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

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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)

Williams AFB (February 1997)
Davis-Monthan AFB (September 1995)
Conceptual Model of SVE using ICE

Contaminated Soil Vapors
ICE Principles of Operation

- Combines vapor extraction and contaminant vapor destruction in a single technology
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- Uses a modified automobile engine with automated computer-monitored operation and emissions controls
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- Remote monitoring options
ICE Technology - Features

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

- On-board computer to monitor engine performance
- 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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- No external power required
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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>
</tr>
</tbody>
</table>
ICE Technology - Considerations

- Soil vapor extraction flow rate dependent on site conditions
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- Soil vapor extraction flow rate dependent on site conditions
- 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>
</table>
# 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$^3$</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$^3$</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$^3$</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$^3$</td>
<td>140,000 ppmv</td>
</tr>
<tr>
<td>Site</td>
<td>Average Daily TVH Removal Rate</td>
<td>Weighted Average</td>
<td>Influent TVH Concentrations</td>
<td>Davis-Month</td>
<td></td>
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<td>--------------</td>
<td>-------------------------------</td>
<td>------------------</td>
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<td>-------------</td>
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<tr>
<td>Davis-Month</td>
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ICE Performance

![Graph showing ICE performance at various AFBs over days of operation since start-up. The graph plots pounds TVH on the y-axis and days of operation since start-up on the x-axis. The AFBs compared are Davis-Monthan AFB, Williams AFB, Luke AFB, and Bolling AFB.](image)
Air Emissions

![Graph showing Air Emissions over Days of Operation Since Start-Up]

- Williams AFB
- Bolling AFB
- Davis-Monthan AFB
- Luke AFB

> 99.8% Average Destruction Efficiency
Cost of Treatment

![Graph showing the cost of treatment over days of operation since start-up for Bolling AFB, Luke AFB, Williams AFB, and Davis-Monthan AFB.](image)
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
FIGURE 3.6
COST COMPARISON AS A FUNCTION OF INFLUENT CONCENTRATION

ICE Demonstration
Comprehensive Technical Report

PARSONS ENGINEERING SCIENCE, INC.
Denver, Colorado

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

- ICE technology easily integrated with traditional SVE systems
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- Capable of achieving stringent discharge limitations (> 99.9% destruction efficiency)
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- 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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