

# ***Headquarters U.S. Air Force***

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## ***Soil Vapor Extraction and Treatment Using Internal Combustion Engine Technology***



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Technology Transfer Division**

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# ***Demonstrations of Engines***

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- **AFCEE/ERT Demonstration Projects since 1993**
- **Evaluate low-cost soil vapor extraction (SVE) technologies and strategies for treatment of petroleum hydrocarbons in soils**
- **Evaluate internal combustion engine (ICE) technology for SVE and off-gas treatment**
- **Develop site-specific and summary reports**
- **Compare ICE technology to traditional approaches**

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# ***Demonstration Locations***

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- **Patrick AFB, FL**
- **Bolling AFB, DC**
- **Luke AFB, AZ**
- **Williams AFB, AZ**
- **Davis-Monthan AFB, AZ**
- **Others**

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# ***ICE Principles of Operation***

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- **Combines vapor extraction and contaminant vapor destruction in single technology**
- **Uses modified automobile engine with computer-monitored emission controls**
- **Catalytic converter completes fuel oxidation**
- **Remote monitoring options**

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# ***ICE Technology - Features***

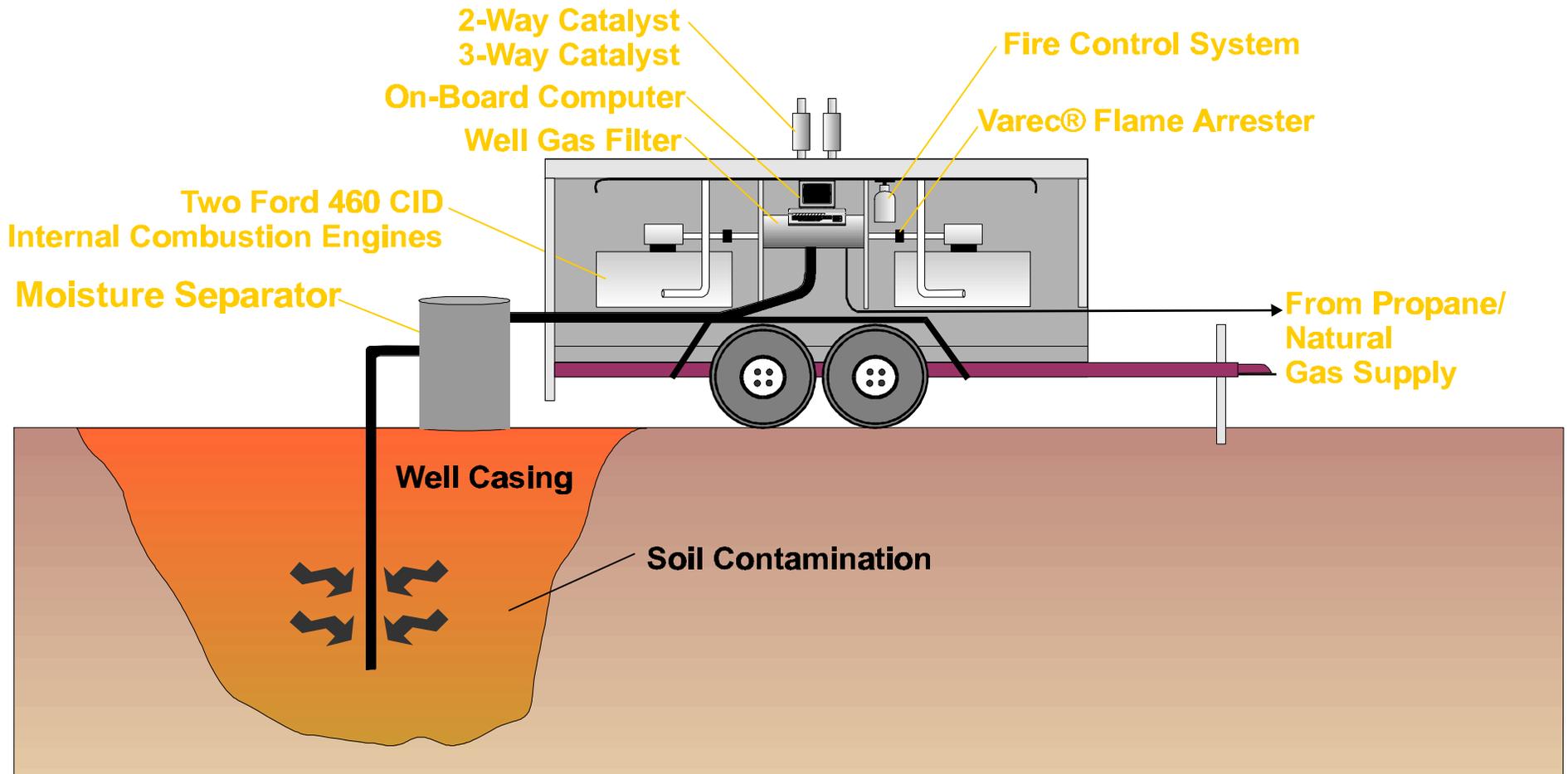
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- **On-board computer that monitors engine performance**
- **Automatic air-fuel ratio control system**
- **Automatic engine shutdown systems**
- **Auxiliary fuel flow regulator**
- **Flame arrestor and fire control system**
- **No external power required**
- **Remote monitoring (non-essential feature)**



