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DEEP DIVE INTO DRY MEDIA SYSTEMS

WEF Air Quality & Odor Control Committee
Tuesday, February 28, 2019
1:00 – 2:30 PM ET

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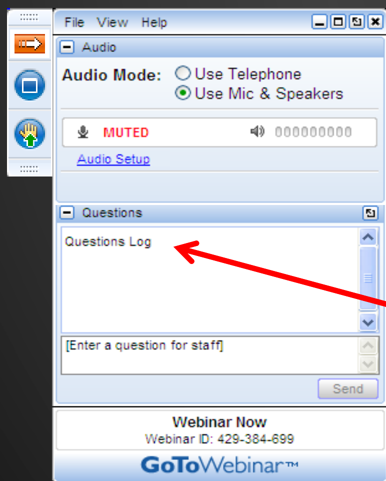
How to Participate Today



- **Audio Modes**
  - Listen using Mic & Speakers
  - Or, select "Use Telephone" and dial the conference (please remember long distance phone charges apply).
- **Submit your questions using the Questions pane.**
- **A recording will be available for replay shortly after this webcast.**

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Today's Moderator

Shirley Edmondson, PE

BLACK & VEATCH

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Webcast Overview

- Overview of dry media systems
- Dry media system considerations and media selection
- Potential for odorant conversion with certain types of media
- O&M elements and challenges
- Case studies

Presenters

- Shirley Edmondson, PE
  Black & Veatch
- Scott Cowden, PE
  Jacobs
- Ryan McKenna, PE
  Hazen and Sawyer
- Dirk Apgar, PE
  King County, WA

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Speaker Introduction

Scott Cowden, PE
(CA, WA, MN, AZ, OR)

JACOBS

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Deep Dive into Dry Media Systems

Part 1: Carbon Adsorption Overview

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Carbon Adsorption Technology Defined

- Dry media
- Activation of carbon creates large surface area
- Systems must be designed for media replacement
- Limitations regarding targeted odor constituents
  - H_2S – good
  - VSCs - Mixed
  - Non-sulfur VOCs - good
  - Ammonia - bad
- Physical adsorption and chemical adsorption

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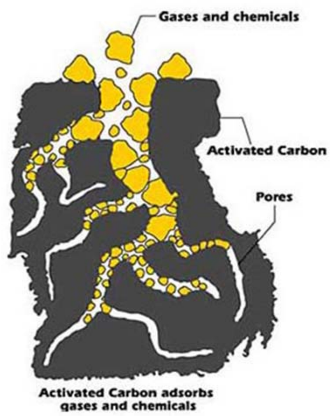
Carbon Adsorption Technology Defined

- Physical adsorption and chemical adsorption



Physical Adsorption:
potential energy from Van der Waal nuclear forces of attraction

Chemical Adsorption:
chemical bonding between the adsorbate and the adsorbent

Reactive Adsorption:
Combination of physical and chemical adsorption

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Carbon Adsorption Technology Pros and Cons

- Advantages
  - Proven
  - Simple passive system
  - Relatively low initial cost
  - Small footprint when compared to biofilters
  - High rate media effective for medium H_2S loadings (≤ 20 ppm H_2S)
  - Virgin activated can remove a wide range of organic compounds
  - Virgin activated good for polishing

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Carbon Adsorption Technology Pros and Cons

- Disadvantages
  - Quickly used in high H_2S environments
  - Replacement can be expensive/labor intensive
  - Can be moisture sensitive
  - Can cake due to moisture/grease
  - Safety issues with media changeout
  - Pressure drop through media high
  - Media disposal issues
  - Difficult to predict media life

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Carbon Adsorption Technology Factors Affecting Performance

- Granular/Pelletized

Pressure drop, in WC. per foot media @ 50 fpm velocity, dense pack	Granular media: 2.0” WC Pelletized media: 0.9 “ WC

Granular media

- Adsorption Properties
  - Iodine number, butane activity
- Moisture/Humidity
  - H_2S: 10-60 percent RH
  - VOCs: <50 percent RH is best

Pelletized media

- Odorant conversion/transformation

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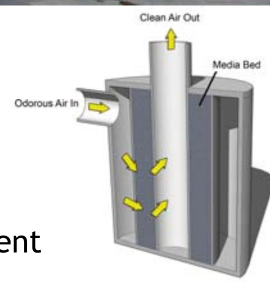
Carbon Adsorption Technology Design Considerations

- Configuration
  - Vertical
    - Most typical
    - Media Bed Horizontal
    - Single Bed, Dual Bed
  - Radial
    - Freestanding vertical single bed
    - Outside-to-inside airflow pattern
    - Smaller footprint requirements
    - Breakthrough can occur rapidly
    - Potential for media density gradient



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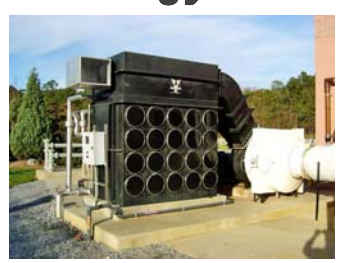
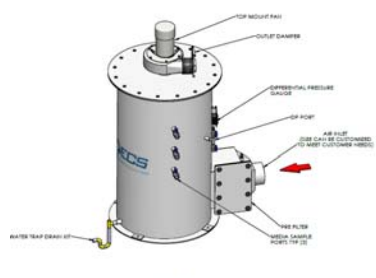
Carbon Adsorption Technology Design Considerations



