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Routine Sampling for Control of Atmospheric Impurities

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ROUTINE SAMPLING FOR CONTROL OF ATMOSPHERIC IMPURITIES*

The control and sampling of atmospheric contaminants in routine production operations are matters with which plant and mine managers today are definitely concerned. A few years ago, such control was more or less limited to firms that were losing a valuable product through faulty operation, or to those that knew that neglect of dust, fly ash, or gas control meant a health, nuisance, or explosion risk, either to themselves or to their neighbors. Today, however, twenty-eight states (Table 1) have industrial hygiene bureaus whose function it is to advise industry on the control of its industrial hazards, while many insurance companies are well equipped to investigate industrial hygiene problems from both the engineering and medical aspect.† Baltimore, Maryland; Detroit, Michigan; Rockford, Illinois, and St. Louis, Missouri, are reported as having industrial hygiene bureaus.

The formulation of codes of good practice is a trend of comparatively recent date. Underwriters' codes covering fire and explosion risks have been available for some years. To them is now being added information, such as the National Silicosis Conference's recommendations on dust counts in relation to silicosis prevention[1], New York State's codes on silica dust control in rock drilling[2], and the American Foundrymen's Association's codes on exhaust systems for general foundry work[3]. The American Standards Association has a committee which, it is understood, will suggest, from time to time, safe concentrations of various contaminants. Some states now furnish, on request, a list of maximum safe concentrations which they recommend for various dusts and gases. (The Massachusetts list is given in Table 2).

In some instances, as in Wisconsin and New York, the codes have been made legally binding. Other states have issued the lists merely for the guidance of persons who ask how clean the air of a workplace should be.

It is not our intention to criticize these codes. The concentrations generally are not fixed by accepted medical standards, but represent zones or ranges arrived at by practical trial. Obviously, the figures must be revised from time to time as medical knowledge on the subject progresses, and especially as industry improves its housekeeping.

The purpose of this bulletin is to give in brief form descriptions of apparatus and methods which are actually being used by one or more laboratories in appraising the environment in which men work. In making such appraisals, two distinct steps are involved: first, measurement of air currents, and second, estimation of impurities. The resulting data can then be applied to the design of control equipment or to the appraisal of the results brought about by such equipment.

Air Movement

Low Air Velocities

Air velocities in workplaces generally are below 100 F. P. M. (feet per minute). Exceptions are warm places where fans or air blasts are used for their cooling effect, mine shafts and haulage ways used as ventilation ducts,

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† Detailed information on insurance-company activities can be had from American Mutual Alliance, 919 North Michigan Avenue, Chicago, and the Association of Casualty & Surety Executives, 60 John Street, New York City.

and atmospheres within the immediate zone of exhaust hoods. Low velocities must be measured by special instruments as they are below the range measurable by pitot tube, venturi meter, or vane anemometer.

Smoke Bombs:

In schoolrooms or auditoriums, air conditioning engineers usually study air distribution by the use of smoke. Smoke from tobacco is of too fine a texture to serve as well as the coarser smoke made from hygroscopic substances.

Titanium tetrachloride smoke tubes for testing work are safer to use and give satisfactory results. They can be made as follows: glass serum ampoules, costing about $2.40 a gross, are filled with 0.10 cc. of titanium tetrachloride. The ampoule is then sealed and the neck pulled out about 0.25 inch, dipped in water-glass as an adhesive, and about an inch of wicking pushed over the neck. The wicking used in a sulfur lamp is satisfactory. Since the compound reacts with air and becomes vitiated, the ampoules should be sealed promptly.

When a smoke test is desired, the neck of the ampoule is broken by laying it on a hard surface and pressing down with the thumb; the wicking will protect the thumb against cutting with the glass. The $TiCl_4$ runs out into the wick and smoke immediately results.

A smoke gun can be made by soaking pumice with titanium chloride and packing in small glass tubes, such as calcium chloride drying tubes. Air is then blown through the pumice by means of a rubber aspirator bulb. When not in use, the ends of the tube should be closed with stoppers.

Titanium tetrachloride is carried by most supply houses and costs about 75 cents per quarter pound, which is enough to fill a large number of ampoules. Smoke tubes and smoke guns in convenient form are supplied by (g), (j).*

Thermo-anemometer:

C. P. Yaglou has recently developed[4] a simple thermo-anemometer capable of measuring velocities between 10 and 6,000 F. P. M. The temperature of the wire is only 10° to 40° above air temperature and is indicated on an ordinary thermometer around the bulb of which the wire is wound. Small dry cells furnish the heating current and the voltage is regulated by means of a rheostat. These auxiliaries are assembled in a small box. Readings to be taken are temperature of heated and of unheated thermometer and voltage used. The velocity is read off a table or chart, or computed from an equation. By varying the voltage, any velocity can be measured with an accuracy of 98%.

A unit which is vest-pocket size and sensitive to very low velocities will be available shortly.

This instrument compensates for variations of air density due to temperature changes, and is negligibly affected by humidity, radiant heat, and convectional currents which it causes. It is particularly useful for measureing air movement in rooms and in exploring "point" velocities in front of exhaust hoods, because it offers negligible obstruction to airflow.

Its disadvantages are that it is not direct reading, it requires a short time for the heated thermometer to reach equilibrium, and its readings must be corrected for partial stem immersion when used inside small pipes. The instrument is too new to have had any widespread field use. It is supplied by (m).

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* (a), (b), etc., refer to firms supplying equipment. For full list and addresses, see Table 4, Page 18, of this bulletin.

High Air Velocities

In the effective zone of exhaust hoods, the minimum velocity is about 150-200 feet per minute extending on up to 1,000 F. P. M. or more at the face of the hood. It is often desirable to increase the hood's effectiveness by changes in design. Velocity contours can be sketched out as indicated in Figure 1 of Bulletin No. 2 of this series. For measurements in such velocity ranges, Yaglou's thermo-anemometer device is well suited.

Vane Anemometer:

In the case of large hoods, such as those placed over electroplating or vats, either a velometer or a small vane anemometer is convenient. For exploring small hoods, however, both instruments take up too much space and interfere seriously with the normal air currents which the hood is intended to form. Furthermore, the portable vane anemometer is a delicate instrument; it needs frequent calibration, and is easily damaged by corrosive chemicals, by dusts, and even by steam or water vapor. It is advisable to use the vane anemometer only when no corrosive substances are being generated.

Velometer:

This is a direct-reading device consisting of a double-pivoted vane which is deflected by impact against the air stream. A pointer attached to the vane indicates the velocity on a calibrated scale. All moving parts are housed in a small case. For low-range readings, the air enters the meter directly through a small port and the whole case must be placed into the air stream. For high-velocity readings, various size orifices are placed within the port to reduce vane deflections. For measurements of velocity inside pipes, a double-pitot tube is provided and connected to the meter ports by rubber tubing.

Velometer readings are instantaneous, but several must be taken to insure a good average. One can measure velocities of several thousand feet per minute, as in exhaust ducts, or a few hundred feet per minute in the vicinity of large exhaust hoods. Although a dust-filter attachment is now available for keeping the mechanism clean, it is questionable whether it is wise to use the instrument in any but clean air. The device is supplied by (h).

A less accurate, but very practical instrument, known as the "Grillometer," has been developed for measuring air velocities through grills. It is a torsion device and is direct reading. It is supplied by (d).

Pitot Tube, Venturi Meter and Orifice Meter:

While these three instruments measure flow rather than velocity, they are too well known to need any description. The pitot tube has long been the sole "self-standard" instrument and the most used for determining flow in pipes or ducts, for making traverses, and the like. Recording venturi meters and orifice meters for measuring the flow of fluids (liquids and gases) are sold today by several firms. In the construction of exhaust systems, it is well to consider the permanent installation of a venturi, or an orifice meter, or even a recording meter near the exhaust fan. The A. S. M. E. book[7] gives full details of the basic principles, design, and use of these instruments.

Atmospheric Impurities

For the purposes of selecting sampling and control methods, in relation to exhaust systems in plants or mines, several distinct types of atmospheric impurities must be considered:

A. Relatively insoluble mineral dusts, such as silica, many silicates, and fly ash.

B. Relatively soluble mineral dusts, like calcite (limestone).

C. Finely-divided fume substances that are difficult to catch in water. Examples are lead, lead oxide, and zinc oxide.

D. Dusts that may be affected by water. Examples are flour, leather, and soap. Many of these dusts are explosive if mixed with air.

E. Aqueous mists, such as chromic acid entrained from electroplating baths, or condensate from vats of various sorts.

F. Water-soluble gases, such as hydrochloric acid. Such soluble gases usually contain mist as well as gas, the proportions depending upon local conditions.

G. Gases or organic vapors, like benzene, soluble with difficulty. These react slowly with most liquids but may be adsorbed readily by solids, such as activated carbon.

Instruments for Dust Sampling

Impinger:

The impinger is commonly used in sampling dusts, like classes A, B, and occasionally mists, like class E, and some gases, like class F. It is definitely unsuited to class G gases, like chlorine or organic vapors. It is not efficient against finely-divided fume substances, Class C, such as lead or zinc oxide, and rarely is it suited to sampling organic dusts, like class D.

The impinger[5] consists in a flask in which a tube with tapered end is held at a fixed distance from an attached glass plate or from the bottom of the flask. Air is drawn through the tube and the impurities are trapped in the liquid in which the tip of the tube is immersed. Suitable fractions of the dusty suspension are then withdrawn and the dust particles counted under the microscope or the total dust concentration is estimated by the usual analytical procedures.

The impinger is now made in two sizes, one sampling at one cubic foot per minute, and the other at three to five liters per minute. Used originally with water as the dust-catching medium, it is now common practice to use other liquids, such as isopropyl alcohol, limitation depending upon volatility of the liquid and its readiness to foam.

The suction device for the impinger can be run by a compressed-air actuated ejector or by a pump driven by an electric motor. The midget-impinger equipment is much smaller and can be run by hand. It is lighter than the large unit. Furthermore, it is hand operable, all of which makes it particularly suited to mine-air sampling. Both types of impinger were developed by the U. S. Bureau of Mines, which recommends both for general use in measuring dustiness. Impingers, either large or midget size, are supplied by (e), (i), (j), (k), (m).

For sampling finely-divided fume substances, like lead, which are well dispersed, a small electric precipitator gives accurate results. While the complete precipitator assembly is not expensive, it requires a transformer

weighing some 15-25 pounds to raise the voltage to 15,000 to 25,000. Construction details with a list of equipment needed for making such precipitators are given in Drinker & Hatch[6]. This equipment is available from (m).

