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CONTROL OF METALLURGICAL AND MINERAL DUSTS AND FUMES IN LOS ANGELES COUNTY, CALIF.

BY GLENN L. ALLEN, FLOYD H. VIETS, AND LOUIS C. McCABE

United States Department of the Interior— April 1952

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UNITED STATES DEPARTMENT OF THE INTERIOR
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April 1952

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by

Glenn L. Allen,[1] Floyd H. Viets,[2] and Louis C. McCabe[3]

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[1] Metallurgist, Bureau of Mines, Washington, D. C.

[2] Consulting engineer, County of Los Angeles, Air Pollution Control District.

[3] Chief, Fuels and Explosives Division, Bureau of Mines, Washington, D. C.

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SUMMARY

The rapid rise of industrial Los Angeles to international prominence has been accompanied by the natural corollary - a record influx of population - together with greatly increased production and fabrication of steel and nonferrous and light metals; industrial mineral processing; and high consumption of fuel oil, gasoline, and chemicals. These have resulted in the release of hundreds of tons of metallurgical and mineral dusts, fumes, and gases into the atmosphere daily. Los Angeles County, intrinsically, is no worse than other industrial centers in respect to the generation of atmospheric contamination. It is, in fact, more fortunate in that no coal is used, and it has no great primary metallurgical industries comparable to those of Chicago and Pittsburgh. Meteorologic and topographic peculiarities of the area, however, which result in poor drainage of the polluted air away from the Los Angeles Basin, serve periodically to greatly increase the intensity and frequency of industrial smog visitations. This combination of intense industrialization, population influx, climate, and topography has made mandatory control of air pollution necessary.

The nonferrous pyrometallurgical industry of Los Angeles has three rather unusual characteristics that contribute to its difficulties in developing suitable fume control: It consists of a multiplicity of relatively small establishments subject to wide variations in products and operating schedules; operations are largely of the secondary or reclaiming nature and, therefore, often work dirty scrap metals; and, unfortunately, much of the industry is concentrated, to a considerable extent, near the center of the city. A difficulty inherent in most nonferrous foundries, including the many brass-works melting alloys containing zinc, is the high volatility of zinc and the extremely small mean particle size of the resulting zinc oxide fume.

The nonferrous industry of the area, after extensive investigation of the causes and nature of its stack emissions, has, at this writing, found only one type of equipment that could be depended upon to adequately remove particulate matter emitted by the larger furnaces in which the gases are characterized by heavy dust loadings at high temperatures. This is a specially equipped baghouse, and its first cost is rather high. For smaller furnaces, particularly of the crucible type, the conventional sock-type baghouse has proved satisfactory and economical where small volumes of cooler gases are treated.

Other established gas-cleaning methods, such as dynamic scrubbers, electrical precipitators, and packed towers, are being adapted and, in time, may provide a choice of equipment capable of producing the necessary reduction of objectionable emissions from nonferrous operations. The inert slag cover, which reduces emission at the source, has proved fairly effective and economical, particularly with the crucible-type furnace and pouring ladle, but its successful use depends on the skill of the operators.

The gray-iron-foundry branch of the ferrous industries has not fared as well as the nonferrous branch, despite extensive investigation and development of equipment for control of cupola emissions. Fumes from most other iron-foundry operations long have been under adequate control. Appreciable progress has been made in adapting equipment suitable technically and costwise for cupola-exit gases, and development continues. Equipment capable of producing the required clearances is undoubtedly available but is not as yet within the financial ability of many small foundries. The baghouse equipped with specially woven glass-fabric bags, as used commercially in the nonferrous industry, has technically been the most successful single device to date for controlling cupola emissions and has been proven in pilot operations. An industrial installation to serve one of the largest custom foundries in the area is under construction.

Electric and open-hearth steel makers, mostly large-scale operators, have been more fortunate. After extensive investigation, electrical precipitation has been adopted for cold-metal open-hearth work, and hydrodynamic scrubbers and baghouses have been adopted for electric-steel-furnace fumes. In addition to the fact that such equipment removes the necessary dust, capital and operating costs were important factors in their selection.

Air-pollution problems of nonmetallic minerals processing industries are, for the most part, subject to resolution through the use of standard, high-efficiency, dust-removal equipment, within the industries' ability to pay. Acceptable and workable standards for solid particulate matter have been established for tolerable emissions under Air Pollution Control District regulations.

Among the many factors in the control of metallurgical and mineral dusts and fumes in the Los Angeles area, two are perhaps most apparent as the campaign matures: (1) The necessity for a high recovery of micron-size particles and the difficulties involved in this are becoming better appreciated; and (2) the fact that the electrical precipitator and the baghouse are the most versatile and positive devices demonstrated industrially to date for accomplishing the necessary end. The precipitators, large and small, operated wet or dry, are the answer to some of the most difficult problems in ferrous and light metals work and industrial-mineral processing. Units as small as 10,000 c.f.m. are in satisfactory operation, and smaller and less expensive ones are expected to be available in the near future. Baghouses, particularly those designed and equipped for operation at high temperature (250°-500° F.), are producing excellent results in both ferrous and nonferrous work at costs that most industries can afford. These and other types of equipment, including the dynamic wet scrubber and packed tower, found suitable for specific applications alone or for use in combination with others, make adequate control of metallurgical and industrial mineral dusts and fumes an eventual certainty.

INTRODUCTION

Industrial Los Angeles

The role of metallurgical dust and fumes in atmospheric contamination in Los Angeles County has become increasingly important because of the phenomenal growth of industrial production and population. "Los Angeles now stands third among the country's metropolitan areas in bank debits and deposits, retail sales almost $5 billion last year (1948) and total income payments to individuals $7.5 billion."[4]

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[4] Fortune, The Undiscovered City: June 1949, p. 82.

Much of this is attributed to industrialization. Value added by manufacture grew from $505 million in 1929 to $2,052 million in 1947,[5] an increase of 400 percent. The population of Los Angeles County concurrently increased from 1,238,000 to 4,125,000.[6] Corresponding increases have occurred in motor vehicle registration from about 800,000 to 1,825,000;[7] gasoline consumption from 500 million to over 900 million gallons annually; and fuel-oil consumption from 1 million to 5 million barrels annually.

Metallurgical Industries

The dollar value of industrial production in Los Angeles exceeds that of the Pittsburgh manufacturing area, including the latter's great steel industry, and probably ranks fourth in the Nation, exceeded only by New York, Chicago, and Detroit.[8] The metallurgical industries of Los Angeles, however, are much smaller individually and are scattered over an area of several square miles. In 1947 about 300 of the 10,000 manufacturing establishments were classed as primarily metal industries.[9] Nevertheless, the value of the production of the metal industries added to that of the closely related metal-fabricating industry is second only to the transportation industry in value of manufactured products in the Los Angeles metropolitan area. If to the value of metallurgical and metal fabricating is added that of the oil and chemical industries, the combined production leads the list of classified industries. This combination is generally thought to be the basis of Los Angeles' smog problem. Other industries, of course, contribute, particularly agriculture, woodworking, industrial-mineral processing, and machinery. In short, the simultaneous growth of industrial production and population, which "in the space of a very few years has developed Los Angeles into one of the great industrial complexes of the world,"[10] has brought smog in its wake and made control of air pollution absolutely imperative.

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[5] Bureau of Census, Census of Manufactures, 1947: Bull. MC 104, 1949, p. 8. In 1947, Los Angeles and Orange Counties were included in the Los Angeles Metropolitan area.

[6] Bureau of Census, 1950, for Los Angeles County; total for the metropolitan area, 4,339,200.

[7] As of January 1, 1950. Tourist entries about double this number.

[8] See footnote 4.

[9] See footnote 5.

[10] See footnote 4.

Other Aspects of Air Pollution

The physiological,[11] administrative,[12] and economic[13] aspects of air pollution and the legal status[14] of its regulation have been dealt with in many authoritative papers. Methods and instrumentation[15] for sampling and determining physical

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[11] Townsend, J. G., Short-Range Exposure to High Concentrations by Air Pollutants: U. S. Tech. Conf. on Air Pollution, May 1950, (in press).
Foulger, John H., Physiological Effects of Chemical Contaminants of the Atmosphere: Proc. 1st National Air-Pollution Symposium, Stanford Research Inst., Los Angeles, Calif., November 1949, p. 121.
Largent, E. J., Effects of Air Pollution in Donora, Pa.: Proc. 1st National Air-Pollution Symposium, Stanford Research Inst., Los Angeles, Calif., November 1949, p. 129
Ashe, W. F., Acute Effects of Air Pollution in Donora, Pa.: U. S. Tech. Conf. on Air Pollution, Washington, D. C., May 1950 (in press).

[12] Los Angeles County Air Pollution Control District, Annual Reports 1947-48, 15 pp.; 1948-49, 56 pp.; 1949-50, 49 pp.
McCabe, L. C., National Trends in Air Pollution: Proc. 1st National Air-Pollution Symposium, Stanford Research Inst., Los Angeles, Calif., November 1949, p. 50.
Larson, Gordon P., Reduction at the Source: Proc. 1st National Air-Pollution Symposium, Stanford Research Inst., Los Angeles, Calif., November 1949, p. 77.
Alpern, A. X., Problems in the Strict Enforcement of Air-Pollution Control: U. S. Tech. Conf. on Air Pollution, Washington, D. C., May 1950, (in press).
Walker, Herb. V., The Hearing Board Under the California Air-Pollution Control Act: U.S. Tech. Conf. on Air Pollution, Washington, D. C., May 1950 (in press).

[13] Gibson, W. B., The Economics of Air Pollution: Proc. 1st National Air Pollution Symposium, Stanford Research Inst., Los Angeles, Calif.,
Welch, Harry V., The Fume and Dust Problem in Industry: Trans. Am. Inst. Min. and Met. Eng., vol. 185, December 1949, p. 934.
Johnson, V. W., Air Pollution in Relation to Economics: U. S. Tech. Conf. on Air Pollution, Washington, D. C., May 1950 (in press).

[14] Hansen, Richard F., Statutory Regulation of Air Pollution: An Appraisal of Existing Laws and Proposals for Future Laws: U. S. Tech. Conf. on Air Pollution, Washington, D. C., May 1950 (in press).
Hartman, M. L., Legal Regulation on Air Pollution: Ind. Eng. Chem., vol. 41, November 1949, p. 2391.

[15] Stanford Research Institute, Second Interim Report on the Smog Problem in Los Angeles County: Los Angeles, Calif., August 1949, 64 pp.
Brunetti, C., and others, New Developments in Instrumentation for Air Pollution Studies: U. S. Tech. Conf. on Air Pollution, Washington, D. C., May 1950 (in press).
Silverman, L., Sampling of Industrial Stacks and Effluents for Air-Pollution Control: Proc. 1st National Air Pollution Symposium, Stanford Research Inst., Los Angeles, Calif., November 1945, p. 55.
Air-Pollution Control District, Test Procedures and Methods of Sampling in Air-Pollution Control: Los Angeles, Calif., 1950.
Western Precipitation Corp., Gas and Dust Measurements: 4th ed., Bull. 50, Los Angeles, Calif.
Brown, C. E., and Schrenk, H. H., Standard Methods for Measuring Extent of Atmospheric Pollution: Bureau of Mines Inf. Circ. 7210, May 1942, 19 pp.

characteristics and concentrations of atmospheric contaminants also have been described. It remains for this report to deal with the steps taken by specific metallurgical and mineral industries in the Los Angeles area to determine the nature and amount of dust and fume they produce and the methods used to control their emissions at the source.

Metallurgical operations have long been recognized as prime producers of atmospheric pollution in the forms of dust, smoke, fumes, and noxious gases. It has been estimated[16] that about 80 tons of metallurgical dust and fume were discharged daily into the Los Angeles atmosphere before the advent of pollution control.

Metallurgical industries historically have been separately grouped into ferrous and nonferrous, although they have much in common from the standpoint of air pollution. That convention is followed here.

Acknowledgments

The Nonferrous Foundrymen's Smog Committee,[17] a voluntary association of local concerns formed under the auspices of the Los Angeles Chamber of Commerce, has financed extensive technical investigation of the problem of air contamination produced in nonferrous-foundry work and has published preliminary results in formal reports[18] and brochures[19] of much practical value to foundrymen. The committee's reports are the source of much of the subject matter contained in this report. Special credit is due to the very capable personnel of the Vernon Works, Aluminum Co. of America, for supplying information concerning control of fume from open-hearth aluminum-alloy furnaces and from dross treatment and to the company for permission to describe some of its findings. Reports of investigations made for the Gray Iron Foundry Smog Committee, a group similar to the nonferrous one, also have been used freely in this report. Producers of electric steel castings, working through the Los Angeles Steel-Foundry Group, supplied valuable data and cooperation. These are but a few of the many organizations now maintaining close liaison with Air-Pollution Control District in the movement to reduce air pollution in the Los Angeles area. Valuable advice and whole-hearted cooperation were obtained from the director and staff of the Air-Pollution Control District of Los Angeles County.

Published reports of many organizations and works of investigators contained in symposiums on air pollution, particularly those relating to the Los Angeles problem, have been drawn upon freely. This applies particularly to the Annual Reports of the Los Angeles County Air-Pollution Control District, 1947-48, 1948-49 and 1949-50 and the First and Second Interim Reports - The Smog Problem in Los Angeles County, published in 1948 and 1949, respectively, by Stanford Research Institute and sponsored by the Western Oil and Gas Association. Other valuable sources of background and specific information include: Atmospheric Contamination and Purification, a symposium reprinted from Industrial and Engineering Chemistry, November 1949; Proceedings of the National Air-Pollution Symposium, sponsored by Stanford Research Institute,

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[16] Los Angeles County Air-Pollution Control District, Annual Report 1948-49: p. 14.

[17] A. L. Goodreau, chairman, 2414 Sante Fe Ave., Los Angeles 11, Calif.

[18] Industrial consultants, Report on the Air Contaminants Produced by Furnaces in the Nonferrous Foundry Industry: April 1948.

[19] Nonferrous Foundrymen's Smog Committee, Furnace Practice Manual: Los Angeles, Calif.

California Institute of Technology, University of California and University of Southern California; United States Technical Conference on Air Pollution, May 1950, sponsored by the Interdepartmental Committee on Air Pollution, Washington, D. C.; Metals Handbook, 1948 edition, published by American Society for Metals; material from the technical press, business concerns, and private correspondence with consulting engineering firms. An effort has been made to properly credit these and many other sources in footnotes in the text.

Special acknowledgment is made to Gordon P. Larson, director, Los Angeles County Air-Pollution Control District, for his assistance in this work and for making available the data upon which this paper is based.

NONFERROUS PYROMETALLURGICAL INDUSTRIES

Introduction

Secondary Metals

Nonferrous pyrometallurgical industries in Los Angeles County, of interest from the standpoint of air pollution, include establishments working the common base metals copper, zinc, and lead; the light metals aluminum and magnesium; and, to a lesser extent, the more valuable metals nickel, tin, silver, and their innumerable alloy combinations. Those currently operating in the Los Angeles area are almost exclusively secondary-metal producers, foundries, or both. Fortunately, from the standpoint of air pollution, no major nonferrous smelteries are in operation in Los Angeles County.

Establishments

Census of Manufactures[20] placed the number of nonferrous metallurgical establishments at 257 in 1947; of these, 168 were foundries. A recent estimate[21] placed brass and bronze foundries at 100; aluminum, magnesium, and light metal alloys, 75; and aluminum-scrap reclaiming, 25. This does not include a few plants making zinc and lead casting and bearing metals, or some of the smaller captive foundries operated intermittently to produce parts only for use in its own assemblies.

Many of the larger nonferrous metallurgical establishments are in the highly concentrated industrial area beginning north of the Union Station and continuing south through the apparel and packing-house districts, spreading both east and west as it continues southward through Vernon, Huntington Park, the central manufacturing district, Maywood, and South Gate, all within 7 miles of the City Hall and extending over an area roughly 3 miles wide and 10 miles long. These areas are shown in figure 1.

Smaller nonferrous plants, mostly alloy foundries making innumerable brass, bronze, zinc, lead, aluminum, and magnesium products and plating and other establishments working cadmium, chromium, and precious metals, may be situated almost anywhere in the Los Angeles Basin, comprising some 1,050 square miles. The larger

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[20] Bureau of the Census, Census of Manufactures, 1947, California: Bulletin MC 104, 21 pp.

[21] Communication from Robert L. Chass, asst. director, Los Angeles County Air-Pollution Control District, September 1949.

Figure 1. - Major industrial areas in the southern end of Los Angeles County.

units of the wrought copper, brass, and bronze industries center in Maywood about 5-1/2 miles southwest of the Civic Center. The largest single unit of the light-metal industry is in Vernon, only 3 miles southwest of the City Hall.

With but few exceptions, the great majority of the 200 or more establishments in this category in Los Angeles are relatively small plants locally owned and operated to serve other industries such as automotive, oil, aviation, construction, chemical, and moving picture. Probably not over 20,000 of the Los Angeles total industrial labor force of some 360,000 are employed in strictly metallurgical industries, and perhaps less than 8,000 are in the nonferrous metallurgical work (excluding metal fabricating and machinery).

Copper and Copper-Base Alloys

Introduction

Copper and copper-base alloys are being produced in increasingly important volume in Los Angeles County. Much of this production is in wrought items from nearly pure copper, such as tubing and cable, in brasses for both working and casting, which may contain upward of 40 percent zinc, and in bronzes containing tin as the chief alloy constituent. The working of nearly pure copper and bronze does not have great interest from the standpoint of air pollution, since little metal is volatilized because of the high boiling points of copper and tin (above 4,000° F.) and their low normal pouring temperatures of about 2,000 to 2,200° F. With good melting practice, total stack losses may be held to a small fraction of 1 percent of the process weight involved. However, the brasses,[22/] containing 15 to 40 percent zinc, which are poured at temperatures near their boiling points (about 2,200° F.), may lose 2 to 15 percent of their zinc content through fuming.[23/]

However, the production, furnacing, and casting of all copper and copper-base alloys require furnace operations at high temperatures that are usually produced by combustion of carbonaceous fuel. Such operations involve production and handling of large volumes of gases, which may accumulate solid particulate matter in the forms of process dust as metal particles, condensed lead and zinc fumes, and unconsumed fuel. In practice this may amount to 2 percent of the total weight of the material charged into the furnace. In the aggregate, nonferrous furnacing undoubtedly makes an appreciable contribution to air pollution unless the dust-suppressing equipment is adequate.

Foundry Practice and Equipment

In the Los Angeles area copper and high-copper alloy shapes for working, such as slabs and billets, are usually produced in large gas- and oil-fired furnaces of the reverberatory type. Brasses and bronzes for working are melted mostly in low-frequency induction furnaces in some of the larger works and in crucible-type fuel-fired furnaces in the smaller job-foundries. Electric furnaces, both arc and induction types, are used in this area for castings also. It is difficult to generalize, therefore, regarding furnaces and their melting practices.

[22/] The term "brasses" as used in this report will not be restricted technically to alloys of copper and zinc but will include high-grade bronzes and alloys containing lead and zinc.

[23/] Fume in this report is used in the metallurgical sense meaning condensed fume, as defined in appendix A of this report, dealing with rules and regulations. Condensed fume is particulate matter.

A check of commercial nonferrous job foundries making castings at midyear 1949 indicated that 80 percent of the furnaces operating in Los Angeles County were the crucible type. About half of these were small pit furnaces of 50 to 200 pounds capacity, and the other half were tilting furnaces with crucibles holding 1,000 to 3,000 pounds of metal per melt. Twenty percent of all active furnaces was about evenly divided between rotary, barrel, and kettle types holding up to 3,000 pounds per charge.

Open-flame furnaces in the area, proved by actual test to be no more efficient in heat utilization than indirect-fired furnaces, are somewhat more difficult to hood effectively, and the metal losses are high, since the metals and the hot, high-velocity combustion gases are in direct contact. The Los Angeles tests on this type of furnace have indicated that it is improbable that any direct-fired furnace melting alloys containing lead and zinc can be operated without producing fumes over the legal allowance based on weight of material processed.

The indirect-fired crucible-type furnace is used extensively in the Los Angeles area, particularly in foundries requiring small- and medium-size melts. The lift-out crucible is frequently employed in small furnaces. Tests in Los Angeles have demonstrated that, with careful practice and use of slag covers, the small crucible furnace is quite capable of low-fume operation within the legal limits of such emissions for alloys containing up to 20 percent zinc.

Larger foundries often employ open-hearth or reverberatory-type furnaces using oil or gaseous fuel. These are charged through the end opposite to the main fuel burners or through an outside charging well. This type of furnace has been shown to produce high losses of lead and zinc fume in exit gases and heavy dust loadings of other particulate matter on account of the direct firing and large volume, and, therefore, usually high velocity, of combustion gases. The use of the reverberatory furnace is favored because of its large capacity and the ease of delivering the gases to recovery equipment.

Large foundries, particularly the large captive establishments, which may enjoy more continuous operation and low electric-energy rates, are finding the induction furnace economical under these conditions and very satisfactory in regard to metal losses and fume emissions. Temperatures are easily controlled and contamination from combustion gases is completely eliminated in the incandescent resistance-type of rocking furnace. It is well adapted to high copper-nickel alloys but not for zinc-rich alloys because of the high local temperatures around the heating element.

Procedures

Foundry procedure varies so much with different foundrymen, furnace types, and alloys that it is sometimes difficult, from the operating standpoint, to distinguish good from bad. Practice considered good at one foundry may be avoided at another. In melting high-copper alloys, for example, the copper and copper scrap may be completely melted before the zinc is added. Another foundry may favor early addition of zinc and other low-melting-point metals and may use no protective cover or flux to reduce the amount of dross formed or the loss of metal by volatilization.

From the standpoint of air pollution, however, there is now little reason to doubt that certain procedures the foundrymen may follow will reduce metal losses and air contamination and improve working conditions simultaneously. In fact, the Los

Angeles Foundrymen's Smog Committee concluded, after testing several common types of furnaces, that the greatest opportunity for reduction of air pollution in the nonferrous foundry is in more careful foundry procedure, meaning the proper control of such factors as the order in which the metals are added to the furnace, fuels used, air:fuel ratios, temperatures and overheating, and pouring and casting. The relation of these factors to air-pollution control will be discussed, giving due consideration to their relation to furnace equipment already installed.

Fuels

Virtually all fuel-fired furnaces in the Los Angeles area burn oil or gas, and use of the latter is increasing. Coke is used very little for fuel but may be employed for cover material where a reducing atmosphere must be maintained. No coal is used. Both direct- and indirect-fuel-fired furnaces are in general use, the open-flame type predominating somewhat in the large-capacity units and the indirect crucible in smaller batch operations in job foundries melting up to 500 pounds. Both have low thermal efficiency (about 15 to 20 percent).

Natural gas delivered to the Los Angeles area is virtually an ideal fuel for furnacing nonferrous metals in either open-flame or crucible-type furnaces. It contains only a few hundredths of a grain of sulfur per thousand cubic feet. Its combustion, therefore, adds no deleterious substances to the metal bath or to the exit stack gases, and furnace emissions contain no smoke or other particulate matter resulting from combustion if proper combustion conditions are maintained.

Fuel oil sold in the Los Angeles area may contain 0.05 to 2.5 percent sulfur and produces a fly ash containing vanadium, up to about 25 percent of the weight of the ash, which is unimportant metallurgically but may contribute to air pollution.

Improper combustion of fuel oil can and does contribute to air pollution through emission of smoke and soot. There is little excuse for this, either practically or economically, because combustion can be closely controlled. However, the emission of noxious sulfur compounds in exit gases cannot be avoided, except through removal of sulfur from the oil during refining or subsequent removal from the stack gas by mechanical or electrical means before release into the atmosphere. The first alternative involves rather complicated chemical procedures during oil refining, and the latter requires installation of expensive collecting equipment. The obvious solution for foundrymen is to purchase only low-sulfur fuel oil, even though it may cost more.

Some of the larger establishments are equipped to burn either oil or gas, a practice that is both efficient and economical. When both are available, the choice may depend on price.

Temperatures

The necessity for close control of temperature and the resulting benefits to quality and cost of product are well-understood by all nonferrous foundrymen. The amount of metal loss and the nature and amount of air pollution resulting from excessive melting and pouring temperatures have received much less study. Air pollution resulting from volatilization of metals from high-copper alloys during furnacing is not too serious with normal care, despite the elevated temperatures required because of the high boiling-point temperatures of copper, tin, nickel, aluminum, and even lead commonly used in such alloys. Copper-base alloys containing 20-40 percent zinc have low boiling points of approximately 2,100° F. and liquidus temperatures of approximately 1,700°-1,900° F. and are poured at approximately 1,900°-2,000° F., which is only slightly below their boiling points. Pure zinc melts at 787° F. and boils at 1,663° F. Even within the pouring range, high-zinc alloys may boil and flash the zinc to zinc oxide if the metal is exposed to open, direct flame. The zinc oxide formed is submicron in size, and its escape to the atmosphere is difficult to prevent without expensive collection equipment.

The relation of melting and boiling points to pouring temperatures is shown in figure 2 for metals and alloys used in nonferrous foundries. The boiling point of alloys containing zinc are lower roughly in proportion to the zinc content.

Slag Covers

A technique locally termed "slagging" has been perfected in the Los Angeles area nonferrous foundries in their efforts to reduce air pollution. This technique decreases the tendency of zinc and of lead in alloys to vaporize at furnace temperatures on contact with air and discharge as oxide fume with the stack gases during the melting and pouring. Slag covers found effective for this work are not a true refining flux or slags in the usual metallurgical sense, such as those formed by borax, soda, silica, lime, and similar materials. They are heavy, tenacious, inert materials, which seldom purge the alloy of undesirable impurities or affect its analysis, but they do prevent oxidation, are easily skimmed, do not tend to flow with the metal into the pouring sprue, and can be used many times. The slag will not form inclusions in the castings. In practice,[24] the slag cover on the crucible in the tilting furnace is not transferred to the pouring ladle during pouring; rather a slag cover is added directly to the ladle. For working with alloys containing more than 10 percent zinc, some foundrymen follow the practice of using one of the well-known fluxes, such as Cuprex, in the furnace crucible and a heavy tenacious cover, such as Perlox, on the pouring ladle to prevent oxidation and fuming during pouring. With melts containing less than 10 percent zinc, others used the Perlox in both melt and pour. Some success has been obtained with slags in the United States revolving-type furnace, but results are not as satisfactory as with the crucible type. Another foundry, melting brass composed of 85 percent copper, 10 percent zinc, and 5 percent lead in Fisher tilting furnaces, keeps the furnace crucible well-covered through the melting period with a 1/4- to 1/2-inch cover of Cuprex and uses Perlox to cover the metal in bottom-pour crucibles during pouring. About 1/4 pound of Cuprex per 100-pounds of melt is required.

The Nonferrous Foundrymen's Smog Committee in the Furnace Practice Manual has listed certain general rules to be observed in the use of slag covers on indirect-fired furnaces:

1. Cleanliness and order in the furnace room are of the utmost importance.

2. The selection of clean metal to melt, either ingot or scrap, which is free from oil or other combustible materials.

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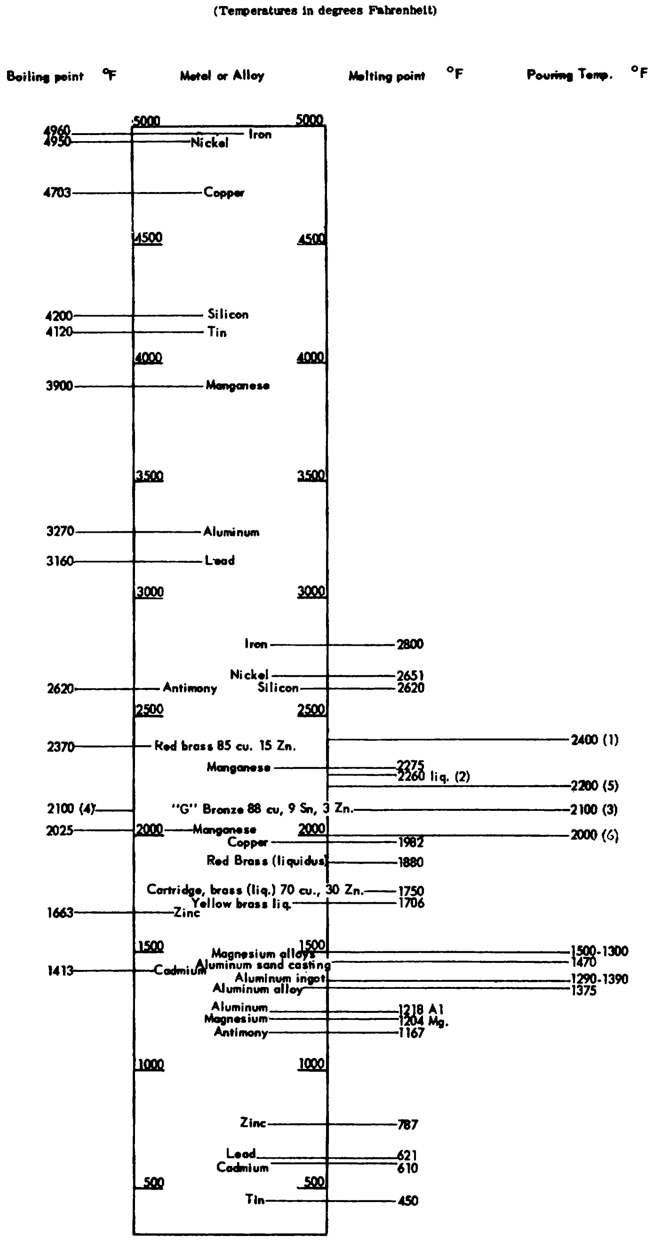
[24] Communications and field demonstrations by Robert H. Haley, Advance Aluminum & Brass Co., 1001 E. Slauson Ave., Los Angeles, to whom much credit is due for pioneering and development of slag-cover practice in the Los Angeles area.



SOURCES

Alloy compositions and pouring temperatures are from Table 1.
Melting and boiling points are from Metals Handbook, 1948 Ed.

Liq. = liquidus temperature.

(1) Hi-Ni alloy, 72.5 Cu, 22.5 Ni, 2.5 Zn. Ni-brass 60 Cu, 18 Ni, 18 Zn, 3 Sn, 1 Pb.

(2) Liq. Hi-Ni alloy, 70 Cu, 30 Ni

(3) Red brass 82, Cu, 8 Zn, 6 Pb, 4 Sn, Runs 6 and 7; red brass 85 cu, 5 Zn, 5 Sn, 5 Pb. Yellow brass, 65 Cu, 35 Zn, Runs 4 and 5.

(4) Cartridge brass, Liq. 70 Cu, 30 Zn.

(5) Hi-Pb alloy, 65 Cu, 30 Pb, 3 Sn, 2 Zn, Runs 14 and 15.

(6) Red brass 80 Cu, 10 Pb, 8 Sn, 2 Zn, Runs 9 and 10.

Figure 2. - Boiling, pouring, and melting points of metals and alloys.

Figure 3. - Nonferrous crucibles, one with cover, other without.

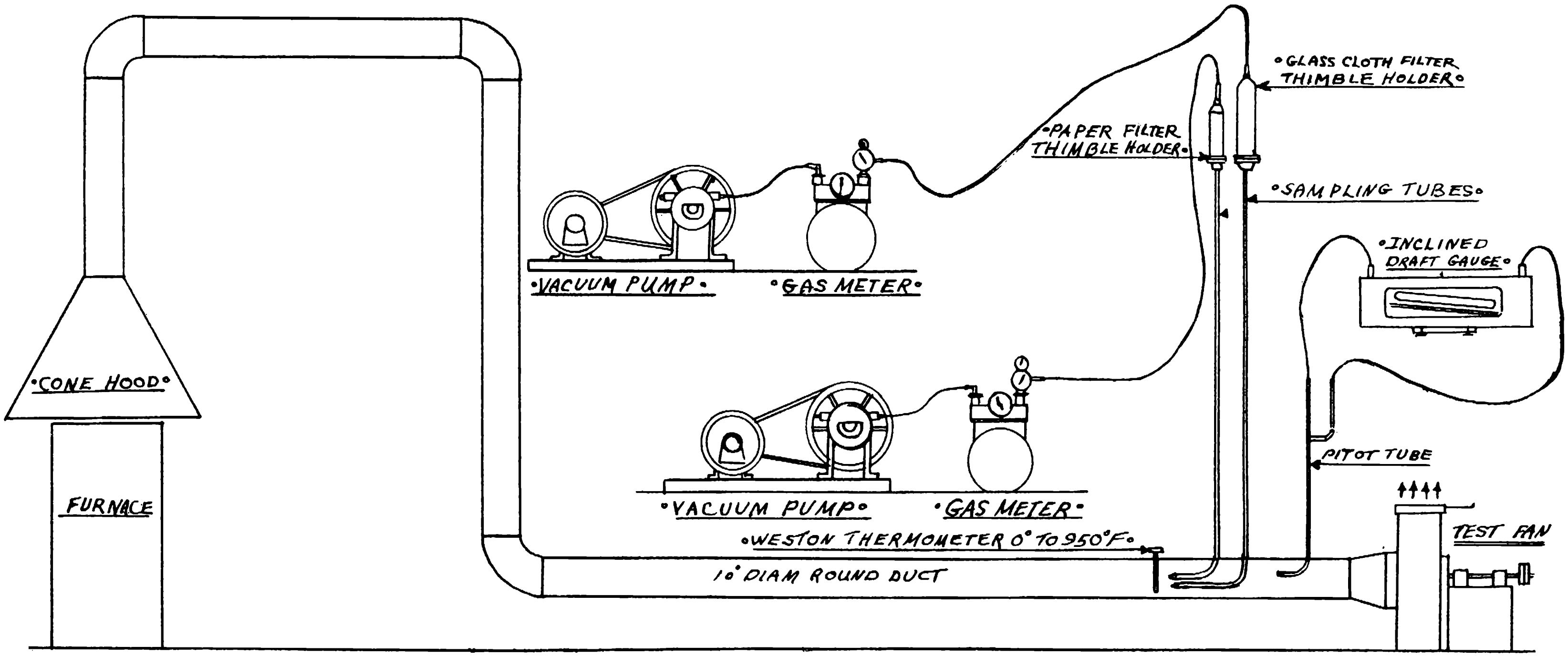


Figure 4. - Diagrammatic sketch of sampling layout for typical brass furnace. (Menardi & Co.).

3. The maintenance of proper fuel combustion by use of the correct-type burner that is adjusted properly.

4. The use of the proper amount of slag, usually 1/4 to 3/8-in. thick is all that is required as a cover. Excessive amounts of slag should not be used as this will increase the melting time, require higher temperatures, lower the life of the crucible, and be a waste of material.

5. Strict caution must be exercised to avoid getting any metal in the combustion chamber outside of the crucible.

6. Metal must be charged into the crucible as rapidly as it can be absorbed by the molten mass.

7. Metal must not be heaped on top of the furnace cover and allowed to burn down.

According to the same authority, one of the greatest difficulties in the use of slag cover has been the matter of teaching furnace operators to determine the temperature correctly. "Many furnace men misjudge the temperature, hold the metal in the furnace much longer than necessary, and often allow it to reach a temperature much higher than required."

The Nonferrous Founders' Society has produced a motion picture in color, Behold a Smoking Furnace, demonstrating the use of slag covers on the crucible-type furnace and on pouring ladles. Information concerning the use of this film can be obtained from the society. A photograph of crucibles with and without covers is shown in figure 3. Foundry magazine[25] contains an illustrated article dealing with the control of foundry fume and the use of slag covers.

Hoods and Stacks

A report made to the Nonferrous Foundrymen's Smog Committee[26] included 16 tests made in representative foundries in the area. Calculations of the volume of gases resulting from products of combustion for comparison with the total volume of dilution gases required to give satisfactory collecting efficiency of fume-control equipment and to protect the health of plant workmen are summarized in table 2. Many smaller plants were found to have no hoods, stacks, or collecting equipment whatsoever but were depending on natural drafts and roof openings to remove furnace gases and fumes.

The Air-Pollution Control District engineers and engineers[27] participating in preparation of the Nonferrous Foundrymen's report, referred to above, used a portable hood and exhaust-fan arrangement, shown in figure 4, to collect furnace gases. The air flow was adjustable from 500 to 350 c.f.m. and was operated to give just enough draft to collect all fume leaving the furnace and to provide satisfactory working conditions for furnace men. Gas volumes and the stack conditions maintained are shown in table 1, columns 33-38. Stack and hood conditions maintained in other Los Angeles foundry establishments are tabulated in table 3, columns 23-27, but gas volumes have been reduced to standard conditions at 60° F. and 29.92 inches mercury.

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[25] Haley, Robert H., How to Control Fume in Nonferrous Melting: Foundry vol. 77, No. 9, September 1949, p. 118.

[26] See footnote 18.

[27] Menardi & Co., consulting engineers, Los Angeles, Calif.

TABLE 1. - Copper-base and light metal alloys[1/]

				Alloy melted						Process weight, lb.		Time in minutes		Particulate matter									Fuel					
															Losses, lb./hr.				ZnO		Lead		Oil				B.t.u./min.	
Date, 1948	Plant No.	Make and type of furnace	Fume exhaust system	Name	Cu per-cent	Zn per-cent	Pb per-cent	Other	Pouring temp., °F.	Total wt. of charge	Per hr.	Process cycle	Length of test	Gr./cu.ft.	Actual	Allowed	Viola-tion	Percent of process weight	Gr./cu.ft.	Percent wt.	Gr./cu.ft.	Percent wt.	G.p.h.	Gravity	Percent S,	Gas c.f.m.	Produced	Lost in stack
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
Jan. 23	1	Barrel, open-flame, oscillating.	Portable hood and blower.	Red brass	85	5	5	5	2,100	600	450	80	73	0.139	3.77	1.63	Yes	0.84	0.100	74	0.007	5	4.1	12.6	1.49	-	10,100	7,100
Jan. 27	2	Crucible.	do.	Yellow brass	65	35	-	-	2,100	800	533	90	100	.105	2.75	1.85	Yes	.52	.094	89	N.D.	N.D.	-	-	-	17	16,100	11,300
Jan. 23	3	Barrel, open-flame, oscillating.	do.	Red brass	85	5	5	5	2,100	600	428	84	83	.159	4.27	1.60	Yes	1.00	.134	84	.012	8	5.1	12.6	1.49	-	12,500	8,800
Jan. 27	4	Crucible.	do.	Yellow brass	65	35	-	-	2,100	800	437	110	80	.161	4.13	1.60	Yes	.95	.155	96	N.D.	N.D.	-	-	-	15	14,300	10,000
Feb. 2	5	Open-flame, rotating barrel	Injector hood and stack.	Red brass	82	8	6	4	2,100	3,800	1,177	194	165	.122	7.93	3.09	Yes	.66	.088	72	N.D.	N.D.	19.0	15.8	1.84	-	47,000	33,000
Feb. 4	6	do.	do.	do.	82	8	6	4	2,100	3,500	1,613	130	127	.320	16.91	3.68	Yes	1.05	.180	57	.012	5	13.3	15.8	1.84	-	32,600	22,800
Feb. 10	7	Open-flame, tilting-kettle type.	Canopy hood and stack.	Red brass 14	80	2	10	8	1,900 and 2,100	2,500	1,250	120	113	.061	10.85	3.19	Yes	.87	.008	14	.018	29	37.0	32.6	.80	-	90,500	63,500
Feb. 10	8	do.	do.	do.	73	1	18	8	1,900 and 2,100	2,500	1,250	120	113	.095	18.03	3.19	Yes	1.44	.017	18	.026	28	43.0	32.6	.90	-	105,000	74,000
Feb. 12	9	do.	do.	do.	73	1	18	8	1,900 and 2,100	2,500	833	180	177	.086	13.75	1.65	Yes	1.65	.027	31	.015	18	34.0	32.6	.80	-	83,000	58,000
Arithmetic averages, brass					76.7	11.1	9.9	-	2,078	1,956	886	123.1	115	.139	9.15	2.39	Yes	.998	.089	59.4	.015	15.5	22.2	-	1.29	-	45,678	32,056
						Copper - nickel alloys																						
Jan. 23	10	Electric arc.	Portable hood and blower.	High Ni alloy	75	2.5	0	25	N.D.	400	325	74	68	.065	.40	1.28	No	.12	.057	87	N.D.	N.D.	-	-	-	-	8,500	N.D.
Jan. 12	11	Pit crucible.	Portable hood and blower, slag cover.	Ni brass	60	18.0	1	18	2,400	300	256	70	50	.020	.59	1.05	No	.23	.012	60	N.D.	N.D.	-	-	-	7.3	7,000	4,900
Feb. 12	12	do.	do.	do.	60	18.0	4	18	2,400	300	231	78	78	.023	.40	.96	No	.42	.012	54	.002	7	-	-	-	5.4	5,100	3,500
Arithmetic averages, copper-nickel alloys					65	12.8	16.7	20.3	2,400	333	271	74	65.3	.036	.46	1.10	No	.257	.027	67	-	-	-	-	-	6.35	68,666	4,200
						Copper - lead alloys																						
Feb. 13	13	Tilting crucible.	Hood and stack.	High Pb alloy	65	2	30	3	2,200	800	343	140	140	.024	.44	1.32	No	.13	.002	8	.012	51	-	-	-	9.8	9,400	6,500
Feb. 14	14	do.	do.	do.	65	2	30	3	2,250	841	315	160	160	.049	1.04	1.25	No	.33	.002	5	.030	62	-	-	-	10.0	9,500	6,600
Arithmetic averages, copper-lead alloys					65	2	30	3	2,225	820	329	150	150	.036	.74	1.285	No	.23	.002	6.5	.021	56.5	-	-	-	9.9	9,450	6,550
						Light metals - alloys																						
Feb. 9	15	Pit crucible.	Portable hood and blower.	Aluminum	See col. 40	-	-	-	1,500	350	108	194	194	.0003	.01	.49	No	.01	N.D.	N.D.	N.D.	N.D.	-	-	-	22.0	21,800	14,500
Feb. 20	16	Crucible.	do.	Magnesium	N.D.	3	N.D.	6	1,425	300	217	83	36	.002	.05	.91	No	.02	N.D.	N.D.	N.D.	N.D.	-	-	-	13.2	12,500	8,800
Arithmetic averages, light metals alloys					-	-	-	-	-	325	162	138.5	115	-	.03	.70	No	.015	N.D.	N.D.	N.D.	N.D.	-	-	-	17.6	17,150	11,650

[1/] Source: Nonferrous Foundrymen's Smog Committee Report of April 1948.
N. D. indicates no data given or available.