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# General Layout of a Dual ICE Unit



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# ***Unit With Two 460 cid Engines***



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# ***Engine at Williams AFB***



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# ***ICE Technology - Performance Specifications***

<i><b>Feature</b></i>	<i><b>V2C</b></i>	<i><b>V3</b></i>	<i><b>V4</b></i>
<b>Maximum Hydrocarbon Destruction Rate</b>	15 lbs/hr	55 lbs/hr	110 lbs/hr
<b>Destruction Efficiency for TVH/BTEX</b>	>99%	>99%	>99%
<b>Engine Size</b>	140 cid	460 cid	2x460 cid
<b>Maximum Vapor Flow Rate</b>	65 cfm	250 cfm	500 cfm
<b>Maximum Vacuum</b>	18" Hg	18" Hg	18" Hg
<b>Maximum Soil Gas Hydrocarbon Concentration (to eliminate supplemental fuel use)</b>	40,000 ppmv as gasoline	40,000 ppmv as gasoline	40,000 ppmv as gasoline

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# ***ICE Technology - Special Considerations/Limitations***

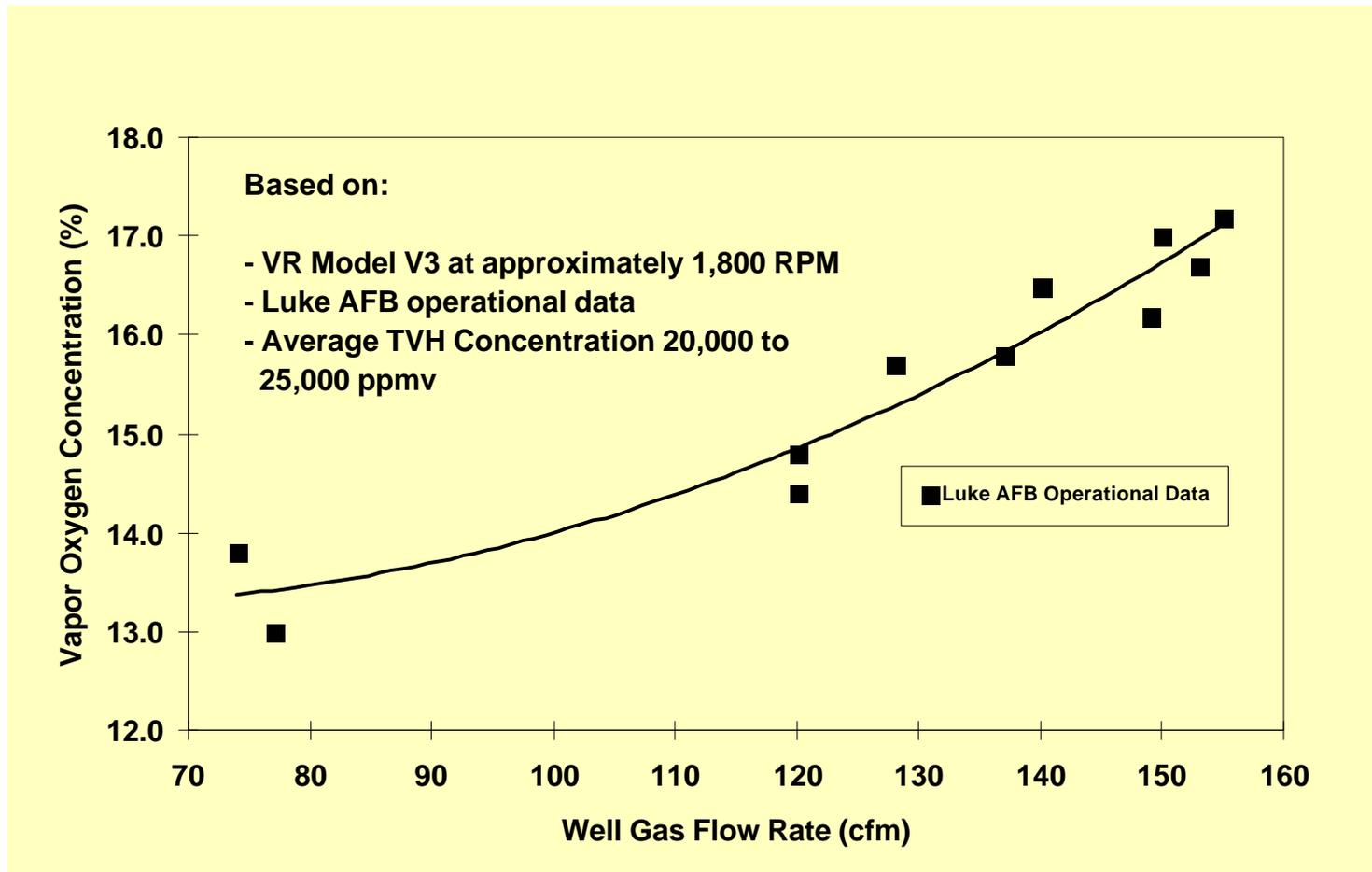
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- **Can treat only non-chlorinated hydrocarbon vapor streams**
- **Auxiliary fuel required (propane or natural gas) below optimum influent TVH vapor concentrations**
- **Soil vapor extraction flow rate dependent on site conditions**
- **Skilled technician required for maintenance/troubleshooting**