Barnes & Penney, of the Westinghouse Electric & Manufacturing Company, have described[5] a small precipitator which should be well adapted to field use and is now available from (j). The high-tension side of this new-type precipitator is grounded, making it more practicable for general field use.

Sampling Dust for Direct Microscopy and Counting

The purpose of taking and counting dust samples is to determine how much the dustiness of the air in question departs from some arbitrary figure or accepted standard. The grab-sample instruments, viz., the konimeter (j), the Bausch & Lomb dust counter (a), (m), and the Owens jet dust counter (e), give useful indications of changes in dustiness. All three instruments are light and are operated entirely by hand. However, they do not imitate the impinger in any way, so that it is impossible to convert impinger to grab-sample counts. The reason why such conversions are faulty is because the grab samplers favor dust sizes below the size-particle range for which the impinger technic is best adapted.

A skilled technician can count about twelve impinger samples in a day. It is easy, however, to compare some thirty to forty grab samples in a short time. In practical field work with the grab sampler, the effectiveness of dust-control equipment or methods can thus be demonstrated rapidly.

Explosive Dusts

Most explosive dusts are affected by water, while some of them, especially organic dusts, such as flour, are difficult to wet. Explosive concentrations of all such dusts are very high (10-15 gms./m³) as compared with dust concentrations of hygienic significance (0.5 gms./m³), so that explosive dusts are determined by weight rather than by count. Air is drawn through a weighed paper extraction thimble and the increase in weight caused by the dust from a known volume of air is noted. An objection to this procedure is the trouble and time required to equilibrate the paper thimble against the moisture in the air. This objection, however, is not serious if the weight of the dust sample, as in the case of explosive dusts, approximates that of the thimble.

It should be remembered that in sampling explosive dusts one must use a suction device that avoids the chance of electric sparks.

Quantitative Analysis

In the case of all dusts, classes A, B, C, and D, the estimation of the sample taken from the air can be made by counting representative fractions under the microscope, or the sample can be analyzed by appropriate chemical methods, or the material can be weighed. The large impinger and the electric precipitator are equally well adapted to either procedure. The midget impinger collects, in reasonable sampling time, a relatively small amount of dust, but enough for counting.

Dusts, like silica, that are troublesome to determine chemically, are generally counted, while those like lead, manganese, and cadmium, are determined chemically.

In places where composition of the dust and the particle size remain

substantially the same day after day, it is possible to estimate roughly dustiness in impinger samples from the turbidity of the dusty emulsions. Such estimates can be made in Nessler tubes, by tyndallmeter[4], or by an adaptation of the turbidity methods commonly used in water analysis.

Light-Field vs. Dark-Field Counting

For routine control work, the relative advantages of these two methods of counting dust samples (no matter what sampling instrument is used) are unimportant. It is immaterial which method is used. If the person doing the counting feels that the light-field set-up is hard on his eyes, or the magnification too low, by all means he should try the dark-field method. On the other hand, if he is using the impinger and wishes to copy in exact detail the procedure recommended by the U. S. Public Health Service, then light-field counts must be made. The Bureau of Mines recommends a micro-projection method for impinger counts[5]. The konimeter, recommended by the Bureau of Mines for control sampling, is used in South Africa, where it originated, with dark-field, while the Bausch & Lomb counter is available with dark-field only. Owens samples can be counted by either light- or dark-field.

Gas Sampling

Gas concentrations commonly met in sanitary air analysis are very low. Concentrations that men may breathe usually are given in parts per million by volume (P. P. M.), or in milligrams per liter, or per cubic meter under specified temperatures and pressures.

Some gases and vapors, notably carbon monoxide, hydrogen sulfide, and mercury, in minute amounts, give strong chemical reactions which makes possible rapid estimations and still better, continuous records of pollution. However, the great bulk of gases and vapors from organic solvents, such as benzene, carbon tetrachloride, and carbon disulfide, cannot be caught efficiently unless sampled at slow rates, such as ½ to 1 liter per minute. Some of them, such as benzene, can be absorbed directly in special solvents or adsorbants, like charcoal or silica gel, or can be converted into another compound which can then be estimated by an appropriate method.

The greatest difficulty in estimating organic vapors in air occurs when mixtures of vapors are present. Unfortunately, this is all too often the case. Then, the devising of short cuts in itself offers a major problem, but local conditions sometimes permit the approximations of the proportions of the several ingredients in the collected sample and calculation of the total by estimating only the most easily-determined single constituent.

Condensation

The general availability of "dry ice" (temperature = —79° C.) makes convenient the routine collection and estimation of volatile compounds, like gasoline, for which liquid air (temperature = —192° C.) formerly was used. A convenient cooling mixture is made by pouring ethyl alcohol or gasoline on cracked dry ice. The condensation apparatus is then immersed in the cooling mixture.

Liquid air is available in most large cities and offers a convenient cooling medium, but it should be remembered that it forms explosive mixtures with inflammable dusts or gases.

Vapor-Pressure Measurements

If only one substance is present—and that in a high degree of purity—measurements of concentration can be made conveniently and quickly by condensing the vapor with the dry-ice mixture and then estimating the concentration by the Burrell-Jones vapor-tension method[9]. This procedure is not in common use in industrial hygiene problems and needs further study.

Routine Sampling and Recording of Air Impurities

If control equipment has been installed, samples should be taken periodically for check-ups. This is the best way to tell whether the equipment is functioning as it should. If concentrations obviously are high, it is usually a waste of time to take the sample and to estimate it. For instance, a leaky elevator in a crushing plant or a defective rattler or an unhooded swing grinder in a foundry may cause such high dust concentrations that an impinger sample will be turbid in a few minutes. Little is gained by going through the sampling routine in such cases, unless one wishes to have records before and after repairs have been made.

Today, many plants operate crushing units and other dust producers at night to take advantage of reduced power rates and to stagger employment over twenty-four hours. During the night shift, dust inspections can be made rapidly, using nothing but the beam from an ordinary flash light to detect dust leaks.

In the case of some gases and vapors, one's sense of smell often permits detection of gas concentrations which exceed desirable limits. Such a test is quite unreliable unless one returns frequently to clean air or carries with him a respirator with an activated charcoal cartridge through which he takes several breaths before attempting to gauge the strength of the odor. One becomes used to even such dangerous or disagreeable odors as hydrogen sulfide in a few monments and it is, therefore, risky to estimate their strength by smell.

Such crude tests do not take the place of regular sampling technic. How often the routine samples should be taken depends entirely upon local conditions. In some places, they are taken daily, while in others, several times a year is enough. It is well to play safe and to take them too often rather than too seldom. The men quickly become used to such sampling and pay no attention to the procedure. Obviously, the sooner the sampler has the man's interest in his results, the better will be the outcome. It is common for the workmen to ask what the results are and to see to it that the samples in their particular departments are satisfactory.

We know of one mining company whose concentrating plant is equipped for the taking of monthly dust samples. Various sampling stations have compressed air piped to convenient points and each station has an arrangement for holding the impinger bottles. In this plant, it is usual for one operator to take, at the same time, samples on four floors of a single building.

Samples should be taken wherever men work. It is a mistake to ignore places where one believes that there is no dust or gas. The samples are about the only proof that the employer can bring forth that he has taken proper precautions to prevent a disease, such as silicosis or a chronic poisoning from benzol. The mere statement that he or anyone else thought the atmosphere sufficiently clean is not enough.

It is advisable to plot the results of periodic samples with the days or

months as abscissae and the concentrations or dust counts as ordinates. Such plots can be made conveniently on a master sheet, comments noted on the plot which is blue printed with each new batch of samples, and the prints given to the appropriate departments.

Continuous Records

It is obvious that continuous records of either dust or gaseous impurities are more informative than occasional or intermittent records. It is possible to take continuous records of relatively heavy pollution, as in the stacks of power plants, and also of ordinary atmospheric pollution which is of relatively low concentration. It is understood that Mine Safety Appliances Company, Pittsburgh, will offer shortly a dust recorder that may prove useful in common sanitary air analyses.

As noted previously, gases that give strong chemical reactions, particularly those involving pronounced heat or color changes, are suited to estimation by continuous recorders. A carbon monoxide recorder (j), which measures the heat liberated by a catalytic combustion reaction, is in wide use today. A recorder for mercury vapor (f) has also found considerable application. The applicability of recorders in sanitary air analyses has hardly been touched upon and it is reasonably certain that others will be developed as need arises.

Photographs

It is common practice in power-plant operation automatically to take photographs at regular intervals of the smoke escaping from the stack. Such records provide useful evidence if the plant is accused of faulty operation.

Occasional photographs of various plant and mine operations are often of greater practical usefulness than are records of dust counts or of gas or vapor concentrations. As an exhibit on the company's bulletin boards, photographs are effective warnings to the men to clean up. In routine sampling, they should certainly be taken occasionally and incorporated as part of the inspector's report.

TABLES

Date: June, 1938

TABLE I.

