to travel and vaporize for miles. Specific odor modifiers have been designed to follow these physical dispersal patterns.

Vaporization of a liquid odor modifier or counteractant is accomplished by clean compressed air (approximately 2 cfm per gun). The liquid odor counteractant is stored in a pressure drum at a convenient location and fed through small connecting lines to the vaporizing nozzles by air pressure as shown in Fig. 3.

Operation is automatic and once the installation is set up and balanced requires little maintenance except for weekly filling of the pressure containers. Odorous sources vaporizing

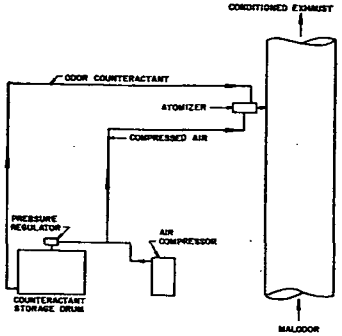

Fig. 3 .... Injection of Odor Counteractant in Duct or Exhaust Stack

at a continuous rate are treated continuously. The intermittent operation of relief valves may be treated during the blow off by automatic valves which operate according to the time of blow off. Equipment is easy to install and no alterations are required to process equipment. No down time is required for installation.

Procedure for getting the best results with odor modification is as follows:

1. Determine whether present effluent is well within the local health or air pollution control requirements for emission of particulate material and toxic gases. Determine rate of discharge (cfm) of all exhaust gases. Approximate intensity of odorous effluent on a percentage scale for each source. Examine the plant for odorous ventilating areas, wet walls, work areas, and stockpiles.

2. Arrange for an odor appraisal survey to be made by an odor counteraction specialist. If the odorous effluent can be reasonably handled, a cost estimate may be in order. Although separate plant processes may be nearly identical, area difference, topography, and temperament of the complaining area might require treatments which differ in cost. In either case the cost of installation is negligible. A full plant run may be made for a period of 30 days without great expense.

COMBUSTION METHODS

Fire is one of the oldest known methods of odor destruction. It is not a method of odor control, however, unless there is complete combustion. Incomplete burning of nitrogenous and sulfurous organic material with the resultant pungent oxides of nitrogen and sulfur is not the ideal conclusion for an odor destruction process.

Partial combustion may be worse than no combustion. Evidence of this is given by incinerators or the incomplete combustion in diesel and internal combustion engines which yield the irritating and sickening aldehydes, including formaldehyde.

From a theoretical standpoint, if complete oxidation of odors in the air can be obtained, deodorization is obtained because the final products are odorless (H_2O, CO_2) or have a higher odor threshold than the products consumed. For example:

Butanol —Mild odor
$\downarrow + O_2$
Butyraldehyde—Bad odor
$\downarrow + O_2$
Butyric acid —Very bad odor
$\downarrow + O_2$
$CO_2 + H_2O$ —Odorless

Considerable progress has been made in an attempt to reach complete deodorization by use of catalytic burners, particularly in eliminating odors from fats, oils and fatty acid processes. The only limitation of a catalytic burner is that the combustible substance introduced into the burner must be in the vapor phase or must be vaporizable at a reasonable temperature. Noncombustible inorganic solvents are not affected by a catalyst and should be absent from the air stream.

Complete oxidation must yield innocuous products in order to serve the purpose of odorous air pollution control. In the compounds of carbon, hydrogen and oxygen, which cover a wide field, this is true. In the case of hydrogen sulfide or organic compounds containing sulfur, catalytic combustion operating at temperatures below 675 F or above 1250 F will convert sulfur to sulfur dioxide which is less offensive and less dangerous than many of the original substances as long as the dispersal level is well below the maximum permissible level in the neighborhood.

General rules for organic compounds containing nitrogen are difficult. The effluent may contain free nitrogen or its oxides depending on the conditions of operation. Reduction of nitrogen oxides will, of course, release free nitrogen.

Catalysts Lower Temperature

Use of catalysts to aid combustion is illustrated by the design of platinum alloy activated alumina coating on porcelain rods or platinum alloy coating on nicrome wire.

Odorous air, passed through a catalytic device, may be oxidized at temperatures 500 to 800 F deg lower than required by uncatalyzed incineration. A major contribution offered by catalytic combustion is the considerable lowering of the firing temperature, with resultant saving of energy for heating air, and capital equipment costs for heating capacity.

Some combustion processes may operate without an outside energy source, except for that required to reach the firing temperature, or with smaller fuel requirements, where such operation would normally have been economically unfeasible in uncatalyzed incineration.

Temperature for effective combustive deodorization depends to a great degree on the chemical nature of the vapor to be oxidized and on concentration in the inlet stream. Self-sustaining catalytic combustion is attainable normally in the

concentration ranges of 15 to 20 percent of the lower explosive limit. When the concentration falls below 5 percent of the lower explosive limit, operation of catalytic combustion becomes more costly because of the decreased heat content and increased firing temperature, as shown in Table 3.