TABLE 1. - Copper-base and light metal alloys[1] (Cont.)

Date, 1948	Plant No.	Make and type of furnace	Fume exhaust system	Orsat gas analyses, percent			Stack diam., in.	Temp., F.	Press., in. Hg	Velocity, ft./sec.	Gas flow c.f.m.	Comb. prod., c.f.m. at 3,000	Dilution ratio	Remarks
				CO_2	O_2	CO								
1	2	3	4	30	31	32	33	34	35	36	37	38	39	40
Jan. 23	1	Barrel, open-flame, oscillating.	Portable hood and blower	N.D.	N.D.	N.D.	12.0	270	29.6	67.3	3,170	See 828 (col. 40)	3.8	Col. 9, Sn 5%. Col. 20, ZnO was 0.21 gr./cu. ft. for 20 min. during pouring; Col. 34, temperatures after dilution in Col. 39; Col. 38, volume of products of combustion; Col. 39 is Col. 37 divided by Col. 38.
Jan. 27	2	Crucible.	do.	N.D.	N.D.	N.D.	12.0	450	29.9	65.0	3,060	1,260	2.4	Col. 20, ZnO concentration average 0.395 gr./cu. ft. during 45 min. preceding the end of pouring.
Jan. 23	3	Barrel, open-flame, oscillating.	do.	N.D.	N.D.	N.D.	12.0	330	29.6	66.6	3,140	1,030	3	Col. 9, Sn 5%; Col. 20, Zn added 24 min. before end of pouring. ZnO concentration increased to 60 gr./cu. ft. for 10.5 min.
Jan. 27	4	Crucible.	do.	N.D.	N.D.	N.D.	12.0	400	29.9	63.5	3,000	1,120	2.7	Col. 20, second addition of Zn just before pouring began increased ZnO concentration to 1.43 gr./cu. ft. for 12 min.
Feb. 2	5	Open-flame, rotating barrel.	Injector hood and stack.	2.4	N.D.	0.0(?)	24.5	560	29.6	38.7	7,600	3,860	2.0	Col. 3, U. S. furnace; Col. 9, Sn; Col. 20, 98 min. after beginning test ZnO concentration increased to 0.17 gr./cu. ft. and to 0.23 during pouring. Some fume escaped at front end. Col. 32, CO believed too low.
Feb. 4	6	do.	do.	1.5	18.2	.0(?)	24.5	450	29.6	31.5	6,180	2,670	2.3	Col. 20, 34 min. after start of test ZnO concentration 0.38 gr./cu. ft.; at 85 min. reached 0.73 gr.; 25 percent of ZnO fume lost at front end of furnace.
Feb. 10	7	Open-flame, tilting-kettle type.	Canopy hood and stack.	N.D.	N.D.	N.D.	36.0	360	29.6	49.0	20.800	7,430	2.8	Col. 3, Schwartz; Col. 9, Sn; ZnO increased to 0.014 gr./cu. ft. during pouring; Col. 22, Pb in fume almost constant during test.
Feb. 10	8	do.	do.	.4	19.8	N.D.	36.0	396	29.6	52.3	22,200	8,650	2.6	Col. 9, Sn; Col. 22, Pb concentration in stack gas reached 0.036 gr./cu. ft. 50 min. after start of test and remained high about 40 min., decreased to 0.011 during 26 min. pour. Col. 30, believed too low.
Feb. 12	9	do.	do.	.6	19.2	.0(?)	36.0	368	30.2	44.2	18,700	6,800	2.8	Col. 30, ZnO average 0.036 during first 30 min. and 0.044 after 125 min.; Col. 22, Pb 0.025 and 0.031 after 150 min. and dropped to 0.015 during last 30 min. Col. 30, believed too low.
Arithmetic averages, brass				-	-	-	-	398	29.73	53.1	9,761	3,739	2.71	
Jan. 23	10	Electric arc.	Portable hood and blower.	N.D.	N.D.	N.D.	12	107	29.6	15.4	725	N.D.	N.D.	Col. 9, Ni 25%; Col. 18, no violation.
Jan. 12	11	Pit crucible.	Portable hood and blower, slag cover.	N.D.	N.D.	N.D.	12	197	30.2	72.9	3,440	544	6.3	Col. 9, Ni 18%; Col. 20, crucible had slag cover through entire test, metal losses low.
Feb. 12	12	do.	do.	N.D.	N.D.	N.D.	12	225	30.2	43.1	2,030	395	5.1	Col. 9, Ni. 18%; Col. 20, crucible had slag cover; average ZnO in fume during first 45 min. of test was 0.029. Col. 37, average two tests.
Arithmetic averages, copper-nickel alloys				-	-	-	-	176	30.0	43.8	2,735	469.5	5.8	
Feb. 13	13	Tilting crucible.	Hood and stack.	.3	18.9	.0(?)	18	362	30.0	20.3	2,150	730	2.9	Col. 3, Fisher; Col. 9, Sn3%.
Feb. 14	14	do.	do.	N.D.	N.D.	N.D.	18	315	30.0	23.5	2,490	780	3.2	Col. 3, Fisher; Col. 9, Sn; Col. 22, Sn 3%; after 120 min. the temperature was raised 50° and Pb loss increased.
Arithmetic averages, copper-lead alloys				-	-	-	-	339	30.0	21.85	2,320	755	3.05	
Feb. 9	15	Pit crucible.	Portable hood and blower.	N.D.	N.D.	N.D.	12	460	29.6	82.0	3,860	1,620	2.4	Col. 5, Zn, Mg, etc. about 2%; Si 7%, balance Al; metal losses insignificant.
Feb. 20	16	Crucible.	do.	N.D.	N.D.	N.D.	12	395	30.0	56.2	2,650	980	2.7	Col. 9, Al 6%, Mg 91; Col. 34, first melt; second melt 450 .
Arithmetic averages, light metals alloys				-	-	-	-	427.5	29.8	69.1	3,255	1,300	2.55	

[1] Source: Nonferrous Foundrymen's Smog Committee Report of April 1948.
N.D. indicates no data given or available.

TABLE 2. - Average gas volumes produced by nonferrous foundry furnaces

Col. No.	1	2	3	4	5	6	7
			Exit gas				
Line	Alloy	Furnace charge per cycle, lb.	C.f.m. stack condition	Temp., °F.	C.f.m. per M lb. of charge	Combustion gases per M lb. of charge	Ratio $\frac{\text{Col. 5}}{\text{Col. 6}}$
1	Red and yellow brasses	700	3,092	363	4,418	1,514	2.9
2	do.	2,960	15,100	427	5,100	1,987	2.57
3	Ave., weighted ..	1,956	9,761	398	4,990	1,920	2.61
4	High-Pb alloy	820	2,320	339	2,840	920	3.1
5	High-Ni alloy	300	2,735	211	9,120	1,567	5.8
6	Brasses	1,660	9,842	323	5,925	N.D.	N.D.

Source: Lines 1-5 incl. are averages calculated from table 1; data in line 6 are averages from table 3.
N.D. indicates no data available.

Most plants having hooded furnaces had exhaust systems incapable of removing enough gases to maintain suitably low concentrations of noxious fumes in furnace rooms.

Effective types of hoods for tilting furnaces are shown in figures 5, 6, and 7. Pouring metal from a crucible furnace without a fume hood is shown in figure 8. Figure 5 illustrates an ingenious hooding device for tilting crucible furnaces; an effective procedure for its use in conjunction with industrially available recovery equipment has been developed for one of the large brass foundries in the area.[28] Capitalizing on the fact that complete collection of the heavy fume given off during pouring would reduce particulate matter enough, under routine operating procedures, to meet Air-Pollution Control District requirements, the simple and effective exhaust hood shown in the illustration has been developed.

The exhaust hooding fits into the pouring lip of the furnace and normally collects fume only during pouring. The hood is provided with a damper that is closed during the firing period. The damper opens automatically as the furnace is tilted to the pouring position and closes again as the furnace is righted. The mechanical design is such that the hooding, of course, moves freely with the furnace but is quickly and easily detached for furnace inspection or repairs.

The device reportedly has reduced emission of particulate matter from each furnace from something over 2 pounds an hour to about 0.125 pound an hour. The process weight per furnace limits the permissible emission of particulate matter to 1.8 pounds per hour from each furnace. As so often happens in fume-control investments, the company has benefited in several ways: It operates well within Air-Pollution Control District requirements; metal pouring is easier and is done with less spillage; working conditions and efficiency are much improved; and other savings are expected to repay the cost of the improvement in a few years.

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[28] Western Metals, Repcal Brass Mfg Co. Installs Unique Fume Control System: March 1950, p. 32.

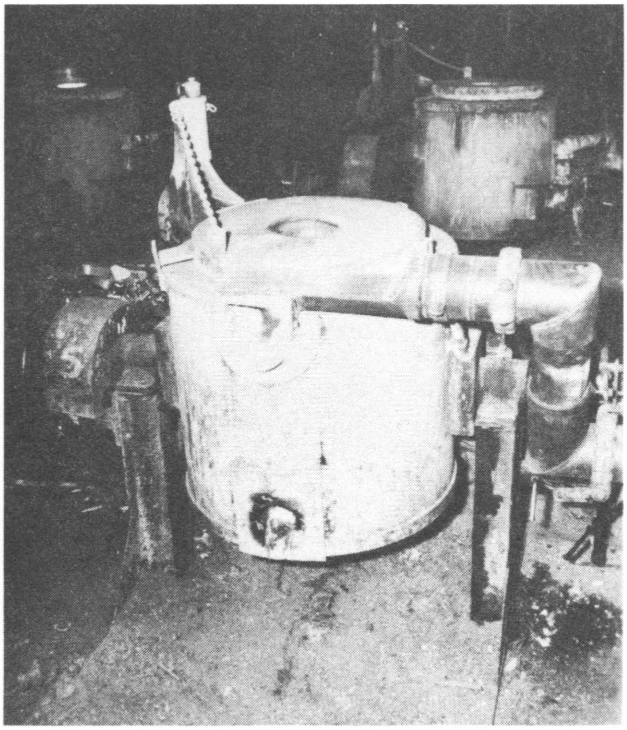

Figure 5. - Fume hood for tilting crucible furnace. (Courtesy of Repcal Brass Mfg. Co. and Western Metals magazine.)

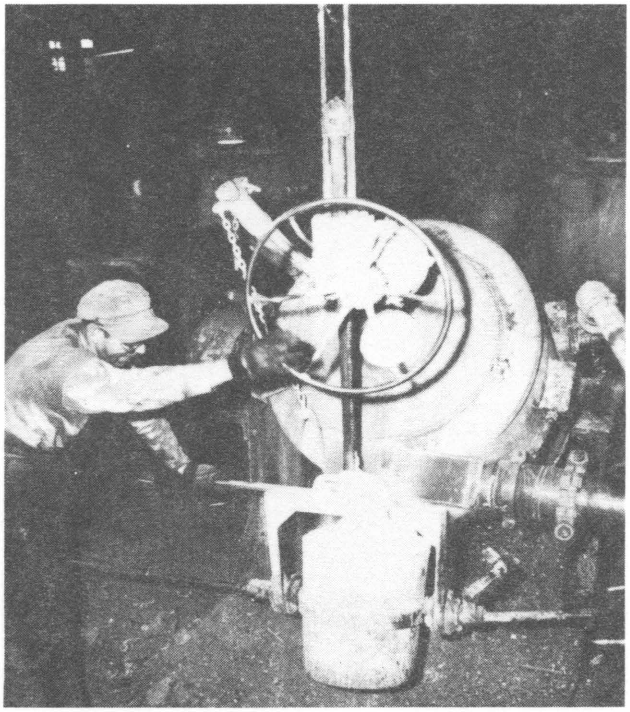

Figure 6. - Pouring metal from crucible furnace with fume hood. (Courtesy of Repcal Brass Mfg. Co. and Western Metals magazine.)

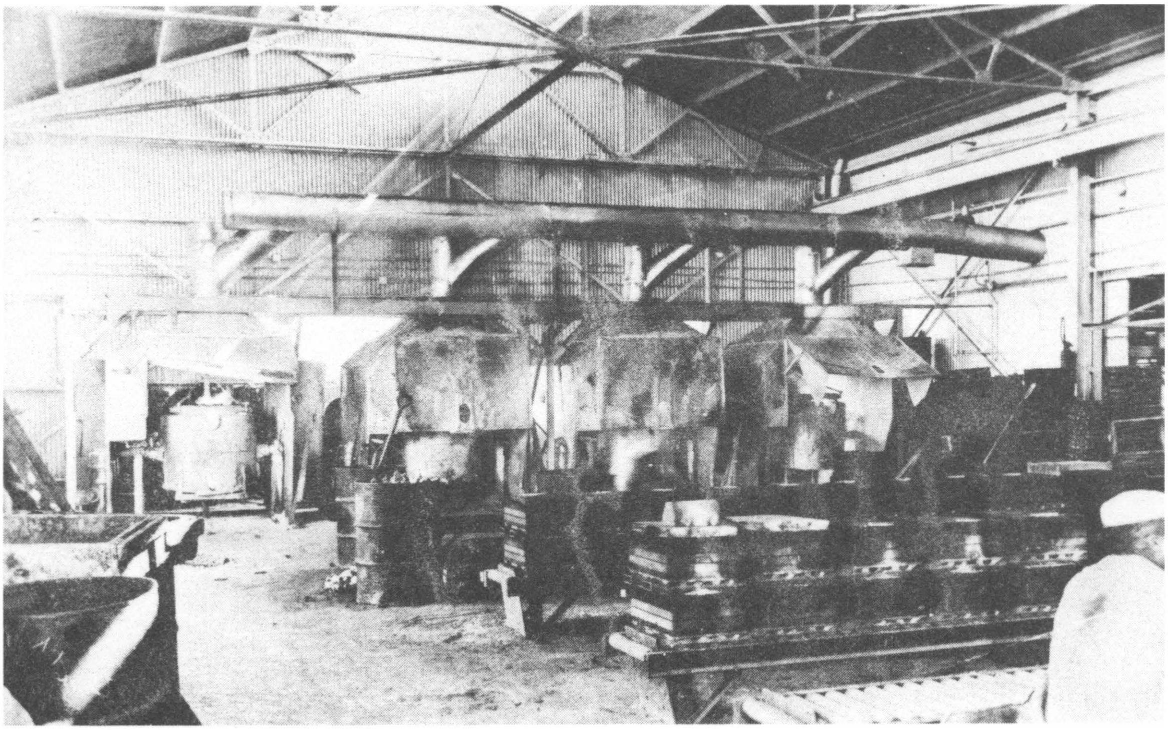

Figure 7. - Hood and duct system collecting fumes from brass furnaces for delivery to glass-bag filters.

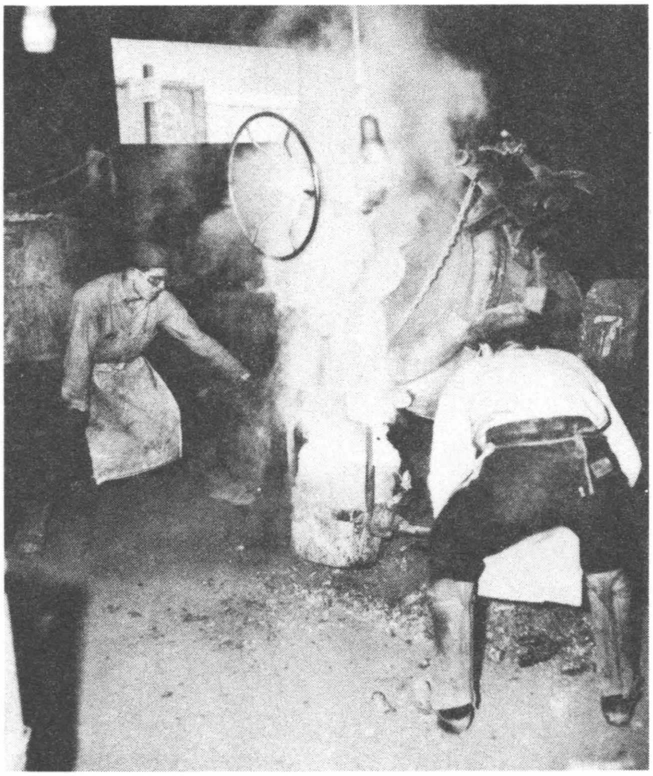

Figure 8. - Pouring metal from crucible furnace without fume hood. (Courtesty of Repcal Brass Mfg. Co. and Western Metals magazine.)

TABLE 3. - Nonferrous metallurgical plants[1]

Date, 1949	Plant No.	Collection equipment installed	Equipment tested	Process cycle, in min.	Length of test, in min.	Process weights, lb.			Particulate matter					Product				Furnace	
						Per hr.	Total charge	Composition	Gr./cu. ft.	Losses, lb./hr.		Percent of process weight	Violation	Composition, percent				Make, type, etc.	Fuel and est. rate
										Actual	Allowed			Cu	Sn	Pb	Zn		
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Apr. 27	1	No	Stack No. 4 furnace	125	60	1,104	2,300	See col. 35	0.771	22.50	2.97	2.04 (See col. 35)	Yes	85	5	5	5	U.S. rotary, direct oil-fired.	Oil
Mar. 25	2 Test No. 1	No	Stack No.1 furnace	114	77	1,267	2,408	do.	.269	26.10	3.21	2.06	Yes	Scrap brass	N.D.	N.D.	4.5	Hawley-Schwartz tilting.	Oil 35 g.p.h.
Aug. 3	3 Test No. 4	No	do.	98	60	1,500	2,445	do.	.171	22.20	3.54	1.48	Yes	80	7	13	See col. 35	do.	do.
June 28	4 Test No. 2	No	do.	100	60	1,465	2,441	do.	.160	15.60	3.49	1.06	Yes	N.D.	N.D.	N.D.	do.	do.	do.
Aug. 4	5	No	Vent stack No. 7 furnace. (See col. 35.)	95	76	700	1,103	do.	.0412	2.84	2.24	.41	Yes	81	3	7	9	Fisher gas-fired crucible tilting.	Gas
Aug. 8	6 Test No. 2	No	Vent stack No. 7 furnace.	107	108	620	1,103	do.	.022	1.47	2.05	.24	No	N.D.	N.D.	N.D.	N.D.	do.	do.
Apr. 5	7	No	Vent stack No. 2 furnace.	123	60	700	1,433	do.	.198	1.16	2.24	.17	No	See col. 35	N.D.	N.D.	N.D.	U.S. rotary, No. 3.	Oil N.D.
May 16	8	No	Vent stack tilting furnace.	91	60	462	700	do.	.033	.75	1.66	.16	No	do.	N.D.	N.D.	N.D.	Tilting gas-fired crucible.	Gas 25 c.f.m.
July 6	9	No	Vent stack No. 2 Schwartz furnace.	95	60	645	1,022	do.	.242	3.69	2.11	.57	Yes	do.	N.D.	N.D.	N.D.	Schwartz oil-fired.	Oil 0.25 g.p.m.
Arithmetic average of plants 1 - 9 inclusive				105	69	940	1,661	-	.212	10.70	2.61	1.14 (See col. 35)	-	-	-	-	-	-	-
1948 Oct. 22	10	Yes	Venturi-type scrubber pilot plant.	N.D.	10	N.D.	N.D.	-	See col. 27-34	-	-	-	-	Brass	N.D.	N.D.	N.D.	N.D.	N.D.
May 23	10a	Yes	Dynamic wet	130	60	924	2,000	Scrap brass.	.367	3.00	2.67	.32	Yes	do.	N.D.	N.D.	N.D.	U.S. rotary No. 1 direct oil-fired.	Oil 30 g.p.h.
Aug. 8	11	Settling chamber	Vent stack of three induction furnaces.	35-40	60	1,580	993 See col. 35	See col. 35	.031	3.47	3.64	.22	No	60	See col. 35	2	38	Ajax induction, holds 2,400 lb. and pours 1,200 in 45 min.	Electric
Sept. 23	12	Yes	Baghouse, glass bags.	1,240	60	2,066	14,434	Brass scrap.	.0042	.223	7.48	.01	No	See col. 35	N.D.	N.D.	N.D.	Two reverberatory.	Gas
July 7	13	Yes	Vent stack from packed tower.	105	60	1,140	2,000	See col. 35	.125	2.33	3.03	.20	No	N.D.	N.D.	N.D.	N.D.	Small gas-fired reverberatory.	do.

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[1] Source: Air Pollution Control District of Los Angeles County.
[2] Proprietary flux.
N.D. indicates no data given or available.

TABLE 3. - Nonferrous metallurgical plants[1] (Cont.)

Date, 1949	Plant No.	Collection equipment installed	Equipment tested	Flue and gas conditions								Collector equipment tested						Remarks
				Source of gas tested	Phase of process cycle covered by test	Gas press, in. Hg	Flue diam., in.	Temp., °F.	Vel., av. ft./sec.	Vol., s.c.f.m.	Spray water rate, g.p.m.	Gas volume, s.c.f.m.		Dust loading, gr./s.c.f.	Total dust, lb./hr.		Eff., percent	
												Inlet	Outlet		In	Out		
1	2	3	4	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
Apr. 27	1	No	Stack No. 4 furnace	Vent stack of No. 3 furnace	Melting period.	29.92	24	500	33.4	3,400 Outlet	-	No collectors in use						Col. 9, charge of scrap valves, 1,500 lb.; scrap brass, 500; brass gates, 300; flux 15. Col. 13 is (Col. 11 divided by Col. 7) 700. Col. 20, 30 gal./heat.
Mar. 25	2 Test No. 1	No	Stack No. 1 furnace	Vent stack of No. 1 furnace	Last 77 min. of melt.	29.92	36.0	275	37.7	11,300 Outlet	-			do.				Col. 3, hood above furnace is 74 x 155 in. Col. 9, scrap brass includes, 5 lb. Kolux and 3 lb. Rittlow flux.
Aug. 3	3 Test No. 4	No.	do	do.	Last 60 min. of melt.	29.92	36	297	38.3	11,150 Outlet	-			do.				Col. 9, charge 6-lb., phos-copper; 1,742, engine and machine scrap; 683, castings; 14, Kolux flux. Col. 18, bearing bronze.
June 28	4 Test No. 2	No	do.	do.	do.	29.92	36	270	37.6	11,350 Outlet	-			do.				Col. 2, Test No. 3 was a blank, no charge or heat, only blast gave 0.94-lb. loss per hour with no Pb content. Col. 9, Phos., Cu 6 lb.; scrap, Cu 200; engine and machine scrap, 1,142; Sn, 26, boring ingot 1,067 lb. Col. 11 solid was 23.0% Pb. Col. 18, bronze.
Aug. 4	5	No	Vent stack No. 7 furnace. (See col. 35.)	Vent stack.	Last 76 min. of melt.	29.92	52 x 54	182	85.2	8,060 Outlet	-			do.				Col. 3, no stack; improvised curtains from furnace to 52 x 54-in. opening in roof; test on Cuprex flux, 3 lb.; Col. 9 gates, 400 lb.; ingot, 700; Cuprex 3; Col. 15, semi-red brass.
Aug. 8	6 Test No. 2	No	Vent stack No. 7 furnace.	do.	Last 88 min. of melt.	29.92	52 x 54	170	8.1	7,820 Outlet	-			do.				Col. 9, test of P-F special No. 1 flux, 3-lb. on 400 lb. gates, 700 ingot.
Apr. 5	7	No	Vent stack No. 2	do.	Last 60 min. of melt.	29.92	22	786	10.3	682 Outlet	-			do.				Col. 9, brass gates and foundry rejects; one-half of charge plus 20 lb. glass melted, then rotation started. Balance of charge and 6 lb. flux added. Small additions glass after each hour. Col. 15, brass.
May 16	8	No	Vent stack tilting furnace.	do.	do.	29.92	29	154	11.4	2,650 Outlet	-			do.				Col. 9, Cuprex flux 6 pieces added with first metal charged. No visible fume. Col. 15, brass.
July 6	9	No	Vent stack No. 2 Schwartz furnace.	Vent stack of No. 2 furnace.	do.	29.92	16	274	30.1	1,780	-			do.				Col. 9, brass scrap 997 lb., lead 20, Cuprex 5. Col. 15, brass.
Arithmetic average of plants 1 - 9 inclusive				-	-	29.92	-	323	325	6,466	-							
1948 Oct. 22	10	Yes Yes	Venturi-type scrubber pilot plant.	In and out stacks.	Melting	29.92 in 29.92 out	12 in 10 out	396 in 97 out	30.1 in 38.2 out	860 Inlet 1,170 Outlet	7.6 -	860 -	- 1,170	2.71 in .704 out cyclone	19.95 -	- 7.04	65 -	Col. 27, 1,418 cu. ft. stack condition. Col. 30 water to venturi; none for cooling ahead of venturi or in following cyclonic scrubber unit.
May 23	10a	Yes Yes	Dynamic wet	Scrubber stack.	do.	29.92 in 29.92 out 29.92 out	8.00 8.75 8.75	858 50	93.0 9.3	770 Inlet 954 Outlet	20 -	770 (dry)	954	.905 in .367 out	5.97 -	- 3.00	50	Col. 4, test on pilot wet scrubber on split of gas stream.
Aug. 8	11	Settling chamber.	Vent stack of three induction furnaces.	Vent stack of 3 furnaces.	60 min.	29.92	48	84	18.1	13,000 Outlet	N.D.	Adequate hooding over furnaces. Individual blowers on each furnace. Gas passes to concrete settling chamber before entering stack.						Col. 7 and 9, No. 2 furnace; 875 clean scrap brass, 1.5 lb. phos; heat held 16 hr. before pour account of mold trouble; No. 3 furnace 1,106 lb. scrap and 2 lb. Pb; Col. 16, No. 240 brass; Col. 22, sample on all of one cycle of No. 3 plus fume from No. 2 banked furnace.
Sept. 23	12	Yes	Baghouse, glass bags.	Baghouse exit.	Melting. (See col. 35.)	29.92	24	325	48.4	6,160 Outlet	Heat exchanger.	N.D.	6,160	N.D. in .0042 out	N.D. in -	- .223 out	- N.D.	Col. 28, cooling-jacket water circulated to cooling tower. Col. 15, brass ingot. Col. 4 only four of the five sections were in use during test, or 80% of capacity. Col. 22, test included lancing period.
July 7	13	Yes	Vent stack from packed tower.	Vent of 2 scrubbers, (See col. 35.)	Last 60 min.	29.92	24	97	12.4	2,180 Outlet	1.6-3.0	N.D.	2,180	N.D. in .125 out	N.D. in -	- 2.33 out	- N.D.	Col. 9, reclaiming typemetal from typemetal scrap and dross. Col. 21, two coke-packed scrubbers in series.

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[1] Source: Air Pollution Control District of Los Angeles County.

[2] Proprietary flux.

N.D. indicates no data given or available.

Stack Effluents

Stack effluents consist of the gases resulting from combustion of fuels, process gases, air, and particulate matter in the form of dust and fume. Excess air is drawn into hoods and stacks to insure adequate collection of fumes that may escape from the furnace and to reduce exit gas temperatures for ease of handling and treatment. The particulate matter making up the dust load varies in nature and amount depending on the alloy constituents and foundry practices in matters of fuels, temperatures, type of furnace, and other factors already mentioned. In addition to the ordinary solid particulate matter, such as fly ash, carbon, and mechanically produced dust, furnace emissions, of course, often contain fumes resulting from the condensation of the more volatile elements, zinc, sulfur, lead, and others.

The control and satisfactory disposal of waste stack emissions have been the subject of extensive theoretical and field investigations,29/ but most of this information was not directly applicable to nonferrous foundry equipment and practice. The Nonferrous Foundrymen's Smog Committee, individual concerns, engineers, and equipment manufacturers, therefore, found it necessary to conduct extensive investigations of emissions from medium and small foundries. Procedures had to be devised for sampling, and techniques were developed for determining the physical characteristics of submicron emissions from nonferrous foundries.30/

Gases of Combustion

Orsat analyses of stack gases used to compute the heat units produced in several furnace tests are reported in table 1, columns 30 and 31. These are not believed to be representative of the products of combustion, since it appears that the gases have been diluted with large quantities of air. Other tests (not reported) on open-flame kettle-type furnaces similar to the one reported in table 1, plant 9, yielded 11.2 percent CO_2 and 3.1 percent oxygen.

Pouring temperatures for red brasses averaged about 2,100° F., for high-lead alloys, 2,200° F., and for high-nickel alloys 2,400° F., within the narrow ranges shown in table 1, column 10. To attain these pouring temperatures furnace gases had to be held at temperatures from 2,500°-3,500° F., and large volumes of gas per unit of product were required.

A comparison of gas volumes at stack conditions for foundry furnace charges of various sizes and alloys is shown in table 2. Data are for copper-base alloys. The volumes in column 5 are for the most part the minimum found that will give adequate collection efficiency.

Air:Fuel Gas Ratios

The ratio of total volume of exit gas to the volume of gases produced by combustion, as shown in table 2, column 7, lines 1-4 inclusive, at 2.6 - 3.1 appear

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29/ Thomas, M. D., Hill, G. R., and Abersold, J. N., Dispersion of Gases from Tall Stacks: Ind. Eng. Chem., vol. 41, No. 11, November 1949, pp. 2409-2417.
Church, Phil E., Dilution of Waste Stack Gases in the Atmosphere: Ind. Eng. Chem., vol. 41, No. 11, November 1949, pp. 2493-2493C.

30/ McCabe, L. C., Mader, P. P., McMahon, H. E., Hamming, W. V., and Chaney, A. L., Industrial Dusts and Fumes in the Los Angeles Area: Ind. Eng. Chem., vol. 41, No. 11, November 1949, pp. 2486-2492.

quite consistent for the several types and capacities of furnaces. The pit-crucible furnace on high nickel-copper alloys appears to be the exception at 5.8. These relations are significant in localities where allowable limits of particulate matter in stack emissions are based on the concentration in grains per cubic foot of gas (volume rate of emission) rather than on the mass rate.[31] In the former, legal requirements could often be met by simple dilution rather than by reduction or elimination of the nuisance. Dilution ratios are also significant in relation to health conditions in the furnace room melting alloys containing high lead and zinc contents.

Sulfur Dioxide

Excluding carbon gases, oxygen, and nitrogen, the most abundant gas in copper-alloy furnace stacks is sulfur dioxide. It originates for the most part from the sulfur in the fuel oil. Table 1, column 26, shows an average of 1.3 percent sulfur in California fuel-oil mixtures used in brass foundries and a maximum of 1.8.

According to the Nonferrous Foundry Report,[32] each percent of sulfur in the oil will produce 0.06 percent sulfur dioxide in the gaseous products of combustion. Thus, oil containing 1.8 percent sulfur would produce combustion gases with 0.11 percent SO_2 or about 0.04 SO_2 in the diluted stack gas. A concentration of 0.2 percent, by volume, at the point of discharge is permitted in Los Angeles. Control standards and regulations in Los Angeles County relating to sulfur gases are contained in appendix A of this report.

No nonferrous foundry test reported in Los Angeles has indicated SO_2 concentrations approaching the maximum limit. Fuel oil, however, is extensively used in industry; and, in the aggregate, the air pollution resulting from the use of high-sulfur oil could be very appreciable. Foundrymen in the area have been advised by their trade association to avoid the use of fuel oils containing high percentages of sulfur and have recommended the use of gas where available because of the greater ease of maintaining the proper conditions of combustion.

Disposal of strictly gaseous constituents of nonferrous foundry stack emissions has proved to be only a minor problem where proper conditions are maintained for complete combustion of the fuels and adequate hoods and stacks are provided. Improper combustion, of course, results in emission of smoke, which is a civic, and sometimes a legal nuisance, as well as an avoidable expense. Control of solid constituents in nonferrous foundry gases has proved to be a much greater problem.

Particulate Matter

Particulate matter has been technically and legally defined[33] but for the purposes of this section may be said to consist mostly of solids in the forms of dust and condensed metallic fumes. In the copper-base-alloy foundries, up to 98 percent of the particulate matter contained in furnace-stack gases may be zinc oxide and

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[31] McCabe, L. C., and others, Dust and Fume Standards: Ind. Eng. Chem., vol. 41, No. 11, November 1949, pp. 2486-2492.

[32] Industrial consultants, Report on the Air Contaminants Produced by Furnaces in the Nonferrous Foundry Industry: April 1948.

[33] McCabe, L. C., and others, Dust and Fumes Standards: Ind. Eng. Chem., vol. 41, No. 11, November 1949, p. 2388 and appendix A, rule 2.

lead, depending on the composition of the alloy. The zinc oxide content of fume averaged for representative red and yellow brass foundry furnaces as shown in table 1, column 21, was 59 percent. Similarly, the lead content, column 23, averaged 15 percent and ranged from 5 to 29 percent. In high-lead alloys, lead constituted 56 percent of the particulate matter in the exit gas. Lesser constituents of fumes, such as tin, copper, cadmium, silica, and carbon, also may be present in varying amounts, depending upon the composition of the alloy and on foundry practice. Their aggregate percentage weights may be estimated roughly by deducting the percentages in column 21 and 23, table 1, from 100. For practical purposes the weight of particulate matter from fuel-fired brass furnaces can be estimated quite safely at about 1 percent of the process weight entering the melt, as shown in tables 1 and 3. This is substantiated by the practice of adding 0.5 to 1.0 percent zinc, depending on the composition of the alloy, to furnace charges to offset losses. This addition of zinc usually is made late in the cycle of operations. The matter of metal losses is discussed in detail in comprehensive papers by Pratt[34/] ans St. John.[35/]

Generally speaking, crucible furnaces far outnumber all others used in brass foundries pouring sand castings. However, probably 95 percent of the melting and alloying of wrought copper alloys is done in electric furnaces.[36/] This relationship was not determined for the Los Angeles area. In both classes of work, the metal losses in the electric furnace are lower by about 0.1 to 0.5 percent of process weight. Most of the tests on Los Angeles brass furnaces in tables 1 and 3 were on furnaces pouring sand castings. Indirect-fired crucible furnaces show the lowest average metal loss for fuel-fired furnaces, other factors remaining the same. Open-flame rocking or tilting furnaces can be operated with low metal losses with care, but grain loadings per cubic foot tend to be higher than with crucibles, as shown in tables 1 and 3. Average losses, in percentage of process weight, are very nearly the same. The Los Angeles Nonferrous Foundrymen's Committee[37/] has concluded that "it is improbable that any open-flame furnace melting alloys containing zinc and lead can be operated without creating excessive emission. It is conceded that anyone choosing to operate that type of furnace will be required to install collection equipment."

Dust loading of foundry exit gases varies so widely with furnace conditions and alloys and alloying constituents that averages are of limited significance. Table 1, column 15, shows loadings of 0.061 to 0.320, which average 0.139 grain per cubic foot for red and yellow brasses at stack conditions. High-nickel and high-lead alloys average 0.036 grain per cubic foot. Under a wide variety of conditions, the average in table 3, column 10 was 0.212 for brasses and limits are 0.022 to 0.771 grain per cubic foot.

The Report on the Air Contaminants Produced by Furnaces in the Nonferrous Industry summarizes four principal factors causing high concentrations of zinc fumes in foundry furnace gases, as follows:

[34/] Pratt, R. S., Melting and Alloying of Wrought Copper-Alloys: Nonferrous Melting Practice, Am. Inst. Min. and Met. Eng., 1946, pp. 62-73.

[35/] St. John, H. M., The Melting of Brass and Bronze in the Foundry: Am. Inst. Min. and Met. Eng., 1946, pp. 47-61.

[36/] American Institute of Mining and Metallurgical Engineers, Nonferrous Melting Practice: 1946, p. 63.

[37/] Nonferrous Foundrymen's Smog Committee, Furnace Practice Manual: Los Angeles, Calif., p. 5.

1. Alloy composition - The rate of loss of zinc will be approximately proportionate to zinc percentage in the alloy.

2. Pouring temperature - For a given percentage of zinc an increase of 100° F. will increase the rate of loss of zinc about three times.

3. Type of furnace - Direct-fired furnaces will produce higher concentration than crucible type, other conditions being equal.

4. Poor foundry practice - Overheating of charge, addition of zinc at maximum temperature of furnace, use of insufficient covering of flux, etc.

Perhaps one of the best ways to understand the difficulty attending proper control of fumes from metallurgical furnaces is to consider their physical characteristics. Examination of fume under the electron microscope[38/] has indicated the shape and size of some of the more common metallic fume particles.[39/] Much of this fume is in submicron sizes below 0.001 mm. or 1/25,400-inch diameter.

Miller's chart (slightly modified) (figure 9) gives the normal range of metallurgical fumes from 10 microns down to 0.1 micron with the possibility that it may extend to 100 microns (about 150-mesh) on the upper end. Zinc oxide fumes are thought to be in the range of 0.3 to 0.03 micron. Recent electron photomicrographs by Chaney[40/] and other appear to substantiate the possible lower limit of about 0.03. Four electron photomicrographs, figure 10, show some characteristic forms, mostly spherical, of lead fume averaging about 0.3 micron in diameter as shown by the scale.

Figures 11a and 11b show typical shapes and the great range of sizes of zinc oxide fumes. They tend to agglomerate as shown in figures 11c and 11d. The radiating, star-shaped crystal, quite characteristic of zinc oxide, was condensed from nascent zinc vapor as the gases from high-zinc-containing materials cooled. The nearly perfect or complete crystal has the acicular-shaped points. Fumes from leaded red-brass furnaces, figures 12a and 12b, are much more complex, and the different metal or oxide crystals lose much of their identity. They are characterized, however, by very small average particle size in the order of 0.1 micron and the distinct tendency to agglomerate and form into chains, figures 12c and 12d. Figures 13a and 13b are photomicrographs of high-zinc yellow-brass fumes in which zinc oxide crystal forms can be identified. Figure 13a in this group is an exceptionally fine picture of clean, nearly perfect, large and small zinc oxide crystal centers at 50,000 diameters; figure 13b shows small chains of zinc oxide fumes, at magnification of 28,000, surrounded by very fine material far below 0.1 micron. This is probably smoke, according to Chaney.