SUMMARY OF INDUSTRIAL HYGIENE ACTIVITIES IN STATES AND CITIES IN THE UNITED STATES

State	Number of Gainful Workers	Number of Workers in Manufacturing Mechanical and Mineral Industries	Agency Responsible for Activity	Department Responsible for Activity	Number and Kind of Personnel				Annual Budget
					Medical	Engineering	Other Technical	Clerical	
Alabama	1,026,320	220,378	State Health Dept.	Division Industrial Hygiene	1	0	0	0	5,600
Arizona	165,304	45,811							
Arkansas	667,870	83,960	State Health Dept.		0	1	0	1	4,200
California	2,500,969	673,646	State Health Dept.	Industrial Hygiene Service	1	1	1	1	22,020
Colorado	402,594	88,830	State Health Dept.		0	0	0	0	4,200
Connecticut	677,292	337,445	State Health Dept.	Bureau Occupational Diseases	1	1	3	2	25,557
Delaware	98,104	35,348							
Florida	599,010	131,480							
Georgia	1,162,174	240,989							
Idaho	162,223	27,934	State Health Dept.		0	0	0	0	5,000
Illinois	3,184,875	1,164,979	State Health Dept.	Division Industrial Hygiene	2	2	3	2	35,000
Indiana	1,251,177	464,549	State Health Dept.	Bureau Industrial Hygiene	1	1	0	1	11,500
Iowa	912,832	167,147	State Health Dept.	Division of Engineering	0	2	0	1	8,350
Kansas	694,276	132,662	State Health Dept.	Section of Sanitation Div.	0	1	1	1	10,920
Kentucky	907,166	220,233							
Louisiana	815,725	156,030							
Maine	308,617	104,201	State Health Dept.		0	0	0	0	
Maryland	672,906	228,599	Baltimore Health Dept.	Bur. Environmental Hygiene Bur. Occupational Diseases	1	2	3	2	12,900
Massachusetts	1,814,422	840,300	State Labor Dept.	Division Occupational Hyg.	0	1	2	2	19,200
Michigan	1,927,498	860,164	State and Detroit Health Depts.	Bureau Industrial Hygiene	1	6	5	4	35,500
Minnesota	992,817	210,299	State Health Dept.		0	0	0	0	1,335
Mississippi	844,887	79,318	State Health Dept.	Div. Industrial Hygiene and Factory Inspection	1	0	1	1	9,100
Missouri	1,458,034	390,399	State and St. Louis Health Depts.	Division of Engineering	0	3	0	1	13,005

Date: June, 1938

TABLE I.— Continued

SUMMARY OF INDUSTRIAL HYGIENE ACTIVITIES IN STATES AND CITIES IN THE UNITED STATES

State	Number of Gainful Workers	Number of Workers in Manufacturing Mechanical and Mineral Industries	Agency Responsible for Activity	Department Responsible for Activity	Number and Kind of Personnel				Annual Budget
					Medical	Engineering	Other Technical	Clerical	
Montana	216,471	44,637							
Nebraska	507,022	71,517							
Nevada	42,885	11,776							
New Hampshire	192,671	89,461	State Health Dept.	Div. Chemistry and Sanitation	0	1	0	1	8,380
New Jersey	1,712,125	741,299							
New Mexico	142,866	23,931							
New York	5,523,085	1,995,924	State Labor Dept.	Division Industrial Hygiene	7	7	12	7	118,614
North Carolina	1,141,129	289,917	State Health Dept.	Division Industrial Hygiene	2	2	1	1	27,500
North Dakota	210,317	18,095							
Ohio	2,615,938	1,094,650	State Health Dept.	Bur. Occupational Diseases	3	1	2	2	25,300
Oklahoma	828,029	172,163							
Oregon	409,680	102,125							
Pennsylvania	3,722,428	1,796,944	State Health Dept.	Division Industrial Hygiene	2	9	0	1	56,490
Rhode Island	297,168	164,303	State Health Dept.	Division of Industrial Hyg.	2	3	1	1	23,000
South Carolina	687,721	146,344	State Health Dept.	Division Industrial Hygiene	1	1	0	1	10,380
South Dakota	247,678	24,207							
Tennessee	958,209	213,077	State Health Dept.	Div. Preventable Diseases	1	1	0	0	11,000
Texas	2,247,118	395,802	State Health Dept.	Division Industrial Hygiene	1	3	1	1	24,200
Utah	170,013	44,977	State Health Dept.						
Vermont	141,190	42,851	State Health Dept.	Tuberculosis Division	1	1	0	1	11,500
Virginia	880,276	227,539	State Health Dept.	Bureau Industrial Hygiene	1	1	1	1	19,000
Washington	664,813	181,765	State Health Dept.	Public Health Eng. Division	0	1	0	1	6,280
West Virginia	570,459	242,115	State Health Dept.	Bureau Industrial Hygiene	1	1	0	1	17,500
Wisconsin	1,129,546	380,229	State Health Dept.	Industrial Hygiene Unit	1	2	0	1	11,000
Wyoming	92,451	19,036							
Totals	48,588,730	15,432,996			32	55	37	39	612,276

TABLE II.

CONCENTRATIONS OF INFLAMMABLE VAPORS, SUGGESTED BY THE U. S. BUREAU OF MINES, AND LIMITS FOR PRACTICAL CONTROL, SUGGESTED BY THE MASSACHUSETTS DIVISION OF OCCUPATIONAL DISEASES

GAS OR VAPOR	Lower Limit, by Volume %
Ammonia	16
Acetaldehyde	4
Acetone	3
Acetone (turbulent mixture)	2.5
Acetylene	3.0
Acetylene (turbulent mixture)	2.3
Benzene	1.4
Benzine	1.1
Blast furnace gas	35
Butane	1.9
Butyl acetate (26° C.)	1.7
Carbon disulfide	1.0
Carbon monoxide	12.5
Cyclohexane	1.3
Dichlorethylene	10
Ethane	3.2
Ethyl acetate	2.5
Ethyl alcohol	4
Ethyl bromide	7
Ethyl chloride	4
Ethyl ether	1.7
Ethyl formate	3.5
Ethyl nitrite	3
Ethylene	3.0
Ethylene dichloride	6
Ethylene oxide	3.0
Furfural (125° C.)	2
Gasoline	1.4
Hydrogen	4.1
Illuminating Gas	5.3
Methane	5.3
Methane (turbulent mixture)	5.0
Methyl acetate	4.1
Methyl alcohol	7
Methyl bromide	13.5
Methyl chloride	8
Methyl cyclohexane	1.2
Methyl ethyl ketone	2
Methyl formate	6
Natural gas	4.8
Pentane	1.45
Propane	2.4
Propyl acetate	2.0
Pyridine (70° C.)	1.8
Toluene	1.4
Vinyl chloride	4
Water gas	6 to 9

GAS OR VAPOR	Maximum Concentration Suggested by Massachusetts P. P. M.
Ammonia	100
Amyl acetate	400
Aniline	5
Arsine	1
Benzol	75
Cadmium	0.1*
Butyl acetate	400
Carbon bisulfide	15
Carbon monoxide	100
Carbon tetrachloride	100
Chlorine	1
Chlorodiphenyls	1*
Chloronaphthalenes	1 to 5*
Chromic acid	0.1*
Dichlorbenzene	75
Dichlorethyl ether	15
Ether	400
Ethylene dichloride	100
Formaldehyde	20
Gasoline	1000
Hydrochloric acid	10
Hydrogen cyanide	20
Hydrogen fluoride	3
Hydrogen sulfide	20
Lead	0.15*
Mercury	0.1*
Methanol	200
Monochlorbenzene	75
Nitrobenzene	5
Nitrogen oxides	10
Ozone	1
Phosgene	1
Phosphine	2
Sulfur dioxide	10
Tetrachlorethane	10
Tetrachlorethylene	200
Toluol	200
Trichlorethylene	200
Turpentine	200
Xylol, coal tar naphtha	200
Zinc oxide fume	15*

* Milligrams/cu. meter

TABLE III.

ANALYTICAL PROCEDURES IN CURRENT USE IN INDUSTRIAL HYGIENE

The substances listed in the following table are more or less commonly found in industrial atmospheres. Methods of determination which are suggested have all been used by laboratories in this country and found to be satisfactory. Not all of the methods listed, however, are specific.

It is assumed that the user of this table is familiar with common analytical procedures and with the general methods of sampling or collecting atmospheric impurities. For example, lead as a dust, such as lead arsenate, would be caught by impinger; lead fume from lead burning by electric precipitator; while lead tetraethyl would be collected by means of a bubbler. Different rates of flow would be used in each case.

MATERIAL	Method of Collection	Method of Determination
Acetone	Draw air through bubbler containing H_2O.	Modified iodometric [39].
Ammonia	Draw air through H_2SO_4 solution in gas wash bottle.	Determine NH_3 by A. P. H. A. Standard Method [32].
	Low Conc. Draw air through bubbler containing acidified (H_2SO_4) dist. water and methyl red indicator. Continue to end point.	Calculate NH_3 concentration as in ordinary acidimetry.
	Conc. Greater Than 1% Draw air through bubbler containing 50 cc. of a saturated solution of boric acid.	Titrate with 0.025 N. H_2SO_4 using methyl red indicator.
Aniline	Draw air through bubblers containing 10% H_2SO_4.	Depends upon reaction of aniline with Br_2 using sodium indigo disulfonate as an indicator [32].
Arsenic (dust)	Draw air through impinger containing water.	Iodometric.
Arsine (gas)	Draw air through bubbler containing alcoholic KOH.	Modified Gutzeit [36].
Benzene	Draw air through nitrating acid.	Colorimetric or volumetric determination as dinitrobenzene. Ref.: Air Hyg. Bull. No. 2, Part 1 (Jan., 1938).
	Draw air through indicating instrument.	Equipment from (j).
Bromine	Draw air through bubbler containing I_2 solution in KI with starch.	Iodometric.

MATERIAL	Method of Collection	Method of Determination
Carbon dioxide	Draw air through "ascarite" after removing water vapor on "drierite" and weigh.	
	Draw air through bubbler containing a buffered $NaHCO_3$ solution and phenolsulphonophthalein indicator.	Compare resulting color against standards. Ref.: Higgins & Marriott. J. Am. Chem. Soc., vol. 39, p. 38 (1917).
	Gas-collecting bottles.	Volumetric gas anal. method. Ref.: U. S. Bureau of Mines Bulletin No. 154 and I. C. 7017 (1938).
Carbon disulfide	Draw air through alcoholic KOH to form potassium ethyl xanthate.	Determine xanthate iodometrically. Ref.: Matuszak, M. P.: Ind. Eng. Chem., Anal. Ed., vol. 4, pp. 98-100 (1932).
Carbon disulfide and hydrogen sulfide in presence of each other	Draw air through 10% $CdCl_2$ solution, then through 2.5% H_2SO_4 and through 5% acoholic KOH.	Iodometric. Determine CS_2 as above. Ref.: Barthelemy, H. L.: Tubize Chatillon Corp., Rome, Ga., or Div. of Ind. Hyg., N. Y. State Dept. of Labor, 80 Centre St., New York.
Carbon monoxide	Low concentrations, 10 to 1,500 PPM, by heat liberated from combustion with Hopcalite as catalyst. Concentration on dial of a milliammeter. High concentrations, 0.05 to 1.0% (500-10,000 PPM) use detector depending upon liberation of I_2 from I_2O_5 or color reaction with $PdCl_2$ ampoules.	Ref.: U. S. Bureau of Mines, Tech. Paper 582. Also: Drinker, C. K.: Carbon Monoxide Asphyxia, Chapt. 8 by Sendroy. Oxford University Press, New York, 1938.
	Details from makers of the above equipment (b) (c) (j).	
Chlorine	Draw air through O-tolidine reagent in special absorption tube.	Transfer sample to Nessler tube and compare with standards after standing. Ref.: Porter: J. Ind. Eng. Chem., vol. 18, p 730 (1926).
	Draw air through 10% KI solution.	Iodometric.
Chlorinated hydrocarbons, general	Physical method such as absorption on activated charcoal or by use of interferometer.	Ref.: Air Hyg. Bulletin No. 2, Part 3 (March, 1938).
	Thermal decomposition method.	Equipment from (l) (m).
Carbon tetrachloride	(As above).	
Chromic acid (mist)	Impinger with approximately normal NaOH, or with electric precipitator.	Iodometric. Ref: Bloomfield and Blum: U. S. Pub. Health Rep., No. 43, p. 2330 (1928). Determine chromate with x-diphenylcarbazide as indicator. Ref.: Yoe, J. H.: Photochemical analysis. 2 vols. Wiley & Sons, New York. 1928-1929.

