High Efficiency Filtration of Airborne Gases

Presented by:
Chris Sipes – Director, Business Development

NAFA National Air Filtration Association
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Key Questions

What is adsorption?

How do adsorption filters work?

Where do High Efficiency adsorption filters work?

Is this just marketing or does it really work?

Agenda

- **Adsorption Basics**
- **Market Structure**
- **Qualifying Applications**
- **Q&A**

Adsorption Basics

Concepts:

- Why carbon?
- Why coconut carbon?
- Pore structure
- Surface area
- Adsorption vs. Absorption
- Physical adsorption
- Chemisorption
- AMC
- PPM
- PPB
- Mesh size
- CTC

Origins of Gas Phase Filtration

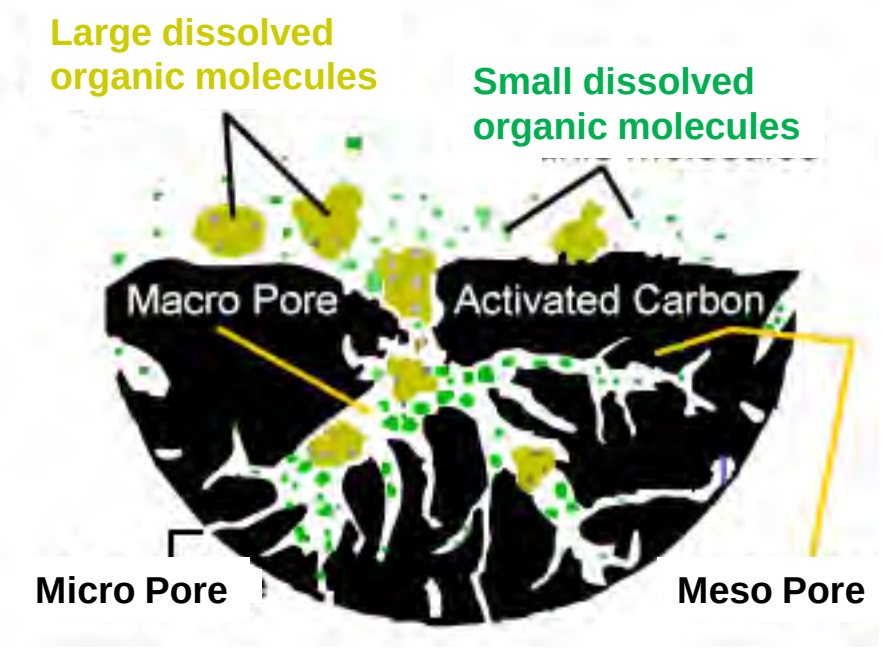
- WWI brought filter technologies for force protection

- Modern day face mask can be power assisted with specialized sorbents to protect from specific toxic gases

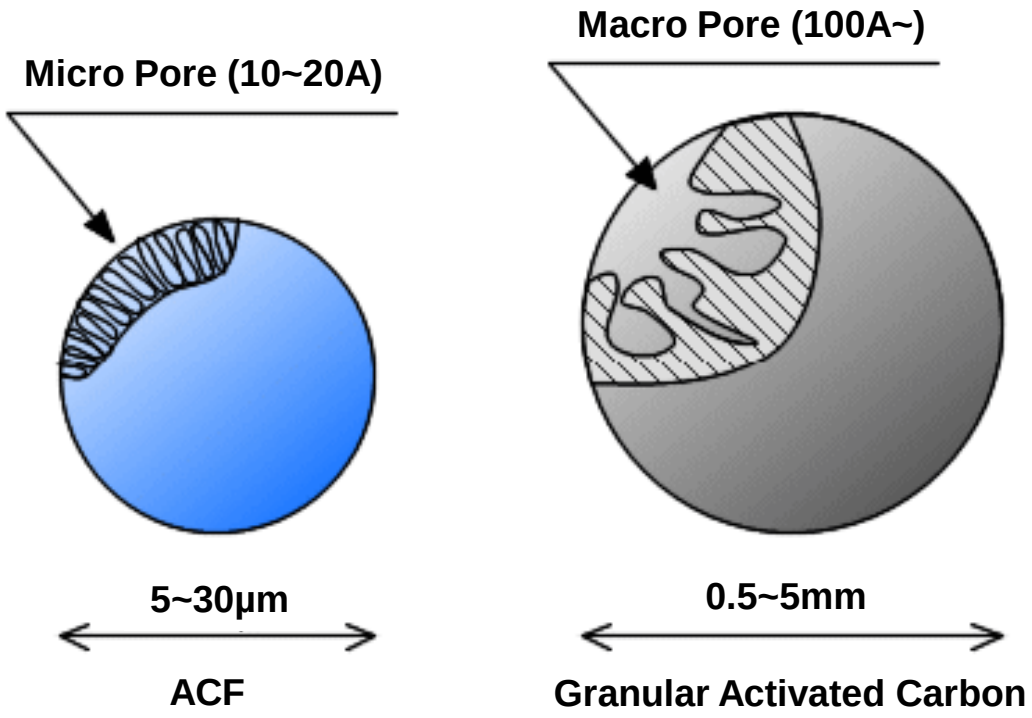
Why Coconut Carbon?

Coconut shell provides:

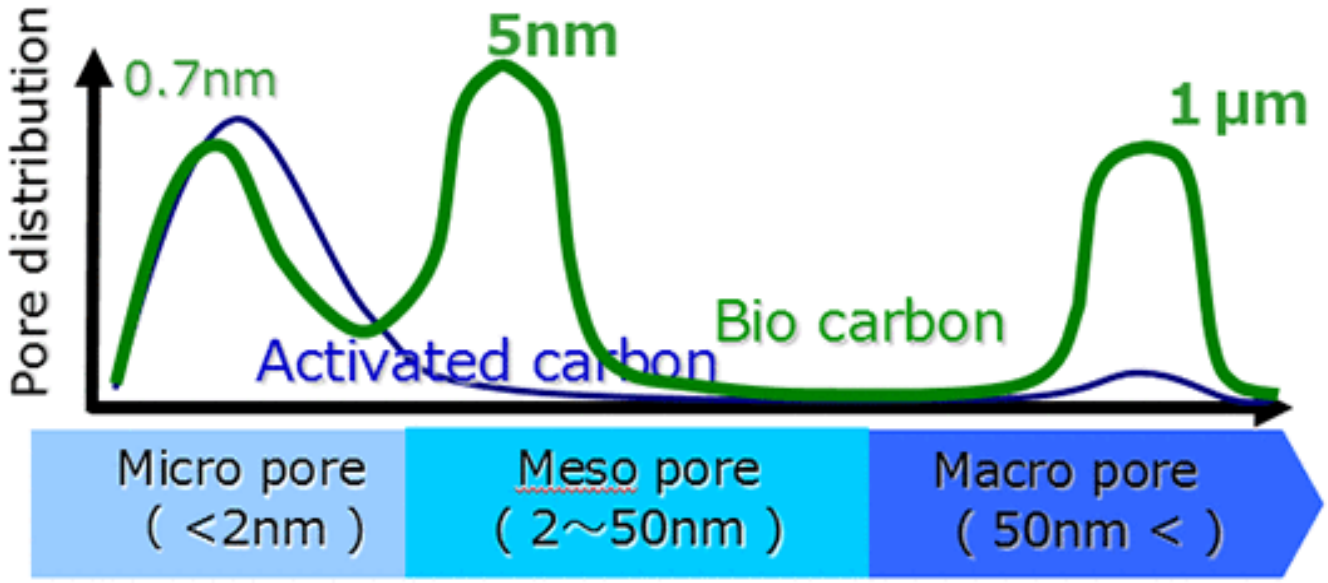
- The cleanest of activated carbons
- Low dusting
- Superior pore structure for gas phase filtration
  - Most amount of micropores