- Configuration
  - Radial Flow Canisters
    - Phoenix System
    - Individual Canisters
    - Water Regenerable Carbon (Centaur)
  - Top Mount
    - Small pump station applications
    - Condensed footprint



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Carbon Adsorption Technology Design Considerations

- Configuration
  - Horizontal
    - 2/3/4 bed configurations available
    - Relative ease of media change-out
    - Risk of bed density gradient
    - Footprint good for large airflows
  - Other
    - V-Bank
    - Custom Configurations

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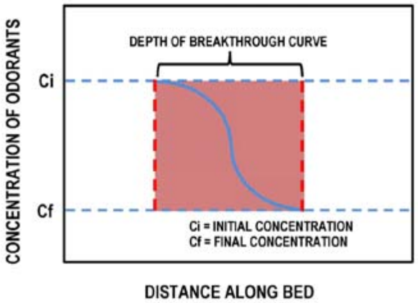
Carbon Adsorption Technology Design Considerations

- Bed Depth
  - Typically 3 feet
  - Dictated by mass transfer breakthrough curve
  - Pressure loss



- Zone 1: Saturated zone - carbon pores are filled
- Zone 2: Adsorption zone - adsorption is occurring
- Zone 3: Final zone - little/no adsorbed compounds

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Carbon Adsorption Technology Design Considerations

- Bed Velocity
  - 40- 60 FPM
- Contact Time
  - 2-4 seconds
- Bed Smoldering
  - VOCs ~ 500 ppm
  - Low bed velocities
  - Low ignition temperature caustic impregnated

Carbon Type	Ignition Temperature
Virgin Coal Based	380-425 °C
Chemical Impregnated	200-225 °C

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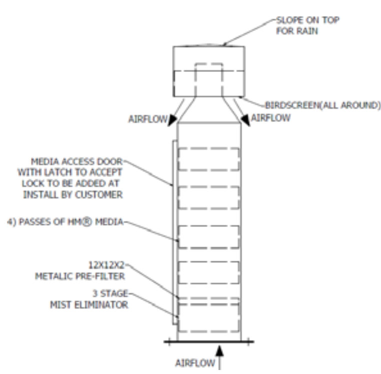
Carbon Adsorption Technology Design Considerations

- Passive Applications



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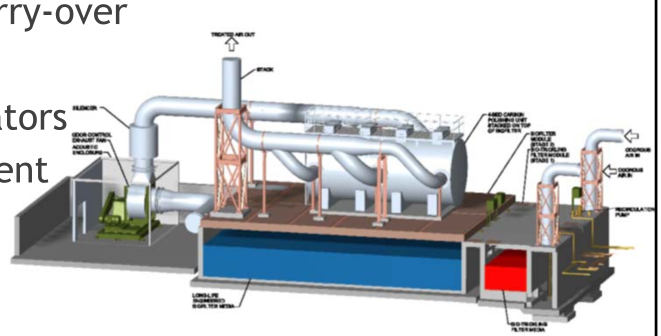
Carbon Adsorption Technology Design Considerations

- Polishing Downstream of primary treatment
  - Moisture carry-over
  - Heaters
  - Mist Eliminators
  - Fan Placement



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Carbon Adsorption Technology Design Considerations

- Media Types
  - Coconut shell carbon
  - Coal-based virgin activated
  - Potassium permanganate impregnated
  - High capacity
  - Water-regenerable
  - Chemical-impregnated

Coconut shell

Virgin activated

$KMnO_4$ impregnated

High capacity

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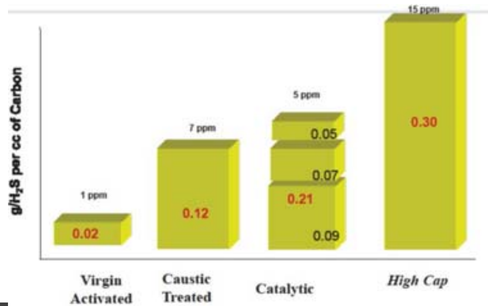
Carbon Adsorption Technology Design Considerations

- Understand odorants to be treated
  - Sampling
  - Tailor media type to odorants treated
  - Layered/blended approach



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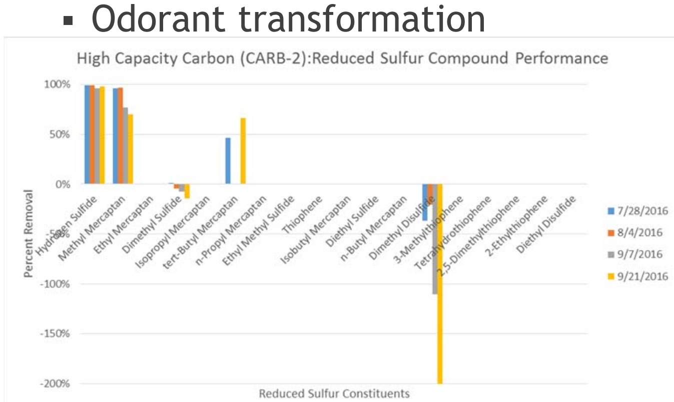
Carbon Adsorption Technology Design Considerations

- Understand odorants to be treated
  - Odorant transformation



Rotten Vegetable (MM)

Rotten Garlic (DMDS)

Rotten Vegetable (MM)

Canned Corn (DMS)

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Carbon Adsorption Technology Best Practices

- Drains
- Redundancy
- Sample Taps
- Insulation
- Prefiltration
- Carbon selection
- Stack size/configuration
- Grounding Rod