MATERIAL	Method of Collection	Method of Determination
Esters	Gas-collecting bottles.	Hydrolyze with NaOH, back titrate excess NaOH. Ref.: Patty, Yant and Schrenk: U. S. Pub. Health Rep. No. 51, p. 511 (1936).
Ethyl bromide Ethyl chloride		See MeBr.
Formaldehyde	Draw air through bubbler containing water.	Colorimetric method using Schiff's soln. [2]. Also, Denige method. Chapin, R. M.: J. Ind. Eng. Chem., vol. 13, p. 544 (1921).
Hydrocarbons, general	(1) Zeiss portable interferometer. (2) Absorption on solid materials, such as activated charcoal or silica gel [15].	Full information from (n).
	Gas-collecting bottle.	Volumetric gas analysis method [16]. Also, U. S. Bureau Mines I. C. 7017 (1938).
	Self-contained instruments operate on the heat of combustion principle and give readings of the percentage of the lower explosive limits directly on dials. Special calibrations of the dials can be obtained depending on the application.	Equipment from (b) (c) (j) (l).
Hydrochloric acid	Draw air through glycerol-potassium carbonate-water soln. of the ratio 1:1:1.	Determine chloride ion by Volhard method. Ref.: Heller: Gesund. Ingenieur, vol. 55, p. 261 (1932). Chem. Abst., vol. 27, p. 155 (1933).
Hydrofluoric acid	Draw air through bubbler containing KOH.	Distill fluorides as hydrofluosilicic acid. Titrate fluorides in distillate with thorium nitrate soln. using sodium alizarine sulfonate as indicator. Ref.: Willard and Winter: Ind. Eng. Chem., Anal. Ed., vol. 5, p. 7 (1933). Boruff and Abbott. (Ibid), vol. 5, p. 236 (1933).
Hydrogen cyanide	Draw air through bubblers containing 0.5% KOH.	Titrate with $AgNO_3$.
	Colorimetric indicator.	Range of 50-1,000 PPM. Equipment from (j).
Hydrogen sulfide	See also carbon disulfide. Draw air through activated alumina coated with AgCN or PbAc.	Concentration is indicated by length of color change. Ref.: Littlefield, Yant and Berger: U. S. Bureau Mines, R. I. No. 3276 (June, 1933).
	Instrument using this method sensitive to 25-400 PPM. Instrument for colorimetric method using test paper sensitive to 0.02% supplied by (j).	See also: Reed, J. F.: J. Soc. Chem. Ind., vol. 57, pp. 43-4 (1938).
	Draw air through bubbler containing I_2 soln. in KI with starch.	Iodometric.

MATERIAL	Method of Collection	Method of Determination
Lead, as dust or fume	Impinger or electric precipitator.	See Air Hyg. Bulletin No. 2, Part 6 (1938).
Mercury	Draw air against SeS coated paper	Compare color change against standards. Ref.: Nordlander, B. W.: Ind. Eng. Chem., vol. 19, p. 522 (1927).
	Lampshade detector (using SeS) available from (f) (j).	
	Freeze vapor with dry ice.	Ref.: Fraser: J. Ind. Hyg. & Tox., vol. 16, p. 67 (1934).
Methane	Gas-collecting bottle. Combustible gas indicator from (b) (c) (j) (l).	Vol. gas anal. method [16]. Ref.: Hoover, Fene, Currie. U. S. Bureau Mines Bull. No. 331 (1930).
	Flame Safety Lamps from (b) (c) (j).	See also: U. S. Bureau Mines I. C. No. 33 (1937).
Methanol		Discussion. Ref.: Wright, L. O.: Ind. Eng. Chem., vol. 19, p. 750 (1927).
	Draw air through bubbler containing water.	Oxidize to formaldehyde and determine colorimetrically (Denige method) [12]. See also: Formaldehyde, Chapin's method.
	Collect sample in partly evacuated bottle.	Determine by modified Denige method.
	Absorb MeOH in distilled water by thorough agitation of water in the bottle.	Ref.: Schrenk and Yant: U. S. Bureau Mines, Personal communication (1933).
Methyl bromide **Methyl chloride** **Ethyl bromide** **Ethyl chloride**	Collect samples by Hg displacement.	Analyse volumetrically by slow combustion with a white-hot platinum coil and large excess of O_2. Ref.:Sayers, Yant, Thomas, and Berger. U. S. Public Health Bull. No. 185 (1929). For MeBr see also: Busbey and Drake: Ind. Eng. Chem., Anal. Ed., vol. 10, p. 390 (1938).
Nitric acid **Nitrogen tetroxide**	Draw air through an acidified 5% H_2O_2 bubbler followed by 2 or 3 5% KOH H_2O_2 bubblers.	Determine N_2O_5 with phenolsulfonic acid by A. P. H. A. Standard method [11]. Ref.: Drinker and Snell: J. Ind. Hyg. & Tox., vol. 20, p. 321, (1938).
	Draw air through liquid air trap.	Oxidize as above and determine by nitron acetate method. Ref.: Coltman: J. Ind. Hyg. & Tox., vol. 20, p. 289 (1938).
Oxygen	*Gas-collecting bottle.*	Vol. gas anal. method [16]. U. S. Bureau Mines I. C., 7017) (1938).

MATERIAL	Method of Collection	Method of Determination
Ozone	Partially evac. bottles containing starch-KI solution.	Iodometric [12].
	In presence of N_2O_4, collect by liquid air.	Ref.: Coltman and McPherson, J. Ind. Hyg. & Tox., vol. 20, p. 465 (1938).
Phenol	Draw air through bubbler containing NaOH solution.	Determine colorimetrically [11].
Phosgene	Draw air through bubbler containing aniline water saturated with diphenyl-urea.	Filter off precipitate of diphenyl-urea in tared Gooch crucible, dry and weigh, dissolve diphenyl-urea with alcohol dry, and weigh. Ref.: Yant, et al.: Ind. Eng. Chem., Anal. Ed., vol. 8, p. 29 (1936).
Phosphorus trichloride	Draw air through bubbler containing Br water.	Boil and determine P by colorimetric molybdate method [13].
Radioactive substances	Physical methods using electroscope.	Ref.: Schwartz, et al.: J. Ind. Hyg. & Tox., vol. 15, p. 362, 368, 433 (1933).
Sulfur chloride	Draw air slowly through HNO_3 solution of $AgNO_3$.	Dissolve the precipitated AgCl in NH_4OH again precipitating with HNO_3 [15].
Sulfur dioxide	Draw air through I_2-KI starch solution.	Iodometric. Ref.: Griffin and Skinner, Ind. Eng. Chem., vol. 24, p. 862 (1932).
	Partially evacuated bottle containing I-KI starch soln.	Solution from sampling bottle brought to same intensity as a blank by addition of standard iodine solution. Ref.: U. S. Bureau Mines, R. I. No. 3005 (1930).
	Draw air automatically through acid H_2O_2.	Conductivity method with recorder. Ref.: Thomas: Ind. Eng. Chem., Anal. Ed., vol. 4, p. 253 (1932).
Sulfuric acid (mist)	Draw air through NaOH in impinger.	Acidify with HCl and determine sulfate as $BaSO_4$.
Toluol	Draw air through fuming HNO_3.	Similar to U. S. Bureau Mines method for C_6H_6 using KOH instead of NaOH.
Trichlorethylene	Draw air through specially designed absorption tube containing absolute EtOH.	Determine colorimetrically on reaction with pyridine and 50% sodium hydroxide. Ref.: Barrett: J. Ind. Hyg. & Tox., vol. 18, p. 241 (1936).
	Combustion method for chlorinated hydrocarbons.	Air Hyg. Bulletin No. 2, Part 3 (March, 1938).

TABLE IV.

FIRMS SUPPLYING EQUIPMENT MENTIONED IN THIS BULLETIN

(a) Bausch & Lomb Company
Rochester, New York.

(b) E. D. Bullard Company
275 Eighth Street, San Francisco, California.

(c) Davis Emergency Equipment Co.
55 Van Dam Street, New York, New York.

(d) Detroit Air Meter Company
Detroit, Michigan.

(e) Fisher Scientific Co.
709-717 Forbes Street, Pittsburgh, Pennsylvania.

(f) General Electric Company
1 River Rd., Schenectady, New York.

(g) E. V. Hill Co.
179 West Washington Street, Chicago, Illinois.

(h) Illinois Testing Laboratories, Inc.
420 N. LaSalle Street, Chicago, Illinois.

(i) Macalaster Bicknell Co.
171 Washington Street, Cambridge, Massachusetts.

(j) Mine Safety Appliances Company
Pittsburgh, Pennsylvania.

(k) Pulmosan Safety Equipment Corp.
176 Johnson Street, Brooklyn, New York.

(l) Union Carbide Company—Linde Air Products, Inc.
30 East 42nd Street, New York, New York.

(m) Willson Products, Inc.
Reading, Pennsylvania.

(n) Zeiss Company
485 Fifth Avenue, New York, New York.

