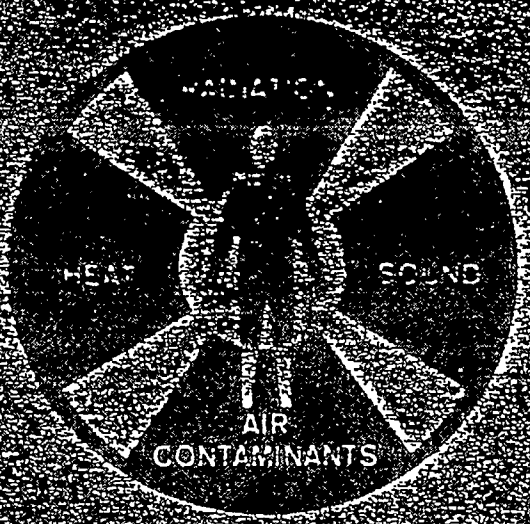
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USX-1184

MONITORING MANUAL



U.S. Environmental Health Services
United States Steel

ENVIRONMENTAL HEALTH MONITORING MANUAL

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FOREWORD

This Manual has been developed by the Environmental Health Division, United States Steel Corporation to train plant personnel to conduct the monitoring of the exposure of workers to potential toxic hazards and harmful physical conditions. Such monitoring is required under the Federal Occupational Safety and Health Act (OSHA). The Manual has been prepared by personnel of the Environmental Health staff with the assistance of Professors Ralph G. Smith and Dohrman H. Byers, School of Public Health, University of Michigan.

It has been developed as the basic text in a United States Steel Corporation training course conducted by the Corporate Environmental Health Division. The course is designed to train plant personnel to properly utilize, maintain and calibrate testing instruments in a proper testing strategy to meet OSHA monitoring requirements and to insure a work environment free of occupational health hazards. The United States Steel monitoring program is under the technical direction of the Headquarters Environmental Health Division, as text references indicate. The training course is not intended to cover the more sophisticated monitoring techniques and procedures, nor chemical analytical procedures. These will be taken by appropriate corporate industrial hygienists.

The Manual will serve as a reference guide for plant personnel responsible for the environmental health monitoring activity. It should be updated from time to time in line with standard industrial hygiene practices and revisions of OSHA regulations.

All material contained in this Manual is for general information only. This material should not, therefore, be used or relied upon for any specific application without independent competent professional examination and verification of its accuracy, suitability and applicability. Anyone making use of the material does so at his own risk and assumes any and all liability resulting from such use. United States Steel Corporation disclaims any and all express or implied warranties of fitness for any general or particular purpose.

Chapter I
Introduction

Chapter I

INTRODUCTION

At no time in modern history has the general public been more conscious of health and environmental issues. The press, other mass communication media, and scientific and quasi-scientific journals have subjected the public to a profusion of environmental reporting, the contents of which have had varying degrees of validity and high degrees of advocacy. The same *advocate* philosophy was developing in university laboratories at about the same period. This stemmed largely from the availability of large health research grants from the U. S. Department of Health, Education and Welfare, for those whose careers depend upon the appropriation and expenditure of public funds are constantly tempted to exploit fears. The "implication" of possible adverse health effects can serve to remove an issue from debate based upon tangible issues, for who can say that he is in favor of harming the health of his fellow man. Therefore, it is somewhat understandable that we have witnessed, in just a very few years, the enactment of more federal legislation in occupational and environmental health than has been legislated in the history of this country, or any other nation. However, this has been achieved during a period of general national unrest induced by many social, economic and political factors. Whether or not legislation enacted in such an environment is to the common good must await evaluation by future generations. Nevertheless, one factor is apparent and this is the paradox in the public attitude on health. The public *overreacts* to factors over which it does not have direct knowledge and individual control, i.e., air pollution, radiation, noise pollution and water pollution, and conversely, *minimizes* its concern for those factors directly within its control, i.e., smoking, over-eating, drinking, self-medication, auto accidents and drugs.

The state of one's health is determined by *hereditary* factors and the quality of the total *environment*. The latter involves the home, community, work place and recreational pursuits, for the conditions in each can present health problems. While the work environment has a significant impact upon employee health, protection of health must be directed to total health and the total environment. In 1966, the World Health Organization Expert Committee on Human Genetics and Public Health stated as follows:

> "Man's body and his mind, and his physical and mental well-being are all products of the interactions between his heredity and the environments he encounters in the course of his life."

The employee spends only one-third of his day in the work place and the remaining time in a home, community and recreational environments. The conditions of these latter environments have a significant impact upon his health. Therefore, to concern one's self with only one environment and ignore the others, as well as one's living habits, largely defeats the full benefit of optimizing any one environment.

As an overview of the situation relative to our total environment, heed should be paid to Dr. Phillip Handler, President, National Academy of Sciences, whose comments were presented at the 79th General Meeting of the American Iron and Steel Institute. Dr. Handler stated as follows:

> "Man and nature have ever been altering the total environment. Yet, even now, our tragically blighted cities are cleaner and healthier than were urban agglomerates anywhere in the world until the middle of the last century. We have not suddenly begun to alter the environment. Our entirely justifiable concern arises from the logarithmic concentration of our ever-increasing numbers, our marvelously productive heavy industry and agriculture and rapid growth of real per capita income, coupled with sensitive chemical analytical procedures which permit detection of contaminants in minute amounts, some of which — like mercury in the swordfish — may well have been there all these years."

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Occupational Environment and Health

The foregoing statements are not intended to diminish the importance of the work environment to health. The great achievements of our modern technology must now be paralleled by equal progress in our knowledge of the effects of *waste products* of this technology upon health, and the application of this knowledge to the development of effective control programs. These *residues* are the chemical agents and physical factors which can characterize the work environment and consist of dust, fumes, vapors, gases, mists, noise, heat and both ionizing and non-ionizing radiation.

It is well known that health and comfort are directly related to the quality of the environment. Most people have experience ill health and lowered human efficiency from communicable diseases arising from viruses and bacteria which may exist in air, food or water. However, it is not as widely understood that ill health can equally arise from excessive exposure to chemical agents and physical factors which may be found in any environment, including that of the work place. These chemical agents comprise *dusts*, *fumes*, *vapors*, *gases* and *mists* while the physical factors consist of *noise*, *vibration*, *heat* and all types of electro-magnetic *radiations*. Excessive exposure involves a time-concentration relationship which, when occurring, can result in work-related effects upon health. Considerable progress has been achieved in the control of these chemical agents and physical factors and through the development of industrial health programs to protect the health of workers. However, considerably more remains to be done and continuous surveillance of hazard potentials needs to be expanded. The rapid advancement in the use of energy and the introduction of many new chemicals, equipment and processes — while knowledge was being developed for one process or chemical or the alteration of an existing process — have sometimes created a situation resulting in a new condition with a new hazard potential. Few people, with the exception of the professionals in industrial hygiene and occupational medicine, have an appreciation of the present situation, the achievements of existing programs of our future needs. However, priorities must be assigned in categorizing the need for controlling work factors, for all situations are not or equal importance and limitations of time, effort and money exist even under the most favorable economic circumstances.

Many companies are, today, concerned as to how to protect the health of their employees and to meet their legal responsibilities under the Federal Occupational Health and Safety Law. This requires the institution and development of an effective occupational health program. United States Steel, and many other companies, have long had such programs. However, the new federal health regulations will require an expansion in the *scope* of such programs, particularly in the area of medical examinations and environmental health tests, to protect the health of the worker. The *goal* of an occupational health program is the maintenance and promotion of employee health and well-being by protecting employees from undesirable health effects which may result from inadequately controlled equipment, processes, materials, products, and wastes. To achieve this goal the full support of all executive and line management is necessary.

The Occupational Health Team

The conduct of the health program requires the services of two main professional disciplines, namely the *physician* and the *industrial hygienist*, each in turn supported by ancillary health professionals, including industrial nurses, industrial toxicologists, and health physicists. The industrial hygienist, or environmental health engineer, requires supporting personnel at the plant level to undertake tests necessary for the extensive in-plant environmental surveillance tests which are required by federal regulations. The first concern of this health team must be the employee's health.

The American Industrial Hygiene Association defines industrial hygiene as that *science and art devoted to the recognition, measurement, evaluation and control of those environmental stress factors which can induce injurious effects in man.* The industrial hygienist is one who, while basically trained in engineering, physics, chemistry or biology, has acquired by post-graduate study and experience a knowledge of the other allied disciplines, the effect of chemical agents and physical conditions upon health under various

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levels of exposure, the monitoring and analytical methods to detect the extent of exposure, and the engineering and other methods for hazard control. Industrial hygiene is frequently referred to as *health engineering* as its aim is to engineer hazards out of, and health into, the industrial environment.

The industrial physician is one who has obtained by graduate training and/or extensive industrial experience a wide knowledge of cause-effect relationships of the chemical and physical agents, the signs and symptoms of chronic and acute exposures, and the treatment of adverse effects. Armed with the information provided by the industrial hygienist on the hazard inventory of the industrial environment, the industrial physician can (1) determine employee response to his work environment; (2) correlate employee complaints with potential hazard areas; (3) undertake special biochemical tests to determine if normal bodily functions have been impaired; (4) provide the employee medical guidance on general health problems in relation to the physical requirements of his job; and (5) through physical examinations, select workers for job assignments where existing conditions will not be aggravated nor will the worker's presence endanger the health and safety of others.

The Significance of Monitoring

The determination of quality requires *testing* whether it be environmental or product quality. Accordingly, standards are established within which *quality* determinations must comply. In environmental or occupational health, regulatory agencies establish such standards. Such health standards have been promulgated by Occupational Safety and Health Administration (OSHA) of the U. S. Department of Labor (DOL) under the authority granted under the Federal Occupational Safety and Health Act of 1970. Pertinent provisions of the Act and the regulations of OSHA are discussed in Chapter II. Failure of employers to comply with the health standards can result in severe monetary penalties as well as possible jail sentences. Therefore, data derived from competent environmental health (industrial hygiene) tests is the determinant of compliance with health standards involving chemical agents and physical conditions. Environmental health tests are also of major significance in determining the effectiveness of engineering measures for *controlling* hazard factors. For example, measurement of dust concentrations before and after installation of an exhaust ventilation system is the most acceptable method of determining whether or not the system has controlled the dust. Finally, the most important value of the data derived from monitoring the work environment is the *correlation* of such information with medical and biological test data obtained through examination of the worker. Such correlation is the final test of the safety of the quality of the work environment. While OSHA compliance activities at present appear to be solely a matter of comparing the "numbers" derived from environmental tests with the "numbers" stated in health standards, the name of the game is *prevention of occupational illness*. Occupational disease or stress can only be determined by biological response of bodily systems to environmental factors. As more and more studies are made of the work environment — worker response relationships — the numbers in present health standards must be reconsidered. Therefore, the *monitor* of the quality of the work environment must undertake his work with the instrumentation and techniques which will provide the most valid data on the environmental quality and the exposures thereto of the workers.

Monitoring the work environment provides the basic information on the extent and magnitude of the hazard potential and the exposures of workers. It is the exposure data which indicates the dose of chemical agents and physical factors that a worker receives in the course of the workday. The OSHA health standards are primarily based upon this value by their reference to *time weighted average exposure*. In some standards peak value numbers are also stated in which case the monitoring procedures require short-term as well as long-term tests which are discussed in this manual. In either type of environmental test, good testing techniques must be employed for a valid description of the environment and the employee's exposure. It is the purpose of this manual to provide USS monitoring personnel with guidance for utilizing the proper testing instrumentation and techniques to provide environmental data of high quality.

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Chapter II

THE FEDERAL OCCUPATIONAL SAFETY AND HEALTH ACT

One of the most far reaching federal laws was signed by the President on December 29, 1970 and became effective April 28, 1971. This law cited is the Occupational Safety and Health Act of 1970. Its impact upon industry will be profound as it will affect all management functions at every level from executive levels to the line foremen. It has been aptly stated that no federal law since the Wagner Labor Act will have a more profound impact upon industry, particularly steel and other heavy industry. Consequently, every member of the management team should be adequately familiar with the provisions of the Act, and the safety and health standards promulgated thereunder, to meet the employer (management) responsibilities.

The Act places all federal and state occupational safety and health enforcement efforts under federal control with the objective to establish more uniform codes, standards and regulations and to provide more vigorous enforcement.

Some of the key provisions of the Act will:

1. Empower the Secretary of Labor (through the Occupational Safety and Health Administration) to issue safety and health regulations and standards which have the force and effect of law.
2. Establish federal supervision of current state programs to achieve more uniform state inspection under federal standards.
3. Provide procedures for investigating alleged violations, issuing citations and assessing monetary penalties at the request of any employee or his representative.
4. To assure, so far as possible, every employee having safe and healthful working conditions.
5. Require employers to maintain accurate records of employee exposures to potentially toxic materials or harmful physical agents which are required in the various safety and health standards to be monitored or measured.
6. Establish a National Institute of Occupational Safety and Health (NIOSH) with the same "right of entry" as OSHA representatives, to undertake health studies of alleged hazardous conditions and to develop criteria to support revisions of, or recommendations to OSHA for new health standards.
7. Create a federal effort to establish new rules and regulations to govern new or anticipated hazards to health and safety.

The Impact of OSHA

The impact of OSHA on all U. S. Steel operations will demand top management coordination of medical, industrial hygiene, and safety activities with production, purchasing, labor relations, and other management functions. Thus, the management team at each facility must have complete familiarization with its responsibilities and the rights of the employee. Management decisions on equipment selection, process design, material use, and job descriptions will not only have to continue consideration of safety and health but such consideration must be expanded to meet the new and more restrictive standards.

In the employee relations area, employers can anticipate that employee demands will include:

1. Manning decisions, e.g. size of crews, employee required to work alone, relief periods, etc.
2. "Hazard Pay" for alleged "hazardous" occupations and for time away from job because of "hazards".
3. Excessive allegations of "hazards" associated with any job based solely upon visual observations or sensory response despite factual test data to the contrary.
4. Claims that supervisors are violating the "law" and/or the standards.
5. Complete information on the exposures to air contaminants, noise, radiation including industrial hygiene test data on the "levels" of such exposures.
6. Physical examinations for employees exposed to suspected hazards conducted by a "physician of choice".
7. Admission to plant of union "expert" to undertake tests of the work environment.
8. The use of invalid, unsupported, unscientific statements from "instant experts" quoted from some members of the scientific professions.

The answers to all the above demands must be based upon valid test data derived from periodic monitoring of the work areas by

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industrial hygienists from Headquarters Environmental Health or by plant personnel performing such tests under Corporate technical guidance and direction.

PROVISIONS OF FEDERAL OCCUPATIONAL SAFETY AND HEALTH ACT

PURPOSE

The declared Congressional purpose and policy of the Act is "to assure so far as possible every working man and woman in the Nation safe and healthful working conditions and to preserve our human resources".

COVERAGE

The provisions of the law apply to every employer engaged in a business affecting commerce. The law applies in all 50 States, the District of Columbia, and territories.

The Act specifically provides that its terms shall not apply to working conditions protected under other Federal occupational safety and health laws (such as those under the Federal Coal Mine Health and Safety Act, the Atomic Energy Act, or the Metal and Nonmetallic Mines, Open Pit and Quarries Safety and Health Standards). Therefore, every USSC operation, division and associated subsidiary may not be affected to the same degree immediately.

DUTIES OF EMPLOYERS AND EMPLOYEES

Employer Duties

The Act sets out two duties for employers, one of which is specific and the other so general in nature that an employer can be cited for most any condition which, in the opinion of the compliance health and safety officer (inspector), may be a hazard. These so-called "general duty" provisions are the following:

1. Furnish to each of his employees employment and a place of employment which are free from recognized hazards that are causing or are likely to cause death or serious physical harm to his employees.
2. Comply with occupational safety and health standards under the Act.

The greatest potential impact of the first of the two above provisions will most likely be in the area of health matters. The reason for this view is based upon the fact that the existence of health hazards cannot be determined by visual observation. Such a determination requires tests with proper instrumentation and evaluation of the test data by one who by his experience and judgment is qualified as an expert in the field of industrial hygiene. This general duty obligation to provide a "hazard-free" work environment can be used by workers to allege a hazard without any requirement of expert judgment. Experience to date has confirmed this view as the vast majority of employee complaints to OSHA relate to health matters. The only effective method to combat invalid complaints is to develop data, through periodic testing of the work environment, which scientifically demonstrates the quality of the work environment.

Employee Duties

The Act states that "each employee shall comply with occupational safety and health standards and all rules, regulations and orders issued pursuant to this Act which is applicable to his own actions and conduct". In reality, this statement appears to be merely words as the law provides no means of issuing citations or assessing penalties against employees. The law requires employers to take disciplinary action against employees violating safe practices. However, an employer can be cited for violating the Act if a compliance officer observes an employee undertaking unsafe practices, such as not utilizing an exhaust system for controlling air contaminants.

ADMINISTRATION

Administration and enforcement of the Act are vested primarily in the Secretary of Labor, who established a new agency, namely, the Occupational Safety and Health Administration (OSHA); and the Occupational Safety and Health Review Commission (OSHRC), a quasi-judicial board of three members appointed by the President. However, the Act also establishes a National Institute of Occupational Safety and Health (NIOSH), which has a major role as discussed herein.

