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DESIGN OF INDUSTRIAL EXHAUST SYSTEMS

How to Design, Build or Buy an Exhaust System that Will Adequately and Economically Perform the Functions Required by Law or Prescribed by Specialists in Industrial Hygiene. This Treatise Covers Exhaust Ventilation, Low-Pressure Pneumatic Conveying, the Design of Hoods, Piping and Structural Details, and the Selection of Dust Separators, Centrifugal and Axial-Flow Exhaust Fans.

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PREFACE

THIS book makes no attempt to cover the broad fields of health hazards, industrial dusts or the pathological phases of industrial hygiene. Able investigators have extended the horizon of these subjects immensely in recent years. Industry, therefore, is well informed of the need for exhaust sanitation. It is *not* well informed as to how best to satisfy that need. The purpose of this book is to tell the engineer how to design and build or how to buy an exhaust system that will adequately and economically perform the functions prescribed by the industrial hygiene expert or by law.

Although exhaust ventilation has been practiced for more than 70 years and has been recognized by statute for more than 40 years, the literature is astonishingly scanty. There seem to have been two major contributing factors. First, the field has been relatively small and inconspicuous and has not attracted the attention of colleges and other independent investigators. The second, and perhaps predominant, factor has been that many of those within the industry have treated their accumulated data as precious trade secrets to be divulged neither to competitors nor to customers. The author aims to dispel most of the mystery surrounding exhaust work and to express many of the trade secrets in straight-forward engineering terms. He is fully conscious of the shortcomings of this book but believes that sufficient data have been presented to permit the design of adequate and low-cost systems or to appraise competitive designs and the claims of rival contractors. It is hoped that the reader will be encouraged to measure, record and publish engineering facts concerning exhaust systems to the end that our collection of basic data will become more complete and more reliable.

The subject of exhaust ventilation embraces the theory of air flow, the application of this theory to practical design, the selection of commercial fans and dust collectors, the construction of the physical plant and the testing of the completed system. There is no lack of published material on the subject of fluid flow. Unfortunately, the information is widely scattered and much of it is to be found in papers not easily accessible to the busy engineer. Moreover, many confusing contradictions are encountered, requiring intensive study to reconcile conflicting statements and conclusions. The author has selected and abridged the most authentic data for the theoretical portions of the book.

Acknowledgments are due to C. H. B. Hotchkiss, Editor, HEATING & VENTILATING, who guided portions of the material through serial publication, and to E. J. Crane, Western Electric Co., Inc., for his advice and criticism of the earlier chapters.

PREFACE TO SECOND EDITION

In the intervening years since this book was first published, advances and refinements in exhaust system practices have taken place. In recognition of these developments, two new chapters have been prepared as well as many lesser additions. The growth of electrochemical processes for surface preparation and finishing of metals has warranted broader treatment of fume control. Axial flow fans, also, have acquired new importance in exhaust work.

In 1914 the author installed a trial exhaust unit on a granite surfacing machine in Barre, Vermont. This unit was never fully developed because of worker opposition. It is, therefore, with considerable personal satisfaction that he reports the successful efforts of others whose persistence in recent years has gained acceptance of exhaust protection in the stone cutting industry.

Appreciation is due to Miss Grace N. Donovan, Librarian of the Kearny Works of the Western Electric Co., Inc., for her patience in reading and abstracting the several hundred technical articles reviewed in the preparation of the second edition of this book.

THE AUTHOR

CHAPTER I.

FLOW OF FLUIDS

THE term "exhaust system" as applied to certain types of low-pressure industrial pneumatic systems is not accurately defined but usually is interpreted as including dust collecting, fume removal and low-pressure conveying systems. Heating, ventilating and air conditioning systems are definitely excluded. A general characteristic of exhaust systems is that the fluid flowing through the piping is not homogeneous. It is a mixture, usually of air as the parent fluid, carrying solids in suspension or vaporous or gaseous materials. Broadly, an exhaust system is a pneumatic conveying system even though its primary purpose may be quite different from the mere transportation of materials.