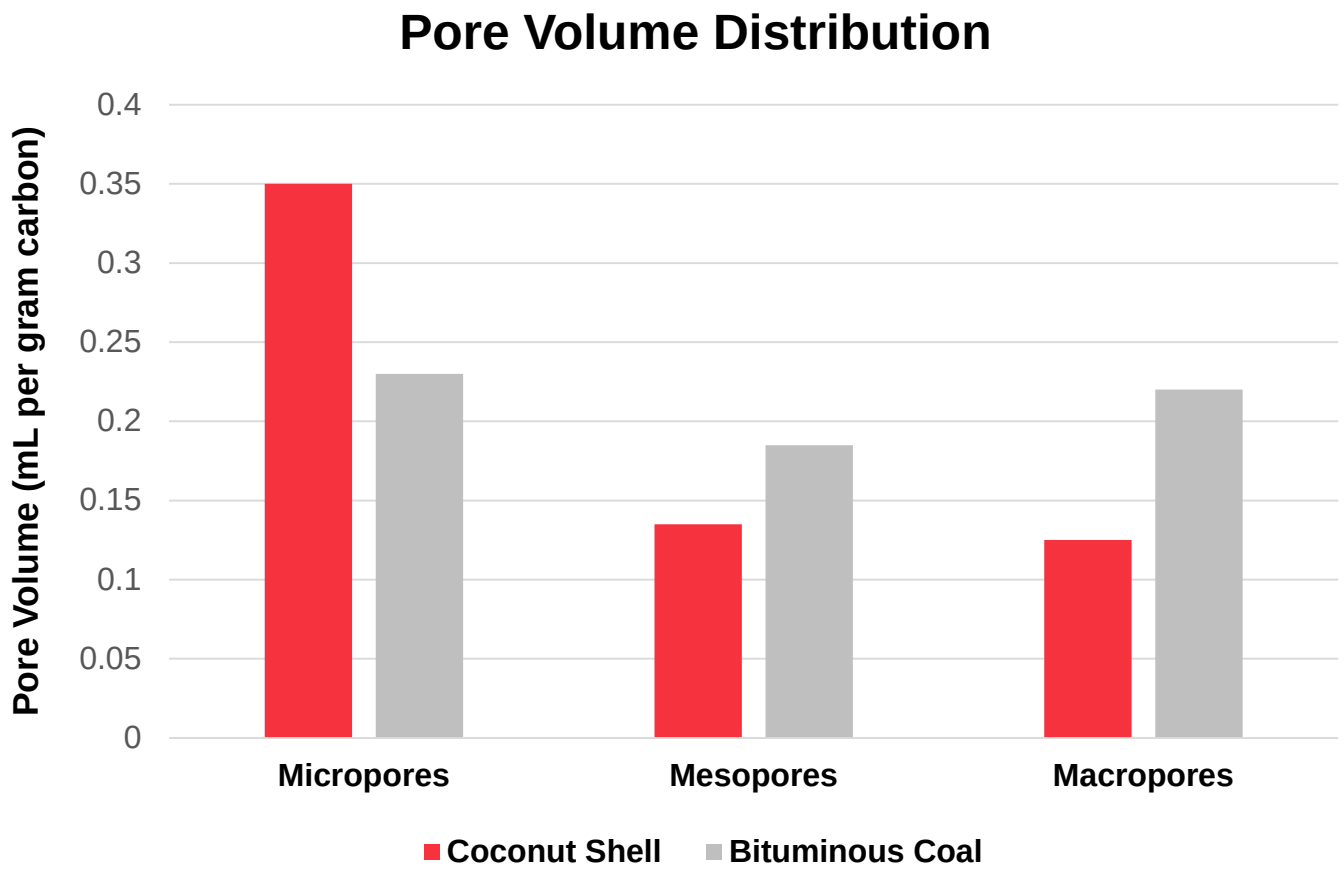
Macro vs. Micro Pore



Pore Distribution

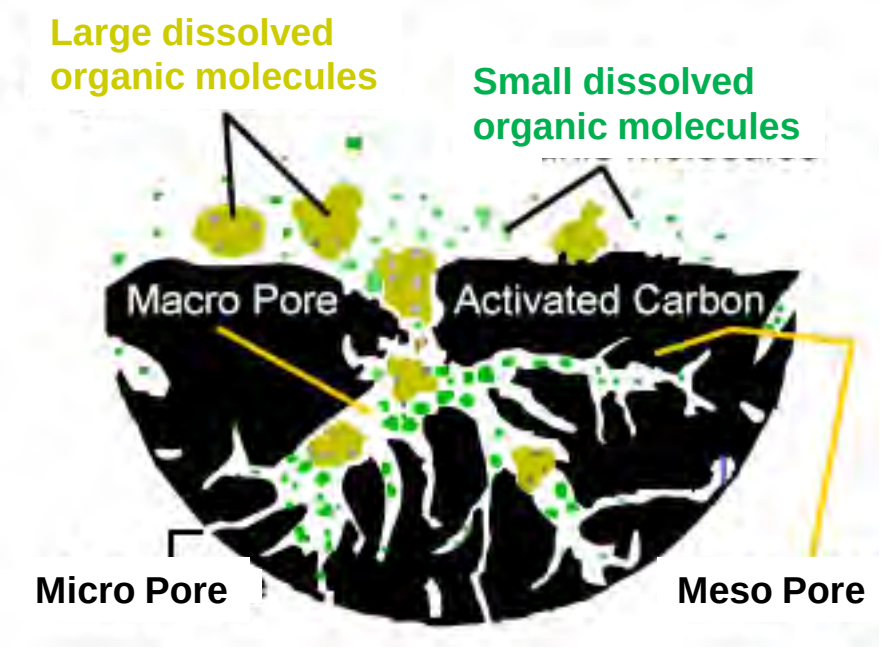


Why Coconut Shell?