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ORGANIZATION OF OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION

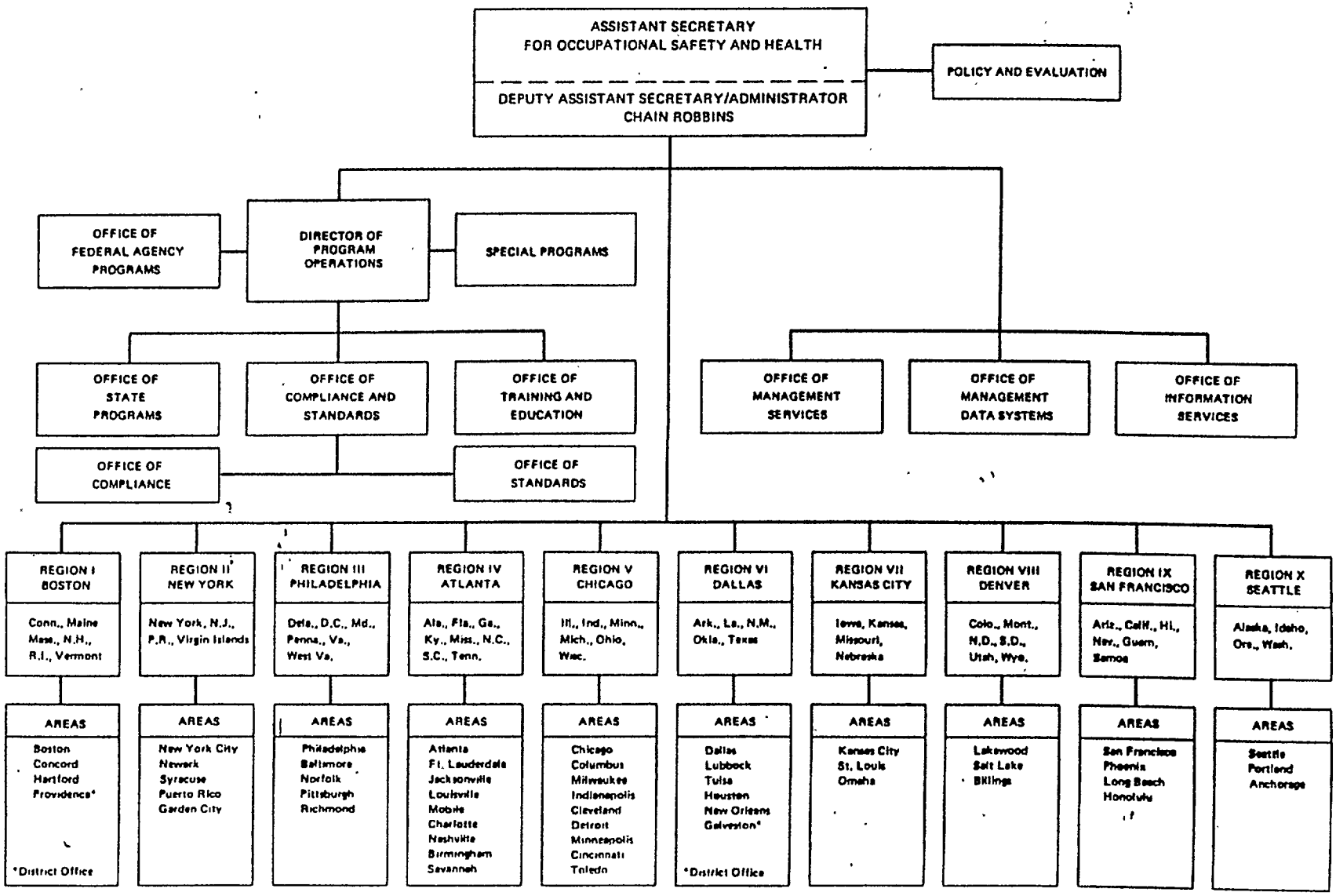


Figure 2.1

OSHA is the standards setting and enforcement agency, OSHRC is the appeals agency, and NIOSH is the agency which develops the criteria upon which standards are set, undertakes research to determine the need for new or revised standards and carries out certain educational functions.

Occupational Safety and Health Administration (OSHA)

The main responsibility for administering the Act rests within OSHA. It is empowered to inspect the facilities of any employer, to promulgate safety and health standards, to issue citations and to assess penalties for violations of the standards. The administrative officer is an Assistant Secretary of Labor, established under the Act. The organization chart of OSHA is shown in Figure 2-1 which indicates the Washington organization and the regional and area offices which are located in the principal cities. Employers will be more directly involved with the regional and area offices relative to inspections, and review of citations and proposed penalties. The Chief Officer in the regional office is the Regional Administrator, while that in the area office is the Area Director.

National Institute for Occupational Safety and Health

The Act establishes within the Department of Health, Education, and Welfare a new National Institute for Occupational Safety and Health (NIOSH), primarily for the purpose of carrying out the research and educational functions assigned to the HEW Secretary under the Act.

In addition to these functions, *the Institute is authorized to develop and establish recommended occupational safety and health standards; to conduct research and experimental programs determined by the Institute's director to be necessary for developing criteria for new and improved job safety and health standards; and to make recommendations* concerning new and improved standards.

Among the Department of Health, Education and Welfare functions which may be carried out by NIOSH is the one which calls for prescribing regulations requiring employers to measure, record, and make reports on the exposure of employees to potentially toxic substances of harmful physical agents which might endanger their safety and health. Employers required to do so may receive full financial or other assistance for the purpose of defraying any additional expense so incurred. Also authorized are programs for medical examinations and tests as may be necessary to determine, for the purposes of research, the incidence of occupational illness and the susceptibility of employees to such illnesses. These examinations may also be at Government expense. Another NIOSH function will be the annual publication of a list of all known toxic substances and the concentrations at which toxicity is known to occur. There will also be published industrywide studies on chronic or low-level exposure to a broad variety of industrial materials, processes, and stresses on the potential for illness, disease, or loss of functional capacity in aging adults *and also authorized is the making of determinations by NIOSH, at the written request of any employer or authorized representatives of employees, as to whether any substance normally found in the place of employment has potentially toxic effects.* Such determinations shall be submitted to both the employer and the affected employees as soon as possible. (The right of the employee to request inspections by both NIOSH and OSHA based upon alleged health hazards or violation of standards, without any valid basis for such allegations, provides a method for harassment and diminishes the constructive purpose of surveys.)

Information obtained by NIOSH and OSHA, under the research provisions of the Act, are to be disseminated to employers and employees and organizations thereof.

The organization of NIOSH, both as it pertains to its headquarters and regional operations, is shown in Figure 2-2.

SAFETY AND HEALTH STANDARDS

The Act provides for the following three general types of standards: early, emergency temporary, and permanent.

Early Standards

The law authorizes OSHA, until April 28, 1973, to promulgate as standards any existing federal standard and any national consensus standard. Consequently, any standard ap-

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ORGANIZATION OF NATIONAL INSTITUTE FOR OCCUPATIONAL SAFETY AND HEALTH

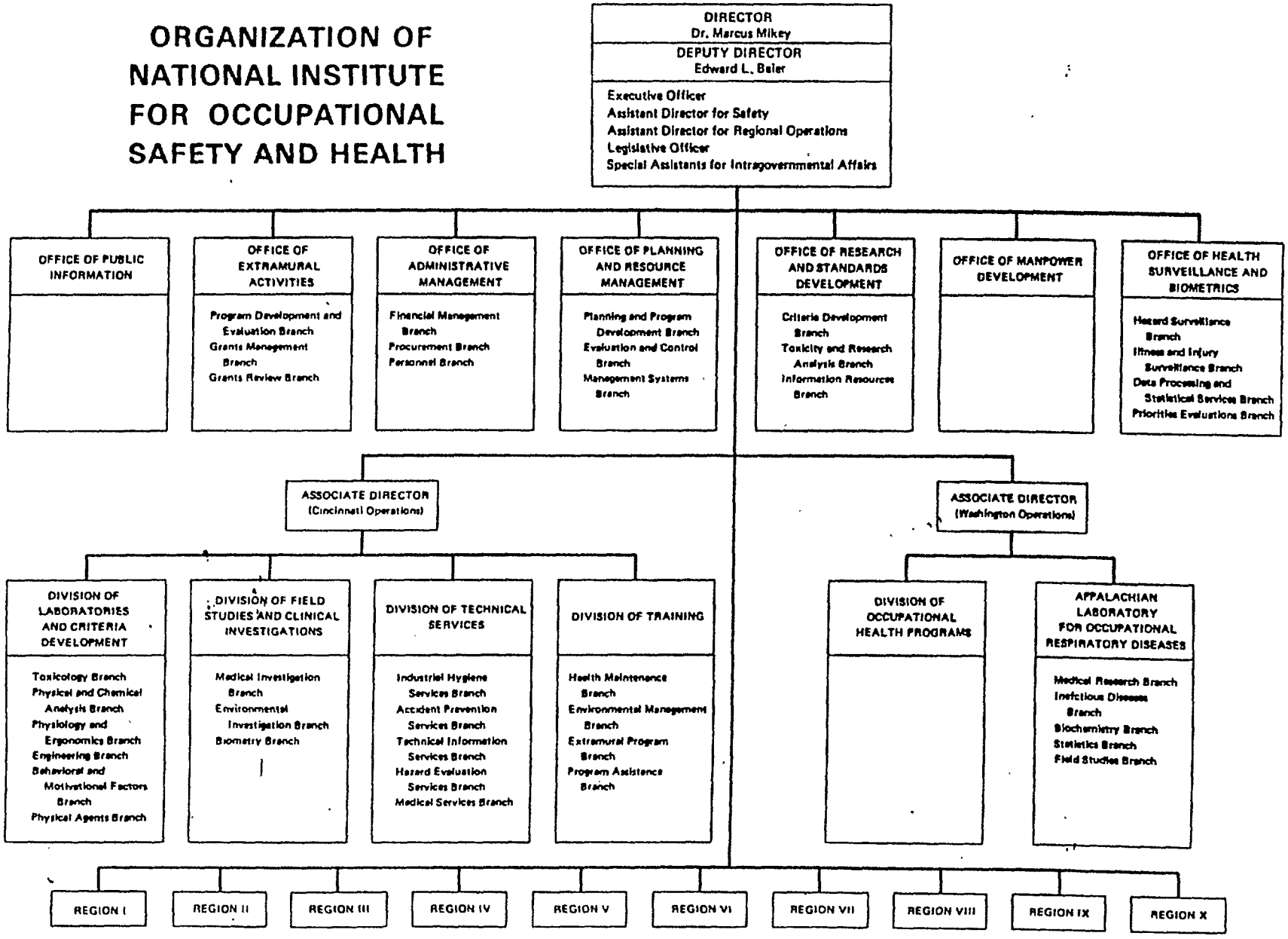


Figure 2.2

HEADQUARTERS

National Institute for Occupational Safety & Health
Health Services and Mental Health Administration
5600 Fishers Lane
Rockville, Maryland 20852

CINCINNATI LABORATORY

National Institute for Occupational Safety & Health
Health Services and Mental Health Administration
1014 Broadway
Cincinnati, Ohio 45202

APPALACHIAN LABORATORY

Appalachian Center for Occupational Safety & Health
National Institute for Occupational Safety & Health
P.O. Box 4292
Morgantown, West Virginia 26505

WESTERN AREA LABORATORY

Western Area Occupational Health Laboratory
National Institute for Occupational Safety & Health
2738 South 20th East
Salt Lake City, Utah 84106
Mailing Address:
P.O. Box 8137
Salt Lake City, Utah 84108

REGION I – Boston
(Conn., Maine, Mass., N.H., R.I. and Vermont)
Regional Program Director, NIOSH
DHEW Region I
Government Center (JFK Fed. Bldg.)
Boston, Massachusetts 02203

REGION II – New York City
(N.J., N.Y., Puerto Rico and Virgin Islands)
Regional Program Director, NIOSH
DHEW Region II – Federal Bldg.
26 Federal Plaza
New York, N.Y. 10007

REGION III – Philadelphia
(Del., D.C., Md., Va., W.Va. and Pa.)
Regional Program Director, NIOSH
DHEW Region III
401 North Broad Street
Philadelphia, Pa. 19108

REGION IV – Atlanta
(Ala., Fla., Ga., Ky., Miss., N.C., S.C., Tenn.)
Regional Program Director, NIOSH
DHEW Region IV
50 Seventh Street, N.E.
Atlanta, Georgia 30323

REGION V – Chicago
(Ill., Ind., Mich., Minn., Ohio and Wisc.)
Regional Program Director, NIOSH
DHEW Region V
300 South Wacker Drive
Chicago, Illinois 60607

REGION VI – Dallas
(Ark., La., N.M., Okla. and Texas)
Regional Program Director, NIOSH
DHEW Region VI
1100 Commerce Street (Rm. 8-C-53)
Dallas, Texas 75202

REGION VII – Kansas City
(Iowa, Kans., Mo. and Neb.)
Regional Program Director, NIOSH
DHEW Region VII
601 East 12th Street
Kansas City, Missouri 64106

REGION VIII – Denver
(Colo., Mont., N.D., S.D., Utah and Wyo.)
Regional Program Director, NIOSH
DHEW Region VIII
19th and Stout Sts. (9017 Fed. Bldg.)
Denver, Colorado 80202

REGION IX – San Francisco
(Arizona, Calif., Hawaii and Nevada)
Regional Program Director, NIOSH
DHEW Region IX
50 Fulton Street (254 FOB)
San Francisco, California 94102

REGION X – Seattle
(Alaska, Idaho, Oregon and Washington)
Regional Program Director, NIOSH
DHEW Region X
1321 Second Avenue (Arcade Bldg.)
Seattle, Washington 98101

Figure 2.2

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plicable under the Walsh-Healey Act is a federal standard. Therefore, the Threshold Limit Values (TLV's) of the American Conference of Governmental Industrial Hygienists which were adopted by reference under this earlier Act have become a federal standard. The major sources of consensus standards are the American National Standards Institute and The National Fire Protection Association.

The original package of initial standards was published in the Federal Register of May 29, 1971 to be effective on August 27, 1971. Incorporated by reference, as national consensus standards are a great many of those developed by the two standards organizations previously mentioned. These occupational safety and health standards were contained in a new Part 1910 of Chapter XVII of Title 29 of the Code of Federal Regulations. Plant personnel responsible for environmental health tests should be thoroughly familiar with Subpart G and Subpart I of Part 1910. The medical director, the general supervisor of safety and other members of the management team in each facility have been distributed copies of these standards. Single copies may be secured free from OSHA regional or district compliance offices. They may also be purchased directly from the U. S. Government Printing Office, located in Washington, D. C. and in principal cities, at a cost of 25¢ per copy.

A point of issue with national consensus standards is that they were developed as guides for good practices and not intended for application as legal standards to be enforced in a literal sense. The numbers contained in such standards are not exact delineations between safe or hazardous conditions. Another concern is the automatic adoption under OSHA of any and all federal standards which were published by a host of governmental agencies, such as Health, Education, and Welfare (food & water standard), Department of Agriculture (pesticides), Department of Transportation (hazardous materials), and many others.

OSHA has the authority to establish any such early standard without any group having the opportunity of review prior to publication in the Federal Register.

Emergency Temporary Standards

OSHA may establish an emergency standard if it is determined that a grave danger to employees exists. Such a standard is effective immediately upon publication in the Federal Register. However, OSHA must develop and publish a permanent standard within six months after publication of an emergency standard. To date two such emergency standards were published. One covered coke oven workers and the other asbestos workers. The temporary standard covering asbestos workers has recently been replaced by a permanent standard.

Permanent Standards

The procedure for establishing this type of standard requires that the proposed standard be published in the Federal Register in order that interested persons have the opportunity to submit written data or comments. In addition, any interested person may file written objections to the proposed standard and request a public hearing.

OSHA may promulgate permanent standards and revoke or revise early or emergency standards on its own initiative or on the basis of information submitted to him by (a) an interested person, (b) any employer or employee organization, (c) a nationally recognized standards-producing organization, (d) NIOSH, (e) Department of HEW, or (f) a state or political subdivision. An advisory committee may be appointed to develop recommendations which must be made within 270 days.

Categories of Standards

OSHA standards consist of the four following categories:

1. *Design Standards*
   An example of these detail design criteria are the ventilation design details contained in Section 1910.94 of the early or initial standards. The major fault with such standards is that they overlook the fact that engineering details are empirical and health and safety standards cannot be stated in terms of absolute numbers. This type of standard by virtue of the many "numbers" contained therein provide the inspector with an unreasonable number of opportunities to cite an employer for violations without truly affecting the health and safety of employees.
2. *Performance Standards*
   Such standards are the threshold limit values (TLV's) of the American Conference of Governmental Industrial Hygienists

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which are contained in Section 1910.93. A performance standard states the objective which must be obtained and leaves the method by which it is reached up to the employer. For example, if the dust standard is stated, the method of achieving it, whether it be by ventilation, wet methods, etc., should not be stipulated, as long as the dust exposure is within the standard.

3. *Vertical Standards*
   A vertical standard applies to particular industries, with specifications that relate to individual operations. Section 1910.261 (Subpart R) of the initial or early standards is in this category.
4. *Horizontal Standards*
   A horizontal standard is one which applies to all workplaces and relates to broad areas, such as illumination and sanitation requirements.