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# Well Gas Flow Rate as Function of Influent Oxygen Concentration (VRS Model V3)



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# *Example Capital and Operating Costs*

<b>Capital Cost:</b>	
<b>Treatment Unit (includes engine rebuild of V4 ICE)</b>	<b>\$85,000</b>
<b>Extraction Well Installation</b>	<b>\$32,000</b>
<b>Design/Labor/Installation</b>	<b>\$45,000</b>
<b>Total Capital Cost = \$162,000</b>	
<b>Operating Cost (daily/accumulative over estimated 3-year treatment period):</b>	
<b>Maintenance and Monitoring</b>	<b>\$57/\$62,415</b>
<b>Supplemental Fuel</b>	<b>\$34/\$37,230</b>
<b>Total Cost = \$91/\$99,645</b>	
<b>Total Cost = \$261,645</b>	

Source: Davis-Monthan AFB Demonstration.



# ***Regulatory Acceptance***

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- **Approved in the United States, Canada, Mexico, and Argentina**
- **Approved in 28 states in the U.S.**
- **Approved in 13 California air quality districts**
- **Approvals based on daily VOC emissions and treatment efficiency**



## *ICE Demonstration Sites*

Demonstration Site	Geology	Depth to Groundwater (ft bgs)	Maximum Soil TPH Concentration (mg/kg)	Initial Estimated Contaminated Soil Volume (yd <sup>3</sup> )	Initial Influent Vapor TVH Concentration (ppmv)
Bolling AFB	intermixed fine- and coarse-grained deposits	20	16,000	43,000	123,000
Davis-Monthan AFB	intermixed fine- and coarse-grained deposits	300	320,000	220,000	43,000
Luke AFB	intermixed fine- and coarse-grained deposits	320	12,000	9,300	38,500
Williams AFB	fine-grained subunits intermixed with coarse-grained beds	200	35,000	100,000	140,000