BET* Surface Area

- ***Activated carbons can provide functional surface area ranging from 400 to more than 1,500 m^2/g !***
- A **BET* device** measures internal surface area and calculates the average pore size, pore volume and pore size distribution.
- 60% ctc carbon 1100 m^2/g
- 85% ctc 1500 m^2/g



*1938 paper by Brunauer, Emmett and Teller

Adsorption and Absorption are Not the Same

How activated carbon works:

Adsorption:

The process by which molecules of a substance, such as a gas or a liquid, collect on the surface of another substance such as a solid.

vs.

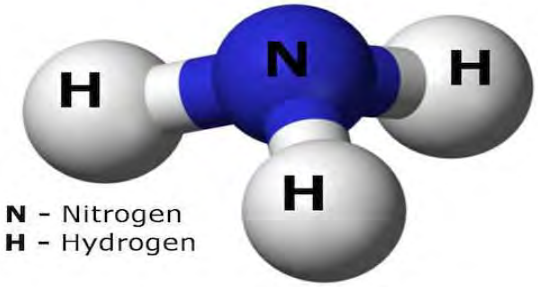
Absorption:

The process by which one substance, such as a solid or liquid, takes up another substance, such as a liquid or gas, through minute pores or spaces between its molecules.

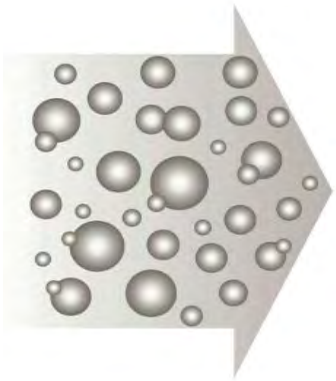
Physical Adsorption

- The process by which one substance is attracted to and held on the surface of another
- The adsorbent is the adsorbing medium (carbon, exchange resin, zeolilte, etc.)
- Physical adsorption is a surface phenomenon
- Analogy: Condensation of water molecules sticking to a drinking glass
- Adsorption, being a physical process, is fully reversible (desorption)

Chemisorption



Low boiling compound

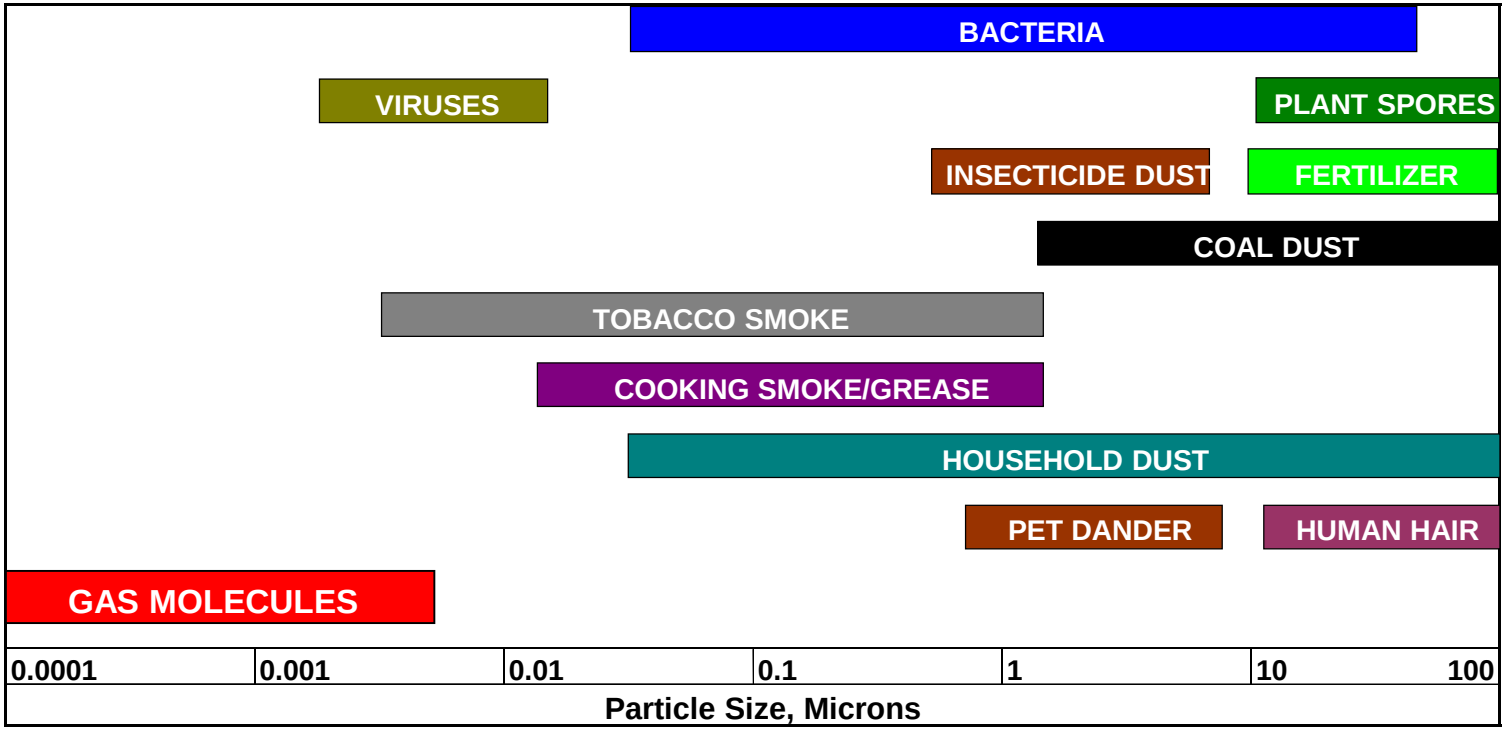


Chemically treated adsorbent

- The process is essentially instantaneous and irreversible
- The result of chemical reactions on the surface of the adsorbent
  - Changes harmful gases to harmless solids
  - Desorption does not occur
  - Acid impregnation system for base gases
  - Caustic impregnation for acids

Airborne Molecular Contaminant

Particulate vs. Gas – Relative Sizes



PPM vs. PPB

1 ppm is relative to:

- 1 inch in 16 miles
- 1 minute in 2 years
- 1 ounce in 31 tons
- 1 drop of vermouth in 80 “fifths” of gin

1 ppb is relative to:

- 1 inch in 16,000 miles
- 1 second in 32 years
- 1 pinch of salt in 10 tons of potato chips
- 1 drop of vermouth in 500 barrels of gin

➢ **Think in Small Parts!**

Mesh Size

A 30×60 carbon is made of particles that will:

- Pass through a U.S. Standard Mesh Size No. 30 sieve (0.84 mm)
  - Generally specified as 85% passing
- Be retained on a U.S. Standard Mesh Size No. 60 sieve (0.42 mm)
  - Generally specified as 95% retained

