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Activated Carbon Beds in Amine Units

Activated carbon is a key component in Amine Units as they removal dissolved contaminants that generally induce amine solution foaming. Activated carbon can be manufactured from any carbonaceous materials such as: coal, wood, coconut shells, and others. The most prevalent (and correctly used) activated carbon in amine units is granular in format. Activated carbon can be manufactured in various grades of coal, sized and formats (i.e. powder, granular and extruded pellets).

Characterization of activated carbon pore structure is attributed to 3 parameters: Iodine number, methylene blue number, and molasses number. Iodine is a common standard adsorbent and is used as a general measurement of the carbon capacity as is a standard molasses solution. Since iodine has a smaller molecular size, the iodine number more accurately defines the small pore volume of a carbon and reflects the ability of the carbon to absorb low molecular weight, small substances. A high iodine number indicates a larger surface area available for adsorption. The methylene blue number and molasses number defines the medium and large pore diameter respectively, and is used as a relative guideline for measuring the capacity of a carbon for larger molecules.

The abrasion resistance of the activated carbon is measured by the abrasion number, which indicates the carbon's ability to withstand degradation during handling. The higher the abrasion numbers the more resistant the carbon is to abrasion. The volume activity is a product of the iodine number and the bulk density and is a measure of the total surface area. An activated carbon with a high iodine number and high abrasion number is desirable for most amine plant applications.

Bituminous coal activated carbon has a broad range of pore diameters and makes an excellent choice for amine applications. However, in amine systems that experience severe emulsion problems due to significant hydrocarbon contamination, a large pore volume, lignite activated carbon that has a high molasses number should be considered. Activated carbon which has been washed with phosphoric acid during manufacturing to reduce the ash content should not be used because residual amounts of phosphorus components can cause amine foaming.

A properly designed activated carbon system can reduce the need for antifoam, reduce amine make up, reduce corrosion and improve scrubbing efficiencies and product quality. The carbon system should treat at least 25% of the circulating lean amine solution. A minimum contact time of 15 minutes and a superficial velocity of 2 to 4 gpm/ft^2 are considered appropriate.

When the amine solution changes color (or clarity), or the solution foaming tendency increases, the carbon is spent and should be changed. Carbon beds should not be changed on pressure drop, as this is not an accurate representation of the activity of the carbon. While activated carbon beds may plug off with solids (especially if there are no pre-filters) raising the pressure drop, it is possible to completely saturate an activated carbon bed with hydrocarbons and not see even a 1 psi pressure drop increase across the carbon bed. Typical maximum carbon life is 6 to 9 months (if the system is correctly designed, operated and employs the correct activated carbon).

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The purpose of activated carbon adsorption is to remove organic, foam-promoting species from a circulating amine solution. These organics, generally hydrocarbons, are effectively and readily adsorbed by activated carbon as long as the available pore structure is not filled to capacity with organic components. Generally, activated carbon removes 20-40% of its weight in organic species, but depending on the type of contaminant and operating conditions (temperature, cross-sectional velocity, etc) these equilibrium values might not be reached.

Activated carbon beds are best employed on the lean stream after the lean amine coolers to take advantage of the increased capacity at cooler bed temperatures. NOTE: Activated carbon beds are not filters. They are intended to removal soluble components only by adsorption. Hence, no suspended matter or emulsified hydrocarbons should ever be introduced to activated carbon bed. The presence of these contaminants will rapidly saturate the carbon bed and most of the time causes a complete failure of the system.

If the plant has proper inlet separation, the most proper activated carbon grade to be used is an 8 x 30 mesh granular activated carbon. It is produced by steam activation of bituminous coal. It is specifically manufactured for the purification of amines and glycols and is intended to remove contaminants that contribute to foaming. This particular activated carbon has the best balance of pore sizes capable of adsorbing a wide range of molecular sizes. However, if the plant has deficient inlet separation, the most beneficial activated carbon to be used is 4 x 10 lignite in origin and granular in configuration. This type of activated carbon has larger pores, allowing for a better and more effective adsorption of larger hydrocarbon molecules. Activated carbon for liquid streams is usually granular as opposed powdered.

Activated carbon beds are also very unique in their use and application. There are a number of activated carbon materials. These can be manufactured from a variety of sources such as walnut shells, bitumen, coconut shells, peat and many others. The origin of activated carbons generally sets its adsorptive power as well as the type and size of molecules it will preferentially separate. They are activated differently in order to enhance their surface area and eliminate impurities from the surface pores. Some activated carbons also have additives to enhance their mechanical resistance to the fluid, flow and process conditions.

Because activated carbon beds, in general, release carbon fines (small carbon particles) from the fracture of activated carbon bed granules in liquid streams, it is necessary to separate these solids before they reach the contactor (or absorber) tower causing foaming, fouling, low sweetening efficiency, and amine losses. More often than not, these particles are found in the rich amine stream, downstream of the rich amine flash tank reaching the regeneration stage.