Provisions of Standards

Standards must contain the following provisions:

1. To the extent feasible, no employee dealing with toxic materials or harmful physical agents will suffer material impairment of health or functional capacity, even if such employee has regular exposure to the hazard dealt with by such standard for the period of his working life.
2. Development and prescription of labels or other appropriate forms of warning so that employees are made aware of all hazards to which they are exposed.
3. Prescription of suitable protective equipment and control or technological procedures to be used in connection with the hazards.
4. Monitoring, or measuring employee exposure, of hazards at such locations and intervals and in such manner as may be necessary for the protection of employees.
5. Prescription of the type and frequency of medical examinations or other tests for employees exposed to health hazards. At the request of an employee, the examination or test results shall be furnished to his physician.

It is vital to the achievement of compliance with the standards that works' managements, from first line supervision to general superintendents and plant managers be adequately knowledgeable of the details of all applicable standards. Work locations will be notified of proposed standards, rules and regulations by Headquarters Safety and/or Environmental Health. It is urgent that the effect of a proposed health standard be determined quickly and that Headquarters Environmental Health be immediately notified of the plant's views so that objections, or a request for a public hearing, can be filed within the stipulated time period.

ENFORCEMENT

In enforcing the standards OSHA safety inspectors may enter without delay, and at any reasonable times, any establishment covered by the Act to inspect the premises and all pertinent conditions, structures, machines, apparatus, devices, equipment, and materials therein, and to question privately any employer, owner, operator, agent, or employee. The Act permits the employer and a representative authorized by his employees to accompany the inspector during the physical inspection of any work place for the purpose of aiding such inspection.

OSHA also has power, in making inspections and investigations under the Act, to require the attendance and testimony of witnesses and the production of evidence under oath.

Where an investigation reveals a violation, the employer is issued a written citation describing the specific nature of the violation. All citations shall fix a reasonable time for abatement of the violation, and each citation (or copies thereof) issued by the Department must be prominently posted at or near each place where a violation referred to in the citation occurred. Notices, in lieu of citations, may be issued for deminimis violations which have no direct or immediate relationship to safety or health.

No citation may be issued after the expiration of six (6) months following the occurrence of any violation.

Employee Complaints

Any employee(s), or representative thereof, who believe that a violation of a job safety or health standard exists which threatens physical harm, or that an imminent danger exists, may request an inspection by sending a signed written notice to OSHA. Such a notice shall set forth with reasonable particularity the grounds for the notice and a copy shall be provided the employer or his agent. The

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names of the complainants need not, however, be furnished to the employer.

If the Secretary finds no reasonable grounds for the complaint and a citation is not issued, the Secretary is required to notify the complainants in writing of his determination or final disposition of the matter. Also, the Secretary is required to set up procedures for informal review in a case where a citation is not issued.

The employee or his authorized representative may request NIOSH to undertake to investigate whether or not any substance normally found in the work place has potentially toxic effects in such concentrations as found in use. Therefore, NIOSH representatives will be undertaking its own initiated investigations and those made at the request of the employee. *NIOSH has formally indicated that if, in the course of its investigations, it uncovers violations of any standard, it will so notify the regional OSHA compliance office.*

Notification of Proposed Penalty

Within a reasonable time after issuance of a citation for a job safety or health violation, OSHA shall notify the employer by certified mail of the penalty, if any, which is proposed to be assessed. The employer then has 15 working days within which to notify the Department that he wishes to contest the citation or proposed assessment of penalty. If the employer fails to notify OSHA within such time that he intends to contest the citation or proposed assessment of penalty, the citation and the assessment shall be final, provided no employee files an objection to the time allowed for abatement. If the employer notifies OSHA within such time that he does wish to contest, OSHA will so advise the Occupational Safety and Health Review Commission and the Commission shall afford an opportunity for a hearing. The Commission then will issue orders affirming, modifying, or vacating the citation or proposed penalty. Orders of the Commission are final 30 days after issuance. Review of Commission orders may be obtained in the U. S. Court of Appeals.

The Review Commission's rules of procedure shall provide affected employees (or representatives thereof) an opportunity to participate as parties to the hearings.

Time for Abatement of Hazards

A citation issued by OSHA shall prescribe a reasonable time for elimination or abatement of the hazard. This time limit may also be contested if notification of such is filed with OSHA within 15 days. The time set for correcting a violation shall not begin to run until there is a final order of the Review Commission, if the review is initiated by the employer in good faith and not solely for delay or avoidance of penalties.

Employees (or representatives of employees) also have the right to object to the period of time fixed in the citation for the abatement of a violation. If, within 15 days after a citation is issued, an employee files a notice with OSHA alleging that an unreasonable time was allowed for abatement, review procedures apply similar to those specified above.

Failure to Correct Violation Within Allowed Time

Where time for correction of a violation is allowed, but the employer fails to abate within such time, OSHA shall notify the employer by certified mail of such failure and of the proposed penalty. Such notice and assessment shall be final unless the employer contests the same by notice to the Secretary within 15 days.

Upon a showing by an employer of a good faith effort to comply with the abatement requirements of a citation, but that abatement has not been completed because of factors beyond his reasonable control, an opportunity for a hearing will be afforded, after which an order affirming or modifying the abatement requirement will be issued.

PENALTIES FOR VIOLATIONS

The following types of violations involve major penalties: (1) willful violation resulting in a death, (2) willful and repeated violation, (3) serious violation, and (4) nonserious violation.

Willful or repeated violations of the Act's requirements by employers may incur monetary penalties of up to $10,000 for each violation. Citations issued for serious violations incur *mandatory* monetary penalties of up to $1,000 for each violation, while penalties in the same amount *may* be incurred

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where nonserious violations are cited. A serious violation exists where there is a substantial probability that death or serious physical harm could result. Any employer who fails to correct a violation for which a citation has been issued within the period prescribed therein may be penalized up to $1,000 each day the violation persists.

A willful violation by an employer which results in the death of any employee is punishable by a fine of up to $10,000 or imprisonment for up to 6 months. A second conviction doubles these criminal penalties.

Criminal penalties are also included in the Act for making false official statements and for giving unauthorized advance notice of any inspections to be conducted under the Act.

RECORD KEEPING REQUIREMENTS

In order to carry out the purposes of the Act, employers are required to keep and make available to OSHA (and also to NIOSH) records on certain employer activities under the Act. Employers are also required to maintain accurate records (and periodic reports) of work-related deaths, injuries, and illnesses. Minor injuries requiring only first-aid treatment need not be recorded, but a record must be made if it involves medical treatment, loss of consciousness, restriction of work or motion, or transfer to another job.

Employers can also be required to maintain accurate records of employee exposures to potentially toxic materials or harmful physical agents which are required to be monitored or measured, and to promptly advise any employee of any excessive exposure and of the corrective action being undertaken. OSHA, in cooperation with NIOSH, is authorized by the law to issue regulations in this area which shall provide employees or their representatives with an opportunity to observe such monitoring or measuring, to have access to the records thereof and to such records as will indicate their own exposure to toxic materials or harmful physical agents.

For record keeping purposes, OSHA regulations may also require employers to conduct their own periodic inspections.

OSHA is also directed to issue regulations requiring employers to keep their employees informed of their protections and obligations under the law through posting of notices or other appropriate means. The information which employers may be required to give their employees may also include the provisions of applicable standards. OSHA also requires employers to file such reports of work injuries and illnesses required to be kept under the Act as it shall deem necessary.

GENERAL NOTICE REQUIREMENT

OSHA is required to publish in the Federal Register a statement of their reasons for any action they take with respect to the promulgation of any standard, the issuance of any rule, order or decision, the granting of any exemption or extension of time, as well as any action he takes to compromise, mitigate, or settle any penalty assessed under the Act.

IMMINENT DANGERS

Any condition or practice in any place of employment which is such that a danger exists which could reasonably be expected to cause death or serious physical harm immediately or before the imminence of such danger can be eliminated through normal enforcement procedures, may be restrained by order of a U. S. District Court upon petition of the Secretary of Labor. If the Secretary arbitrarily or capriciously fails to seek action to abate an imminent danger of such kind, a *mandamus* action to compel him to act may be brought in the U. S. District Court by any employee who may be injured by reason of such failure. *An OSHA compliance officer who concludes that such imminent danger conditions or practices exist in any place of employment is obligated to inform the affected employees and employers of the danger and that he has recommended to the Secretary of Labor that relief be sought.*

PROTECTION AGAINST HARASSMENT

No person shall discharge or in any manner discriminate against any employee because he exercises any right under the Act or files a complaint or other proceeding or because he testifies or is about to testify in any proceeding under the Act. Any employee who believes that he has been discharged or otherwise discriminated against in violation of this

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provision may, within 30 days of such illegal action, file a complaint with the Secretary of Labor. The Secretary is authorized to investigate the matter and to bring action in the U. S. District Court for appropriate relief, including rehiring or reinstatement of the employee to his former job with back pay. The Secretary must notify the complainant of his action on the complaint within 90 days of its receipt.

STATE PARTICIPATION

The Act encourages the States to assume the fullest responsibility for the administration and enforcement of their occupational safety and health laws by providing grants to the States for the purposes listed later in this guide. A specific disclaimer of Federal preemption is included in order to permit any State agency or court to assert jurisdiction under State law over any occupational safety or health issue with respect for which no Federal standard is in effect under this law.

In addition, any State may assume responsibility for the development and enforcement of occupational safety and health standards relating to any job safety and health issue covered by a standard promulgated under Section 6 of the Occupational Safety and Health Act, if such State submits an approved plan for so doing to the Secretary of Labor. The Secretary shall approve such a plan under the following conditions:

1. An agency, or agencies, of the State must be designated or created to carry out the plan.
2. The State standards (and enforcement thereof) must be at least as effective as the counterpart Federal standards in providing safe and healthful employment.
3. There must be effective provisions for rights of entry and inspection of work places, including a prohibition on advance notice of inspections.
4. Enforcement capacity must be demonstrated.
5. Adequate funds for administration and enforcement must be assured.
6. Effective and comprehensive job safety and health programs for all public employees within the State will be established to the extent permitted by the particular State's law.
7. The State, and employers within the State, will make such reports as may be required by the Secretary of Labor.

Following approval of a State plan for the development and enforcement of State standards, the Secretary of Labor may continue to exercise his enforcement authority with respect to comparable Federal occupational safety and health standards until he determines on the basis of actual operations that the criteria for approving a State plan are in effect. Once he makes such determination (but he cannot do so during the first 3 years after the plan's approval), the Federal standards and the Secretary's enforcement of them become inapplicable with respect to issues covered under the plan.

However, the Secretary is required to make a continuing evaluation of the manner in which each State plan is being carried out and to withdraw his approval whenever there is a failure to comply substantially with any provision thereof. Such a plan shall cease to be in effect upon receipt of notice by the State of the Secretary's withdrawal of approval.

The Secretary of Labor is authorized, after consultation with the Secretary of Health, Education, and Welfare, to make grants to States for experimental and demonstration projects consistent with the objectives of the Act for administering and enforcing approved programs, for assisting them in identifying their needs, in developing their plans, in establishing systems for collection of information concerning the nature and frequency of occupational injuries and diseases, for developing and administering programs dealing with occupational safety and health statistics and otherwise improving the expertise of personnel or the administration and enforcement of State occupational safety and health laws consistent with the objectives of the Act.

If the Secretary of Labor rejects a State plan for development and enforcement of State standards, he shall afford the State submitting the plan due notice and opportunity for a hearing before so doing. The subsequent withdrawal of an approved State plan or the rejection of a State's plan is subject to review in the U. S. Court of Appeals.

The law also permits the Secretary of Labor to enter into an agreement with any State under which the State will be permitted to continue to enforce its own occupational

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safety and health standards until approval of its plan for development and enforcement of occupational safety and health standards, or until December 29, 1972, whichever comes first.

EDUCATION AND TRAINING PROGRAMS

The Act provides for programs to be conducted by OSHA in consultation with NIOSH for the education and training of employers and employees in the recognition, avoidance, and prevention of unsafe and unhealthful working conditions, and in the effective means for preventing occupational injuries and illnesses. The Act also makes provision for educational and training programs to provide for adequate supply of qualified personnel to carry out the law's purposes and for informational programs on the importance of and proper use of adequate safety and health equipment to be conducted primarily by NIOSH but also to some extent by OSHA.

OTHER PROVISIONS

Advisory Committees

The Act creates a 12-member National Advisory Committee to be appointed by the Secretary of Labor (including four designees of the Secretary of Health, Education and Welfare) to advise, consult, and make recommendations on matters relating to the administration of the Act and permits the establishment of *ad hoc* advisory committees to assist the Secretary in his standard-setting functions.

Nonobstruction Requirement

Any information obtained by any agency under the Act shall be obtained with a minimum burden upon employers, especially those operating small businesses. Unnecessary duplication of efforts in obtaining information shall be reduced to the maximum extent feasible.

Occupational Safety and Health Review Commission

The Act establishes a new independent Federal agency, called the Occupational Safety and Health Review Commission. This Commission is a quasi-judicial body whose functions are: (1) to hear and review cases of alleged violations brought before it by the Secretary of Labor; and, where warranted, (2) to issue corrective orders, and (3) to assess civil penalties.

Federal Protection for Labor Department Inspectors

The Act broadens the provisions of Title 18 of the United States Code, which make it a Federal criminal offense to assault, kill, or otherwise interfere with certain law enforcement officials in the course of their assignments, by extending this protection to all employees of the Department of Labor assigned to perform investigative, inspection, or law enforcement functions.

Trade Secrets

Any trade secrets revealed to Labor Department personnel during the course of their duties under the Act shall be considered confidential.

TARGET HEALTH HAZARDS PROGRAM

OSHA announced its Target Health Hazards Program early in 1972. The program was in part a response to the finding that 60% of the employee complaints, received by OSHA, involve health hazards. The program is directed to the five toxic air contaminants, namely asbestos, cotton dust, silica, lead and carbon monoxide. These compounds were selected as (1) being among the ten most hazardous compounds in industry, (2) involve exposures to five million workers, (3) represent compounds for which OSHA contends that standards for exposure levels are intact and fully valid, and (4) swift compliance action in assessing environmental effects against standards is more practical than for other compounds.

Hazard levels have been established to guide OSHA compliance officers in issuing citations when these are exceeded. These hazard levels and the type of violations involved when they are exceeded are shown in Figure 2-3.

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HAZARD LEVELS IN OSHA TARGET HEALTH HAZARD PROGRAM

COMPOUND (Material)	HAZARD LEVELS AND VIOLATIONS INVOLVED		
	Imminent Danger	Serious Violation	Nonserious Violation
CARBON MONOXIDE	> 500 ppm, at anytime.	> 150 ppm over a period of one hour or more.	TWAC = > 50 ppm < 150 ppm
ASBESTOS	Generally not applicable.	TWAC exceeded 1. Prior to 7/1/76 5 fibers per milliliter of a size longer than 5 micrometers. 2. After 7/1/76 2 fibers per milliliter. CEILING LIMIT: 10 fibers longer than 5 micrometers, per milliliter.	Not Applicable
LEAD	Generally not applicable.	> 0.6 mg/m^3 Averaged over 8 hour period.	> 0.2 but < 0.6 mg/m^3 Averaged over 8 hour period.
SILICA (CRYSTALLINE)	Generally not applicable.	QUARTZ (TWAC) In excess of $4\left(\frac{10}{\%\ RFS + 2}\right)$ CRISTOBOLITE AND TRIDYMITE In excess of 50% of the quartz value.	QUARTZ If TWAC is between 1-4 Times $\frac{10}{\%\ RFS + 2}$ CRISTOBOLITE AND TRIDYMITE In excess of 50% of the quartz value.

NOTES:
TWAC – Time Weighted Average Concentration over 8 hour shift.
% RFS – Percent of Crystalline Silica in the Respirable Portion of the Airborne Dust.

Figure 2.3

Chapter III
Mathematics

Chapter III

MATHEMATICS AND UNITS IN INDUSTRIAL HYGIENE

In any technical work, measurements and standards must be expressed in some system or systems of well-defined and standardized units and terms. This gives the values exact meaning so that they can be understood, compared, interrelated, and used as needed. Although the measurements may be made by different people, by different methods or at different times and places, their meanings and relationships are indicated exactly when the values are expressed in accepted standardized units and terms.

When more than one system of units is used, the precise relationship between units must be known in order to convert values from the units of one system to the units of another system. When making calculations, it is essential to convert all terms to units of a single system; otherwise, there is danger of trying to "multiply apples by oranges".

In order to work with and to understand industrial hygiene measurements and standards, the user must know these systems of measurement and be able to make calculations in them and conversions from one to another.

Systems of Measurement

In industrial hygiene, the measurements and standards are expressed in three systems: English system, metric system, and a special system which is specific to industrial hygiene. The basic units used in both the English and metric systems are shown in Table 3-1.

The English system expresses values in terms of feet, pounds, minutes, etc. This is the standard system in the United States and is used in commerce and some fields of technology. This is the system which is taught in elementary schools and used in most daily transactions. In the development of industrial hygiene, those aspects which are basically engineering in their orientation tend to make use of the English system of measurement. Volumes are expressed in cubic feet, pressures in pounds per square foot, speed in feet per second, etc. Ventilation rates are usually expressed as cubic feet per minute (CFM), and stack emission rates are given as pounds per hour (lb/hr) or tons per day.

