Contents

3. Source Control by Centrifugal Force and Gravity

Knowlton J. Caplan

4. Filtration

Koichi Iinoya and Clyde Orr, Jr.

5. Electrostatic Precipitation

Sabert Oglesby, Jr., and Grady B. Nichols

6. Scrubbing

Seymour Calvert

7. Mist Elimination

Werner Strauss

8. Adsorption

Amos Turk

9. Combustion

Chad F. Gottschlich

PART C PROCESS EMISSIONS AND THEIR CONTROL

10. Fuels and Their Utilization

Richard B. Engdahl and Richard E. Barrett

11. Space Heating and Steam Generation

R. E. Barrett, R. B. Engdahl, and D. W. Locklin

12. Power Generation

F. E. Gartrell

13. Incineration

Richard C. Corey

14. The Control of Motor Vehicle Emissions

Donel R. Olson

15. Agriculture and Agricultural-Products Processing

W. L. Faith

16. The Forest Products Industry

E. R. Hendrickson

17. Mineral Product Industries

Victor H. Sussman

Part A

CONTROL CONCEPTS

1

Control of Systems, Processes, and Operations

Melvin W. First

I. Introduction

Hatch has wisely pointed out (*1*) that "Prevention of community air pollution from industrial operations starts within the factory or mill." Resort to air and gas cleaning devices to eliminate or reduce emissions of air polluting substances and to tall discharge stacks to disperse and dilute offensive substances to acceptable ground-level concentrations becomes unnecessary when process, operational, and system control is effective in preventing the formation and release of air pollutants.

Even when gas cleaning and atmospheric dispersion must be used as final steps, process, operational, and system control is a means of minimizing the quantities of substances entering cleanup systems and, ultimately, being discharged to the atmosphere. Process, operational, and system control will concentrate contaminants in the smallest possible volume of air. This is important as the cost of control equipment is based principally on the volume of gas that must be handled and not on the amount or concentration of the substances that must be removed. Also, most air and gas removal equipment is more efficient when handling higher concentrations of contaminants, all else being equal. Control of emissions with highly efficient industrial air and gas cleaning devices often costs in excess of $2.5/m^3/second of installed capacity and entails high and continuing operational and maintenance expenses.

Emission of untreated gases to the atmosphere can also be costly. The 1974 construction cost of a 330-m reinforced concrete chimney, complete with free standing steel liner, was estimated at $15,000/m of height, or $5 million per chimney (*2*). Shorter stacks were less expensive; a 120-m stack costing approximately $1 million. Much innovative process, operational, and system control can be engineered into production activities for sums of this magnitude. Although seldom the subject of technical publications, the chief air pollution control officer of Pittsburgh, Pennsylvania, commenting on the improvements that had occurred in the atmosphere of that city, stated that "A major portion of our success has been attained by process changes, as opposed to installing control devices" (*3*).

Reduction of air polluting emissions by process, operational, and system control is not only an important adjunct to air and gas cleaning technology and to atmospheric dispersion but is a definitive response to the concept of zero emissions when it can be employed for total control.

Many innovative methods of exercising operational control of processes that emit undesirable substances to the atmosphere have been proposed. They include modulating the scale of operations or the concentration of emitted pollutants to match the variable dispersive powers of the atmosphere and, thereby, to maintain ground-level concentrations within prescribed air quality standards. When modulating operational scale, the concentration of pollutants in the off-gases remains unchanged but the total volume of emissions is variable; whereas, when modulating concentration, the volume of emissions remains constant but the concentration of pollutants is altered by such methods as changing the sulfur content of fossil fuels utilized for generating electricity.

The United States Environmental Protection Agency (USEPA) (4) permits individual states to establish zones in which air polluting emissions may be increased over existing levels so long as applicable air quality standards are not exceeded. This makes it possible to utilize presently untapped air resources to promote the commercial and industrial developments that are considered essential for a region's economic well-being without risking detrimental human health effects. Decentralization of the decision-making process to the local level will permit balancing the effects of increased air contamination levels on agriculture, tourism, industrial production, etc., so as to optimize community well-being.