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# ICE

## Testing Conditions

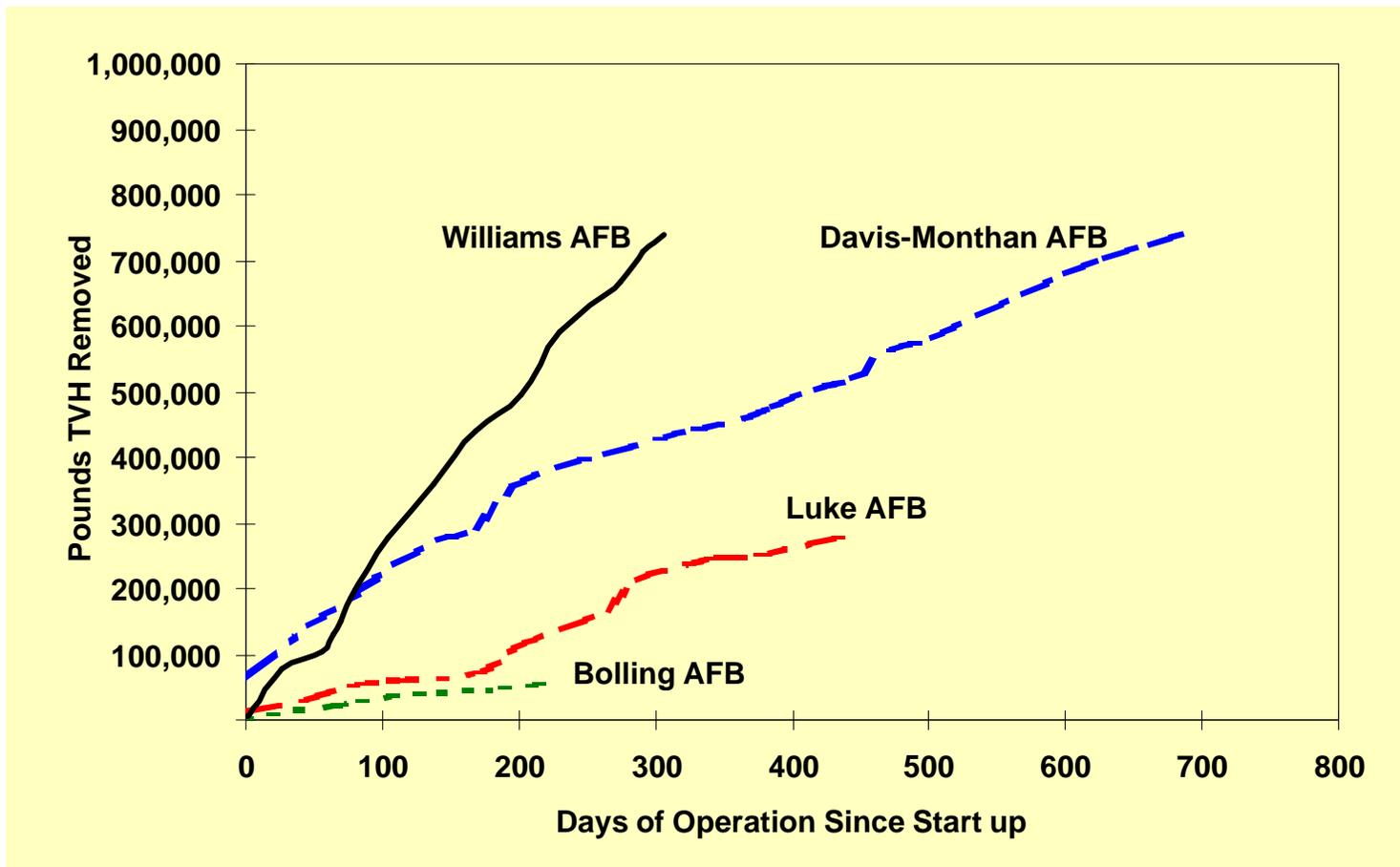
Demonstration Site	Unit Type	Days of Actual Operation	Avg. Flow Rate (cfm)	Avg. Influent Concentration (ppmv TVH)
Bolling AFB	1-Model V4 1-Model V3	193	94	8,500
Davis-Monthan AFB	1-Model V4 1-Model V3	634	109	25,500
Luke AFB	1-Model V3	327	91	20,150
Williams AFB	2-Model V4			
Unit V4-A		≈257	99	57,300
Unit V4-B		≈125	84	45,500

