

# Evaluation of Bench- and Pilot-Scale Adsorption Systems to Capture and Recover Organic Vapors via Electrothermal Desorption

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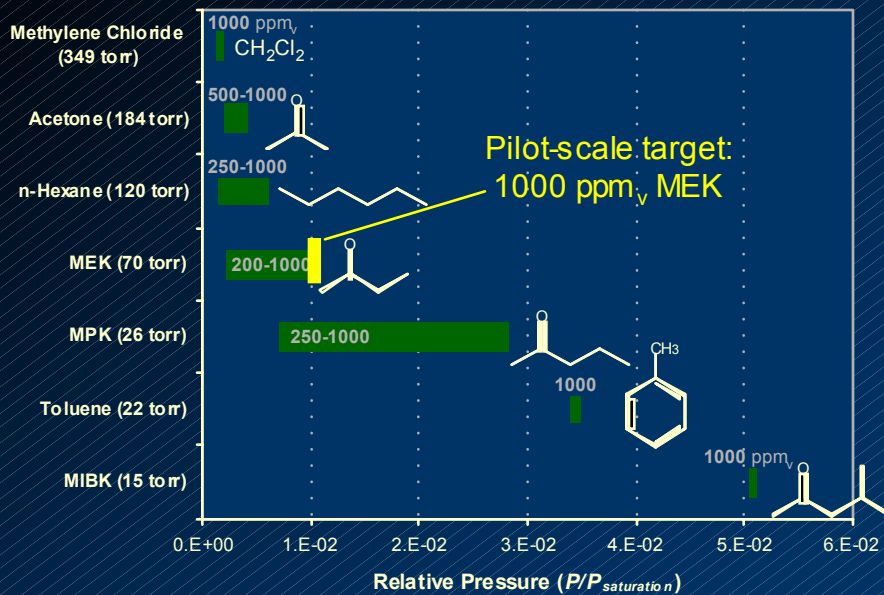
## Motivation

- $1.6 \times 10^7$  kg of anthropogenically-generated Hazardous Air Pollutants (HAPs) were released to atmosphere in U.S. in 1998 (U.S. EPA, 2000).
- ~30% of HAP emissions are solvents.
- Develop new control technology to capture/recover HAPs to meet Maximum Achievable Control Technology (MACT) standards for various applications.

## Project Goals

- Bench-scale adsorption-electrothermal regeneration vapor recovery system was previously evaluated to determine pilot-scale design parameters.
- Evaluate pilot-scale vapor recovery system:
  - Ability to run continuously
  - Closure of mass and energy balances
  - Determine liquid recovery limitations at low relative pressures
  - Obtain data for transient and equilibrium adsorption modeling
  - Complete detailed cost analyses

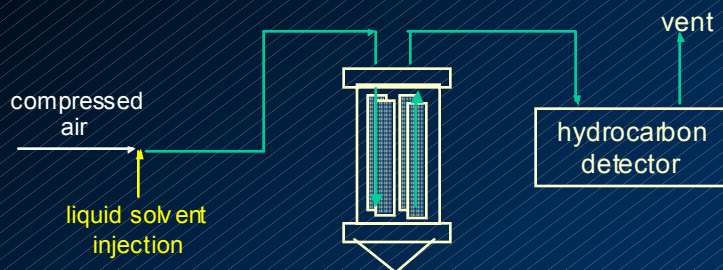
## Adsorbates Tested on Bench-Scale



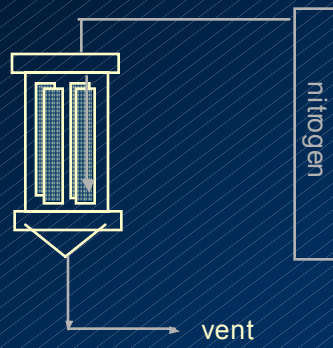
## Activated Carbon Fiber Cloth (ACFC)

- American Kynol ACC-5092-20
- Surface Area = 1970 m<sup>2</sup>/g
  - >95% microporous area (pore  $w < 20 \text{ \AA}$ )
- 95% pure carbon
  - balance H, O, N
  - ~0% ash
- Readily shapeable
- Electrically conductive
  - Electrothermally regenerable in-situ
- Cost: ACFC ~\$800/kg, GAC ~\$2/kg