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13. Cook, W. A.; and Coleman, A. L.: Determination of Solvent Vapors in Air by Means of Activated Charcoal. J. Ind. Hyg. & Tox., 18: 194-210, 1936.
14. Cook, W. A.: The Industrial Hygiene Laboratory. J. Ind. Hyg. & Tox., 18: 623-636, 1936.
15. Flury, F.; and Zernik, F.: Schädliche Gase. Julius Springer, Berlin (1931).
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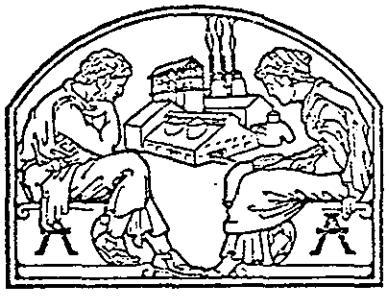

Routine Sampling for Control of Atmospheric Impurities

PITTSBURGH, PENNSYLVANIA
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ROUTINE SAMPLING FOR CONTROL OF ATMOSPHERIC IMPURITIES*

The control and sampling of atmospheric contaminants in routine production operations are matters with which plant and mine managers today are definitely concerned. A few years ago, such control was more or less limited to firms that were losing a valuable product through faulty operation, or to those that knew that neglect of dust, fly ash, or gas control meant a health, nuisance, or explosion risk, either to themselves or to their neighbors. Today, however, twenty-eight states (Table 1) have industrial hygiene bureaus whose function it is to advise industry on the control of its industrial hazards, while many insurance companies are well equipped to investigate industrial hygiene problems from both the engineering and medical aspect.† Baltimore, Maryland; Detroit, Michigan; Rockford, Illinois, and St. Louis, Missouri, are reported as having industrial hygiene bureaus.

The formulation of codes of good practice is a trend of comparatively recent date. Underwriters' codes covering fire and explosion risks have been available for some years. To them is now being added information, such as the National Silicosis Conference's recommendations on dust counts in relation to silicosis prevention[1], New York State's codes on silica dust control in rock drilling[2], and the American Foundrymen's Association's codes on exhaust systems for general foundry work[3]. The American Standards Association has a committee which, it is understood, will suggest, from time to time, safe concentrations of various contaminants. Some states now furnish, on request, a list of maximum safe concentrations which they recommend for various dusts and gases. (The Massachusetts list is given in Table 2).

In some instances, as in Wisconsin and New York, the codes have been made legally binding. Other states have issued the lists merely for the guidance of persons who ask how clean the air of a workplace should be.

It is not our intention to criticize these codes. The concentrations generally are not fixed by accepted medical standards, but represent zones or ranges arrived at by practical trial. Obviously, the figures must be revised from time to time as medical knowledge on the subject progresses, and especially as industry improves its housekeeping.

The purpose of this bulletin is to give in brief form descriptions of apparatus and methods which are actually being used by one or more laboratories in appraising the environment in which men work. In making such appraisals, two distinct steps are involved: first, measurement of air currents, and second, estimation of impurities. The resulting data can then be applied to the design of control equipment or to the appraisal of the results brought about by such equipment.

Air Movement

Low Air Velocities

Air velocities in workplaces generally are below 100 F. P. M. (feet per minute). Exceptions are warm places where fans or air blasts are used for their cooling effect, mine shafts and haulage ways used as ventilation ducts,

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† Detailed information on insurance-company activities can be had from American Mutual Alliance, 919 North Michigan Avenue, Chicago, and the Association of Casualty & Surety Executives, 80 John Street, New York City.

and atmospheres within the immediate zone of exhaust hoods. Low velocities must be measured by special instruments as they are below the range measurable by pitot tube, venturi meter, or vane anemometer.

Smoke Bombs:

In schoolrooms or auditoriums, air conditioning engineers usually study air distribution by the use of smoke. Smoke from tobacco is of too fine a texture to serve as well as the coarser smoke made from hygroscopic substances.

Titanium tetrachloride smoke tubes for testing work are safer to use and give satisfactory results. They can be made as follows: glass serum ampoules, costing about $2.40 a gross, are filled with 0.10 cc. of titanium tetrachloride. The ampoule is then sealed and the neck pulled out about 0.25 inch, dipped in water-glass as an adhesive, and about an inch of wicking pushed over the neck. The wicking used in a sulfur lamp is satisfactory. Since the compound reacts with air and becomes vitiated, the ampoules should be sealed promptly.

When a smoke test is desired, the neck of the ampoule is broken by laying it on a hard surface and pressing down with the thumb; the wicking will protect the thumb against cutting with the glass. The $TiCl_4$ runs out into the wick and smoke immediately results.

A smoke gun can be made by soaking pumice with titanium chloride and packing in small glass tubes, such as calcium chloride drying tubes. Air is then blown through the pumice by means of a rubber aspirator bulb. When not in use, the ends of the tube should be closed with stoppers.

Titanium tetrachloride is carried by most supply houses and costs about 75 cents per quarter pound, which is enough to fill a large number of ampoules. Smoke tubes and smoke guns in convenient form are supplied by (g), (j).*

Thermo-anemometer:

C. P. Yaglou has recently developed[4] a simple thermo-anemometer capable of measuring velocities between 10 and 6,000 F. P. M. The temperature of the wire is only 10° to 40° above air temperature and is indicated on an ordinary thermometer around the bulb of which the wire is wound. Small dry cells furnish the heating current and the voltage is regulated by means of a rheostat. These auxiliaries are assembled in a small box. Readings to be taken are temperature of heated and of unheated thermometer and voltage used. The velocity is read off a table or chart, or computed from an equation. By varying the voltage, any velocity can be measured with an accuracy of 98%.

A unit which is vest-pocket size and sensitive to very low velocities will be available shortly.

This instrument compensates for variations of air density due to temperature changes, and is negligibly affected by humidity, radiant heat, and convectional currents which it causes. It is particularly useful for measureing air movement in rooms and in exploring "point" velocities in front of exhaust hoods, because it offers negligible obstruction to airflow.

Its disadvantages are that it is not direct reading, it requires a short time for the heated thermometer to reach equilibrium, and its readings must be corrected for partial stem immersion when used inside small pipes. The instrument is too new to have had any widespread field use. It is supplied by (m).

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* (a), (b), etc., refer to firms supplying equipment. For full list and addresses, see Table 4, Page 15, of this bulletin.

High Air Velocities

In the effective zone of exhaust hoods, the minimum velocity is about 150-200 feet per minute extending on up to 1,000 F. P. M. or more at the face of the hood. It is often desirable to increase the hood's effectiveness by changes in design. Velocity contours can be sketched out as indicated in Figure 1 of Bulletin No. 2 of this series. For measurements in such velocity ranges, Yaglou's thermo-anemometer device is well suited.

Vane Anemometer:

In the case of large hoods, such as those placed over electroplating or vats, either a velometer or a small vane anemometer is convenient. For exploring small hoods, however, both instruments take up too much space and interfere seriously with the normal air currents which the hood is intended to form. Furthermore, the portable vane anemometer is a delicate instrument; it needs frequent calibration, and is easily damaged by corrosive chemicals, by dusts, and even by steam or water vapor. It is advisable to use the vane anemometer only when no corrosive substances are being generated.

Velometer:

This is a direct-reading device consisting of a double-pivoted vane which is deflected by impact against the air stream. A pointer attached to the vane indicates the velocity on a calibrated scale. All moving parts are housed in a small case. For low-range readings, the air enters the meter directly through a small port and the whole case must be placed into the air stream. For high-velocity readings, various size orifices are placed within the port to reduce vane deflections. For measurements of velocity inside pipes, a double-pitot tube is provided and connected to the meter ports by rubber tubing.

Velometer readings are instantaneous, but several must be taken to insure a good average. One can measure velocities of several thousand feet per minute, as in exhaust ducts, or a few hundred feet per minute in the vicinity of large exhaust hoods. Although a dust-filter attachment is now available for keeping the mechanism clean, it is questionable whether it is wise to use the instrument in any but clean air. The device is supplied by (h).

A less accurate, but very practical instrument, known as the "Grillometer," has been developed for measuring air velocities through grills. It is a torsion device and is direct reading. It is supplied by (d).

Pitot Tube, Venturi Meter and Orifice Meter:

While these three instruments measure flow rather than velocity, they are too well known to need any description. The pitot tube has long been the sole "self-standard" instrument and the most used for determining flow in pipes or ducts, for making traverses, and the like. Recording venturi meters and orifice meters for measuring the flow of fluids (liquids and gases) are sold today by several firms. In the construction of exhaust systems, it is well to consider the permanent installation of a venturi, or an orifice meter, or even a recording meter near the exhaust fan. The A. S. M. E. book[7] gives full details of the basic principles, design, and use of these instruments.

Atmospheric Impurities

For the purposes of selecting sampling and control methods, in relation to exhaust systems in plants or mines, several distinct types of atmospheric impurities must be considered:

A. Relatively insoluble mineral dusts, such as silica, many silicates, and fly ash.

B. Relatively soluble mineral dusts, like calcite (limestone).

C. Finely-divided fume substances that are difficult to catch in water. Examples are lead, lead oxide, and zinc oxide.

D. Dusts that may be affected by water. Examples are flour, leather, and soap. Many of these dusts are explosive if mixed with air.

E. Aqueous mists, such as chromic acid entrained from electroplating baths, or condensate from vats of various sorts.

F. Water-soluble gases, such as hydrochloric acid. Such soluble gases usually contain mist as well as gas, the proportions depending upon local conditions.

G. Gases or organic vapors, like benzene, soluble with difficulty. These react slowly with most liquids but may be adsorbed readily by solids, such as activated carbon.

Instruments for Dust Sampling

Impinger:

The impinger is commonly used in sampling dusts, like classes A, B, and occasionally mists, like class E, and some gases, like class F. It is definitely unsuited to class G gases, like chlorine or organic vapors. It is not efficient against finely-divided fume substances, Class C, such as lead or zinc oxide, and rarely is it suited to sampling organic dusts, like class D.

The impinger[5] consists in a flask in which a tube with tapered end is held at a fixed distance from an attached glass plate or from the bottom of the flask. Air is drawn through the tube and the impurities are trapped in the liquid in which the tip of the tube is immersed. Suitable fractions of the dusty suspension are then withdrawn and the dust particles counted under the microscope or the total dust concentration is estimated by the usual analytical procedures.

The impinger is now made in two sizes, one sampling at one cubic foot per minute, and the other at three to five liters per minute. Used originally with water as the dust-catching medium, it is now common practice to use other liquids, such as isopropyl alcohol, limitation depending upon volatility of the liquid and its readiness to foam.