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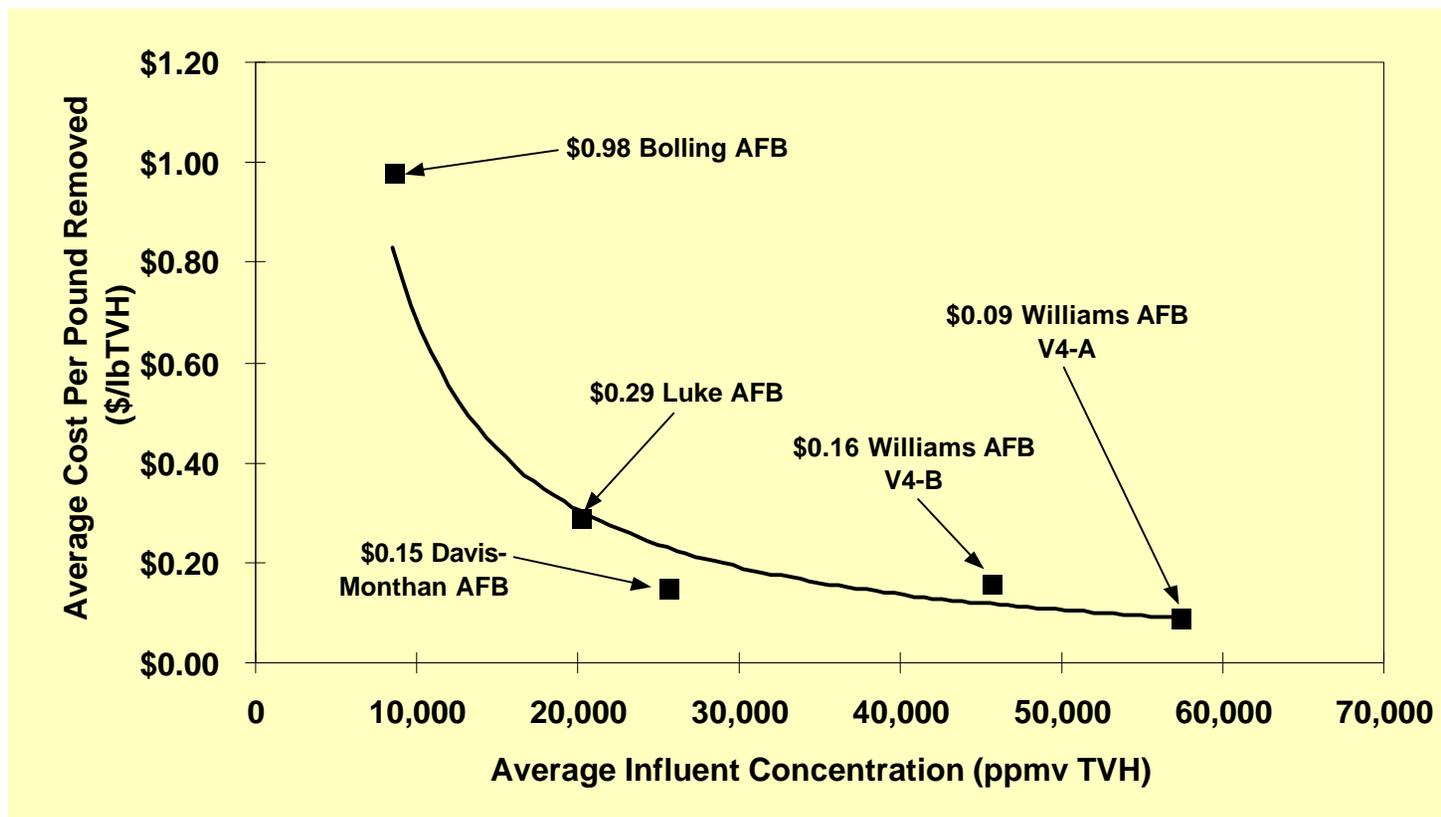
# Cumulative Pounds of Total Volatile Hydrocarbons Removed