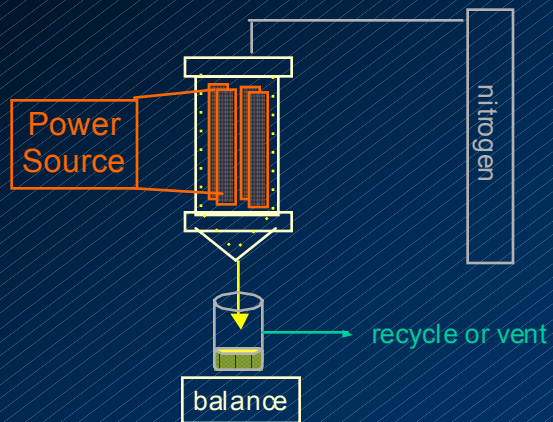
### A. ADSORPTION CYCLE



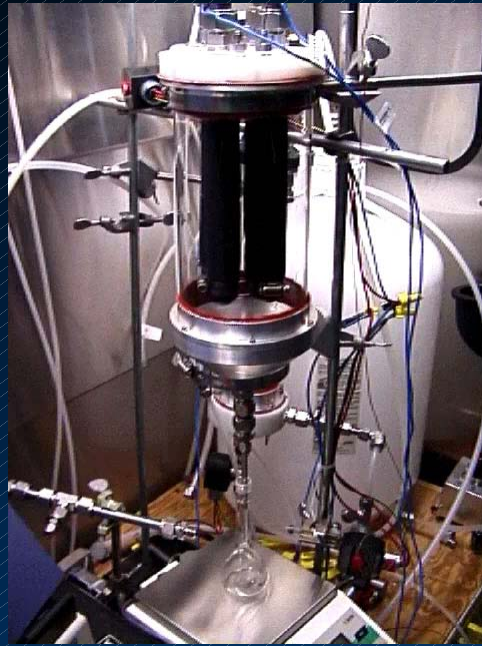
## B. PURGE CYCLE



## C. REGENERATION CYCLE



## Bench-Scale System



## Scale-Up of Vapor Recovery System

Control of 1000 ppm<sub>v</sub> MEK in Air

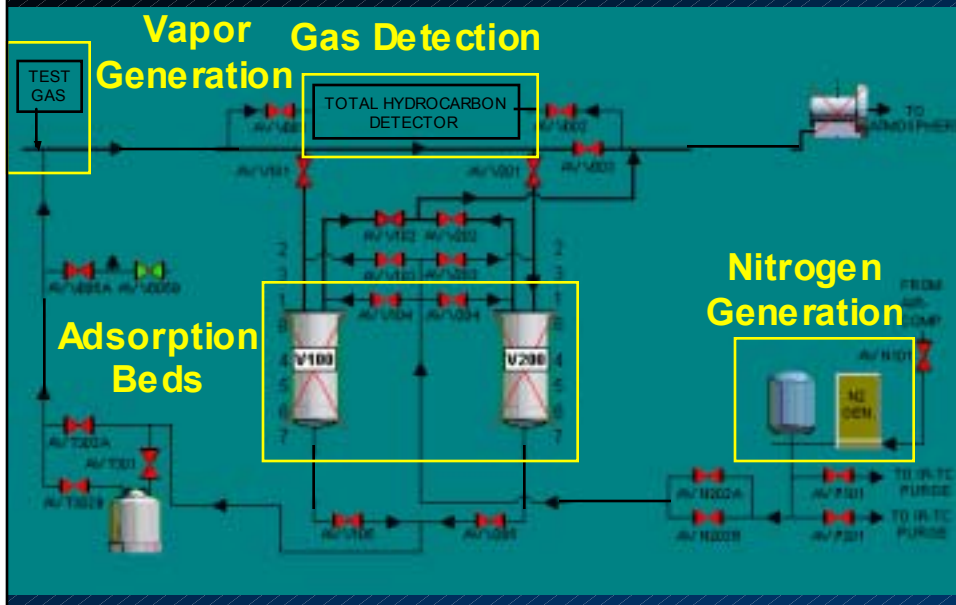
|                        | Bench Scale | Pilot Scale |
|------------------------|-------------|-------------|
| Gas Flow [slpm]        | 50          | 2500        |
| Adsorbate Flow [ml/hr] | 11          | 550         |
| Cycle Time [min]       | 380         | 60          |
| Mass Carbon [kg/bed]   | 0.13        | 1.8         |
| AC Voltage [V]         | 0 - 120     | 0 - 480     |