Widespread adoption of restrictive emission limitations and rigorous air quality standards makes it essential that all methods of air pollution control be utilized to the maximum possible degree in areas where the air environment is threatened with excessive pollution.

II. Elimination of Air Pollution Emissions

A. Substituting Products

Offensive substances often may be eliminated entirely from processes that cause air pollution by substituting materials that perform equally well in the process but discharge innocuous products to the atmosphere, or none at all. When this method of air pollution control can be applied, it usually produces very satisfactory results at trivial cost. The numerous new chemical products that enter the commercial market annually make it worthwhile to maintain a continuing search for substitute materials of low pollution potential, even when past searches have failed.

An example from industry of a product change controlling an air pollution problem is substitution of a cold-setting synthetic resin for rubber in the manufacture of paint brushes. Before this change, it was necessary to vulcanize the rubber bond at the base of the bristles for a period of many hours, causing severe odor nuisances in the vicinity of the factory from the emission of sulfur-containing volatile products. The cold-setting resins selected as rubber substitutes produce no odors and completely eliminate air polluting emissions from this operation. Another example involves the application of finishing agents to knitted and felted textiles to give them a number of desirable surface characteristics. Acrylic latex, commonly used for this purpose, contains a few hundred parts per million (ppm) of unreacted ethyl acrylate monomer that is volatilized into the curing oven off-gases and often creates a severe odor nuisance in the vicinity of the textile plant. The cost of stripping ethyl acrylate monomer from hot curing oven gases would be excessively costly. However, an investigation of the latex manufacturing process showed that ethyl acrylate monomer, which has a distinctive unpleasant smell and an odor threshold of 0.002 ppm, can be vacuum stripped to a few parts per million in the latex during manufacture and the residual monomer totally destroyed by the addition of a suitable redox catalyst prior to application, thereby totally eliminating the odor nuisance from this operation at a trivial increase in the cost of the latex product (*5*).

In the field of transportation there has been considerable interest in electric battery power as a substitute for the internal combustion automobile engine for commuting and intraurban family use. A battery-powered automobile would be virtually pollution free, in contrast to emissions from conventional automobiles of carbon monoxide, nitrogen and sulfur oxides, and a long list of organic compounds. However, the great weight, limited driving range, and high cost of lead-acid battery-powered vehicles have restricted their use to light urban delivery service (e.g., home milk routes) up to the present.

Concentrations of lead in urban air originate principally from exhaust emissions of automobiles using leaded fuel. It has proved possible to substitute unleaded gasoline (i.e., less than 0.0225 gm of lead per liter) for use in 1975 model United States automobiles by reducing engine compression ratios and increasing the octane rating of unleaded gasolines with the addition of larger amounts of ring compounds (e.g., benzol). Future cars will be engineered to burn unleaded fuels and the manufacture of leaded gasoline may be discontinued some time in the future (USEPA has proposed 1979). When this occurs, lead levels in urban air will decrease in proportion. Hydrogen has been proposed (*6*) as a noncarbonaceous fuel for motor vehicles that burns without forming carbon monoxide, hydrocarbons, or, when pure oxygen is used as the oxidizing agent, nitrogen oxides, thereby totally freeing the motor vehicle of air polluting engine exhaust emissions.

In power generation, little technological effort is required to substitute low-sulfur for high-sulfur fuels but these desirable fuels have limited availability. Complete freedom from sulfur oxides and other gaseous emissions associated with the burning of fossil fuels for heat and power may be obtained by changing to water power and nuclear fuels, but there appears to be little prospect that these sources of electricity will be able to satisfy the entire demand for the foreseeable future.

