mixes with air almost like a gas
- Applications include fueling for burners and engines



Novatio fuel pre-conditioner is based on patented aerosol generator that produces a fine aerosol mist with liquid fuels

The underlying principle is flash-vaporization from heating in a capillary flow pathway and expansion through orifice.



- Capillary bundles are extremely small and can be integrated a valve or fuel existing fuel lines
- Aerosol fuels have been shown to mix with air almost equivalent to a gas
- Technology is in controls

US Military has for years been searching for a practical power source in the 0-3000W range that can operate on jet fuels and diesel.

Benefits of COTS gasoline inverter generators:

- Lightweight
- Low cost
- Proven engine and generator technology
- Very quiet: 50 dB(A) at rated load

Challenges of COTS gasoline inverter generators operating on mid-distillates:

- Engine knock
- Cold-start without assist
- Oil dilution
- Endurance

Can this technology be used as oil-fired back-up power for oil-fired boilers and furnaces?

System runs on DF-2. How much bio-diesel content can this technology accommodate reliably?

How to effectively integrate with boiler/furnace?



Honda EU1000i
29 pound, 900W generator

Various ways to coax COTS SI engine generators to operate on mid-distillate fuels

- Method 1: Modify/reform JP-8 or diesel into SI engine compatible (may include lower octane rating) fuels
- Method 2: Make use of starting agent to get engine started and then rely on engine heat to allow carburetor to operate with JP-8 or diesel
- Method 3: Vaporize/aerosolize oils for fuel injection into gasoline engine intake manifold

Notes:

- COTS generator operates in spark ignition mode (Otto cycle), not diesel mode
- These methods are similar in that none of them should require significant modifications to the engine.
- These methods differ in their complexity and in their tunability for different conditions or applications.

To enable operation of an SI engine on mid-distillates, we replace the carburetor with a fuel injector integrated with a capillary aerosol generator (CAG).

Unmodified carburetor



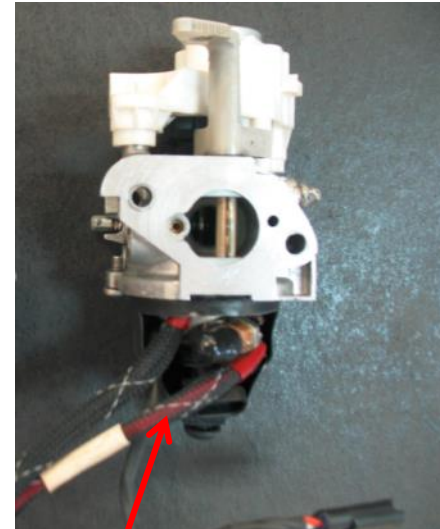
CAG/injector



Heaters

CAG/injector

Novatio kit



Multi-fuel generator line-up

Initial technology: fuel aerosolization technology



Integrate technology into fuel supply stream of SI engine

Ex-Power 1000

Multi-fuel expeditionary power generator

FEATURES

- Lightweight
- Quiet
- Efficient
- Multi-fuel
- E-start capable
- Parallel capable



0-900W, 1000W peak system, 34 lbs
JP-8, gasoline, DF-2 capable

Ex-Power 2000

Multi-fuel expeditionary power generator

FEATURES

- Lightweight
- Quiet
- Efficient
- Multi-fuel
- E-start capable
- Parallel capable



0-1500W, 2000W peak system, 52 lbs
JP-8, gasoline, DF-2 capable



PPG subsystem
In development,
0-500W, 15 pounds

Current offerings to US Military, both systems e-start capable



Challenges of operation on heating oil (automotive DF-2)

- Operation on DF-2
 - Cold start demonstrated at 20°F, not attempted lower
 - Slight de-rating of systems compared to gasoline or jet fuels to avoid engine knock
 - Slight oil dilution – recommended oil change after 20 hours of operation to avoid problems from build-up of oil levels and burning through breather tube