Laboratory techniques of sampling and determining the sizes and other properties of submicron particulate matter are steadily being perfected. The Second Interim

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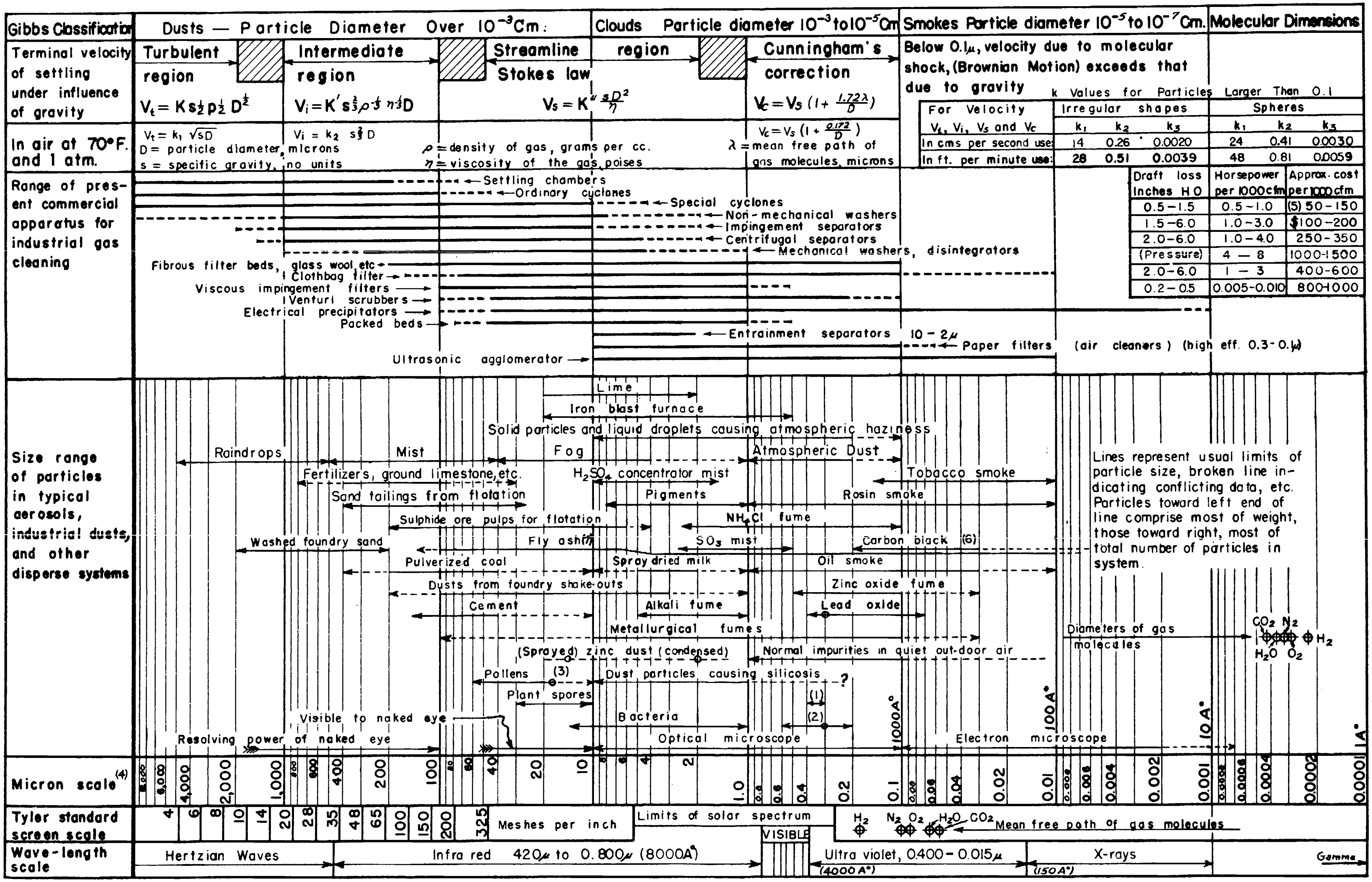
[38/] Resolves with certainty particle sizes down to about 30 Angstrom units or 0.003 micron, or, say, 0.000,003 mm. Burton and Kohl, The Electron Microscope: 2d ed., Reinhold Publishing Corp., Miller's chart, fig. 6, shows relationships of micron to Angstrom and other units.

[39/] McCabe, L. C., and others, Industrial Dust and Fume in the Los Angeles Area: Ind. Eng. Chem., vol. 41, No. 11, November 1949, p. 2486.

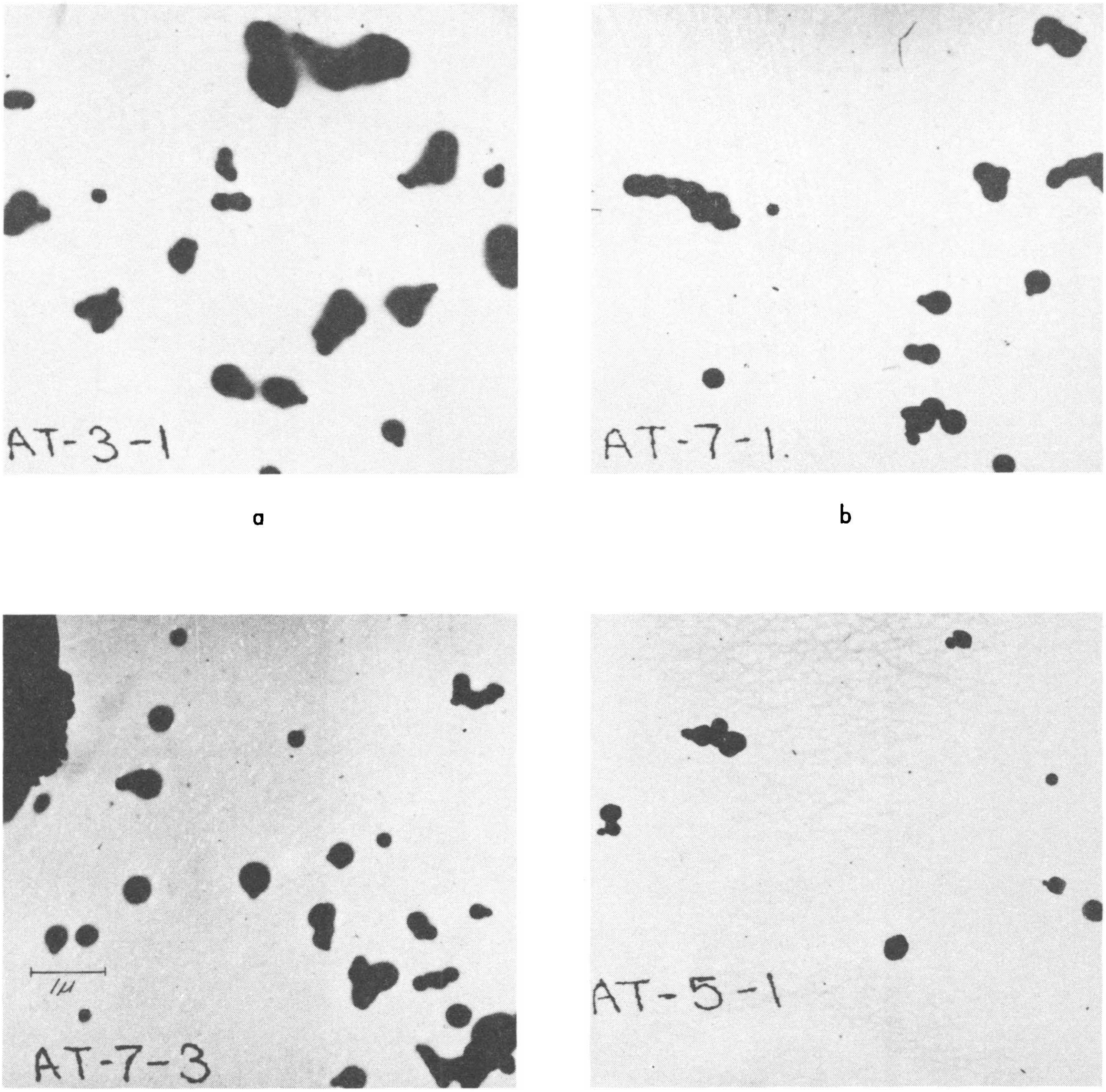
[40/] Albert Chaney Laboratories, Los Angeles.



(1) 0.3-0.4 P.M. particles having maximum light-scattering power
(2) Range of particulate matter sizes producing maximum obscuration of light – *mean effective size* ± 0.3μ
(3) Ragweed median 18μ
(4) 1 micron = 0.001mm. = 10,000 A°
(5) Double all costs
(6) Primary 0.04-0.05; thermal 0.5-0.005μ
(7) By weight 0-5μ, 35%; 5-10μ, 22 %

COMPILED BY C. E. MILLER, CHEMICAL & METALLURGICAL ENGINEERING, VOL. 45, PAGE 133, (1938)
(COURTESY CHEMICAL & METALLURGICAL ENGINEERING)

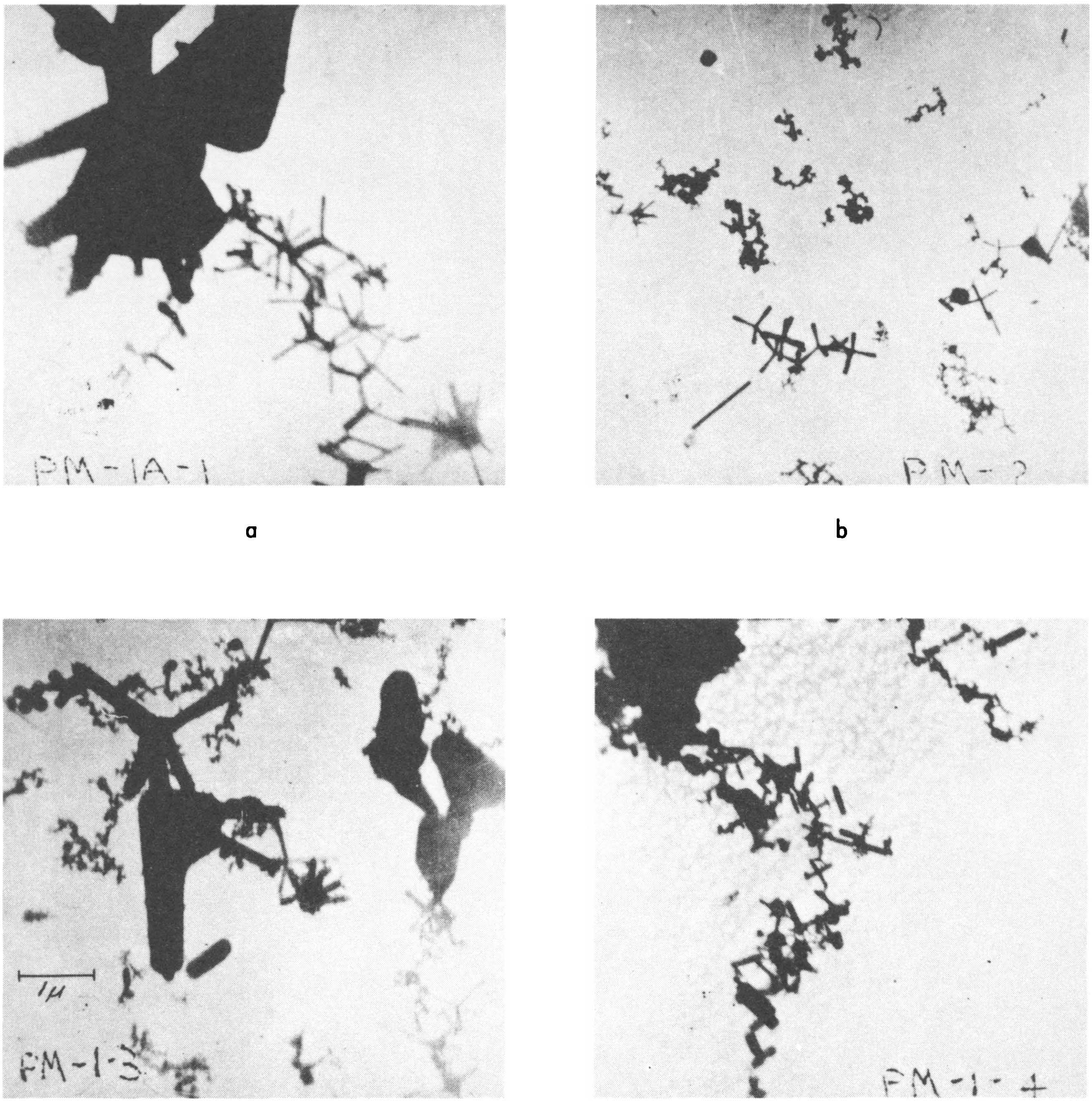
Figure 9. - Summary of properties of some typical aerosols, size relationships to physical characteristics. (C. E. Miller's chart, with some additions.)



a b

c d

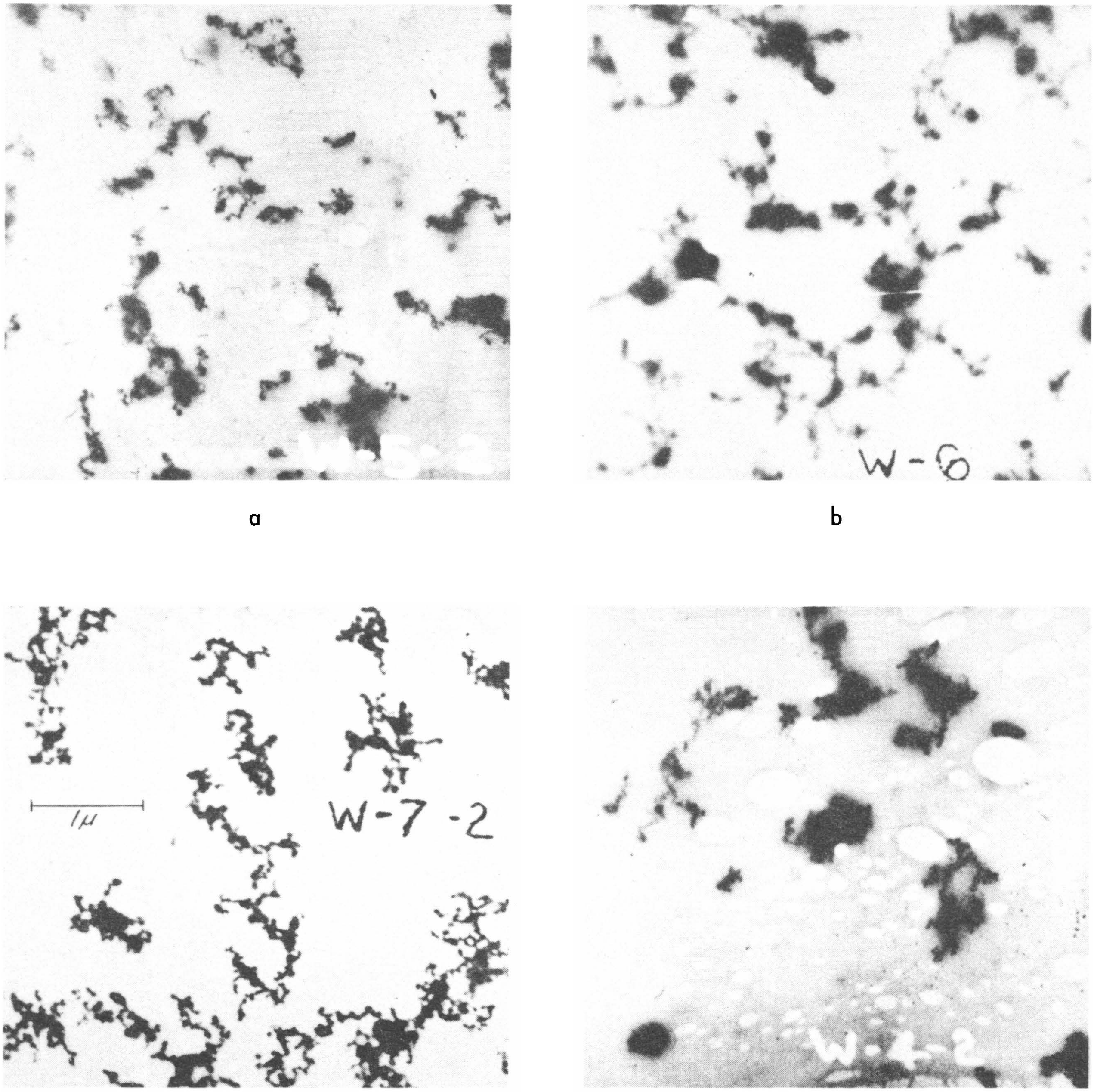
Figure 10 a, b, c, and d. - Electron-photomicrographs of lead fumes.



a b

c d

Figure 11 a, b, c, and d. - Electron-photomicrographs of fume from zinc smelter.



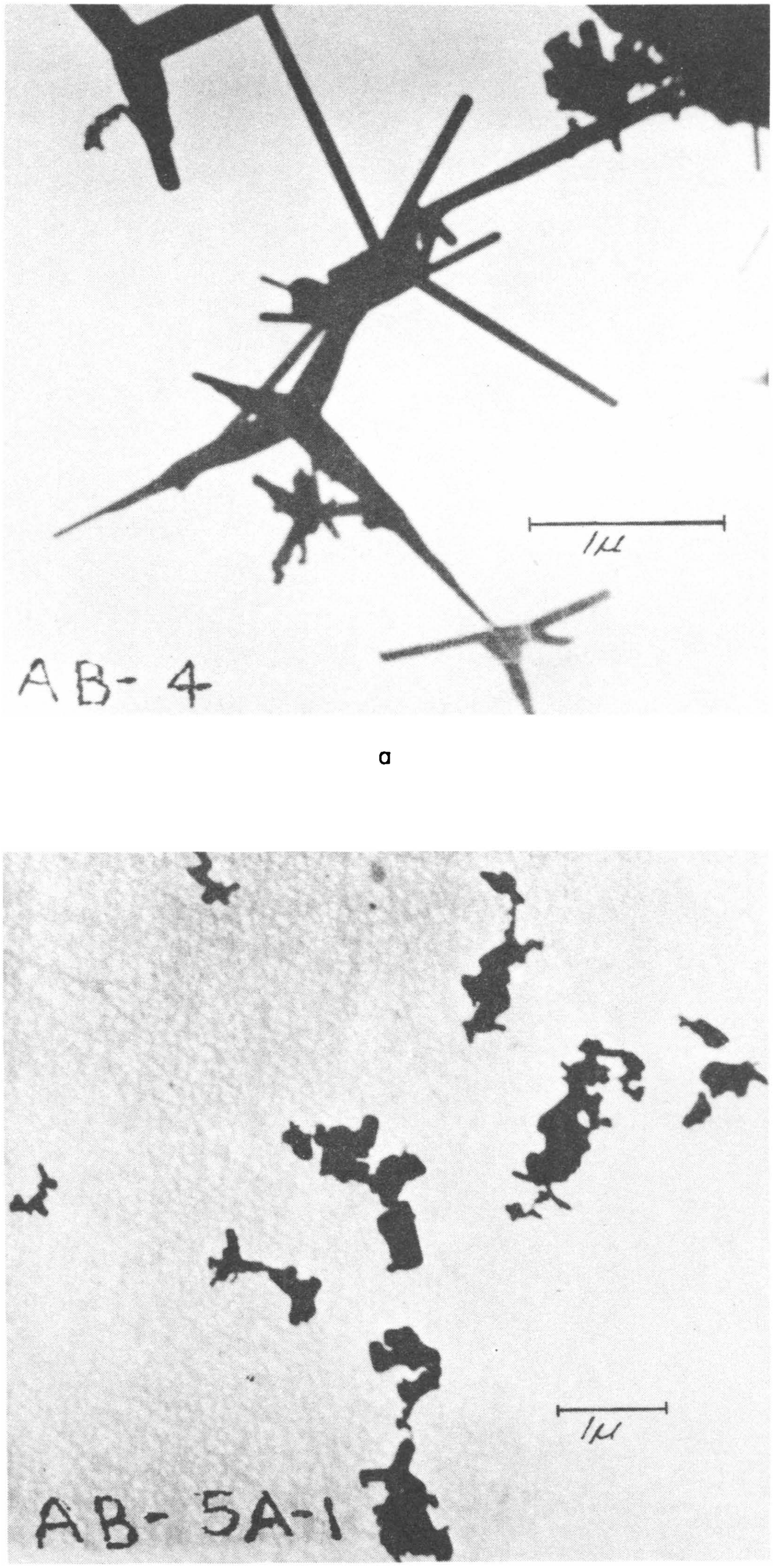
a

b

c

d

Figure 12 a, b, c, and d. - Electron-photomicrographs of fume from leaded red brass.



a

b

Figure 13 a and b. - Electron-photomicrographs of fume from yellow brass furnace.

Report[41] describes some of those used in the Los Angeles area. Other aspects of submicron examinations were briefly outlined by McCabe and others.[42] More recently, many authoritative papers concerning the physical and chemical properties of air pollutants and methods for determining them were presented in the Analytical Methods and Properties Panel of the United States Technical Conference on Air Pollution in Washington, D. C., in May 1950. This material is now in press.

Recovery Equipment

Most medium and large-scale foundries already have dust-recovery equipment for miscellaneous operations, such as grinding, core knock-outs, and sand blasting. Equipment for recovering metal fumes from nonferrous furnaces, however, was not in general use in small and medium-size copper-base-alloy foundries in the Los Angeles area before the Air-Pollution Control District began to function early in 1948. Consequently, the American Foundrymen's Society, at the suggestion of the Los Angeles Chamber of Commerce, formed a committee in cooperation with the Engineering Department of the Air-Pollution Control District to investigate foundry-fume problems and to test proposed and installed equipment to determine its effectiveness in meeting the new requirements. Data contained in table 1 resulted from one such investigation of foundries having no recovery equipment. Investigations conclusively prove that the most troublesome fumes consist of particles of zinc and lead compounds submicron in size, and that equipment capable of collecting particulate matter from 1.0 down to about 0.03 micron is required. Some of Chaney's photomicrographs of samples taken when furnace emissions were heavy with smoke indicated that the smoke particles accompanying the fumes may be about 0.01 micron and smaller.

Standard collecting equipment suitable for the range from 200-mesh (about 75 microns) diameter down to about 10 microns is available. Therefore, this range holds no particular problem other than capital and operating costs. Dynamic scrubbers or mechanical washers have proved in some applications to be quite effective in the range from 10 to 1 micron, but in addition to being ineffective in the range below 1 micron they have the drawback of high power consumption and mechanical wear and usually require separation of the metallic fumes and other particulate matter from the circulating water or wetting solution. Electrical precipitators of the Cottrell type are extremely effective collectors for many substances in any range of size from 200-mesh to perhaps 0.001 micron,[43] cold or hot, wet or dry. So far, this equipment has not been available in small units suitable for small nonferrous-foundry use, has not always been entirely satisfactory on lead and zinc fumes, and the first cost may be prohibitive.

Another approach to the collection of submicron particulate matter employs a combination of a device to agglomerate fume particles into aggregates large enough to be collected in a second operation with standard equipment such as cyclones. Such a combination is now in the development stages and may prove applicable to the nonferrous foundry industry. It consists of the sonic agglomerator[44] and small,

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[41] Stanford Research Institute, Los Angeles, Calif., Second Interim Report on the Smog Problem in Los Angeles County: August 1949, 64 pp.

[42] See footnote 29.

[43] General Electric Co., Bull. GEA-5212, p. 7.

[44] St. Clair, H. W., Theory and Basic Principles of Sonic Flocculation and Collection: U. S. Tech. Conf. on Air Pollution, Washington, D. C., May 3-5, 1950, (in press).

Neuman, E. P., Design, Application, Performance and Limitations of Sonic-type Flocculator and Collector: U. S. Tech. Conf. on Air Pollution, Washington, D.C., 1950, (in press).

Danser, W. H., and Neuman, E. P., Industrial Sonic Agglomeration and Collection Systems: Ind. Eng. Chem., November 1949, p. 2439.

multitube centrifugal or an entrainment-type collector. The sonic precipitator, if found applicable, promises comparatively inexpensive collection of particulate matter from 10 microns down to perhaps 0.01 micron in any range of temperature from 0° to about 900° F. Insofar as known to date, its application to nonferrous-foundry work is still in the development stage.

The bag filter or baghouse has long been known as a highly efficient collector of dry, solid, particulate matter in the range of 200-mesh to about 0.1 micron, as indicated in figure 9. Its ultimate limit probably extends down to 0.01 but with lower efficiency.[45/] One of its most successful large-scale applications has been in the collection of lead and zinc fumes, a field in which it has demonstrated advantages over the electrical precipitator. Fortunately for the foundry industries, efficient small baghouse units have been perfected, but for general acceptance in medium and small foundry work, some departures from conventional industrial design seem necessary to adapt the small baghouse to wider variations in operating conditions, especially temperature and humidity. Fully automatic instrument control appears essential for the most economical operation because of the intermittent nature and wide variations in operating conditions in nonferrous work. Glass-fabric bags have been used successfully in several industrial installations in Los Angeles at operating temperatures of 500° F., occasionally for very brief periods at 800° F., and with some resistance to acid atmospheres.

Development Trend in Los Angeles Area

The basic principles employed in the separation of particulate matter from gases may be used singly or in combination. The type of equipment used is described in detail in the literature.[46/] For the present, those immediately available for small and medium-size nonferrous foundries may be classified as settling chambers, packed towers and entrainment separators, wet washers and dynamic scrubbers, cyclone or centrifugal collectors, and gas filters and baghouses.

One other type, the highly efficient and versatile Cottrell electrical precipitator, will not be considered, since it is normally manufactured in units of large size and at costs comparable to other equipment of equivalent capacity. It is now available in small units of about 10,000 c.f.m., but the first cost per unit of capacity is relatively higher.

Dust Chamber

Insofar as is known, no copper-alloy foundry in the Los Angeles area depends on the simple settling chamber alone to clear gases from fuel-fired furnaces, but a few establishments are using them very effectively for collecting heavy dust larger than 200-mesh and for cooling the gases before they enter baghouses or other devices better suited to recovery of the finer particulate matter. Some of the larger establishments have built masonry chambers or utilized available steel tanks, sections of

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[45/] Silverman, L., Filtration Through Porous Materials: Am. Ind. Hyg. Quart., vol. 11, March 1950, pp. 11-20.

[46/] Perry, J. H., and others, Chemical Engineers' Handbook: McGraw-Hill Book Co., New York, 3d ed., 1950, 1,942 pp.
Schmidt, Walter A., Waste Gases: Chem. Eng. News, vol. 27, No. 45, November 1949, pp. 3272-3276.
Welch, Harry V., The Fume and Dust Problem in Industry: Trans. Am. Inst. Min. and Met. Eng., vol. 185, December 1949, pp. 934-947.

steel stacks, and even existing brick stacks as settling and cooling chambers. One foundry, which effectively meets all Air-Pollution Control District requirements, employs a settling chamber alone to serve electric induction-type furnaces, which characteristically produce low gas volume with light dust and fume loadings.

Scrubbers

Both static- and dynamic-type scrubbers have been tested on copper-alloy furnaces with rather indifferent results so far, but the shortcomings of the equipment may be overcome by alterations in design to adapt it better to the operating conditions. Table 3, plant 10, gives the result of a brief pilot-size test made with a venturi-type wet scrubber and cyclonic collector on very heavily laden gas from a brass furnace. Under these conditions, only 65 percent of the particulate matter in the gas was collected. The washed gas leaving the wet cyclone collector contained 0.70 grain of particulate matter per cubic foot and thus exceeded the limit allowed under Air-Pollution Control District regulations. An earlier test at this plant, made under almost identical conditions, yielded about the same results. An impinger[47] and thimble were used to collect the fume sample. The particulate matter caught by the impinger contained 70 percent zinc oxide and that in the thimble, 58 percent. The venturi-type scrubber[48] and wet-cyclone collector[49] have been applied elsewhere on industrial scale to some difficult dust and fume problems with satisfactory results. The wide working range of venturi equipment is indicated in Miller's chart, figure 6.

Another type of dynamic wet scrubber also treating a very dirty gas from a direct-fired, rotating-type brass furnace reduced the particulate matter from 0.91 to 0.37 grain per s.c.f. This furnace was treating 924 pounds per hour as shown in table 3, plant 10a. Actual loss per hour was 3.00 pounds, which slightly exceeded the limit allowed under Los Angeles regulations. Here again the scrubber efficiency was low, about 50 percent.

There is some reason to doubt that the dynamic wet-scrubber type of dust collector operating under variable load conditions can be made to meet nonferrous-foundry requirements of the district because of the inherent difficulties encountered in wetting extremely finely divided metallic fumes and oxide. However, scrubbers have certain advantages in treating furnace emissions containing soluble gases or particulate matter, such as sulfur trioxide and common-salt fumes, but these are not usually present in copper-alloy furnace gases in important concentrations.

Centrifugal collectors

Collectors depending on the centrifugal principle alone are not well-adapted to brass-furnace dust collecting because of the low efficiency of such apparatus on particulate matter below 1 micron in diameter, the sizes normally found in the gases

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[47] Air-Pollution Control District, Test Procedures and Methods of Sampling in Air-Pollution Control: Los Angeles, Calif., 1950.

[48] Jones, W. P., and Anthony, A. W., Jr., Pease-Anthony Venturi-Scrubber: U. S. Tech. Conf. on Air Pollution, Washington, D. C., May 1950 (in press).

[49] Kleinschmidt, R. V., and Anthony, A. W., Jr., Pease-Anthony Cyclonic Spray Scrubber: U. S. Tech. Conf. on Air Pollution, Washington, D. C., May 1950 (in press).

from a leaded-brass furnace. In addition, one concern,[50] which has tested several collectors for fumes from its crucible-type brass furnaces, is experimenting with a simple wet entrainment separator for recovering partly agglomerated zinc oxide fume. If proved satisfactory, this collector may be used in conjunction with the pouring-lip hooding device illustrated by figure 5.

Filters

Sock-type gas filters for fume and dust from copper-alloy furnaces are the most effective and satisfactory collectors employed industrially in the Los Angeles area. This type of collector is available in many useful and effective forms. Cloth and other filter medium can separate particulate matter from gases effectively, even though the interstices in the filter fabric are much greater in diameter than the dust and fume particles. This, undoubtedly, is due to the formation of a layer of particulate matter on the nap and within the interstices of the filter fabric. With some modifications, the sock type, as contrasted to the flat-frame type, has been used in connection with medium-size copper-alloy furnaces with complete success for reducing air pollution at low operating costs. In fact, one installation using bags made of a specially woven glass fabric has been in use nearly 3 years and has recovered metal fumes valued at several times the capital and operating costs of the equipment.

A representative small baghouse is that built by the Berg Metal Co.[51] This installation was designed to treat gases from two gas-fired reverberatory furnaces melting scrap brass and using existing stacks and flues insofar as possible. The system normally is expected to serve one furnace at a time but is capable of handling both furnaces for a limited period. Each furnace melts a 25-ton charge in a 20- to 24-hour cycle. Charging may continue up to 18 hours, followed by lancing, or otherwise adjusting to specifications and pouring.

As shown in figure 14, the gases leaving the reverberatory furnaces at 2,200° F. flow through a 60-foot stack, which served them before the installation of the dust-collecting equipment. A butterfly valve at the top of the stack is normally closed but can be opened in an emergency to bypass gases to the atmosphere. The gases leave the stack at 2,200° F. and are cooled to 900° F. in a water-jacketed horizontal steel cylinder. They are normally further cooled to 500° F. in radiation coolers before entering the glass bags, but temperatures up to 800° F. have been tolerated for short intervals without material damage. Sustained exposure to high temperatures shortens the useful life of the bags. Some coarse dust settles out in the flues and stacks. The gases are drawn through the sock-type bags by a 10,000-c.f.m. exhaust fan at 8 inches water-gage vacuum and a temperature of 350° F. and discharged to the atmosphere through a new steel stack. The baghouse, shown in figure 15, is a steel structure divided into five cells, each containing 24 glass-fabric bags 9 inches in diameter and 8 feet long. Each cell was designed to clear 1,500 c.f.m. gas at 500° F. with a pressure drop of 4 to 4.5 inches of water. Four cells can normally handle about 6,000 c.f.m., leaving one available in reserve. The bags are automatically rapped when pressure drop of the gas through the glass fabric reaches a predetermined figure. Draft at the fan is controlled by a diaphragm-pressure regulator of the type used to regulate boiler draft. Full automatic control of the rapping interval and of the flow rate, temperature, and pressure of gases is necessary for best recovery performance and economy. Cooling water is circulated through the water-jacketed cooler at the rate of 30 g.p.m.; it enters at 110° F. and leaves at 140° F., returning by gravity flow to a 4- by 6- by 8-foot high cooling

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[50] Communication, F. V. Cowing, vice president, Repcal Brass Mfg. Co., August 1950.
[51] 2492 Long Beach Blvd., Vernon, Calif.

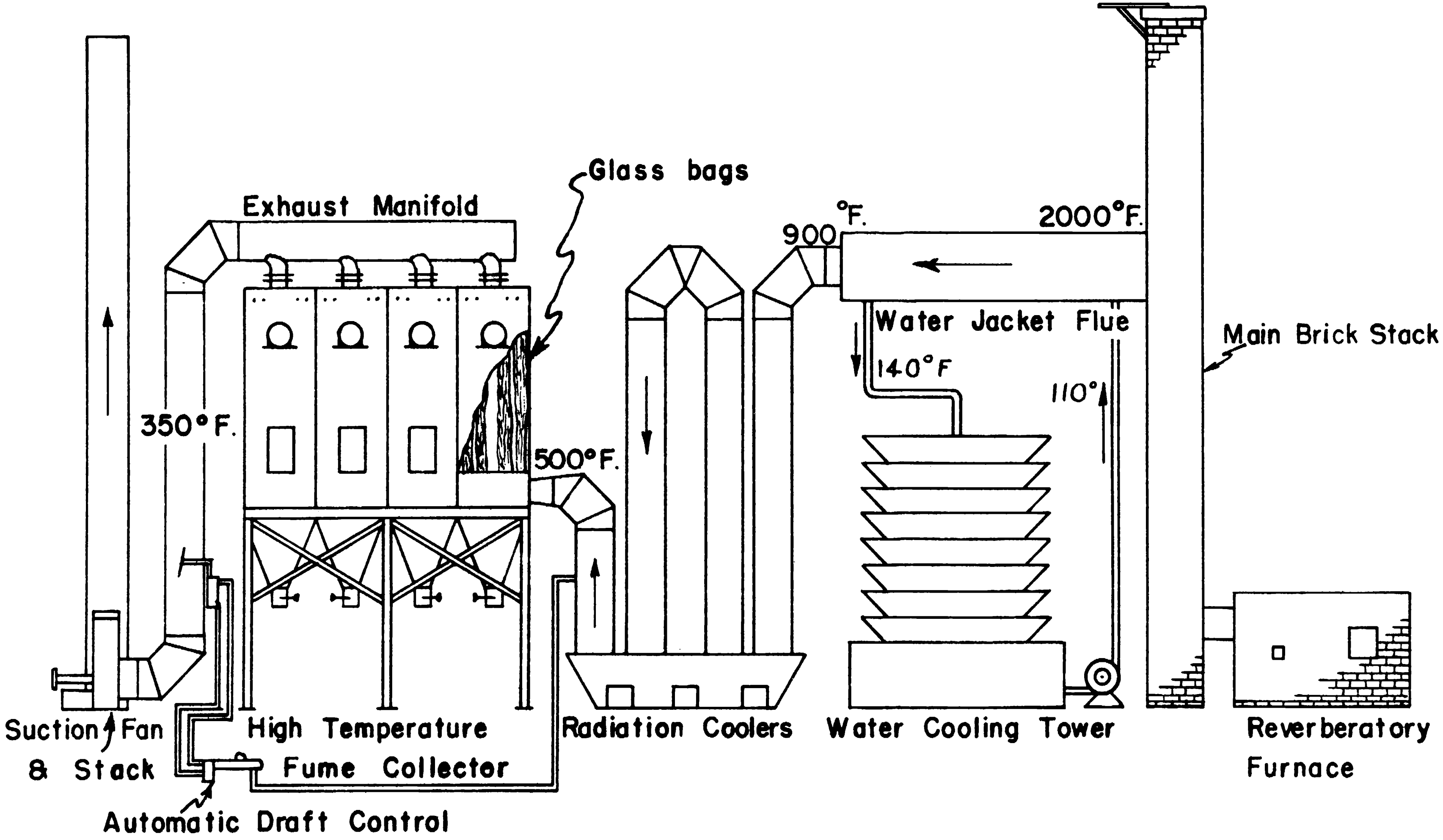

Figure 14. - Sketch of small baghouse for lead or zinc fume.

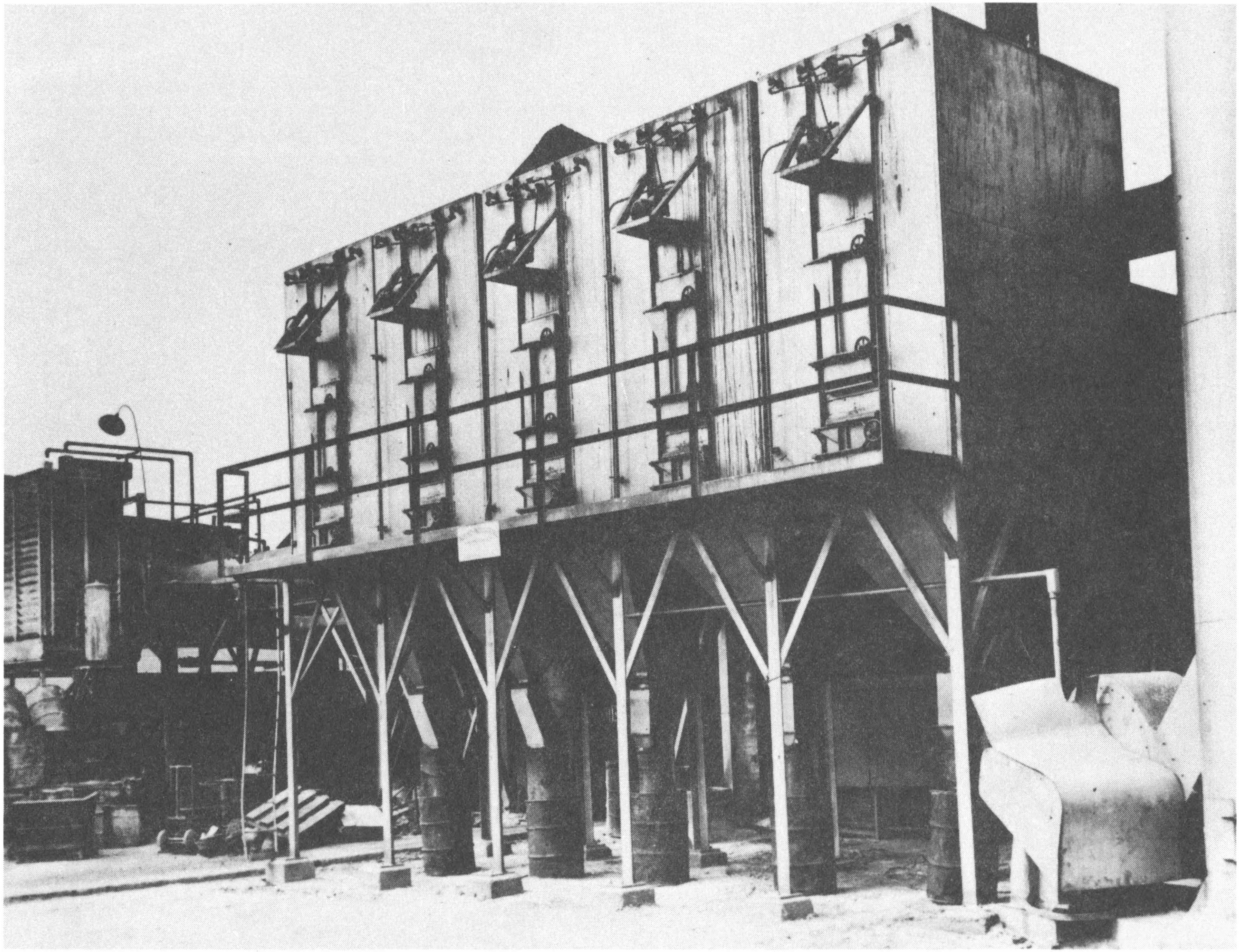

Figure 15. - Baghouse using special glass fabric filter medium for brass furnace fume. (Courtesy of Allied Industrial Engineering Co. and Berg Metals Company, Los Angeles.)

tower. Glass bags or socks used in this installation are fabricated by a local firm from specially woven glass-fiber fabric, which has been found best adapted to the special conditions encountered in nonferrous-foundry operations. Bags are checked for any necessary repairs after about 10 weeks of operation. Most bags have a useful life of about 2 years.

