DISRUPTIVE INNOVATION: INI POWER SYSTEMS

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Cincinnati, OHIO

Session 11: Generators/Man portable
(South Meeting Rooms 232-233)
ABOUT INI Power Systems

- **Who we are**
  - Small U.S. Business in Morrisville, NC
  - DOD Operational Energy focus

- **What we do**
  - Bridge Operational Energy Capability Gaps
  - SOLVE WARFIGHTER PAIN POINTS!!

- **Why we do it**
  - Support the Warfighter
  - Enhance Combat effectiveness

- **How we do it**
  - Boots on the ground observation
  - Closed loop innovation strategy
OPERATIONAL ENERGY MANDATES

- **Reduce JP-8 /Log Tail**

- **Lighten the Load**
  a) Weight $\approx$ fuel and maintenance

- **Enhance Combat/Mission Effectiveness**
  a) Safe/Simple/Reliable solutions
  b) Easy for operator to maintain
  c) Field maintainable / Field sustainable
Disruptive Innovation =

*Rapid* iterative development of *cost effective* material *solutions* that successfully *bridge* capability *gaps* while fulfilling established and emerging *requirements*
Paradigm Shift from primary to rechargeable batteries to reduce logistics burden and cost:

- FY12 52% of DOD battery spend on rechargeables compared to 26% in FY05
- Handheld rechargeable mobile devices become ubiquitous and typically require less than 50W to recharge
- DOD battery chargers require 50-300W max power
- The smallest DOD generator is sized for 2kW and weighs 145lbs
- Wetstacking becomes common DOD terminology

Capability gap emerges for a reliable DOD generator with the following emerging requirements:

- weight <45lbs (one man portable)
- Right sized to the battery charger critical
- Produces 300W of minimum sustained power
- Quiet is better than loud
- Must be JP8 compatible

• Jet Fuel differences:
  – JP-8 properties
    • < 3000 ppm sulfur; variance allowed in fuel properties including cetane number and distillation curve
      – Referee grade more specific

  – JP-8 is Jet-A1 with three additives
    • fuel system icing inhibitor (MIL-DTL-85470), corrosion inhibitor and lubricity enhancer (MIL-PRF-25017), and static dissipator additive

  – Jet-A1 has lower freeze point than Jet-A (-53 F vs. -40 F)
**JP-8 and Spark Ignition Engines**  
*(Bridge the Gap)*

JP-8 has both spark and compression ignition windows. 4 cycle spark engines are light and quiet!
One Man Portable Flex Fuel Generator (1MPG)

Start Count and Run Length, Unit 1
Total Starts: 381, 25 May – 27 Nov 2012

Version 2.0 nearly
1. 32lbs (MCOTS)
2. 400 consecutive cold starts (two methods)
   • Chemical and/or
   • Thermal
One Man Portable Flex Fuel Generator (1MPG)

Third Party Validated at Temperature Extremes:

-20°C Cold Start  Performance Measurements  Battery Charging at 110°F
V 2.0 1MPG JP8 consumption linear with load and time

- no load (blue ⬤)
- 200 W (red ■)
- 400 W (green ▲)
- 600 W (purple ✗)
- 800 W (light blue ✶)
One Man Portable Flex Fuel Generator (1MPG)

- Version 2.0 1MPG (CY12)
  - six months development
  - 300 hour simple maintenance
  - 1MPG ran over 1800 hours
  - root failure ID’d
V 2.0/2.1 conclusions
✓ JP8 requirement validated with 4 cycle spark engine
✓ Weight requirement validated
✓ Power requirement validated
✓ Fixed jet carburetor provides long life time with simple routine maintenance cycles
✓ NIE 14.1 favorable DP3

New or emerging requirements for V2.5
1) Need simple method to tune A/F ratio in the field
   a) Lifetime improvements
   b) EPA emissions/combustion efficiency
   c) High altitude battery charging
2) F-24 validation(CONUS)
INI Intelli 1kW Flex Fuel Gen v2.5

CS15 ARMY 1MPG Increased Capabilities:

1. High Impact Resistant Ether shroud (tool free)
2. Fuel leaning valve (tool free)
3. Carburetor jet screw (tool free)
   red = sea level - 5000ft
   blue = 5000 - 10000ft
4. Welded Exhaust
5. Improved fuel labeling (primary, alternate, contingency, emergency)