## Pilot System Construction

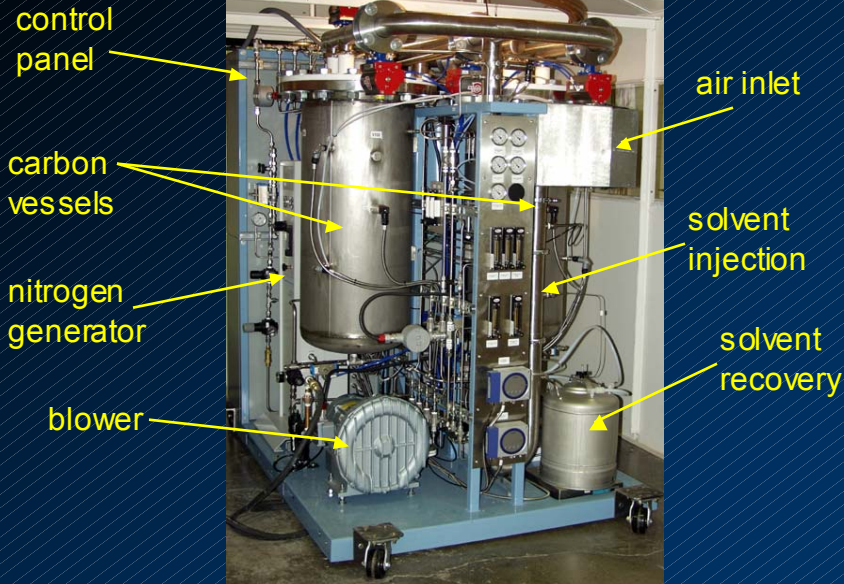
- ACFC rolled into 4 cylindrical cartridges
  - 2 in series, 2 in parallel
  - 1.8 kg total ACFC
- In-situ regeneration by voltage application