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Carbon Adsorption Technology Suppliers

System

- ECS
- Daniel Company
- Evoqua
- Continental Carbon Group
- Spundstrand
- PureAir

Media

- Evoqua
- Continental Carbon Group
- Jacobi
- Carbon Activated Corporation
- Cabot Norit Activated Carbon
- Purafil
- Calgon

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Speaker Introduction

Ryan McKenna, PE (FL)

Senior Principal Engineer

Hazen

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Deep Dive into Dry Media Systems

Part 2: Media Selection and Considerations

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Topics Covered

- Sampling
- Types of Media
- Odorant Conversion
- Case Study
- Media Monitoring

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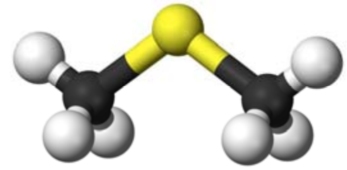
Odor Sampling

- What compounds are present?
- What concentrations/loading?
- Select appropriate media



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Odor Sampling

- Hydrogen sulfide (H_2S)
- Reduced sulfur compounds (mercaptans, dimethyl sulfide, etc.)
- Volatile organic compounds (VOCs)
- Ammonia, amines

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Dry Media

Activated Carbon

- Coal (bituminous or anthracite)
- Coconut shell
- Wood, lignin, peat
- Granular
- Pelletized

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Dry Media

Activated Carbon

- Coal (bituminous or anthracite)
- Coconut shell
- Wood, lignin, peat
- Granular
- Pelletized

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Dry Media

Activated Carbon

- **Virgin:**
  - Not chemically treated
  - Can be coal or coconut-based
  - Good for VOCs (coconut shell)
  - Not as good for H_2S or RSCs

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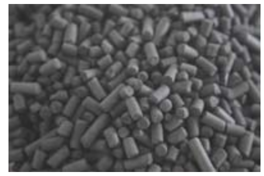
Dry Media



Activated Carbon

- **Impregnated**:
  - KOH, NaOH (potential for combustion)
  - Potassium or sodium permanganate
  - Metallic oxides

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Dry Media

Activated Carbon

- **Water Regenerable**:
  - Proprietary, coal-based
  - Catalytic oxidation, H_2S to SO_4
  - Washed in-situ
  - H_2SO_4 – low pH wash water
  - 75 to 85% of previous capacity

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Dry Media

Activated Carbon

- **High Capacity Catalytic:**
  - Highest H_2S loading rates
  - Non-impregnated
  - Surface functional groups
  - Less effective for RSCs - conversion

Activated Carbon Summary

Type	Advantage	Disadvantage	~H_2S Capacity*
Virgin	Least expensive	Lowest H_2S capacity	0.06
Impregnated	Higher H_2S capacity than virgin	Potential for combustion (caustic)	0.14
Regenerable	Regenerable on site	Deteriorating capacity	0.12
High Capacity	Very high H_2S capacity	Primarily H_2S specific	0.30

* g H_2S/cc carbon

(Not Just) H_2S Capacity

- Competition for adsorption sites
- Water vapor and other compounds
- Media life calculations longer than reality
- Early breakthrough for some compounds

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Odorant Conversion/Desorption

High capacity catalytic carbon:

- Methyl mercaptan oxidized to DMDS
- Presence of oxygen and moisture

Desorption:

- Some compounds very strongly adsorbed
- Weakly adsorbed compounds can desorb

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Dry Media

Specialized Media

- Non carbon-based
- Impregnated
- Permanganate (oxidant)
- Ferritic-based

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Dry Media

Specialized Media

- Activated alumina substrate
- Highly porous form of aluminum oxide
- Impregnated with permanganate (K or Na)
- 4%, 6%, 8%, 12% (by weight)

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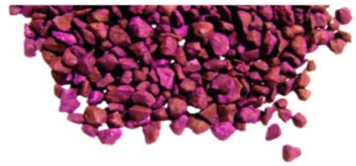
Dry Media



Specialized Media

- Zeolite substrate
- Highly porous aluminosilicate
- Can be mined or produced industrially
- Impregnated with permanganate (K or Na)
- 6% (by weight)

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Dry Media

Specialized Media

- Lower H_2S capacity
- Good for a “polishing” layer
- Can also be blended
- Moisture considerations

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Case Study: DC Water

- PI – 50 miles, ~40 MGD ADF
- 6 radial, single bed OCFs
- Odor complaints shortly after startup
- DMS in exhaust

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Case Study: DC Water

- Blended media avoided extensive modifications to vessel
- 75% permanganate-impregnated zeolite/25% activated carbon
- Worked effectively for only ~2 months

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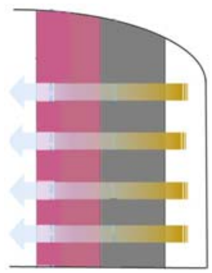
Case Study: DC Water



- Radial configuration made installing a polishing media layer difficult
- Modifications included vessel lids, access hatches, exhaust stacks, and internal screens
- But, would greatly enhance performance and media life

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Case Study: DC Water

Goal: Identify most effective, cost-efficient polishing media for DMS

Six specialized media were pilot tested:

- 6% potassium permanganate zeolite
- 6% sodium permanganate activated alumina
- 12% sodium permanganate activated alumina
- Potassium iodide carbon pellet
- 12% permanganate carbon pellet
- Ferritic-based alumina media

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Case Study: DC Water

Best Performers:
1. Permanganate-impregnated alumina
2. Permanganate-impregnated zeolite

