7.10 Toxic Gas Treatment

Toxic gas emissions come in diverse forms depending on the source of this emission. When selecting the collection method for polluted gas and the treatment methods, it is necessary to take into consideration the properties of the raw gas, at the same time taking into account the facility site, surrounding environment, and economical efficiency. ①The thermal combustion method, ②catalytic method, ③condensation method, ④adsorption method, and ⑤absorption method are just some of the processes found when categorizing the treatment methods available. ①Combustion, ②catalytic, and ③condensation methods are described in Chapter 7.12 under hydrocarbon control. In this chapter we will focus on the ④adsorption and ⑤absorption methods.

7.10.1 Adsorption Method

The adsorption method utilizes a porous substance with a large internal surface area, has a special affinity for the adsorbed gas, and is selective. Consequently, it is necessary to make selections based on the components of the gas to be treated.

Exhaust gas treatment using the adsorption method makes it possible to obtain a solid removal efficiency with a relatively basic equipment. It is necessary to take into consideration such factors as the treatment of used adsorbents, the recycling of the adsorbed components or their disposal. In general, in the treatment of low concentrate gases, most methods perform an exchange with a new adsorbent which does not utilize the desorption process. In cases where high concentrate gases are treated, the desorption process is incorporated and the recycle of desorbed components and regeneration of the adsorbent are performed. Also, the adsorption device is employed as an gas concentration device in conjunction with other equipment such as a combustion device, for use in treatment methods.

(1) Adsorbent

Fig.7.10.1[1] illustrates the types of adsorbents and their main uses. Adsorbents are divided up into two different categories, physical adsorbents and chemical adsorbents. Physical adsorbents consist of such items as activated carbon and zeorite. The most commonly used adsorbent is the activated carbon. Adsorbents come in different forms, granular, fibrous, spherical, and honeycomb shaped. On the other hand, chemical adsorbents include impregnated carbon which retains acids, alkali, oxidizing agents, and catalytic substances on the surface of the activated carbon. For example, as a treatment for base substances such as ammonia and amine, sulfonated carbon, chemically treated coal, is used. And for the treatment of acidic substances, sulfonated soda carbon is used. In addition, for the treatment of sulfur compounds, there are chemical adsorbents which use iron ions as a base agent or which apply the use of ion-exchange resins.

Table 7.10.1 Types of Adsorbents and their Usage

	Type of Adsorbent		Main Use
Physical Adsorbent	Activated carbon		Recovery of deodorant hydrocarbon related solvents, desulfurization, denitrification, recovery of chlorofuluorocsrbon, recovery of halogenated hydrocarbons, adsorption of styrene
	Zeolite (hydrophilic)		Adsorbs ammonia, demoisturize air, deodorize night soil treatment facility , oxygen in air, substrate for biological deodorizing method, adsorbent for methyl sulfide and methyl disulfide
	High silicazeolite (hydrophobic)		Adsorption of alcohol, aromatics, and paraffinfrom squeous solution
	Molecular sieving carbon		Oxygen in air
	Silica gel		Demoisturization, deodorization of air
	Alumina		Demoisturization, deodorization of air
	Activated clay		Refine solution, decoloring deodorization of fats
Chemical adsorbent	Additive/adsorbent agents	Basic gas	Adsorption of ammonia, trimethylamine
		Acid gas	Adsorption of hydrogen sulfide, methyl mercaptan
		Metal impregnated carbon	Adsorption of carbon monoxide, hydrogen cyanide, carbonyl chloride
		W/oxidizing agent impregnated carbon	Decomposition/adsorption of nitrogen monoxide, hydrogen sulfides, amine, aldehyde, acrolein
	Ion-exchange resin		Adsorption of ammonia, trimethylamine, hydrogen sulfide, methyl mercaptan
	Iron oxide deodorant		Adsorption of hydrogen sulfide, acetic acid

(2) Adsorption equipment (Adsorber)

The methods available methods for contact between the adsorbent agent and treated gas in the adsorber are the moving bed, fixed bed (packed) and rotary honeycomb method. In most cases the fixed bed method is used due to its easy equipment structure and operation management.

The fixed bed adsorber is illustrated in Fig.7.10.1. There are two types of packing methods into fixed bed, one where the fixed bed is immediately filled with adsorbent and another where it is exchanged using a removable cartridge.