The characteristics of the system and its design problems are dictated principally by the laws of flow of the conveying fluid. Knowledge of these laws is fundamental equipment for the competent designing engineer. Admittedly, simple systems of the types covered by state codes may be constructed without specific reference to the principles of fluid flow. Nevertheless, a thorough understanding of the basic theory is essential to the successful solution of the unconventional problem or to the refinement of design which distinguishes the truly good job from the merely passable. A speaking acquaintance with the fundamentals is desirable even for the buyer of exhaust systems if only to test the competence of the contractor-designer.

Functions of the Conveying Fluid

The conveying fluid not only transports the material to its destination but also is instrumental in introducing the material into the system initially. Flying in. long. It appears that numbers of particles rather than total weight of dust is significant in the evaluation of health hazards. Thus, it is reported that of certain foundry dusts investigated, 99%, by number of particles, were of dangerous size, 10 microns or finer, whereas these particles comprised but 27% of the total weight of the samples.

The author makes no pretense of treating the pathological aspects of dusts and fumes. It is recommended strongly that the more recent literature be consulted. It must be recognized that knowledge of dusts and their effects is far from complete. The field has been cultivated intensively, however, and much valuable material has been published. The engineer concerned with dust control in hazardous industries will do well to inform himself of the latest results available.

Relative Dust Hazard

While authorities differ as to the harmfulness of certain industrial dusts, a few are known definitely to be hazardous. Chief among these is silica, occurring commonly as quartz. It is encountered in industries as dissimilar as granite cutting and hard-rock mining on the one hand and those employing abrasive processes such as sand blasting and grinding on the other. Asbestos, also, is known to produce pulmonary disability.

The toxic dusts, including lead, mercury, arsenic and others, are hazardous when inhaled. In fact, there is considerable evidence that the likelihood of poisoning through inhalation may be greater than that through food contamination.

Coal dust alone is believed not to produce disabling fibrosis. Calcium and magnesium carbonates as represented by limestone, marble, dolomite and magnesite have been shown to be comparatively harmless. The vegetable dusts such as cotton, jute, hemp and wood also are in this category. However, lacking positive evidence that a given dust is not harmful, it is best to assume that it is dangerous and to provide adequate protection.

Dispersion of Dusts

The manner and degree of dispersion of dust is a function of particle size. Large particles thrown from a wheel or cutter may be distributed over a wide area by virtue of their kinetic energies and without assistance from air currents. Small particles, on the other hand, are dependent entirely upon air currents for their dispersion. The mass of a tiny particle is so small and the kinetic energy so little that it is incapable of sustained flight. It loses velocity rapidly and cannot be projected far from the point of generation.[2]

Fine dusts in suspension drift with the general air currents. Their dispersion depends almost entirely upon drift. Fine dusts, therefore, must be controlled by controlling the flow of the entraining air. Coarse particles, on the contrary, are but little affected by local currents of mild intensity. Their dispersion by dynamic projection requires that the hood be placed, target-like, so that the particles are thrown directly into the pipe mouth.

Local Air Movements and Counteracting Velocities

Some evaluation of stray air currents is necessary before effective counteracting velocities can be determined. Convection currents from radiators, ovens and furnaces seldom exceed 25 to 75 f.p.m. Direct window drafts may be much more brisk but can be controlled by closing windows or by installing screens, baffles or deflectors. Flywheels, large pulleys and even abrasive wheels frequently cause disturbance over considerable area. Excessive machine vibration, particularly of large flat panel surfaces, often keeps in suspension dust which would settle otherwise. The first puff of dust-bearing

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[2]A 10 micron abrasive particle thrown from a wheel at 10,000 f.p.m. can fly about 1 in. in still air. At the same speed a particle 1/16 in. diameter may be thrown 100 ft.