The operating efficiency of this installation is clearly indicated by results of a test shown in table 3, plant 12. Actual losses while furnacing 44,434 pounds of scrap brass at a process weight of 2,066 pounds per hour was 0.22 pound per hour, or less than 0.01 percent. Allowable loss under Los Angeles regulations was 7.48 pounds per hour. Furthermore, the molten metal was lanced with compressed air during the test, an operation that produces excessive zinc oxide fumes. The volume of gas leaving the baghouse was 6,160 s.c.f.m., containing 0.004 grain per cubic foot of particulate matter with four cells, or 80 percent of the bags, in use during the test. The fumes and dust collected in the bottom hopper of each cell are drawn into steel drums for further treatment. As much as 1,500 pounds of fume per day has been recovered while melting high-zinc scrap.

Two units very similar to the ones just described are in regular operation at the Eastern Smelting & Refining Co. in Los Angeles. One baghouse serves the brass furnaces and the other the lead smelting and alloying.52/

Several excellent designs of flat-bag or leaf-type filters are in use in many industries. Although such filters have been used for many years in foundries where gas temperatures and humidity are low, they have not been applied generally or entirely successfully to nonferrous furnace gases in the Los Angeles area. The main difficulties in a single-unit bag filter are in removing deposited material and in the pronounced tendency of the zinc oxide fume to agglomerate detrimentally under the conditions at the plant, thus requiring dual-unit operation for best over-all results.

Lead Reclaiming and Lead-Alloy Foundries

Introduction

Although Los Angeles is not a primary lead-smelting center, it has an appreciable amount of secondary smelting in reclaiming lead scrap, particularly battery plates. As noted in a previous section of this report, some 175 copper-base alloy foundries normally are in production in the area, and many of these melt leaded-copper alloys. Actual statistics of production of lead and lead-alloy products were not available for the area, but the lead metallurgical industries are known to be appreciable contributors to air pollution.

The concentration of lead in the Los Angeles atmosphere, based on an early estimate, was calculated to be in the order of 0.0065 mg. per cubic meter, far below the 0.15 mg. per cubic meter or 0.000066 grain per cubic foot recently adopted as the threshold limit.53/ The lead in the Los Angeles atmosphere from industrial sources is thought to be in the form of lead oxide and from automotive exhuasts in the form of lead chloride or bromide. The concentration of lead in the high-lead copper-alloy fumes, table 1, plant 8, column 22, following dilution of the fumes

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52/ Brundage, N. C., Smog Control Helps Bag More Profits: Western Metals, vol. 7, No. 6, June 1949, pp. 21-23.

53/ Adopted at a meeting of the American Conference of Governmental Hygienists in Detroit, Mich., April 1949.

with 2.6 volumes of air from outside the furnace amounted to 0.026 grain per cubic foot, or about 394 times the threshold limit. The role of lead fumes as possible smog-forming contaminants in Los Angeles air is still a matter of considerable conjecture. Nevertheless, a concerted effort is being made, and with considerable success, by nonferrous industrial concerns to reduce their lead emission and thereby protect employees and improve air hygiene.

Chemical lead melts at about 618°-621° F. and boils at about 2,935° F. Corresponding figures for soft or corroding lead are somewhat higher.[54] Thus, lead is not readily distilled like zinc at furnace temperatures (800°-1,300° F.) used in lead reclaiming. Lead in alloys containing low-boiling-point metals, such as zinc and antimony, vaporizes to a very considerable degree and is fumed along with the other metals. Although lead in furnace fumes is usually reported as elemental lead, there can be little doubt that it exists as some form of lead oxide, probably PbO.[55] Electron photomicrographs (fig. 10) by Chaney, of fumes from a lead-refining furnace indicated that unagglomerated, relatively pure fume particles probably vary in diameter from about 0.07 to 0.4 micron, with a mean of about 0.3. All photomicrographs showed the quite consistent spherical form, but particles have a distinct tendency to agglomerate. Excellent electron photomicrographs of fumes from secondary blast furnaces and lead reverberatory furnaces, which support Chaney's findings, are shown in a bulletin[56] describing gas-scrubber equipment.

In fumes from leaded red brass, however, both lead and zinc oxide particles seem to lose their identity or are individually too small to identify with any degree of certainty under the electron microscope. Collectively they tend to form chain-like aggregates, figure 12.

Metallurgical Practice

Three concerns in the Los Angeles area operate small blast furnaces for reduction of lead oxide, fume, and metal scrap. The resulting metal is cast into pigs or pumped directly to refining or alloying kettles or to reverberatory holding furnaces. Two large- and four medium size (25-ton) reverberatories are operated on scrap lead and dross and as softening furnaces, along with several drossing kettles.

The blast furnace, usually of 8- to 10-ton capacity, depends, of course, on coke for fuel, while the reverberatories and kettles are fired with oil, gas, or both. The melting-temperature range of chemical-grade lead is 750°-830° F., and ingot castings are poured around 790°-850° F. Stack-gas temperatures range from 1,200° to 1,350° F. Slag or flux covers are not in use in the Los Angeles area for the purpose of reducing fumes from lead melting, but ammonium chloride and other salts are used to reduce loss of metal retained in dross and skimmings. Kettles and furnaces are usually housed in open-sided, well-ventilated buildings, and exhaust hoods are used where needed.

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[54] Authorities differ. Most temperature figures quoted and shown in figure 1, Boiling, Pouring, and Melting Points of Metals and Alloys, are from Metals Handbook, 1948 Edition.

[55] Liddell, D. M., and others, Handbook of Nonferrous Metallurgy: McGraw-Hill Book Co., New York, N. Y., 2d ed., 1945, p. 149.

[56] Chemical Construction Corp., Bull. M-102: New York, N. Y.

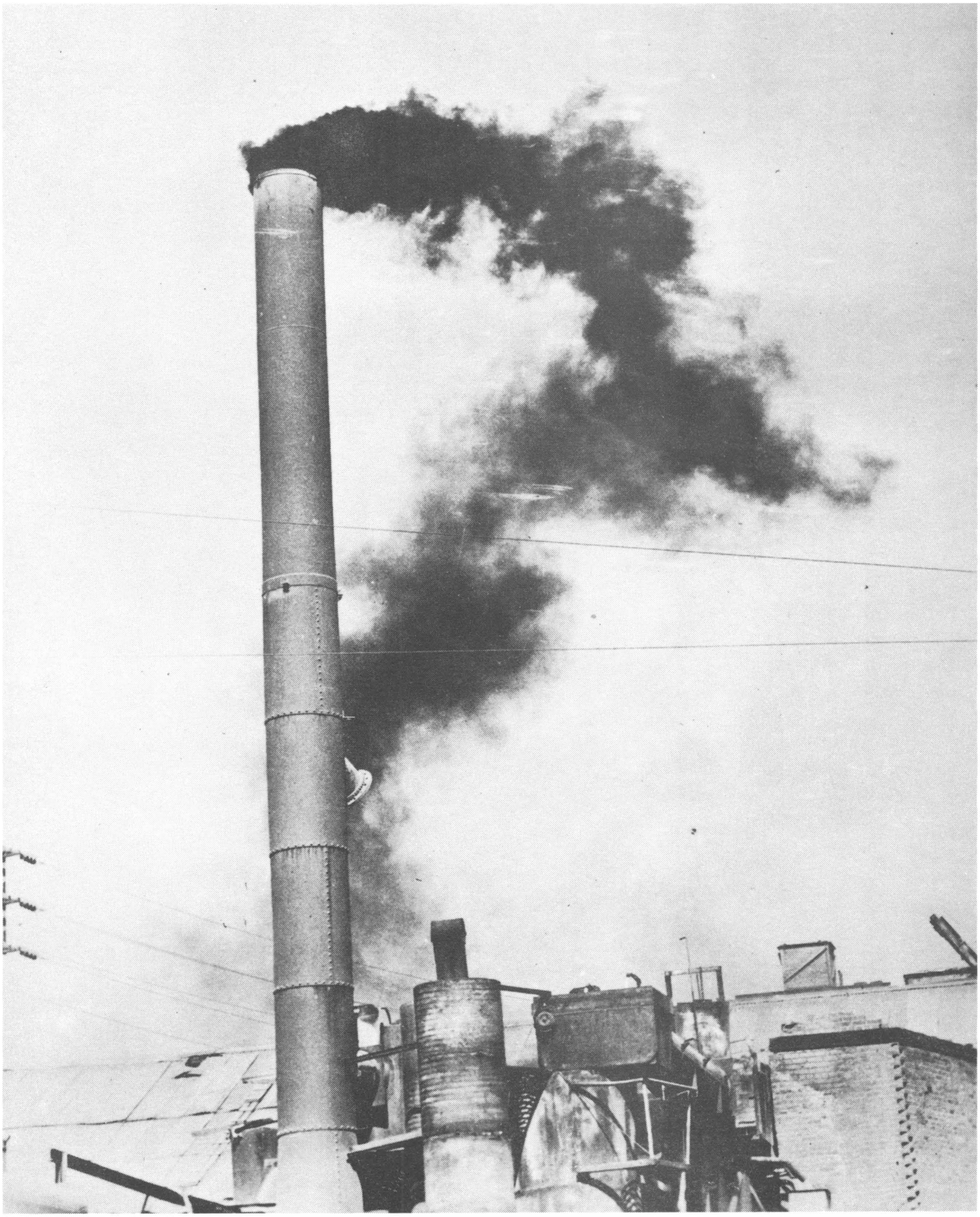

Figure 16. - Lead plant stack before installation of baghouse.

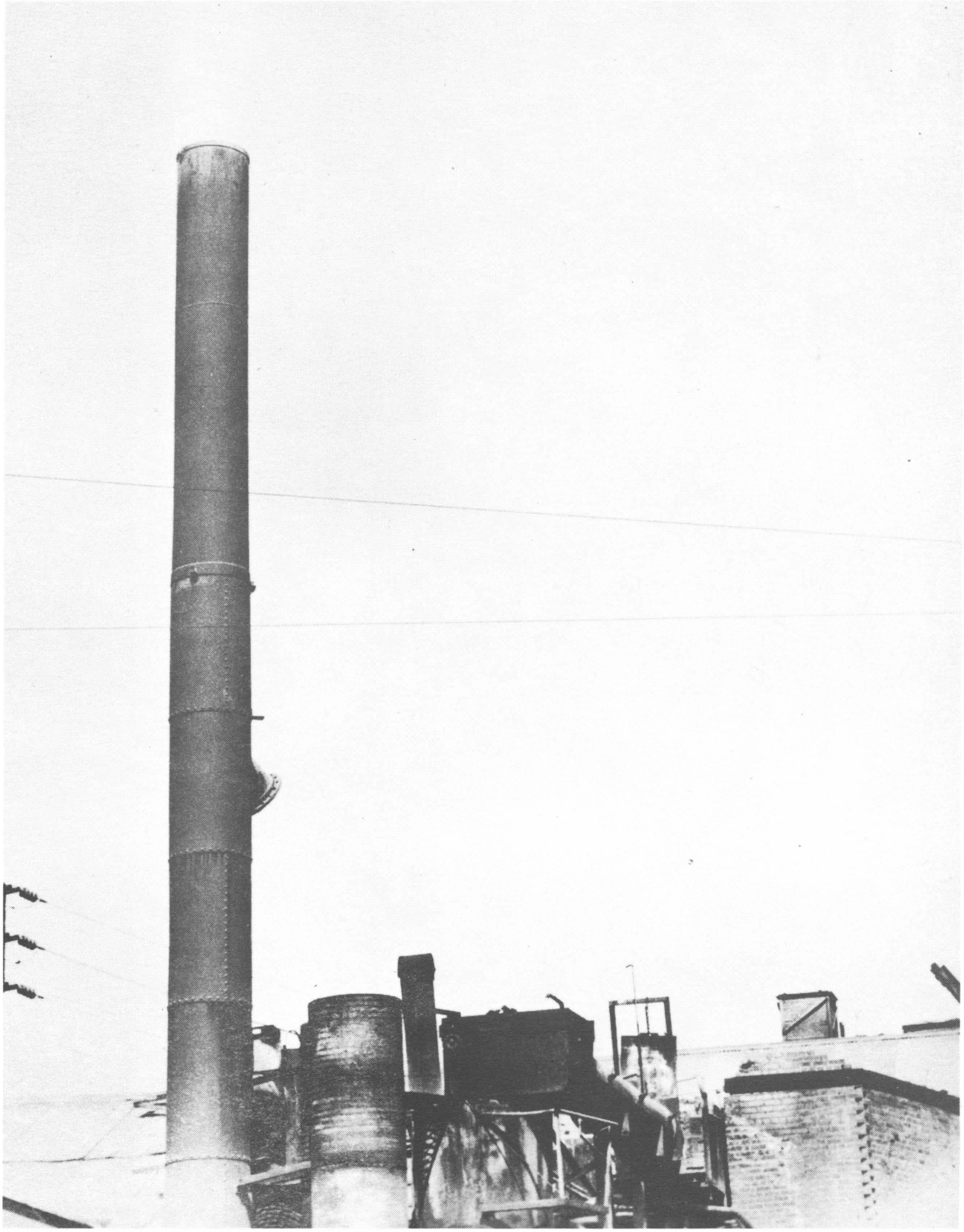

Figure 17. - Lead plant stack after installation of baghouse.

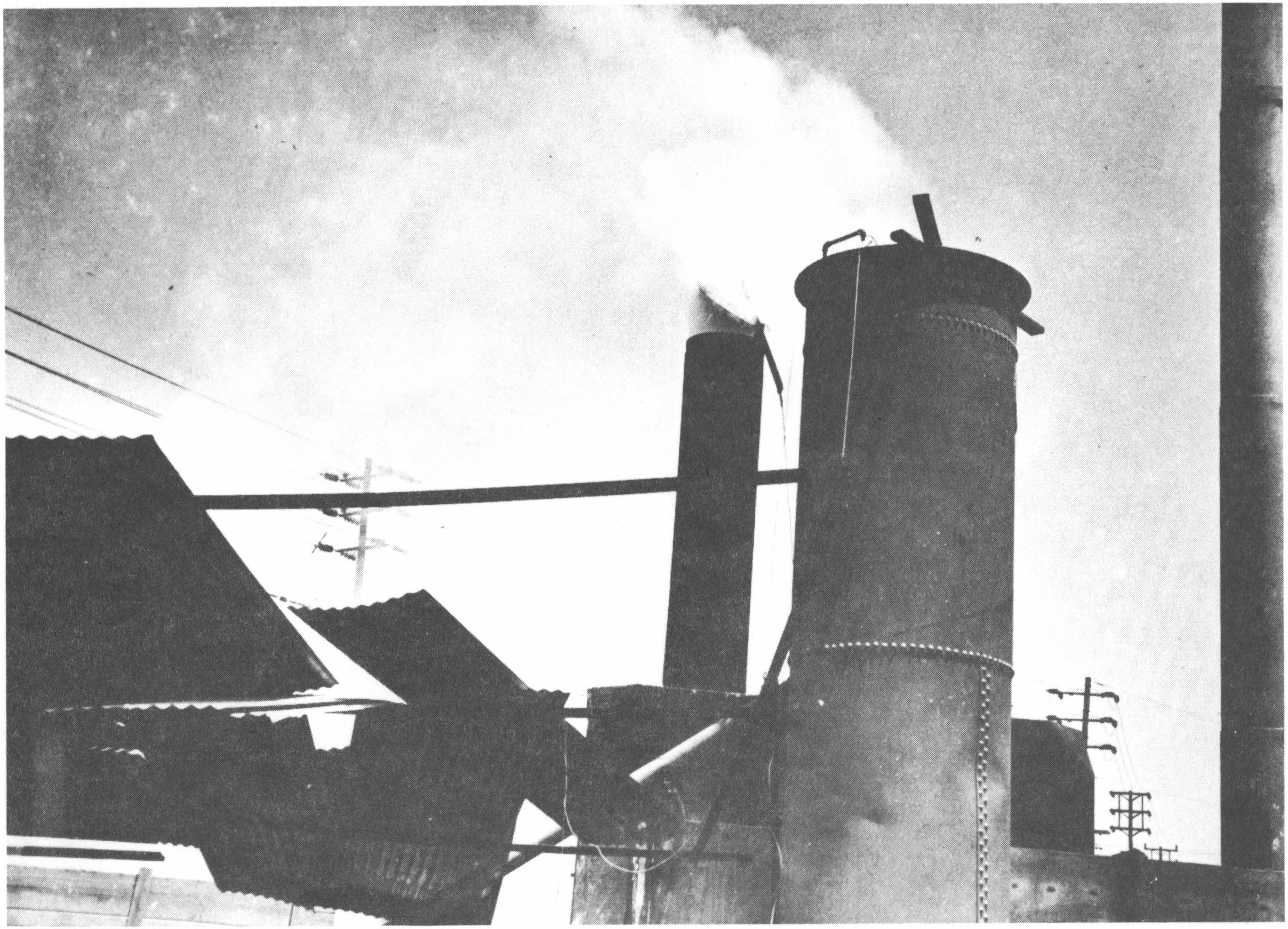

Figure 18. - Exhaust fumes from lead-reclaiming plant.

Stack Effluents

From the foregoing, the impression might be gained that the amount of particulate matter in stack emissions from lead works may be inconsiderable. This certainly was not the case before adequate fume-collecting equipment was employed. This is illustrated in figures 16 and 17 by the appearance of stacks before and after recovery equipment was installed. Figure 18 shows exhaust fumes from a lead-reclaiming plant. Purely gaseous constituents resulting from combustion of fuels in reverberatories are much the same as described in the section dealing with copper-base alloys. Blast-furnace gases, of course, contain the products of combustion of the reducing material. When battery plate is melted in blast furnaces, it often produces heavy smoke and fume emissions because of the presence of some organic matter and acid salts, dross, baghouse dust, and dirty scrap in the blast-furnace charge, together with coke and slag-forming material. Particulate matter in lead-plant emissions has been exceedingly heavy, up to 4 grains per cubic foot.

In tests on a 5- by 12-foot hearth reverberatory at one plant where exit gases were scrubbed before being released to the air, it was found that gas volumes were from 3,240-3,400 c.f.m. at stack conditions of 1,280°-1,340° F., with moisture content of 9 to 14 percent by volume and grain loadings of 1.4-4.5 grains per cubic foot.[57] Losses amounted to 1,600-3,000 pounds per 24 hours of operation. Similarly, a 6- by 14-foot hearth-drossing furnace was found to emit 5,300 c.f.m. at 290° F. containing 1.4 grains per cubic foot.

In a test on a natural-gas-fired dross furnace operating at natural draft without a collector and processing about 2,000 pounds of type metal in 5-hour heats, it was found that 1,500-1,700 c.f.m. of gas at temperatures of 1,300°-1,500° F. and dust loads averaging about 0.5 grain per cubic foot were emitted. Stack losses were 6.5-7.2 pounds per hour.

Recovery Equipment

Settling chambers and water curtains or spray-type collectors were formerly used in lead-reclaiming plants in the Los Angeles area with unsatisfactory results. Part of the coarser particulate matter was collected, but the metal fumes and smoke were difficult to wet and were discharged into the atmosphere, and the plants were civic nuisances. Nothing of value was recovered from the sludge. The wet, dynamic-scrubber principle was tested with indifferent results. However, packed towers in which dirty gas travels countercurrent to a shower of water cascading through a packing may be fairly effective, as indicated by the results on plant 13, table 3, but may have some distinct disadvantages. At this plant, two coke-filled packed towers in series quite effectively reduced particulate matter in fume from a gas-fired reverberatory furnace (remelting type) to within the permissible limits. The furnace was treating 2,000 pounds per hour, which, according to Los Angeles regulations, would allow a dust and fume loss of 3.03 pounds per hour. The actual loss was only 2.33 pounds per hour or 0.2 percent as shown in columns 11 and 13, table 3.

The baghouse has long been considered as the most acceptable device for collecting lead fumes, and many large installations are in operation at primary lead-reduction works. In connection with the Waelz and similar fuming processes in which

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[57] Communication from Norman C. Brundage.

lead and zinc are purposely volatilized to separate them from worthless material in a primary extractive operation, baghouses are used to recover particulate matter for further treatment to separate the lead and zinc.

The larger secondary-lead works in the Los Angeles area have adopted, on a greatly reduced scale, modified designs for their baghouses similar to those used by the much larger primary-lead smelters elsewhere. At one of these works, gas and fumes collected from small lead-blast furnaces, from lead-refining pots, and from reverberatories are first passed through large spray chambers where the gas temperature is reduced to about 230° F., and the coarse particulate matter is collected. The volume, temperature, and humidity of the gases leaving the cooling chamber are closely controlled by automatic instruments. The baghouse is a well-designed gunite structure divided into compartments containing long woolen bags similar to those used in baghouses at the primary-lead smelters. The bags are automatically rapped when the bag resistance builds up to about 4 inches water pressure. Dust removed from the hoppers beneath the bags is briquetted and returned to the blast furnace for re-treatment.

Another concern, operating a small blast furnace, drossing kettles, and reverberatories on lead scrap, battery plates, dross, and lead residues, has collected its furnace fumes for over 2 years in a five-cell baghouse designed to treat 9,000 c.f.m. of gas. The gas is first cooled to about 500° F. in a settling chamber and a series of water-jacketed, steel U-flues, 12 inches in diameter. This gas-cleaning plant, similar in design to that illustrated in figure 15, was designed to utilize, as far as possible, the existing structures, so the plant is somewhat improvised. The investment in recovery equipment has been repaid by the value of the metal recovered. A ratio of 3.5 c.f.m. per square foot of bag area was used in designing this installation because of the extremely small particle size of the lead fumes.

Zinc Smelting

Introduction

The zinc metallurgical operations in the Los Angeles area, like those of lead, consist essentially of metal reclaiming and refining. For this reason their raw materials are mostly scrap and zinc residues, such as zinc fume and dross, often containing lead, copper, and other metals. No zinc sulfide ore and only limited tonnages of carbonate ore are smelted, hence, sulfur fumes, which sometimes plague the primary zinc smelters, are no problem. The number of secondary zinc smelters operating in Los Angeles has never been large, probably not over three. A description of the method of operation and the recovery equipment used in one of these establishments follows.

Metallurgical Practice

Mixed scrap is hand-sorted as completely as practicable to reduce the amount of copper and other metallic scrap, also fabrics, rubber, and other combustibles. The selected scrap is charged into the open end of a hooded, rotating, oil-fired, sweating furnace. The temperature of the furnace is maintained just above the melting point of lead and below that of zinc. Thus, most of the lead is melted out and cast into pigs. Zinc is removed in a similar way, leaving unmelted copper, aluminum, and iron scrap. The zinc is cast into pigs, which are remelted in an oil-fired reverberatory holding furnace along with clean zinc scrap and held for further refining by distillation.

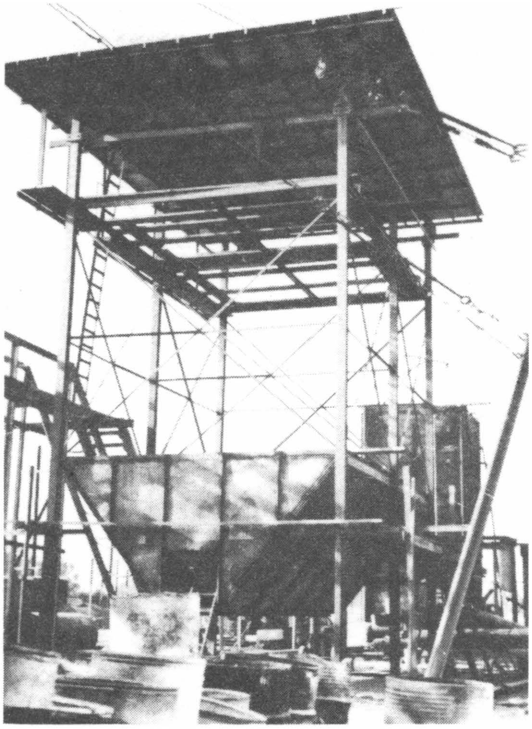

Figure 19. - Pressure-type baghouse (under construction).

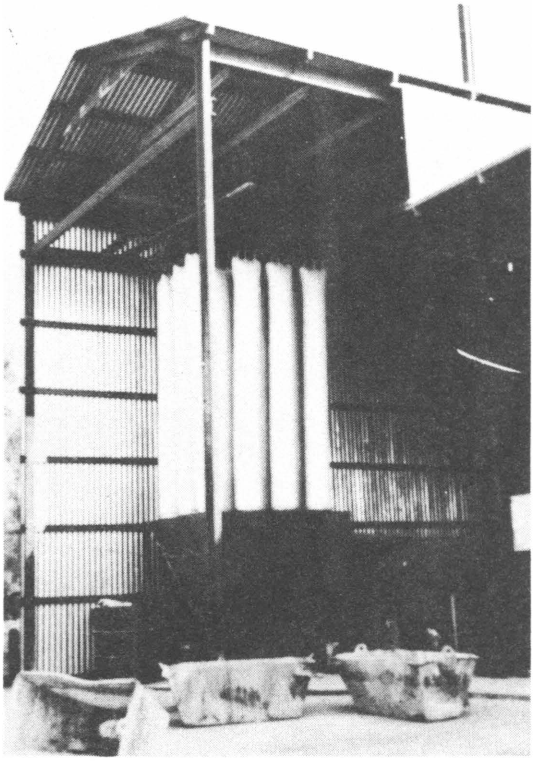

Figure 20. - Small unit of pressure-type baghouse in operation at a zinc smelter.

Each distillation furnace contains a graphite retort large enough to hold a charge of 3,200-3,500 pounds. In a typical furnace cycle, the cold retort is charged with clean scrap and metallic skimmings, then closed and heated. Molten remelted pig metal, making up the remainder of the charge, is pumped from the holding furnaces into the closed, hot, oil-fired retort. The retort is driven at about 2,000° F. for 10 to 12 hours. During this time the zinc is vaporized and condensed in large, water-chilled, cast-iron condensers. Temperatures are closely controlled during the entire cycle. Prime Western grade zinc is tapped from the condensers into molds. The retort is cooled, the residue (containing copper, iron, and some lead) is removed, and the retort is readied for another charge. Retorts are hooded during charging, and any escaping dust and fume are sent to the baghouse.

This concern operates a block of conventional-type retort furnaces to reduce oxidized zinc ores, fume, and residues. Materials to be smelted are mixed with crushed coal; and plant secondaries, such as blue powder, are charged into horizontal, cylindrical clay retorts provided with conventional, truncated, cone-shaped clay condensers. Molten zinc is periodically scraped from the condensers during the active distillation and cast into slabs for market. Oil is used for fuel, and all combustion gases are exhausted to a stack.

Stack Effluents

The dust load carried by the metallurgical gases varies with the method of metal drawing, retort charging, and the distillation cycle inherent in the retort-reduction process. An average of four samples of the dirty gas entering the baghouse gave dust loading of 0.78 grain per cubic foot, 90 percent of which was zinc oxide. During about two-thirds of the distillation periods the blue-green tinge of burning zinc can be seen escaping from the condensers. This and other losses entering the atmosphere may amount to 1.0-2.5 percent of the metal charge.

The physical nature of nascent zinc oxide fume, characterized by its extremely small particle size from 0.5 down to probably 0.03 micron diameter, and its quite typical star-shaped crystal, is illustrated in figures 11 and 13. The sample in figure 11 was taken from the gas stream entering the baghouse described below.

Recovery Equipment

At this zinc smelter, recovery equipment for collecting dust and fume consists of closets and hoods placed over the condensers during the charging and metal drawing. Large volumes of fresh air are admitted into the vent system at the hoods to collect any escaping fumes and dusts and cool the gases. The diluted gas is drawn by exhaust fans through a long system of horizontal, steel flues in which the gases are cooled down to about 150° F. The gases then enter the baghouse, a simple steel frame structure supporting a roof over a series of closed steel hoppers. The sock-type bags are of cotton drill, 12 inches in diameter and 15 feet long and closed at the top. They are suspended from a simple steel rapping mechanism at the top, which is operated periodically by hand, and the open ends of the bags are clamped to 15-inch-diameter collars welded to the top of the hoppers in rows or in a manifold arrangement. The simple design of the pressure-type baghouse is shown in figures 19 and 20.

Despite some inconveniences of semimanual operations, the simple pressure-type baghouse is well-suited for dust collecting at such plants as that just described. It is extremely simple to construct and operate, and its first cost is low in comparison to some of the fully automatic custom-made equipment supplied by many manufacturers of dust-collecting systems. With the exception of the exhaust fans and a few simple castings, the baghouse illustrated was designed and constructed by the comapny's small staff.

Light Metals

Introduction

The term "light metals" as used here includes aluminum, magnesium, and alloys in which they predominate. The light-metal industry comprises some 75 establishments engaged mostly in the production of gravity castings. Some of the larger concerns, however, cast billets for working into sheet, tube, and many other wrought products as well. In addition there are some 25 concerns whose principal operations consist of reclaiming and refining aluminum- and magnesium-alloy scrap, skimmings, and dross.[58] No strictly primary light metals are produced in the area.

Large and increasing tonnages of aluminum- and magnesium-alloy products, however, are used in the manufacture of airframes, in structural work, in transportation, and in other major Los Angeles industries. As much as 25 to 40 percent of the metal fabricated may be returned eventually to the remelting furnaces as plant scrap. Whenever feasible, such scrap is carefully segregated and may often be remelted in the furnace making the original alloy. Otherwise, the remelt scrap may have to be brought to specifications by the addition of pure metals or alloying constituents.

The national aggregate of fresh plant scrap, together with the obsolete scrap, such as old cable and pistons, is approximately 330,000 tons annually. This represents some 25-35 percent of the normal total aluminum consumption in the United States. Secondary-aluminum processing is, therefore, an important metallurgical industry. Secondary magnesium is relatively unimportant but is growing. Production, stocks, and movements of some 30 or more classifications of light-metal scraps are reported monthly.

The consumption curve for light metals in this country continues sharply upward year after year, and there is little doubt that the Los Angeles area will continue to process and consume increasing amounts. Aluminum, which constitutes the major portion of light-metals tonnages, fortunately does not volatilize readily at the temperatures required in processing the alloys. Some fume, of course, is produced from the low-boiling-point alloying metals and from the fluxes used. Control of fume from carefully operated, small, indirect-fired furnaces is comparatively easy. Handling of dross and reclaiming of dirty scrap usually produce more fume, as does operation of the large open-flame reverberatory-type furnaces. Serious efforts extending over many months have gone into the matter of controlling these fumes in the Los Angeles area and with some very good results, which are described later.

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[58] Dross refers to the oxidation products formed during melting, usually containing some metal mechanically entrained during skimming.

Aluminum Foundry Practice

Most of the aluminum furnaced in foundries in the Los Angeles area is in the light-metal alloys for industrial castings and in alloy ingots to be wrought. Copper, magnesium, and silicon are the most common alloying constituents in about the order named, although other metals are used as well. Aluminum-alloy ingots for working may contain any of the following elements: Copper, manganese, magnesium, zinc, silicon, chromium, and several other less-used ones in an almost endless variety of combinations.

For castings, temperatures range from 1,200°-1,450° F., but most operations are at approximately 1,300° F. Die castings are poured at about 100° F. below the melting temperatures, and sand castings are poured at temperatures of 1,250° to 1,500° F. Temperatures are closely controlled with pyrometers in every pot. The larger reverberatories usually use two or more thermocouples connected to recording instruments. Operators can depend very little on color indications from the charge.

Boiling-point temperatures of the major metal constituents, as indicated in figure 2, are high, about 4,700° F. for silicon, 3,270° F. for aluminum, and 2,025° F. for magnesium. Most alloys probably boil at considerably lower temperatures but still high enough so that, with care, the losses of metals by fuming are not great. Much of the fume from aluminum-alloy furnaces consists of volatile elements contained in fluxes, such as sodium, potassium, and aluminum chlorides and mechanically generated dust, and of some metal oxides of the low-boiling-point metals.

Furnaces

Aluminum alloys for casting usually are melted in small, crucible-type gas- or oil-fired furnaces for metallurgical reasons: The molten alloy has an avidity for harmful hydrogen, which may be obtained from the water vapor in air, from water vapor formed as a product of combustion of the fuels used, or from other sources. Therefore, in furnaces of this type, it is easier to control the formation of oxide film and dross and the temperatures, degassing, and pouring. Molten aluminum oxidizes readily in air, but the oxide clings to the surface of the exposed metal and prevents excessive formation of fumes. Crucibles may be of cast iron, graphite, and other nonmetallic materials. Several induction-type electric furnaces are in use in the area, especially in foundries melting alloys of the same composition day after day. Crucible-type furnaces, both stationary and tilting, are in common use for pours from 200 to 400 pounds per charge. For medium and large melting operations, either for casting or working ingot or for holding metal, the open-hearth reverberatory furnace is most used.

Larger furnaces of approximately 25 tons are usually charged from overhead boats, and the metal is tapped into ladles for casting. Smaller reverberatories of about 10 tons or less capacity are charged by hand through one end or through a small charging well on one side of the furnace. Metal is ladled out or tapped into pig molds.

A few barrel-type open-flame sweating furnaces are used by small operators for treating dirty scrap to produce aluminum pigs for remelting. Such furnaces are usually rather crude, gas-fired, stationary or revolving cylinders open at the high end and sloping steeply toward the lower, closed end. Scrap is charged into the open end, and molten metal trickles from the small openings in the lower end of the cylinder into the casting molds. Scrap iron and brass are raked from the furnace periodically. There is an excessive issue of fumes from the open end. Some of these furnaces are operated in the open or are poorly hooded and, therefore, are heavy contributors to air pollution. Stringent legal regulations and considerable vigilance have been necessary to control this intermittent, junk-yard type of operation.

Dross

Formation of dross is virtually unavoidable. The amount formed depends on on many factors, such as the equipment used in melting, the character of the materials comprising the charge, alloying procedure, and processing. Dross is an important cause of metal loss; requires careful handling to prevent fuming, dusting, and mechanical losses; and requires special treatment to recover the entrained metals and eliminate alumina. The larger establishments therefore re-treat dross in special equipment and furnaces, usually in a separate section of the works. Smaller operators and foundries may remove the easily recovered metals and sell the oxide to others for special treatment. Dross is skimmed and collected into steel dross buggies or boats for delivery to the dross plant or to storage.

Flux

Fluxing is practiced to some extent in virtually all secondary-aluminum melting. This is important from the standpoint of air pollution because some of the components of the fluxes are volatile and toxic, and if no fume-collecting equipment is provided, they are exhausted with other furnace gases to the stack.

This practice of fluxing is not to be confused with the inert slag covers, sometimes referred to as flux, used in copper-base alloy melts. In lightweight metal furnaces, in addition to providing a cover, aluminum fluxes are expected to remove included gas and oxide particles from the molten bath and to produce a dry dross containing the minimum of trapped, molten metal particles. In general use are various mixtures of potassium or sodium chloride with aluminum sodium fluoride (cryolite) and chlorides of aluminum, zinc, and sodium. One widely used flux59/ in secondary-aluminum work consists of 85 percent sodium chloride and 15 percent calcium fluoride; another is zinc chloride, often used to reduce oxidation during melting and to promote coalescence of the metal particles occluded in the dross. Full details of light metal fluxing practices are contained in a comprehensive manual, Process Control of Aluminum Foundry Procedure.60/

Chlorine and nitrogen are perhaps the most widely used gaseous fluxes. Helium, and more recently boron trichloride,61/ have been used in alloys for sand castings. The gases are introduced into the bath by lancing with a refractory tube connected to the gas source by a hose.

59/ Liddell, D. M., and others, Handbook of Nonferrous Metallurgy: McGraw-Hill Book Co., New York, N. Y., 2d ed., 1945, p. 34.

60/ Special publication, Soc. Auto. Eng., Inc., SP-8. 29 W. 39th St., New York 18, N. Y., $2.50.

61/ Corson, M. G., Nonferrous Melting Practice: Am. Inst. Min. and Met. Eng., 1946, p. 109.

Stack Effluents

Gases resulting from combustion of fuels used in light metals furnaces are the same as those mentioned previously for copper-base-alloy foundries. Use of helium and nitrogen gases also has been mentioned. They are used in small amounts and may pass off with the stack gases, although some of the nitrogen may combine to form aluminum nitride. Chlorine gas lanced into the molten bath appears to be entirely consumed. The volatile alkali chloride and fluoride in fluxes in general use readily pass into the stack effluents and when condensed may constitute the bulk of the particulate matter in the gases from reverberatories melting clean scrap. Table 4, Light-metal foundries, shows the significant data obtained when gases are tested from reverberatories melting clean scrap and oily scrap, and from the treatment of dross with salt-cryolite flux. Gaseous chlorides are evolved when reverberatories are fluxed with aluminum chloride. Very small quantities of gaseous florides and chlorides, up to about 0.006 grain per cubic foot, were found in the gas from salt-cryolite furnace-fluxing tests described later.

The amount of particulate matter in aluminum furnace gas varies greatly with the furnace operating conditions, the materials making up the charge, and the fluxes used. Under the conditions tabulated for tests in plant 2, table 4, particulate-matter loadings from a reverberatory furnace provided with a wet scrubber were rather high, 0.21 to 0.25 grain per cubic foot, indicating an average actual loss of 13.9 pounds per hour during a 13- to 20-minute fluxing period, as compared to a permissible loss of 5.3 pounds per hour. Table 1, plants 15 and 16, shows tests on pit-crucible furnaces melting aluminum and magnesium alloys with virtually insignificant losses of 0.01 to 0.05 pound per hour. In table 4, plant 1, a test on a 15-ton reverberatory-furnace charge melting selected scrap and aluminum pigs, indicated a loss of 2.2 pounds per hour as compared to a permissible loss of 3.9 pounds. A salt-cryolite flux was added at the charging well. The well was not hooded, therefore any chloride volatilized there would not be reported in the stack-gas analyses.

The major constituents in fumes from salt-cryolite dross treatment and in furnace fluxing was sodium chloride. Qualitative spectrographic analyses of exit-gas residues after ignition indicated that sodium and aluminum contents represented more than 10 percent of relative concentration, total elements reported as 100 percent. On the same basis, Mg and Si represented up to 10 percent. Many other elements were present in concentrations from 0.01 to 1.0 percent, including Fe, Pb, Mn, B, K, Cr, Zn, Ti, and Ni, to mention but a few. Furnace metal, with some exceptions, contained, in percent: Cu, 0.3 to 1.7; Fe, 0.2 to 0.6; Si, 0.2 to 0.7; Mg, 0.2 to 2.5, average about 0.5; and Mn, Zn, Cr, and Ni in the ranges below 0.25.

Recovery Equipment

Results of investigations of the performance of dust- and fume-collecting equipment suitable for aluminum-furnace work and dross treatment available at this time are rather meager. However, some trends are beginning to develop, and the electrical precipitator and venturi scrubber appear to be effective. Dust and fume loadings of gases from the larger remelt furnaces of the reverberatory type and the open-flame barrel-type furnaces are high, especially during charging and fluxing. This is especially true when much of the material charged is light or dirty scrap. Furthermore, much of the particulate matter evolved is chemical, resulting from the use of gases and chemical salts for fluxing, and is submicron in size. These fumes are mostly soluble in water or alkali solutions and suggest the use of wet scrubbers. In the dry state they tend to agglomerate and therefore may respond to sonic or ultrasonic vibrations.