The metric (or international) system expresses measurements in meters, grams, seconds, etc. This system is used in most scientific work. It is the standard system for most other countries of the world and is being accepted in the United States. In industrial hygiene those aspects deriving primarily from chemistry, physics, and biology use the metric system of expressing values. Common examples of such usage in industrial hygiene are the expression of concentrations of contaminants in air as milligrams per cubic meter (mg/m^3), and the statement of sampling rates as liters per minute (lpm).

The special system is not a true system but consists of certain special types of units of measurement applicable to industrial hygiene. Examples are the expression of con-

Table 3-1

BASIC UNITS OF MEASUREMENT IN METRIC AND ENGLISH SYSTEMS

Physical Quantity	Metric System	"English" System
length	meter (m)	foot (ft)
mass (weight)	gram (g)	pound (lb)
time	second (s)	second (sec)
electric current	ampere (a)	ampere (amp)
temperature	degrees Kelvin (K)	degrees Farenheit (F)
luminous intensity	candela (cd)	footcandle (ft-c)
amount of substance	mole (mol)	pound-mole (lb-mol)

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centrations of gases or vapors as parts per million parts of air (ppm) and of dust concentrations as millions of particles per cubic foot of air (mppcf).

Units of Systems

Americans are most familiar with the units of the English system since these are commonly used in most walks of life as well as in the various professions. However, the metric system is being increasingly used by the science professions, and the United States has agreed to standardize on this system over a period of years. The most common units of both the English and metric systems, and the conversion factors for converting the units of one system into the other are shown in Table 3-2.

Metric System

A major advantage of the metric system is that the units are related to each other by multiples, or powers, of 10. Therefore, it is quite simple to convert from one level of metric units to another by multiplying or dividing by the appropriate multiple of 10. A series of prefixes has been established by international agreement and by the U. S. National Bureau of Standards to designate these multiples or fractions of the basic units. In the following table the prefixes most frequently used in metric measurements in industrial hygiene are shown, with the abbreviation symbol and the multiplying factor indicated by the prefix.

Prefix	Symbol (abbreviation)	Multiplier		
mega	M	1,000,000.	or	10^6
kilo	k	1,000.	or	10^3
deci	d	0.1	or	10^{-1}
centi	c	0.01	or	10^{-2}
milli	m	0.001	or	10^{-3}
micro	μ	0.000001	or	10^{-6}
nano	n	0.000000001	or	10^{-9}

Thus, these prefixes and symbols indicate larger and smaller units. Note the following examples with the abbreviations shown in parentheses:

kilometer (km) = 1,000 meters = 10^3m
1 megaton (mt) = 1,000,000 tons = 10^6t
1 microgram (μg) = 0.000001 grams = 10^{-6}g
1 milliampere (ma) = 0.001 ampere = 10^{-3}a

The relationships between these different units will be some multiple of 10 and can be readily determined – one centigram equals 10 milligrams, one kilometer equals 10 thousand decimeters, etc. These multiple or fractional units may also be used in derived unit terms such that a velocity of 15 centimeters per second (cm/sec) is easily converted or shown to be the same as 0.15 meters per second (m/sec) or 150 millimeters per second (mm/sec).

The particle size of a dust or fume is often expressed in terms of microns, which is abbreviated as μ. The micron is 1/1000 of a millimeter, or one micrometer, in length. The micfon is not recognized as a sanctioned unit in the metric or international system; however, it has been used so extensively in small particle work that it is necessary to be familiar with it, and able to relate it to other sizes. The micron is approximately 1/25,000 of an inch.

The wave lengths of light are commonly measured in terms of angstrom units and millimicrons (0.001 micron); however, the recent trend is to express them in terms of nanometers. A nanometer and a millimicron are identical units of length, and are each equal to 10 angstrom units. The millimicron is about 1/25,000,000 of an inch.

Powers and Exponents

As previously mentioned, units of the metric system are related to each other by multiples of 10. Therefore, a brief discussion of "powers" and "exponents" of numbers is helpful in the use of units in any technical work. A number multiplied by itself one or more times is said to have been raised to a power. The number is referred to as the base, and the number of times it appears in the multiplication exercise is the power to which the base has been raised. Mathematically, this is indicated by giving the base number an exponent (superscript) indicating the power to which it has been raised. Thus, 10^2 indicates that the base 10 has been used two times:

$$10^2 = 10 \times 10 = 100$$

Similarly,

$$10^3 = 10 \times 10 \times 10 = 1{,}000$$
$$10^4 = 10 \times 10 \times 10 \times 10 = 10{,}000$$

The base 10 is the most useful base; however, any other number may be used as a base, if desired:

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Table 3-2

Conversion Factors and Equivalents

Metric Units to English Units		English Units to Metric Units
1 kilometer (km) = 0.621 mile (mi)	LENGTH	1 mile (mi) = 1,609 kilometers (km)
1 meter (m) = 3.281 feet (ft)		1 yard (yd) = 0.914 meter (m)
1 meter (m) = 39.37 inches (in)		1 foot (ft) = 30.5 centimeters (cm)
1 centimeter (cm) = 0.3937 inch (in)		1 inch (in) = 2.540 centimeters (cm)
1 millimeter (mm) = 1000 microns (μ)		
1 millimicron (m μ) = 10 angstroms (a)		
1 nanometer (nm) = 1 millimicron (m μ)		
1 square meter (m^2) = 10.76 square feet (ft^2)	AREA	1 square foot (ft^2) = 0.0929 square meters (m^2)
1 square centimeter (cm^2) = 0.155 square inch (in^2)		1 square inch (in^2) = 6.452 square centimeters (cm^2)
1 cubic meter (m^3) = 1000 liters (l)	VOLUME	1 cubic foot (ft^3) = 0.00283 cubic meters (m^3)
1 cubic meter (m^3) = 35.31 cubic feet (ft^3)		1 cubic foot (ft^3) = 28.32 liters (l)
1 liter (l) = 0.2642 gallon (gal)		1 cubic foot (ft^3) = 7.481 gallons (gal)
1 liter = 1000 milliliters (ml)		1 gallon (gal) = 3.785 liters (l)
1 cubic centimeter (cm^3) = 0.999972 milliliters (ml)		1 gallon (gal) = 0.1337 cubic feet (ft^3)
1 liter (l) = 1.05672 quarts (qt)		1 cubic inch (in^3) = 16.387 milliliters (ml)
		1 cubic inch (in^3) = 16.387 cubic centimeters (cm^3)
		1 fluid ounce (fl. oz.) = 1.80469 cubic inch (in^3)
		1 fluid ounce (fl. oz.) = 29.5735 cubic centimeters (cm^3)
1 liter/min = 0.0353 ft^3/min	FLOW	1 ft^3/min = 28.32 liters/min
1 liter/min = 0.2640 gal/min		1 ft^3/min = 1.699 m^3/hr
1 liter/min = 0.001 cubic meters/min (m^3/min)		
1 kilogram (kg) = 2.205 pounds (lb)	MASS	1 pound (lb) = 453.59 gram (g)
1 gram (g) = 15.43 grain (gr)		1 ounce (oz) = 28.35 gram (g)
1 gram (g) = 0.03527 ounce (oz)		1 grain (gr) = 64.8 milligrams (mg)
1 g/cm^3 = 62.43 lb/ft^3	DENSITY	1 lb/ft^3 = 0.01602 g/cm^3
1 g/cm^3 = 8.345 lb/gal		1 lb/ft^3 = 0.1337 lb/gal
1 atmosphere (atm) = 14.696 lb/in^3	PRESSURE	1 lb/in^2 = 0.068 atm
1 atmosphere (atm) = 29.92 in Hg (0°C)		1 lb/in^2 = 2.036 in Hg (0°C)
1 atmosphere (atm) = 760 mm Hg (0°C)		1 lb/in^2 = 51.71 mm Hg (0°C)
1 mm Hg (0°C) = 0.01934 lb/in^2		1 lb/in^2 = 27.71 in H_2O (15°C)
1 joule = 0.737 ft-lb	HEAT ENERGY WORK	1 ft-lb = 1.285 x 10^{-3} Btu
1 joule = 0.2390 calories (cal)		1 ft-lb = 2.766 x 10^{-7} kilowatt-hour (kw-hr)
1 joule = 9.478 x 10^{-4} Btu		1 ft-lb = 0.3241 calorie (cal)
1 calorie (cal) = 4.184 joule		1 hp-hr = 0.7455 kw-hr
1 kilocalorie (kcal) = 3.97 Btu		1 Btu = 0.252 kilocalorie (kcal)
1 candella (cd) = 1 candle (c)	ILLUMINATION	1 footcandle (ft-c) = 1 lumen/ft^2
1 candella (cd) = 12.57 lumens		1 footcandle (ft-c) = 10.76 lux (lx)
1 lux (lx) = 1 lumen/m^2		1 candle/in^2 = 0.487 lambert (L)
1 lux (lx) = 0.0929 footcandle (ft-c)		

$3^5 = 3 \times 3 \times 3 \times 3 \times 3 = 243$
$8^2 = 8 \times 8 = 64$

In these examples, 10^2, 10^3, 10^4, 3^5 and 8^2 are exponential numbers. Any value or number represented by a base number with an exponent (superscript showing the power) is called an exponential number.

A number multiplied by itself is said to have been raised to the second power (squared). If multiplied again, it has been raised to the third power (cubed). Multiplication yet another time would yield the fourth power, etc. However, when a base number is used as a factor only once, it is said to have been raised to the first power and is equal to itself; in other words, there has been no multiplication.

$10^1 = 10$
$3^1 = 3$
$8^1 = 8$

Exponents may also be used to indicate the taking of the root of a number, which is the opposite of raising a number to a power. A root of a number is another number which, when used as a base and carried to the same numerical power as the root, will give the original number. Thus, the second root (square root) is a number which, when multiplied by itself, will equal the original number.

$\sqrt{100} = 10 \quad (10 \times 10 = 100)$
$\sqrt[3]{8} = 2 \quad (2 \times 2 \times 2 = 8)$
$\sqrt[4]{256} = 4 \quad (4 \times 4 \times 4 \times 4 = 256)$

Referring to the previous examples, it can be seen that the fifth root of 243 is 3, and that the fourth root of 10,000 is 10. These could be written $\sqrt[5]{243}$ and $\sqrt[4]{10{,}000}$. Roots may be expressed mathematically by the use of fractional exponents in which the divisor, or denominator (the number below the line) of the fraction indicates the root. For simple roots, the numerator (number above the line) of the fractional exponent will be 1.

$$(100)^{1/2} = \sqrt{100} = 10$$
$$(1{,}000)^{1/3} = \sqrt[3]{1{,}000} = 10$$
$$(243)^{1/5} = \sqrt[5]{243} = 3$$

In some cases, fractional exponents are used (both the numerator and denominator will be numerals other than 1). In such instances, the numerator indicates the power to which the number has been raised and the denominator indicates the root which has been taken. It makes no difference in which order this is done if the actual mathematical operations are carried out stepwise:

$$(243)^{2/5} = \sqrt[5]{(243)^2} = (3)^2 = 9$$

In actual calculations, it is frequently more convenient to use the tables of squares, cubes, and roots which are contained in most mathematical handbooks. When fractional exponents, exponents larger than 3, or exponents which are not simple whole numbers are involved, the calculation can be made more easily by the use of logarithms for the conversion to normal (non-exponential) numbers.

Calculations with Exponential Numbers

The *addition* and *subtraction* of exponential numbers is limited to the addition and subtraction of coefficients of numbers having the same base and power. The coefficient is a non-exponential number which is multiplied by the exponential number. Thus, in 4×10^2, 4 is the coefficient of the exponential number 10^2.

When the exponential numbers have the same base and power, the coefficients are added to, or subtracted from, each other. Thus:

$(2 \times 10^3) + (4 \times 10^3) = 6 \times 10^3 = 6{,}000$
and
$(6 \times 10^3) - (4 \times 10^3) = 2 \times 10^3 = 2{,}000$

When the exponents or powers are not the same, or the base numbers are not the same, the addition or subtraction can be accomplished only by carrying out the mathematical operations to remove the exponents, so that the addition or subtraction takes place between non-exponential figures.

$(2 \times 10^3) + (4 \times 10^2) = 2{,}000 + 400 = 2{,}400$
and
$(2 \times 8^2) - (4 \times 3^2) = (2 \times 64) - (4 \times 9) =$

$$128 - 36 = 92$$

Exponential numbers can be directly *multiplied* or *divided* only when they have the same base; it is not necessary that they have the same exponents. For multiplication of exponential numbers having the same base, the exponents are added, and the product is

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the base raised to the power which is the sum of the exponents. For example:

$$10^2 \times 10^3 = 10^{(2+3)} = 10^5 = 100{,}000$$

Exponential numbers having the same base may be divided by subtracting the exponent of the divisor (denominator) from the exponent of the dividend (numerator). For example:

$$\frac{10^5}{10^3} = 10^{(5-3)} = 10^2 = 100$$

Division may also be indicated by a negative exponent. When a base number is raised to a negative exponent, the resultant number is the reciprocal of the base number raised to that positive power. Reciprocal is described as the inverse function of a number. For example, the reciprocal of 5 is 1/5; the reciprocal of 1/2 is 2. Any number multiplied by its reciprocal is one. By changing the sign of the exponent, it can be transferred from the numerator to the denominator or vice versa in a mathematical equation:

$$10^{-2} = \frac{1}{10^{+2}} = \frac{1}{100}$$

and

$$\frac{1}{10^{-3}} = 10^{+3} = 1{,}000$$

Using negative exponents, the foregoing example of division of exponential numbers could have been written:

$$\frac{10^5}{10^3} = 10^5 \times 10^{-3} = 10^{5+(-3)} = 10^{(5-3)} = 10^2 = 100$$

When needed, exponential numbers may be raised to powers by multiplying the exponent by the power to which the number is to be raised:

$$(10^2)^3 = (10^2) \times (10^2) \times (10^2) = 10^{(2+2+2)} = 10^6 = 1{,}000{,}000$$

Conversely, the root of an exponential number is obtained by dividing the exponent by the root:

$$\sqrt[2]{10^6} = 10^{6/2} = 10^3 = 1{,}000$$

Powers of Ten

Extremely large or extremely small numbers are conveniently expressed by the use of exponential numbers using the base 10. Any number may be expressed as an integer power of 10 or as the product of two numbers, one of which is an integer power of 10. The powers of 10 are:

$10^0 = 1$	
$10^1 = 10$	$10^{-1} = 0.1$
$10^2 = 100$	$10^{-2} = 0.01$
$10^3 = 1{,}000$	$10^{-3} = 0.001$
$10^4 = 10{,}000$	$10^{-4} = 0.0001$
$10^5 = 100{,}000$	$10^{-5} = 0.00001$
$10^6 = 1{,}000{,}000$	$10^{-6} = 0.000001$
etc.	etc.

Multiplication of any number of one of these powers of 10 will result in a shifting of the decimal point to the right for the positive powers (multiplication), and to the left for the negative powers (division). For example:

$5.2 \times 10^2 = 520$

$5.2 \times 10^4 = 52{,}000$

$5.2 \times 10^{-2} = \frac{5.2}{10^2} = 0.052$

$5.2 \times 10^{-4} = \frac{5.2}{10^{-4}} = 0.00052$

This is particularly useful as a way of indicating the decimal point when it would be inconvenient to write the large number of zeroes included in a very large or a very small number. The power of 10 is quickly determined by counting the number of places the decimal point has been moved to obtain the simple number coefficient. When the decimal point is moved to the left, then a positive power of 10 will be indicated because the new coefficient must be multiplied by 10 to that power. Conversely, when the decimal point is moved to the right to obtain the simple number, the exponent number of 10 becomes negative. For example:

$8{,}000{,}000 = 8.0 \times 10^6 = 80 \times 10^5 = 800 \times 10^4$ etc.

and

$0.0000624 = 0.624 \times 10^{-4} = 6.24 \times 10^{-5} = 62.4 \times 10^{-6} = 624 \times 10^{-7}$ etc.

One word of caution, particularly applicable when using volume units, is that in order to factor-out, combine, or cancel units, they must be measuring the same thing. Only if volume without regard to substance is the consideration, can the units be treated as being the same units. In calculations, it is advisable to label the units to show what was measured, such as 1000 ft^3 air, in order to keep the values identified.

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Calculating Atmospheric Concentrations

The concentrations of airborne contaminants are usually expressed in one of two basic manners in industrial hygiene work:

(1) Weight or mass of contaminant per specified volume of air, such as mg/m^3, or

(2) Volume of contaminant gas or vapor per specified volume of air, such as ppm.

Various units of mass and volume may be used in different circumstances or applications.

Mass (Weight) per Specified Volume

This manner of expressing concentrations is applied both to particulates (dusts, fumes and mists), and to gases and vapors in air. The calculations of such concentrations are straightforward and mostly concerned with conversions of the mass and the volume to the units desired. This method of expressing concentrations is usually referred to as mass per unit, and common examples employed in industrial hygiene are:

milligrams per cubic meter	mg/m^3
milligrams per liter	mg/liter
micrograms per liter	µg/liter
grains per cubic foot	gr/ft^3

Consider an example of a calculation which might be necessary to determine the concentration of a sample collected in an industrial atmosphere. If air were sampled for 30 minutes at a sampling rate of 2 liters of air per minute, and an analysis of the sample showed that 0.5 mg. of the contaminant had been collected, what would be the concentration in terms of milligrams of contaminant per cubic meter of air?