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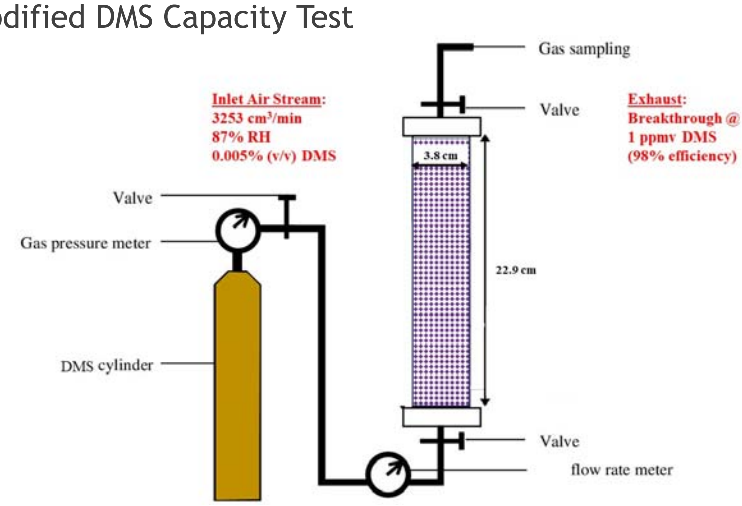
Case Study: DC Water

Modified DMS Capacity Test



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Case Study: DC Water

Modified DMS Capacity Test at independent lab:

- Hydrosil HS600 – 6% potassium permanganate zeolite
- Nichem PPM8 – 8% potassium permanganate alumina
- Purafil SP-12 – 12% sodium permanganate alumina
- PureAir PA-6 – 6% potassium permanganate alumina
- PureAir PA-8 – 8% potassium permanganate alumina

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Case Study: DC Water

Polishing Layer:

- Varying substrates, oxidant types, permanganate concentrations
- 8% permanganate alumina products showed best removal capacity
- Also most cost-effective

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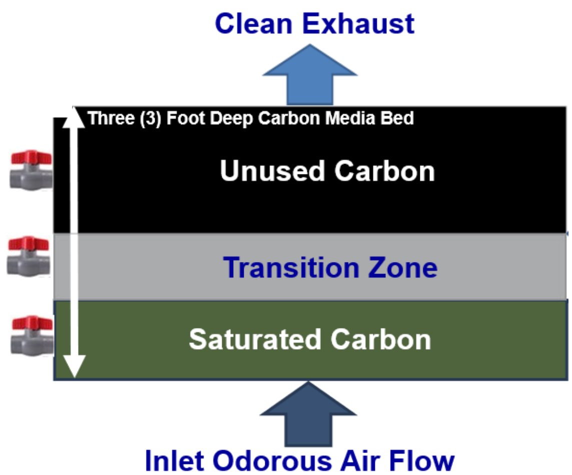
Breakthrough Monitoring



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Breakthrough Monitoring

H_2S-Specific:

- Media bed rod: manual or electronic
- Visual indicator – changes color
- H_2S exhaust gas monitor
- Lab testing

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Breakthrough Monitoring

Broader Spectrum of Odors:

- Canister Sampling, 20 sulfur-based compounds
- Exhaust Odor Sampling (D/T)
- "Sniff test"



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Speaker Introduction

Dirk Apgar, PE, PMP

King County, WA – Wastewater Treatment Division

King County

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Deep Dive into Dry Media Systems

Part 3: Operations and Maintenance

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Topics of Discussion

- Routine Operations
- Routine Inspections & Maintenance
- Major Maintenance
  - Media removal & replacement
  - Scrubber internal repairs and modifications
- Design Tips to Ease O&M

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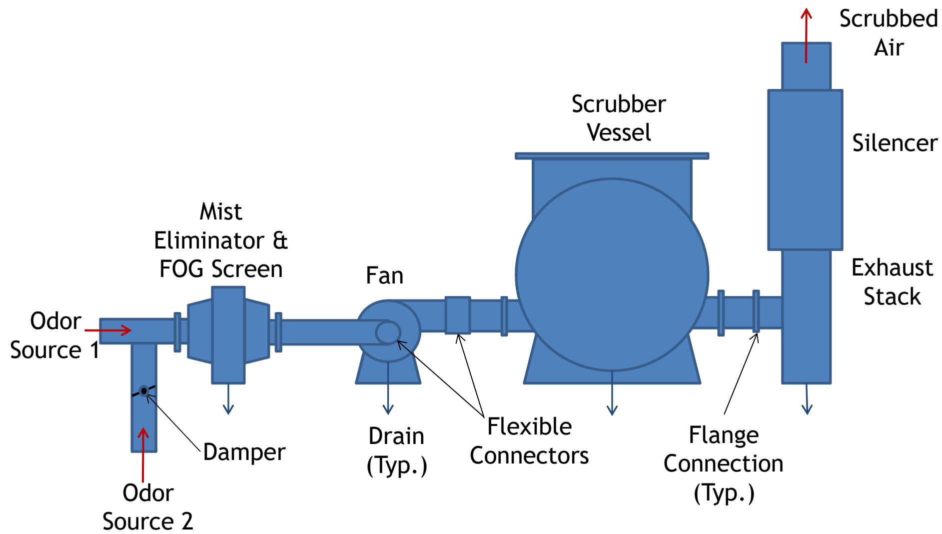
Typical System Components



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Routine Operations

- The beauty of dry media scrubbers is the simplicity of their operation
  - Step 1: Fill vessel with media
  - Step 2: Turn fan on

