Introduction

Dry gas scrubbers are process equipment which utilize solid adsorbents to remove harmful gaseous contaminants from air, including: hydrogen sulfide, amines, mercaptans, and acid gases. Applying the principle of adsorption, the adsorbents remove contaminants both ways either through physisorption (van der waal forces) or chemisorption (chemical reaction). Adsorption is usually carried out in an up flow packed bed vessel with the granular adsorbent meshed according to the application to produce as little resistance to flow as possible to reduce pressure drop.

Gas phase adsorbents can be classified into three types:

1. Nonpolar adsorbents for removal of organics, non-polar compounds. Example: Activated Carbon

2. Polar adsorbents for removal of water vapors. Example: Silica Gel

3. Chemically impregnated adsorbents for removal of compounds either by reacting with the contaminant or by acting as a catalyst. Example: Iodine impregnated carbon for mercury elimination.

For the purpose of this article, we will only be discussing Activated Carbon-based scrubbers in detail.

Operating Parameters

Since, gas phase scrubbing is a dynamic process, there are many process variables to be considered for the successful operation of scrubbers. Most common operating parameters are listed below:

1) Grain size of carbon to determine the resistance to flow and the total pressure drop across the cross-sectional bed.
2) Total depth of carbon bed. Deeper bed means longer contact time of contaminant with carbon surface for near complete removal from gas streams.
3) Gas stream velocity. Faster velocities will result in shorter empty bed contact times and higher pressure drops.
4) Temperature of the gas mixture. Higher temperature will leave to desorption and the contaminant will revive in the gas stream. Various literatures recommend operating temperature for the adsorber/ scrubber should be kept below 130 F (54.4 C).
5) Pressure of the influent gases. Increasing pressure will result in better adsorption as more gas molecules are immobilised onto the carbon surface.
6) Concentration of target contaminant. Higher concentration will result in faster saturation of the adsorbent bed.
7) Concentration of competing contaminants in the gas mixture. If other contaminants in the mixture have higher molecular weight than the target molecule then, the heavier adsorbates will settle on the carbon surface.
8) Vapor pressure of the adsorbate. Carbon best adsorbs compounds with lower vapor pressure.
9) Moisture/ relative humidity content of the gas stream. Higher moisture content results in reduced adsorption capacity of carbon as the condensing water vapors block the pores where the adsorbates reside. It is recommended that relative humidity during operation is below 50%. If possible.
10) Adsorption capacity of the carbon used. Depending on the application carbon can be of different types including regular activated, catalytic and chemical impregnated with chemicals

(like Potassium Iodide). Each type of carbon will have its own loading capacity of absorbing contaminants.

Scrubber Design

To efficiently engineer a gas adsorbing system using activated carbon, the first and foremost step is to collect the following data:

- Air analysis of the gas stream to determine the concentration of the target vapor coupled with concentration of other gases in the mixture.
- Process conditions including temperature, pressure, relative humidity, CFM (cubic feet per min) volumetric flow rate and air flow velocity through the adsorber bed.

If the application is for indoor air quality or ventilation, volume of the room (or space) and air changes per hour are additional data that will be required. A rule of thumb states that the air flow velocity should be between 50 to 75 feet per minute for carbon bed and should not exceed 90 feet per minute.

Some common design equations used for scrubber design are listed below.

• Empty Bed Contact Time, $EBCT = Volume\ of\ Carbon\ Bed\ (cubic\ feet) \div Flow\ rate\ (in\ CFM)$

• Weight of Carbon required, $W_c = T * Eff * Q * M * VC \div S * 6.43 * 10 \wedge 6$

Where, T is Time of operation before saturation

Eff is adsorption efficiency of the carbon

Q is velocity of air

M is molecular weight of vapor

VC is vapor concentration in ppmV

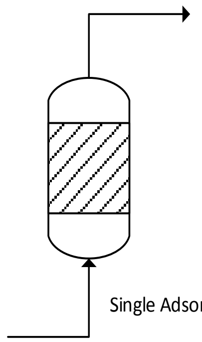
S is saturation percentage of carbon

• Volume of carbon required, $V_{bed} = Wc \div D$ (D is bulk density of carbon)