The calculation is: weight of contaminant collected, divided by volume of air sampled, multiplied by 1000 (to convert contaminants per liter to contaminants per cubic meter). In this case:

$$\frac{0.5\text{ mg}}{30\text{ min}} \times \frac{1\text{ min}}{2\text{ litters}} \times \frac{1000\text{ liters}}{1\text{m}^3} = \frac{0.5 \times 1000}{30 \times 2}$$

$$x\frac{\text{mg}}{\text{m}^3} = \frac{500\text{ mg}}{60\text{ m}^3} = 8.3\text{ mg/m}^3$$

Volume per Unit Volume

Generally the concentrations of gases and vapors, particularly in reference to acceptable limits, are expressed in terms of the volume of the contaminant in a specified volume of air. This is usually called volume per unit volume, and is frequently indicated by vol/vol. In industrial hygiene there are two commonly used expressions of this type: parts per million, and per cent by volume.

(1) *Parts per million (ppm).* This is the most common method, in industrial hygiene, of expressing concentrations of gases or vapors in the atmosphere and may be more specifically stated as volumes of contaminant per 1,000,000 volumes of air. Any volume unit can be used so long as the same unit is used for both the contaminant and the air. For example, it might be liters of contaminant per million liters of air or cubic centimeters of contaminant per million cubic centimeters of air.

(2) *Per cent by volume.* This manner of expressing concentration is used most in relation to the explosibility of gases and to some extent for relatively high concentrations of gases. Per cent by volume might also be stated as volumes of contaminant per one hundred volumes of air. It is calculated by converting both the contaminant and air volumes to the same units and determining percentage in the usual manner.

The advantage of the volume/volume basis of expressing concentrations is that it does not change with changes in temperature or pressure of the gases. When the temperature or pressure of air increases or decreases, the air expands or contracts accordingly, and the volume of the contaminant changes in the same ratio. Therefore, their relationship does not change and the concentration expressed on the volume per volume basis remains unchanged.

When concentration is expressed in terms of mass of contaminant per volume of air, changes in temperature and pressure result in changes in the volume of air but not in the mass of the contaminant. Therefore, the concentration expression is accurate only at a specified temperature and pressure.

In order to calculate gaseous volumes of materials, it is necessary to understand the use of molecular weights and molecular volumes. Likewise, it is necessary to understand the effects of pressure and temperature changes and to be able to use these in calculations.

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Effects of Temperature and Pressure

To calculate changes in gas volumes with changes in temperature, absolute temperature must be used. Absolute temperature is based on a theoretical "absolute zero" as the lowest possible temperature or zero point on the scale. Absolute zero has been determined to be -273°C (degrees Centigrade) or -460°F (degress Fahrenheit).

Two absolute temperature scales are used. The Kelvin scale is based on Centigrade units and the Rankine scale is based on Fahrenheit units. Conversions to absolute temperatures are made by the following formulae:

Degrees Rankine (R) =
degrees Fahrenheit (F) +460

Degrees Kelvin (K) =
degrees Centigrade (C) +273

Changes in gas volume due to temperature changes may be calculated by the following formula, in which V_1 is the volume at absolute temperature T_1, and V_2 is the volume at absolute temperature T_2:

$$\frac{V_1}{V_2} = \frac{T_1}{T_2}$$

For example: if a volume of gas is 40 ft^3 at 40°F, what is its volume at 70°F?

$$\frac{V_1}{V_2}=\frac{T_1}{T_2} \text{ or } \frac{40}{V_2}=\frac{460+40}{460+70} \text{ or } V_2 =$$

$$\frac{40 \times (460+70)}{(460+40)}=\frac{21200}{500} \text{ or } V_2 = 42.4 \text{ ft}^3$$

The formulae for converting from Centigrade (C) to Fahrenheit (F) and vice versa are:

$$C = \frac{5}{9}(F - 32)$$

and

$$F = (\frac{9}{5}C) + 32$$

Ordinarily, barometric changes in a given location do not produce sufficient volume changes to be important in most industrial hygiene calculations. However, there is sufficient change in pressure with significant changes in altitude that corrections must sometimes be made. Table 3-3 presents a series of factors which can be used to calculate volumes at different altitudes. A volume at sea level multiplied by the factor indicated for a certain altitude will convert the volume to that which would exist at that altitude.

Conversely, to calculate from volume at any altitude to volume at sea level, the volume at the altitude should be divided by the factor. Ordinarily, corrections are not applied at altitudes of less than 1,000 feet. For example, at sea level (0 ft. elevation), a burner requires 1000 ft^3 of air per minute (cfm); what volume of air would be required at an altitude of 6000 ft?

Table 3-3

Factors for Correction of Gas Volumes to Altitudes Other Than Sea Level

(volume at 0 ft x factor = volume at selected altitude)

Altitude ft. above sea level	Factor
-1000	0.965
- 500	0.982
0	1.000
500	1.018
1000	1.035
2000	1.074
3000	1.115
4000	1.156
5000	1.200
6000	1.248
7000	1.295
8000	1.349

Table III shows the factor as 1.248. Thus:

Volume at 6000 ft. = 1000 ft^3 x
1.248 = 1248 ft^3

Because the volume of gas does vary with temperature and pressure, a stated volume of gas can be related to the actual amount (mass or weight) of gas only if the conditions of temperature and pressure are specified. In physics and chemistry, standard conditions of temperature and pressure (STP) are arbitrarily set at 0°C (32°F) and 760 millimeters of mercury pressure (sea level or one standard atmosphere).

When volumes of gases are given, they are considered to be at standard temperature and pressure unless otherwise stated. Inasmuch as

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0°C is a temperature not often encountered in working environments, most statements of gaseous volumes in industrial hygiene work are referred to under "normal" conditions, which are arbitrarily assumed to be 25°C (77°F) and 760 mm of mercury. Only when temperature or pressure varies significantly from these normal conditions is it necessary to make the volume corrections.

Molecular Weight and Molecular Volume

At fixed conditions of temperature and pressure, the volume occupied by a specified amount (mass or weight) of a gas or vapor is related exactly to its molecular weight. The molecular weight is the sum of the atomic weights of all the atoms in the molecule of the element or compound. From the molecular formula of a compound, the molecular weight can be easily calculated.

Using the list of atomic weights which can be found in any chemistry text, select the atomic weight of each element in the molecule, multiply it by the number of atoms of that element, then add all of these together to get the total, which is the molecular weight of the compound in question. For example: the formula for trichloroethylene is C_2HCl_3. The atomic weights are carbon (C) 12.01, hydrogen (H) 1.01, and chlorine (Cl) 35.45. Then:

$12.01 \times 2 = 24.02$
$1.01 \times 1 = 1.01$
$35.45 \times 3 = 106.35$
Total 131.38 = molecular weight of C_2HCl_3.

The term gram molecular weight (GMW) refers to a quantity which is used to give the molecular weights meaning in terms of units of mass or weight. The GMW of a substance is the amount of that substance which has a mass (weight) in grams numerically equal to its molecular weight. Using the example above, the GMW of C_2HCl_3 would be 131.38 grams.

One GMW of any gas or vapor has a volume of 22.4 liters at standard temperature and pressure (0°C, 760 mm of mercury). This volume is known as the gram molecular volume (GMV). The GMV changes in accordance with the laws for gas volume changes with temperature and pressure. Accordingly, the GMV at normal conditions (25°C and 760 mm of mercury) is 24.45 liters. For most circumstances encountered in industrial hygiene, the value of 24.45 liters can be considered to be the GMV of any gas or vapor. Sometimes this is rounded off to 25 liters for convenience in estimating volumes in concentrations. When conditions of temperature or pressure are widely different from normal conditions, the change in volume must be calculated.

Calculation of ppm (Vol/Vol)

Most often, calculation of concentration as ppm (parts or volumes of contaminants per one million parts or volumes of air) is made on the basis of a known weight of the contaminant in a known volume of air. The calculation involves the use of molecular weight and molecular volume. For example: If 50 mg of benzene (C_6H_6) is evaporated into the air in a chamber with a volume of 1200 liters, calculate the concentration of benzene as ppm. Use 78 for the molecular weight of C_6H_6.

The calculation may be done as follows:

$$\frac{50 \text{ mg } C_6H_6}{1200 \text{ liters air}} \times \frac{1 \text{ g } C_6H_6}{1000 \text{ mg } C_6H_6} \times \frac{1 \text{ GMW } C_6H_6}{78 \text{ g } C_6H_6} \times$$

$$\frac{24.45 \text{ liters } C_6H_6}{1 \text{ GMW } C_6H_6} \times \frac{10^6}{10^6} =$$

$$\frac{50 \times 24.45 \times 10^6 \text{ liters } C_6H_6}{1200 \times 1000 \times 78 \times 10^6 \text{ liters air}} =$$

$$\frac{50 \times 24.45 \times 10^6}{1200 \times 78 \times 10^3} \times \frac{\text{liters } C_6H_6}{(10^6 \text{ liters air})} =$$

13.05 ppm (vol/vol) benzene in air.

Please note that our last unity ratio is 1,000,000 divided by 1,000,000 ($10^6/10^6$). This is necessary in order that we can arrive at the expression in terms of parts per million or liters of benzene vapor per million liters of air; without this unity ratio our result would be in terms of liters of benzene vapor per liter of air. After the multiplication, the million in the denominator becomes part of the ppm term and must not be used in the actual arithmetic calculations.

The following equations may be used to convert from milligrams per liter (at normal conditions).

$$\frac{\text{mg/liter} \times 24450}{\text{mol. weight}} = \text{ppm}$$

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$$\frac{\text{ppm} \times \text{mol. weight}}{24450} = \text{mg/liter}$$

Table 3-4 lists conversion factors for converting from parts per million to milligrams per liter and vice versa. The appropriate conversion factors are found in the two columns opposite the molecular weight. The left column is for conversion from milligrams per liter to parts per million and the right column is for conversion from parts per million to milligrams per liter.

Table 3-4

Conversion Table for Gases and Vapors[a]

(Milligrams per Liter to Parts per Million and Vice Versa; 25° C. and 760 mm. mercury, barometric pressure)

Mol. wt.	1 mg/liter ppm	1 ppm, mg/liter	Mol. wt.	1 mg/liter ppm	1 ppm, mg/liter
1	24,450	0.0000409	36	679	0.001472
2	12,230	.0000818	37	661	.001513
3	8,150	.0001227	38	643	.001554
4	6,113	.0001636	39	627	.001595
5	4,890	.0002045	40	611	.001636
6	4,075	.0002454	41	596	.001677
7	3,943	.0002863	42	582	.001718
8	3,056	.000327	43	569	.001759
9	2,717	.000368	44	556	.001800
10	2,445	.000409	45	543	.001840
11	2,223	.000450	46	532	.001881
12	2,038	.000491	47	520	.001922
13	1,881	.000532	48	509	.001963
14	1,746	.000573	49	499	.002004
15	1,630	.000614	50	489	.002045
16	1,528	.000654	51	479	.002086
17	1,438	.000695	52	470	.002127
18	1,358	.000736	53	461	.002168
19	1,287	.000777	54	453	.002209
20	1,223	.000818	55	445	.002250
21	1,164	.000859	56	437	.002290
22	1,111	.000900	57	429	.002331
23	1,063	.000941	58	422	.002372
24	1,019	.000982	59	414	.002413
25	978	.001022	60	408	.002554
26	940	.001063	61	401	.002495
27	906	.001104	62	394	.00254
28	873	.001145	63	388	.00258
29	843	.001186	64	382	.00262
30	815	.001227	65	376	.00266
31	789	.001268	66	370	.00270
32	764	.001309	67	365	.00274
33	741	.001350	68	360	.00278
34	719	.001391	69	354	.00282
35	699	.001432	70	349	.00286

[a] A. G. Fieldner, S. H. Katz, and S. P. Kinney, "Gas Masks for Gases Met in Fighting Fires," U. S. Bur. Mines, Tech. Paper No. 248 (1921).

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Table 3-4

Mol. wt.	1 mg/liter ppm	1 ppm, mg/liter	Mol. wt.	1mg/liter ppm	1 ppm, mg/liter
71	344	0.00290	111	220.3	0.00454
72	340	0.00294	112	218.3	.00458
73	335	.00299	113	216.4	.00462
74	330	.00303	114	214.5	.00466
75	326	.00307	115	212.6	.00470
76	322	.00311	116	210.8	.00474
77	318	.00315	117	209.0	.00479
78	313	.00319	118	207.2	.00483
79	309	.00323	119	205.5	.00487
80	306	.00327	120	203.8	.00491
81	302	.00331	121	202.1	.00495
82	298	.00335	122	200.4	.00499
83	295	.00339	123	198.8	.00503
84	291	.00344	124	197.2	.00507
85	288	.00348	125	195.6	.00511
86	284	.00352	126	194.0	.00515
87	281	.00356	127	192.5	.00519
88	278	.00360	128	191.0	.00524
89	275	.00364	129	189.5	.00528
90	272	.00368	130	188.1	.00532
91	269	.00372	131	186.6	.00536
92	266	.00376	132	185.2	.00540
93	263	.00380	133	183.8	.00544
94	260	.00384	134	182.5	.00548
95	257	.00389	135	181.1	.00552
96	255	.00393	136	179.8	.00556
97	252	.00397	137	178.5	.00560
98	249.5	.00401	138	177.2	.00564
99	247.0	.00405	139	175.9	.00569
100	244.5	.00409	140	174.6	.00573
101	242.1	.00413	141	173.4	.00577
102	239.7	.00417	142	172.2	.00581
103	237.4	.00421	143	171.0	.00585
104	235.1	.00425	144	169.8	.00589
105	232.9	.00429	145	168.6	.00593
106	230.7	.00434	146	167.5	.00597
107	228.5	.00438	147	166.3	.00601
108	226.4	.00442	148	165.2	.00605
109	224.3	.00446	149	164.1	.00609
110	222.3	.00450	150	163.0	.00613

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Table 3-4

Mol. wt.	1 mg/liter ppm	1 ppm, mg/liter	Mol. wt.	1 mg/liter ppm	1 ppm, mg/liter
151	161.9	0.00618	186	131.5	0.00761
152	160.9	.00622	187	130.7	.00765
153	159.8	.00626	188	130.1	.00769
154	158.8	.00630	189	129.4	.00773
155	157.7	.00634	190	128.7	.00777
156	156.7	.00638	191	128.0	.00781
157	155.7	.00642	192	127.3	.00785
158	154.7	.00646	193	126.7	.00789
159	153.7	.00650	194	126.0	.00793
160	152.8	.00654	195	125.4	.00798
161	151.9	.00658	196	124.7	.00802
162	150.9	.00663	197	124.1	.00806
163	150.0	.00667	198	123.5	.00810
164	149.1	.00671	199	122.9	.00814
165	148.2	.00675	200	122.3	.00818
166	147.3	.00679	201	121.6	.00822
167	146.4	.00683	202	121.0	.00826
168	145.5	.00687	203	120.4	.00830
169	144.7	.00691	204	119.9	.00834
170	143.8	.00695	205	119.3	.00838
171	143.0	.00699	206	118.7	.00843
172	142.2	.00703	207	118.1	.00847
173	141.3	.00708	208	117.5	.00851
174	140.5	.00712	209	117.0	.00855
175	139.7	.00716	210	116.4	.00859
176	138.9	.00720	211	115.9	.00863
177	138.1	.00724	212	115.3	.00867
178	137.4	.00728	213	114.8	.00871
179	136.6	.00732	214	114.3	.00875
180	135.8	.00736	215	113.7	.00879
181	135.1	.00740	216	113.2	.00883
182	134.3	.00744	217	112.7	.00888
183	133.6	.00748	218	112.2	.00892
184	132.9	.00753	219	111.6	.00896
185	132.2	.00757	220	111.1	.00900

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Table 3-4

Mol. wt.	1 mg/liter ppm	1 ppm, mg/liter	Mol. wt.	1 mg/liter ppm	1 ppm, mg/liter
221	110.6	0.00904	261	93.7	0.01067
222	110.1	.00908	262	93.3	.01072
223	109.6	.00912	263	93.0	.01076
224	109.2	.00916	264	92.6	.01080
225	108.7	.00920	265	92.3	.01084
226	108.2	.00924	266	91.9	.01088
227	107.7	.00928	267	91.6	.01092
228	107.2	.00933	268	91.2	.01096
229	106.8	.00937	269	90.9	.01100
230	106.3	.00941	270	90.6	.01104
231	105.8	.00945	271	90.2	.01108
232	105.4	.00949	272	89.9	.01112
233	104.9	.00953	273	89.6	.01117
234	104.5	.00957	274	89.2	.01121
235	104.0	.00961	275	88.9	.01125
236	103.6	.00965	276	88.6	.01129
277	103.2	.00969	277	88.3	.01133
238	102.7	.00973	278	87.9	.01137
239	102.8	.00978	279	87.6	.01141
240	101.9	.00982	280	87.3	.01145
241	101.5	.00986	281	87.0	.01149
242	101.0	.00990	282	86.7	.01153
243	100.6	.00994	283	86.4	.01157
244	100.2	.00998	284	86.1	.01162
245	99.8	.01002	285	85.8	.01166
246	99.4	.01006	286	85.5	.01170
247	99.0	.01010	287	85.2	.01174
248	98.6	.01014	288	84.9	.01178
249	98.2	.01018	289	84.6	.01182
250	97.8	.01022	290	84.3	.01186
251	97.4	.01027	291	84.0	.01190
252	97.0	.01031	292	83.7	.01194
253	96.6	.01035	293	83.4	.01198
254	96.3	.01039	294	83.2	.01202
255	95.9	.01043	295	82.9	.01207
256	95.5	.01047	296	82.6	.01211
257	95.1	.01051	297	82.3	.01215
258	94.8	.01055	298	82.0	.01219
259	94.4	.01059	299	81.8	.01223
260	94.0	.01063	300	81.5	.01227

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Calculation of Per Cent by Volume

The calculation of concentration as per cent by volume is similar to the calculation of any percentage. The formula ordinarily used is:

$$\frac{\text{volume of contaminant}}{\text{total volume of air}} \times 100 = \% \text{ by volume}$$

In this calculation, it makes no difference which units of volume are used as long as they are the same for both the volume of contaminant and the total volume of air.