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Routine Inspections & Maintenance

- Scrubber vessel
- Ductwork/Exhaust stack
  - Dampers
  - Flexible connectors
  - Flanges
- Fan & Motor
- Mist eliminator/FOG screens

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Mist Eliminator Basics

- Simple device used to prevent moisture from contaminating system
- Two basic types:
  - Mesh pad – higher pressure drop/energy req.
  - Vane – typically lower pressure drop & control efficiency than mesh pads
- Mesh pads can also prevent grease from contaminating, ducts, fan & dry media

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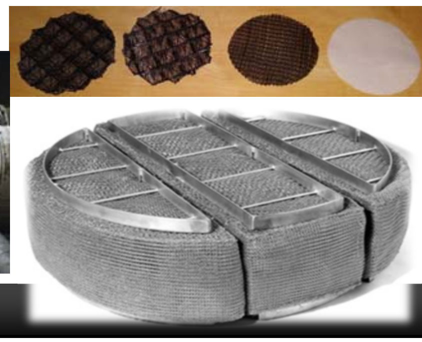
Routine Inspections - Mist Eliminators

- Check pressure drop across mist eliminator
  - High pressure drop indication of fouled mesh pads and reduced airflow
  - Inspect pads for degradation at cleaning intervals



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Routine Inspections – Mist Eliminators

Check for leaks at flanges & improperly plumbed drains

Acidic moisture caused corrosion

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Proper Drains for Equipment and Ducts

Mist eliminator drain

Duct drain

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Routine Inspections – Fan/Motor

- Fan & Motor
  - Verify both motor and fan sheaves are rotating
  - Listen for unusual noise that could indicate bearing failure
  - Lubricate bearings per mfg. recommendations or more frequently in dirty environments

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Ductwork/Exhaust stack

- **Connections (flanged & flexible)**
  - Check for leaks (liquid & gas)
- **Dampers**
  - mark & verify position
  - Check for leaks (liquid & gas)

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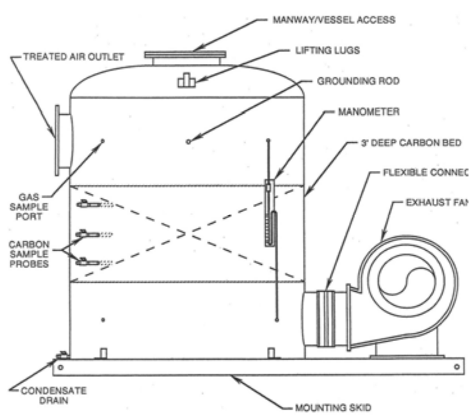
Routine Inspections Scrubber Vessel

- Check pressure drop across media bed
  - High pressure drop indication of fouled media and reduced airflow



Traditional Deep Bed (WEF 2004)

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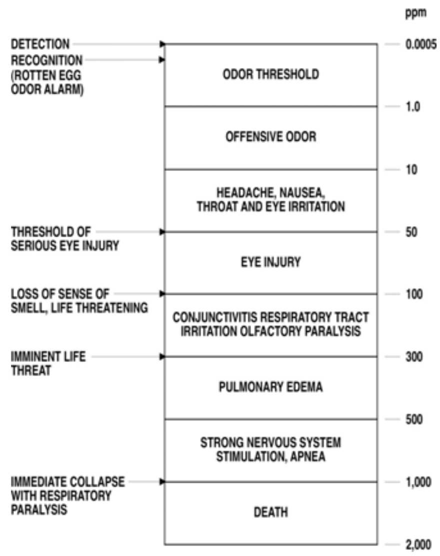
Routine Inspections - Emissions

- Use caution when sampling odors
- Always check for hazardous H_2S concentrations
  - Use a calibrated electronic detector or colorimetric tubes to verify concentration is not at a hazardous level prior to using your nose!



(WEF 2004)

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Routine Inspections – H_2S Testing

Electrochemical Cell

Colorimetric Tubes

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Routine Inspections Stack Gas Sampling

- Odor & Gas Sampling
  - Check H_2S and odors at stack

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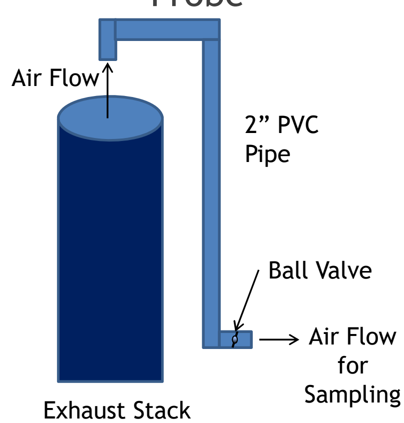
Routine Inspection Stack Gas Sampling

- If no stack sampling port exists
  - Fabricate PVC sampling probe as shown to the right
  - Stack air velocity usually sufficient to drive sample through 25’ of pipe
- Stack Gas Sampling Probe



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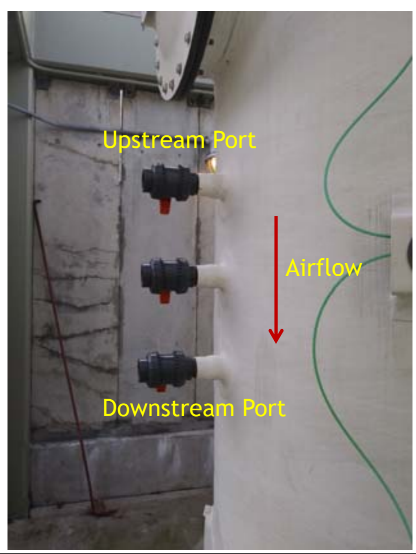
Routine Inspections

- Check hydrogen sulfide (H_2S) and odors at scrubber sampling ports
- Provides an indication of how much adsorption capacity remains
- Start at downstream port and work back
- A little record keeping will help you manage the asset!