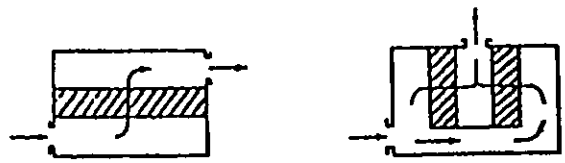

Fig.7.10.1 Fixed Bed Adsorber [1]

For granular activated carbon, the adsorbent is used in a 30-80cm depth single bed or multi-layer bed. If the packed bed is too thin, then the concentration distribution within the inner layer will become disproportionate and if it is too thick then pressure loss will increase. For granular activated carbon, the basic current velocity of the raw gas is about 30 cm/s~60 cm/s. For continuous fixed bed systems, it is necessary to have at least 2 towers in order to perform adsorption and desorption alternately. This is in order to perform adsorption in one tower while doing desorption in the other. When repeatedly performing this cycle, desorption is completed prior to saturation of the adsorbent by the adsorption substance, and cooling must be done to the adsorption temperature.

The moving bed adsorption method, shifts the adsorbent during treatment, transferring the adsorbent to the recycling process, resulting in consecutive operation. It is a suitable method for the treatment of large volumes of gas. The drawbacks of the moving bed which utilizes granular activated carbon, is that activated carbon is easily worn away and the device becomes easily clogged due to dust. One type of moving bed type is the concentration equipment, which uses granular bead-shaped carbon and is shown in the Fig.7.10.2. In this method, the globular (about 0.7 mm in diameter) activated carbon is slid down a sloped porous board where it moves down successively to the lower level. The raw gas is introduced into the system from the bottom of the tower where it is absorbed. The used adsorbent is continuously sent back to the desorption tower for reuse and the treated gas components are separated and concentrated. Then they are transferred to another treatment device, such as an incinerator, for final treatment.

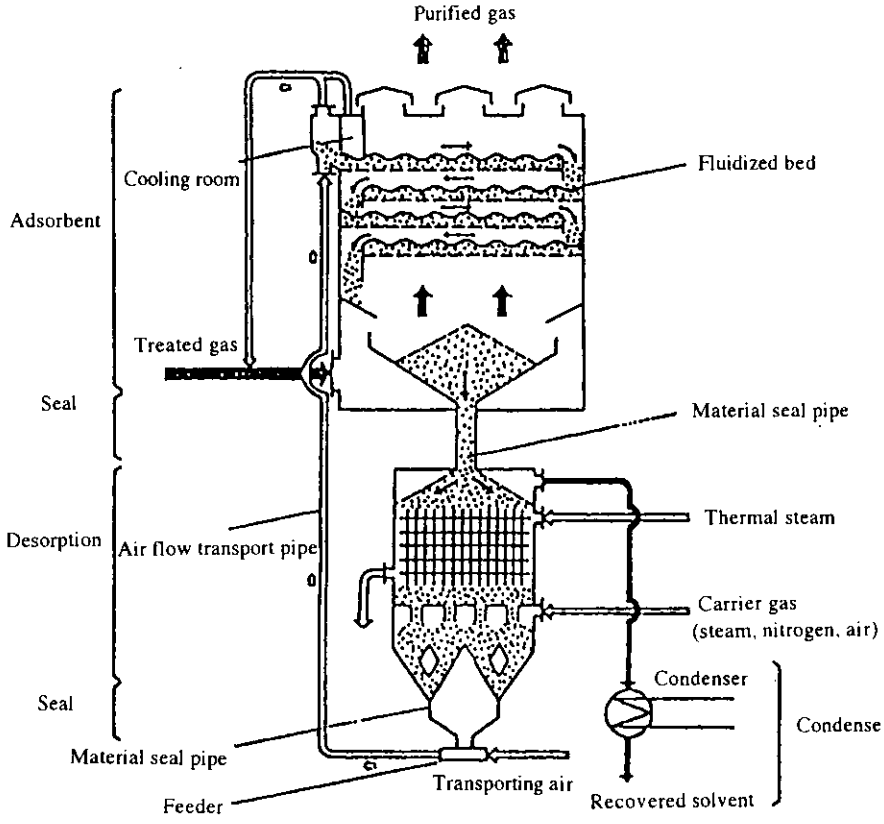

Fig.7.10.2 Continuous adsorption/desorption device using bead-shaped carbon [2)]

The rotary honeycomb adsorber is illustrated in Fig.7.10.3. Activated carbon in the shape of a honeycomb is formed into a cylinder shaped device. The cylinder shaped device is rotated. Adsorption and heated desorption are continually performed and is used for concentration of the treated gas. When the components of the raw gas are combustible, the volume of the gas is reduced and the concentration of the elements are increased. It is then possible to effectively treat these components using a combination of a combustion system and catalytic oxidation system.

