for effective cleaning of the air stream. Water is frequently used as the absorbent, though, in some cases, other chemical solutions are necessary to increase collection efficiency. In all absorption processes, the waste liquid may have to be treated to prevent a secondary pollution problem. When wastes have product value, the absorbent-gas solution is processed, and the absorbent is reused.

A *packed tower* (Fig. 5) is another means of contacting objectionable gas and absorbent. Ceramic rings, pebbles, tile, wood, and glass fiber pads are used for packing. When the contaminated air stream contains particulate matter, the tower has a tendency to plug up and must be cleaned periodically to maintain low pressure loss.

A *venturi scrubber* (Fig. 6), used for absorbing objectionable gases contacts gas and absorbent in the throat of a venturi nozzle. The gas-liquid mixture enters the entrainment separator tangentially, and centrifugal force separates liquid from the contaminated air. This same type of collector is also used to collect particulates.

A variety of packing materials are used in order to increase the area of contact. These are Raschig rings, Berl saddles, eggcrate patterns, expanded metals, honeycomb, and many other types. The equipment most extensively used for mass transfer operations in the air-conditioning industry for odor removal, humidification, and dehumidification are the spray air washer and the packed scrubber, because they may be designed to allow the flow of air at high velocity with little frictional resistance.

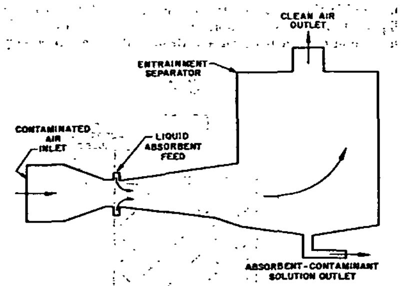

Fig. 6 . . . . Venturi Scrubber

Once the gas contacts the absorbing liquid, the diffusion of the gas in the liquid becomes important. Where a gas is highly soluble in a liquid, its diffusion into the bulk of the liquid from the surface is relatively easy. For such applications, spray-type washers are used. If water is the absorbent, it is generally discarded to prevent it from becoming concentrated with odors and returning the odors to the air stream.

More expensive absorbent liquids may be regenerated and purified. The mechanism of a regenerator is opposite that of the absorber. In the absorber, the concentration of odor solute must be small, and its partial pressure must be less than the partial pressure of the odor in the air. In the regenerator, the absorbent may be heated, which raises the partial pressure of the odorant in solution. The odorant is removed from the solution to the stripping air, provided that the partial pressure of the odorant in this air is lower than that in equilibrium with the solution.

Odor removal efficiency of an air washer depends on the extent of contact of air with the liquid and on the concentration of odorant in the liquid. Thus, for all practical purposes, deodorization by physical absorption is never a process that operates at 100 percent efficiency. By the use of extended surfaces and freshly generated absorbent, efficiencies approach 100 percent.

Neutralization, Masking, and Counteraction

Odors can be chemically destroyed, neutralized, or counteracted and masked. Antiseptic and disinfectant deodorizers are used to kill odor-producing bacteria. The disinfectant may in itself be odorless or have a masking or neutralizing odor.

Where the composition of the objectionable odor can be ascertained, it may be possible to compound another odor that will cancel or counteract the objectionable odor. The result may be an odorless atmosphere, or one having a more desirable or less objectionable odor than the basic objectionable odor or the applied neutralizer. Obviously the selection of the antagonistic odor as well as the applicable amount requires considerable skill and is a matter for the specialist. The use of an odor counteractant results in a lower odor intensity and removal of the malodor as sensed by the nose.