Activated carbon beds are key to separating dissolved components such as some heat stable salts and their precursors, amine degradation products and also dissolved hydrocarbons.

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Questions & Answers

What are important properties of activated carbon?

Since adsorption is a rate based process, both available surface area and residence time are important. A carbon with a high volume activity has more active surface area per m3 of bed volume, so that is an important parameter. High molasses and iodine numbers are also important because they signify capacity for many types and molecular weights of hydrocarbons. Low ash content is important because ash signifies contaminants. And finally, low or negligible phosphate levels are important as these are leachable into the amine solution and will present detergent-like properties to the amine solution.

What is organic adsorption?

Adsorption is when organic molecules bond to the internal pores of the activated carbon. This occurs in pores slightly larger than the molecules that are being adsorbed, which is why it is very important to match the molecule you are trying to adsorb with the pore size of the activated carbon. They are then trapped within the carbon's internal pore structure by electrostatic attraction or chemical bonding and accumulate into a solid surface.

How much void space is in carbon?

A container of carbon is roughly 20% carbon, 40% interstitial space (the volume between the carbon granules), and 40% pore volume (the volume inside the carbon granules). Another way to visualize this is: If you had a 208 liter drum full of dry carbon, you could add 166 liters of water to the drum before it would overflow. Therefore, 80% of the drum volume is air.

In liquid applications, why is it important to de-aerate (fully wet) the carbon?

Roughly, 80% of a container of carbon is air; if we do not displace the air in the pore space, fluid being treated cannot access adsorption sites. Air acts as a barrier to the carbon functioning properly.

How long does it take to fully wet the carbon?

Typically, we recommend filling the system with amine and allowing the system to sit idle for 24 hours. This time will allow the fluid to displace all of the air in the pores of the carbon. After the system has been idle for 24 hours, the next step is to use an upwards flow backwash to displace any air that has been trapped in the carbon bed. This backwash will also remove most of the carbon fines in the system.

What is the pore space?

Pore space is the internal volume of the carbon granule. It consists of all the cracks and crevices created when the coal is crushed and glued back together, and the volume between the graphite plates. The distance between graphite plates determines if the pore is an adsorption pore or a transport pore.

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What is an adsorption pore?

Adsorption pores are the internal volume where the graphitic plates are very close together creating a higher energy. Higher energy is important to adsorption because it is the energy that "holds" the contaminant (the carbon "adsorbs" the contaminant). The volume where the graphite plates are far apart and the cracks and crevices make up the transport pores. It is important to note that all adsorption takes place in the adsorption pores and not the transport pores.

What do you mean - an adsorption pore is a higher-energy area?

There is a natural attractive force between all things in the universe. Gravity is one of these forces. In adsorption theory, the force between the contaminant and the carbon is the adsorptive force. It technically is a "Van der Waals" force. It is this attractive force that enables adsorption to occur. The forces are a function of the distance between the two objects. The closer together the objects are, the higher the attractive force is. The higher the attractive force, the higher the "energy" level of the pore space.

What is a transport pore?

Transport pores are the internal volume of the carbon granule where the graphitic plates are far apart or the cracks and crevices of the particle. The transport pores act as the "highways" for the contaminants to reach the adsorption pores where they are adsorbed. It is important to note that no adsorption takes place in the transport pores. Transport pores are important as they allow access to the adsorption pores, especially those deeper within the carbon granule.

How does the carbon remove the contaminant?

Once the contaminant enters the carbon granule via the transport pore space, it diffuses into the carbon matrix until it enters the smaller pores where the adsorptive forces begin to take effect. Once it reaches a higher-energy area it can no longer migrate (or diffuse) because the adsorptive force is stronger than the diffusional force. The contaminant is adsorbed to the carbon surface by the adsorptive forces (the Van der Waals forces). In this state, the contaminant is referred to as the adsorbate.

How much adsorbate can the carbon adsorb?

The amount that the carbon can adsorb is dependent upon the type and concentration of the adsorbate. Generally, the higher the concentration and the larger the molecule, the greater the amount adsorbed. The typical range experienced is about 15 to 35 weight percent. That is, one hundred kilos of carbon will adsorb 15 to 35 kilos of contaminant. When the maximum amount of adsorbate is on the carbon, the carbon is referred to as being spent or exhausted.

What happens when the carbon is spent?

The concentration of the adsorbate in the outlet from the carbon column increases as the carbon becomes loaded with adsorbate. The adsorbate concentration increases until the outlet concentration is equal to the inlet concentration because the adsorption pores are filled with contaminant.

For more information, please contact **Amine Filtration** at Help@AmineFiltration.com