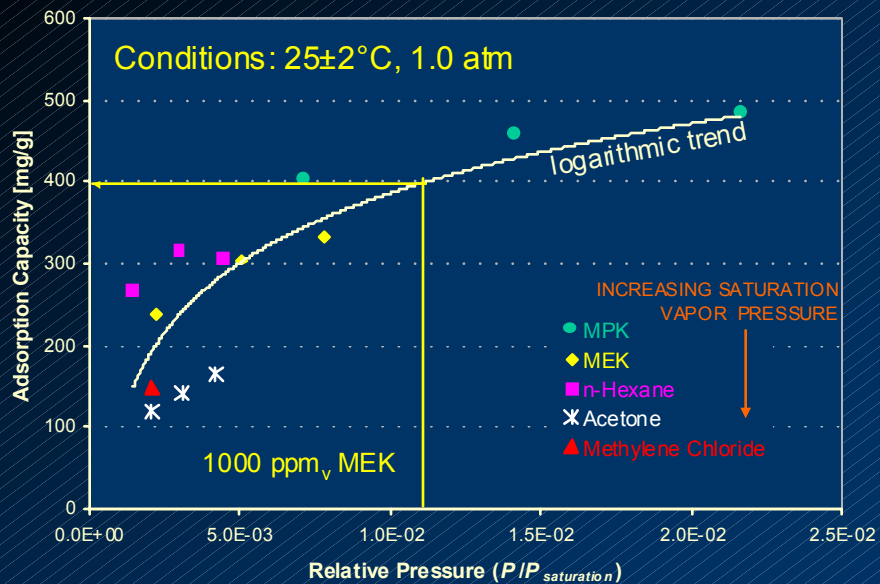
## Pilot System Construction



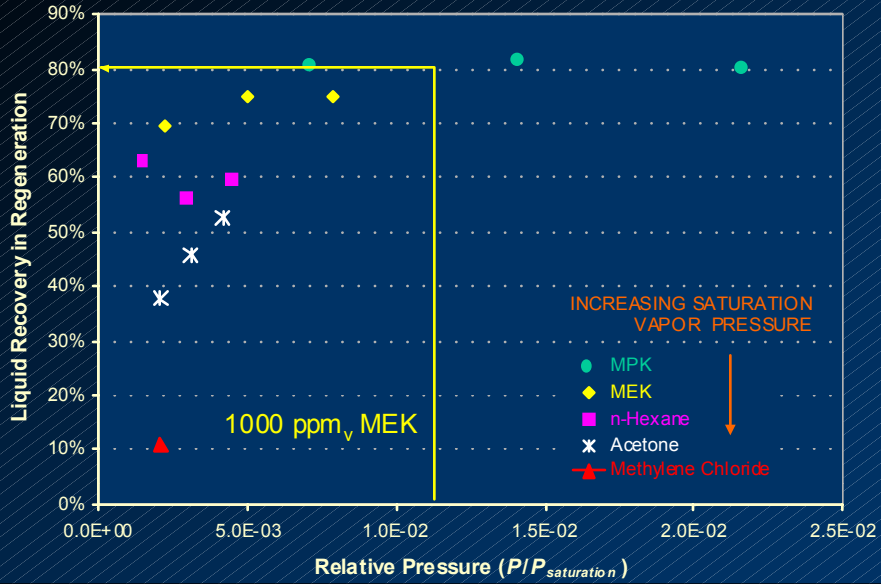
## Pilot-Scale System



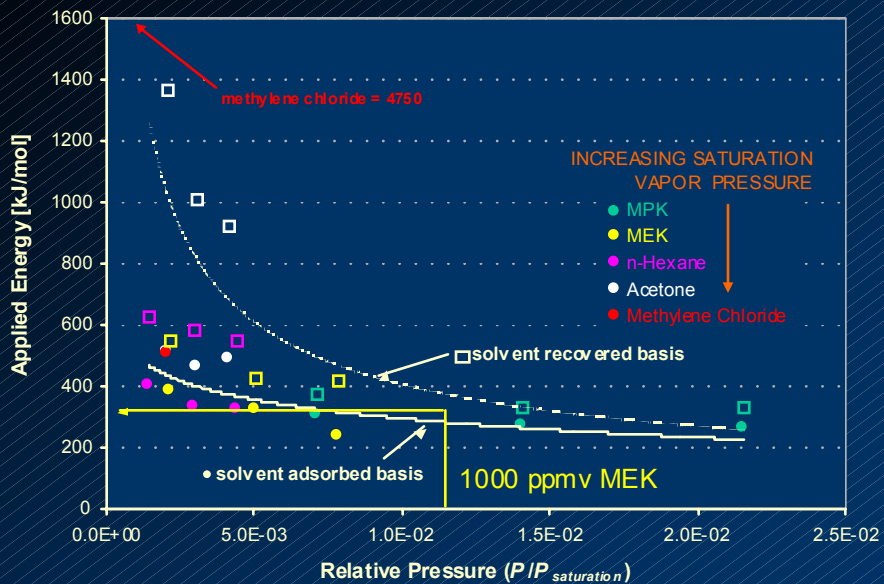
## Bench-Scale Adsorption Capacity



## Bench-Scale Solvent Recovery Single Run Basis



## Bench-Scale Regeneration Energy

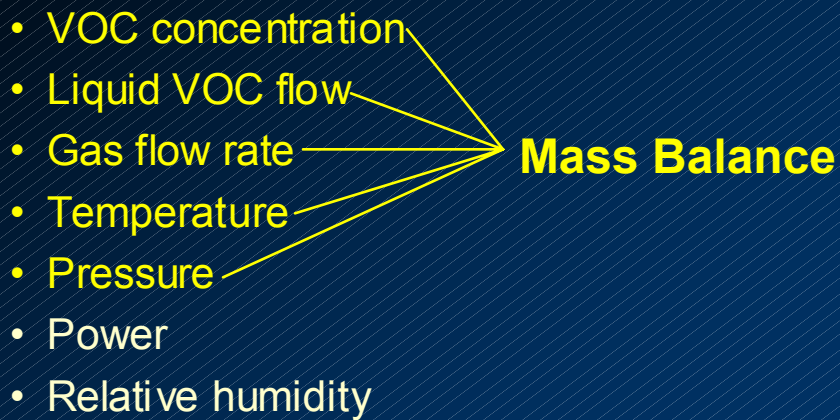




## Parameters Monitored to Evaluate Pilot-Scale Unit

- VOC concentration
- Liquid VOC flow
- Gas flow rate
- Temperature
- Pressure
- Power
- Relative humidity