The suction device for the impinger can be run by a compressed-air actuated ejector or by a pump driven by an electric motor. The midget-impinger equipment is much smaller and can be run by hand. It is lighter than the large unit. Furthermore, it is hand operable, all of which makes it particularly suited to mine-air sampling. Both types of impinger were developed by the U. S. Bureau of Mines, which recommends both for general use in measuring dustiness. Impingers, either large or midget size, are supplied by (e), (i), (j), (k), (m).

For sampling finely-divided fume substances, like lead, which are well dispersed, a small electric precipitator gives accurate results. While the complete precipitator assembly is not expensive, it requires a transformer

weighing some 15-25 pounds to raise the voltage to 15,000 to 25,000. Construction details with a list of equipment needed for making such precipitators are given in Drinker & Hatch[6]. This equipment is available from (m).

Barnes & Penney, of the Westinghouse Electric & Manufacturing Company, have described[8] a small precipitator which should be well adapted to field use and is now available from (j). The high-tension side of this new-type precipitator is grounded, making it more practicable for general field use.

Sampling Dust for Direct Microscopy and Counting

The purpose of taking and counting dust samples is to determine how much the dustiness of the air in question departs from some arbitrary figure or accepted standard. The grab-sample instruments, viz., the konimeter (j), the Bausch & Lomb dust counter (a), (m), and the Owens jet dust counter (e), give useful indications of changes in dustiness. All three instruments are light and are operated entirely by hand. However, they do not imitate the impinger in any way, so that it is impossible to convert impinger to grab-sample counts. The reason why such conversions are faulty is because the grab samplers favor dust sizes below the size-particle range for which the impinger technic is best adapted.

A skilled technician can count about twelve impinger samples in a day. It is easy, however, to compare some thirty to forty grab samples in a short time. In practical field work with the grab sampler, the effectiveness of dust-control equipment or methods can thus be demonstrated rapidly.

Explosive Dusts

Most explosive dusts are affected by water, while some of them, especially organic dusts, such as flour, are difficult to wet. Explosive concentrations of all such dusts are very high (10-15 gms./m^3) as compared with dust concentrations of hygienic significance (0.5 gms./m^3), so that explosive dusts are determined by weight rather than by count. Air is drawn through a weighed paper extraction thimble and the increase in weight caused by the dust from a known volume of air is noted. An objection to this procedure is the trouble and time required to equilibrate the paper thimble against the moisture in the air. This objection, however, is not serious if the weight of the dust sample, as in the case of explosive dusts, approximates that of the thimble.

It should be remembered that in sampling explosive dusts one must use a suction device that avoids the chance of electric sparks.

Quantitative Analysis

In the case of all dusts, classes A, B, C, and D, the estimation of the sample taken from the air can be made by counting representative fractions under the microscope, or the sample can be analyzed by appropriate chemical methods, or the material can be weighed. The large impinger and the electric precipitator are equally well adapted to either procedure. The midget impinger collects, in reasonable sampling time, a relatively small amount of dust, but enough for counting.

Dusts, like silica, that are troublesome to determine chemically, are generally counted, while those like lead, manganese, and cadmium, are determined chemically.

In places where composition of the dust and the particle size remain

substantially the same day after day, it is possible to estimate roughly dustiness in impinger samples from the turbidity of the dusty emulsions. Such estimates can be made in Nessler tubes, by tyndallmeter[4], or by an adaptation of the turbidity methods commonly used in water analysis.

Light-Field vs. Dark-Field Counting

For routine control work, the relative advantages of these two methods of counting dust samples (no matter what sampling instrument is used) are unimportant. It is immaterial which method is used. If the person doing the counting feels that the light-field set-up is hard on his eyes, or the magnification too low, by all means he should try the dark-field method. On the other hand, if he is using the impinger and wishes to copy in exact detail the procedure recommended by the U. S. Public Health Service, then light-field counts must be made. The Bureau of Mines recommends a micro-projection method for impinger counts[5]. The konimeter, recommended by the Bureau of Mines for control sampling, is used in South Africa, where it originated, with dark-field, while the Bausch & Lomb counter is available with dark-field only. Owens samples can be counted by either light- or dark-field.

Gas Sampling

Gas concentrations commonly met in sanitary air analysis are very low. Concentrations that men may breathe usually are given in parts per million by volume (P. P. M.), or in milligrams per liter, or per cubic meter under specified temperatures and pressures.

Some gases and vapors, notably carbon monoxide, hydrogen sulfide, and mercury, in minute amounts, give strong chemical reactions which makes possible rapid estimations and still better, continuous records of pollution. However, the great bulk of gases and vapors from organic solvents, such as benzene, carbon tetrachloride, and carbon disulfide, cannot be caught efficiently unless sampled at slow rates, such as ½ to 1 liter per minute. Some of them, such as benzene, can be absorbed directly in special solvents or adsorbants, like charcoal or silica gel, or can be converted into another compound which can then be estimated by an appropriate method.

The greatest difficulty in estimating organic vapors in air occurs when mixtures of vapors are present. Unfortunately, this is all too often the case. Then, the devising of short cuts in itself offers a major problem, but local conditions sometimes permit the approximations of the proportions of the several ingredients in the collected sample and calculation of the total by estimating only the most easily-determined single constituent.

Condensation

The general availability of "dry ice" (temperature = —79° C.) makes convenient the routine collection and estimation of volatile compounds, like gasoline, for which liquid air (temperature = —192° C.) formerly was used. A convenient cooling mixture is made by pouring ethyl alcohol or gasoline on cracked dry ice. The condensation apparatus is then immersed in the cooling mixture.

Liquid air is available in most large cities and offers a convenient cooling medium, but it should be remembered that it forms explosive mixtures with inflammable dusts or gases.

Vapor-Pressure Measurements

If only one substance is present—and that in a high degree of purity—measurements of concentration can be made conveniently and quickly by condensing the vapor with the dry-ice mixture and then estimating the concentration by the Burrell-Jones vapor-tension method[3]. This procedure is not in common use in industrial hygiene problems and needs further study.

Routine Sampling and Recording of Air Impurities

If control equipment has been installed, samples should be taken periodically for check-ups. This is the best way to tell whether the equipment is functioning as it should. If concentrations obviously are high, it is usually a waste of time to take the sample and to estimate it. For instance, a leaky elevator in a crushing plant or a defective rattler or an unhooded swing grinder in a foundry may cause such high dust concentrations that an impinger sample will be turbid in a few minutes. Little is gained by going through the sampling routine in such cases, unless one wishes to have records before and after repairs have been made.

Today, many plants operate crushing units and other dust producers at night to take advantage of reduced power rates and to stagger employment over twenty-four hours. During the night shift, dust inspections can be made rapidly, using nothing but the beam from an ordinary flash light to detect dust leaks.

In the case of some gases and vapors, one's sense of smell often permits detection of gas concentrations which exceed desirable limits. Such a test is quite unreliable unless one returns frequently to clean air or carries with him a respirator with an activated charcoal cartridge through which he takes several breaths before attempting to gauge the strength of the odor. One becomes used to even such dangerous or disagreeable odors as hydrogen sulfide in a few monments and it is, therefore, risky to estimate their strength by smell.

Such crude tests do not take the place of regular sampling technic. How often the routine samples should be taken depends entirely upon local conditions. In some places, they are taken daily, while in others, several times a year is enough. It is well to play safe and to take them too often rather than too seldom. The men quickly become used to such sampling and pay no attention to the procedure. Obviously, the sooner the sampler has the man's interest in his results, the better will be the outcome. It is common for the workmen to ask what the results are and to see to it that the samples in their particular departments are satisfactory.

We know of one mining company whose concentrating plant is equipped for the taking of monthly dust samples. Various sampling stations have compressed air piped to convenient points and each station has an arrangement for holding the impinger bottles. In this plant, it is usual for one operator to take, at the same time, samples on four floors of a single building.

Samples should be taken wherever men work. It is a mistake to ignore places where one believes that there is no dust or gas. The samples are about the only proof that the employer can bring forth that he has taken proper precautions to prevent a disease, such as silicosis or a chronic poisoning from benzol. The mere statement that he or anyone else thought the atmosphere sufficiently clean is not enough.

It is advisable to plot the results of periodic samples with the days or

months as abscissae and the concentrations or dust counts as ordinates. Such plots can be made conveniently on a master sheet, comments noted on the plot which is blue printed with each new batch of samples, and the prints given to the appropriate departments.

Continuous Records

It is obvious that continuous records of either dust or gaseous impurities are more informative than occasional or intermittent records. It is possible to take continuous records of relatively heavy pollution, as in the stacks of power plants, and also of ordinary atmospheric pollution which is of relatively low concentration. It is understood that Mine Safety Appliances Company, Pittsburgh, will offer shortly a dust recorder that may prove useful in common sanitary air analyses.

As noted previously, gases that give strong chemical reactions, particularly those involving pronounced heat or color changes, are suited to estimation by continuous recorders. A carbon monoxide recorder (j), which measures the heat liberated by a catalytic combustion reaction, is in wide use today. A recorder for mercury vapor (f) has also found considerable application. The applicability of recorders in sanitary air analyses has hardly been touched upon and it is reasonably certain that others will be developed as need arises.

Photographs

It is common practice in power-plant operation automatically to take photographs at regular intervals of the smoke escaping from the stack. Such records provide useful evidence if the plant is accused of faulty operation.

Occasional photographs of various plant and mine operations are often of greater practical usefulness than are records of dust counts or of gas or vapor concentrations. As an exhibit on the company's bulletin boards, photographs are effective warnings to the men to clean up. In routine sampling, they should certainly be taken occasionally and incorporated as part of the inspector's report.

TABLES

Date: June, 1938

TABLE I.