The expression of concentration as per cent by volume is comparable to the expression of parts per million, except that per cent by volume is parts per hundred (volume of contaminant per hundred volumes of air). The calculation of per cent by volume can be done exactly as for parts per million except that the final factor of the multiplication is $10^2/10^2$ rather than $10^6/10^6$. In other words, the factor used in obtaining ppm is 10^4 greater than the factor used for per cent by volume. Thus, there is an exact and constant relationship between these two expressions of concentration, and

$$\% \text{ by vol} \times 10{,}000 \text{ (or } 10^6) = \text{ppm}$$

Because per cent by volume is a much larger unit than ppm, per cent by volume is usually used for expressing relatively high concentrations of contaminants in air, and ppm is much more frequently used in industrial hygiene evaluations.

Density of Liquids and Gases

The density of a substance is defined as the mass of that substance per unit volume of the substance. This may be expressed in a number of ways. Sometimes weight is used interchangeably with mass since the materials are being dealt with when they are under the influence of gravity. The following terms for expressing density are commonly encountered:

grams per cubic centimeter	g/cm^3
grams per liter	g/liter
kilograms per liter	kg/liter
pounds per cubic foot	lb/ft^3
pounds per gallon	lb/gal

To obtain the density of a solid, liquid, or gas, determine the weight of a known volume and divide by the volume.

Another expression, specific gravity, is closely related to density; however, there is a certain distinction that must be remembered. The specific gravity of a substance is the weight of a given volume of that substance compared to the weight of an identical volume of a reference substance.

In most work with solids and liquids, specific gravity is expressed in relation to the weight of an equal volume of water at a specified temperature. Inasmuch as materials expand and contract with changes in temperature, their volumes change so that very precise expressions of specific gravity must also specify temperature.

Most often the reference used is water at 4°C. At this temperature the density of water is so close to one gram per cubic centimeter that specific gravity and density expressed as grams per cubic centimeter are identical for all practical purposes. For most industrial hygiene calculations, the specific gravity of solids and liquids can be considered to be the same as density.

The term specific gravity is also used with reference to gases, particularly air; however, the reference point in this instance is standard air or air at 70°F and 760 mm of mercury. Under these conditions air has a density of 0.075 lb/ft^3. Thus, a mixture of gases and vapors having a specific gravity of 1.35 would be 1.35 times as heavy or dense as standard air, and its density would be calculated as follows:

specific gravity of gas x 0.075 = density in lb/ft^3 or

$1.35 \times 0.075 = 0.101$ lb/ft^3

Explosive Limits

A flammable vapor or gas mixed with air in appropriate proportions will form an explosive mixture. If the concentration of the flammable vapor is either smaller or greater, it will not propagate an explosion. Therefore, there are two limiting concentrations, one *above* which no explosion will take place and the other *below* which no explosion will take place.

The concentrations of these explosive limits are usually expressed in terms of per cent by volume. They are of concern to the industrial hygienist because of the need for safety and because some of the instruments used for the measurement of combustible vapors are calibrated in terms of per cent of the lower explosive limit.

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Of course, it is the safer practice to provide ventilation such that concentrations are kept below the lower explosive limits. Even highly flammable explosive vapors have lower explosive limits on the order of 1% by volume or more, which corresponds to concentrations of 10,000 ppm or more. With very few exceptions, the Threshold Limit Values of health significance for various vapors and gases are well below 1,000 ppm. Thus, if safe exposure levels are maintained for reasons of health, they will almost certainly be safe levels with respect to the possibility of explosion.

For example, benzene's lower explosive limit is 1.3% by volume and its upper explosive limit is 7.1%. These correspond to 13,000 ppm and 71,000 ppm respectively, whereas the same limit for protection of health is set at 10 ppm.

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Chapter IV
Contaminants

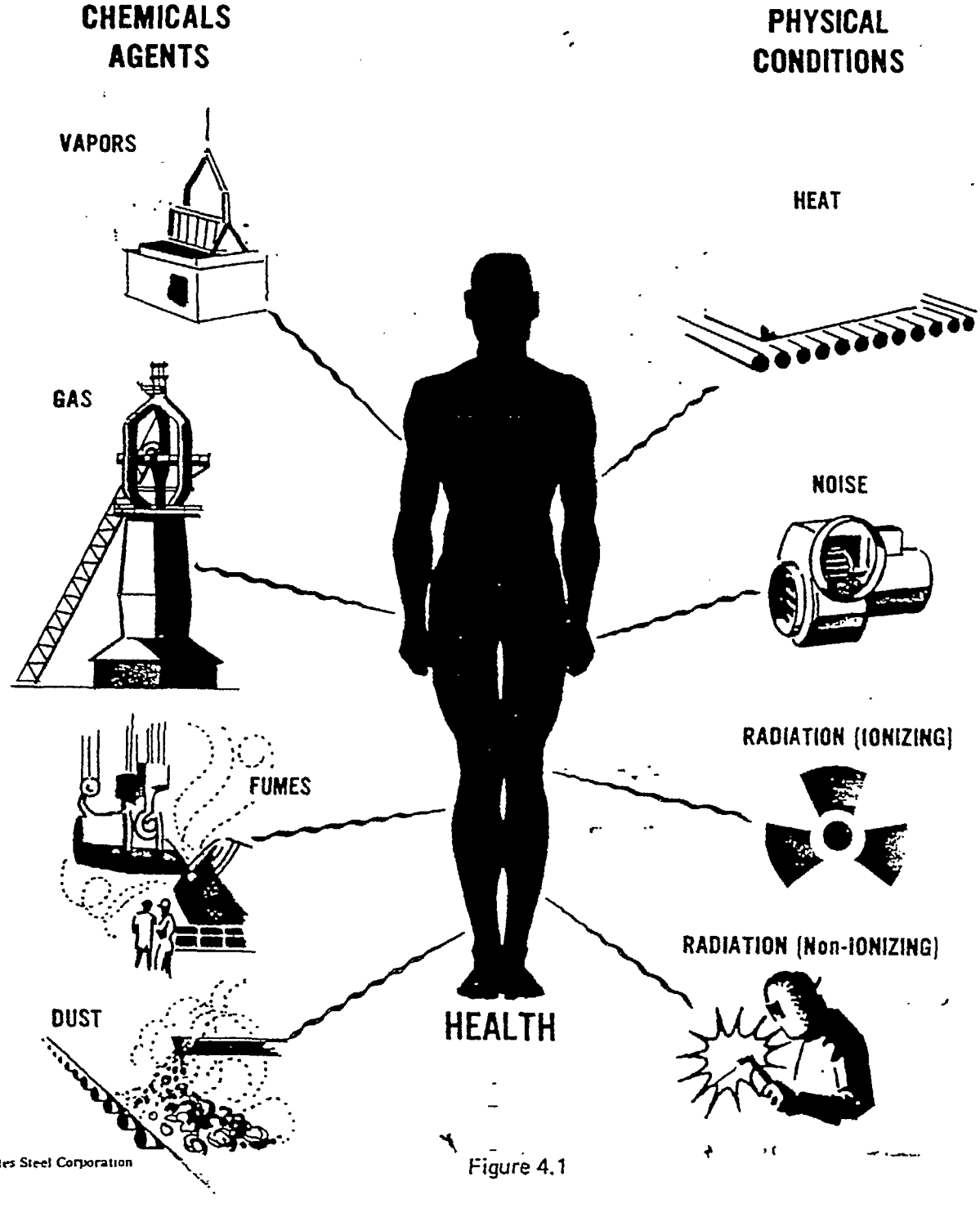
Chapter IV

CHEMICAL AND PHYSICAL AGENTS

Man is exposed to air contaminants and physical hazards every moment of his life. They are present in the home, in the community, and in the work place. Generally, they are found in greater variety, and with more significant exposure, in industry. But the role of the home environment cannot be overlooked, if the individual frequently handles insecticides and pesticides, or engages in home maintenance and workshop activities.

Steel, construction, coal and coke chemicals, and cement operations utilize raw materials and processes from which air contaminants and physical hazards develop, which may require periodic monitoring. These potential chemical and physical hazards are dust, fumes, vapors, gases and mists, as well as noise, heat, vibration, and ionizing and non-ionizing radiation.

Some typical operations which may be



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Figure 4.1

AIR CONTAMINANTS FROM VARIOUS PROCESSES

Process	Contaminant Types	Typical Chemical Composition
Coal Handling	Dust	coal, free silica
	Gas	sulfur dioxide, carbon monoxide
Coking	Gas	carbon monoxide, ammonia, hydrogen sulfide, sulfur dioxide, phenols, cyanides, naphthalene and other polycyclics, benzene, pyridine, carbon disulfide
Coke Handling	Dust	coke, free silica
Ore Handling	Dust	iron oxide, free silica, carbonates, silicates, fluorides
Sintering	Dust	iron oxide, free silica, fluorides
	Gas	sulfur dioxide, carbon monoxide
BOF (OSM) Material Handling	Dust	iron oxide, graphite, limestone, ore, mill scale, fluorspar
Ferromanganese Handling	Dust	ferromanganese
	Gas	hydrogen
Furnace Operations (all types)	Dust, Fume	iron oxide, other metal oxides
	Gas	sulfur dioxide, carbon monoxide, other combustion products
Leaded Steelmaking	Fume, Dust	lead oxide, iron oxide
Foundry Operations	Dust	free silica
	Gas	acrolein
Tandem Mills	Mist	oil mist
Scarfing (hot conditioning)	Fume, Dust	iron oxide, alloying metal oxides (e.g., lead)
	Gas	oxides of nitrogen
Pickling	Mist	sulfuric acid, hydrochloric acid
	Gas	hydrogen chloride, oxides of nitrogen, hydrogen fluoride
Lead Patenting	Fume, Dust	lead oxide
Galvanizing	Fume	zinc oxide, ammonium chloride, lead oxide
	Gas, Mist	hydrochloric acid, chromates, hydrogen chloride
Electro-Tinning		
Halogen	Mist	fluorides, chromates
Alkaline	Mist	sulfuric acid, caustics, chromates
Welding	Fume	iron, chromium and manganese oxides, fluorides, oxides of metals welded
	Gas	ozone, oxides of nitrogen, pyrolysis-products from coatings
Metallizing	Dust, Fume	metals and oxides of metals sprayed
	Gas	carbon monoxide
Solvent Degreasing	Vapor	trichloroethylene, perchloroethylene, others
	Gas	vapor decomposition products (e.g., phosgene)
Spray Painting	Vapor	organic solvents
	Dust, Mist	lead, chromates, other pigments
Refractories Handling	Dust	free silica
Babbitting	Fume, Dust	lead oxide, zinc oxide, antimony oxide, tin oxide
Maintenance Cleaning	Vapor	organic solvents
	Mist, Dust	caustic

Figure 4.2

sources of chemical agents and physical factors are shown in Figure 4.1. Their mere existence does not mean that they constitute hazardous conditions. They must be present in a sufficient concentration or intensity, and the individual must be exposed to them over a sufficient period of time, for a hazardous exposure to occur. However, their existence does constitute a potential hazard which can be evaluated only by proper testing of the work environment.

The general methods used to determine the magnitude of the environmental hazards are sampling of air contaminants, and measurement of the intensity of physical factors. These tests are necessary to provide data with which to evaluate work conditions and the exposure of workers in relation to federal, state, and local government standards. It is necessary to have some understanding of the physical form (dust, gas, etc.) and the basic properties of air contaminants and physical agents to insure that the environmental measurements are representative, useful, and accurate.

The Nature of Air Contaminants

"Pure" air has a fixed composition. It contains about 78% nitrogen and 21% oxygen, with very small amounts of argon (0.9%), carbon dioxide (0.03%), and rare gases (0.003%). The rare gases include neon, helium, krypton, hydrogen, xenon, radon, ozone, oxides of nitrogen, and acetylene. In addition, the air may contain water vapor, methane and other hydrocarbons. Any increase in the concentrations above those indicated, or the presence of any other substance, may be regarded as air contamination.

The possibilities of such contaminants are legion. As a matter of fact, the air of the home, the community, the work environment, and even the air high above the earth, is always contaminated, since some dust or extraneous gas is present. Such contaminants arise from human activity, natural phenomena and other sources, although the degree of such contamination is usually small.

All contaminants, except the physical agents (noise, heat, radiation), are present in the air as either small particles or gases and vapors. Many substances can be present in the air, both as particles and as vapors, at the same time – for example, water vapor and fog, or metallic fumes and metallic dust. An exact distinction between particles and gases is difficult, especially when the particles are extremely small but, in general, particles can be collected by filters and gases cannot. A further complication may arise in that gases or vapors may adhere to particles by processes known as absorption and adsorption. The effect of such entrainment is that, although a gas may not be collected by a filter, particles with gases adsorbed on them are retained on a filter.

The types of air contaminants which can arise from various processes common to steel and allied operations are shown in Figure 4.2.

Particulates (Dust, Fumes, Mists)

The most obvious air contaminants are usually the small particles which reduce visibility and hence may be observed with the unaided eye. Generally, the particles themselves are far too small to be seen but, as particulate matter, they absorb or scatter light, so that the air is seen as "dirty" or "smoky". Particulate matter, frequently shortened to "particulates", is the term generally applied to small particles, either liquid or solid, in the air. Another term which means the same thing, but is less widely used, is "aerosols". People usually associate aerosols with pressurized spray cans; however, the term is not limited to clouds of small droplets, but refers to any suspension of fine liquid or solid particles in the air.

As shown in Figure 4.3, particulates may range in size from less than one micron (μ) to 10 or more microns in diameter. In Chapter II, it was stated that the common unit of length for small particles is the micron, which is approximately 1/25,000 of an inch. Since 1-micron particles are much too small to be seen by the naked eye, they can only be viewed under a microscope. Figure 4.4 shows the comparative sizes of common particulates and other materials.

It is often said that particles greater than about 5 microns in diameter do not reach the lung, and that the very smallest particles are not effectively deposited in the lung because they tend to behave like gases. These very small particles are drawn into the lung during inhalation, but most are expelled during exhalation.

