GAS CLEANING FOR AIR QUALITY CONTROL

Industrial and Environmental Health and Safety Requirements

edited by

JOSEPH M. MARCHELLO • JOHN J. KELLY

Gas Cleaning for Air Quality Control

INDUSTRIAL AND ENVIRONMENTAL HEALTH AND SAFETY REQUIREMENTS

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FOREWORD

This Chemical Engineering and Processing Series will be a welcome addition to the literature in that it provides new material on a series of topics important to the chemical engineering aspects of the process industries.

Today we are in great need of carrying new scientific and engineering developments through to the application state. Unfortunately chemical engineering had a lull in attention to new information via university research having to do with the real world of the process industries. It is believed this situation has turned around both in research and teaching and this series of books should assist in the educational effort in this direction. The bridge between science and engineering application is a continuing challenge to chemical engineers and has been taken up by the editors of this series.

One important characteristic of the book or series is the background and ability of the authors and editors, their discernment of what is important and what should be left out, their dedication to the task of communicating the essence of ideas to the reader, and their preparation of material from the viewpoint of the user overrides most other considerations. I wish to commend Marcel Dekker, Inc., for the leadership they have chosen and the editors in turn for prospective lists of authors.

I wish the editors and authors well in their efforts to increase the use of technical knowledge for the benefit of process industries and hence the people of our nation.

DONALD L. KATZ

PREFACE

Gas-solid systems is an interdisciplinary subject requiring application of physics, chemistry, mathematics, and engineering. Many practical problems have been solved by engineers in the metal, chemical, food, and pharmaceutical industries. The objective of this book is to bring together the latest theories and practice on the control of particulate emissions to provide an integrated view and reference source of the field.

Control of fine particle emissions to the atmosphere is a subject of concern from the standpoint of reducing material losses and in terms of improving the quality of the environment. This book is directed toward gas cleaning as required and practiced by industry to meet air pollution control requirements. The basic aspects of particle removal and experience and design of separation systems are presented with the aim of providing the reader with the background to better handle this growing problem.

The chapters of this book lead to a concluding summary of particle control practice in Chapter 6, which presents equipment costs, comparisons, and applications. Chapter 1 deals with air quality regulations, characteristics of emission sources, and sampling. Chapters 2, 3, 4 and 5 present detailed discussions of the design and operation of major types of equipment for reducing emissions to the atmosphere.

The contributing authors possess wide and extensive levels of experience in control of particulate emissions. Some have years of experience in industry with both equipment manufacturers and users. Others have experience in federal, state, and local government regulatory activities. This book draws upon their collective experience and summarizes it for the convenience of future workers.

Joseph M. Marchello

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Chapter 1

INTRODUCTION

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I. GAS CLEANING

A variety of man's activities result in the emission to the atmosphere of solid and liquid particles and reactive gases that subsequently participate in the formation of particles. The cumulative effect of such activities poses a threat to the health and welfare of the public and has been the basis for regulations requiring that gaseous emissions be cleaned prior to release (1). The removal of particulate matter from gases is generally known as gas cleaning.

Control of particulate emissions may be divided into the control of material present in gas streams inside equipment or building enclosures and the control of materials arising in open or unconfined areas. Strategies for control include basic changes in procedures and materials which eliminate or alter emissions and the use of add-on or auxiliary equipment to remove pollutants prior to release of the carrier gas to the atmosphere.

Changes in hooding, materials handling, and general housekeeping can sometimes significantly reduce the emission of particulate matter into the atmosphere. Process changes involving new techniques and the use of alternate materials may also offer important ways of abating emissions.

In most cases, pollution control equipment is selected to control the quantity of particulate matter. Emission regulations usually stipulate the maximum allowable mass emission rate but frequently also contain a visibility limitation on the plume expressed as equivalent opacity or Ringlemann number. Particle concentration, size distribution and optical properties establish the opacity of emissions. Thus mass and visibility regulations are interrelated for many process sources. Either kind of regulation establishes the efficiency for which the control equipment must be designed, based on given inlet conditions.

Equipment for the control of particulate emissions (2) includes dry inertial and centrifugal collectors such as cyclones, low- and high-energy scrubbers, electrostatic precipitators, cleanable fabric filters, and mist eliminators. Gas incinerators (afterburners) are sometimes used for removal of combustible particles.

The primary design consideration in gas cleaning is to establish what control devices will be able to meet the emission regulations for a given source. Specifications for a particular application require information on the pollutant and carrier gas characteristics such as: particle and gas concentration (average and range), average particle size and size distribution; particle shape, density, packing characteristics, and resistivity; gas flow rate, temperature, and moisture content, corrosivity, and flammability.

The estimated level of control, on a weight basis, of major sources of particulate matter for new installations is summarized in Table 1 based on sales of equipment of all types to various industries in 1967 (3). Potential weight efficiencies are generally over 90% and in some cases over 99%. There has been a steady improvement in the collection efficiencies over the years, but some operational changes can have marked effects on collector system performance. For example, the removal of sulfur trioxide from coal burning power plant effluents significantly lowers the performance of electrostatic precipitators. This results from the removal of sulfur, leading to the formation of a more resistive fly ash.