SUMMARY OF INDUSTRIAL HYGIENE ACTIVITIES IN STATES AND CITIES IN THE UNITED STATES

State	Number of Gainful Workers	Number of Workers in Manufacturing Mechanical and Mineral Industries	Agency Responsible for Activity	Department Responsible for Activity	Number and Kind of Personnel				Annual Budget
					Medical	Engineering	Other Technical	Clerical	
Alabama	1,026,320	220,378	State Health Dept.	Division Industrial Hygiene	1	0	0	0	5,600
Arizona	165,304	45,811							
Arkansas	667,870	83,560	State Health Dept.		0	1	0	1	4,200
California	2,500,969	673,646	State Health Dept.	Industrial Hygiene Service	1	1	1	1	22,020
Colorado	402,894	88,830	State Health Dept.		0	0	0	0	4,200
Connecticut	677,292	337,445	State Health Dept.	Bureau Occupational Diseases	1	1	3	2	25,557
Delaware	98,104	35,348							
Florida	599,010	131,480							
Georgia	1,162,174	230,989							
Idaho	162,223	27,934	State Health Dept.		0	0	0	0	5,000
Illinois	3,184,875	1,164,979	State Health Dept.	Division Industrial Hygiene	2	2	3	2	35,400
Indiana	1,251,177	464,549	State Health Dept.	Bureau Industrial Hygiene	1	1	0	1	11,500
Iowa	912,832	167,147	State Health Dept.	Division of Engineering	0	2	0	1	8,350
Kansas	694,276	132,662	State Health Dept.	Section of Sanitation Div.	0	1	1	1	10,820
Kentucky	907,166	220,233							
Louisiana	815,725	156,030							
Maine	308,617	104,201	State Health Dept.		0	0	0	0	
Maryland	672,906	228,599	Baltimore Health Dept.	Bur. Environmental Hygiene Bur. Occupational Diseases	1	2	3	2	12,900
Massachusetts	1,814,422	840,300	State Labor Dept.	Division Occupational Hyg.	0	1	2	2	19,200
Michigan	1,927,498	860,164	State and Detroit Health Depts.	Bureau Industrial Hygiene	1	6	5	4	35,500
Minnesota	992,847	210,299	State Health Dept.		0	0	0	0	1,345
Mississippi	844,887	79,318	State Health Dept.	Div. Industrial Hygiene and Factory Inspection	1	0	1	1	9,100
Missouri	1,458,054	390,399	State and St. Louis Health Depts.	Division of Engineering	0	3	0	1	13,005

Date: June, 1938

TABLE I. — Continued

SUMMARY OF INDUSTRIAL HYGIENE ACTIVITIES IN STATES AND CITIES IN THE UNITED STATES

State	Number of Gainful Workers	Number of Workers in Manufacturing Mechanical and Mineral Industries	Agency Responsible for Activity	Department Responsible for Activity	Number and Kind of Personnel				Annual Budget
					Medical	Engineering	Other Technical	Clerical	
Montana	216,471	44,637							
Nebraska	507,022	71,517							
Nevada	42,885	11,776							
New Hampshire	192,671	89,461	State Health Dept.	Div. Chemistry and Sanitation	0	1	0	1	8,480
New Jersey	1,712,125	741,299							
New Mexico	142,866	23,931							
New York	5,523,085	1,995,924	State Labor Dept.	Division Industrial Hygiene	7	7	12	7	118,614
North Carolina	1,141,129	289,917	State Health Dept.	Division Industrial Hygiene	2	2	1	1	27,500
North Dakota	210,317	18,095							
Ohio	2,615,938	1,091,650	State Health Dept.	Bur. Occupational Diseases	3	1	2	2	25,300
Oklahoma	828,029	172,163							
Oregon	409,680	102,125							
Pennsylvania	3,722,428	1,796,944	State Health Dept.	Division Industrial Hygiene	2	9	0	1	56,490
Rhode Island	297,168	164,304	State Health Dept.	Division of Industrial Hyg.	2	3	1	1	23,000
South Carolina	687,721	146,344	State Health Dept.	Division Industrial Hygiene	1	1	0	1	10,300
South Dakota	247,678	24,207							
Tennessee	958,209	213,077	State Health Dept.	Div. Preventable Diseases	1	1	0	0	11,000
Texas	2,237,118	395,802	State Health Dept.	Division Industrial Hygiene	1	3	1	1	24,290
Utah	170,013	44,977	State Health Dept.						
Vermont	141,190	42,851	State Health Dept.	Tuberculosis Division	1	1	0	1	11,500
Virginia	880,276	221,539	State Health Dept.	Bureau Industrial Hygiene	1	1	1	1	19,000
Washington	664,813	181,765	State Health Dept.	Public Health Eng. Division	0	1	0	1	6,200
West Virginia	570,459	242,115	State Health Dept.	Bureau Industrial Hygiene	1	1	0	1	17,500
Wisconsin	1,129,546	380,229	State Health Dept.	Industrial Hygiene Unit	1	2	0	1	11,000
Wyoming	92,451	19,046							
Totals	48,588,730	15,432,996			32	55	37	39	612,276

TABLE II.

CONCENTRATIONS OF INFLAMMABLE VAPORS, SUGGESTED BY THE U. S. BUREAU OF MINES, AND LIMITS FOR PRACTICAL CONTROL, SUGGESTED BY THE MASSACHUSETTS DIVISION OF OCCUPATIONAL DISEASES

GAS OR VAPOR	Lower Limit, by Volume %	GAS OR VAPOR	Maximum Concentration Suggested by Massachusetts P. P. M.
Ammonia	16	Ammonia	100
Acetaldehyde	4		
Acetone	3	Amyl acetate	400
Acetone (turbulent mixture)	2.5		
Acetylene	3.0	Aniline	5
Acetylene (turbulent mixture)	2.3	Arsine	1
Benzene	1.4		
Benzine	1.1	Benzol	75
Blast furnace gas	35		
Butane	1.9	Cadmium	0.1*
Butyl acetate (30° C.)	1.7	Butyl acetate	400
Carbon disulfide	1.0	Carbon bisulfide	15
Carbon monoxide	12.5	Carbon monoxide	100
Cyclohexane	1.3	Carbon tetrachloride	100
Dichlorethylene	10	Chlorine	1
Ethane	3.2	Chlorodiphenyls	1*
Ethyl acetate	2.5	Chloronaphthalenes	1 to 5*
Ethyl alcohol	4	Chromic acid	0.1*
Ethyl bromide	7	Dichlorbenzene	75
Ethyl chloride	4	Dichlorethyl ether	15
Ethyl ether	1.7	Ether	400
Ethyl formate	3.5		
Ethyl nitrite	3		
Ethylene	3.0		
Ethylene dichloride	6	Ethylene dichloride	100
Ethylene oxide	3.0		
Furfural (125° C.)	2	Formaldehyde	20
Gasoline	1.4	Gasoline	1000
Hydrogen	4.1	Hydrochloric acid	10
		Hydrogen cyanide	20
		Hydrogen fluoride	3
Illuminating Gas	5.3	Hydrogen sulfide	20
		Lead	0.15*
Methane	5.3		
Methane (turbulent mixture)	5.0	Mercury	0.1*
Methyl acetate	4.1		
Methyl alcohol	7	Methanol	200
Methyl bromide	13.5		
Methyl chloride	8	Monochlorbenzene	75
Methyl cyclohexane	1.2		
Methyl ethyl ketone	2	Nitrobenzene	5
Methyl formate	6	Nitrogen oxides	10
Natural gas	4.8	Ozone	1
Pentane	1.45	Phosgene	1
Propane	2.4	Phosphine	2
Propyl acetate	2.0	Sulfur dioxide	10
Pyridine (70° C.)	1.8	Tetrachlorethane	10
Toluene	1.4	Tetrachlorethylene	200
Vinyl chloride	4	Toluol	200
Water gas	6 to 9	Trichlorethylene	200
		Turpentine	200
		Xylol, coal tar naphtha	200
		Zinc oxide fume	15*

* Milligrams/cu. meter

TABLE III.

ANALYTICAL PROCEDURES IN CURRENT USE IN INDUSTRIAL HYGIENE

The substances listed in the following table are more or less commonly found in industrial atmospheres. Methods of determination which are suggested have all been used by laboratories in this country and found to be satisfactory. Not all of the methods listed, however, are specific.

It is assumed that the user of this table is familiar with common analytical procedures and with the general methods of sampling or collecting atmospheric impurities. For example, lead as a dust, such as lead arsenate, would be caught by impinger; lead fume from lead burning by electric precipitator; while lead tetraethyl would be collected by means of a bubbler. Different rates of flow would be used in each case.

MATERIAL	Method of Collection	Method of Determination
Acetone	Draw air through bubbler containing H_2O.	Modified iodometric [10].
Ammonia	Draw air through H_2SO_4 solution in gas wash bottle.	Determine NH_3 by A. P. H. A. Standard Method [11].
	Low Conc. Draw air through bubbler containing acidified (H_2SO_4) dist. water and methyl red indicator. Continue to end point.	Calculate NH_3 concentration as in ordinary acidimetry.
	Conc. Greater Than 1% Draw air through bubbler containing 50 cc. of a saturated solution of boric acid.	Titrate with 0.025 N. H_2SO_4 using methyl red indicator.
Aniline	Draw air through bubblers containing 10% H_2SO_4.	Depends upon reaction of aniline with Br_2 using sodium indigo disulfonate as an indicator [12].
Arsenic (dust)	Draw air through impinger containing water.	Iodometric.
Arsine (gas)	Draw air through bubbler containing alcoholic KOH.	Modified Gutzeit [10].
Benzene	Draw air through nitrating acid.	Colorimetric or volumetric determination as dinitrobenzene. Ref.: Air Hyg. Bull. No. 2, Part 1 (Jan., 1938).
	Draw air through indicating instrument.	Equipment from (j).
Bromine	Draw air through bubbler containing I_2 solution in KI with starch.	Iodometric.