In order to achieve maximum benefits, engineering design under the guidance of catalytic reaction experts, is very important in the application of catalytic processes. Each process must be studied in relation to stream temperature; variability of the concentration of oxidizables; volume and space rate of the stream through the catalyst; oxygen content of the stream; attrition and the effects of loading of the catalyst with inorganic matter.

Table 3 .... Heat Content of Major Oxidizable Pollutants in Air

Pollutant	Basis	Heat Content of Air Mixture, Btu/Cu Ft	Temp Rise, F[a]
Pollens, bacteria, dust, fibers, smokes			
200 mg/cu meter	8000 Btu/dry lb	0.099	5.5
Carbon monoxide			
1000 ppm	321.8 Btu/cu ft	0.322	18
3.15 vol %, ¼ LFL[b]	321.8 Btu/cu ft	10.16	565
Hexane (normal)			
100 ppm	4412 Btu/cu ft	0.441	25.5
0.315 vol %, ¼ LFL[b]	4412 Btu/cu ft	13.90	770
0.63 vol %, ½ LFL[b]	4412 Btu/cu ft	27.80	1540
Hydrogen sulfide			
1000 ppm	596 Btu/cu ft	0.596	33
1.08 vol %, ¼ LFL[b]	596 Btu/cu ft	6.44	357

[a] 100% catalytic reaction (no heat loss).
[b] Lower flammability limit.

As with any other process used in air pollution control, there are cost considerations which must be weighed against benefits achieved.

The most readily accepted catalytic processes are those which yield usable heat with the possibility of writing off the investment with heat savings. Heat transfer may be used to bring the stream of waste effluents to a satisfactory firing temperature level. After once starting the catalytic process, product heat can be recirculated or used to heat the incoming stream. Where fuel must be used to heat a stream to a level necessary for sustaining the catalytic reaction, limiting cost becomes the cost of heating the entering stream less the value of heat leaving the catalytic process.

Variability and concentration of oxidizable material must be controlled in the catalytic process. Since the process depends on concentration level, upper and lower limits must be accommodated.

A concentration too low requires that the stream be preheated; a high concentration requires dilution. Where the limiting concentrations are of brief (a few minutes) duration, the heat retaining capacity of the procelain supported catalyst automatically adjusts to accommodate the variation. Oxygen content of the stream need only be sufficiently in excess of the stoichiometric requirements to assure adequate distribution of oxygen to the catalyst.

Prolong Catalyst Life

Particles of inorganic materials may not be a problem when velocities are low. Where the inorganic particles have an abrasive or attrition effect upon the catalyst, its life is shortened. Where the inorganic particles fuse readily or are in extremely high quantity, the catalyst might become heavily loaded with this material and have consequently shortened life.

Loss of catalyst activity, which determines catalyst life and hence equipment maintenance cost, is related to three major factors:

1. Presence of catalyst poisons (such as metallic or organometallic vapors) in the odorous air.
2. Obstruction of the catalyst surface either by deposit of carbonaceous material by incomplete combustion of some contaminant or by mechanical adherence of particulate material.
3. Mechanical loss of the catalyst by abrasion.

Specific catalytic poisons are vapors of pure metal, such as mercury, arsenic, zinc, lead, etc. These quickly stop catalytic action by permanently depositing on the active catalyst. Occurrence of high concentration of these substances is relatively rare in air pollution control problems.

For air free from particles and metal containing vapors, a long catalyst life may be realized. Some installations are reported to have given over 23,000 hr of service without catalyst regeneration.

Recovery of Heat Values

A pilot run, before installing full-scale equipment should be made, unless it can be definitely ascertained by other means that serious attrition or replacement factors are not involved.

As shown in the Table 3, cleanup of low concentrations of combustibles will require additional energy. In terms of heat, energy recovery will be negligible considering the cost. Benefits and advantages will depend on better public relations and the avoidance of nuisance complaints in the surrounding residential area. Since air dilution of stack exhausts has long been used to avoid neighborhood complaints, it is possible that reconsideration and redesign of ventilation equipment to include employment of catalytic oxidation rather than air dilution can result in:

1. Savings in heating fuel and air conditioning costs.
2. A supply of heat from the catalytic oxidation, which can further reduce heating costs in addition to the primary objective of the elimination of odorous organic air pollutants.

A great deal of heat value can be recovered for high concentrations of combustibles which are safely below the lower flammability limits.

Steps to Follow in Combustion

An approach to removal of odors by catalytic combustion would involve the following steps.[12]

1. An analysis of stack gases and other exhausts to determine characteristics and quantity of odorous elements.
2. A determination of those elements oxidizable in air and the heat content per cubic foot, based on concentration.
3. Estimates from a competent manufacturer of catalytic burners on the cost of installation, life expectancy of the unit, maintenance and efficiency in heat recovery and exchange.
4. Preparation of cost analysis on the basis of calculated costs of operation, including investment vs usable energy returns. Comparison of this method with the appraisal costs of other methods of odor removal, taking into consideration advantages and disadvantages of each method of operation which might affect the situation.
5. If the catalytic combustion method appears to be the best solution, arrange for pilot-plant installation and ascertain the