TABLE 4. - Light metals foundries[1]

Date 1949	Plant No.	Collection equipment	Equipment tested	Time, min.		Process weight in lb.			Particulate matter				Products	Furnace, make and type	Fuel	Source of gas tested
				Process cycle	Length test	Per hr.	Total charge	Composition	Gr. per cu. ft.	Actual	Allowed	Violation				
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Sept. 7	1	None	Reverberatory stack.	1,200	60	1,857	37,150	Scrap and pig Al, salt, chlorine, (see col. 28.)	0.182	2.22	3.91	No	Al ingot, see col. 28 low-Mg. (0.01%).	Reverberatory, charging well on side.	Oil	Stack
Nov. 2	2	Yes	Pilot venturi, wet scrubber and cyclone.	480	20	3,386	27,050	Al scrap plus 12 lb. AlCl flux.	.25				Al pig.	Reverberatory 13-ton 18 hr.	P.S. 200 oil, 1 g.p.m.	Scrubber inlet and cyclone separator outlet
Nov. 2	2	Yes	do.	480	17	3,386	27,050	Scrap plus 90 lb. salt-cryolite flux.	.22	13.9	5.34	Yes	do.	do.	do.	do.
Nov. 3	2	Yes	do.	480	13	3,386	27,050	Oily Al scrap.	.21				do.	do.	do.	do.
Nov. 3	2	Yes	do.	N.D.	15	N.D.	N.D.	Salt-cryolite additions to dross buggies.	.048	N.D.	N.D.	N.D.	Al dross.	Gas from hood over buggy. Dross stirred during test.	N.D.	do.
Oct. 13	3	None See col. 8	Stack to reverberatory	270	60	2,220	10,000	Al scrap.	.179	.859	4.34	No	Al castings.	8' x 8' reverberatory	Gas, 60 c.f.m.	Stack.
1950 July 13	4	do.	Al reverberatory	1,440	77	1,800	43,255	Scrap, see col. 28.	4.1	62.4	3.91	Yes	Secondary Al pig.	Reverberatory.	Oil, 40 g.p.h.	Reverberatory stack.

Date 1949	Plant No.	Collection equipment	Equipment tested	Flue and gas conditions						Recovery equipment				Remarks
				Phase of process covered by test	Flue gas, press	Flue diam., in.	Temp., °F.	Av. vel., ft./sec.	Volume, s.c.f.m.	Est. spray, g.p.m.	Fume loading, gr./cu. ft. In	Fume loading, gr./cu. ft. Out	Eff., %	
1	2	3	4	18	19	20	21	22	23	24	25	26	27	28
Sept. 7	1	None	Reverberatory stack.	Charging and gassing.	29.9	28	1,150	17.2	1,420	-	See col. 28	See col. 28	N.D.	Col. 9, clean scrap and pig Al. Chlorine gas, 3 lb. bubbled into bath; 30 lb. (salt) flux cover added with scrap to charging well. Col. 25-26, no recovery equipment in use.
Nov. 2	2	Yes	Pilot venturi, wet scrubber and cyclone	Charging and fluxing.	29.9 29.9	N.D. N.D.	In 1,314 Out 162	N.D. N.D.	1,262 -	See col. 28 -	2.06 .043	0.25 .0023	88 95	Col. 10, solids dried at 105° C. Col. 23, about 50% of total volume. Col. 24, precooler, 2.5 g.p.m.; scrubber, 7.5; cyclone washer, 24. Col. 25 and 26, solids at 105° C. At 500° C. solid fume: in 0.64, out 0.085, 87% eff.; Col. 25 gaseous chlorides 0.043% by vol. 26 gaseous chlorides 0.0023% by vol. Col. 27, 88% eff. on solid; 95% on gaseous chlorides.
Nov. 2	2	Yes	do.	do.	29.9 29.9	N.D. N.D.	In 1,240 Out 146	N.D. N.D.	1,260 -	See col. 28 -	.80 .11	.22 .00	72 100	Col. 24, precooler, 25 g.p.m.; scrubber, 7.6; cyclone washer 24. At 500° C. solids in, 0.57 and out, 0.07. Col. 25 and 26 particulate fluoride; gaseous chlorides in, 0.0017, out, 0.0021%, by volume.
Nov. 3	2	Yes	do.	do.	29.9	N.D. N.D.	In 1,450 Out 153	N.D. N.D.	908 -	See col. 28 -	.38 -	.21 -	45 -	Col. 24, precooler water, 2.5 g.p.m.; venturi, 12.1; washer, 28; col. 25 and 26, solids dried at 105° C. Col. 11 and 12, average 3 test, 13.9 lb./hr. loss.
Nov. 3	2	Yes	do.	Fluxing dross in buggy.	29.9	N.D. N.D.	In 190 Out 120	N.D. N.D.	1,230	See col. 28	1.02 .91	.048 .009	95 99	Col. 24, water in scrubber 10.3 g.p.m., none in precooler or washer; Col. 25 and 26, solids at 105° C. Col. 25 and 26, solids at 500° C. Gaseous chlorides out 0.0005%; gas fluoride out 0.0% by volume.
Oct. 13	3	None See col. 8	Stack to reverberatory	Normal operation	29.9	15-1/2	1,210	22.9	560	N.D.	See col. 28	See col. 28	-	Col. 26, no visible fume from stack during test. No $AlCl_3$ caught in water wash of fume. Col. 25 and 26, no recovery equipment in use.
1950 July 13	4	do.	Al reverberatory	Mg removal by Cl.	29.9	23	570	20.2	1,780	-	-	-	-	Col. 6, test to determine fume emission during chlorination of Mg. Used 522 lb. Cl_2 during 114 min. Dense gray fume of Al salts and containing free Cl_2 emitted; Col. 9, 27,400 lb. cast scrap, 15,000 lb. dural; 855 Cu scrap.

[1] Source: Air Pollution Control District of Los Angeles County.
N.D. indicates no data given or available.

Tests reported in table 4, plant 2, on the performance of a dynamic wet scrubber employing the venturi principle have indicated high efficiency in the collection of fumes resulting from the treatment of dross with salt-cryolite flux. Collection efficiency improved with the increase in velocity of the gas through the venturi orifice.

A light metals concern, which processes aluminum alloys in open-hearth furnaces, has recently completed thorough pilot-plant tests of the performance of a Cottrell precipitator for collecting the stack emissions. When operated wet as a scrubber precipitator, it proved highly efficient and well-adapted for recovery of fumes and gases evolved during fluxing of dross, both in the furnace and in the dross buggy. Fumes from fluxes in general use in the industry were tested, including salt-cryolite and a proprietary formula, in the furnace and in outside dross treatment. Aluminum chloride flux was used in furnace and ladle fluxing. Normal operating conditions were maintained during furnace-fluxing tests, and other operations simulated actual conditions as closely as possible.

In salt-cryolite furnace-fluxing tests, the particulate-matter totals in inlet and outlet grain loadings in the precipitator were about 0.012 to 0.017 and 0.0002 to 0.002 grain per s.c.f., respectively, and precipitator efficiencies ranged from 87 to 99 percent. Metal temperatures in the furnace ranged from 1,370° to 1,400° F., and gas volumes were about 8,200 s.c.f.m. Gas velocities through the precipitator were about 800 feet per minute at stack conditions. The mean-gas temperatures were about 240° F. at the inlet and 135° F. at the outlet.

Elimination of gaseous chlorides from exit gases in the salt-cryolite furnace tests was 100 percent. Inlet grain loadings were low, about 0.008, and outlet, 0.0 grain per cubic foot.

Recovery of gaseous fluorides ranged from 90 to 98 percent and averaged about 94. Grain loadings in and out ranged from 0.005 to 0.012 and 0.0002 to 0.0013 grain per s.c.f., respectively, in terms of fluorine.

Furnace fluxing with aluminum chloride resulted in materially higher grain loads up to 0.62, but exit gases were cleared to 0.02 to 0.06 grain per s.c.f. for efficiencies of about 93 percent.

Over-all results obtained with the electrical precipitator were excellent. In all tests of practical significance, the precipitator exit gases were far below the permissible limits for particulate matter and well below the acceptable threshold limit of 5 p.p.m., by volume, of chlorine gas in gaseous chlorides. Exit gases also averaged less than the 3 p.p.m. threshold for hydrofluoric acid[62/] in gaseous fluorides. Under extreme conditions, some tests on salt-cryolite fluxing of dross in dross buggy and salt-cryolite treatment in the furnace resulted in some effluents containing over 3 p.p.m. of hydrofluoric acid. Under proper operating conditions, no fume was visible in the exit gases from the precipitator stack.

Examination of thermal precipitator[63/] samples of fume from salt-cryolite fluxing under the electron microscope indicated that all particles were less than 2

[62/] Silverman, Leslie, Industrial Air Sampling and Analysis: Ind. Hygiene Foundation, Bull. 1, Pittsburgh, Pa., 1947, p. 3.

[63/] Stanford Research Institute, Second Interim Report on the Smog Problem in Los Angeles County: Los Angeles, Calif., August 1949, p. 24.

microns and most of them are below 0.1 micron diameter. There was no apparent selectivity in the catch of the electrical precipitator as to the chemical composition of fume from salt-cryolite and other fluxing tests.

Construction of an electrical precipitator scrubber was nearly completed. It is designed to treat fumes from dross-recovery units, which are said to operate on chemical principles and to require no extraneous fuel.

The precipitator is designed to treat 10,000 s.c.f.m. of process gas with dust loadings up to 7.0 grains per s.c.f. within the temperature range of 70°-200° F. and with a pressure drop of not over 2 inches of water. Particulate matter to be collected will consist primarily of condensed metallurgical fumes containing sodium, potassium, and aluminum chlorides and small percentages of silicon, magnesium, and other metallic oxides. Some hydrochloric acid may be formed, and the gas stream may contain small amounts of gaseous fluorides. Up to 50 g.p.m. water may be used for sprays and flushing.

The precipitator will consist of a redwood shell 12 feet in diameter containing 10 redwood ducts 9 inches by 8 feet by 8 feet. Discharge electrodes will be of twisted square-steel rods; collecting electrodes are to be of transite with slot-type scrubbers. A 10-kv.-a. transformer tapped for 75 kv. maximum will serve a 10-kv.-a. mechanical rectifier. The erected cost of this type of small precipitator is said to be about $2 per s.c.f.m. of rated capacity.

Magnesium

Pure magnesium melts at 1,202° F. and boils at 2,025° F. It burns in air at casting temperatures and, therefore, must be handled with exceptional care. Its alloys usually contain aluminum, zinc, and manganese and make excellent sand castings and permanent mold and die castings. All require special fluxes and close temperature control. Casting of ingots for working requires even more care and special refining and fluxing steps. Foundry furnaces are mostly of the small pot-type, having cast-steel or steel-plate crucibles lined with aluminum.

Both solid and gaseous fluxes are used in foundries making sand castings. Solid fluxes consisting of chloride salts are used to form a dry crust over the surface of the metal in the pot at about 1,400° F., because the metal will burn immediately on contact with air. Fluxes of somewhat similar composition that remain fluid at casting temperatures are also used. Melts are usually purified by lancing with chlorine gas. Pours are made at 1,450° to 1,600° F., but the metal temperature may be raised to about 1,700° F. for a short period just before pouring.

Permanent-mold castings are made from magnesium alloys containing about 2 percent zinc and 9 percent aluminum. The alloys are melted in cast-steel crucibles holding up to 800 pounds and are poured at 1,200° to 1,350° F. Fluxes are charged along with ingot and clean scrap.

Metal for die casting contains aluminum and zinc and, in addition, about 1 percent manganese and sometimes beryllium in extremely small (0.001-percent) amounts. The surface of the molten metal is prevented from igniting by maintaining an atmosphere of sulfur dioxide over the melt. Refining fluxes are usually employed but not as covers.

All processes for making ingots require fluxes[64] usually containing chloride salts of potassium, magnesium, barium, and magnesium oxide and calcium fluoride. Ingots are cast under controlled conditions between 1,240° and 1,275° F.

Some of the larger magnesium foundries in the Los Angeles area operate gas-fired, 2,000-pound-capacity, tilting crucible furnaces. Many smaller crucible furnaces of 200 to 400 pounds capacity are used for holding and pouring. Most castings are made in permanent molds. Large annealing furnaces in the district use floor trucks containing electrically ignited pyrite or sulfur burners to maintain an atmosphere of sulfur dioxide. The truck, loaded with metal, is placed inside a furnace chamber in which a slightly positive pressure is maintained. Any escaping sulfur dioxide gas is caught in vented hoods and exhausted. This gas may be recirculated to conserve sulfur and to preclude the possibility of air pollution.

Very few tests on magnesium-furnace fumes in the Los Angeles area have been published. The use of volatile fluxing materials containing noxious chlorine and fluorine compounds and the tendency of the metal to burn at pouring temperatures would seem to make magnesium-furnace gases similar in character to those encountered in aluminum work. Most magnesium furnaces in the district are small, however, and are closely controlled. So far as known, no open-flame-type furnaces are in use in magnesium foundries in the area, even on scrap containing magnesium as a major constituent. A test made on a typical, small magnesium furnace reported in table 1, plant 16, indicated a very low concentration of particulate matter in furnace-exhaust gases.

Fumes from burning magnesium grindings contained dust loadings well over the allowable limit of 0.4 grain per cubic foot under the conditions set up for testing. The electrical precipitator removed about 97 percent from inlet gases containing 0.4 grain per cubic foot. No fumes were visible in the exit gases.

The Nonferrous Foundry report[65] concluded that "furnaces melting magnesium and aluminum alloys containing low percentages of zinc produced negligible quantities of particulate matter, and should require no more ventilation than is required to take care of the products of combustion and hot gases." This conclusion may be justified for small crucible-type furnaces but is not supported by the data in table 4, plant 2, and elsewhere in this report, for large reverberatory funaces of the type used for aluminum scrap.

FERROUS PYROMETALLURGICAL INDUSTRIES

Introduction

Stature of the Industries

Ferrous-pyrometallurgical industries in the Los Angeles area include gray-iron foundries and electric and open-hearth steel production. Pig iron and iron and steel scrap, together with coke, limestone, and minor alloying constituents, such as manganese, silicon, and nickel, are the raw materials required for steel manufacture.

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[64] Gustafson, K. R., The Casting of Magnesium Ingots for Working: Metals Handbook, Am. Soc. Metals, 1948 ed., p. 974.

[65] Industrial Consultants, Report on the Air Contaminants Produced by Furnaces in the Nonferrous Foundry Industry: April 1948, p. 14.

Because no primary pig iron is produced in the County, the ferrous foundry and part of the steel industry, like the nonferrous industries, are classed as secondary-metal operations.

In addition to the gray-iron- and steel-foundry industries, two large national concerns produce open-hearth and electric steel billets for working. Their combined nominal capacity was estimated to be 240,000 - 300,000 tons per year on a 40-hour-per-week basis. Their dust and fume losses are lower than in gray-iron industries, amounting to about 0.5 percent of process weight when operated without dust-collecting equipment. Owing to the great preponderance of particulate matter below 2 microns in diameter in their stack emissions, a large amount of it will remain in suspension. Air pollution from steel manufacturers in Los Angeles County obviously has been very considerable.

Concerning the area's steel industry, the current annual report of the Air-Pollution Control District states that one major concern is progressing rapidly with installation of electrical precipitators on its open-hearth furnaces, and another large producer, which has been operating open-hearths, will replace them66/ with electric furnaces complete with control equipment. Data indicate that 12.8 pounds (0.6 percent of process weight) of dust and fume are released into the atmosphere for every ton of material charged to the open-hearth furnace.

Adequate control of fumes from electric furnaces pouring steel castings appears in sight. Two basic types of collecting equipment have been found to reduce emissions to acceptable limits. These are bag filters and in some instances dynamic wet collectors. An average figure of 5.9 pounds per ton (0.3 percent) of process weight has been obtained from tests on furnace emissions in the electric steel-casting industry without collecting equipment. About 68 percent of the weight of the particulate matter is less than 5 microns in diameter, according to the District's annual report.

Approximately 60 gray-iron foundries were active in the Los Angeles area at the time of this writing. About 75 percent of these are medium to small independent establishments, and some of the rest, mostly larger concerns, are captive foundries. About half of the latter are medium to large shops producing principally pipe and hollow ware at the rate of 1,200-1,400 tons per week. Some 1,800 tons per week, mostly light castings, made up the balance of the industry's current rate of about 2,200 tons per week. At an over-all yield of about 64 percent,67/ the metal poured would be about 3,300-3,400 tons per week or about 173,000 tons per year. This is about 60 percent of the industry's nominal rated capacity of 290,000 tons per year.

Seven steel foundries are now in operation. Their stack losses have been 0.3-0.4 percent of process weight. At current rates of production about 31,000 tons of steel castings would be poured per year. Thus the combined foundry industries at present will pour about 200,000 tons metal per year and at nominal capacity would pour something like 340,000 tons. Without effective dust-collecting equipment, particulate matter discharged into the air would amount to about 0.9 percent of the process weight, somewhat over 1 percent of the weight of metal poured.

66/ Orders for strategic equipment may make the continued operation of the open-hearths necessary.

67/ Industry statistical estimates were supplied by Robert Gregg, director, American Foundrymen's Society, Los Angeles.

Foundrymen acting through technical committees of their trade association and in cooperation with the equipment manufacturers, the Los Angeles Chamber of Commerce, and the Engineering Department of Air-Pollution Control District, are vigorously campaigning to reduce air pollution produced by the ferrous industry. Control of metallurgical dust and fume adequate to meet legal standards in the Los Angeles area is entirely feasible and is underway among the larger concerns operating on a basis that justifies the installation of adequate but rather expensive equipment. Entirely satisfactory and economic solutions to the difficulties of small to medium foundries operating the conventional type open-top cupola, however, have not yet been found, but considerable progress has been made. These matters will be discussed in some detail later in this report.

Problems of the gray- and malleable-iron foundries are very different from those of the electric and open-hearth steel manufacturers and are treated separately.

Acknowledgments

The Technical Subcommittee Report of the Gray-Iron-Foundry Smog Committee, prepared by Industrial Air Control Associates, has been used freely in the preparation of the gray-iron section of this report. Table 5 was assembled entirely from data contained in the subcommittee report, and acknowledgments have been made in the text wherever the report was quoted directly. Members of the subcommittee and many operators and engineers in the industry have supplied valuable information and assistance through direct communications. Experimental and routine production operations were observed at several establishments. Much background and direct help were obtained from sources acknowledged in the introduction at the beginning of this report. Every effort has been made to give proper credit to these and all other sources in the text or in footnote references, but some inadvertently may have been overlooked.

Gray-Iron Foundry

In June 1948, the Technical Subcommittee of the Gray-Iron Foundry Smog Committee,68/ after careful consideration of a survey of the existing literature pertaining to gray-iron cupola-stack emissions, decided to initiate and finance a thorough technical investigation of the subject. Accordingly, Industrial Air-Control Associates69/ was retained as prime contractor to conduct the work and report its findings to the subcommittee. Three foundries in the area representing typical small-, medium-, and large-scale operations were selected, and suitable test methods were adopted. Much of the procedure had to be developed and checked in the field, because no satisfactory precedent for complete analysis of foundry cupolas was available.

Operations

The report containing data resulting from this investigation constitutes an excellent analysis of the conditions that prevailed in the gray-iron-foundry industry in Los Angeles. A summary of resulting data is, therefore, presented in table 5, quoted directly from the subcommittee's report. The table also discloses most of the pertinent conditions of furnace operation, and these are said to be quite representative of general practice in the county.

68/ A committee of Los Angeles foundrymen.
69/ A group of six well-known Los Angeles consulting and testing engineering firms.

TABLE 5. - Test cupola operations[1]

Operating conditions	Cupola A	Cupola B	Cupola C
Diameter of melting zone	48 in.	37 in.	48 in.
Height - bottom plate to top of stack ..	41 ft. 5 in.	30 ft. 3-1/4 in.	51 ft. 1 in.
Height - bottom plate to bottom of charging door	20 ft. 8 in.	16 ft. 1/4 in.	16 ft. 6 in.
Size of charging door (height by width).	8 ft. 9 in. x 5 ft. 3 in.	2 ft. 3 in. x 2 ft. 6 in.	3 ft. 7 in. x 3 ft. 6 in.
Charging method	Mechanical	Hand	Hand
Air-weight control	Yes	Yes	No
Type of blower	Positive	Positive	Positive
Type of blast	Regular	Regular	Regular
Height of bed coke	73 in.	56 in.	44 in.
Kind of bed coke	(2/)	(3/)	(4/)
Weight of coke in bed, pounds	3,000	1,400	2,000
Kind of coke charge, cupola A	(5/) (7/)	(3/)	(4/)
Charge:[6]			
Scrap iron .... 450 lb.	375 lb.	100 lb.	800 lb.
Scrap steel .... 300 lb.	675 lb.	225 lb.	-
Returns .... 750 lb.	300 lb.	300 lb.	500 lb.
Pig .... -	150 lb.	175 lb.	-
Coke .... 240-300 lb.	240-300 lb.	130 lb.	-
Limestone .... 60 lb.	60 lb.	17 lb.	30 lb.
Ferroglaze .... -	-	5 lb.	3 lb.
Cast iron .... -	-	-	1,200 lb.
Melted-iron temperature, °F.	2,760-2,800	2,700-2,840	-
Tap method	Intermittent	Intermittent	Intermittent
Total tons melted	14.35	5.2	45
Total time of blast	2 hr. 36 min.	1 hr. 20 min.	5 hr. 20 min.
Melting rate, tons iron per hour	5.52	3.9	8.3
Process weight, pounds per hour	13,500	9,282	18,900
Results from sampling and testing emissions			
Light-off period			
Volume of cupola emissions .... cu. ft./min. (note 1)	16,300	3,000	5,920
Velocity of emissions at stack temp. .... f.p.s.	12.6	5.7	7.6
Orsat analysis of gases ..... percent			
CO_2	0.3-0.8	1.0-10.3	0.8-3.0
O_2	19.3-20.3	10.1-19.2	17.4-20.5
CO	0.0	0.0	0.0
Particulate matter...grain per cu. ft.	0.009	0.0014	0.360
Particulate matter ....lb.	1.260	0.026	18.300
Condensible oils, greases, etc. ...... grain per cu. ft.	0.002	0.00002	0.001
Smoke opacity (see note 2)	0	2	52
Melting period			
Volume of emissions .... cu. ft./ min.	20,570	5,020	15,600
Velocity of emissions at stack temp. .... f.p.s.	41.7	31.8	37.5
Orsat analysis of gases ...... percent			
CO_2 ...	2.0-5.4	10.0-13.4	2.2-510
O_2 ...	14.4-18.5	6.5-10.1	14.5-19.2
CO	0.0	0.0	0.0
Results from sampling and testing emissions (Cont.)	**Cupola A**	**Cupola B**	**Cupola C**
Melting period (Cont.)			
Particulate matter..grains per cu. ft.	1.110	1.604	0.798
Particulate matter..lb. per hour, loss	196	69	107
Loss .... percent of process weight	1.45	0.74	0.57
Allowable loss .... lb. per hr.	12.5	9.5	15.5
Condensible oil, greases, etc. .... grain per cu. ft.	0.019	0.008	0.025
Volatiles .... do.	Negligible	Negligible	Negligible
Zinc oxide .... do.	.008	.009	.003
Lead .... do.	.006	.010	.003
Sulfur compounds (SO_2) percent by volume	.002	.012	.013
Proximate analyses of emissions, percent:			
Volatile	6.77	6.70	6.66
Fixed carbon	11.93	3.04	19.17
Ash	81.30	90.26	74.17
Sulfur content of bed coke .... percent by weight	0.630	0.520	0.660
Sulfur content of charge... do.	.550	.520	.660
Sulfur content of cast iron do.	.143	.130	.170
Smoke opacity (see note 2)	90	83	18
Volume of emissions at stack conditions .... c.f.m.	65,000	20,400	37,000
Volume of emissions at standard conditions .... c.f.m.	20,570	5,020	15,600
Maximum stack temperature .... °F.	1,280	1,700	1,200
Average stack temperature .... do.	1,188	1,656	775
Particulate matter ...... gr./cu. ft.:			
At stack conditions	0.355	0.655	0.190
At standard conditions	1.110	1.604	0.798
Report of tests: Screen analysis, percent:			
+ 60-mesh	19.8	8/5.91	8/10.90
- 60- + 80-mesh	2.9	4.43	6.26
- 80- +100-mesh	3.0	5.80	6.64
-100- +200-mesh	15.5	18.38	16.88
-200- +325-mesh	45.1	12.46	31.64
-325-mesh	13.7	53.02	27.68
Total	100.0	100.02	100.00
Particle size of the -325-mesh material:	Percent	Percent	Percent
50 to 25 microns	35 4.8	25 13.3	25 6.9
25 to 10 microns	25 3.4	30 15.9	30 8.3
10 to 5 microns	10 1.4	25 13.3	15 4.2
Minus 5 microns	30 4.1	20 10.6	30 8.3
	100 13.7	100 53.1	100 27.7
Condensible oils, grease, etc. at stack conditions .... gr./cu. ft..	0.006	0.002	0.010
Volatiles at stack conditions do.	Negligible	Negligible	Negligible
Volatiles at standard conditions do.	do.	do.	Do.
Water-soluble sulfates in particulate matter, as SO_3 ..... percent by weight	1.81	1.47	1.04

[1] Source: Industrial Air-Control Associates, Technical Subcommittee Gray-Iron-Foundry Smog Committee Report, Dec. 16, 1948.

[2] Indianapolis Power & Light - sulfur content, 0.63 percent. [3] Mixture of 1 and 2 - sulfur content, 0.52 percent.

[4] American Brake Shoe Byproducts - sulfur content, 0.66 percent. [5] St. Paul Koppers - sulfur content, 0.55 percent. [6] 8 charges. [7] 13 charges.

[8] Wet screened "brush-down" sample as received, using distilled water and wetting agent.

Note 1. - Volumes and concentrations are reduced to standard conditions of 60° F. and 14.7 lb. pressure.

Note 2. - Percent of time in period during which opacity equaled or exceeded prescribed limit of 40 percent by Ringlemann chart.

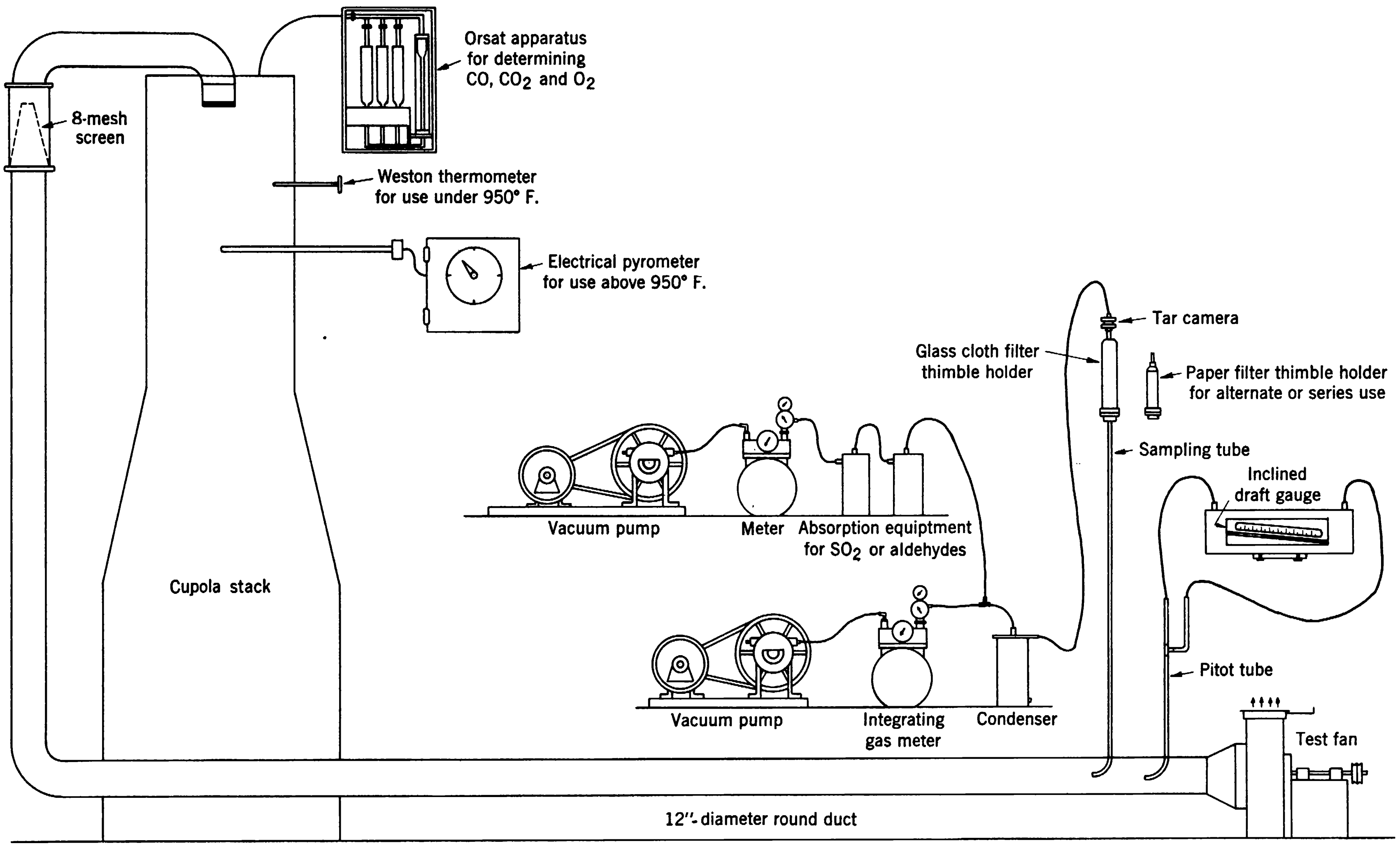

Figure 21. - Diagrammatic sketch of cupola-sampling layout. (Courtesy of Menardi & Co.)

Methods and equipment for sampling, based on Bulletin WP-50,[70] were first tested and procedures were established in full-scale preliminary runs on a cupola in regular operation using the lay-out diagramed in figure 21. A brief description of methods used in the final sampling is included here for a better understanding of the matter presented in the table. It is quoted directly from the Technical Subcommittee Report.[71]

> ## Sampling Methods and Equipment
>
> The taking of final samples at the test cupola was accomplished by a two stage method. A primary sample was drawn from the stack through a 12" duct by an exhauster. An eight mesh screen in this duct removed large particulate matter. A secondary sample was removed from the duct near the suction blower.
>
> The secondary sample was withdrawn from the 12" duct by a stainless steel sampling nozzle, and tube which led to a thimble holder containing a Whatman paper thimble on which particulate matter and condensible oil, grease and tar were deposited. Beyond this filter the sampling circuit was divided into three lines, each actuated by a separate vacuum pump. Two of these lines led through a series of gas dispersion flasks, one set of which contained sodium carbonate for the absorption of sulphur compounds, the other containing carbon tetrachloride for absorption of volatile oil, grease and tar. The balance of the filtered gases was led through a condenser and moisture trap, and its volume measured in a test gas meter. Three separate meters, equipped with temperature and vacuum gauges were used to measure volumes through the three branches of the sampling circuits.
>
> Analyses of combustion gases were made at the secondary sampling point with a portable Orsat method gas analyzer. Temperatures were measured at this point as well as velocity, which was determined at intervals with a Pitot tube and draft gauge.
>
> Stack temperatures were measured with a thermocouple leading to an electrical pyrometer at the sampling station. Frequent velocity checks at stack top were made by Pitot tube measurement.
>
> Smoke density observations were made by visual observation, the time and degree of opacity of each change of condition being noted.

Conclusions drawn in the Technical Subcommittee Report are, essentially, the following:

(1) The total particulate matter emitted from these cupolas varied from 0.8-1.6 grains per s.c.f. or from 13-35 pounds per ton of iron produced.

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[70] General methods for sampling industrial furnace gases are contained in:
Western Precipitation Corp., Gas and Dust Measurements: 4th ed., Bull. WP-50, Los Angeles, Calif.
Air-Pollution Control District of Los Angeles County, Test Procedures and Methods of Sampling in Air-Pollution Control: 1950.

[71] Industrial Air Control Associates, Technical Subcommittee Gray-Iron-Foundry Smog Committee Report: Dec. 16, 1948.

(2) From 14-53 percent of the particulate matter was smaller than 325-mesh, or approximately 44 microns in diameter, as indicated in table 5. This matter can be removed only by carefully designed equipment. The portion larger than 44 microns (86-47 percent) is coarse enough to be collected by simple devices.

(3) Probably most of the cupola emissions in the area exceeded the legal limits for total particulate matter, since no remedial equipment had been installed at that time.

(4) Zinc and lead in the particulate matter were low enough to offer no significant pollution. The same was true with respect to volatile and condensible oils and tars and to gaseous sulfur compounds.

(5) Sulfur content of the particulate matter in the form of soluble sulfates, on the other hand, was important from the standpoint of the design of remedial equipment.

(6) Opacity of the smoke during light-off period varies and was often in violation. The smoke, however, can be controlled and has been controlled by proper light-off practice.

(7) Dry centrifugal collectors or wet washers may be used to collect the coarser part of the emission. A wet washer placed on top of the stack will control the coarser particles, but all the data available indicate that it is not suitable for collection of the finer particulate matter.

(8) If an open charging door is used, the resulting dilution not only increases the volume of the gases that must be cleaned, but much higher temperatures are encountered owing to burning in the upper portion of the stack.

(9) In any equipment using water, the soluble sulfate content of the emission must be considered since corrosion problems may arise unless corrective measures are provided. Also, since large volumes of water are needed for effective washing, a recirculation system probably will be required to keep the water consumption to a reasonable figure. Recirculation of the wash water would simplify chemical treatment to prevent corrosion.

Analyses of the gaseous components of the stack effluents are shown in table 5 for the two periods of the cupola cycle, light-off and melting, together with the total gas volumes reduced to standard conditions of 60° F. and 14.7 p.s.i.a.

Stack Effluents

Volumes of stack gases are very considerable even for small- and medium-capacity cupolas and therefore require substantial blower equipment. The dust-collecting equipment will have to be proportionally large. The cupolas tested, for example, use volumes of 5,000-20,500 s.c.f.m., equivalent to 20,400-65,000 c.f.m. at stack conditions. This corresponds to 39-112 s.c.f. of gas per pound of metal poured or, on the basis of total process weight, from 32-91 s.c.f. per pound of material charged. Later tests (table 6) with cupolas having some form of preliminary dust-recovery equipment, resulted in volumes ranging from 2,000 to 30,000 s.c.f.m.

TABLE 6. - Test data on gray-iron cupolas[1]

Cupola diam., in.	Volume, s.c.f.m.	Particulate matter			Recovery equipment
		Gr./s.c.f.	Loss, lb./hr.	Allowable, lb./hr.	
1-37	6,300	1.06	57.2	8.77	No data.
1-42[2]	10,100	.321	27.2	9.52	After spray-type water curtain, and wet impinger scrubber.
1-63	30,600	.414	108.5	26.8	Part of gas burned for preheating blast air. Figures given are totals.
1-27	3,000	1.07	27.6	6.0	No data.
1-36	2,000	.897	15.2	11.5	Closed top through dry collectors: 4-stage packed towers: Spray eliminator.

[1] Source: Air-Pollution Control District of Los Angeles County.
[2] Making malleable iron castings.

The most recent tests on five cupolas by Air-Pollution Control District showed an aggregate process weight of 50,826 pounds per hour. The five cupolas were supplied with a total volume of tuyère air of 11,410 s.c.f.m. This corresponds to 13.5 s.c.f. per pound of process weight. District engineers add 80-100 percent to the tuyère air to allow for dilution at the charging door of conventional open-door cupolas to arrive at the total volume of stack gas expected. Many useful weight ratios with the usual or recommended ranges are tabulated in a recent review[72] of methods for removal of dust and fume from cupola stacks.

Sulfur contents of the coke and cast iron, which for the most part are discharged in the stack gases, resulted in concentrations of 0.002-0.013 percent SO_2, by volume, as shown in table 5. The amounts of volatile lead and zinc and condensable oils and greases were determined and represent a small percentage of the total particulate matter emitted during the melting period.

Particulate matter emitted during the light-off period was, of course, relatively low; but, during melting, dust loads ran up to 0.8-1.6 grains per cubic foot, which, on the basis of mass rate of emission, far exceeds the permissible limits. The permissible limits for cupola B are a particulate matter stack-discharge loss of 9.5 pounds per hour as compared to the actual of 69 pounds. The grain loading would have to be reduced from 1.6 to 0.22 grain per cubic foot. From 14 to 53 percent of the particulate matter emitted by the test cupolas was smaller than 40 microns, and 4 to 10 percent of the total particulate matter was below 5 microns. The amount of particulate matter in the lower range of particulate sizes is enough to give difficulty in obtaining complete clearance of the exit gases but is not beyond the recovery range of the more expensive industrial equipment.

Foundry Equipment and Dust Suppression

Equipment capable of reducing particulate matter in iron cupola-stack emissions to the extent required by law is available but in a price range that some small

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[72] Witheridge, W. N., Foundry Cupola Dust Collection: Heating and Ventilating, vol. 46, No. 12, December 1949, pp. 70-84.

foundries cannot afford to pay. Limited, but quite favorable experience in Los Angeles with other types of gray-iron melting furnaces indicate that the following types of furnaces might comply with the Los Angeles code. These types are: (1) The electric furnace; (2) gas- or oil-fired reverberatory; and (3) continuous gas-fired rotary melting furnaces.

The use of the electric furnace is an expedient open to the small foundryman where energy is available at a low enough cost. Capital cost of this type of furnace is in the order of four times that of the simple cupola of equal capacity. Dust emissions from most types of electric furnaces are lower and much easier to control. One such operation by a resourceful foundryman is briefly described later. Experience in the Los Angeles area is limited, but results so far indicate competitive operating costs and great flexibility.

At least one small, commercial, reverberatory-type melting-furnace operation has been tested by Air-Pollution Control District. This was a tilting-type, gas-fired furnace melting a 1,000-pound charge at the rate of 546 pounds process weight per hour. The charge consisted of 300 pounds pig iron; 500, scrap; and 200, returns, with 2 pounds soda ash. Orsat analyses of stack exit gases averaged 1.5 percent CO_2; 18.4, O_2; and 80.1, N_2. The volume of dirty gas was 12,270 c.f.m. at 775° F., including much dilution with air at the entrance to the stack; no gas-cleaning equipment was in use or required. Gas-fuel consumption was 70 c.f.m. The exit gas contained 0.00288 grain per cu. ft., and actual losses were only 0.13 pound per hour, as compared to an allowable loss of 1.9 pounds per hour.

Based on experience with reverberatories used in the malleable- and roll-iron industries in the Middle West, some authorities believe that the oil-fired reverberatory, capable of maintaining temperatures up to 2,900° F., could be used to advantage in the Los Angeles area. The estimated cost of a 5-ton batch furnace (4 by 16 feet inside), equipped with oil burners is about $12,000 f.o.b. factories in the Middle West. Operating costs are said to be competitive with other types of furnaces of like capacity.

A third type suggested as a substitute for the cupola is the gas-fired continuous rotary melting furnace. One large manufacturer73/ of all types of gray-iron-foundry equipment has had experience elsewhere with the rotary furnace, producing 1.5 tons per hour at 2,800° F. Refractory costs were said to be higher, but because of the high cost of coke in the Los Angeles area (currently about $32 per ton), the over-all operating cost on the continuous basis was estimated to about equal the cupola operation.

The first cost of this type of furnace, f.o.b. factory in the Middle West, ranges from about $10,000 for 1,000-pound-per-hour capacity to $16,000 for the range from 3,000- to 5,000-pound capacity. Considering production operations elsewhere, the manufacturer, who is familiar with the Los Angeles conditions, believes that the continuous rotary furnace could comply with the Air-Pollution Control District code.

Almost all small- and medium-capacity gray-iron cupolas in the Los Angeles area are of the conventional type, with open top, discharging their stack gases directly

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73/ Communications from Whiting Corp., Harvey, Ill.