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Major Maintenance

- Dry media removal & replacement
- Scrubber vessel internals repair

Traditional Deep Bed Scrubbers

Horizontal Airflow/Vertical Bed Dry Media Scrubber

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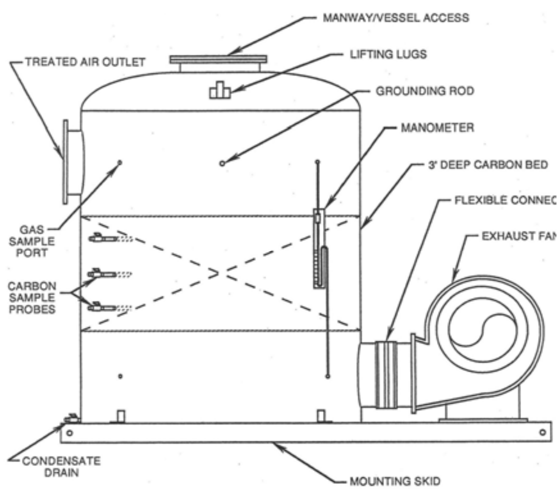
Traditional Deep Bed Scrubber



Traditional Deep Bed WEF (2004)

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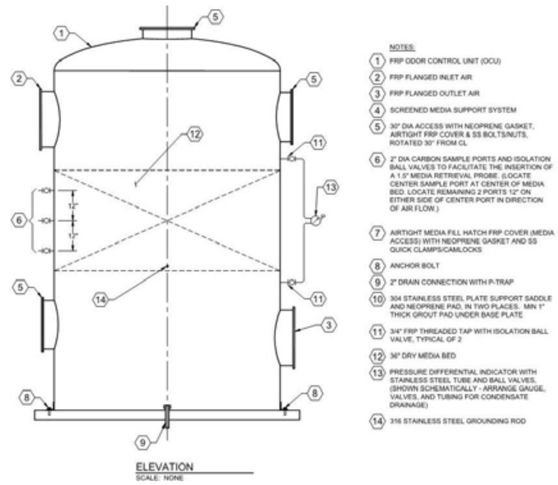
Traditional Deep Bed Scrubber – Enhanced Access



(King Co. 2016)

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Horizontal Airflow/Vertical Bed Scrubbers

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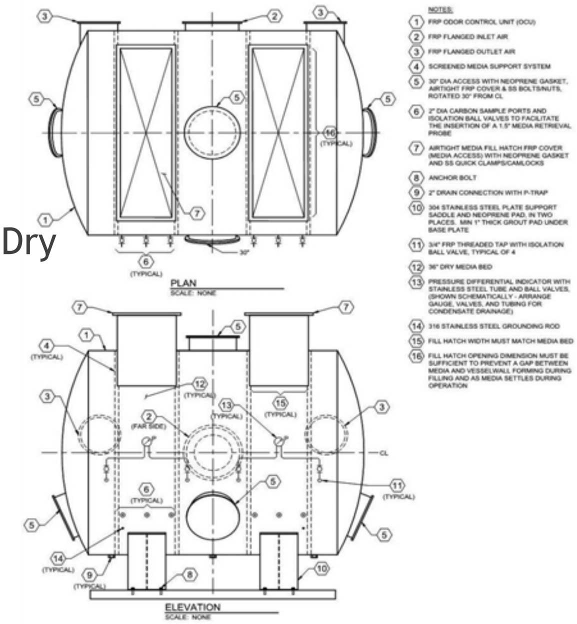
- King County HAVB Dry Media Scrubber Standard Design
  (King Co. 2016)



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Toggle Clamps Vs. Nuts & Bolts

4 Clamps or 16 Nuts & Bolts

So much easier!

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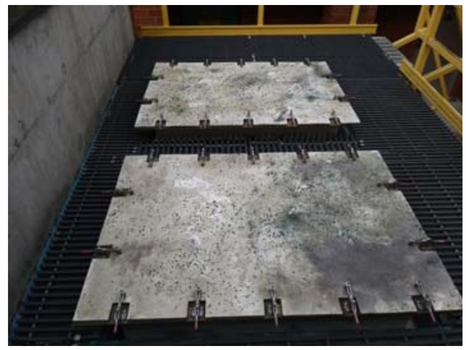
Toggle Clamps Ease Access

- Shut down fan(s) prior to clamp release
- Allows quick hatch opening and closing
- More likely hatches will be completely secured



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Traditional Deep Bed Media R&R

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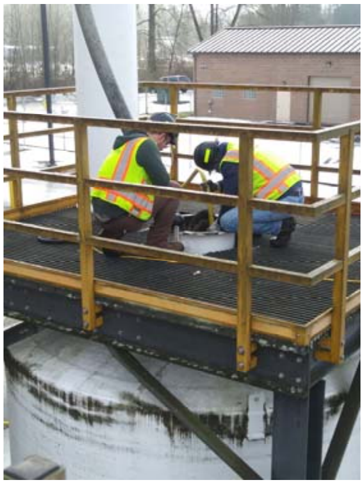
Traditional Deep Bed Media R&R