## Parameters Monitored to Evaluate Pilot-Scale Unit

- VOC concentration
  - Liquid VOC flow
  - Gas flow rate
  - Temperature
  - Pressure
  - Power
  - Relative humidity
- Mass Balance**
- 
- A diagram showing five parameters listed in a bulleted list on the left. Five yellow arrows originate from the text of each of these five parameters and point towards the text 'Mass Balance' on the right. The parameters are: VOC concentration, Liquid VOC flow, Gas flow rate, Temperature, and Pressure. The other two parameters, Power and Relative humidity, are listed below but do not have arrows pointing to 'Mass Balance'.

## Parameters Monitored to Evaluate Pilot-Scale Unit

- VOC concentration
  - Liquid VOC flow
  - Gas flow rate
  - Temperature
  - Pressure
  - Power
  - Relative humidity
- Energy Balance**
- 

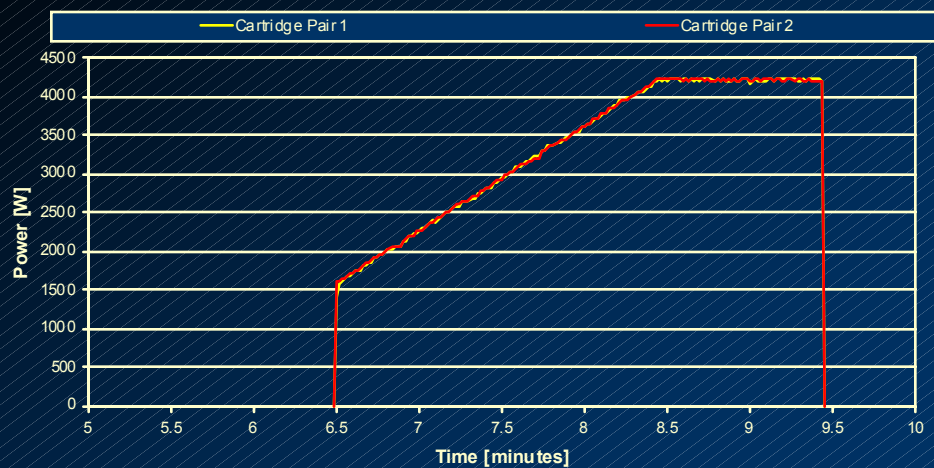
## Parameters Monitored to Evaluate Pilot-Scale Unit

- VOC concentration
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  - Pressure
  - Power
  - Relative humidity
- Inlet Conditions**
-

## Parameters Monitored to Evaluate Pilot-Scale Unit

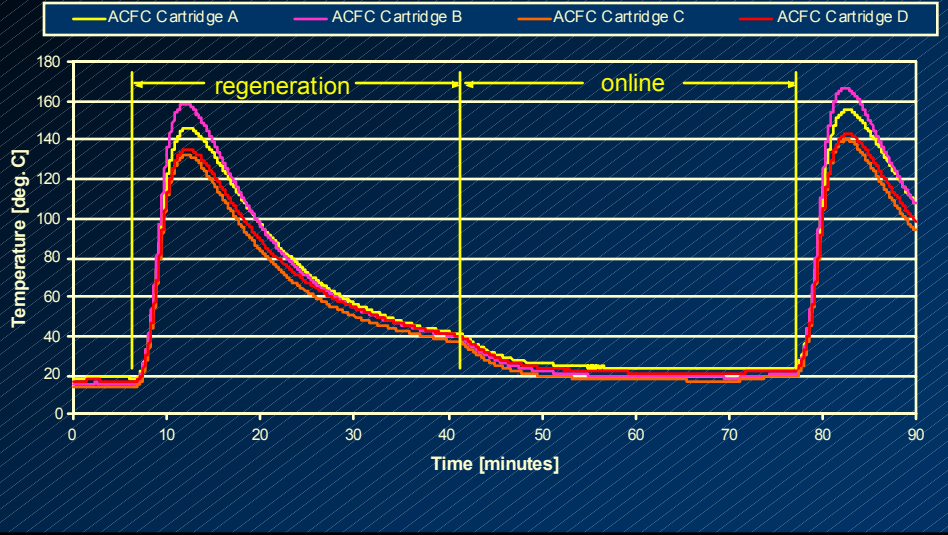
- Regeneration Operation:
  - Power application profile
  - Cartridge temperature profile
- Gas Detection Sensors
  - Relative humidity