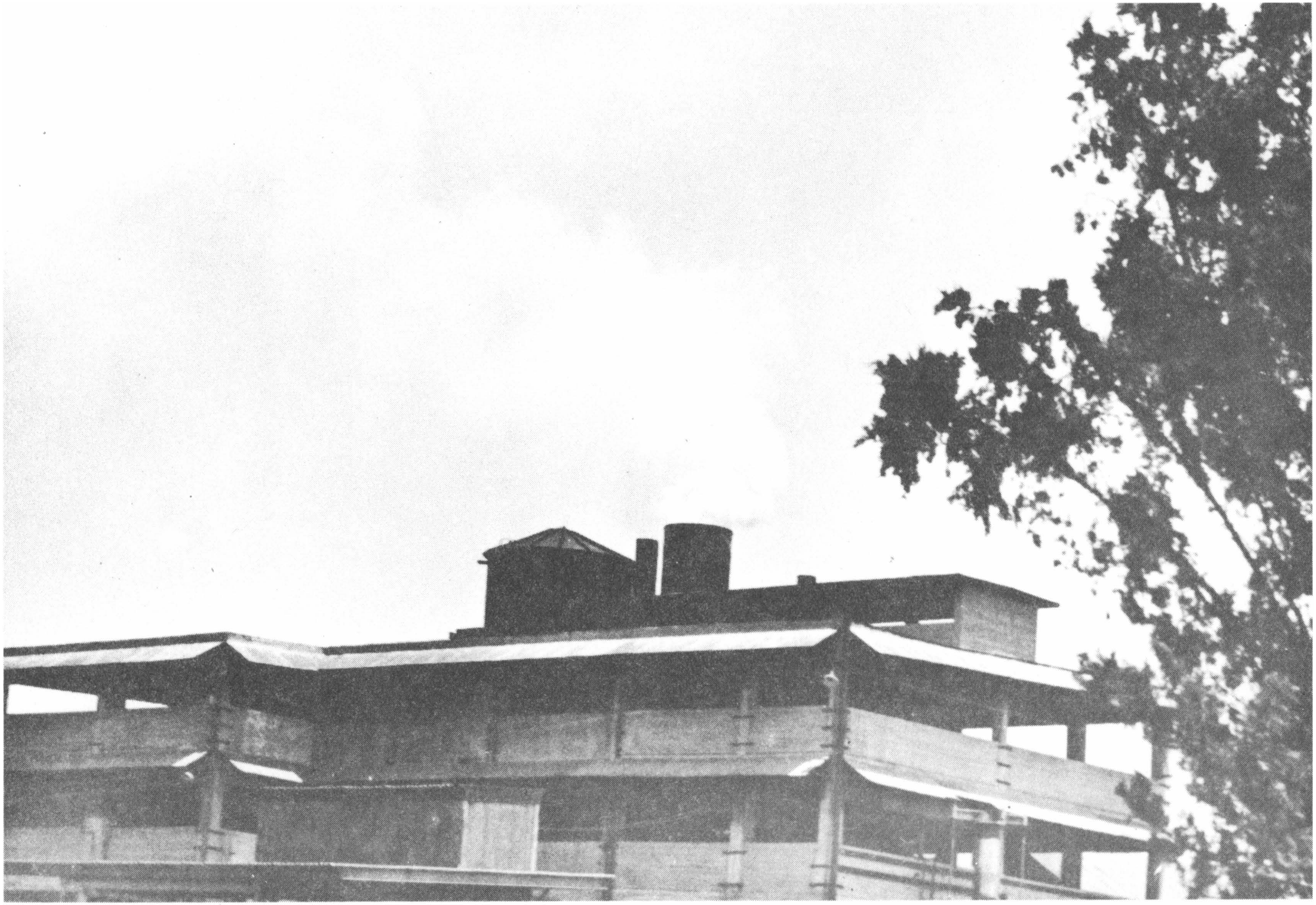

Figure 22. - Stack exhaust from cupola having no fume collection.

into the atmosphere (fig. 22). Many foundrymen are traditionally afraid of gas explosions if cupola gases are confined, and this apparently has deterred achieving effective dust recovery, expecially at small foundries. Mechanical complications of charging the closed-top cupola and collecting the gas apparently can be overcome by adopting the technique long used on blast furnaces but on a very much smaller scale. This will be discussed later. Overcoming the small foundryman's fear of the closed-top cupola and paying for the additional equipment are perhaps greater obstacles.

It is becoming quite apparent that no single, inexpensive dust-recovery principle, such as a simple water curtain, scrubber, or even the multitube, dry, centrifugal collector, will be adequate. One exception to this is the high-temperature baghouse, but at a materially higher cost. Therefore, the use of two or more types of equipment in series may be required. Equipment indicated for the first stage includes almost any of the high-efficiency, dry, cyclonic, multitube separators. A rather large settling chamber with baffles or other means of partly cooling and reversing the direction of the gas stream and dropping out the coarser particles has been used with some success. Such devices may account for about 50 percent by weight of the particulate matter in the gas. It was thought that some of the many types of dynamic wet scrubbers or of the more efficient packed towers might be found satisfactory for the second stage, and that some combination of the simpler and inexpensive types of equipment would prove adequate and practical. If not, for a third step, some of the proved equipment, such as bag filters or electrical precipitators, will be required to collect particulate matter smaller than 10 microns. This indeed appears to be a formidable train, especially for the smaller establishments, but may be materially simplified by pending developments involving the use of equipment mentioned later.

A type of dry, inertial collector found surprisingly effective as a preliminary cleaner for cupola-stack gases is reported[74] to give 50-75 percent reduction of dust load from gases in which about 50 percent, by weight, of the particulate matter was smaller than 50 microns (300-mesh) in diameter. Dalla Valle[75] states that, while probably not as efficient as others, this device is without question the most compact inertial unit available for cupola work. This cleaner, recently described,[76] appears simple and inexpensive. Its efficiency was claimed to equal that obtained with one of the best-known hydrodynamic scrubbers tested on gas from Los Angeles cupola B (table 5), a gas also containing about 50 percent of its particulate matter in sizes smaller than 50 microns.

Development Trends

Several methods of abating cupola dusts and fumes are being pursued in the Los Angeles area, leaving little doubt that means of satisfactory control are in sight. To date, the high-temperature baghouse and the electrical precipitator, in pilot operations, have achieved adequate collection of particulate matter, including the

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[74] Witheridge, W. N., Foundry Cupola-Dust Collection: Heating and Ventilating, vol. 46, No. 12, December 1949, pp. 70-84.

[75] Dalla Valle, J., Principles of Design, Application, and Performance of Dry Inertial and Motor Powered Dynamic Separators: U. S. Tech. Conf. on Air Pollution, Washington, D. C., May 1950 (in press).

[76] See footnote 74.

difficult-to-collect sizes below 40 microns. Several full-industrial-scale baghouses similar to that described below are under construction. A third method in full-scale operation, involving the use of the packed tower and hydrodynamic scrubber in conjunction with the closed-top cupola, is approaching satisfactory performance. A fourth involves use of the electric furnace in conjunction with the sock-type baghouse. Capital and operating costs may be the deciding factor in the choice of methods adopted.

General Metals Corp., one of the largest malleable foundries in the area, operates a pair of Whiting standard No. 3-1/2 cupolas similar to that diagramed in figure 23. These are operated singly on alternate days. A typical charge for a 7-1/2-hour shift consists of about 64,000 pounds of metal, coke, and flux, resulting in a process weight of approximately 9,000 pounds per hour. On this basis, tests have indicated that from 17,000 to 19,000 c.f.m. stack gas leaves the hydrodynamic collector at about 350°-400° F., which is equivalent to 8,000-12,000 s.c.f.m. carrying from 0.38 to 0.27 grain per cubic foot, or about 20 to 33 pounds per hour. The permissible discharge for a process weight of 9,000 pounds is 9.36 pounds per hour.

After considerable testing and experimental operation, the Corporation decided to clean its cupola gases by the use of a high-temperature (500° F.) baghouse. Self-closing charge doors will be used, and gas burners will be provided 30 inches above the top of the charge-door elevation to insure complete secondary combustion in the cupola stack. The hydrodynamic collector will be provided with explosion-door covers, and enough spray water will be used to prevent emission of gases above 1,000° F. to protect the metal duct work. Radiation from the duct work connecting the cupola stack with the baghouse will be enough to insure gas temperatures not over 500° F. at the baghouse. A 20-hp. fan speeded to deliver about 12,500 c.f.m. at 500° F. against a pressure of 6 inches of water will maintain a pressure of 4 inches maximum on the bags.

The pressure-type baghouse will consist of five units, each containing 20, 11-inch diameter by 15-foot glass-fiber bags suspended from an automatic rapping device at the top closed end of the bag. The hot gases are forced into the manifold feeding the lower open end of the bag. The bags and rapping mechanism will be protected by a well-ventilated shed. Available bag area will be 4,315 square feet thus providing for 3 c.f.m. per square foot of bag surface.

The efficiency and economy of the glass bag have been demonstrated over several years of operation under severe conditions in the nonferrous-foundry industry in the Los Angeles area, as noted earlier in this report. The General Metals Corp. baghouse will be the first installation in the area using glass bags for ferrous cupola-dust recovery. At least one installation of woolen bags has been used on fumes from electric steel furnaces. Results in this case were rather unsatisfactory on account of occasional excessively high gas temperatures.

Closed-Top Cupola

Development of the closed-top cupola similar to the design used in iron blast-furnace practice is attracting serious attention, even though it involves a radical departure from conventional practice in an industry that in the past has been traditionally slow in accepting change. Good precedent for the closed-top cupola exists

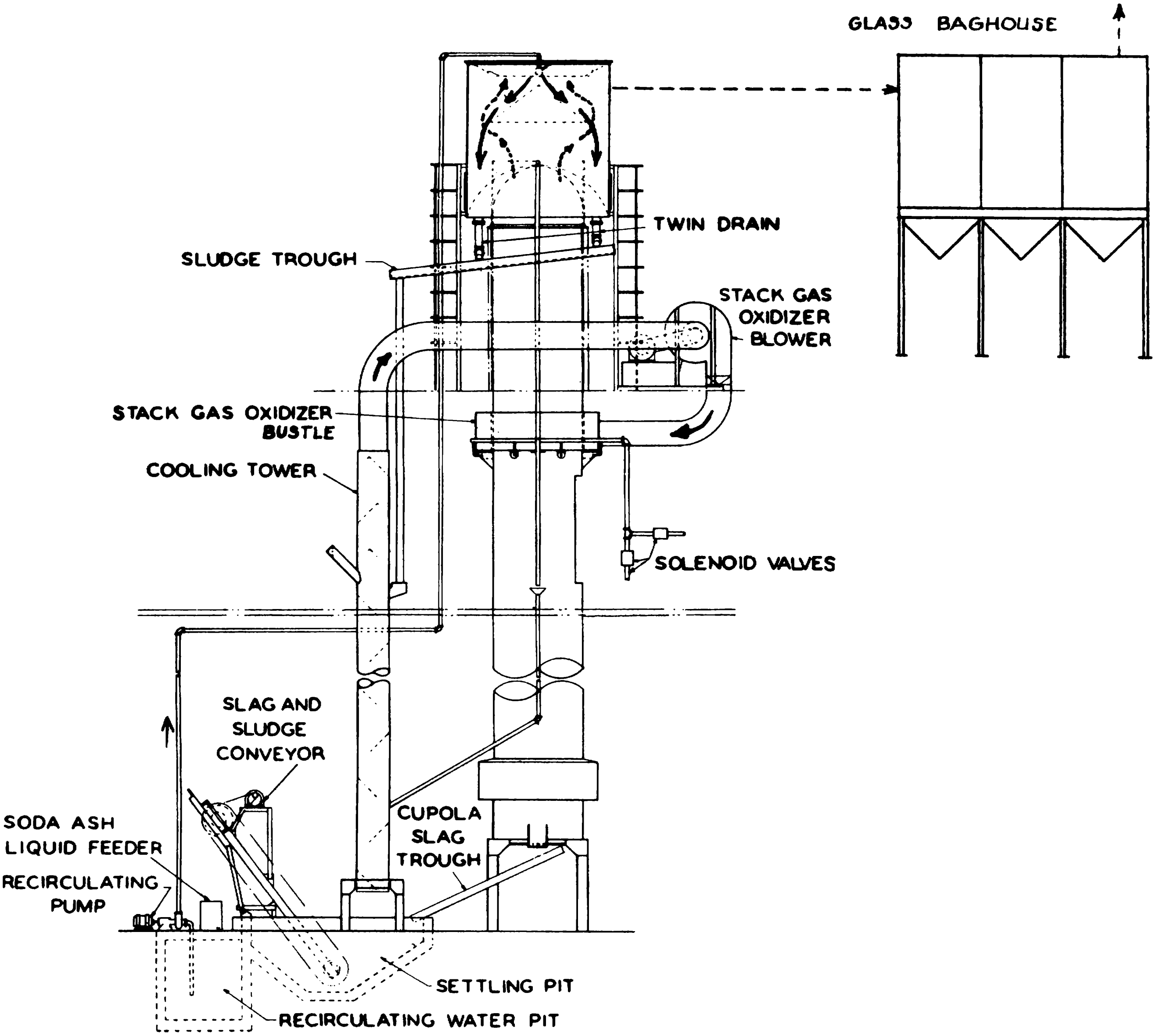

Figure 23. - Side-charge cupola with spray-type water curtain hood; gas to high-temperature baghouse. (Courtesy of Whiting Corporation, Harvey, Ill.)

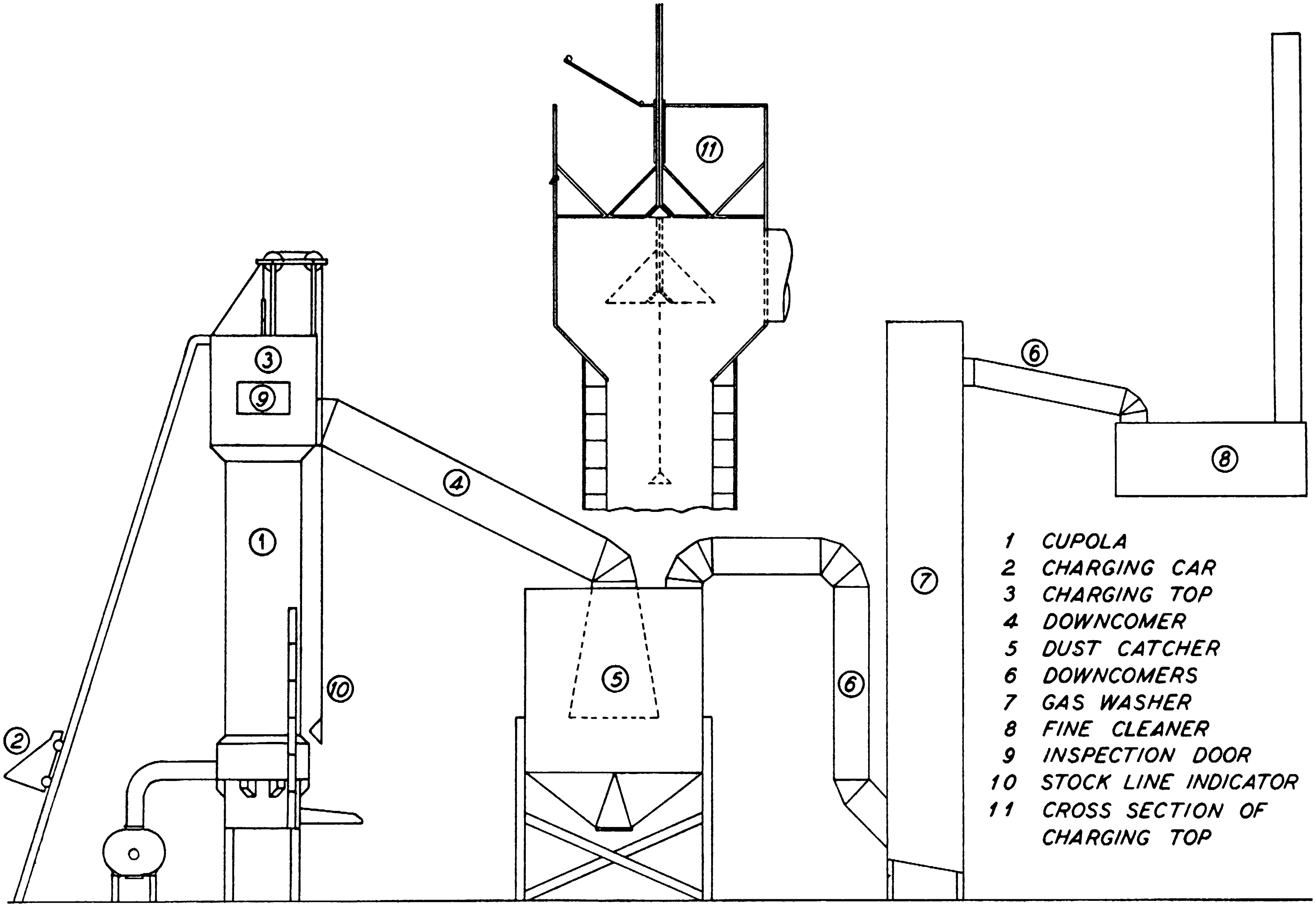

Figure 24. - Diagram of the closed-top cupola system. (Courtesy of American Foundryman, and Kennard and Drake, Consultants, Los Angeles.)

in development of the modern blast furnace, which, although handling enormous volumes of heavily laden gas,[77] delivers a final exit gas virtually free of particulate matter and suitable for almost any industrial fuel requirement.

The closed-top cupola is shown in figure 24. It is charged from the top through a bell roughly simulating that used in the blast furnace. Unburned gas is drawn out below the bell and delivered to a primary dust collector to trap the coarse particulate matter and reduce the grain loading to the secondary collector. Gases are then washed and cooled in a packed tower. This may be supplemented by a baghouse. Use of a heat exchanger is proposed to produce hot-blast air for use at the tuyeres. This system has been described by its designers.[78]

Some advantages claimed for this system are: (1) Use of the closed top prevents the combustion of the gases and fuel in the upper part of the cupola, thus lowering the temperature and volume of dirty gas to be cleaned; and (2) a material saving of reducing fuel should result through the proposed use of the hot blast. The closed-top cupola has been in full-scale operation in one of the Los Angeles foundries for many months and is in an advanced stage of development. According to the sponsors, melting results have been improved, and scrap losses and coke consumption have been decreased.

To avoid the cupola foundryman's fume difficulties at least two gray-iron foundries have abandoned cupola melting in favor of the electric furnace. One is using a single-phase, rocking-type indirect-arc[79] on malleable castings and another the direct-arc furnace.[80] The latter is using a 2-ton tilting, side-charging, Heroult furnace operating on a 3-phase alternating current supplied from a 1,000-kv.-a. transformer. A small motor-generator set supplies direct current for control equipment and auxiliaries. Metal, flux, and ferro-alloys are charged at a rate of about 1.5 tons per hour during 6-hour melts. Gases are cooled by dilution to about 4,100 c.f.m. at 125° F., the operating temperature at the baghouse, with about 180° F. as the maximum. Ability to use a wide range of raw materials, great flexibility of operation, and low gas volumes and fume emissions are some of the advantages claimed for this operation.

The final cleaning of the gases is through a conventional sock-type baghouse equipped with 178, 5-inch-diameter by 6-foot cloth bags. Gas flow is restricted to 3 c.f.m. per square foot of bag area. A 4,800-c.f.m. fan at 5-inch static head is used. Silicone-treated and special-weave glass-fabric bags will compete with cloth-fabric bags.

Another promising field now being investigated in the Los Angeles area is that of adaptation of the Cottrell-type electrical precipitator to cupola work. A small, low-cost unit suitable for foundry use is now under development. The electrical precipitator may be preceded by a wet scrubber to reduce the coarse-dust load and to humidify the gas.

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[77] Blast furnace gas initial load, 12.5 grains per cubic foot, final 0.015; volume 166,460,000 cubic feet per day while producing 1,400 short tons of iron (Metals Handbook, 1948 ed., pp. 317-18).

[78] Drake, J. F., Kennard, T. G., and Saylor, W. A., Control of Cupola Stack Emissions: Iron Age, vol. 163, No. 14, 1949, pp. 88-92.

[79] Detroit Furnace. Electric Casting Co., 777 Georgia St., Azusa, Calif.

[80] Dar Howell-Manning Co., Inc., 6131 Maywood Ave., Huntington Park, Calif.

Of the different types of equipment available in the low-priced field that have been tested thus far by engineers employed by the Gray-Iron-Foundry Smog Committee, only the baghouse equipped with glass-fabric bags has met the legal requirements of the district fully. Two types of dynamic wet scrubbers, one of which is widely used in industry, have proved inadequate when used alone. Approved types of dry centrifugal equipment and spray towers also failed to meet requirements under the same conditions.

Of the more expensive types of equipment, the bag filter, preceded by a centrifugal dry-type precleaner, was tested. Gases were cooled to 450°-600° F., then filtered through three types of glass bags. All met Air-Pollution Control District requirements, but the life of the bags was not determined in the test.[81] Some of these tests, the equipment used, and future plans of the Gray-Iron-Foundry Smog Committee to test the small electrical and perhaps the sonic precipitators are described in Western Metals.[82]

The plight of the small independent gray-iron foundryman, as viewed from his standpoint, was summarized by the chairman[83] of the Gray-Iron-Foundry Smog Committee as follows:

> In evaluating the economics (of the Gray-Iron-Foundry Industry in the Los Angeles Area) it should be apparent that the monetary cost of corrective equipment for the cupola dust suppression is vitally important. The outlay for satisfactory equipment may represent an undue strain on the foundry's available capital.
>
> In the gray-iron-foundry industry such an outlay is naturally a nonprofit production expenditure. It does not improve the quality of the product. It does not reduce the cost of the product, and it does not produce a marketable byproduct to be recovered from the collector emissions.
>
> Although in the aggregate the industry is large, each unit or foundry is in itself usually a relatively small business. It has a limited capital and works on an extremely narrow profit margin.
>
> There is also the problem of continuing cost of operation. Such equipment by its very nature is a high replacement item. Repairs and renewal parts must be resorted to in order to maintain the installation at acceptable efficiency.

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[81] Special-weave glass bags are described in another section of this report dealing with nonferrous metals. Bag life under difficult conditions encountered in that industry has proved quite satisfactory. Silicone-treated glass fabric bags are also in experimental use on fumes from malleable iron cupolas in the Los Angeles area as mentioned heretofore (p. 24).

[82] Harsell, P. L., Jr., Los Angeles Foundryman Test Air-Pollution Control Equipment: Western Metals, March 1950, p. 25.

[83] I'Anson, J. E., and others, Gray-Iron Foundries Take the Stand: Western Metals, March 1950, p. 23.

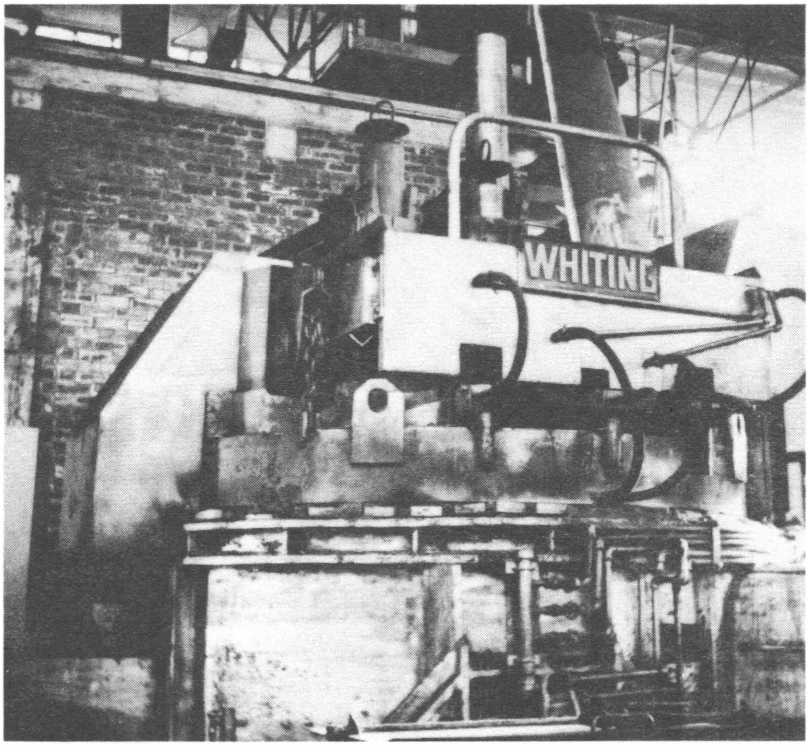

Figure 25. - Electric-steel furnace with fume-collecting hood.

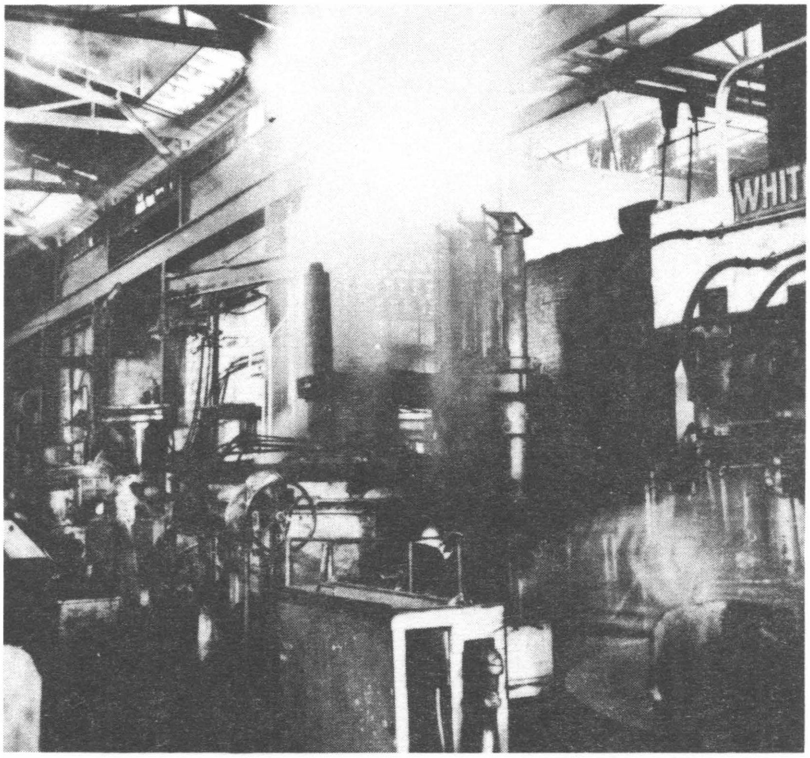

Figure 26. - Electric-steel furnace without fume-collecting hood.

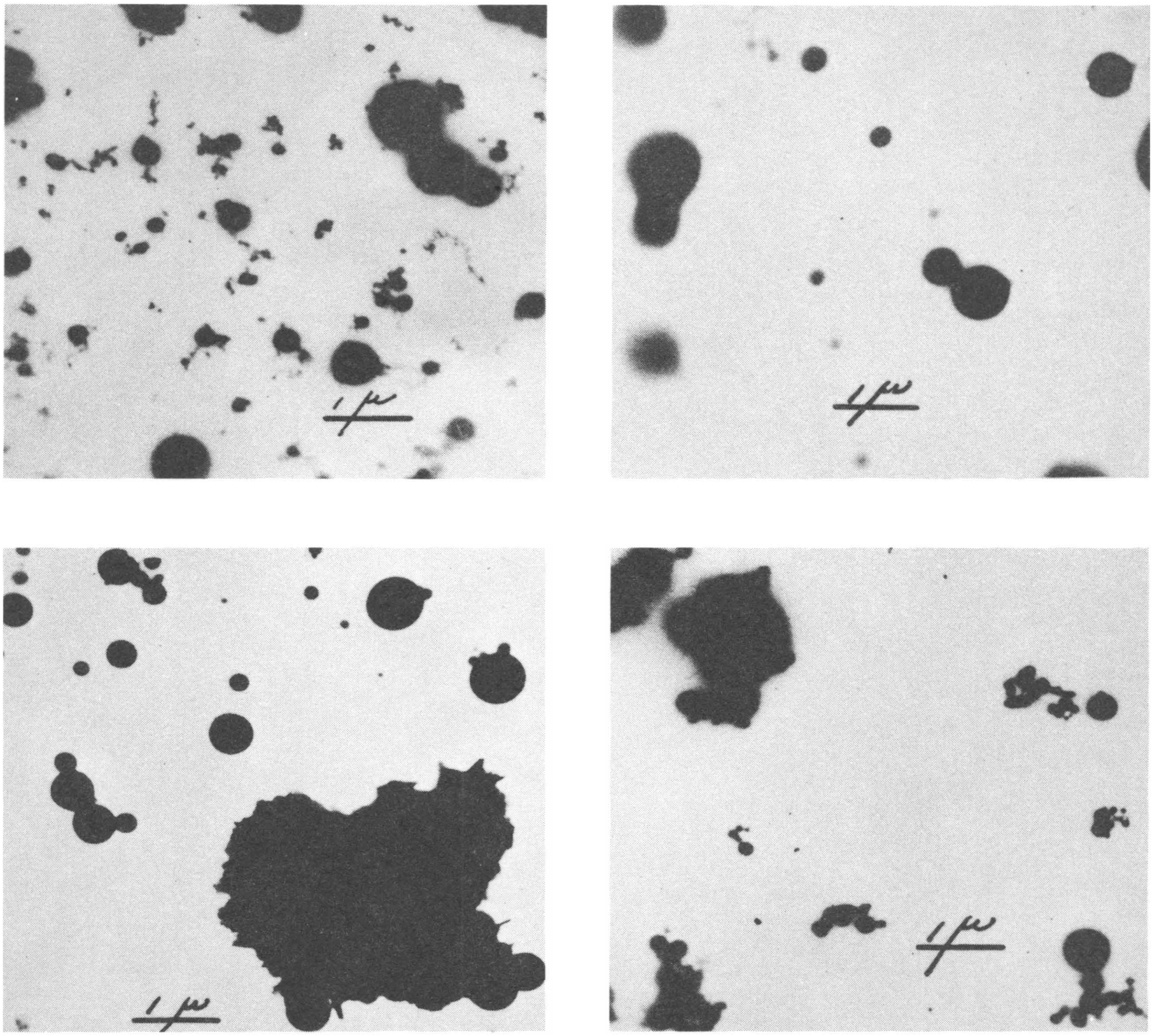

Figure 27. - Electron-photomicrographs of fumes from electric furnace producing steel for castings. (Courtesy of Albert L. Chaney Chemical Laboratory and Ind. Eng. Chem.)

Electric Steel

Castings

Normally some seven establishments pour castings from steel produced in electric furnaces. Industrial demand for such products varies greatly, but approximately 30,000 to 50,000 tons of metal per year might be considered normal for the 40-hour week operating basis. Steel casting, therefore, is still a small industry in the Los Angeles area, and its contribution to air pollution before collecting equipment was in use was comparatively low, being about 0.3 or 0.4 percent of the process weight.

Operations

Metallurgical practice[84] varies widely, and even local practice is not easily generalized. Furnaces are charged mostly with steel scrap, which is often oxidized and usually contains small amounts of nonferrous and organic materials. Ferro-alloys and fluxing materials are usually added. The process cycle is completed in 1.5 to 2.0 hours and is essentially a batch operation, with melting temperatures ranging up to 3,200° F.

Medium and small tilting furnaces with removable tops are in general use in steel foundries. Electrodes and other gear protruding from the top of the furnace make adequate hooding difficult, but quite satisfactory equipment for some applications in this size range has been developed by manufacturers of dust-recovery equipment. Examples are shown in their catalogs and in figures 25 and 26. A paper by Kane[85] describes applications of exhaust ventilation to electric steel furnaces.

Effluents

Gases from small electric furnaces used in the foundry industry may vary from 2,000 to 3,000 s.c.f.m. per 1,000 pounds of process weight per hour. Air dilution at the hoods may reduce gas temperatures to 450° F. or lower. Dust and fume loading may amount to 0.4 grain per s.c.f. in the dirty gas and 0.02-0.05 grain per cubic foot in the cleaned gas, depending of course on the efficiency of the recovery equipment. Stated another way, furnace emissions of 5 to 8 pounds of particulate matter per ton of metal melted per hour may be anticipated. Emissions during the boil and purification steps of the process are several times the mean rate.

Particulate matter emitted by furnaces tested in the area consists mostly of oxides of iron and other metals, with some smoke from combustible matter. Particles are predominantly spherical, mostly smaller than 3 microns diameter with over 95 percent below 0.5 micron Figure 27 illustrates the characteristically round images of fume particles from an electric furnace making steel castings, indicating their spherical shape and tendency to agglomerate.

Recovery Equipment

Dynamic wet scrubbers, particularly those providing positive and violent mixing of gas and water followed by separation of gas and particulate matter by centrifugal

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[84] Metals Handbook, 1948 ed., contains discussions of basic and acid electric steel furnace practice.

[85] Kane, John M., The Application of Local Exhaust Ventilation to Electric Melting Furnaces: Trans. Am. Foundrymen's Assoc., vol. 52, No. 4, June 1945, pp. 1351-1356.

action, have produced good results in some applications. Electric steel-foundry furnace gases properly cooled and conditioned no doubt can be recovered with bag filters and, of course, by electrical precipitation.

The electric steel-foundry industry in the Los Angeles area thus has been somewhat more fortunate than the gray-iron industry, and is believed well along in its campaign against air pollution and for better operating conditions in its plants. Operating conditions, and the results of dust-recovery-equipment tests, for typical small, 3- to 6-ton electric-arc steel furnaces pouring castings in Los Angeles plants are shown in table 7.

Ingot

Larger electric tilting-type furnaces for the production of ingots are in production or are scheduled for early operation in the steel plants in the area. These are rated from 50-75 tons per batch, or up to 33,000 pounds process weight per hour. Electrode consumption is about 10 pounds of carbon per ton melted, and this adds somewhat to the air-pollution problem if furnaces are not well-hooded and the gases are not treated.

In one large plant, the furnace top with electrodes and connecting gear, including dust hooding, is raised and swung aside during charging. Dust characteristics and operating conditions for the larger furnaces are similar to the smaller ones, varying with the nature of the raw material and the kind of steel produced, but fume losses are higher - 0.5 to 0.6 percent of process weight. Some hooding difficulties on the larger furnaces are yet to be overcome, particularly to obtain more complete fume collection and in the use of materials to withstand high temperatures and corrosion. Recovery equipment, of course, must be of correspondingly greater capacity. Dynamic-scrubber-type equipment was selected by one large producer in preference to the electrical precipitator because of the much lower capital cost for the scrubber per unit volume of gas treated. Their applicability on larger operations, however, is still to be proved.

Open-Hearth Steel

Procedure and Equipment

Steel making in the cold-metal open-hearth furnace is a highly perfected process subject to wide variations in practice. Procedures and equipment are described in detail in many published works on steel. Pig iron, steel and steel scrap, limestone, and coke are melted in a reverberatory-type furnace, usually heated with oil or gas or both. The sensible heat of the hot furnace gases is usually partly recovered in waste-heat boilers or recuperative brick checkerwork or both. Part of the coarser particulate matter accumulates in the heat-recovery equipment and must be removed periodically, but most of the particulate matter in the low-micron and submicron ranges must be recovered in efficient collectors. The time cycle for open-hearth operation is longer, and the gas volumes are usually much larger than for the electric furnace. Open-hearth furnaces in the Los Angeles area melt charges of 50 to 60 tons of metal with 2 or 3 tons of limestone and a ton of coke in an 8- to 10-hour operating cycle. Stack temperatures range from 1,100° to 1,250° F.

TABLE 7. - Ferrous metallurgical industries[1]

Date, 1949	Plant No.	Collection equipment installed	Equipment tested	Time, min.		Process weight, in lb.			Particulate matter					Products	Furnace	
				Process cycle	Length of test	Per hr.	Total charge	Composition, lb.	Gr./s.c.f.	Losses, lb./hr.		Percent of process weight	Violation		Make and type	Fuel
										Actual	Allowed					
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
	Gray Iron Foundries															
Apr. 29	1	None	Cupola furnace (both stacks).	300	60	37,488	221,193	Iron, 198,569; new coke, 18,725; old coke, 900.	0.370 .497	102	26.8	0.27	Yes	Gray iron car-wheels	Cupola with preheat. (See col. 33.)	Coke, 3,320 lb./hr.
		do.		300	60	37,488	221,193	limestone, 2,625; purite (Na_2CO_3), 374.	.376 N.D.	114.8	26.8	.31	Yes			
May 6	2	Settling chamber and packed tower, see col. 33.	Vent stack of packed tower.	233	60	10,650	41,408	Scrap-iron, 3,300 (See col. 33.)	.790	13.7	10.41	.13	Yes	Gray iron castings.	Closed-type 36-in., cupola charged by skips to charging bell.	Coke
Aug. 31	3	Settling chamber and dry filter.	Dry filter 4 x 4 x 8-ft. long with 12 16-mesh screens 3-in. centers.	120	60	11,700	27,380	Coke, 4,500; iron, 22,000; limerock, 770; soda ash, 110 lb.	.91	16.1	11.08	.14	Yes	do.	do.	Coke, 1,930 lb./hr.
Aug. 9	4	None	Cupola stack.	127	60	4,080	8,648	Scrap, 7,000; coke, 1,410; limerock, 210; Mn flux, 28.	1.07	27.6	6.0	.68	Yes	do.	Cupola.	Coke, 665 lb./hr.
Dec. ND	5 Cupola A	do.	do.	156	156	13,500	-	Scrap iron and steel, pig, coke, lime. (See col. 33.)	1.110	196.0	12.5	1.45	Yes	do.	48-in. diam. cupola.	Coke
Dec. ND	6 Cupola B	do.	do.	80	80	9,280	-	do.	1.604	69.0	9.5	.74	Yes	do.	37-in. diam. cupola.	do.
Dec. ND	7 Cupola C	do.	do.	320	320	18,900	-	Scrap iron, returns, pig, coke, lime. (See col. 33.)	.798	107.0	15.5	.57	Yes	do.	48-in. diam. cupola.	do.
Aug. 10	12	do.	Reverberatory stack.	110	80	546	1,002	See col. 33.	.003	.13	1.9	.02	No	do.	Sklenar tilting reverberatory.	Gas, 70 c.f.m.
	Steel Casting Foundries															
May 5	8	Dynamic scrubber.	Vent stack from scrubber, one basic and one acid melt.	120	60	3,502 2,880	7,003 7,054	N.D. N.D.	.077	6.0	10.5 See col. 33.	.09	No	Steel castings.	Electric arc.	Electric energy.
Oct. 6	9 (1)	do.	6-ton electric furnace, gas to scrubber.	138	180	5,220	12,000	Scrap steel	.053	6.4	6.9	.12	No	do.	White	do.
	9 (2)	do.	do.	84	98	5,000	7,000	do.	.057	7.0	6.7	.14	Yes	do.		do.
	Open-hearth Steel															
Dec. 7	10	None	Stack, open-hearth.	485	See col. 33	N.D.	136,568	Steel scrap, pig iron, limestone.	.65	93.9	14.3	.56	Yes	58 tons steel.	Open-hearth.	Oil and gas
	Malleable Iron Foundry															
Jan. 17	11	Hydrodynamic scrubber.	Scrubber stack.	327	60	8,940	48,726	See col. 33.	.265	28.4	9.32	.32	Yes	Malleable iron castings.	Whiting No. 3-1/2 cupola.	Coke, 1,270 lb./hr.

[1] Sources: Technical Subcommittee of Gray Iron Foundry Smog Committee; Air Pollution Control District of Los Angeles County.
N.D. indicates no data given or available.

TABLE 7. - Ferrous metallurgical industries[1] (Cont.)