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SIZES OF TYPICAL AIRBORNE PARTICULATES

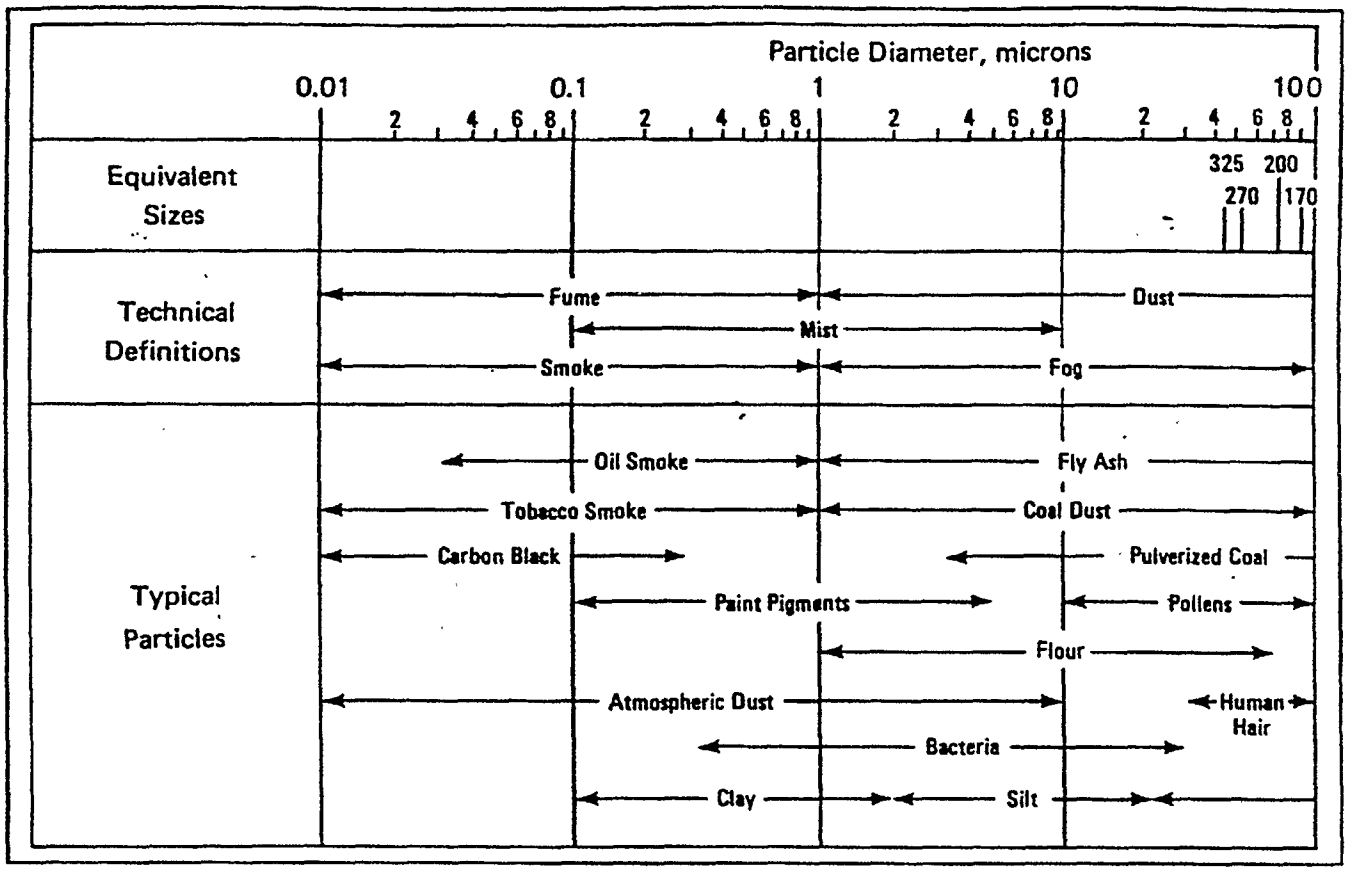


Figure 4.3

It has been shown that particles ranging from several tenths of a micron to about 5 microns are most effective in entering and being retained in the lung. Therefore, the particulates in this size range are potentially the most hazardous. For this reason, when speaking of pneumoconioses-producing dusts, the concept of "respirable dust" and "respirable dust samplers" has developed. Samplers of this type are discussed in Chapters VII and VIII.

Generally, when particles are substantially larger than 10 microns in diameter, they are not of great concern because they do not remain airborne and, fortunately, they are unable to penetrate in the lung where they could be damaging. Instead, they are removed, and collected, by the nasal passages or upper respiratory system, where they may be disagreeable or irritating. However, toxic dusts or fumes may enter the bloodstream by absorption through the respiratory system, or they may be absorbed after being swallowed and, in either case, systemic poisoning can develop.

Particulates are usually divided into several classes. The most commonly used terms for solids are dust, fumes and smoke; for liquids, mists and fogs. In general, dusts are coarser than fumes, and fumes are somewhat larger than most smokes. Mists are generally larger than fogs, and range from extremely small droplets to droplets sufficiently large that they approach a fine drizzle.

Dusts are small particles of solid matter which have been dispersed into the air by such processes as grinding, crushing, pulverizing, mechanical attrition, etc. When viewed under a microscope, dusts tend to be very irregular in shape and to occur in a wide range of sizes. In the air, the very largest particles settle out almost immediately and can be seen on window ledges, floors, equipment surfaces, etc. The finer particles remain airborne almost indefinitely and are carried wherever air currents take them.

Most dusts are mineral substances, and many dusts and organic substances are of

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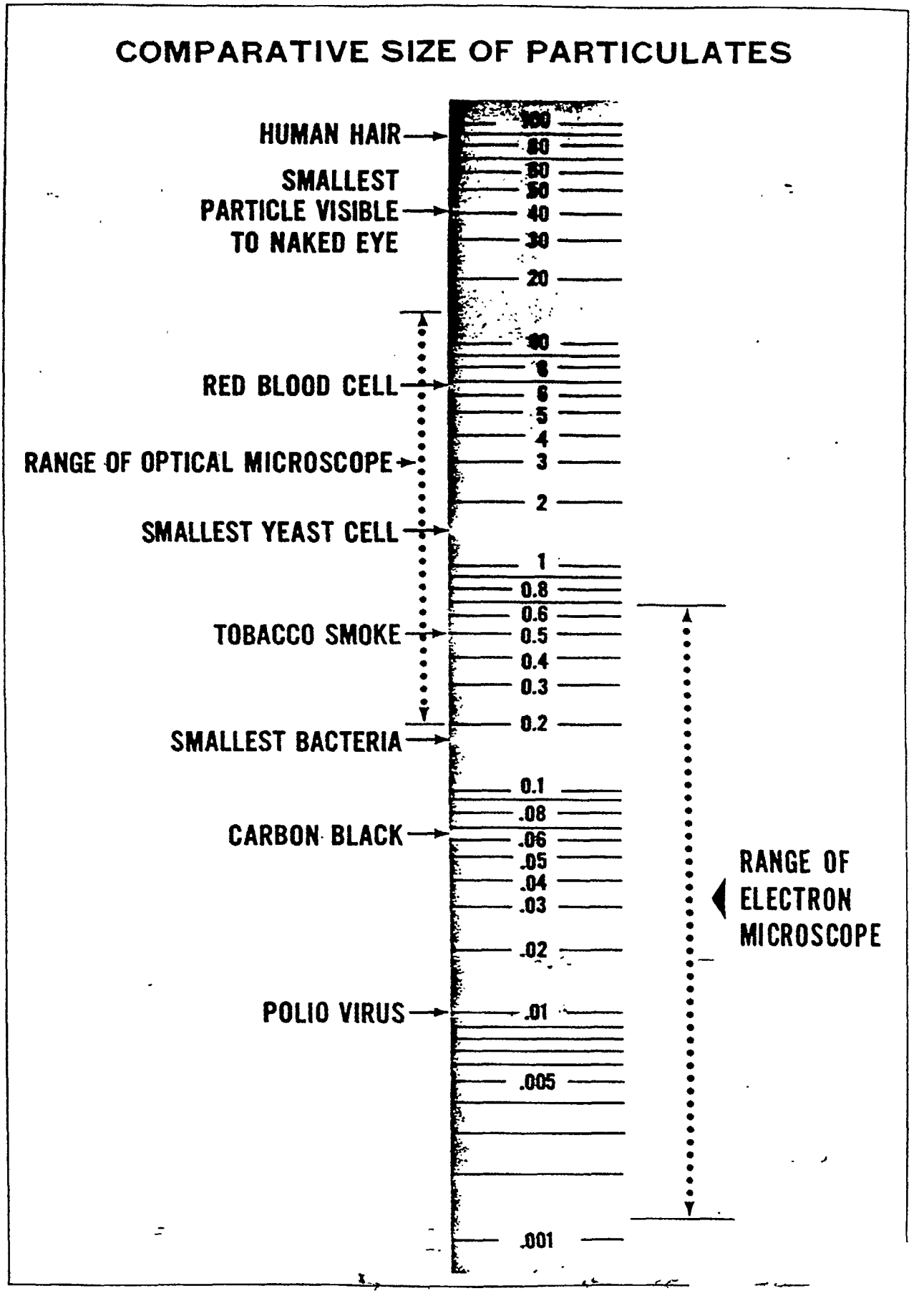


Figure 4.4

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industrial origin. In very high concentrations, clouds of fine dust are well known as potential explosion hazards. However, health hazards may be caused by concentrations many times lower than explosive concentrations. For example, a U. S. Bureau of Mines investigation has indicated that the minimum explosive concentration for manganese dust is 210,000 mg/m^3, whereas the TLV for manganese dust is 5 mg/m^3.

Some of the major sources of dust in steel and other operations (Figure 4.5) are associated with raw materials (ore, limestone, coal and coke), refractories, foundry operations, sintering and pelletizing, blast furnace and steel furnace operations, cement production, and chemical and fertilizer operations.

Fumes are small particles which have condensed in the air. Fumes are created when a solid substance, such as a metal, is heated to such an extent that it vaporizes and then condenses to form small particles. The most common fumes are metallic and, due to reaction with oxygen in the air, are usually metallic oxides. Freshly formed fumes are extremely fine and, although they grow in size in air, they tend to remain in the respirable size range. Some of the major sources of fumes in the steel industry (Figure 4.6) are from melting operations (electric and BOP furnaces), welding, scarfing, scrap preparation, rolling mills, etc.

Smoke consists of fine particles which are of a size substantially less than one micron, and whose chemical composition is generally very complex. Smoke usually results from incomplete combustion, although chemical smoke can be formed by other reactions. A black smoke may consist of soot (carbon) particles, while other smokes may be primarily small particles containing the mineral residue of the substance being burned. Some of the major sources of smoke (Figure 4.7) include the incomplete combustion of organic materials such as ingot mold coatings, coal, oil and grease lubricants, and flux chemicals.

Mists are made up of liquid particles that have been dispersed into the air. Generally, this dispersion is the result of atomization of a liquid, as in spray painting. In addition, mist can also be caused by a boiling solution or by the release of a gas from solution. Such mist

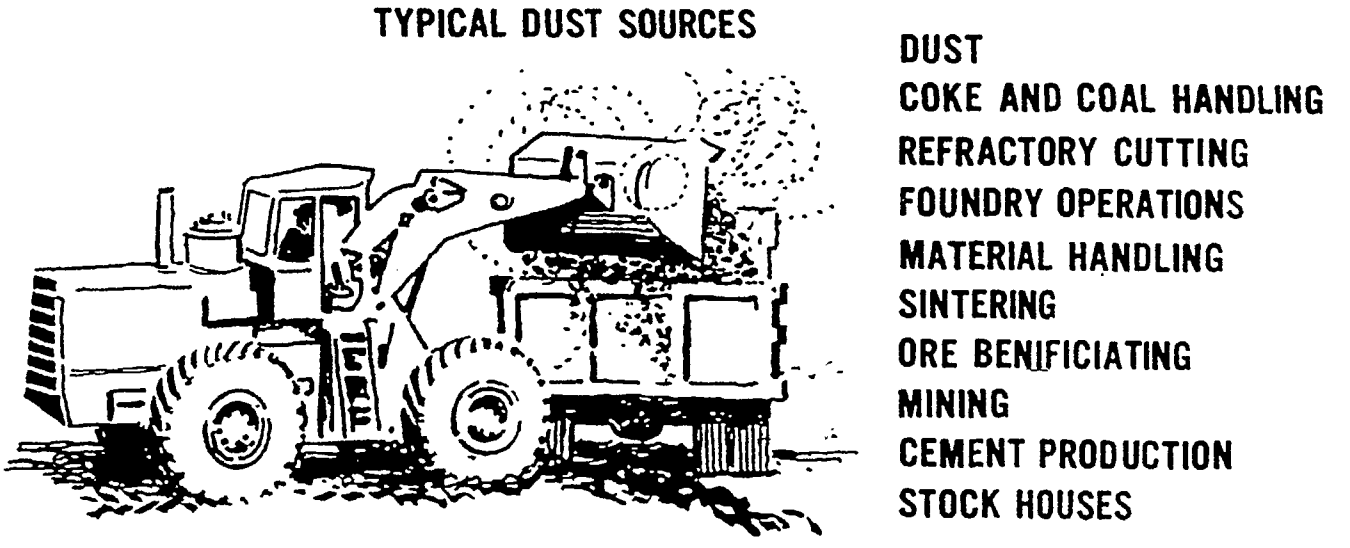


Figure 4.5

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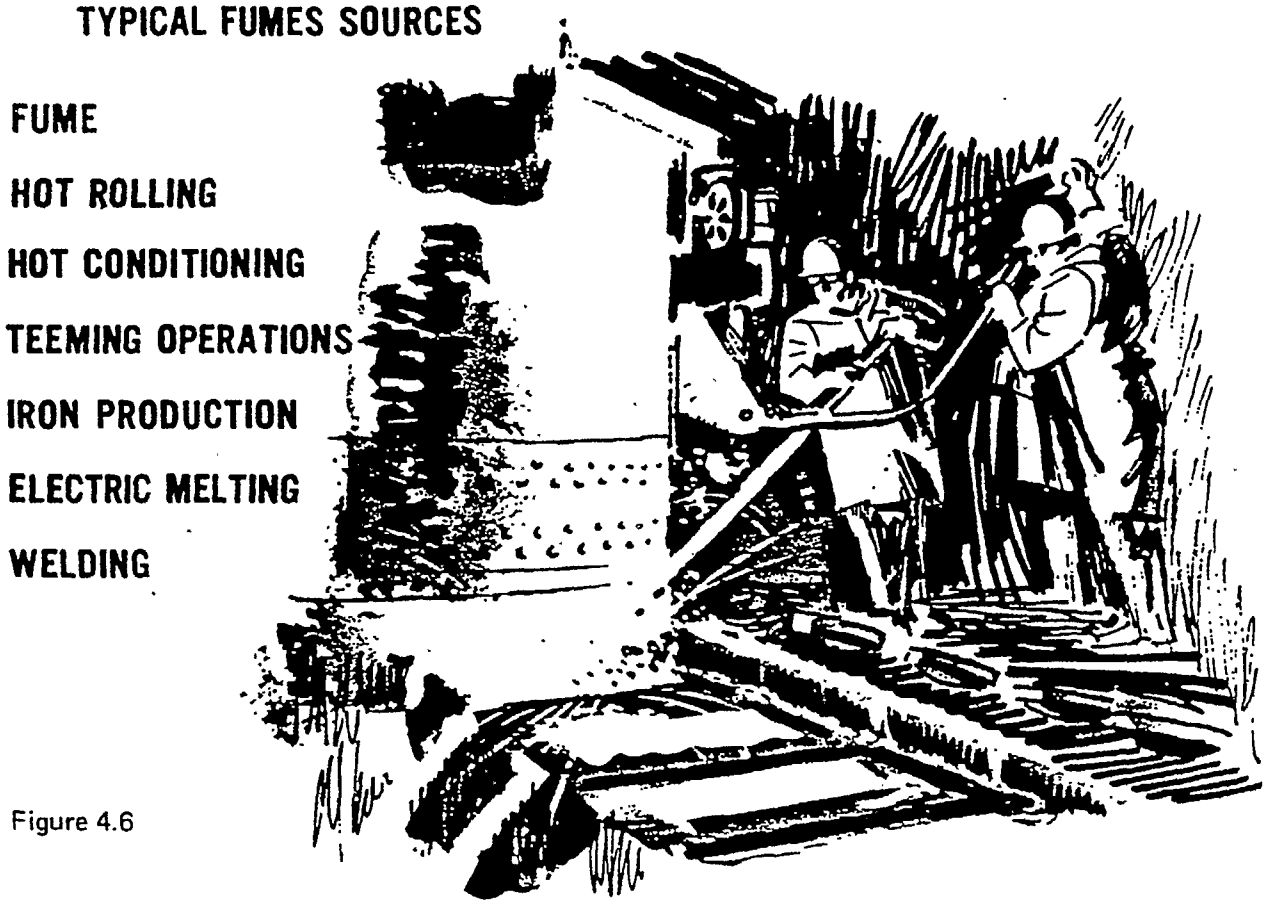


Figure 4.6

consists of very small droplets suspended in the air. The droplet can be water containing dissolved chemicals, such as acids or alkalies, or be a single material such as oil. Depending upon their size and chemical nature, mists may be very irritating to the upper respiratory tract, or may penetrate deeply into the lungs and cause tissue damage.

Some of the major sources of mist in the steel industry (Figure 4.8) include pickling, plating, spray painting and lubricating oils.

Gases and Vapors

In environmental health and industrial hygiene, a substance is considered a gas if this is its normal physical state at normal room temperature and atmospheric pressure. A vapor is the gaseous state of a substance which is ordinarily a liquid or solid at normal room temperature and atmospheric pressure. Thus, carbon monoxide is a true gas because it is never found as a liquid at room temperature while benzene, a liquid at room temperature, evaporates to form a vapor.

In reality, the distinction between gases and vapors is vague. Both have the ability to diffuse (mix) readily into other gases or vapors and to distribute readily and with almost complete uniformity throughout the whole of a container.

Most gases and vapors are colorless at low concentrations and, hence, invisible. Many – such as hydrogen sulfide, sulfur dioxide and ammonia – have characteristic odors and are readily detected by smell. Odorless gases, such as carbon monoxide, cannot be positively detected except by sampling and analysis.