FLEX-FUELS

<table>
<thead>
<tr>
<th>Primary Military</th>
<th>Alternate Civilian</th>
<th>Contingency*</th>
<th>Emergency*</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. JP-8</td>
<td>1. Gasoline</td>
<td>Diesel #1</td>
<td>Alcohol</td>
</tr>
<tr>
<td>2. JP-5</td>
<td>2. Kerosene</td>
<td>Diesel #2</td>
<td>F-76</td>
</tr>
<tr>
<td>3. JP-4</td>
<td>3. White Gas</td>
<td>Paint thinner</td>
<td>Nail Polish</td>
</tr>
<tr>
<td>4. F-34 (NATO)</td>
<td>4. Rubbing Alcohol</td>
<td>Rubbing Alcohol</td>
<td></td>
</tr>
<tr>
<td>5. F-24</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. AVGAS</td>
<td>5. Diesel #1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. MOGAS</td>
<td>6. JET A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Any blend of above</td>
<td>7. 50/50</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(Gasoline/Diesel٢)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>8. Any blend of above</td>
<td>8. Propane (UPAK req'd)</td>
<td></td>
</tr>
</tbody>
</table>

*Check oil level every 5 hours

Autostart or BB-2500 Start:
1. JP-8
2. F-34
CO Emissions

- Normal (red square)
- Economy (blue diamond)
- Lean (green triangle)
- EPA limit (dotted line)

V2.5 passes EPA requirement
Test Plan

Purpose:
• Verify INI Intelli 1kW Flex Fuel Generators v2.5 performance improvements over v2.1
• Verify flex-fuel capabilities

Three Tests:
• Test 1 (8-11 DEC 2014) - v2.5/multi-fuel verification
• Test 2 (5-10 JAN 2015) - v2.5 atmospheric testing
• Test 3 (09-12 FEB 2015) – Company Charging Capacity Test
Test 1

- At Tobyhanna Army Depot Generator Shop
- 08-11 December 2014
- Verification of v2.5 configuration and its ability to flex fuels
## Test 1 - Metrics

<table>
<thead>
<tr>
<th>Date</th>
<th>FUEL (ml)</th>
<th>Fuel Consumed (ml)/GEN</th>
<th>AVG Total Run Time/GEN</th>
<th>AVG Tank Run Time (2500ml/.6gal)</th>
<th>AVG ml/hr</th>
<th>AVG GAL/Hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>8-Dec</td>
<td>JP-8</td>
<td>5000</td>
<td>11:31</td>
<td>6:21</td>
<td>430</td>
<td>0.11</td>
</tr>
<tr>
<td>9-Dec</td>
<td>DF-1</td>
<td>3000</td>
<td>7:51</td>
<td>7:20</td>
<td>378</td>
<td>0.10</td>
</tr>
<tr>
<td>10-Dec</td>
<td>GAS</td>
<td>2750</td>
<td>6:35</td>
<td>5:32</td>
<td>425</td>
<td>0.11</td>
</tr>
<tr>
<td>11-Dec</td>
<td>Kero</td>
<td>3500</td>
<td>8:29</td>
<td>6:35</td>
<td>413</td>
<td>0.11</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Date</th>
<th>FUEL (ml)</th>
<th>AVG ENGINE RUN TIME (hrs)</th>
<th>AVG ENGINE TEMP (C)</th>
<th>AVG OUTPUT (Volts)</th>
<th>AVG LOAD (Amps)</th>
<th>AVG LOAD (Watts)</th>
<th>AVG HOSE TEMP (C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8-Dec</td>
<td>JP-8</td>
<td>11.6</td>
<td>159.5</td>
<td>122.3</td>
<td>4.9</td>
<td>599.4</td>
<td>104.5</td>
</tr>
<tr>
<td>9-Dec</td>
<td>DF-1</td>
<td>7.9</td>
<td>156.2</td>
<td>122.2</td>
<td>4.9</td>
<td>599.9</td>
<td>97.0</td>
</tr>
<tr>
<td>10-Dec</td>
<td>GAS</td>
<td>6.5</td>
<td>161.1</td>
<td>122.3</td>
<td>4.7</td>
<td>573.2</td>
<td>97.5</td>
</tr>
<tr>
<td>11-Dec</td>
<td>Kero</td>
<td>8.5</td>
<td>163.7</td>
<td>122.2</td>
<td>4.9</td>
<td>599.7</td>
<td>104.2</td>
</tr>
</tbody>
</table>