Mesh Size Chart

U.S. MESH	INCHES	MICRONS	MILLIMETERS
3	0.2650	6730	6.730
4	0.1870	4760	4.760
5	0.1570	4000	4.000
6	0.1320	3360	3.360
7	0.1110	2830	2.830
8	0.0937	2380	2.380
10	0.0787	2000	2.000
12	0.0661	1680	1.680
14	0.0555	1410	1.410
16	0.0469	1190	1.190
18	0.0394	1000	1.000
20	0.0331	841	0.841
25	0.0280	707	0.707
30	0.0232	595	0.595
35	0.0197	500	0.500
40	0.0165	400	0.400
45	0.0138	354	0.354
50	0.0117	297	0.297
60	0.0098	250	0.250

CTC % Ranks the Level of Activation and Cleanliness

- **Carbon Tetrachloride Activity** (ASTM D3467) (**CTC**) of activated carbon measures the porosity of an activated carbon by weighing the adsorption of saturated carbon tetrachloride vapor.

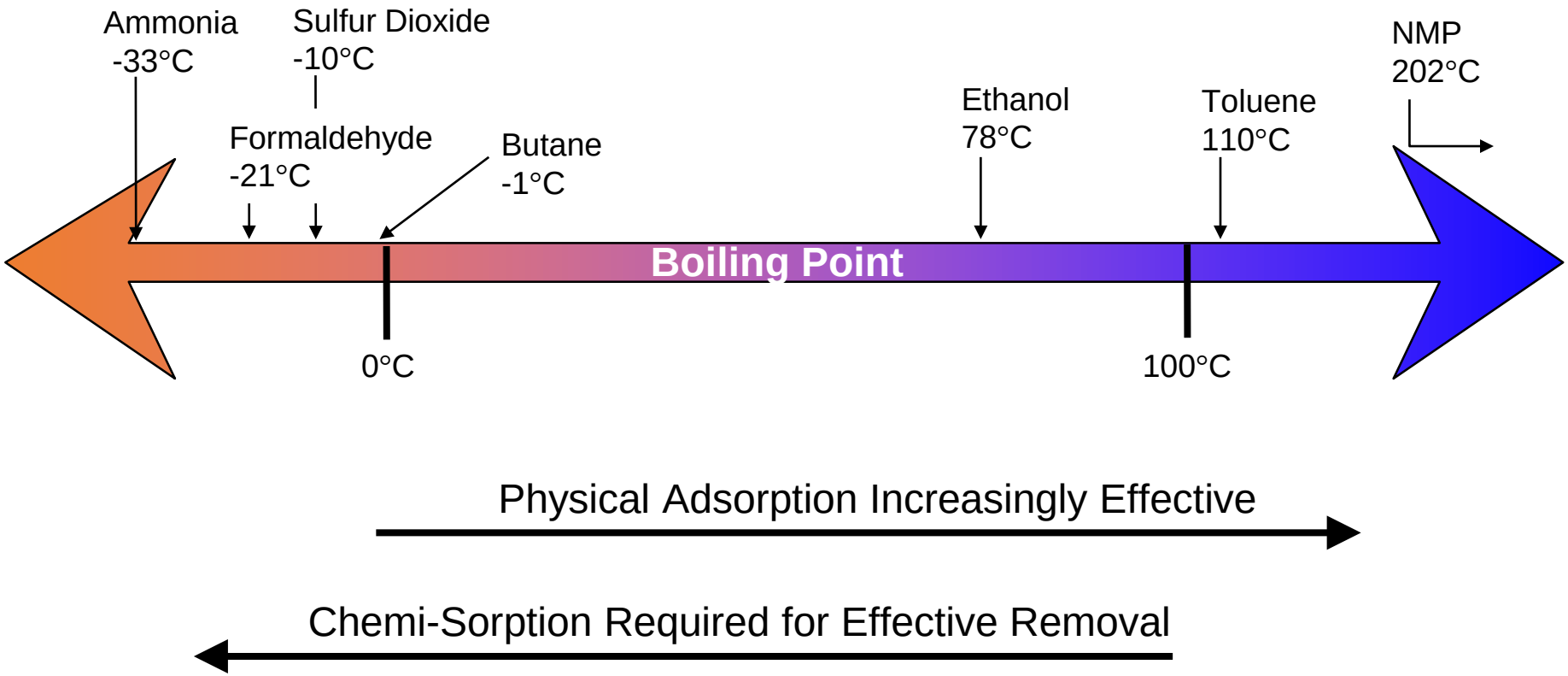
- The Carbon Tetrachloride Activity has been replaced by the **Butane Activity** (ASTM D5742) test due to the ban on carbon tetrachloride. CCl_4 activity = 2.55 x the Butane Activity

Adsorption Basics

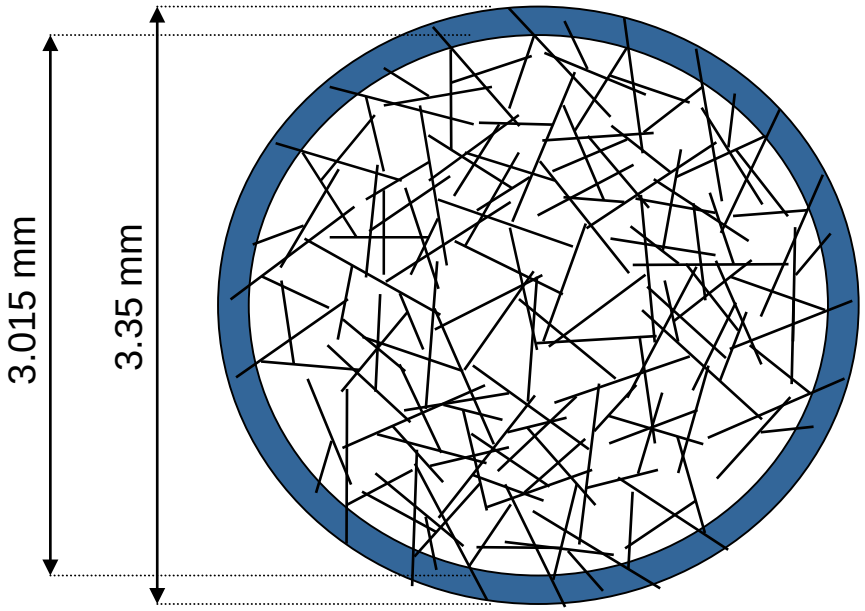
Additional Concepts:

- How does boiling point of compounds impact their capture?
- What is the impact of mesh size in vapor phase filtration?
- Adsorption curves
- Filter and media examples
- Thin bed nonwoven
- Extremely high efficiency for small concentration levels
  - HEPA analogy
- Application successes