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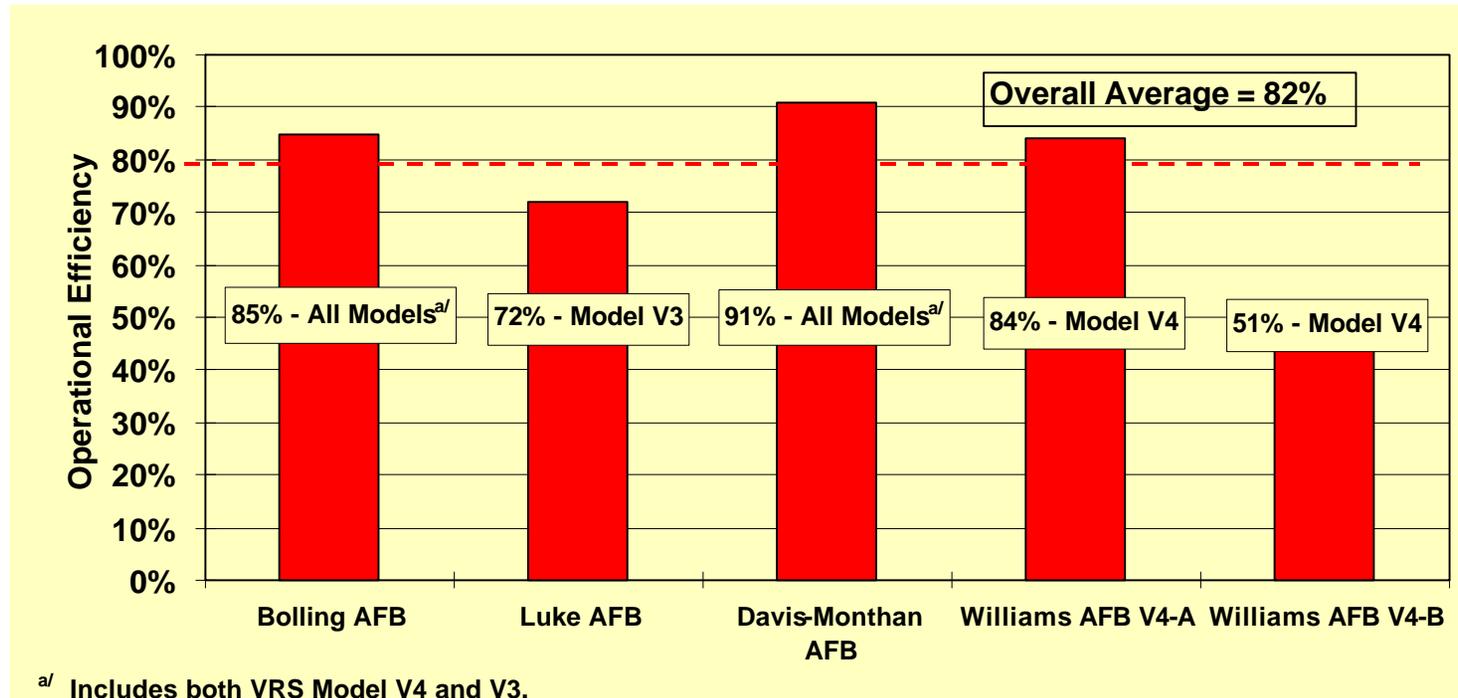
# Cost Per Pound of Total Hydrocarbons Removed Versus Influent Concentration





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# Average Operational Efficiency



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# *Maintainability*

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- **Potential Mechanical Problems**
  - Alternator/Voltage Regulator
  - Battery (especially in hot climates)
  - Oxygen sensor
- **Long-Term Issues**
  - Engine rebuild (10K-15K engine hours)
  - Catalytic converter replacement (5K-10K engine hours)

