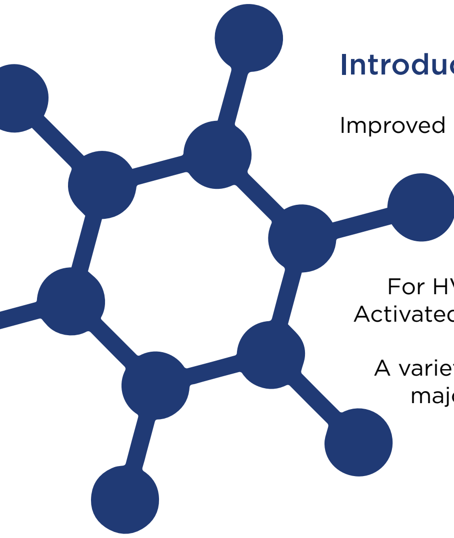
ACTIVATED CARBON IN HVAC SYSTEMS



Introduction

Improved Indoor Air Quality continues to be one of the MAJOR issues facing the HVAC industry.

The Air Movement Industry has been very effective in the areas of human comfort and the removal of particulates. However, to totally "clean" the air, the gases and vapors – the chemical pollution that affects health and productivity – must also be removed.

For HVAC applications, adsorption is the most effective and the most economical process. Activated carbon, known as the universal adsorbent, is the most effective adsorbent.

A variety of products utilizing activated carbon are readily available. When applied properly, the vast majority have proven to be effective in eliminating the chemical pollution found in HVAC systems.

Why Is It Used?

Theoretically, we can remove almost all particulate matter from the air stream. We are now faced with "how should the gases and vapors – the chemical pollution – be removed?"

HEPA filtration is effective down to the 0.3micron range and will remove some particulates smaller than 0.3 microns. Gases and vapors are 0.01 microns and smaller. Benzene and naphthalene, two compounds that are strongly adsorbed by carbon, are approximately 0.0006 and 0.0007 microns respectively. One micron equals 1/25,400 of an inch.

Very simply, particulate filters do not, and cannot, remove material that is this small and is a gas. If particulate means cannot be used to remove gases, then how can they be removed?

For HVAC applications, where the concentrations are very low and the contaminant loading varies constantly, adsorption has proven to be the most effective and the most economical process.

Adsorption with activated carbon is also the process of choice for applications such as gas masks, space capsules, nuclear submarines and radioactive iodine removal (nuclear plants).

Are there other processes to remove gases from an air stream? Certainly, there are other processes. When higher concentrations are present, incineration, chemisorption and solvent recovery [an adsorptive process] all have their places.

ABSORPTION VS. ADSORPTION

A question that is often asked –

"What is the difference between **ABSORPTION** and **ADSORPTION**?"

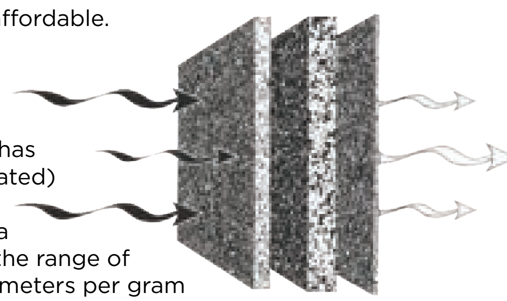
ABSORPTION can be understood if we think of sugar being dissolved in water and mixing evenly throughout, or cream being mixed into coffee. Industrial absorption would be a gas being **ABSORBED** (taken into and mixing evenly) by a "scrubbing" liquid.

In contrast, **ADSORPTION** is the physical attraction and adherence of gas or liquid molecules to the surface of a solid. The attractive force is very small, van der Waal's forces, and exists between any two bodies, such as between the earth and the moon. Gas molecules are **ADSORBED** by activated carbon.

Why is it known as the Universal Adsorbent? Why is activated carbon used as the adsorbent with HVAC Processes?

Activated carbon is truly a unique material. There are no other materials, natural or man-made, that will do all that it will do.