As discussed in Chap. 6, costs of particulate control equipment (2,4) vary widely. Costs cover a range of values because of local conditions, the nature of the particles and the gas stream, equipment size (gas volume), and design collection efficiency.

The high mass efficiencies for particle collection can lead to deceptive conclusions about emissions because of the large tonnages involved. Weight percentages that pass through the control equipment collectively represent large quantities of material escaping to the atmosphere on a total mass basis.

TABLE 1

Average Efficiency (Weight Basis) Of Newly Installed Industrial Air Pollution Control Equipment For Removal Of Particulates (3)

Industry description	Average operating efficiency %	Expected efficiency at optimum conditions %
Coal-fired electric utilities	93	98
Coal-fired industrial boilers	90	95
Crushed stone/sand and gravel	94	96
Agriculture operations	92	94
Iron and Steel		
Ore crushing	70	90
Materials handling	95	97
Sinter plants	95	97
Coke ovens	70	90
Blast furnaces	97	99
Basic oxygen	97	99
Electric arc	97	99
Scarfing	95	97
Cement	97	99
Woodpulp	96	97
Lime	92	94
Clay	96	97
Primary nonferrous		
Aluminum	85	90
Copper	97	98
Zinc	97	98
Lead	97	99
Phosphate rock	97	98
Fertilizer	96	98

TABLE 1 (continued)

Industry description	Average operating efficiency %	Expected efficiency at optimum conditions %
Asphalt	98	99
Ferroalloys	90	95
Iron foundries	85	90
Secondary nonferrous		
Copper	96	99
Aluminum	96	99
Lead	96	99
Zinc	96	99
Coal cleaning	99	99
Petroleum	99	99
Acids	94	96

Moreover, efficiencies for the finest particles, which play a key role in air pollution effects, are significantly less than for larger particles. For some types of collectors, theory indicates that particle size removal efficiency passes through a minimum in the size range between 0.1 and 1.0 μm, which is a particularly important range so far as visibility, health effects, and weather modification are concerned. In the case of high-temperature particulate sources such as combustion of fossil fuel, there appears to be a concentration of metals such as cadmium, chromium, and lead in the smaller size fraction--possibly by vaporization and condensation of metal fumes.

II. AIR QUALITY REGULATIONS

At the beginning of the industrial revolution manufacturers had little or no conscience about the atmospheric discharge of noxious effluents. However, modern industrialization, growth of cities, increased vehicular traffic on the roads, crowded living conditions, and waste problems have joined together in recent years to magnify the air pollution problem.

Atmospheric particulate matter is produced from natural sources and from man-made sources such as fuel combustion in power plants, industrial processes of diverse nature, and internal-combustion engines. Formation processes can be classified as primary, which means that particles are introduced into the atmosphere in particulate form, or secondary, which refers to the formation of particles from gases and vapors.

The most easily observed effect of air pollution is the reduction in visibility produced by the scattering of light from the surface of airborne particles. The degree of light obstruction is related to particle size, aerosol density, distance, and other factors. The destruction of metals, coatings, fabrics, and vegetation is mainly due to acid mists, oxidants of various kinds, and particulate products of combustion and industrial processing.

Knowledge of sources of air pollution in a community and the quantities of the various pollutants emitted to the air provides the basic framework for air conservation activities. Through an emission inventory, information relating to the quantities of the various pollutants released, the relative contribution of pollutants from different source categories, and the geographical distribution of pollutant emissions within the study area may be obtained. The results of an emission survey may be used effectively in metropolitan planning, pollution abatement activities, sampling programs, and diffusion models for predicting atmospheric levels of pollutants.

National primary and secondary ambient air quality standards have been set by the Environmental Protection

Agency, EPA (5). Primary ambient air quality standards define levels of air quality judged to allow an adequate margin of safety to protect the public health. National secondary ambient air quality standards define levels judged to protect the public welfare from adverse effects associated with the presence of air pollutants in the ambient air. Part 410, Chapter IV, Title 42, Code of Federal Regulations contains the standards for air pollutants and the reference methods for their measurement.

The national primary ambient air quality standards for particulate matter are:

a. 75 $\mu g/m^3$--annual geometric mean;

b. 260 $\mu g/m^3$--maximum 24-hr concentration not to be exceeded more than once per year.

The national secondary ambient air quality standards for particulate matter are:

a. 60 $\mu g/m^3$--annual geometric mean, as a guide to be used in assessing implementation plans to achieve a 24-hr concentration;

b. 150 $\mu g/m^3$--maximum 24-hr concentration not to be exceeded more than once per year.

The national ambient standards are continually under review by EPA and may be changed and extended in the future. In addition to particulate matter, the present standards cover sulfur dioxide, nitrogen oxides, hydrocarbons, carbon monoxide, and photochemical oxidants. Polycyclic hydrocarbons, trace elements, and other specific chemicals may be included in the standards in the future.

Under the Clean Air Amendments of 1970 (7) the States were required to submit plans which provide for implementation, maintenance, and enforcement of these standards. The States may adopt more stringent standards. Recommendations by EPA (6) to the States for possible inclusion in their implementation plans cover emissions of particulates. These,