There are prospects for nonpolluting electrical energy from solar, geothermal, and tidal sources. At this time, 88,000 kg-Cal are required per kilowatt-hour from a dry steam field whereas only 33,000 kcal are needed for 1 kW-hour from a modern fossil fuel-burning plant. Geothermal hot water systems contain even less energy for conversion. Solar power is still three times as expensive as nuclear, and tidal power can be harnessed in only a few places. Until one or more of these new electricity sources becomes practical, major reliance must be placed on water and nuclear power as the principal new sources for electricity that do not pollute the air.

B. Changing Processes

Process changes can be as effective as product substitutions in eliminating air pollution emissions. The chemical and petroleum refining industries have undergone radical changes in processing methods which emphasize continuous automatic operations, often computer controlled, and completely enclosed systems that minimize release of materials to the atmosphere. It has been found possible, and often profitable, to control loss of volatile materials by condensation and reuse of vapors (e.g., condensation units on volatile petroleum product storage tanks) and by recycling noncondensible gases for additional reactions (e.g., polymerization and alkylation of gaseous hydrocarbons to produce gasoline).

Examples of process changes from power production are (a) the development of ultrahigh voltage systems for long-distance transmission of electricity which has made it economically feasible to substitute distant water-powered turbines for urban fuel-burning steam stations; and (b) a substantial reduction in oxidation of SO_2 to SO_3 in coal- and oil-burning boilers which can be obtained by reducing excess air from 15 to 20% to less than 1% when burning fossil fuels. This helps to eliminate sulfuric acid formation but the absence of excess air tends to result in greater soot production. Firing with low excess air is also effective for reducing the formation of nitrogen oxides in the flame when burning gas and oil. Further reductions in nitrogen oxides can be obtained by supplying substoichiometric quantities of primary air to burners and accomplishing complete burnout of fuel "by injecting secondary air at lower temperatures, where NO formation is limited by kinetics" (7).

Examples of process changes from agriculture include: (a) the use of liquid and gaseous fertilizer chemicals, e.g., anhydrous ammonia, applied by injection into the earth instead of being spread across the surface as finely divided powders subject to wind entrainment, which reduces fugitive dust pollution; and (b) use of natural biological enemies and synthetic sex lures to disrupt mating for control of insect pests instead of widespread spraying of persistent pesticides such as DDT.

Many innovative methods for handling municipal waste disposal begin with mechanical methods for separating recyclable materials for reprocessing and reuse, thereby reducing the quantities of materials that must be handled by conventional waste disposal methods that are often severe local air pollution sources (*8*).

III. Minimizing Emissions of Gaseous and Gas-Borne Wastes

A. Ground-Level Wide-Area Pollution Sources

Although primary emphasis is usually placed on emissions from stacks, polluting substances may enter the air in other ways, usually at or near ground level and often over extended areas. Both situations tend to restrict natural atmospheric dilution and create severe local pollution problems. For example, sulfite process pulp mills often discharge odorous liquid wastes into streams that slowly release offensive substances to the air by degassing or volatilization for many miles downstream. Areas subjected to air pollution by this means may be larger than from a tall stack, with the added disadvantage of not being relieved, even intermittently, by changes in wind direction. Treatment of this waste liquor prior to discharge to a river, by removal of volatile and putrescible fractions, will reduce its air pollution potential to a level that can be met by the natural cleansing capabilities of the stream.

Similar considerations apply to air pollution from open dump burning; now outlawed nationwide in the United States. This can be an extensive source that releases intensely offensive airborne substances at ground level that sweep across large land areas without substantial dilution. Substitution of sanitary landfilling for open dump burning has largely eliminated air pollution from this operation. When sanitary landfill sites are unavailable, modern high-temperature central-station incinerators equipped with dust-removal equipment minimize air polluting emissions from the disposal of solid wastes.

Other wide-area sources of fugitive dusts that originate at ground level are land clearance and site preparation for road building and erection of structures. Although these sources are almost invariably of limited duration, they often produce intense local air pollution levels for a year