Activated carbon:
1. Has a capacity for virtually any vapor contaminant; it will adsorb "some of almost any vapor".
2. Has a large capacity for organic molecules, especially solvents.
3. Will adsorb and retain a wide variety of chemicals at the same time.
4. Has an extremely large capacity to catalytically destroy ozone, a major component of smog.
5. Works well under a wide range of temperature and humidity conditions.
6. Adsorbs odors and chemicals preferentially to moisture. It is not a desiccant and will release moisture to adsorb chemicals.
7. Can be used as a carrier of one material to attract and hold or react with another material.
8. Is inert and safe to handle and use.
9. Is available and affordable.



What Is It?

It is a material that has been treated (activated) to increase the internal surface area of the structure to the range of 950 to 1150 square meters per gram for gas phase applications. The internal area is the area that holds the adsorbed chemicals, in effect, this is where the "work" is done.

How Much Internal Area Is Available For "Work"?

Using the number 1000 square meters per gram, which equals 1197 square yards, and multiplying 1197 by 454 (454 grams/ lb.), results in 543,438 square yards of available surface area per pound of carbon. Comparing this to a football field, which is 50 by 100 yards, or 5000 square yards, this would be the surface area of more than 100 football fields.

When the 543,438 sq. yards is multiplied by 9 (9 sq. ft/sq. yd.), it equals almost 5 million square feet of available surface area per pound of carbon. Utilizing a maximum working capacity of 33%, up to 1,650,000 square feet would be available for adsorption.

How Much Gas, Or How Many Gas Molecules Can Be Adsorbed And "Held" On This Area?

Consider the gas molecule benzene, which has a molecular weight of 78 and is approximately 6 x 10 –4 microns in diameter. Utilizing one pound (454 grams) of carbon and a maximum capacity of 33%, then 150 grams of a gas, (in this case, benzene) can be adsorbed. Dividing 150 grams by 78 gram moles of benzene yields 1.9 gram moles of benzene that can be adsorbed by one pound of carbon. Multiplying the Avogadro number*, 6.023 x 1023, by 1.9 yields 11.44 x 1023 molecules. Therefore, 1 pound of carbon would have enough internal surface area to adsorb (hold) 11.44 x 1023 molecules the size of benzene.

Activated Carbon

There are many types and grades of carbon that can be used for adsorption. There are carbons used for liquid and gas phase applications; they are not interchangeable.

For the purpose of this presentation, only gas phase carbons that are used for general HVAC applications will be addressed. The commercial quality HVAC carbons that are being manufactured today are typically produced from either coal or coconut shells. These materials are interchangeable, as long as the activity level and the average particle size are the same.

Activated Carbon Specifications For HVAC Applications

The HVAC industry typically uses 60% activity** carbons in a variety of mesh sizes depending upon the manufacturing process and the application. In the filter products, where fibers and granular carbons are blended, 20/50 mesh carbons are applied. Where polyesters are impregnated by a slurry process, fine carbon powders are used. For the filled trays, used in older style Vbanks, either 6/8 mesh (3mm) [pelletized] or 6/12 mesh [granular] are utilized.

Some gases do not have the affinity to adsorb into general activated carbons. In these cases, a blend can be used where general activated carbon is blended with an impregnated alumina pellet. The result is a good mix for multipurpose gas phase filtration for many harsh and diverse gaseous conditions.

***This activity level will ensure that the internal surface area is in the range of 1000 – 1100 square meters/gram.*

WHY USE ACTIVATED CARBON?

The term CHARCOAL is used widely, and the question often asked "What is the difference between activated carbon and activated charcoal?"

There is only one material, and the terms are used interchangeably. Normally, those who are in the carbon business will use the term carbon. Those outside the industry, or just learning, will use the term charcoal. ASTM – The American Society of Testing Materials – utilizes the term carbon.

HOW DOES IT WORK? WHAT DOES IT DO?

Activated carbon ADSORBS a wide variety of gases and vapors – chemical pollutants.