MATERIAL	Method of Collection	Method of Determination
Carbon dioxide	Draw air through "ascarite" after removing water vapor on "drierite" and weigh.	
	Draw air through bubbler containing a buffered $NaHCO_3$ solution and phenolsulphonophthalein indicator.	Compare resulting color against standards. Ref.: Higgins & Marriott. J. Am. Chem. Soc., vol. 39, p. 38 (1917).
	Gas-collecting bottles.	Volumetric gas anal. method. Ref.: U. S. Bureau of Mines Bulletin No. [illegible] and I. C. 7017 (1938).
Carbon disulfide	Draw air through alcoholic KOH to form potassium ethyl xanthate.	Determine xanthate iodometrically. Ref.: Matuszak, M. P.: Ind. Eng. Chem., Anal. Ed., vol. 4, pp. 98-100 (1932).
Carbon disulfide and hydrogen sulfide in presence of each other	Draw air through 10% $CdCl_2$ solution, then through 2.5% H_2SO_4, and through 5% acoholic KOH.	Iodometric. Determine CS_2 as above. Ref.: Barthelemy, H. L.: Tubize Chatillon Corp., Rome, Ga., or Div. of Ind. Hyg., N. Y. State Dept. of Labor, 80 Centre St., New York.
Carbon monoxide	Low concentrations, 10 to 1,500 PPM, by heat liberated from combustion with Hopcalite as catalyst. Concentration on dial of a milliammeter. High concentrations, 0.05 to 1.0% (500-10,000 PPM) use detector depending upon liberation of I_2 from I_2O_5 or color reaction with $PdCl_2$ ampoules.	Ref.: U. S. Bureau of Mines, Tech. Paper 582. Also: Drinker, C. K.: Carbon Monoxide Asphyxia, Chapt. 8 by Sendroy. Oxford University Press, New York, 1938.
	Details from makers of the above equipment (b) (c) (j).	
Chlorine	Draw air through O-tolidine reagent in special absorption tube.	Transfer sample to Nessler tube and compare with standards after standing. Ref.: Porter: J. Ind. Eng. Chem., vol. 18, p 730 (1926).
	Draw air through 10% KI solution.	Iodometric.
Chlorinated hydrocarbons, general	Physical method such as absorption on activated charcoal or by use of interferometer.	Ref.: Air Hyg. Bulletin No. 2, Part 3 (March, 1938).
	Thermal decomposition method.	Equipment from (i) (m).
Carbon tetrachloride	(As above).	
Chromic acid (mist)	Impinger with approximately normal NaOH, or with electric precipitator.	Iodometric. Ref: Bloomfield and Blum: U. S. Pub. Health Rep., No. 43, p. 2330 (1928). Determine chromate with s-diphenylcarbazide as indicator. Ref.: Yoe, J. H.: Photochemical analysis. 2 vols. Wiley & Sons, New York. 1928-1929.

MATERIAL	Method of Collection	Method of Determination
Esters	Gas-collecting bottles.	Hydrolyze with NaOH, back titrate excess NaOH. Ref.: Patty, Yant and Schrenk: U. S. Pub. Health Rep. No. 51, p. 811 (1936).
Ethyl bromide Ethyl chloride		See MeBr.
Formaldehyde	Draw air through bubbler containing water.	Colorimetric method using Schiff's soln. [12]. Also, Denige method. Chapin, R. M.: J. Ind. Eng. Chem., vol. 13, p. 844 (1921).
Hydrocarbons, general	(1) Zeiss portable interferometer. (2) Absorption on solid materials, such as activated charcoal or silica gel [13].	Full information from (n).
	Gas-collecting bottle.	Volumetric gas analysis method [16]. Also, U. S. Bureau Mines I. C. 7017 (1938).
	Self-contained instruments operate on the heat of combustion principle and give readings of the percentage of the lower explosive limits directly on dials. Special calibrations of the dials can be obtained depending on the application.	Equipment from (b) (c) (j) (l).
Hydrochloric acid	Draw air through glycerol-potassium carbonate-water soln. of the ratio 1:1:1.	Determine chloride ion by Volhard method. Ref.: Heller: Gesund. Ingenieur, vol. 55, p. 261 (1932). Chem. Abst., vol. 27, p. 155 (1933).
Hydrofluoric acid	Draw air through bubbler containing KOH.	Distill fluorides as hydrofluosilicic acid. Titrate fluorides in distillate with thorium nitrate soln. using sodium alizarine sulfonate as indicator. Ref.: Willard and Winter: Ind. Eng. Chem., Anal. Ed., vol. 5, p. 7 (1933). Boruff and Abbott, (Ibid), vol. 5, p. 236 (1933).
Hydrogen cyanide	Draw air through bubblers containing 0.5% KOH.	Titrate with $AgNO_3$.
	Colorimetric indicator.	Range of 50-1,000 PPM. Equipment from (j).
Hydrogen sulfide	See also carbon disulfide. Draw air through activated alumina coated with AgCN or PbAc.	Concentration is indicated by length of color change. Ref.: Littlefield, Yant and Berger: U. S. Bureau Mines, R. I. No. 3276 (June, 1935).
	Instrument using this method sensitive to 25-400 PPM. Instrument for colorimetric method using test paper sensitive to 0.02% supplied by (j).	See also: Reed, J. F.: J. Soc. Chem. Ind., vol. 57, pp. 43-4 (1938).
	Draw air through bubbler containing I_2 soln. in KI with starch.	Iodometric.

MATERIAL	Method of Collection	Method of Determination
Lead, as dust or fume	Impinger or electric precipitator.	See Air Hyg. Bulletin No. 2, Part 6 (1938).
Mercury	Draw air against SeS coated paper	Compare color change against standards. Ref.: Nordlander, B. W.: Ind. Eng. Chem., vol. 19, p. 522 (1927).
	Lampshade detector (using SeS) available from (f) (j).	
	Freeze vapor with dry ice.	Ref.: Fraser: J. Ind. Hyg. & Tox., vol. 16, p. 67 (1934).
Methane	Gas-collecting bottle. Combustible gas indicator from (b) (c) (j) (l).	Vol. gas anal. method [16]. Ref.: Hoover, Fene, Currie. U. S. Bureau Mines Bull. No. 331 (1930).
	Flame Safety Lamps from (b) (c) (j).	See also: U. S. Bureau Mines I. C. No. 33 (1937).
Methanol		Discussion. Ref.: Wright, L. O.: Ind. Eng. Chem., vol. 19, p. 750 (1927).
	Draw air through bubbler containing water.	Oxidize to formaldehyde and determine colorimetrically (Denigè method) [22]. See also: Formaldehyde, Chapin's method.
	Collect sample in partly evacuated bottle.	Determine by modified Denigè method.
	Absorb MeOH in distilled water by thorough agitation of water in the bottle.	Ref.: Schrenk and Yant: U. S. Bureau Mines, Personal communication (1933).
Methyl bromide Methyl chloride Ethyl bromide Ethyl chloride	Collect samples by Hg displacement.	Analyze volumetrically by slow combustion with a white-hot platinum coil and large excess of O_2. Ref.:Sayers, Yant, Thomas, and Berger. U. S. Public Health Bull. No. 185 (1929). For MeBr see also: Busbey and Drake: Ind. Eng. Chem., Anal. Ed., vol. 10, p. 390 (1938).
Nitric acid Nitrogen tetroxide	Draw air through an acidified 5% H_2O_2 bubbler followed by 2 or 3 5% KOH H_2O_2 bubblers.	Determine N_2O_5 with phenolsulfonic acid by A. P. H. A. Standard method [21]. Ref.: Drinker and Snell: J. Ind. Hyg. & Tox., vol. 20, p. 321, (1938).
	Draw air through liquid air trap.	Oxidize as above and determine by nitron acetate method. Ref.: Coltman: J. Ind. Hyg. & Tox., vol. 20, p. 289 (1938).
Oxygen	Gas-collecting bottle.	Vol. gas anal. method [16]. U. S. Bureau Mines I. C., 7017) (1938).

MATERIAL	Method of Collection	Method of Determination
Ozone	Partially evac. bottles containing starch-KI solution.	Iodometric [8].
	In presence of N_2O_4, collect by liquid air.	Ref.: Coltman and McPherson, J. Ind. Hyg. & Tox., vol. 20, p. 405 (1938).
Phenol	Draw air through bubbler containing NaOH solution.	Determine colorimetrically [11].
Phosgene	Draw air through bubbler containing aniline water saturated with diphenyl-urea.	Filter off precipitate of diphenyl-urea in tared Gooch crucible, dry and weigh, dissolve diphenyl-urea with alcohol dry, and weigh. Ref.: Yant, et al.: Ind. Eng. Chem., Anal. Ed., vol. 8, p. 20 (1936).
Phosphorus trichloride	Draw air through bubbler containing Br water.	Boil and determine P by colorimetric molybdate method [12].
Radioactive substances	Physical methods using electroscope.	Ref.: Schwartz, et al.: J. Ind. Hyg. & Tox., vol. 15, p. 362, 368, 433 (1933).
Sulfur chloride	Draw air slowly through HNO_3 solution of $AgNO_3$.	Dissolve the precipitated AgCl in NH_4OH again precipitating with HNO_3 [15].
Sulfur dioxide	Draw air through I_2-KI starch solution.	Iodometric. Ref.: Griffin and Skinner, Ind. Eng. Chem., vol. 24, p. 862 (1932).
	Partially evacuated bottle containing I-KI starch soln.	Solution from sampling bottle brought to same intensity as a blank by addition of standard iodine solution. Ref.: U. S. Bureau Mines, R. I. No. 3005 (1930).
	Draw air automatically through acid H_2O_2.	Conductivity method with recorder. Ref.: Thomas: Ind. Eng. Chem., Anal. Ed., vol. 4, p. 253 (1932).
Sulfuric acid (mist)	Draw air through NaOH in impinger.	Acidify with HCl and determine sulfate as $BaSO_4$.
Toluol	Draw air through fuming HNO_3.	Similar to U. S. Bureau Mines method for C_6H_6 using KOH instead of NaOH.
Trichlor-ethylene	Draw air through specially designed absorption tube containing absolute EtOH.	Determine colorimetrically on reaction with pyridine and 50% sodium hydroxide. Ref.: Barrett: J. Ind. Hyg. & Tox., vol. 18, p. 341 (1936).
	Combustion method for chlorinated hydrocarbons.	Air Hyg. Bulletin No. 2, Part 3 (March, 1938).

TABLE IV.

FIRMS SUPPLYING EQUIPMENT MENTIONED IN THIS BULLETIN

(a) Bausch & Lomb Company
Rochester, New York.

(b) E. D. Bullard Company
275 Eighth Street, San Francisco, California.

(c) Davis Emergency Equipment Co.
55 Van Dam Street, New York. New York.

(d) Detroit Air Meter Company
Detroit, Michigan.

(e) Fisher Scientific Co.
709-717 Forbes Street, Pittsburgh. Pennsylvania.

(f) General Electric Company
1 River Rd., Schenectady, New York.

(g) E. V. Hill Co.
179 West Washington Street, Chicago, Illinois.

(h) Illinois Testing Laboratories, Inc.
420 N. LaSalle Street, Chicago. Illinois.

(i) Macalaster Bicknell Co.
171 Washington Street, Cambridge, Massachusetts.

(j) Mine Safety Appliances Company
Pittsburgh, Pennsylvania.

(k) Pulmosan Safety Equipment Corp.
176 Johnson Street, Brooklyn, New York.

(l) Union Carbide Company—Linde Air Products, Inc.
30 East 42nd Street, New York, New York.

(m) Willson Products, Inc.
Reading, Pennsylvania.

(n) Zeiss Company
485 Fifth Avenue, New York, New York.

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