Odors can be masked by other more desirable odors applied in the proper concentrations. A change in odor quality and increased intensity occurs with this process. This has been the work of the perfumer from ancient times. Chemical destruction of odors, neutralization, and odor modification have come into extensive use. Agents are available for deodorizing source materials such as rubber and plastics,[26] and industrial exhausts such as sulfur odors from a cement kiln,[27] or to remove odor from the enclosed air space or atmosphere that may be contaminated by cooking or tobacco smoke.[28] Some deodorants are standard items, while others are compounded for the special application. In some cases, the use of a deodorant results in the chemical destruction, neutralization, or masking of the odor, or a combination of them. The principles of odor masking are listed in Reference 6 as follows:

1. Odor masking is the process of cancelling one odor by superimposing another odor to create a more overpowering sensation, preferably pleasant.
2. The masking agent does not alter the composition of pre-existing odors, but simply covers such odors during the period of its addition to, and presence in, the air.
3. Masking is an effect produced at the point of sense perception in the respiratory passages, together with final interpretation in the brain, and does not constitute an aromatic correction of the aerial components.
4. The application of an inherently pleasant masking agent to an offensive atmosphere may result in a final combination that is still objectionable as a consequence of odor incompatibilities.
5. The objectionable odor concentration must not be so intense that the masking agent is itself required in objectionable concentrations. In such cases, other control methods are indicated.

Odor counteraction is defined as the process by which undesirable odors are eliminated or significantly reduced in olfactory intensity by the addition in the vapor phase of certain odorous components or mixtures. The result obtained from true counteraction is the lowering of odor intensity, and the elimination of malodor as sensed by the human nose to a degree where it is no longer objectionable. The counteraction process for controlling odors is based on the fact that certain odorous substances are antagonistic and tend to compensate or neutralize their individual olfactory effects when mixed together in the vapor state. Zwaardemaker was probably the first to study the cancelling effects of two dissimilar odors. He found that when various pairs of odors are mixed in certain proportions, their odor characteristics are cancelled, resulting in no odor, or significantly reduced odor. Aronsohn and Backman's observations also demonstrated the cancelling effect of odor pairs. During the past twenty years, developments based on this principle have resulted in practical means of application to a wide variety of malodorous conditions, including application in air-conditioning systems.

The threshold concentration, Classification 1 (not objectionable) on the sensory scale, of chemical and industrial odors and their physiological reactions has been developed by DallaValle and appears in References 6 and 29. These data show no agreement of threshold concentrations for the various substances. Care must be taken never to use a reodorant to mask or cover up a toxic concentration of gas. Personnel in refineries and other industries are accustomed to the presence of odor as the signal that dangerous concentrations of gas are being reached.

Combustion Methods

Since the usual objectionable odors are combustible and can be destroyed by burning, combustion processes are employed for odor destruction in higher temperature gases. Where it is desired to remove odors from industrial exhausts at temperatures above 125 F, and where the gas density is above 1000 ppm, the gases can be caused to flow over a catalyst at about 500 F and be destroyed by catalytic combustion (see Chapter 37, Industrial Air and Gas Cleaners). For high-temperature gases, direct combustion at temperatures of 1200 F and above is employed to destroy odors by passing the gas through a furnace to the exhaust stack.[25] Partial combustion may cause a more objectionable odor than the original gas. Incomplete burning of nitrogenous and sulfurous organic material with the resultant pungent oxides is not a satisfactory odor destruction process. Careful consideration should be given to the gases and to means of obtaining complete combustion in order to assure effective odor control.

Catalytic combustion has a major advantage of lowering the fuel or heating requirement for combustion. In some cases no additional fuel source is required, and heat recovery may amortize the investment. The catalyst may consist of a noble metal, such as a platinum alloy coating on porcelain rods, or a platinum alloy coating on nichrome wire. Catalyst effectiveness and life are adversely affected by: (1) presence of metallic or organometallic vapors in the air, (2) deposits of carbonaceous material on the catalyst due to incomplete combustion, and (3) mechanical loss of the catalyst by abrasion.

For air free from particles and metallic vapors, a catalyst life of 20,000 hours may be expected.

A consideration of catalytic combustion should involve the following analytical approach.[29]

1. Analyze the gas to determine quality and quantity of odorous elements.
2. Determine the oxidizable elements in the air and the heat content per cubic foot based on concentration.
3. Obtain estimates from a competent manufacturer on cost of installation, life, maintenance, and efficiency of heat recovery.
4. Make a cost comparison of owning and operating costs and other methods including fixed charges, maintenance, and service costs, similar to Table 5, Chapter 86 of the 1964 GUIDE AND DATA BOOK.

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