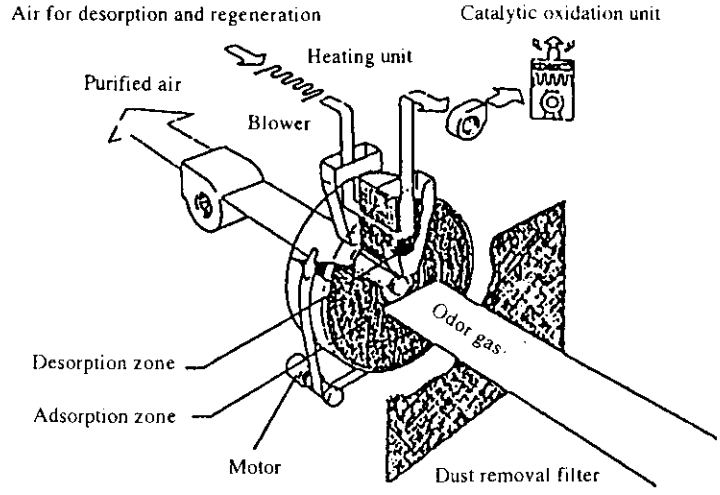

Fig.7.10.3 Rotary honeycomb type continuous condensation equipment [2]

(3) Regeneration of adsorbents

Under the desorption method, there exists the thermal swing method using heat and the pressure swing method by reduced pressure. In particular the heated desorption methods, on of thermal swing methods, is widely used. As a heating medium, heated water vapor, heated air, and heated nitrogen gas are used. There are methods performing desorption by carrying out heating and depressurizing at the same time as well. Fire and explosion must be considered when utilizing combustible organic solvents. Especially, in the recovery of ketones such as methylethyl ketone and cyclohexanone, there are instances of fire occurring due to a rise in temperature resulting from the oxidation or thermal storage in ketone. In particular, adequate desorption is necessary when the device stops operating.

In general, in the regeneration of adsorbents, a fair amount of time is required for complete desorption, therefore 100% desorption is not performed. In actuality, from the technical and economical standpoints, a suitable rate of desorption is performed for reusing the absorbents.

(4) Pre-treatment of Exhaust Gas

In the event that the treated gas is of high temperature and contains a large amount of dust or mist, it is not suitable for adsorption. It is also the reason for loss of adsorbents. Also, when the treated gas has a high concentration, in order to extend operations over a long period of time, it is necessary to attach appropriate facilities for pre-treatment. The water absorption method is commonly used as a pre-treatment method. Ample care must be taken that spray from the cleaning fluid is not carried into the adsorption bed in order to keep the activated carbon from becoming wet. The lower the temperature the more effective removal is. In general, it is essential to keep the temperature of the treated gas below 40℃.

7.10.2 Absorption Method

(1) Neutralization Absorption Method and Oxidation Absorption Method

The purification-absorption method is most frequently used as a removal method for toxic gas. When largely categorizing the absorption treatment methods, one method calls for absorption by water, while other methods are forms of chemical absorption which utilize absorbents to cause chemical reaction with polluted gas. The latter is divided into two methods, one which neutralizes the toxic components in the gas and one which separates the toxic components from the non-toxic components through oxidation. Water absorption method must be applied for the dissolvable substance in water. Neutralization method includes the removal of basic gas such as ammonia, trimethylamine by acid washing, and other type of removal which removes acid gas such fluorine, hydrogen fluoride, chlorine, hydrogen chloride, mercaptan, and hydrogen sulfide by alkaline washing. In the oxidation absorption method, aqueous solutions such as hypochlorous acid soda, potassium permanganate, and hydrogen peroxide are used as absorbents. In particular, this is used in the decomposition treatment of odor gases.

In situations where dust coexists, it is effective in removing dust at the same time absorbing gas substances. The solubility of organic compound toxic gases in water is in general low. It is difficult to achieve the necessary amount of removal results by just using the adsorbent method. In most cases it is used in conjunction with other treatment methods.

(2) Absorption Equipments (Absorber)

Among absorption equipments, there are those types which disperse the absorbent into the gas and those which disperse the treated gas into the liquid absorbent. For those gases which are highly soluble in absorbent solutions, the device which disperses the absorbent liquid into the gas is a suitable system. For those gases which a less soluble in the absorbent, the treatment method where the gas is dispersed into the absorbent is appropriate. In general, highly soluble agents for should be removed substances are used as the absorbent. Therefore, in most cases a packed tower or spray tower which disperses the absorbent solution is used. In the treatment of large volumes of gas, porous plate-type tower (Moretana-tower) and cross flow contact equipment are used.

(3) Mist Removal

In general, the absorption washing method results in secondary pollution as the absorbent turns to mist and scatters into the atmosphere. Therefore it is necessary to install a mist removal device. In most cases mist removal is performed by putting packing into the upper portion of the absorption tower. However, this method has a low effect in the removal of mist. In particular, when gas temperatures are high and include condensed gas, after the mist leaves the absorption tower, the substance becomes condensed within the piping and is littered. For this reason, it is best to install the mist removal device as near as possible to the exhaust outlet.