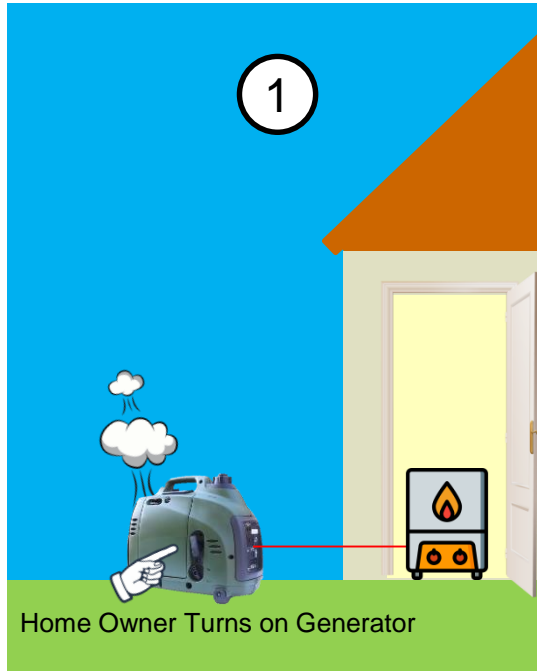
Diesel is currently considered an “emergency fuel” for our generators to US Military

Challenges of operation on bio-diesel blends

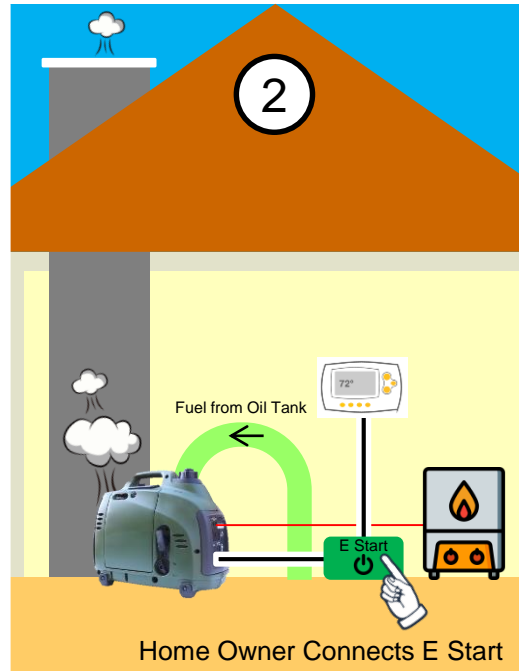
- Brief experiment on B33 with 900W system, using “trims” to DF-2 settings:
 - Room temperature start demonstrated, ~5 pulls
 - Power output to 750W demonstrated on 900W generator
 - Clean (invisible) combustion exhaust demonstrated within 5 minutes of start
 - Requires more heat to adequately aerosolize fuel than DF-2
 - No conclusions on oil dilution
- B50 trial less successful – will require more substantial changes to settings at higher blends of bio-diesel

Integration concepts for oil-fired boilers and furnaces

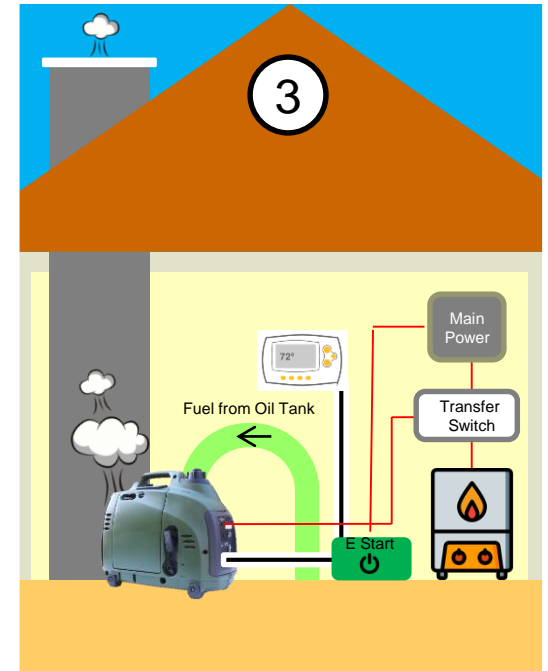
Concept 1:
Simple solution



Concept 2:
Semi-Integrated solution



Concept 3:
Fully-Integrated solution



Maintenance and Market Questions

Maintenance

- Oil changes, timing tbd
- Spark-plugs
- Fuel-fouling mitigation
- Valve adjustments recommended every 300 hours operation
- Not clear how bio-diesel will affect maintenance requirements

Other Market questions:

- How much is such a technology worth to oil heated homes?
- Gasoline generators <\$1000 without Novatio technology
- Current configuration ~\$2500 cost (\$350 fuel pump) at low volumes
 - Cost reduction has not been a driver so far
- Would a larger system (2kW?) for other “priority” loads, wired with load shedding transfer switches be of interest?