1MPG V2.5 flex fuel validated for short durations
Test 2

• Electronic Proving Grounds Environmental Test Facility
• 05-10 January 2015
• v2.5 Atmospheric testing (simulating 5000 feet & 10,000 feet)
• In parallel with the SPM-622 atmospheric testing
5K altitude and ambient temp had no effect on running with F-24, generator performed very well

- Similar SPM battery charging pattern pulling 120W load for battery charging at ambient temperature
- 400W Light load remains constant

- 10K altitude had an affect on power production indicated by engine rpm and output power oscillation*
- When load dropped below ~420W oscillation stopped*
- Similar SPM battery charging pattern pulling 120W load for battery charging at freezing
- 400W light load remains constant
Generator Testing Key Finding

- v2.5 is a marked improvement over v2.1
- Runs best with F-24 or JP-8
- Operator experience key to optimal performance
- Tweaks necessary for flexing fuels and high altitude performance

<table>
<thead>
<tr>
<th>Test</th>
<th>S/N</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>01074</td>
<td>66.7 hrs</td>
</tr>
<tr>
<td></td>
<td>01076</td>
<td>62.9 hrs</td>
</tr>
<tr>
<td></td>
<td>01077</td>
<td>62.4 hrs</td>
</tr>
<tr>
<td>2</td>
<td>00991</td>
<td>40.2 hrs</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>232.2 hrs</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Operation at 2000ft</th>
<th>Operation at 5000ft &amp; 12C</th>
<th>Operation at 10,000 &amp; -1C</th>
<th>Charging Profile Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>JP-8</td>
<td></td>
<td></td>
<td></td>
<td>Not Tested</td>
</tr>
<tr>
<td>F-24</td>
<td>Not Tested</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gasoline</td>
<td></td>
<td></td>
<td></td>
<td>Not Tested</td>
</tr>
<tr>
<td>Diesel</td>
<td></td>
<td></td>
<td></td>
<td>Not Tested</td>
</tr>
<tr>
<td>Kerosene</td>
<td></td>
<td></td>
<td></td>
<td>Not Tested</td>
</tr>
</tbody>
</table>

* yellow indicates maintenance problems, red indicates eventual engine failure if PM not performed within 8-12 hours

- Flexing fuels comes with a maintenance cost
  - Oil changes become more frequent at much shorter intervals
  - Increase in random spark plug failures
V 2.5 conclusions
✓ F24 requirement validated with 4 cycle spark engine
✓ JP8/F24 validated at high elevations and battery charging
✓ A/F tuning works well
✓ EPA small engine requirements met
Need some tweaks for D1/D2

New or emerging requirements for V3.1
USMC Autostart on JP8 from 0-40°C in less than 5 minutes
USMC One man portable Autostart kit
**USMC 1MPG POTENTIAL SYSTEM CONFIGURATIONS**

**Manual Start (manned)**

1) Chemical Start: -20-55°C

2) Thermal Start: 0-40°C

**Electric/Auto Start (unmanned)**

3) Autonomous Thermal Start: 0-40°C
1MPG AUTOSTART ON JP8

V3.1 Autostarts in 2-5 minutes

1MPG Manual Start (Battery)

1MPG Autostart Delivered

1MPG Autostart Improved

NOTE: TIMES TYPICAL OF START FROM 25C AMBIENT AND FULLY CHARGED AUTOSTART CONTROLLER
V 3.1 conclusions
✓ Autostart validated 3-5 minute start-up
✓ KPPs met for USMC 1MPG
✓ POR downselect

New or emerging requirements for V3.5 (PPG)
<30lbs
900W continuous power
28VDC (10A)
Keys to a successful disruptive innovation process:

- Identify the capability gap
- Embrace the requirements
- Lean forward with emerging requirements
- The faster you can iterate….the faster you can innovate
- Don’t overlook the obvious
- Don’t be afraid to fail!
ACKNOWLEDGEMENTS

1. US ARMY CERDEC
   a) Early Funding
   b) Testing/SAR development
2. US ARMY Rapid Equipping Force (REF)
   a) Safety confirmation
   b) Emerging requirements
3. US ARMY PM Soldier Warrior (SWAR)
   a) Performance validation
   b) Requirements development
4. Marine Corps Systems Command (MCSC)
   a) Well defined and achievable KPPs
   b) Supporting small business
5. The entire INI Power Systems Team