Whether there is one gas molecule and one carbon particle, or many of each, the adsorption process is the same. The physical process begins with a gas molecule coming into contact with the surface of an activated carbon particle and coming to rest in a large surface pore. Then, due to unbalanced forces on and within the carbon particle, the gas molecule will begin to move "down" into the carbon particle – into the smaller pores, where it will finally stop and be held in place. At some point between the surface and the "stopping point", this gas molecule will condense and become a liquid particle.

For those who would like a more technical version: The adsorbate diffuses through the surface film to the macropore structure. Then, due to van der Walls' forces, the gas molecule migrates into the micropore structure, condensing during this movement, and finally stopping when either the forces become balanced or it becomes physically blocked.

This molecule, which was an objectionable gas, will remain a liquid inside the carbon until it receives enough energy, in the form of heat, to excite it.

If this condition arises, the molecule will begin moving toward the surface. If enough energy (heat) is absorbed, it will be vaporized, returned to a gas and be released back into the air stream, i.e. the process will be reversed.

In HVAC applications, there is normally not enough heat to excite, or re-energize, adsorbed molecules. With regular carbon filter or bulk carbon "changeouts", sufficient capacity will always be available.

It is interesting to note, the adsorbed gases that condense and become liquid molecules will "line" the internal surface area – and this "lining" will be one (and only one) molecule thick.

How Is It Applied In HVAC Applications?

The application of carbon to HVAC installations is considerably different when compared to how carbon is applied to solvent recovery systems and other industrial removal applications.

For the latter, air streams with hundreds to thousands of parts per million (ppm) of gas molecules are recovered, or removed, with beds that can be several feet thick and contain thousands of pounds of carbon.

For HVAC applications, thin bed filters with comparatively small amounts of carbon are utilized. Therefore, it is not only important that these differences be recognized, but that the parameters be defined.

First, air in a structure can be treated as it: enters; leaves; is re-circulated; or as a combination thereof.

For the majority of HVAC applications, the air to be treated is a combination of air entering (make-up) and air that is recirculating.

The gaseous contaminant loading that should be removed:

1. Is always a combination of many odors and pollutants – chemicals.
2. Is normally unknown either as to the chemical make-up, the amount of each pollutant, or the total loading.
3. Varies constantly with changes in occupancy levels, activity within or without the structure, and shifts in the wind.
4. Is in the 1 ppm range.

Loading Variations

In four above, the "1 ppm range" has been used. When the loading increases, which it can do for short periods, there are concerns and questions. Knowing that the industry has utilized, and continues to utilize, thin bed carbon filters the following situations must be considered:

How high are these higher loadings (peaks), and how long do they last?

Answer: Unless the structure has been studied over a period of time, there is no definite answer. 10 to 20 ppm would be a heavy overload and may be within reason for this application. This condition may last for minutes to hours as opposed to days.

During the peaks, how effective is the filtration system?

Answer: The percentage of these peaks, which exceeds the design capability of the filter or the capacity of the carbon at that time, will pass through and into the inside air. Since the air is being re-circulated, these peaks will be adsorbed on future passes until the filter is at capacity.

As stated earlier, carbon must be changed on a regular basis. This regularity, which should be established during the first year of operation by utilizing test samples, will ensure that these peaks, typical to that installation, will be quickly adsorbed.

How Much Carbon Should Be Used?

The old ASHRAE specification of 45 pounds per 1000 cfm per year has been used for many years as the design guideline. In all probability, the vast majority, if not all, of the "older" carbon V-banks that are being utilized in airports, sports stadiums, and commercial buildings were designed with these numbers.

When this amount of carbon is changed regularly, these filters perform effectively. Is this the optimum amount of carbon? 'From experience with many installations, the answer would certainly be "This has proven to be enough carbon."

A remaining question is "Would somewhat less carbon be as effective; and if so, how much less?" The "older" V-banks were designed to be changed out in approximately one [1] year.

This time would be adjusted, based on the specifics of the application. Obviously, utilizing less carbon per filter, but changing more frequently, would produce similar results. For the newer "clean room" type applications, which may call for the removal contaminants in the ppb or less range, filters with significantly less carbon are being used successfully.