Date, 1949	Plant No.	Collection equipment installed	Equipment tested	Flue and gas conditions: Source of gas tested	Phase of process covered by test	Flue gas press., Hg in.	Flue diam., in.	Temp., °F.	Av. vel., ft./sec.	Std. volume, 14.7 p.s.i. and 60° F.	Collector equipment tested: Est. spray, g.p.m.	Gas vol., 14.7 p.s.i. and 60° F.: Inlet	Outlet	Dust loading, gr./cu. ft.: In	Out	Total dust, lb./hr.: In	Out	Eff., percent	Remarks
1	2	3	4	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
	Gray Iron Foundries																		
Apr. 29	1	None	Cupola furnace (both stacks).	Cupola stack.	Middle of cycle.	N.D.	N.D.	110	14.8	22,900 Cupola		No Collection Equipment Tested							Col. 4, part of cupola gas went to stack; other part drawn off to burn in preheater, then vented to atmosphere. Both vents tested by two complete tests. Griffin hot-blast process.
				Preheater stack.				560	46.0	6,900 Preheat									
		do.		Cupola stack.				130	12.2	24,600 Cupola									
				Preheater stack.				560	46.2	6,920 Preheat									
May 6	2	Settling chamber and packed tower, see col. 33.	Vent stack of packed tower.	Outlet packed tower.	From 2d to 8th tapping.	29.9	18	94	20.2	2,020	60	N.D.	2,020	N.D.	0.792	85.5	13.7	84	Col. 3, dry collector 199.5 lb. dust and 79.4 lb. dust removed by water. Dust held in coke packing not determined. Col. 9, charge 1,280 lb. bed coke and 33 charges containing scrap, 1,000; ferromanganese, 6; lime, 35; Pet. coke, 25; coke, 150; cupola closed-type.
Aug. 31	3	Settling chamber and dry filter.	Dry filter 4 x 4 x 8-ft. long with 12 16-mesh screens 3-in. centers.	Dry-filter inlet. Dry-filter outlet.	From 1st to 6th pour, inclusive.	29.9	18	81	18.6	2,050 Exhaust	60	N.D.	2,050	1.044	.910	19.9	16.1	N.D.	Col. 3, settling chamber caught 72.5 lb./hr. dust. Pressure increases during 1-hr. test in in. water: at tuyere from 12 to 14; packed tower 3-1/2 to 5; dry-filter 1/8 to 1-in. Col. 17, outlet gas: CO_2, 11.8; CO, 3.4; O_2, 0.6%. Col. 25, sprays on packed tower ahead of dry filter.
Aug. 9	4	None	Cupola stack.	Cupola stack. (See col. 33.)	Melt and first pours.	29.9	35	396	12.3	3,000		No Collection Equipment Tested							
Dec. ND	5 Cupola A	do.	do.	Cupola stack.	Melting period.	29.9	N.D.	1,188	41.7	20,570				do.					Col. 2 and 9, details Cupola A in text of report, Table 5. Col. 22 average stack temperature during melting period. Col. 23 at stack temperature.
Dec. ND	6 Cupola B	do.	do.	do.	do.	29.9	N.D.	1,656	31.8	5,020				do.					Col. 2 and 9, details Cupola B in text of report, Table 5. Col. 22 average stack temperature during melting period. Col. 23 at stack temperature.
Dec. ND	7 Cupola C	do.	do.	do.	do.	29.9	N.D.	775	37.5	15,600				do.					Col. 2 and 9, details Cupola C in text of report, Table 5. Col. 22 average stack temperature during melting period. Col. 23 at stack temperature.
Aug. 10	12	do.	Reverberatory stack.	Stack, plus dilution. (See col. 33.)	Normal melting.	29.9	20 x 48	775	30.7	5,160				do.					Col. 9, charge: 300 pig iron, 500 scrap, 200 returns, 2 soda ash. Col. 12, stack gas after some dilution, average, Orsat, 1.5% CO_2, 18.4% O_2, 80.1% N_2.
	Steel Casting Foundries																		
May 5	8	Dynamic scrubber.	Vent stack from scrubber, one basic and one acid melt.	Scrubber outlet.	Melt.	29.9	16 x 18-1/2	95	79.0	9,050	N.D.	N.D.	9,050	N.D.	See col. 10	N.D.	See col. 11	N.D.	Col. 12, acid furnace allowable loss, 5.5; basic, 5.00; total, 10.5 lb./hr.
Oct. 6	9 (1)	do.	6-ton electric furnace, gas to scrubber.	do.	Entire melt.	29.9	26	77	N.D.	14,170	N.D.	N.D.	14,170	N.D.	do.	N.D.	do.	N.D.	Col. 4, tests by Albert L. Chaney Chemical Laboratories, Glendale, Calif. Col. 24, calculated 14,300.
	9 (2)		do.	do.	do.	29.9	26	82	N.D.	See col. 33	N.D.	N.D.	See col. 33	N.D.	do.	N.D.	do.	N.D.	
	Open-hearth Steel																		
Dec. 7	10	None	Stack, open-hearth.	Stack.	Entire cycle.	29.9	N.D.	1,300	N.D.	14,400		No Collection Equipment Tested							Col. 6, average of 5 months' operation. (Full details in Open-hearth section of report.
	Malleable Iron Foundry																		
Jan. 17	11	Hydrodynamic scrubber.	Scrubber stack.	Scrubber outlet. (See col. 33.)	3 hr. after blast-on.	29.9	63	365	15.3	12,500	N.D.		See col. 10-14 inclusive						Col. 9, steel scrap, pig iron, ferroalloys, coke, limestone, soda ash; Col. 17, natural gas pilot for secondary combustion above charge door. Col. 18, gas oxidizer in operation: Orsat, 5% CO_2; 16.2% O_2; 0.0% CO.

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[1] Sources: Technical Subcommittee of Gray Iron Foundry Smog Committee; Air Pollution Control District of Los Angeles County.
N.D. indicates no data given or available.

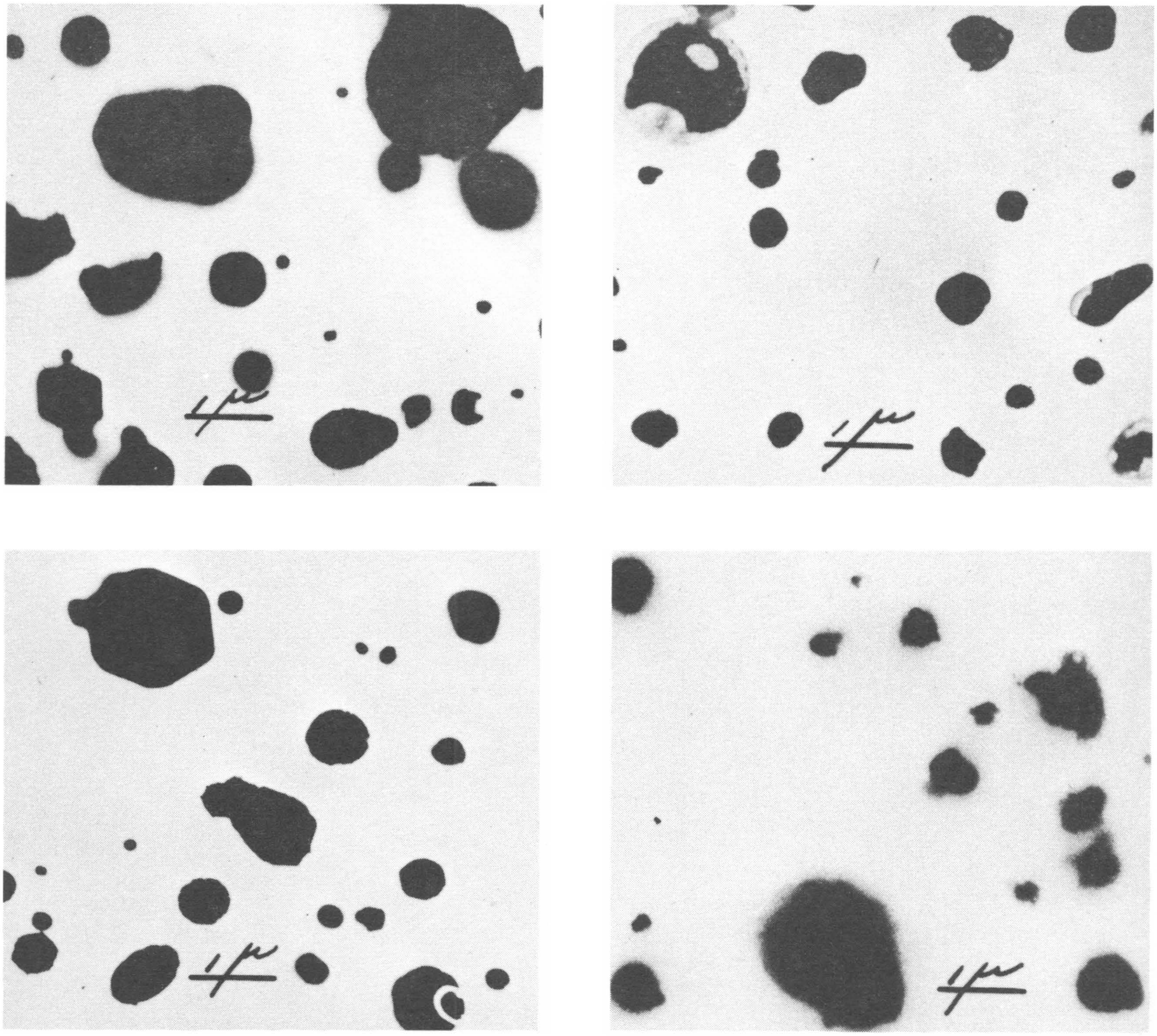

Figure 28. - Electron-photomicrographs of fumes from cold-metal open-hearth steel furnace. (Courtesy of Albert L. Chaney Chemical Laboratory and Ind. Eng. Chem.)

Stack Effluents

Dust and fume loading varies over a wide range from 0.10 to a maximum of 2.0 grains per cubic foot during certain periods of the open-hearth cycle, with a norm of about 0.6-0.7 grains per cubic foot for the installations tested. Normal gas volume is about 930 s.c.f.m. per 1,000 pounds of process weight per hour. Stack dust losses may amount to from 8 to 20 times the allowable limit under the existing regulations detailed in appendix A. Reduction of these losses to allowable limits of 10 to 14 pounds per hour, corresponding to process weights of 10,000 to 16,500 pounds per hour, requires high-efficiency, costly recovery equipment capable of removing extremely small average-size particles. This and other characteristics of cold-metal open-hearth fume are indicated in figure 28.

Extensive tests of furnace conditions and of equipment believed suitable for controlling open-hearth fumes have consumed time and money but were unavoidable because of the almost entire absence of precedent and knowledge of the factors involved. This pilot work, conducted by Western Precipitation Corp., resulted in installation of electric precipitator equipment at the Torrance works of Columbia Steel Co guaranteed by the manufacturer (Research Corp.) to meet requirements of the Air-Pollution Control District over a wide range of operating conditions.

The actual performance of the initial unit during its acceptance tests and after correction of numerous minor deficiencies usually encountered in pioneering installations far exceeded the manufacturer's guarantee summarized later. During four series of tests with the complete installation aggregating 17 tests, dust loadings of the precipitator discharge gases were; maximum 5.86 pounds per hour, minimum 0.14 pound, and weighted average of all tests 1.95 pounds per hour, compared with a guaranteed performance of 11.5 pounds per hour. The precipitator efficiency ranged from a minimum of 96.0 to a maximum of 99.0 percent; the weighted average of 17 tests was 97.9 percent.

Recovery Equipment and Test Data

Many types of recovery equipment were tested or carefully considered for use in suppressing open-hearth reverberatory exit gases. The experience of one plant, which selected an electrical precipitator, will be discussed in detail. Plant records of operating conditions averaged over a period of 5 months established a basis for the design and operating scale of the electrical precipitator test unit. Examinations of the physical and chemical characteristics of furnace gases and of the products of the precipitator, of course, were made. These data made it possible for suppliers to design and guarantee the operating results to the purchaser.

The general problem was as follows: Operating oil- and gas-fired open-hearth furnaces of 58-ton capacity are connected through existing ducts and flues to tall stacks. Reverberatories are charged with cold pig metal and scrap, limestone, coke, fuel, atomizing steam, and combustion air. Furnace products are steel ingot, slag, and waste gases. The exit gases are used in a waste-heat boiler to produce steam to be used in the plant. The cooled gas is drawn into the electrical precipitator, which collects and delivers particulate matter mechanically in the dry state to existing disposal equipment.

Plant engineers determined that each open-hearth normally handled a charge consisting of about 129,500 pounds of cold metal, 5,600 limestone, 1,500 coke, an average total charge of 136,600 pounds. The average elapsed time from the start of charging to the end of tapping was 8.1 hours; process weight per hour was 16,900 pounds; fuel consumption varied from 20,000 c.f.h. of natural gas and 72 g.p.h. of fuel oil to 0.0 c.f.h. gas and 250 g.p.h. of oil. The volume of flue gas was 12,500 to 14,000 s.c.f.m., and the approximate volume of gases at stack conditions amounted to some 33,600 c.f.m. Gases entered the stack at about 1,300° F. and carried a maximum of 2.0 grains particulate matter per s.c.f.

Extensive sampling and testing of untreated open-hearth stack gases by consulting engineering firms[86] before the pilot-plant operations established the following:

1. Concentration of particulate matter was in excess of 0.4 grain per s.c.f. at all times, except during the last one-third of the melting period, thus violating Air-Pollution District rule 52 then governing.
2. Concentration of zinc oxide per s.c.f. ranged from 0.103 to 1.344 grains, and concentrations of lead ranged from 0.046 to 0.138.
3. Relative opacity of emissions equaled or exceeded 40 percent (No. 2 Ringlemann) almost continuously for the duration of the furnace cycle.
4. Mean particle size of the particulate matter was 0.5 micron, with no particles larger than 3 microns.
5. Zinc, lead, iron, sulfur, and chlorine were the major constituents of the emissions.

The following data are from the engineers' report:

> A total of seven samples was taken. Three of these, designated Samples A, B, and C were taken during the period between the first and second charges. Samples A and B were taken with filtration apparatus, and Sample C with absorption apparatus for the sole purpose of determining the presence of gaseous sulfur compounds.
>
> Samples D, E, F, and G were taken with filtration apparatus between the end of the second charge and the end of the heat.

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[86] Tests by Menardi & Co. and engineering staff of Columbia Steel Co.; analyses by Smith-Emery Co.

Sampling results of untreated open-hearth stack gases

Sampling periods

I. Between first and second charges.
II. Early part of melting period.
III. Middle part of melting period.
IV. Late part of melting period.

Summary of concentrations in samples collected
(Grains per cubic foot at 60° F. and 14.7 p.s.i.)

Sample	Time, P.M.	Particulate matter	Zinc oxide	Lead
A	2:51 - 5:02	1.421	-	-
B	2:51 - 4:21	1.962	1.344	0.138
C	4:26 - 5:02	-	-	-
D	5:46 - 9:30	0.420	-	-
E	5:46 - 6:46	1.104	0.482	0.095
F	7:09 - 8:09	0.441	0.153	0.048
G	8:30 - 9:30	0.368	0.103	0.046

Particle-size distribution is summarized as follows:

Size	Average sample A and D
1-3 microns	7.3
0.5-1 micron	28.4
0.15-0.5 micron	49.5
Below 0.15 micron	14.8
	100.0

Summary of chemical analyses of samples B, E, F, and G

					Water soluble			
	Percent				Percent			Loss on ingition
Sample	Zinc	Lead	Iron	Sulfur	Zinc	Sulfur	Chlorine	
B	55.02	7.02	3.03	3.24	18.24	0.76	2.39	13.13
E	35.04	8.64	14.12	4.06	16.32	1.30	5.45	24.97
F	27.84	10.90	9.08	10.08	25.44	7.75	None	14.55
G	22.57	12.42	4.03	15.18	14.88	8.22	1.07	15.28

Qualitative spectrographic examinations confirmed the existence of lead, zinc, and iron as major constituents; silicon, calcium, and aluminum as intermediates in the order of 1.0 percent; and copper, manganese, chromium, nickel, magnesium, antimony, bismuth, titanium, molybdenum, vanadium, and barium were estimated to be in the range of 0.5 to 0.01 percent.

Subsequent operation of the electrical precipitator test-unit further established that, on a dry basis, high-efficiency collection could be attained with practical equipment in reasonable sizes. This was proved over a wide range of operating temperatures using gas that was not preconditioned. Tests were made when the furnace was fired with oil and steam and with natural gas with some oil added. Dust and fume loadings were shown to be lower than in some other furnace processes, at

0.36 to 1.45 grains per s.c.f. during oil firing, and 0.30 to 1.96 grains per s.c.f. during gas-oil firing. A composite of all dust collected had the analysis shown in table 8. Satisfactory results were obtainable between 400°-650° F. At temperatures above 750° F. the dust formed sinter-type agglomerate, which resulted in crusts difficult to remove, indicating that operation above 700° F. should be avoided.

TABLE 8. - Analysis of composite samples of Cottrell dust from open-hearth furnace[1/]
(as collected)

Element	Analysis	Calculated
Zn	28.3	34.8
Pb	10.7	11.5
Fe	6.1	12.8
Cr	.58	.9
Mn	.31	.5
Cd	.5	.4
Sulfur, total (as S)	11.1	27.8
Total		88.7

[1/] Source: Columbia Steel Co., analyses by Smith-Emery Co.

Sulfur content, determined as total S and as SO_4, was identical. Qualitative tests of sulfide sulfur were blank, therefore, it was concluded that the metals were present as oxides.

Pilot-plant inlet temperatures ranged from 450°-750° F. during oil firing and from 290°-680° F. during gas firing. Collection efficiency ranged from 98.4 to 100 percent and averaged above 99.0 percent. Power consumption ranged from 53 to 67 kw., and averaged about 58 to 59 kw. Test voltages ranged from 47 to 67 kv., and averaged about 56 kv. This indicated a 25-kv.-a power supply per industrial unit would be needed, and an energy consumption of somewhat less than one kw.-hr. per 1,000 c.f.m. was anticipated. A secondary voltage of 75 kv. was indicated to make up a rectifier loss of 25 kv. and about 50 kv. on the ducts.

Results determined over a wide variety of operating conditions by Cottrell pilot-plant tests are reported in table 9 for fume loads at 60° F. and 29.9 inches mercury.

TABLE 9. - Cottrell pilot-plant results on open-hearth steel furnace gases

Gas		Maximum	Approx. Av.	Minimum
Inlet	gr./s.c.f.	1.96	0.60-0.70	0.36
Outlet	do.	.01	.005	.0

On a basis of 14,400 s.c.f.m. inlet gas carrying 0.7 grain per cubic foot, the burden would be 86 pounds per hour, and on an indicated process weight of 16,900 pounds per hour, this would amount to about 0.5 percent. The permissible emission under rule 54 (appendix A) is 14.3 pounds per hour.

On the basis of 33,600 c.f.m. (each furnace having a separate precipitator unit) at 500°-600° F., maximum inlet loading 2.0 grains per s.c.f. of gas volume of 12,500 to 14,400 s.c.f.m., equal to maximum of about 246 pounds per hour, the equipment manufacturer guaranteed the efficiency of the equipment as summarized below.[87/]

[87/] Communication, P. F. Kohlhaas, Vice President in charge of Engineering, Columbia Steel Co.

The supplier guarantees that when the installation covered by the specifications and the agreement is adjusted and operating within but not to exceed its rated capacity of gas and under the normal operating conditions set forth in the specifications and data sheets, the suspended matter present in the exit gases from the installation will not exceed 11.5 lb. per hour per furnace for any one hour, including the precipitator rapping cycle and waste heat boiler lancing period, and further guarantees that for a period or periods aggregating not more than three minutes in any one hour the discharge from the flue system will be (a) as dark or darker in shade as that designated as No. 2 on the Ringlemann Chart, as published by the Bureau of Mines, or (b) of such opacity as to obscure an observer's view to a degree equal to or greater than does smoke described in condition (a) above.

The above guarantee is contingent on the purchaser operating the installation in accordance with instructions from the supplier and the boiler manufacturer, and is based upon boiler lancing with steam so arranged that only a small portion of the boiler will be lanced at any one time. This guarantee is also based upon conditioning of the gases, if found necessary, as set forth in the specifications.

Methods of measurements to demonstrate the above guarantee shall be in agreement with the methods and equipment now employed by the Los Angeles County Air-Pollution Control District, set forth in Bulletin WP-50 and the supplier's Bulletin 3-A.

In the event of failure of the installation to meet the guarantee, the supplier shall, at its own expense, make the necessary changes to meet the guarantees by means and methods acceptable to the purchaser and in such manner as not to inconvenience or disrupt normal plant operations.

The data finally used as the basis for the design of the electric precipitators and significant mechanical details of their construction listed below were supplied by P. F. Kohlhaas, of Columbia Steel Co.

I General Data

The Torrance Works (Columbia Steel Company) open-hearth shop consists of four 58 ton, cold metal furnaces. In the final design electrostatic precipitators, of the dry type, were decided on as being best suited to meet Torrance conditions. Inasmuch as the above type of precipitator requires that the temperature of the gases be reduced to a normal of about 550° F. with a maximum of about 700° F., waste heat boilers are being installed ahead of the precipitators. The installation consists of a precipitator and a waste heat boiler at each furnace.

II Open-Hearth Operating Data

(a)	Fuel Rate combination firing: Natural Gas	20,000 c.f.h.
	Fuel Oil	72 g.p.h.
(b)	Volume of waste gases (at standard conditions)	12,500 to 14,000 c.f.m.
(c)	Temperature of waste gases	1,300° to 1,550° F.
(d)	Los Angeles County restrictions allow a maximum dust discharge per furnace in pounds per hour (based on a and b)	14.3

III Particulate Matter Loading and Gaseous Constituents

All in grains per standard cubic foot.

(a)	Maximum	2.00
(b)	Average during charging	0.87
(c)	Average during meltdown	0.51
(d)	Average during working	0.34
(e)	Average over total heat time	0.69
(f)	The majority of samples taken immediately after the first charge, during rapid melting showed at or above	1.25
(g)	Stack dust produced for one open hearth furnace in pounds per hour: Maximum @ 2 grains	240 lbs.
	Average @ 0.7 "	75 lbs.

(h) Gaseous Constituents:

Sulphur Compounds:	0.013%	by volume
Carbon Dioxide:	11.0%	" "
Carbon Monoxide:	0.0%	" "
Oxygen:	3.0%	" "

IV Waste Heat Boiler Data (for each furnace)

(a)	Horizontal, fire tube type with superheater	
(b)	Designed for, pounds of gases per hour	62,500
(c)	Average temperature of gases	1,200° to 1,300° F.
(d)	Maximum temperature of gases	1,550° F.
(e)	Operating pressure	200 p.s.i.g.
(f)	Final steam temperature	550° F.
(g)	Temperature of gases leaving boiler	500° to 600° F.
(h)	Boiler shell diameter	8'6"
(i)	Number of tubes 2" dia. x 17'11-1/2" long	560

V Electrical Precipitator (for each furnace)

(a) Dry plate type, horizontal gas flow, 2 sections in series, 17 horizontal ducts wide, collecting plates in each section 9'0" x 17'6" high.

(b) Gas flow 33,600 c.f.m. at 550° F.
(Increased from furnace and boiler volumes to allow for air dilution if necessary to meet temperature requirements)

(c) Waste disposal: Hopper under each section with screw conveyor to storage bin.

(d) Induced draft fan, located on discharge side of precipitator, discharging to existing furnace stack, and driven by steam turbine.

(e) Emergency and standby arrangement: by manipulation of flue dampers the gases can by-pass the boiler and precipitator and flow to the stack direct.

Although not so stated above, it is believed that automatic rapping controls were supplied, that collecting electrodes were pneumatically and electrically vibrated, that discharge electrodes were pneumatically rapped, and that a motor-driven rectifier of about 75 kv. maximum was supplied for each precipitator unit. A preliminary estimate of capital outlay including cost of installation of four precipitators, together with auxiliary boilers, special valves, ducts, and flue systems, was about $600,000.

INDUSTRIAL MINERAL DUSTS AND FUMES

Introduction

Aside from the major sources of air contamination, such as industrial gases, metallurgical dusts and fumes, chemical and petroleum fumes, and smoke and pollution resulting from incomplete combustion, there remain other sources, such as paints, solvents, plating, and nonmetallic mineral industries, to mention but a few. One of these sources pertinent to the Los Angeles smog problem is discussed in this section. The former categories at present are less important, but installations are increasing in number and size as the Los Angeles industrial complex becomes more integrated and self-sufficient. Industrial mineral processing, however, already includes broad fields of production almost as sesential to the area's economy as the metallurgical industries.

The business of processing industrial minerals has grown to one of large proportions in the Los Angeles area. Over 500 establishments process clay, glass, stone, and miscellaneous nonmetallic minerals. The much larger agricultural, oil, and construction industries (including highways) have consumed immense quantities of these products, and the demands of those and many smaller industries are increasing with the growth of population and industry. The principal segments, but by no means a complete list, of industries that are known to be appreciable contributors to air pollution in the area, fall into six related and somewhat overlapping groups of nonmetallic mineral processors: (1) Rock products, (2) asphalt-paving mixing, (3) ceramics and clay catalysts, (4) glass and enamel, (5) rock wool, and (6) asbestos.

Rock Products

The preparation of rock products for construction, aggregates, ballast, and related purposes has become an important industry countrywide and in Los Angeles County. Industrial Minerals and Rocks,[88] the industry's most comprehensive reference work, devotes about 100 pages to crushed stone, sand, and gravel.

Sand and Gravel

Rock-product plants include a wide range of sand, gravel, and rock-crushing and sizing plants. These include simple equipment for washing and grading; simple and semiportable concrete batching plants; the complete, compact, portable rock-crushing and grading plants; and the elaborate and costly plants for producing accurately sized granules for roofing, lightweight aggregates, and other special uses.

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[88] American Institute of Mining and Metallurgical Engineers, Industrial Minerals and Rocks: Seeley W. Mudd Series, 1949, 1,156 pp.

Most of the rock-products plants are in areas zoned for such operations and are often removed from residential, business, and manufacturing districts. Many are plainly in violation of the air-pollution regulations, and some study has been given to their problems by pollution control authorities. Many of the larger plants are equipped with dust-suppressing apparatus, and others have since added such equipment and are making sincere efforts to have their plants operate within the law.

Dust from rock-products plants, generally speaking, is not difficult to control. Available equipment, if properly installed and operated, is unquestionably capable of meeting Air-Pollution Control District regulations.

Dry centrifugal or cyclone-type equipment is favored for the first step of collecting the coarser dust down to 325-mesh and dynamic wet scrubbers for the material below that size. It may be necessary on some materials difficult to collect, particularly where large tonnages are ground dry to fine sizes or are subsequently dried, to resort to air filters or electrical precipitators, since even rather complex spray-towers have not been satisfactory generally.

Sand- and gravel-washing and sizing plants offer no problem because they are mostly operated wet, or without drying to the point of dusting.

Concrete Batching

Concrete batching plants are comparatively simple arrangements of steel hoppers, elevators, and batching scales for proportioning rock, gravel, and sand aggregates with cement for delivery, usually to transit mixer trucks. Aggregates usually are crushed and sized in separate plants and are delivered by truck or belt conveyors to ground or other storage from which they can be reclaimed and placed in the batch plant bunkers. Smaller plants are often portable or can easily be knocked down and removed to a new location; permanent plants are usually larger and more elaborate. Bucket elevators in steel housings are in general use. Dusting occurs at elevator boots and discharge spouts and at the hopper when bulk cement is received.

By careful use of sprays, felt, or other filter material over breathers in the cement silos and canvas curtains drawn around the cement dump trucks while dumping, dust losses can be controlled. Aggregate stocks in bunkers are wet down with sprays to prevent dusting, and the sand naturally contains 3.5 to 6.0 percent moisture, usually sufficient to suppress dust. With careful operation, losses in these plants can be held well within acceptable limits. A typical concrete batching plant handles about 100 tons per hour during 6 to 8 hours a day. On such a tonnage, allowable loss will be the maximum of 40 pounds per hour. Air-Pollution Control District inspectors have estimated the losses from such a plant at about 4 to 5 pounds per hour.

Permits to construct and operate these plants must be approved by Air-Pollution Control District engineers. This serves as an additional safeguard against faulty design and is insurance against dusting and careless operation. The district must also be notified before such plants are moved to new locations.

Aggregates

Concrete aggregate crushing and sizing plants may be simple or elaborate and complicated, but the tendency is toward the latter, especially in plants designed for large tonnage rates, multiple products, and close grading of sizes. A range of sizes can be produced to meet almost any specifications for crushed rock or gravel.

A typical large rock-products plant in the Los Angeles area may handle several hundred tons an hour of pit-run rock, boulders, and gravel. Mining is usually by power shovel. A system of belt conveyors often is used to deliver the rock to a primary jaw crusher or breaker in the pit or quarry, thence, by more and often very long conveyors up out of the pit to ground storage at the plant. From there, the rock is delivered to very heavy scalping screens. Undersize usually goes to a wet-screening and sizing plant, which produces pea gravel and sand with very little dust. The scalping-screen oversize is crushed in stages in a series of gyratory crushers and delivered to a second set of vibrating screens in closed circuit with the gyratories. Two or more sizes of undersize may be delivered to a final screening plant for the production of the final sizes of crushed stone. Most of the screens are covered, and fine sprays of water are used to hold down the dust. The California State Health and Safety Code requires that the dust count in the air in crushing plants be kept below the statutory breathing limit for the protection of the workmen. The necessary precautions, therefore, have been taken in many plants to meet these requirements. None of the major plants of this type had been tested for possible violation of Air-Pollution Control District regulation when this report was written.

Granule Plants

Specialty plants for producing roofing granules and similar products requiring very accurate sizing of rock products have encountered considerable difficulty in holding dust emissions within permissible limits. This is especially true when spray towers have been selected for collecting fine dust.

A specific plant of this type producing roofing granules treats 25 tons per hour of rock-crusher fines in a continuous process. Raw material is received in a truck hopper and fed by an elevator into a rotary drier. The dried material is closely sized in a series of vibrating screens, and the oversize of each set of screens is crushed in rolls and returned to the screens. Elevators are housed, and screens either are enclosed or hooded. The final products are the clean, sized, and sometimes colored granules for delivery to the roofing-paper impregnating plant and rock dust, which is discarded or sold for fillers.

The plant is served by two separate systems for collecting dust. One treats only the hot gases drawn off the feed-end of the drier, which is fired from the discharge end. The dirty, hot gas is delivered to an impact-type separator, which effectively recovers the coarse particulate matter. The gas next enters a multitube centrifugal collector, thence proceeds into the final cleaner, consisting of a rectangular tower receiving 50 g.p.m. spray water. This system was treating 6,900 s.c.f.m. at the time the plant was tested. For convenience of description this is designated the west tower.

A second system collects dust from the elevators and vibrating screens and delivers it to a multiple-tube centrifugal collector and then to a spray tower. This east tower consumes about 50 g.p.m. water and handles 7,100 s.c.f.m. Opacity observations were of little value because of the water vapor masking the particulate matter.

Losses from both towers aggregated 80.6 pounds of particulate matter per hour versus the allowance of 34.3 pounds permitted for a process weight of 25 tons per hour. Test data are summarized as follows:

Item[1]		
Volume of gas discharged		
West tower, hot gases from drier	s.c.f.m.	6,900
East tower, elevator and vibrator vents	do.	7,100
Total volume, both towers	do.	14,000
Temperature at point of sampling		
West tower	°F.	80
East tower	do.	74
Concentration of Particulate Matter in discharge gases		
West tower	gr./s.c.f.	1.13
East tower	do.	.23
Total	do.	1.36
Total allowable	do.	.40
Losses		
West tower, particulate matter	lb./hr.	66.6
East tower, particulate matter	do.	14.0
Total, both towers	do.	80.6
Total allowable on 50,000 lb. process weight per hr.	lb.	34.3

[1] Test by Smith-Emery Co., Los Angeles.

Lightweight Aggregates

Another form of aggregate preparation that is becoming increasingly important in Los Angeles County is that of expanding in furnaces natural minerals, such as perlite, having up to 2 percent effective water of crystallization available for intumescence. The general method consists of crushing and sizing the raw mineral, then "popping" it at about 1,800° F. usually in a rotary kiln. The expanded mineral is sized mechanically or by air separators or both and bagged for market. The finished products are used in lightweight concrete and plaster aggregates, plaster finish, loose-fill insulation, glazed and unglazed brick, and other forms.

Technical aspects of the business have been the subject of recent articles.[89] Hot furnace gases are passed through cyclone collectors to recover fine popped

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[89] Conley, J. E., and Rupert, J. A., Lightweight Aggregates: Trans. Am. Inst. Min. and Met. Eng., vol. 187, Mining Engineering, April 1950, pp. 479-85.
Taylor, C. W., Popping Perlite, a New Industry: Chem. Eng., January 1950, pp. 90-94.
Wilfley, R. D., and Taylor, C. W., Perlite Mining and Processing, a New Industry for the West: Eng. and Min. Jour., vol. 151, No. 6, June 1950, p. 80.

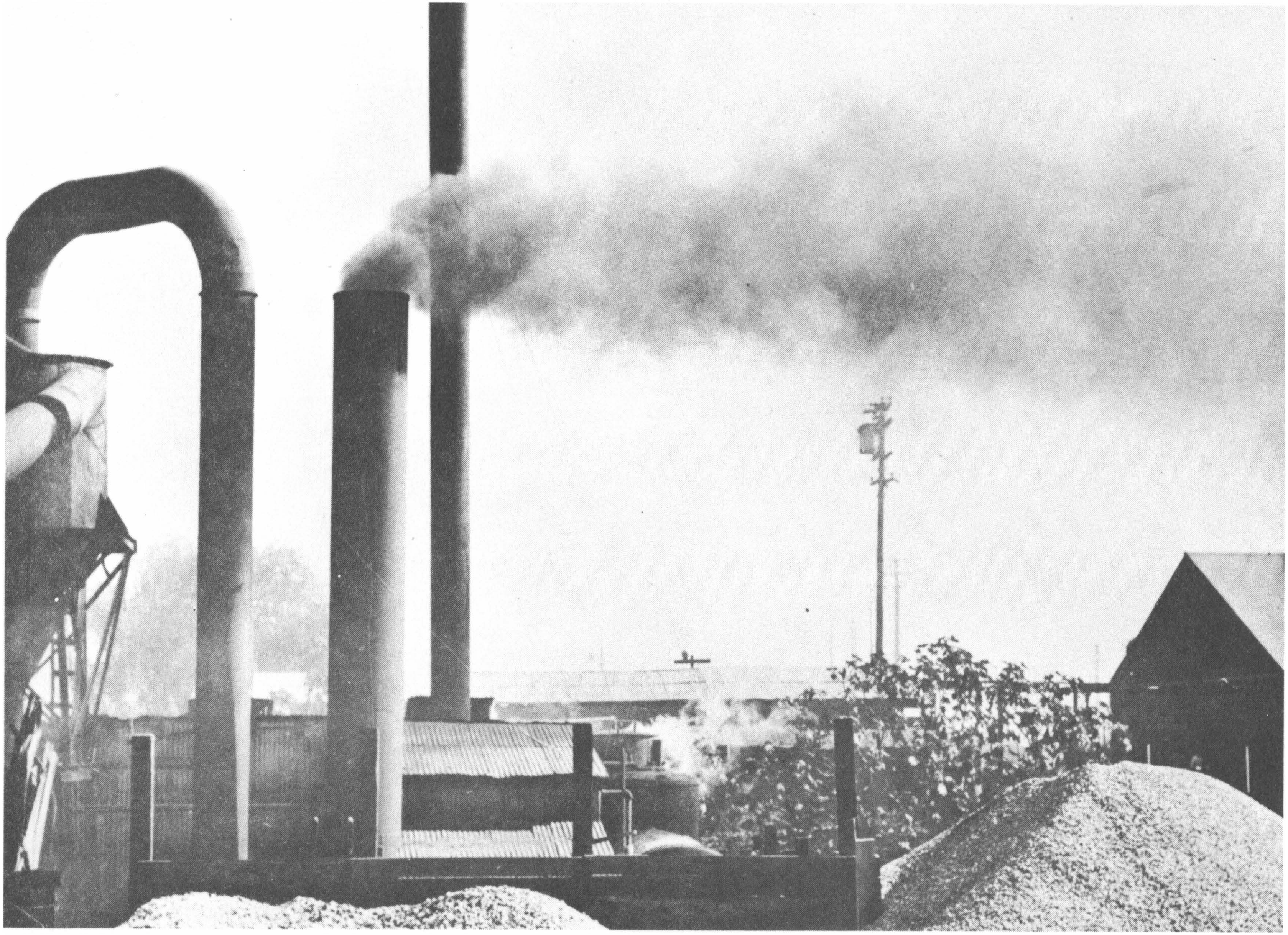

Figure 29. - Asphalt paving-mix plant producing excessive dust and fumes.

perlite and to reduce the dust load in the gases released to the air. Part of the hot gases may be returned to the furnace as preheat, or used for drying ore. Careful control of temperatures and operating conditions reduces the amount of very fine dusts produced in the operation, but the low density of the material, 12-15 pounds per cubic foot, probably adds to the difficulty of satisfactory dust separation. Specific tests had not been made on plants of this type at the time of this writing, but from inspections it appears that dust losses are high and recovery equipment suitable for micron sizes will be required.

ASPHALT PAVING-MIX PLANTS

It has been said that the Southern California area has more asphalt-mixing plants than any comparable area in the United States, and it is certain that an immense tonnage of paving mix is required annually. Plants range from 75- to 360-ton-per-hour capacity and may average about 100 tons. These plants are usually equipped with cyclone collectors for the coarse dust, and this is often followed by wet collectors, which may be horizontal or vertical spray-towers, multitube centrifugal, or other types of separators. If properly installed and carefully operated this equipment is capable of meeting Air-Pollution Control District requirements. However, table 10 shows that about half of the plants tested violated these requirements, even with some form of collecting equipment. Such was the case with the plant in figure 29. Its normal process rate of far over 60,000 pounds per hour entitles it to the maximum of 40 pounds allowed to any size plant under Air-Pollution Control District Rule 54. For a plant producing 100 tons per hour, this amounts to only 0.02 percent allowable loss or 2 pounds from every 5 tons of material processed. Some authorities believe that, for so complete a removal, high-efficiency spray towers or dynamic wet scrubbers may be required following the dry cyclone collectors and that they may have to be supplemented by air filters.

A conventional asphalt paving-mix plant consists of some suitable equipment to feed properly proportioned aggregate material, such as crushed rock and sand, onto a conveyor belt delivering usually to a bucket elevator. This in turn feeds a rotary kiln, most often oil-fired. Hot rock discharged from the kiln is elevated to the top of a batching machine, which accurately proportions the hot aggregate and steam-heated asphalt into a pugmill mixer. The asphalt-aggregate mixture is caught in a hopper beneath the pugmill and discharged into trucks. A 6,000-pound batch machine will produce 180 tons of asphalt mixture per hour operating on a 60-second cycle or 360 tons on a 30-second cycle.

Most of the dust to be collected will be from the ends of the drier and the hot-stone elevator. Dust is usually drawn into a conventional-type cyclone collector, which may recover 80-90 percent of dust coarser than about 40 microns. This dry dust may be fed back to the boot of the elevator feeding the batcher, or part of it may go to a silo to be discarded. Specifications usually make the return of at least a portion of the dust necessary. Fine dust and asphalt fumes or mist are collected from hoodings in the batch plant and from storage bins, screen housings, and several other points in the plant and materials-handling equipment. The dust and fumes may be combined with the hot gases at the dry collector or may be drawn directly to violent wet scrubbers, spray washers, or towers. The sludge from the wet machines is usually discarded.

TABLE 10. - Asphalt paving-mix plant data

Plant No.	Collection equipment	Gas volume, s.c.f.m.	Process wt/hr., lb.	Spray water, g.p.m.		Loss, lb./hr.		Violation A.P.C.D. rules
				Added	Recycled	Allowable	Actual	
1	Deduster; Multiclone scrubber	27,900	200,000	240	Yes	40	26.2	No
1-a	10-ft. cyclone; Multiclone scrubber (8 x 40 ft.)	18,700	250,000	240	Yes	40	58.6	Yes
1-b	12-ft. cyclone; 25-tube Multiclone scrubber (8 x 40 ft.)	11,020	180,000	273	Yes	40	48.1	Yes
1-c	10-ft. cyclone; horiz. scrubber (4 x 24-ft.); (5 x 40-ft.)	14,000	180,000	206 in horiz. No water in vertical scrubber	Yes	40	67.2	Yes
2	Cyclone; unpacked spray tower	13,100	309,220	374	No	40	30.6	No
3	Scrubber	12,200	200,000	50	No	40	84	Yes
4	6-ft. cyclone; 8 x 10 x 30-ft. wood scrubbers	17,600	175,000	200	Yes	40	62.5	Yes
5	Cyclone; horiz. scrub. with baffle and spray, not tangential	ND	145,000	250	250	40	26.5	No
6	Cyclone; horiz. scrub.; 10-ft. vert. scrub.	18,676	192,000	250	50	40	13.61	No
7	Cyclone; vert. scrub., 15-g.p.m. before fan	19,200	160,000	115	100 plus 15 fan inlet	40	13.8	No
7-a	do.	12,200	32,000	40	Yes	40	33.6	No
8	Cyclone; horiz. scrubber, tang. in and out	17,600	190,000	ND	ND	40	256	Yes
8-a	do.	15,200	190,000	8.75	8.75	40	344	Yes
8-b	do.	6,000	190,000	16.6	16.6	40	273	Yes
9	Cyclone scrubber	7,200	180,000	ND	ND	40	74.0	Yes
10	Stack outlet of water vent line	7,090 stack 2,680 water flue	236,000	25	No	40	64.0	Yes
10-a	Outlet stack from scrubber	11,200	240,000	150	No	40	47.5	Yes
10-b	Outlet stack spray scrubber	8,300	236,000	65	No	40	32.6	No
10-c	Spray scrubber with plate spiral	10,500 Stack gas	ND probably same as above	75	No	40	34	No

ND indicates no data given or available.

