The Internal Combustion Engine as a Low-Cost Soil Vapor Treatment Technology

Prepared by Steve R. Archabal

Remediation Service, Intl.,
a division of

Innovative Environmental Solutions, LLC

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Technology in Support of the Environment
Project Objectives

- AFCEE/ERT Demonstration Project
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- Evaluate low-cost soil vapor extraction (SVE) technologies and strategies for treatment of petroleum hydrocarbons in soils
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- Evaluate internal combustion engine (ICE) for SVE and off-gas treatment
- Develop site-specific and summary reports
- Compare ICE to traditional approaches
Demonstration Sites

- Bolling AFB (November 1994)
- Davis-Monthan AFB (September 1995)
- Williams AFB (February 1997)
Conceptual Model of SVE using ICE
ICE Principles of Operation

Combines vapor extraction and contaminant vapor destruction in a single technology
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- Remote monitoring options
ICE Technology - Features

- On-board computer to monitor engine performance
ICE Technology - Features

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- Automated air-fuel ratio control system
ICE Technology - Features

- On-board computer to monitor engine performance
- Automated air-fuel ratio control system
- Automated engine shutdown systems
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- Automated fire suppression system
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- Automated engine shutdown systems
- Automated fire suppression system
- No external power required
- Remote monitoring/operation capability
## ICE Technology-Performance Specifications

<table>
<thead>
<tr>
<th>Feature</th>
<th>V2C</th>
<th>V3</th>
<th>V4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. Hydrocarbon Destruction Rate</td>
<td>12 lbs/hr</td>
<td>35 lbs/hr</td>
<td>70 lbs/hr</td>
</tr>
<tr>
<td>Destruction Efficiency for TVH / BTEX</td>
<td>&gt;99%</td>
<td>&gt;99%</td>
<td>&gt;99%</td>
</tr>
<tr>
<td>Engine Size</td>
<td>140 cid</td>
<td>460 cid</td>
<td>920 cid (2 x 460)</td>
</tr>
<tr>
<td>Max. Vapor Flow Rate</td>
<td>25 scfm</td>
<td>70 scfm</td>
<td>140 scfm</td>
</tr>
<tr>
<td>Max. Vacuum (Inches of Mercury / Water)</td>
<td>20 / 270</td>
<td>20 / 270</td>
<td>20 / 270</td>
</tr>
<tr>
<td>Soil Gas Hydrocarbon Concentration (ppmV as gasoline) required to eliminate supplemental fuel use</td>
<td>30,000</td>
<td>30,000</td>
<td>30,000</td>
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</tbody>
</table>
ICE Technology - Considerations

- Soil vapor extraction flow rate dependent on site conditions
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- Auxiliary fuel required (propane or natural gas) below optimum influent TVH vapor concentrations
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- Bimonthly (twice per month) maintenance required
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- Auxiliary fuel required (propane or natural gas) below optimum influent TVH vapor concentrations
- Bimonthly (twice per month) maintenance required
- Can treat only low concentrations of chlorinated hydrocarbons
## Discharge Requirements

<table>
<thead>
<tr>
<th>Site</th>
<th>Average Daily TVH Emissions</th>
<th>Discharge Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Davis-Monthan AFB, Arizona</td>
<td>0.70 lb/day</td>
<td>2.4 lb VOCs/day</td>
</tr>
<tr>
<td>Luke AFB, Arizona</td>
<td>0.22 lb/day</td>
<td>3.0 lb VOCs/day</td>
</tr>
<tr>
<td>Bolling AFB, DC</td>
<td>0.84 lb/day</td>
<td>1.0 lb VOCs/day</td>
</tr>
<tr>
<td>Williams AFB, Arizona</td>
<td>1.28 lb/day</td>
<td>3.0 lb VOCs/day</td>
</tr>
</tbody>
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## Site Descriptions

<table>
<thead>
<tr>
<th>Site</th>
<th>Geology</th>
<th>Depth to Groundwater</th>
<th>Maximum Soil TPH Concentration Range</th>
<th>Initial Estimated Contaminated Soil Volume</th>
<th>Initial Influent Vapor TVH Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Davis-Monthan AFB, Arizona</td>
<td>Intermixed fine and coarse - grained deposits</td>
<td>300 ft bgs</td>
<td>11,000 mg/kg (TRPH)</td>
<td>220,000 yd&lt;sup&gt;3&lt;/sup&gt;</td>
<td>43,000 ppmv</td>
</tr>
<tr>
<td>Luke AFB, Arizona</td>
<td>Intermixed fine and coarse - grained deposits</td>
<td>320 ft bgs</td>
<td>12,000 mg/kg</td>
<td>9,300 yd&lt;sup&gt;3&lt;/sup&gt;</td>
<td>38,500 ppmv</td>
</tr>
<tr>
<td>Bolling AFB, DC</td>
<td>Intermixed fine and coarse - grained deposits</td>
<td>20 ft bgs</td>
<td>42,000 mg/kg</td>
<td>43,000 yd&lt;sup&gt;3&lt;/sup&gt;</td>
<td>123,000 ppmv</td>
</tr>
<tr>
<td>Williams AFB, Arizona</td>
<td>Fine-grained subunits intermixed with coarse-grained beds</td>
<td>200 ft bgs</td>
<td>35,000 mg/kg</td>
<td>100,000 yd&lt;sup&gt;3&lt;/sup&gt;</td>
<td>140,000 ppmv</td>
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</table>
### Site Descriptions (cont.)

<table>
<thead>
<tr>
<th>Site</th>
<th>Average Daily TVH Removal Rate</th>
<th>Weighted Average</th>
<th>Influent TVH Concentrations</th>
<th>Davis-Month</th>
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ICE Performance

![Graph showing ICE Performance over Days of Operation Since Start-Up](image-url)
Air Emissions
Cost of Treatment

[Graph showing the cost of treatment over time for different locations: Bolling AFB, Luke AFB, Williams AFB, and Davis-Monthan AFB.]
Full-Scale Performance

- Over 500,000 Pounds of Jet Fuel removed in 240 days
Full-Scale Performance

- Over 500,000 Pounds of Jet Fuel removed in 240 days
- 99.9% Destruction Consistently Achieved
Full-Scale Performance

- Over 500,000 Pounds of Jet Fuel removed in 240 days
- 99.9% Destruction Consistently Achieved
- No exceedance of 2.4 lb/day air emissions limit
O&M Requirements & Costs

- Weekly system checks
O&M Requirements & Costs

- Weekly system checks
- Monthly engine service
O&M Requirements & Costs

- Weekly system checks
- Monthly engine service
- Monthly emissions sampling
O&M Requirements & Costs

- Weekly system checks (Recommended)
- Bimonthly engine service
- Monthly emissions sampling
- Propane delivery
ASSUMPTIONS:

1. See Appendix C.
2. Well gas flow rate approximately 100 cfm.

FIGURE 3.6
COST COMPARISON AS A FUNCTION OF INFLUENT CONCENTRATION

ICE Demonstration
Comprehensive Technical Report

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado
Conclusions

- ICE technology easily integrated with traditional SVE systems
Conclusions

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- Capable of achieving stringent discharge limitations (> 99.9% destruction efficiency)
Conclusions

- ICE technology easily integrated with traditional SVE systems
- Capable of achieving stringent discharge limitations (> 99.9% destruction efficiency)
- Cost per pound of TVH removed: $0.04 to $0.46
"...ICE technology is similar to that of thermal and catalytic oxidation when influent concentrations range between 3,000 to 5,000 ppmv TVH. Above these concentrations, ICE technology becomes more cost-effective.”*

Contact Information

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