Boiling Point Continuum

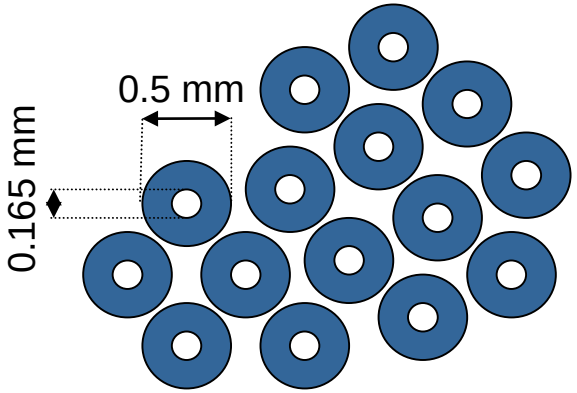


Mesh Size Impact



6 Mesh Particle

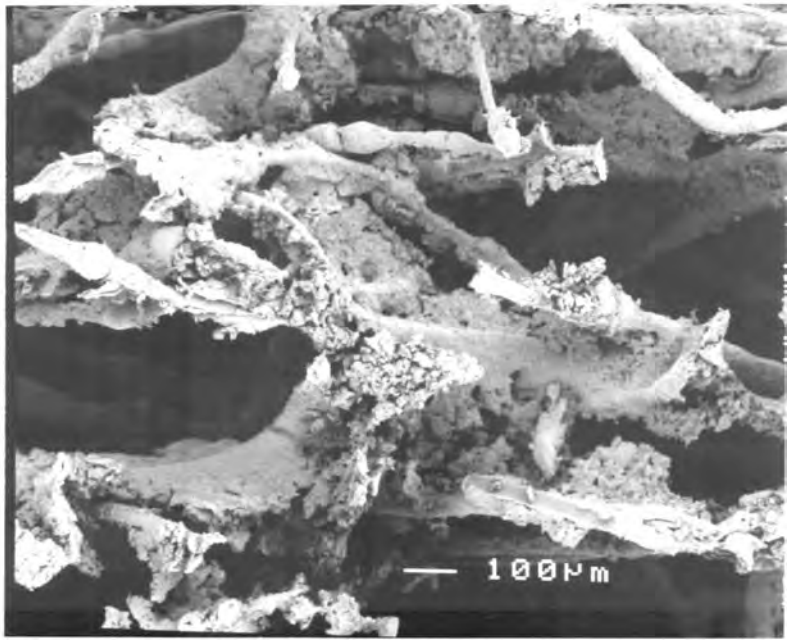
- At a given point in time, assume penetration to 5% depth (0.167 mm) from surface
- Uses 27% of carbon volume



32 Mesh Particle

- Takes 300+ particles to get equal weight
- Equal penetration depth uses 96% of carbon volume

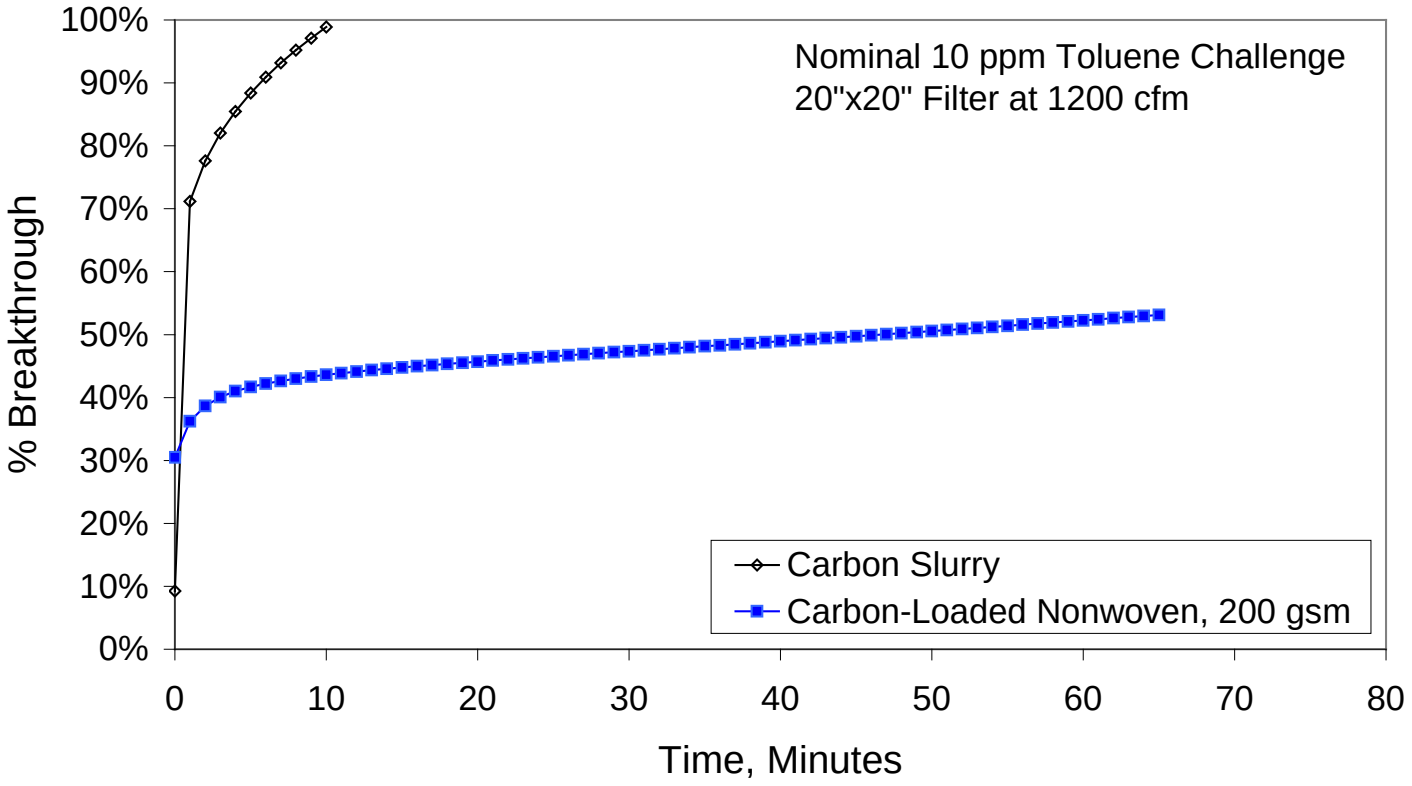
Carbon Slurry vs. Carbon-Loaded Nonwoven