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Traditional Deep Bed Media R&R

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Traditional Deep Bed Media R&R

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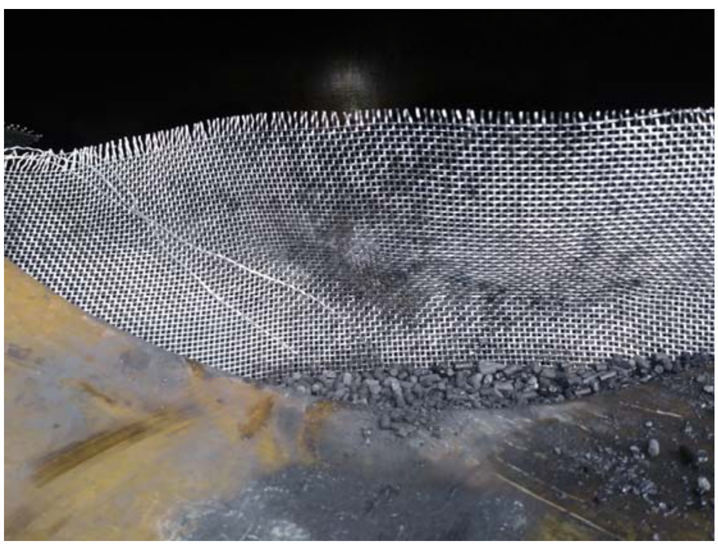
Traditional Deep Bed Media R&R



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Traditional Deep Bed Media R&R

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Traditional Deep Bed Media R&R

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Traditional Deep Bed Media R&R

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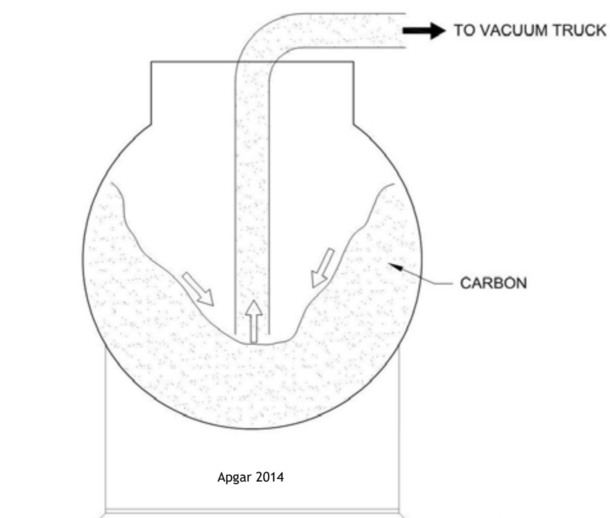
Media Removal from HAVB Scrubber



Apgar 2014

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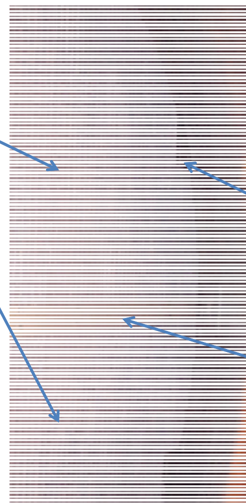
Media Retention Grating & Supports

FRP Grating Media Retention Panels



FRP Perimeter Grating Gussets (note bolts through panels)

FRP T-Section to Bridge Multiple Panels

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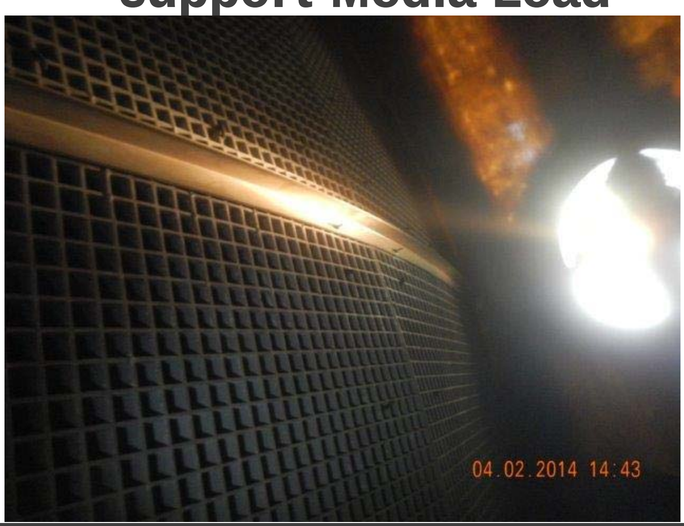
Insufficient Structural Integrity to Support Media Load



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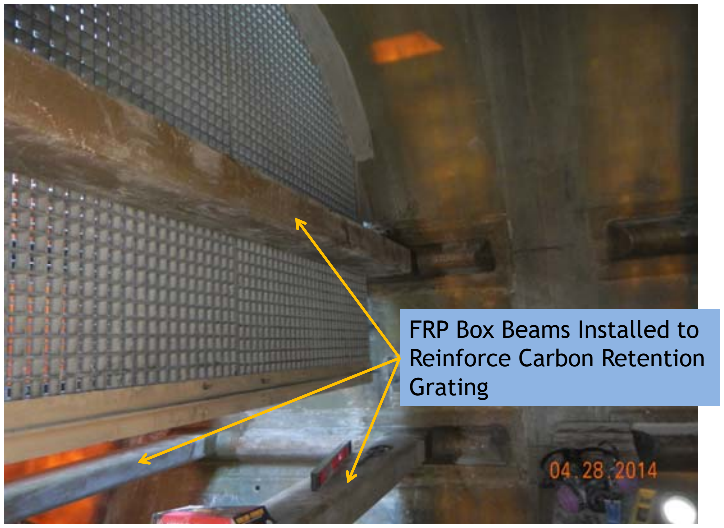
Box Beam Supports Added