Commercial vs. Industrial Application

The carbon adsorption products that have been designed and utilized for HVAC applications are very effective. When they are misapplied in industrial applications, problems can and do arise.

Normally, it is not that the carbon does not adsorb, but rather the concentration exceeds the capability of thin bed products, and neither the pass efficiency nor the life (capacity) are satisfactory.

Industrial applications, although they will contain many of the same chemicals found in HVAC applications, can be defined as having:

1. Primarily one contaminant (chemical).
2. A chemical that is known, both to it's formulation and quantity (ppm).
3. Either a constant quantity or a constant range.
4. A loading well above the 1 ppm range.

Very simply, this will be, by comparison, a heavy-duty application, and the information concerning the contamination will be known.

Below is one example that helps explain the differences between these applications:

A printing company with a large printing press may have a solvent recovery system to recover the solvents from the inks. This system will remove the high concentrations of solvent with large amounts of carbon. However, the solvent "leakage" that escapes into the general air and into the air handling system will be heavily diluted and be just one of the many other chemicals in the HVAC system. This air, that re-circulates thru the offices, lunchrooms, laboratories, etc., would now be treated as an HVAC application, with thin bed filter products.

Non-Vented Areas

Activated carbon will adsorb without the air being drawn thru it, i.e. without a fan or blower. This is of importance when there are rooms or closed areas that do not have ventilation ducts, electricity and/or where the use of a portable air cleaner would not be practical. Carbon pads can be placed in these areas and be a very effective solution.

How Does Carbon Work in Non-Vented Areas?

Gas molecules will disperse (mix) themselves evenly throughout a given area, in accord with the "Perfect Gas Laws". Activated carbon will attract and adsorb the odor or pollutant molecules to which it is closest, causing an unequal mixture to result. Whereupon the gases will redistribute themselves, the carbon will again adsorb the closest, and the process will continue until the air is "cleaned" or the carbon reaches its capacity.

A relatively small amount of carbon can, and will, keep these types of areas odor and pollutant free.

An example of utilizing a small amount of carbon is to maintain a refrigerator odor free. By adsorbing gases, it thereby eliminates the transfer of odors and tastes from one food to another, and to ice cubes.

HVAC Applications For Activated Carbon

As stated earlier, activated carbon, the universal adsorbent, will adsorb "some of almost any vapor". Detailed lists of gases and vapors – chemical compounds – are available from carbon and equipment manufacturers. The following is a partial list of gases that are of concern in the air purifcation systems and can be removed with carbon:

- **ORGANIC COMPOUNDS:** Acids, Alcohols, Aldehydes
- **CHLORINATED HYDROCARBONS:** Esters, Ethers, Ketones, Mercaptans, Amines
- **INORGANIC COMPOUNDS:** Halogen Acids, Halogens, Sulphuric Acid, Sulphur Dioxide, Phosgene
- **MISCELLANEOUS ODORS FROM:** Humans, Animals, Foods, Cooking, and Waste Processes

Where Are The HVAC Applications?

Odor and gaseous pollution occur in:

- airports, libraries, hospitals, research facilities, office buildings, computer rooms.
- clean rooms, electrical rooms, microelectronic applications.
- retail stores, print shops, stadiums, auditoriums, municipal buildings, restaurants.
- homes, pet hospitals, pet groomers, medical laboratories, nursing homes and health care facilities.

CONCLUSIONS

The removal of chemical contaminants, which affect the health and productivity of many Americans at work and at play, must and will continue to be addressed by the Air Movement Industry. Due to the comparatively low contamination levels found in HVAC applications, adsorption has, and will continue to be, the most economical process. Activated carbon, the universal adsorbent, has a capacity for virtually all vapor contaminants and will adsorb and retain a wide variety of chemicals at the same time. Adsorption products utilizing activated carbon are available from a variety of sources. These products, when properly applied and maintained, can eliminate the vast majority of pollution problems caused by the gases and vapors – the chemical pollution – found in HVAC systems.

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