## Pilot-Scale Power Application



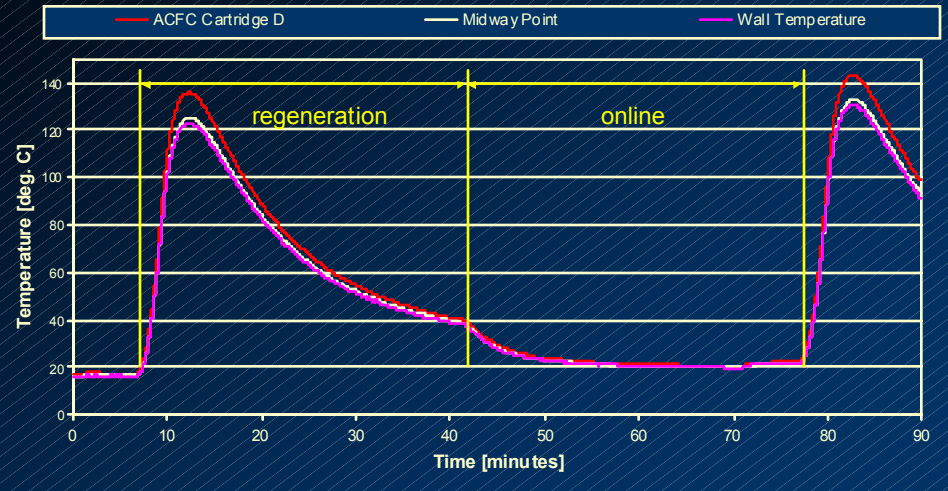
# Pilot-Scale Regeneration Temperature

## Comparison of 4 Cartridges

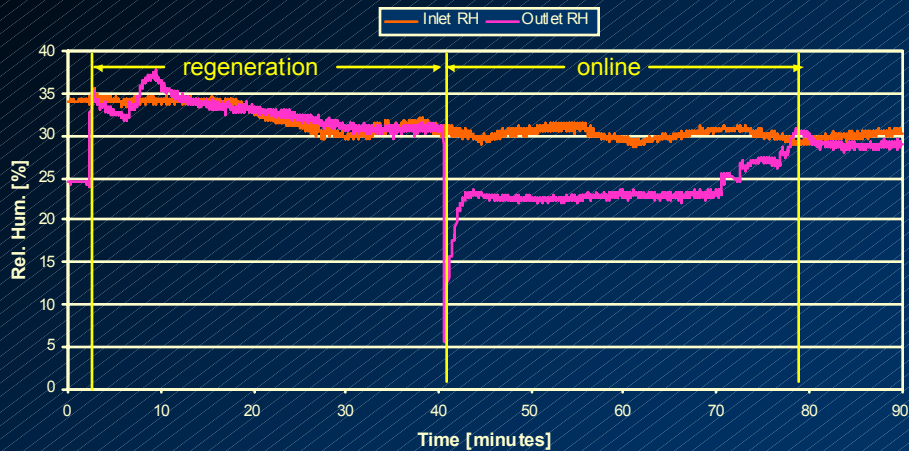


# Pilot-Scale Regeneration Temperature

## Temperature Profile Between Cartridge and Vessel Wall



## Pilot-Scale Relative Humidity



## Future Goals

- Complete evaluation of pilot-scale unit under controlled laboratory conditions using material and energy balances for closure
  - Determine liquid recovery limitations at low relative pressures
  - Obtain data for transient and equilibrium adsorption modeling
  - Complete detailed cost analysis
- Revise unit in preparation for field demonstration

## Acknowledgements

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