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Circumferential Retention Improved

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Media Retention Beams

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Selecting Replacement Media

King County – WTD Dry Media Standards for Hydrogen Sulfide Concentrations

(King Co. 2016)

Dry Media	Hydrogen Sulfide Concentration	
	Average	Maximum
Plain, virgin activated carbon	5	10
Caustic impregnated carbon	10	50
High H_2S capacity carbon	30	70
Proprietary dry media	Manufacturer's recommendation[a]	Manufacturer's recommendation[a]

[a] Verified by independent third-party testing or pilot testing at a WTD facility by WTD personnel.

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Estimating Media Life & Annual Cost

(Apgar 2016)

Target Pollutant: Hydrogen Sulfide	**Pollutant Molecular Weight:** 34 lb/lbmol	**Media H_2S Adsorption Capacity:** 0.04 g/cm^3	**Media Density:** 33 lb/Ft^3
Target Pollutant Concentration (ppmv) 5 ppmv	**Media Bed Volume** 150 Ft^3	**Media Price** $1.5/lb	**Assume molar volume of foul air to be 385 Ft^3 at 68^o F**
Step 1: Calculate Pollutant Mass Flow Rate (PMFR)			
PMFR = (Air Flow Rate) / (Molar Volume of Air) x (Pollutant Concentration) * (Pollutant MW) PMFR = (2,500 Ft^3/min) / (385 Ft^3/lbmol) * (5 parts/1,000,000 parts) * (34 lb/lbmol) PMFR = 0.001 lb H_2S/min			
Step 2: Calculate Media Bed Life (MBL)			
MBL = (Media H_2S Adsorption Capacity) x (Media Volume) / (PMFR) MBL = (0.04 g H_2S/cm^3 media) x [(2.54 cm/in) x (12 in/ft)]^3 x (150 ft^3) / (454g/lb) / [(0.001 lb H_2S/min) x (1440 min/day) x (30 day/month)] MBL = 8.7 months			
Step 3: Calculate Annualized Cost (AC)			
AC = (Media Cost per Pound) x (Media Volume) x (Media Density) / Media Bed Life AC = ($1.50/lb) x (150 Ft^3) x (33 lb/Ft^3) / [(8.7 month) x (1 year / 12 month)] AC = $10,241/year			

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References

- WEF. 2004. *Control of Odors and Emissions from Wastewater Treatment Plants.* Manual of Practice 25. Water Environment Federation, Alexandria, VA.
- Apgar, D. 2016. “A Method for Choosing Between Carbon Media Alternatives for Wastewater Odor Control.” *Water Environment Federation Air Pollutants and Odor Emissions Conference Proceedings*. Milwaukee, Wisconsin. March 21 - 24, 2016.
- King County – Wastewater Treatment Division 2016. *Odor and Hydrogen Sulfide Induced Corrosion Control – Design Standards.* Seattle, WA.

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Questions?

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Bullpen Slides

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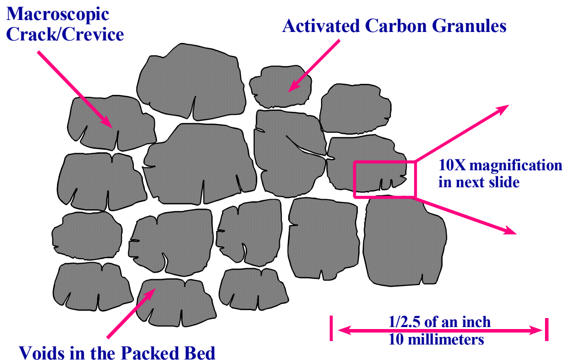
Carbon Adsorption Technology Defined



Carbon Bed – 10X Magnification

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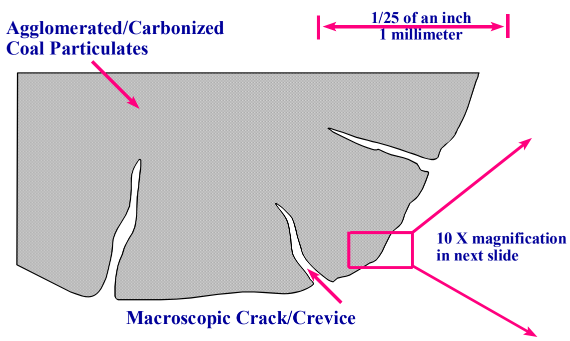
Carbon Adsorption Technology Defined



Carbon Bed – 100X Magnification

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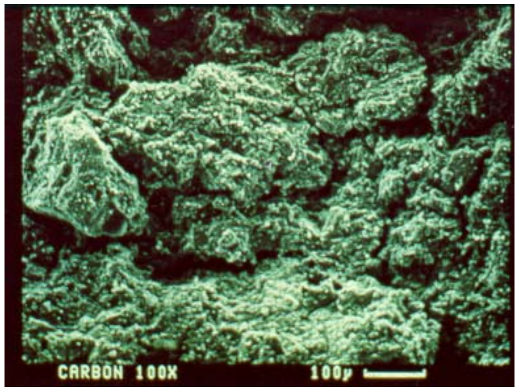
Carbon Adsorption Technology Defined



Photomicrograph – 100X

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