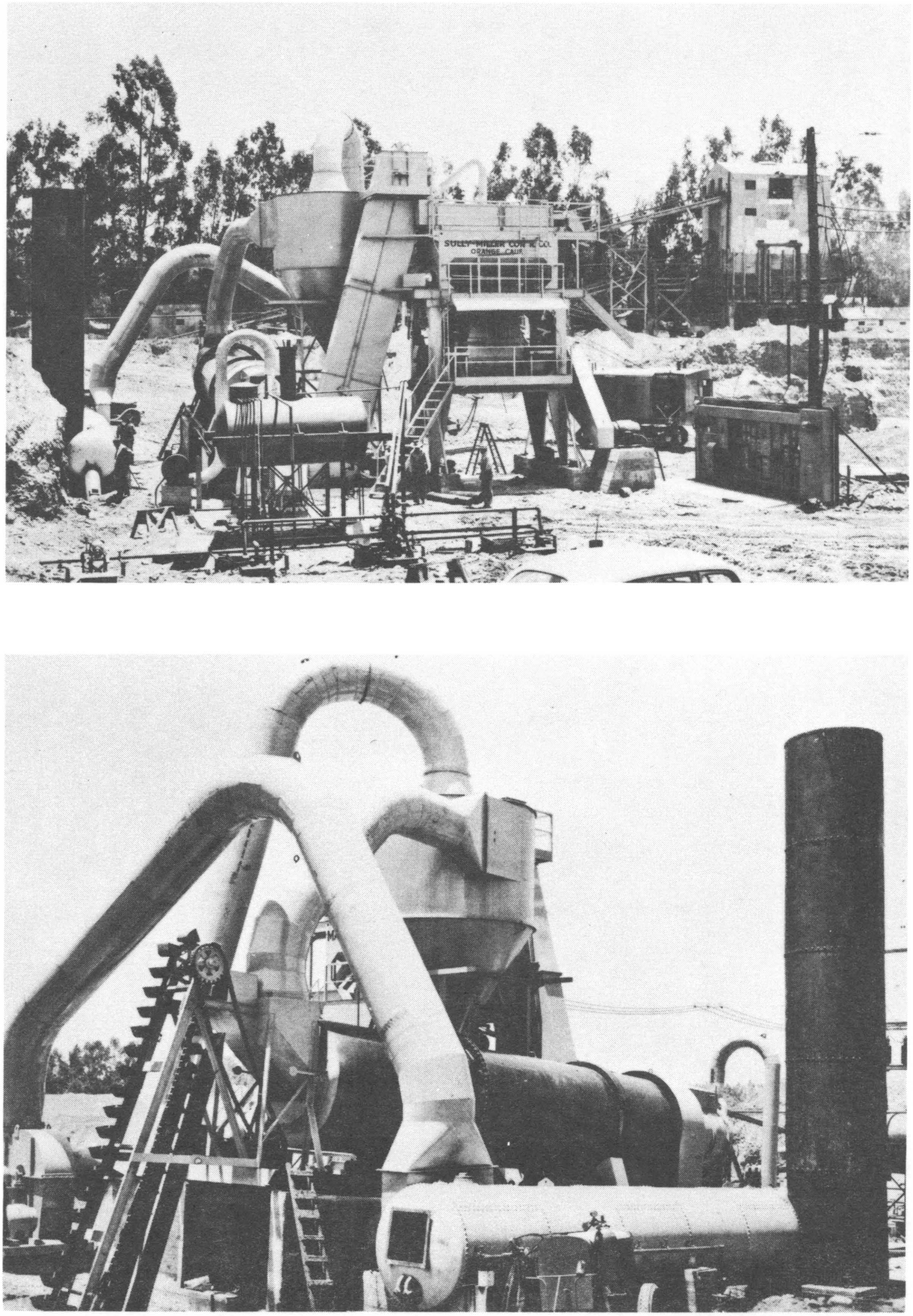

Figure 30. - Asphalt paving-mix plant with cyclone and horizontal wet scrubber.

Asphalt plants in the area are never enclosed. Mechanically, they generally follow the pattern illustrated in figure 30, which shows a well-designed plant under construction. They are usually in rock-producing areas, but business and even residential areas have encroached on these making dust-suppression even more necessary.

CERAMICS AND CLAYS

Some 450 establishments[90] in the Los Angeles area make ceramic and clay products, such as brick, tile, sewer pipe, pottery, and vitreous wares. Growth of petroleum-refining, chemical, dye, and cleaning industries has created demand for activated-clay products, catalysts, filter aids, and related materials. The preparation of essentially inert clay products for fillers also has become increasingly important. Only a few of the plants processing such materials have been checked for objectionable stack emissions. Almost all California ceramic and clay plants have some type of dust-suppressing equipment and some have quite elaborate recovery systems, but few plants have entirely satisfactory dust and fume controls.

Settling chambers, cyclones, and impact separators are in general use for the coarse particulate matter. For the collection of finer dusts, spray towers, dynamic centrifugal separators, wet scrubbers, sometimes supplemented by electrical precipitators and air filters, are used. The latter two are perhaps the most effective for dry dust, generally speaking, although some of the other types have been found satisfactory in some instances. Operations most often involve wet and dry fine grinding, processing at elevated temperatures in kilns or driers, and sometimes acid or other chemical treatment. Process weights are characteristically large and dust loadings heavy - up to 5 or 6 grains per cubic foot in untreated gases. Plants 2, 8, and 10 in table 11 are indicative of the dust losses in some types of clay-products operations. However, it is not feasible to generalize because of the great variety of raw materials and products and because only a few Los Angeles County plants have been investigated.

Examples of modern clay-processing operations are those for the manufacturing diatomaceous filter aids and for activating bentonitic clays. In the process of activating clays, the raw bentonite is crushed and ground in machinery especially developed for processing wet, sticky materials. The ground clay is pugged with water, pelletized, and partly dried. The pelletized clay is drawn continuously from storage into a tower where it is treated with sulfuric acid. The activated pellets are dried and calcined in large rotary kilns, cooled in rotary coolers, and sent to storage for packaging or for regrinding in Raymond mills. The latter are operated dry in a closed circuit with air-classifier cyclones. The air leaving the cyclones is satisfactorily cleared through bag-type filters.

Hot gases collected from the rotary driers and hoods at the feed and discharge-ends of the kilns and coolers are treated in multiple-tube centrifugal separators to collect the coarser dust, and then are put through a multiple washing tower receiving about 200 p.g.m. spray water, which is recirculated. Part of the sludge is bled off to settlers for clarification. Dirty gas entering the dust-recovery system may carry 4 to 6 grains per cubic foot or 720 to 1,000 pounds per hour, and the exit gas may carry about 60 pounds per hour. The legal limit for one source is 40 pounds per hour, so despite the high collection efficiency of over 90 percent, the plant described was in violation of County regulations.

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[90] United States Department of Commerce, Census of Manufactures, 1947: Bull. Mc104, p. 9.

TABLE 11. - Industrial minerals plants[1]

Date, 1949	Plant No.	Collection equipment installed	Equipment tested	Time, min.		Process weight, in lb.			Particulate matter, exits				Products	Furnace make and type	Fuel, c.f.m.
				Process cycle	Length of test	Per hr.	Total charge	Composition	Gr./cu. ft.	Losses, lb./hr.		Violation			
										Actual	Allowed				
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Apr. 25	1	None.	Outlet stack, putty mixer.	50	60	15,200	12,700	Lime and water.	173	5.81	13.26	No.	Lime putty (line and water).	None	None
May 19	2	Cyclone and sprays in vent.	Dryer exhaust vent of scrubber.	Continuous.	60	15,000		Diatomaceous earth treated with acid, etc.	.102	20.7	13.13	Yes.	Catalyst.	N.D.	Natural gas.
June 14	3	None.	Six exhaust stacks cupola, cookers, dryers.	do.	60	3,900	See col. 24	Slag, gravel and binder. See col. 24.	.047 to .22	70.1	5.85	Yes.	Slag wool.	Cupola.	Coke, 525 lb./hr.
June 16	4	Cyclone.	Cyclone outlet willow machines.	20	60	4,860	N.D.	Asbestos fiber.	.259	7.5	6.58	Yes.	Asbestos pipe and shapes.	None	None
June 11	5	None.	Reverb. furnace stack, blow-box vent, cooling vent, oven vent.	Continuous. do. do. do.	60 60 60 60	3,050 3,050 3,050 3,050	See col. 24 do. do. do.	See col. 24. do. do. do.	.314 .051 .109 .177	7.34 7.76 8.39 1.96	5.14 - - -	Yes. - - -	Rock wool. do. do. do.	Reverb. hand-charge top. - -	Gas and oil. - - -
Sept. 6	6	do.	Stack, melting furnace.	do.	60	11,600	do.	do.	.10	26.0	11.0	Yes.	Glass.	Mach. chgd. reversing recuperative reverberatory.	Gas, 900.
Sept. 19	7	do.	do.	do.	60	6,540	do.	do.	.151	12.3	7.71	Yes.	do.	do.	Gas, 415.
Apr. 26	8	Multiple-unit cyclones and wet scrubber.	Stack, spray scrubber.	do.	60	29,300	do.	do.	.371	56.1	21.79	Yes.	Catalytic material.	Rotary dryer, kiln and cooler.	Gas.
Sept. 30	8 (Test 1)	do.	do.	do.	60	31,000	do.	do.	.651	127.0	22.8	Yes.	do.	do.	do.
	8 (Test 2)		do.	do.	60	31,000	do.	do.	.517	92.4	22.8	Yes.	do.	do.	do.
Oct. 14	9	None.	Cupola stack.	do.	60	2,720	777 lb./chg. 3.5 chg.per hr.	74.6% slag, 17.5% coke, 7.9% SiO_2.	2.44 cupola .0006 blow-chamber	95.7	4.86	Yes.	Rock wool bats.	Cupola (See col. 24)	Coke.
Nov. 7	10	Dynamic centrifugal collector.	Collector exit stack.	do.	60	1,500	N.D.	Bisque.	.023	1.46	3.54	No.	Ground bisque.	None	None
Nov. 7	10	Cyclones.	Cyclone collectors.	do.	60	3,300	N.D.	See col. 24	.276	24.8	5.36	Yes.	Ceramic clay.	Instant spray dryer.	Gas.
Aug. 17	11 (See col. 24)	None.	Reverberatory stack.	185	60	908	2,800	do.	1.95	45.0	2.64	Yes.	Enamel frit.	Reverberatory	do.

[1] Source: Air Pollution Control District of Los Angeles County.
N.D. indicates no data given or available.

TABLE 11. - Industrial minerals plants[1] (Cont.)

Date, 1949	Plant No.	Collection equipment installed	Equipment tested	Flue and gas conditions							Remarks
				Source of gas tested	Phase of process covered by test	Flue gas Press., in. Hg.	Flue diam., in.	Temp., °F.	Av. vel., ft./sec.	Volume, s.c.f.m.	
1	2	3	4	17	18	19	20	21	22	23	24
Apr. 25	1	None.	Outlet stack, putty mixer.	Mixer Vent.	Complete cycle.	29.9	Area 0.993 sq. ft.	158	7.83	392	Col. 9, quicklime is slowly added to water to make putty in inclosed agitator. Steam and entrained lime vented to the air.
May 19	2	Cyclone and sprays in vent.	Dryer exhaust vent of scrubber.	Dryer.	Regular operation.	29.9	4x7-ft.	66	16.7	23,800	
June 14	3	None.	Six exhaust stacks cupola, cookers, dryers.	Cookers, dryer, ovens, blow-chamber.	do.	29.9	30	310	22.9	4,550	Col. 9, slag 2,730, gravel 270, coke 525, plus 375 binder/hr. Binder contains: linseed oil, 60.7%; asphalt, 38.4%; dryer, 0.9% at blower. Col. 11, cupola stack 49.7 lb./hr. with 1.28 gr./cu. ft. Stack from dryer heater 8.95 lb./hr. at 0.22 gr./s.c.f. Col. 19-23, cupola stack only. SO_2, 0.5-32.6 mg./s.c.f.; aldehydes as HCOH, 0.07-1.3 mg./s.c.f.
June 16	4	Cyclone.	Cyclone outlet, willow machines.	Cyclone outlet, reverberatory.	do.	29.9	30	39	12.4	3,380	Col. 3, plant operates several types of dust-recovery equipment.
June 11	5	None.	Reverb. furnace stack,	Reverberatory furnace.	do.	29.9	36	625	13.5	2,740	Col. 9, mix of silica-borax residue, lime, dolomites phenolic resin.
			blow-box vent,	-	-	29.9	29x39	79	46.0	17,700	Col. 11, total from stacks, 25.45 lb./hr.
			cooling vent,	-	-	29.9	29x39	142	27.5	8,980	Col. 16, 25 million B.t.u./hr.
			oven vent.	-	-	29.9	17	154	20.1	1,290	Col. 20, gases cooled by waste-heat boiler.
Sept. 6	6	do.	Stack, melting furnace.	Reverberatory stack.	Regular operation.	29.9	90	1,035	32.8	30,300	Col. 9, batch mix: sand, 1,756; soda ash, 710; limestone, 425; felspar, 345; salt coke, 20; fluorspar, 15; cullet (crushed glass), 900; niter, 4. As_2O_3, 5 lb.
Sept. 19	7	do.	do.	do.	do.	29.9	33	788	N.D.	22,900	Col. 9, batch lb./hr.; sand, 2,927; soda ash, 838; lime, 682; CaF_2, 59; barytes, 29; niter, 23; salt cake, 13.3; cullet, 1,962; Se, 2 oz.; copowder, 3-1/3 oz.; arsenic, 5 lb.
Apr. 26	8	Multiple-unit cyclones and wet scrubber.	Stack, spray scrubber.	Wet scrubber discharge.	do.	29.9	N.D.	109	60.2	17,670	Col. 8 and 9, activated bentonitic mineral. Col. 10-11, average 3 tests.
Sept. 30	8 (Test 1)	do.	do.	do.	do.	29.9	78	See col. 24	See col. 24	23,900	Col. 10, average 3 tests a.m. Col. 21 and 22, 159° F. and 17.6 ft./sec. Relative humidity, 100%.
	8 (Test 2)		do.	do.	do.	29.9	78	do.	do.	27,300	Col. 10, average 3 tests p.m. Col. 21 and 22, 160° F. and 19.8 ft./sec. Relative humidity, 100%.
Oct. 14	9	None.	Cupola stack.	Stack.	do.	29.9	51	3.15	8.0	4,570	Col. 11, vent of blow chamber only 0.07 lb./hr. solid. Col. 14, molten slag blown with 125 p.s.i. steam; plus 24 g.p.h. of mix of phenol, water, and ammonia.
Nov. 7	10	Dynamic centrifugal collector.	Collector exit stack.	do.	do.	29.9	20	63	59.5	7,440	Col. 9, crushed scrap tile.
Nov. 7	10	Cyclones.	Cyclone collectors.	Cyclone exit, gas from dryer.	do.	29.9	30	244	51.0	10,500	Col. 9, mixture of wet talc, whiting, silica clay, and other ceramic materials.
Aug. 17	11 (See col. 24)	None.	Reverberatory stack.	Stack.	First hr., melting.	29.9	30	1,382	N.D.	2,700	Col. 2, test by Smith-Emery Co. Col. 9 components similar to glass but usually contain more fluorides. Col. 10 filterable particulate matter only, gaseous losses not included, probably high.

[1] Source: Air Pollution Control District of Los Angeles County.

N.D. indicates no data given or available.

After much testing of the amount and character of the scrubber effluent by the operating concern and by Air-Pollution Control District, the latter approved the construction of the following additional gas-cleaning equipment. A wet-type electrical precipitator will be superimposed on the scrubber. Spray and flushing water from the precipitator will drain into the scrubber for further use, and clean treater-gas will be discharged through a short stack. To insure clean exit gas, the electrical precipitator design will be based on 25,000 c.f.m. and 0.5 grain per cubic foot at 160° F. with a maximum velocity of 8.5 feet per second. The precipitator will contain 90, 10-inch-diameter pipes. It is expected to reduce the exit gas loading to about 0.075 grain per cubic foot and the hourly emission of particulate matter to well within the permissible limit.

GLASS AND FRITS

About 70 concerns are engaged in the manufacture of glass and glass products from purchased glass. The manufacture of glass for processed and blown ware involves the high-temperature furnacing of specially prepared glass sands with limestone, fluorspar, feldspar, and other nonmetallic minerals, plus such chemicals as saltcake, niter, and arsenic.

It may be noted that neither of the two glass works tested (plants 6 and 7, in table 11) had dust-recovery equipment for their furnace exit gases. Machine-charged, recuperative, reverberatory furnaces are used in the plants mentioned. Grain loadings of the exit gases were low, 0.10 to 0.15 grain per s.c.f., but the large volumes, 23,000 to 30,000 s.c.f.m., carried particulate matter exceeding the allowable mass rate of emission for the weight of material processed.

Processes for preparing "frit" for enameling iron and steel and "slip" or glaze for porcelain and pottery work are similar to those for glass but are usually on a much smaller scale in the Los Angeles area. Raw-material components are much the same as those used in other glasses, but in quite different proportions, and batching formulas often are complex and sometimes carefully guarded.

In a typical plant, the raw ingredients are proportioned in batching weighers and ground dry in pebble mills in closed circuit with conventional cyclone separators. A slight negative pressure is maintained on the circuit to reduce dusting at sealing rings and vents. Excess air from the grinding circuit is exhausted through a miltitube centrifugal collector. The mixed charge is melted in small, gas-fired reverberatories at about 2,300°F., and the fluid is poured into water for granulating. Granules are dewatered, dried, and bagged for market. Enamel frit containing litharge is melted in a hooded oil-fired tilting furnace. Exit gases from both types of furnaces are discharged to the air without cleaning through dust and fume equipment and are often in violation, as indicated by tests at plant 11, table 11.

ROCK WOOL

The manufacture of mineral wool for heat- and sound-insulation material is a well-established industry in the Los Angeles area. The wool consists of thin fibers of silicate glass drawn from 10 to 1 micron in diameter. Either long or short fiber is made, depending on the raw materials and the purpose for which the fiber is used. A wide range of materials may be used in manufacture, but chemically the essential components of most wools are silica, lime, alumina, magnesia, and much smaller amounts of iron oxide. Silica constitutes about 35 to 40 percent of the raw materials, and blast-furnace slag with the addition of lime is mainly used as the raw material.

The general procedure in manufacture consists of melting the mineral raw materials in cupola furnaces using coke as fuel, or in reverberatory furnaces, which are usually oil- or gas-fired. Molten slag is continuously tapped from the furnace at about 2,800° F. in small streams, which are blown with steam jets at about 125 p.s.i. or are drawn mechanically into continuous fibers.

Blown fiber is collected on a moving belt in the form of a thick blanket. Binders such as asphalt and linseed oil are sometimes added, and the wool passes through a drier, is cooled, and delivered to the fabricating department. Shot is sometimes inadvertently formed during blowing and is removed by a special machine. The finished product may be in the form of loose wool, pellets, batts, boards, felt, and many other forms.

Dust and fume losses occur at several stages in the process. In plants using cupola furnaces, the major air pollution is from the cupola stack. In plant 3, Table 11, for instance, the cupola stack gases amounted to 4,550 s.c.f.m., carried 1.28 grains per cubic foot, and contained to 49.7 pounds per hour. Exit gases from the stack on the drier heater amounted to 4,740 s.c.f.m. at 0.22 grain per cubic foot and contained 8.95 pounds per hour. Losses at other vents were much lower. The cupola-stack gas was found to contain 32.6 milligrams of sulfur dioxide per s.c.f. Aldehydes in other vents amounted to 1.3 milligrams per s.c.f.

Table 11 contains test data pertaining to dust losses at three mineral-wool plants. None had dust-recovery equipment at the time they were tested and all were heavy violators of Air-Pollution Control District regulations. Losses for plant 5 were the total of the losses shown in column 11 for that plant.

ASBESTOS

Plant 4, table 11, manufactures pipe and sheet from a composition of asbestos fiber, sand, binder, and other nonmetallic materials. Pipe and other shapes are machined and fabricated, but no high temperature furnacing is required. An investigation of exhaust from a cyclone collector in the plant indicated that some further reduction of the dust load would be required. The plant was equipped with a complete dust-collection system employing cyclones and air filters, a combination that usually proved effective for nonmetallic dusts. Lathe, grinder, and other machine cuttings are drawn from the collecting hoods into flat-bag-type air filters, which are provided with metal-cloth screen frames covered with cotton-filter fabrics. From 10,000 to 14,000 c.f.m. of dirty air is satisfactorily cleared through 4,230 square feet of active filter area.

Dry grinding of siliceous minerals is accomplished in ball mills in closed circuit with air classifiers (cyclone collectors). Air vented from this system, with dirty air from other points in the raw-materials handling system, is cleared through a 2,000-cubic foot unit of bag-type filters providing an area of 990 square feet. Operating results of the filter have proved entirely satisfactory.

APPENDIX A. - RULES AND REGULATIONS OF AIR-POLLUTION CONTROL DISTRICT

As amended June 20, 1950

REGULATION I. GENERAL PROVISIONS

RULE 1. TITLE. These rules and regulations shall be known as the rules of the Air Pollution Control District.

RULE 2. DEFINITIONS. a. Except as otherwise specifically provided in these rules and except where the context otherwise indicates, words used in these rules are used in exactly the same sense as the same words are used in Chapter 2, Division 20 of the Health and Safety Code.

b. Person. "Person" means any person, firm, association, organization, partnership, business trust, corporation, company, city, county, municipality, district, or other political subdivision.

c. Board. "Board" means the Air Pollution Control Board of the Air Pollution Control District of Los Angeles County.

d. Director. "Director" or "Director of Air Pollution Control" means the Air Pollution Control Officer of the Air Pollution Control District of Los Angeles County.

e. Section. "Section" means section of the Health and Safety Code of the State of California unless some other statute is specifically mentioned.

f. Rule. "Rule" means a rule of the Air Pollution Control District of Los Angeles County.

g. Vent. "Vent" means any stack, chimney, flue, duct, conduit, exhaust, structure or opening of any kind whatsoever capable of or used for the emission of air contaminants.

h. Regulation. "Regulation" means one of the major subdivisions of the Rules of the Air Pollution Control District of Los Angeles County.

i. Particulate Matter. "Particulate matter" is material which is suspended in or discharged into the atmosphere in finely divided form as a liquid or solid at atmospheric temperature and pressure.

j. Process Weight Per Hour. "Process Weight" is the total weight of all materials introduced into any specific process which process may cause any discharge into the atmosphere. Solid fuels charged will be considered as part of the process weight, but liquid and gaseous fuels and combustion air will not. "The Process weight per hour" will be derived by dividing the total process weight by the number of hours in one complete operation from the beginning of any given process to the completion thereof, excluding any time during which the equipment is idle.

k. Dusts. "Dusts" are minute solid particles released into the air by natural forces or by mechanical processes such as crushing, grinding, milling, drilling, demolishing, shoveling, conveying, covering, bagging, sweeping, etc.

l. Condensed fumes. "Condensed fumes" are minute solid particles generated by the condensation of vapors from solid matter after volatilization from the molten state, or may be generated by sublimation, distillation, calcination, or chemical reaction, when these processes create airborne particles.

m. Solid Products of Combustion. "Solid Products of Combustion" are finely divided solid materials discharged into the atmosphere from the burning of carbonaceous materials.

RULE 3. STANDARDS. All analyses and tests shall be calculated or reported at the standard gas temperature of 60 degrees Fahrenheit and the standard pressure of 14.7 pounds per square inch.

REGULATION II. PERMITS

RULE 10. PERMITS REQUIRED.

a. Authority to Construct. Any person, building, erecting, altering or replacing on or after February 1, 1948, any article, machine, equipment or other contrivance, the use of which may cause the issuance of air contaminants or the use of which may eliminate or reduce or control the issuance of air contaminants, except an article, machine, equipment or other contrivance described in Section 24265 of the Health and Safety Code, shall first obtain authorization for such construction from the Air Pollution Control Officer.

b. Permit to Operate. Before any article, machine, equipment or other contrivance described in Rule 10 (a) may be operated or used, a permit shall be obtained from the Air Pollution Control Officer.

RULE 11 EXCEPTIONS. a. No permit shall be required from any city, county, municipality, district or other political subdivision.

b. No permit shall be required for building, erection, alteration or replacement costing less than $300.00 except combustion equipment as noted in Rule 11c.

c. No permit is required on combustion equipment having a combustion volume of less than 15 cubic feet measured above the grates and not including stacks or flues. All other combustion equipment will require an authority to construct and a permit to operate.

RULE 12. TRANSFER OF PERMITS. Permits shall not be transferable.

RULE 13. BLANKET PERMITS. Every person who, at any time between December 1, 1947, and the effective date of Rule 10, operated or used any article, machine, equipment, or other contrivance for the operation and use of which these rules require a permit, and so operated or used such article, machine, equipment or other contrivance in compliance with all laws, statutes, and ordinances applicable thereto, is hereby, by these rules granted a permit to continue or resume such operation or use.

RULE 14. APPLICATIONS FOR PERMITS. Applications for permits required under Rule 10 shall be filed with the Air Pollution Control Officer, accompanied by plans and specifications, in duplicate.

RULE 15. FORMS. Application forms furnished by the Air Pollution Control Officer shall be accurately and fully completed, and signed by the applicant.

RULE 16. PLANS. Plans shall be filed in duplicate and shall clearly show:

a. An outline of that portion of the building or buildings in which air pollution control equipment is to be installed.

b. The name and location with respect to the building floor plan of each article, machine, equipment or contrivance to be connected to the air pollution control equipment.

c. Plan and elevation views of air pollution control equipment, drawn to scale with all vents clearly shown and with scale indicated.

d. The size of all vents.

e. Type, design, size, rating and horsepower of each fan employed.

f. The location of the point of discharge of the air pollution control equipment with respect to the proximity of windows, doors, and other openings of the premises and adjacent premises.

g. Construction details of the air pollution control equipment employed, except that when standard commercial equipment is used the manufacturer's catalog number will be considered sufficient.

h. Location of clean-outs, cross-section and elevation-section of the furnace, oven, kiln, or still using gas, liquid or a solid-fuel fired apparatus.

RULE 17. SPECIFICATIONS. Specifications shall be in sufficient detail so that when read in conjunction with the plans they shall clearly reveal the proposed means for the control of emission of air contaminants and shall show the extent of such control anticipated in the design or use of said control equipment, except that when standard commercial equipment is used, the manufacturer's catalog number or other designation shall be acceptable. Specifications may appear on the same sheet as the plans.

RULE 18. ACTION ON APPLICATIONS. The Air Pollution Control Officer shall act on all applications within a reasonable time, and shall notify the applicant in writing of his approval, conditional approval or denial of the application.

RULE 19. APPROVAL OF APPLICATIONS. Written notice of approval of an application for a permit shall be equivalent to the granting of such a permit.

RULE 20. STANDARDS FOR GRANTING PERMITS. No application shall be approved or permit granted unless it is shown that every article, machine, equipment or other contrivance the use of which may cause the issuance of air contaminants, is so designed or controlled, or equipped with such air pollution control equipment, that with proper supervision and use it may be expected to operate without emitting air contaminants in violation of Sections 24242 or 24243, Health and Safety Code or of the Rules of the Air Pollution Control District.

RULE 21. CONDITIONAL APPROVAL. The Air Pollution Control Officer may approve an application subject to conditions which will bring it within the standards of Rule 20, in which case the conditions shall be specified in writing. Commencing work under such a permit shall be deemed acceptance of all the conditions so specified.

RULE 22. DENIAL OF APPLICATIONS. In the event of denial of the application the Air Pollution Control Officer shall notify the applicant in writing of the reasons therefor All denials shall be without prejudice to the applicant's filing a further application when he has complied with the objections specified by the Air Pollution Control Officer as his reasons for denial of the permit.

RULE 23. FURTHER INFORMATION. Before acting on an application the Air Pollution Control Officer may require the applicant to furnish further information, or further plans or specifications.

RULE 24. APPLICATIONS DEEMED DENIED. The applicant may at his option deem the application denied if the Air Pollution Control Officer fails to act on the application within 30 days after filing, or within 30 days after applicant furnishes the further information, plans and specifications requested by the Air Pollution Control Officer, whichever is later.

RULE 25. APPEALS. Within 10 days after service of notice of denial of the application, or of conditional approval, or within 10 days after applicant's election to treat the application as denied for failure to act, in accordance with Rule 24, applicant may file with the Hearing Board a written demand for a public hearing.

RULE 26. PUBLIC HEARING. Within 30 days after the applicant has requested a public hearing, the Hearing Board shall hold such a hearing and give notice of the time and place of such hearing to the applicant, to the Air Pollution Control Officer and to such other persons as the Hearing Board deems should be notified, not less than 10 days before the date of the public hearing.

RULE 27. ACTION OF HEARING BOARD. After a public hearing, the board may:

(a) Deny the application for a permit.
(b) Approve the application for a permit.
(c) Approve the application for a permit subject to conditions which it shall specify.

REGULATION III. FEES

RULE 40. PERMIT FEES. Every applicant for authorization to construct or for a permit to operate shall pay a fee at the rate of $4.00 per hour for each hour or fraction thereof for the time required for consultations, the checking of plans and specifications and making necessary inspections, but excluding the time required in going to and from the premises being inspected.

It is hereby determined that the cost of issuing or denying authorization for construction or permits to operate and making the necessary inspections pertaining to such issuances or denials exceeds $4.00 per hour or fraction thereof.

On approval or denial of the application, the actual time taken for checking plans and specifications and for making the necessary inspections shall be determined and the applicant so notified. If the payment of this fee is not made to the Air Pollution Control Officer within 10 days of the notice of the amount due, the application shall be deemed to have been withdrawn.

RULE 41. EXCEPTIONS. a. No fee shall be charged if the time required for consultations, the checking of plans and specifications and making necessary inspections is less than one-half hour.

b. No fee shall be charged for any blanket permit granted pursuant to Rule 13.

RULE 42. VARIANCE FEES. a. Every applicant or petitioner for a variance or for the revocation or modification of a variance, and every person requesting a hearing to determine whether and under what conditions a variance will be permitted, shall pay a fee in accordance with the following schedule:

On the filing of the petition or request the petitioner shall pay to the clerk of the Hearing Board a fee in the sum of $50.00. It is hereby determined that the cost of administration of Article 5, Chapter 2, Division 20, Health and Safety Code, exceeds $50.00 per petition.

b. At the same time and in addition to such fee, every petitioner shall deposit or secure the cost of publication of notice of hearing; any unused portion of this deposit, or the whole thereof in case the Hearing Board dispenses with publication of notice, shall be refunded to the petitioner. In addition to such fee and deposit, any person requesting a transcript of the hearing shall pay the cost of such transcript.

c. This Rule shall not apply to petitions filed by the Air Pollution Control Officer.

d. No filing fee shall be charged for petitions or requests for a hearing to determine whether a permit shall be revoked or a suspended permit reinstated, or to review the denial or conditional granting of a permit.

RULE 43. ANALYSIS FEES. Whenever the Air Pollution Control Officer finds that an analysis of the emission from any source is necessary to determine the extent and amount of pollutants being discharged into the atmosphere which cannot be determined by visual observation, he may order the collection of samples and the analysis made by qualified personnel of the Air Pollution Control District. The time required for collecting samples, making the analysis and preparing the necessary reports, but excluding time required in going to and from such premises shall be charged against the owner or operator or said premises in a reasonable sum to be determined by the Air Pollution Control Officer, which said sum is not to exceed the actual cost of such work. If the sum required by this rule is not paid within ten (10) days after notice, the provisions of Section 24269 and 24270 of the State Health and Safety Code shall immediately become effective.

RULE 44. TECHNICAL REPORTS - CHARGES FOR: Information, circulars, reports of technical work, and other reports prepared by the Air Pollution Control District when supplied to other governmental agencies or individuals or groups requesting copies of the same may be charged for by the District in a sum not to exceed the cost of preparation and distribution of such documents. All such monies collected shall be turned into the general funds of the said District.

REGULATIONS IV. PROHIBITIONS

RULE 50. RINGELMANN CHART. A person shall not discharge into the atmosphere from any single source of emission whatsoever any air contaminant for a period or periods aggregating more than three minutes in any one hour which is:

a. As dark or darker in shade as that designated as No. 2 on the Ringelmann Chart, as published by the United States Bureau of Mines, or

b. Of such opacity as to obscure an observer's view to a degree equal to or greater than does smoke described in subsection (a) of this Rule.

RULE 51. NUISANCE. A person shall not discharge from any source whatsoever such quantities of air contaminants or other material which cause injury, detriment, nuisance or annoyance to any considerable number of persons or to the public or which endanger the comfort, repose, health or safety of any such persons or the public or which cause or have a natural tendency to cause injury or damage to business or property.

RULE 52. PARTICULATE MATTER. Except as otherwise provided in Rules 53 and 54, a person shall not discharge into the atmosphere from any source particulate matter in excess of 0.4 grain per cubic foot.

RULE 53. SPECIFIC CONTAMINANTS. A person shall not discharge into the atmosphere any one or more of the following contaminants, in any state, or combination thereof exceeding in concentration at the point of discharge:

Sulphur Compounds (calculated as SO_2) 0.2 percent by volume.

Solid Products of Combustion 0.4 grain per cubic foot of gas calculated to 12% of carbon dioxide. (CO_2).

RULE 54. DUST AND FUMES. A person shall not discharge in any one hour from any source whatsoever dust or fumes in total quantities in excess of the amount shown in the following table: (See next page)

To use the following table, take the process weight per hour as such is defined in Rule 2 (j). Then find this figure on the table, opposite which is the maximum number of pounds of contaminants which may be discharged into the atmosphere in any one hour. As an example, if A has a process which emits contaminants into the atmosphere and which process takes 3 hours to complete, he will divide the weight of all materials in the specific process, in this example, 1,500 lbs. by 3, giving a process weight per hour of 500 lbs. The table shows that A may not discharge more than 1.77 lbs. in any one hour during the process. Where the process weight per hour falls between figures in the left hand column, the exact weight of permitted discharge may be interpolated.

RULE 55. EXCEPTIONS. Rules 50 to 54, inclusive, do not apply to:

a. Fire set by any public officer in the course of his official duty, for the purpose of weed abatement, the prevention of a fire hazard, or the instruction of public employees in the methods of fire fighting.

b. Agricultural operations in the growing of crops or raising of fowls, or animals, or,

c. The use of an orchard or citrus grove heater which does not produce unconsumed solid carbonaceous matter at a rate in excess of one (1) gram per minute, or

d. The use of other equipment in agricultural operations in the growing of crops, or raising of fowls, or animals.

NOTE: Regulation V, Procedures Before the Hearing Board, and VI, Orchard and Citrus Grove Heaters (omitted here) may be obtained by addressing Major Harry E. Kunkel, Air Pollution Control District, 5201 Santa Fe Avenue, Los Angeles, California.

TABLE

*Process Wt/hr(lbs)	Maximum Weight Disch/hr(lbs)	*Process Wt/hr(lbs)	Maximum Weight Disch/hr(lbs)	*Process Wt/hr(lbs)	Maximum Weight Disch/hr(lbs)
50	.24	1,900	4.03	4,700	6.45
100	.46	2,000	4.14	4,800	6.52
150	.66	2,100	4.24	4,900	6.60
200	.852	2,200	4.34	5,000	6.67
250	1.03	2,300	4.44	5,500	7.03
300	1.20	2,400	4.55	6,000	7.37
350	1.35	2,500	4.64	6,500	7.71
400	1.50	2,600	4.74	7,000	8.05
450	1.63	2,700	4.84	7,500	8.39
500	1.77	2,800	4.92	8,000	8.71
550	1.89	2,900	5.02	8,500	9.03
600	2.01	3,000	5.10	9,000	9.36
650	2.12	3,100	5.18	9,500	9.67
700	2.24	3,200	5.27	10,000	10.0
750	2.34	3,300	5.36	11,000	10.63
800	2.43	3,400	5.44	12,000	11.28
850	2.53	3,500	5.52	13,000	11.89
900	2.62	3,600	5.61	14,000	12.50
950	2.72	3,700	5.69	15,000	13.13
1,000	2.80	3,800	5.77	16,000	13.74
1,100	2.97	3,900	5.85	17,000	14.36
1,200	3.12	4,000	5.93	18,000	14.97
1,300	3.26	4,100	6.01	19,000	15.58
1,400	3.40	4,200	6.08	20,000	16.19
1,500	3.54	4,300	6.15	30,000	22.22
1,600	3.66	4,400	6.22	40,000	28.3
1,700	3.79	4,500	6.30	50,000	34.3
1,800	3.91	4,600	6.37	60,000 or more	40.0

*See Definition in Rule 2 (j).

APPENDIX B. - LIST OF ABBREVIATIONS, SYMBOLS, AND CONVERSION FACTORS

Abbreviations and symbols:

°A.	angstrom
a.c.	alternating current
amp.	ampere
av.	average
Am. Inst. Min. and Met. Eng.	American Institute of Mining and Metallurgical Engineers
B.t.u.	British thermal unit (s)
Bull.	Bulletin
Chem. Eng. News	Chemical and Engineering News
col.	column
c.f.m.	cubic feet per minute
°C.	degrees centigrade
cm.	centimeter (s)
cu. ft.	cubic foot (feet)
c.	cycle (s)
d.c.	direct current
ed.	edition
°F.	degrees Fahrenheit
fig.	figure
ft.	foot (feet)
f.p.m.	feet per minute
f.p.s.	feet per second
gal.	gallon (s)
g.	gram (s)
g.p.m.	U. S. gallon (s) per minute

g.p.h.	U. S. gallon (s) per hour
gr.	grain (s)
hr.	hour (s)
hp.	horsepower
Bureau of Mines Inf. Circ.	Information Circular, Bureau of Mines
in.	inch (es)
Ind. Eng. Chem.	Industrial and Engineering Chemistry
Jour. Ind. Hyg. Toxicol.	Journal of Industrial Hygiene and Toxicology
kv.	kilovolt (s)
kv.-a.	kilovolt-ampere (s)
kw.	kilowatt (s)
kw.-hr.	kilowatt-hour (s)
lb.	pound (s)
m.	meter (s)
mm.	millimeter (s)
M	thousand
mg.	milligram (s)
min.	minute (s)
N.D.	No data available (used in tables)
p.s.i.	pounds per square inch
p.p.m.	parts per million
p.s.i.g.	pounds per square inch, gage
p.	page
pp.	pages
r.p.m.	revolutions per minute
ref.	reference

s.c.f.m.	standard cubic feet per minute (Standard gas conditions in this report are 60° F. and 29.9 in. Hg)
s.c.m.	standard cubic meter (s)
sec.	second
sq. ft.	square foot (feet)
Stanford Res. Inst.	Stanford Research Institute
Trans. Am. Inst. Min. and Met. Eng.	Transactions of American Institute of Mining and Metallurgical Engineers

Conversion factors:

1 gr. = 0.0647989 g.

1 g. = 15.4324 gr.

1 gr. per cu. ft. = 2288 mg. per $m.^3$

1 mg. per $m.^3$ = 0.0004369985 gr. per cu. ft.

lb. per hour. = gr. per cu. ft. x c.f.m. x 0.0085542

1 micron = 1/25400 in. = 0.00003937 in.
this is Greek letter mu

1 micron = 0.001 mm. = 10,000° A.

1° A. (Angstrom) = 0.0001 micron

1 p.p.m. = 0.0001 percent

1 percent = 10,000 p.p.m.