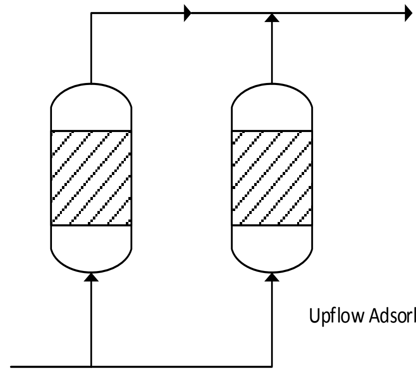
• For HVAC, volumetric flow in CFM$= Volume\ of\ Room * Air\ changes\ per\ hour$

Equipment Configuration

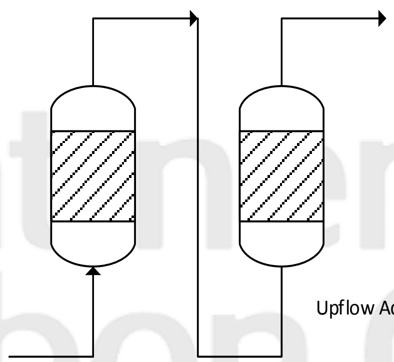
Three most common configurations and their characteristics are listed below:



Single Adsorber



Upflow Adsorbers Parallel



Upflow Adsorbers in Series

Configuration	Characteristics
Single	•Low volumetric flow rate •Carbon bed saturation is very fast after breakthrough
Parallel	•High volumetric flow rate •Effluent streams can be blended •Operation like two single bed absorbers
Series	•High volumetric flow rate •Effluent stream will be virtually free of contaminant •Inlet concentration for second adsorber can vary depending on the saturation rate of first adsorber

Advantages of Dry Carbon Scrubbers Over Wet Scrubbers

Wet Scrubbers have certain characteristics and general rules of thumb:

1. There should be 1 GPM of recirculation water per 100 cfm of air flow.

2. The sump capacity in gallons is normally 3 times the amount of the recirculation rate.

3. The standard velocity through the packed section of the scrubber should be 500 fpm with a preferred minimum of 350 fpm.

If the water flow exceeds the recommended rate, there is a potential for flooding the media and reducing the contaminant removal efficiency. If the water flow is lowered, you will have insufficient contact with the airstream and reduced odor removal efficiency. If the air velocity is reduced by more than 30-35% there will be insufficient dispersion of the scrubbing solution to cover the entire packing surface. This will create dry areas with less resistance in the bed and allow short circuiting of the influent air. If the velocity is too fast then there will be channeling in the scrubber and again, poor contact with the air stream.

Wet scrubbers also require a lot of maintenance and attention during their operation, the most common parameters to be monitored include:

- Continuous chemical addition for pH adjustment.
- ORP probe needed for monitoring oxidant strength.
- pH probe needed for measurements for acid addition.
- Soft water needed to prevent carbonate deposits on nozzles and packing. Also, water hardness should not exceed 5 grains per gallon (5 gpg= 85.5 ppm)
- Monitoring of chemical and recirculation pumps.
- Handling of dangerous chemicals (sodium hydroxide, sodium hypochlorite, etc.).
- Continuous water drainage is required for “blow down” purposes.
- Automatic chemical monitor and control units are required.
- Odor removal efficiency is lower than dry media scrubbers. On the average, wet scrubbers have a 90 to 92% removal efficiency compared to 99% + for dry carbon scrubbers.
- Chemical control systems require regular monitoring to insure proper operation and regular maintenance.

Compared to Wet scrubbers Dry Carbon Scrubber require very little maintenance, these include:

• No pumps, chemicals or monitoring equipment needed.

• Activated carbon has a massive internal surface area (1 pound = six million square feet of surface area).

• Usually removes 99.5 to 100% of contaminates.

• System can be left to run unattended for weeks and months.

• Carbon bed service life can easily be determined with simple tests.

• Media pressure drop typically varies from 4” to 6” depending on bed depth and carbon type.

• Blower must be properly sized for flow and static pressure requirements.

• Pre-filtration is easily done, and outlet misting is not an issue.

• Carbon media is easily replaced (usually on a one-year basis) which is usually the only required maintenance other than changing a particulate or grease/mist filter if necessary.

• Removes a vast assortment of contaminants with a single carbon vessel.