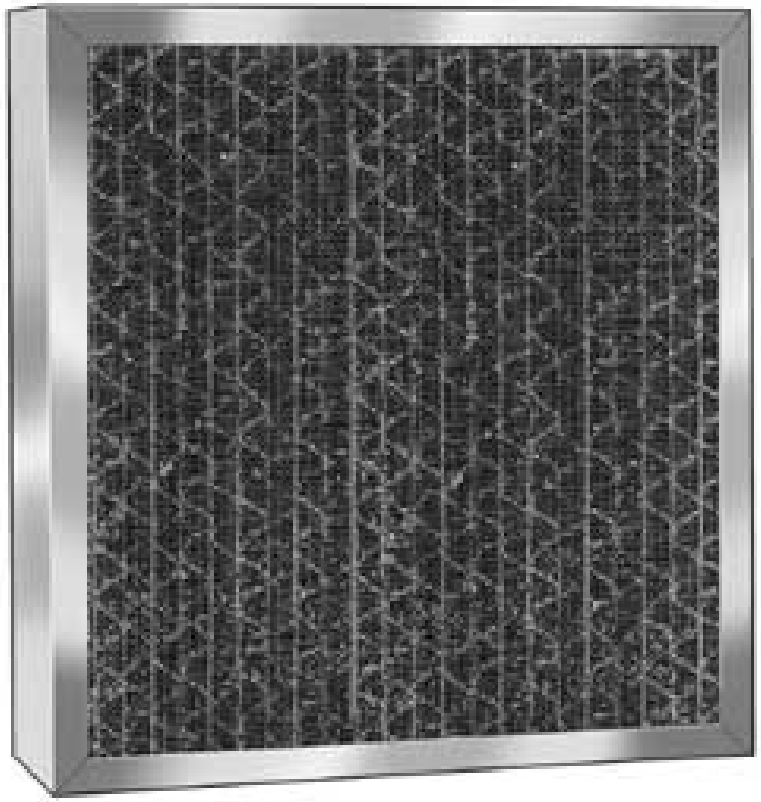
Glue covering surface area

Adsorbent surface area
available to contaminant

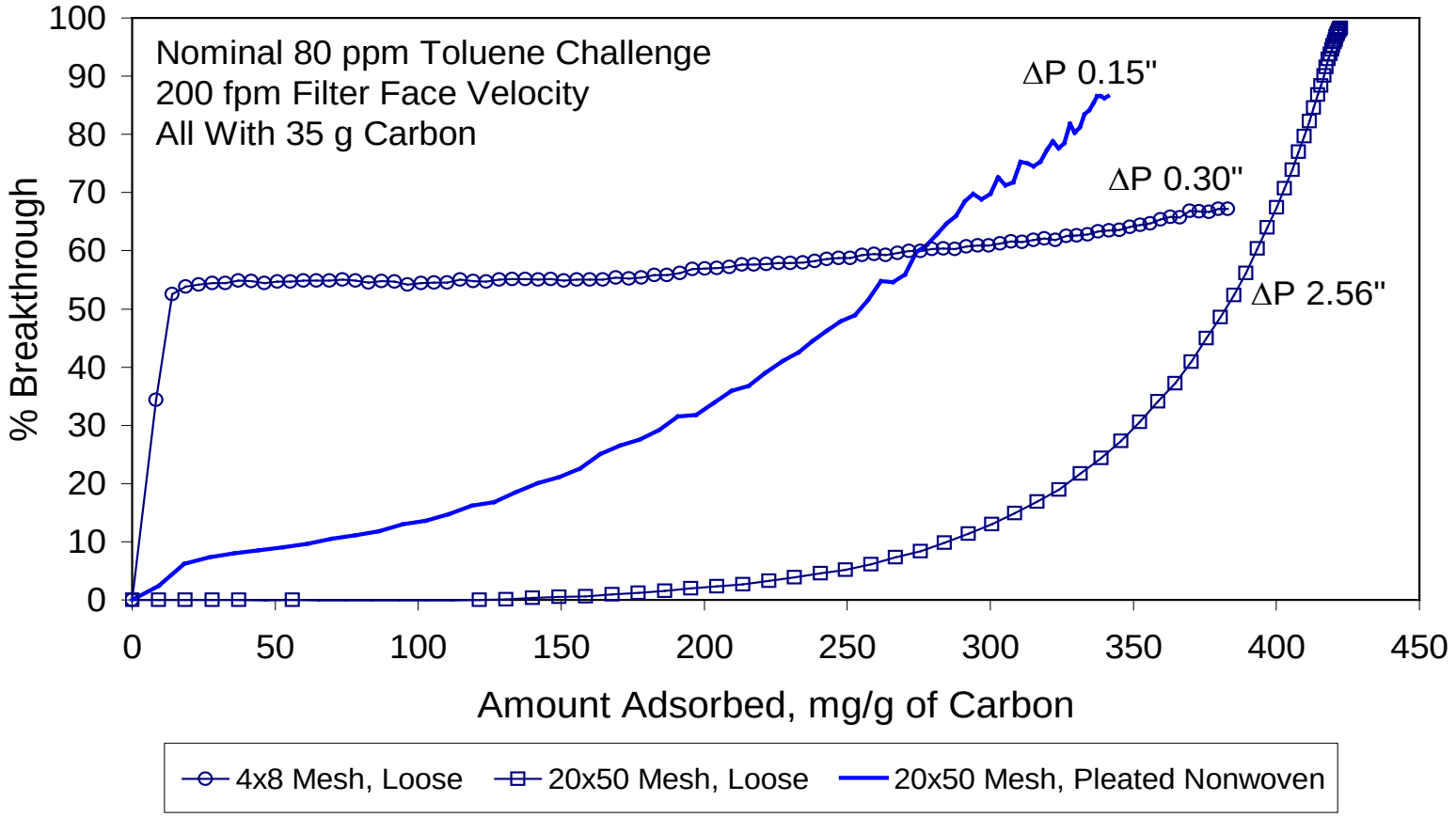
Carbon Slurry vs. Carbon-Loaded Nonwoven



Filter Type: Honeycomb Panel



VOC Adsorption vs. Filter Type



HEPA Analogy

Thin Bed Nonwoven

- Small mesh carbon for trace elements
- High efficiency on trace elements
- Polishes coarse deep bed filtration
- Crashes quickly in high concentration levels

HEPA Filtration

- Small fibers for small particles
- MPPS
- Polishes coarse fat fiber filtration
- Crashes quickly in without prefiltration of large particles

Agenda

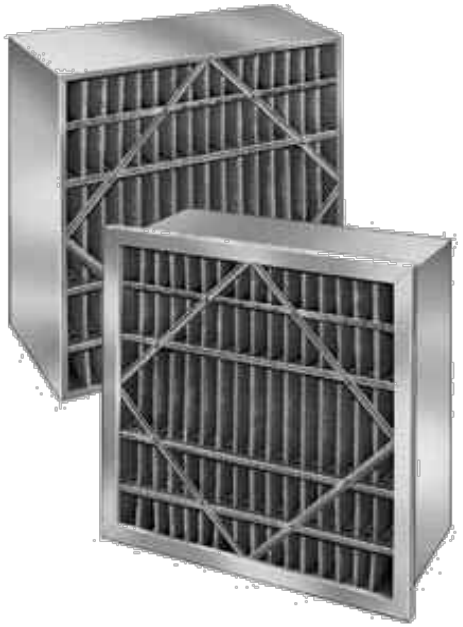
- Adsorption Basics
- **Market Structure**
- Qualifying Applications
- Q&A

Market Structure

Concepts:

- Material supply chain
- Media construction
- Where used?