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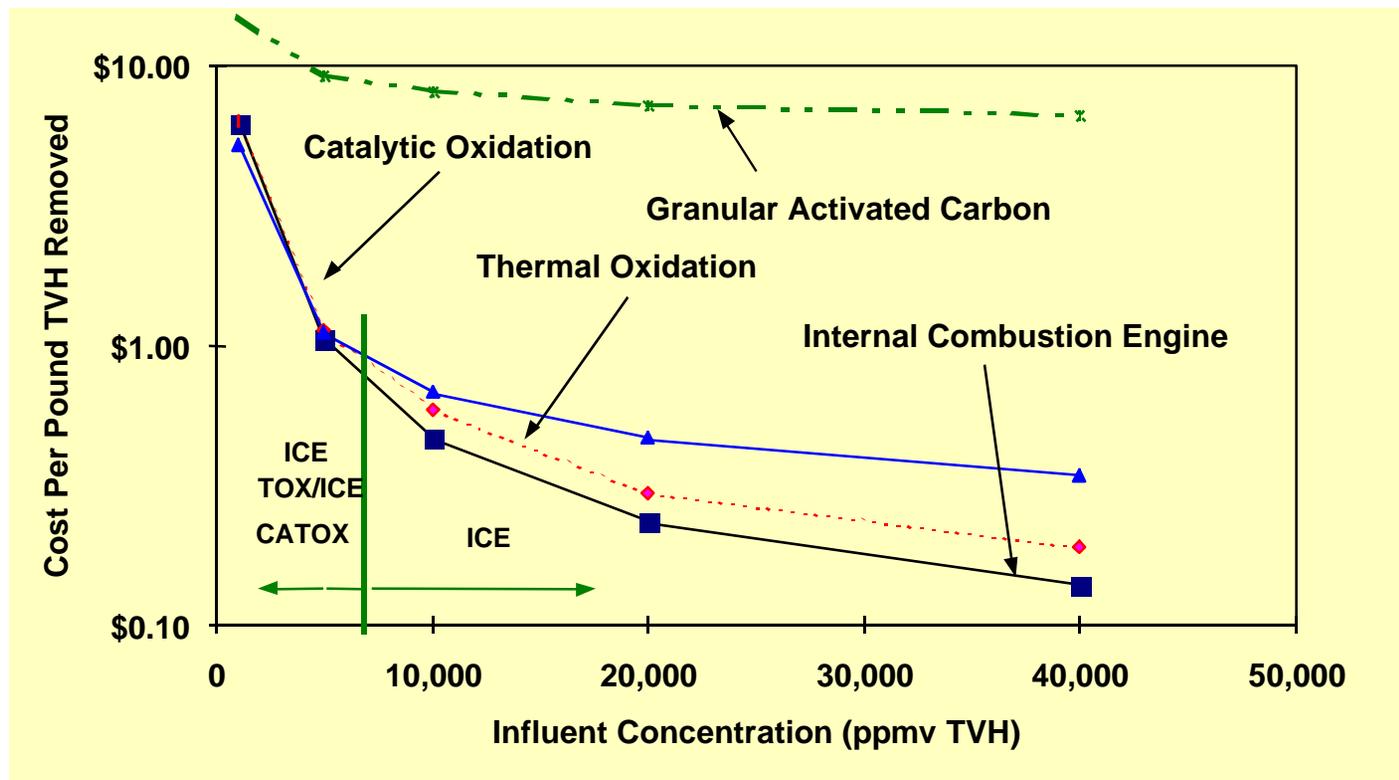
# ***Discharge Requirements***

<b>Site</b>	<b>Average Daily TVH Emissions</b>	<b>Discharge Limitations</b>
<b>Davis-Monthan AFB</b>	<b>0.70 lb/day</b>	<b>2.4 lb VOCs/day</b>
<b>Luke AFB</b>	<b>0.22 lb/day</b>	<b>3.0 lb VOCs/day</b>
<b>Bolling AFB</b>	<b>0.84 lb/day</b>	<b>1.0 lb VOCs/day</b>
<b>Williams AFB</b>	<b>1.28 lb/day</b>	<b>3.0 lb VOCs/day</b>

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# Cost Comparison as a Function of Influent Concentration



## ASSUMPTIONS:

1. Well gas flow rate approximately 100 cfm.



# ***ICE Technology Performance Summary***

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- Capable of treating highly concentrated, non-chlorinated vapor streams of up to 140,000 ppmv TVH while maintaining DRE's of greater than 99.9-percent
- Maximum hydrocarbon removal rates of 1,200 (V3) to over 2,400 lb/day (V4) were achieved
- Average operational efficiency was 82 percent
- Average cost per pound of TVH removed ranged from \$0.09 to \$0.98

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# ***Recommendations***

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- **Generally best suited for initial (0 to 6 months) response at highly contaminated sites**
  - **Well-suited for remote sites or areas where electricity would be expensive to supply to the site**
  - **Becomes more cost effective than thermal and catalytic above 3,000 to 5,000 ppmv**

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# *Future Improvements*

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## ■ Diesel Engines

- AFCEE/ERT ongoing project with SWRI operated Fuels and Lubricants Research Facility (US Army)
  - Diesels may be able to reduce makeup fuel by 30%
  - Possible modifications to allow for combustion of chlorinated solvents
  - Tougher, longer lasting engine
- Need to develop a method of “smoothing” out widely fluctuating vapor concentrations such as Bioslurping system vapor discharges



# *Engines*

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- **AFCEE/ERT has several engines available for loan to bases**
  - **UNICOR (Federal Prison) is rebuilding one engine - they may become a lower cost repair source available to bases and government contractors**
  - **For more information contact AFCEE/ERT**
    - **phone (210) 536-4331, DSN 240-4331**