Supply Chain: From Coconut to Filter



Supply Chain

Raw Coconut Shell Harvesting

- Shell broken manually to harvest meat
- Open air drying to ease meat removal

Carbonization

- At grower or central facility
- Shell carbonized by burning in ground or in charring equipment

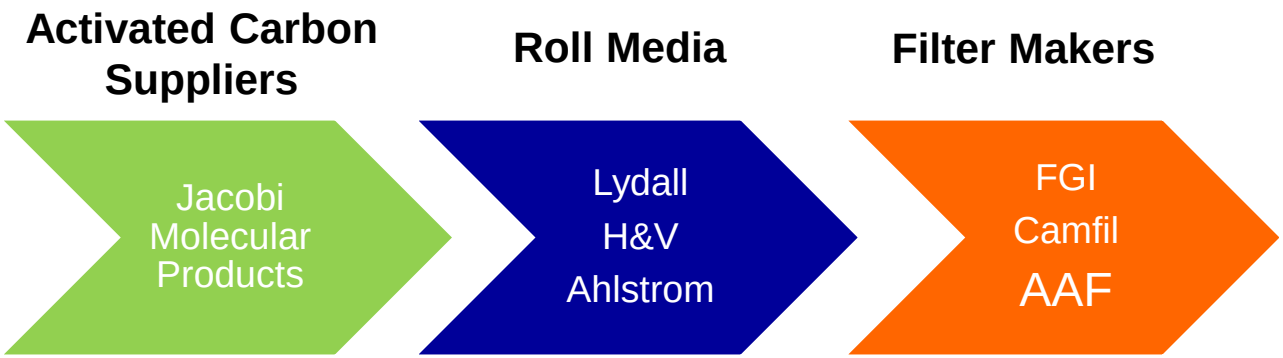
Activation

- At manufacturer
- -1000°C, steam addition

To make 6000 MT carbon/year:
= 16,250 MT carbonized shell
= 40,625 MT raw shell
= 258 million coconuts!

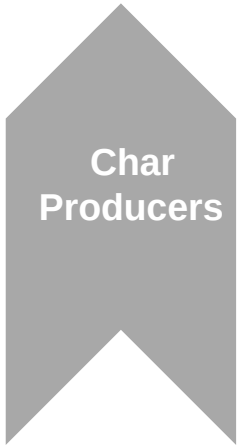
Supply Chain: Thin Bed Media

Char Producers	Carbon Activation	Media Sellers	Filter Makers	End Users



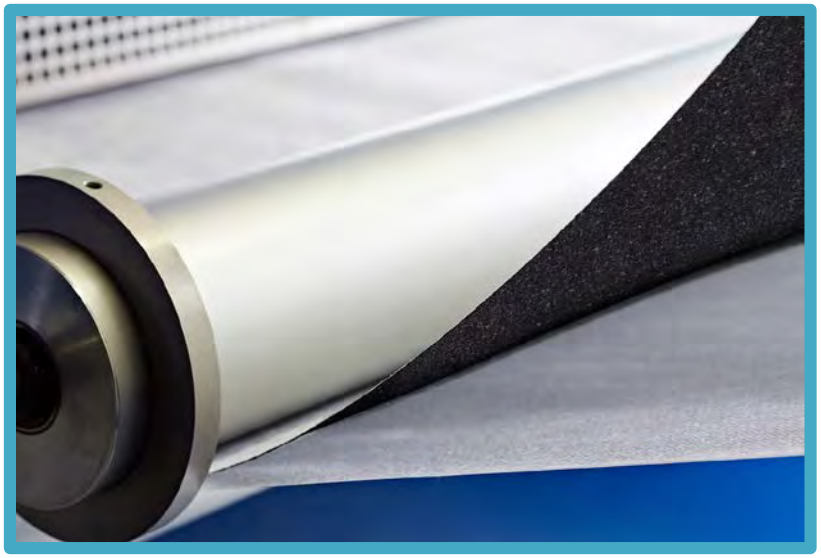
Applications

- Clean room
- Bio-safety
- Respirator
- Consumer
  - RAC, Vacuum
- HVAC



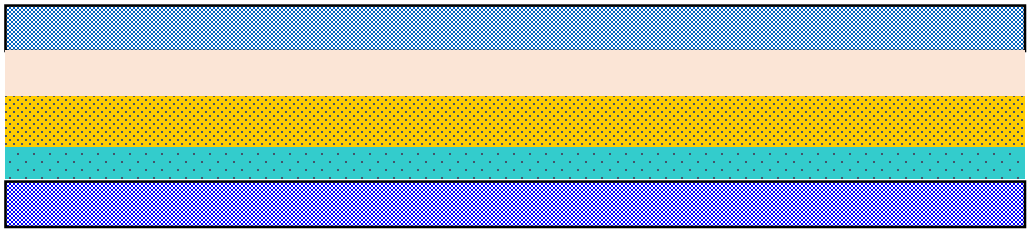
Thin bed media allows composites to match applications

Combination of layers through co-pleating or lamination



- **Carbon- VOC**
- **Impregnated Carbon- Acid/ Base**
- **Synthetic membrane**
- **Meltblown**
- **Synthetic Composite Grades**

Multi-Layer Construction



- **Functional Layer**
- **Impregnated for Base/ VOC Removal**
- **Impregnated for Acid Removal**
- **Particulate Filtration**
- **Cover Sheet**

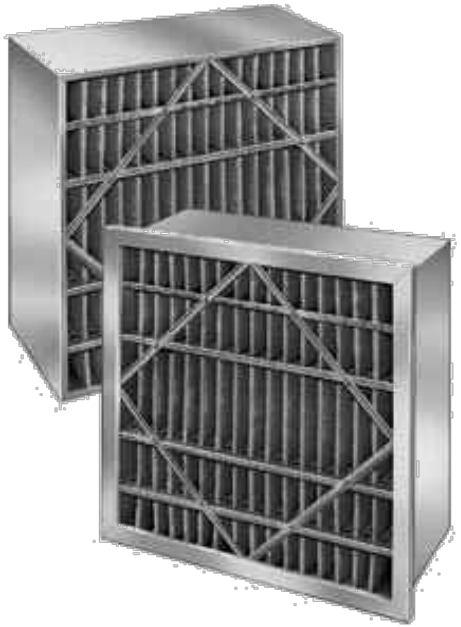
Complete Portfolio covers Acids, Bases, and VOC's

640 g/m² high performance media for semiconductor

Full Product Line:

- **Acids**
- **Bases**
- **VOC's**

Filter Formats



Markets for High Efficiency Adsorption

Municipal Water

Industrial Water

Gold Recovery

Home Water

Tobacco

Oil & Gas

Personal Protection

Pharma & Medicinal

Food

Cabin Air

Indoor Air Quality

Reactivation

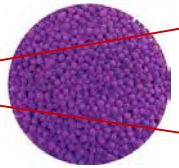
Super Capacitors

Chemical Processing

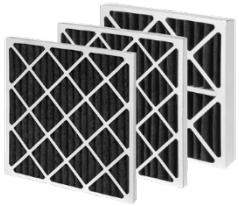
Thin Bed Media: High Efficiency Low Concentration

Gas Phase Filters are typically sold as:

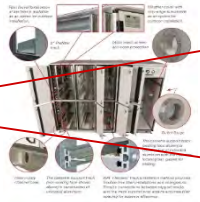
Coarse Chemical Media



Pleated Filters



Cassettes



Applications for Gas Phase Filtration

Odor

Corrosive

Toxic

Today's Applications

- Airport tarmacs
- Hospitals
- Zoos
- Las Vegas hotels
- Restaurants
- Loading docks
- Cleanrooms
- Industry emissions

Gases

- VOCs
- Ammonia
- Sulphur dioxide
- Formaldehyde
- Ozone
- Hydrogen sulfide

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Media Service Life

What is the service life of the chemical filter media?

- Most often referred to in terms of removal efficiency
  - Most accurate method involves monitoring upstream and downstream of media filters
  - Direct gas monitoring may be required
  - Some labs will build a typical life curve with spent filters and media

- Key inputs:
  - Upstream concentration of contaminant
  - Downstream removal target

Application Continuum: entry level to high value

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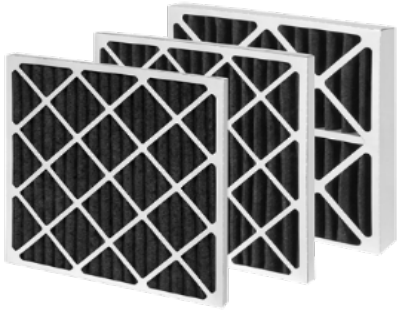
Application Knowledge

Reference testing

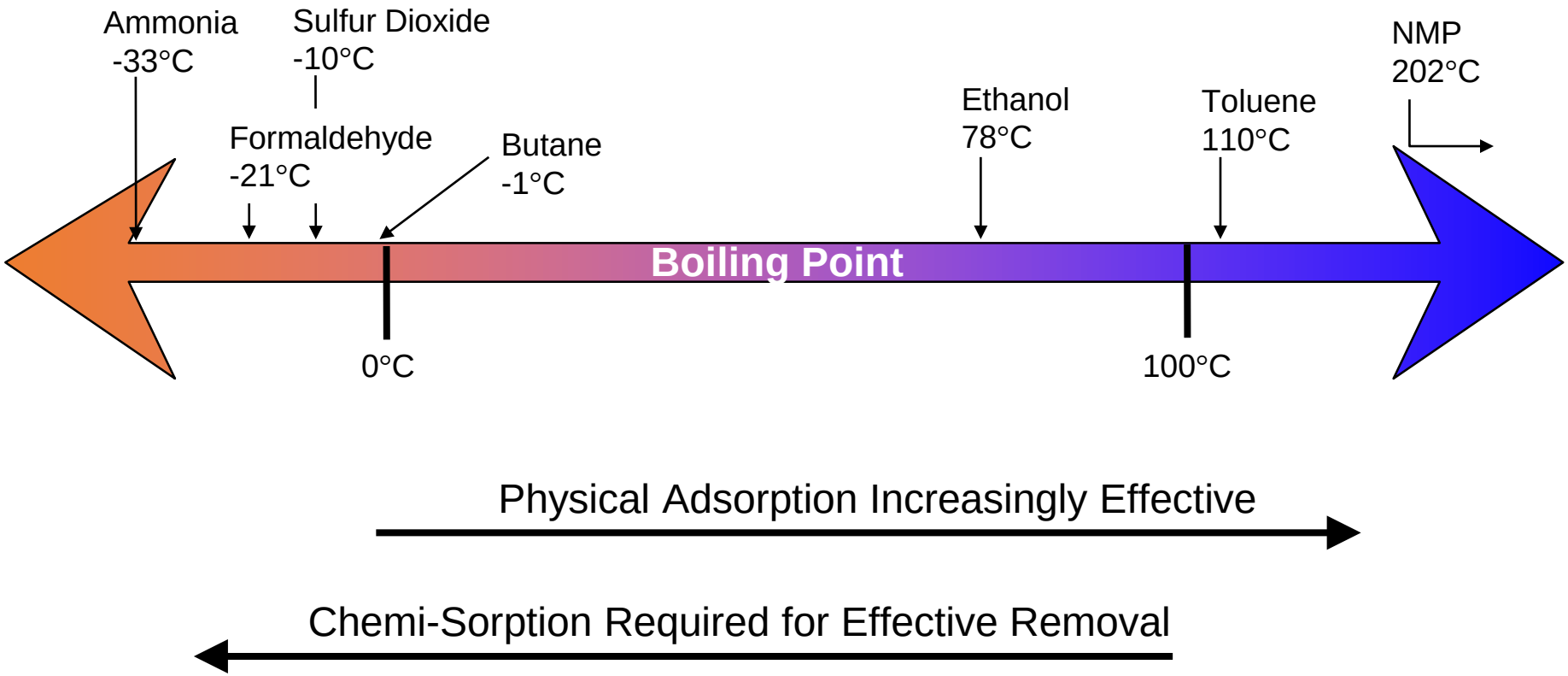
Application testing required



Key Questions to Qualify an Application

- Type of adsorbent – Carbon, resin, zeolite?
- Amount of adsorbent – weight in gsm or pounds
- Mesh size – What size mesh is the carbon you use?
- Impregnation system – Is your carbon impregnated?
- Contaminant types – What is your contaminant of concern?
- Contaminant concentrations – What is the ppm/ppb level?
- Humidity (Temperature)
- Filter type – What is your filter format now?
- Flow conditions (rated flow and pressure drop budget)

Boiling Point Continuum



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High Efficiency Thin Bed Really Works

Freedom Tower

- Ammonia and Acid carbon combination media

Fertility group cuts Presby ties

- Acid and VOC carbon combination media
- https://www.bizjournals.com/charlotte/stories/2004/02/23/story1.html

Apollo 13 – “Houston….we have problem”

Agenda

- Adsorption Basics
- Market Structure
- Application Triage
- **Q&A**

Thank you!