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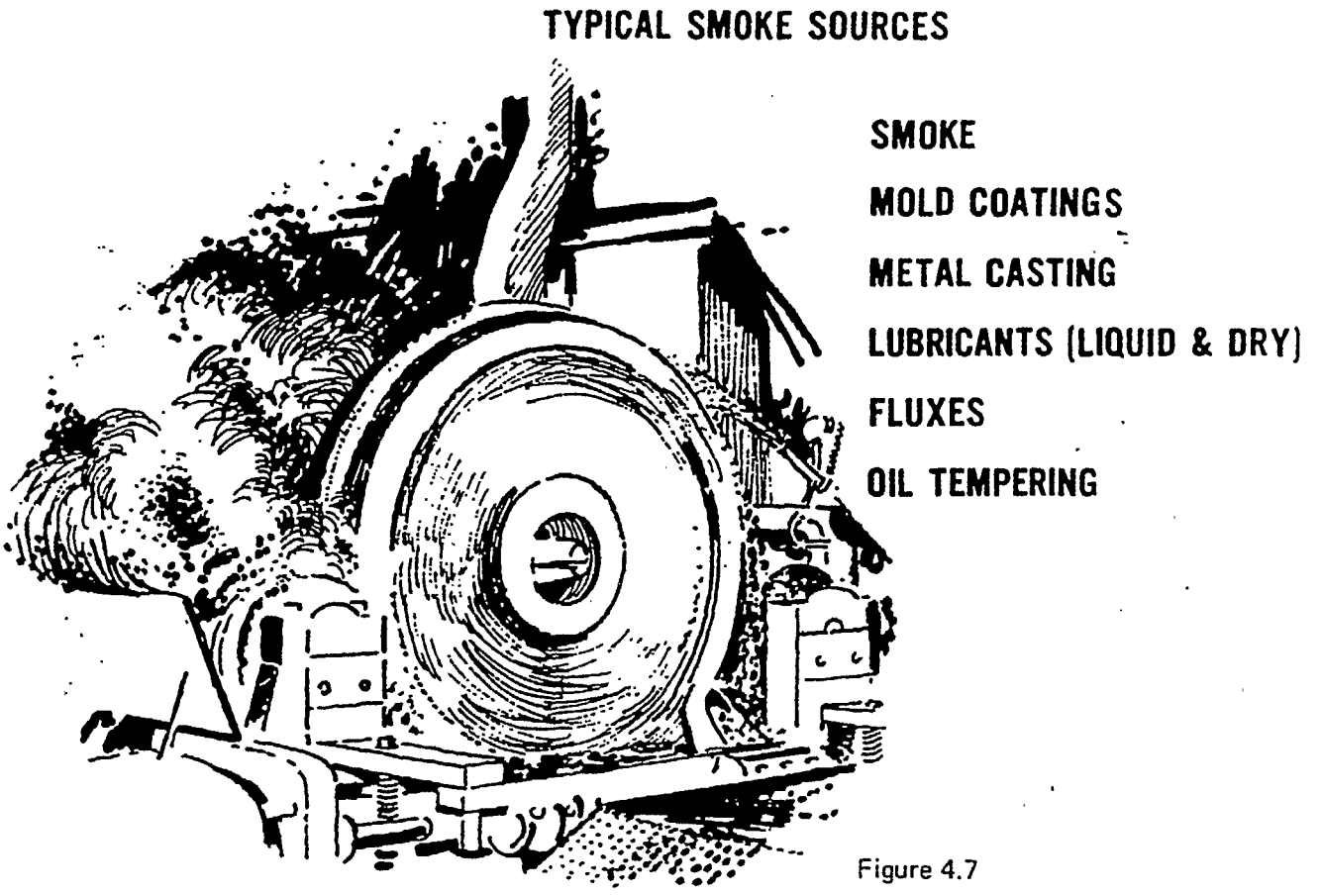


Figure 4.7

Gases and vapors are present in the air as individual molecules. Since molecules are too small to be collected by filters (Figure 4.9), some other method is required to collect them for analysis. These methods will be discussed in Chapter IX. All gases can be drawn into the lung where they may be either absorbed into the blood, or exhaled, depending upon their solubility and other properties. Some gases, such as sulfur dioxide, are irritating and affect both the upper respiratory system and the lung. Others are completely non-irritating and, as in the case of carbon monoxide, are absorbed by the blood and become potentially damaging as a result of their toxicity.

As noted earlier, gases and vapors may adhere to particles and exert an effect which is out of proportion to their actual concentration in air. Frequently, particles which hold onto small amounts of sulfur dioxide, for example, are potentially more damaging than either the particles by themselves or the sulfur dioxide by itself. The number and complexity of possible mixtures of gases and vapors is so great that knowledge of their effects is very incomplete.

Some of the major sources of gases and vapors in the steel industry (Figure 4.10) are (gases) in the blast furnace, welding and annealing areas, and (vapors) from the solvents used to clean products and equipment. In the coal-chemical areas, there are both gases, such as hydrogen cyanide, hydrogen sulfide and sulfur dioxide, and vapors such as those from light oils (BTX), naphthalene, etc.

Effects of Air Contaminants

Air contaminants can affect the body through various physiological actions, and some authorities classify them as: irritants, asphyxiants, anesthetics and narcotics, systemic poisons, and particulate matter other than systemic poisons. However, the physio-

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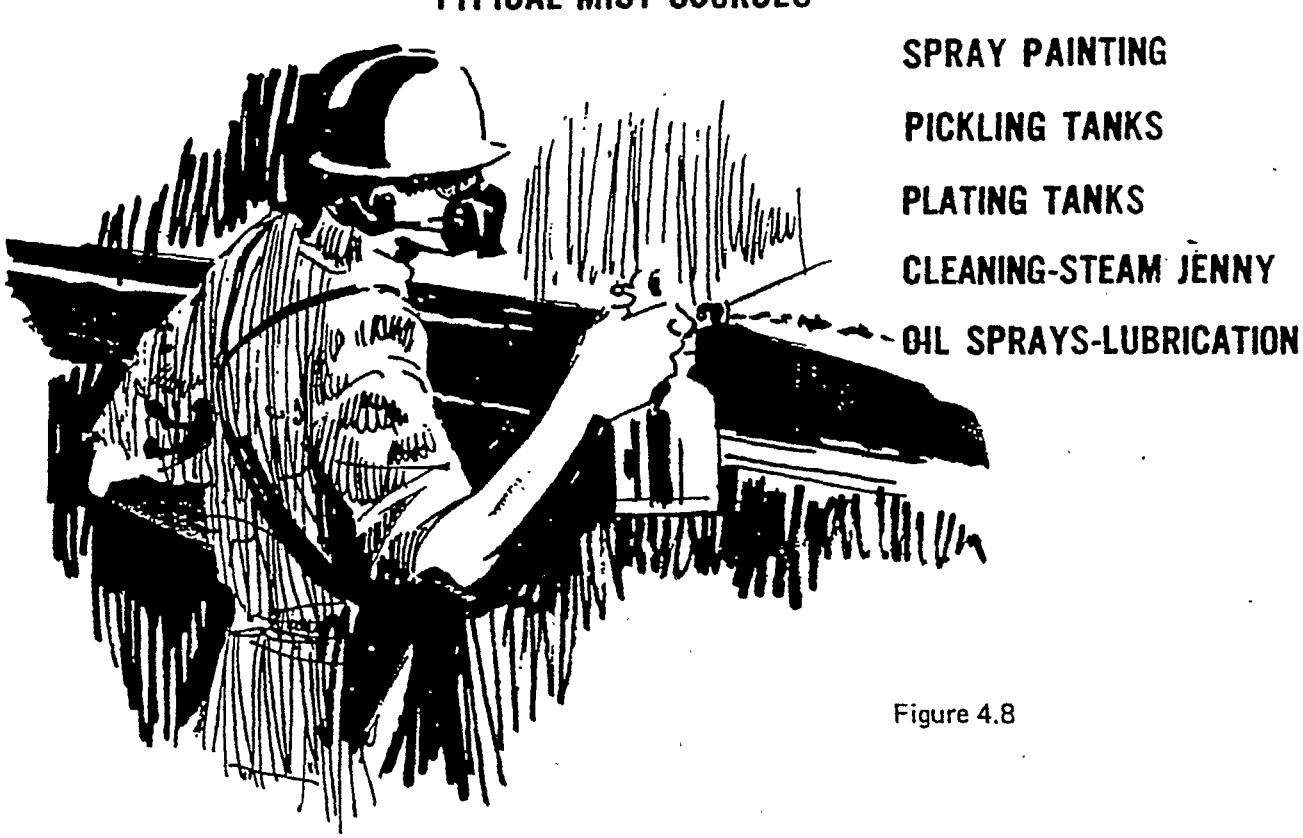


Figure 4.8

logic responses, especially to many gases and/or vapors, depend upon concentration and time of exposure. For example, a vapor or gas at one concentration may exert its principal action on the body as an anesthetic, while at higher concentrations the same gas or vapor may injure the central nervous system, some internal organ or the blood system. So while a particular air contaminant may be classified in only one category, it is possible that it just as logically could be included in one or more other categories as well.

Irritant materials are corrosive in their actions. Generally, they inflame moist or mucous surfaces and the concentration factor is of far greater importance than the time (duration of exposure) factor. Examples of irritant materials are: aldehydes, alkaline dusts and mists, ammonia, sulfur dioxide, chromic acid, sulfuric acid, hydrogen chloride and hydrogen fluoride. These affect chiefly the upper respiratory tract. On the other hand, irritants such as bromine, chlorine, fluorine, ozone and sulfur chlorides affect both the upper respiratory tract and lung tissues. Nitrogen dioxide and phosgene are two which affect primarily the terminal respiratory passages and air sacs and, because their action frequently causes asphyxial death, they are related to chemical asphyxiants.

Asphyxiants exert their effects by interfering with oxygenation of the tissues with the result that the individual may literally suffocate. This class is generally divided into simple asphyxiants and chemical asphyxiants. Simple asphyxiants are inert gases that act principally by lowering the oxygen content in air to a level where it will no longer support life. Chemical asphyxiants either prevent the blood from transporting oxygen from the lungs, or prevent normal oxidation of the tissue by chemical action (although the blood is well oxygenated). Carbon dioxide, hydrogen, helium, methane, nitrogen and nitrous oxide are examples of simple asphyxiants. Chemical asphyxiants include carbon monoxide, which combines with hemoglobin in the blood at the expense of oxygen; hydrogen cyanide and cyanogen, which inhibit the utilization of oxygen by the body; aniline and methyl aniline, which form methemoglobin;

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THE SIZES OF AIR-BORNE CONTAMINANTS

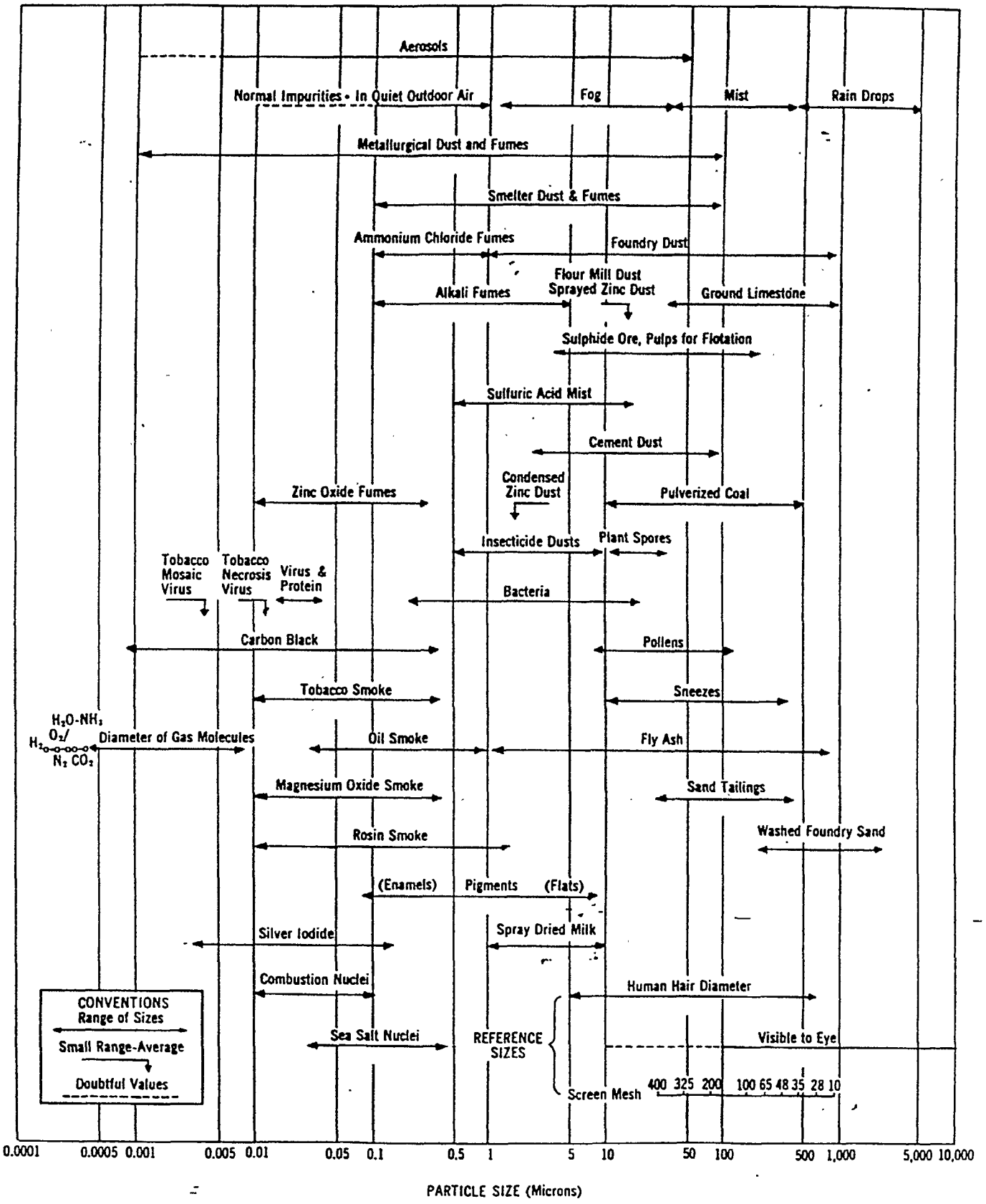


Figure 4.9

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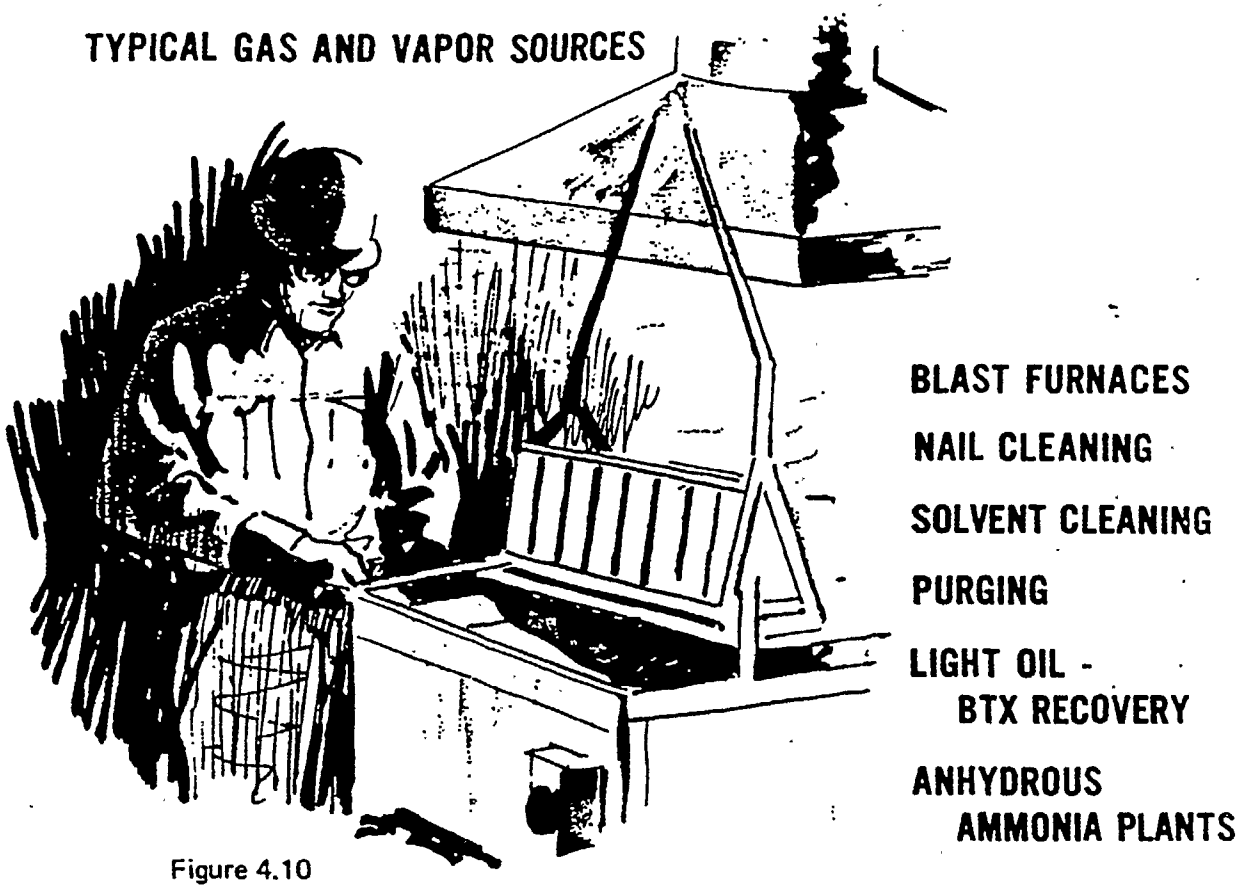


Figure 4.10

and hydrogen sulfide, which causes respiratory paralysis.

Anesthetics and narcotics exert their principal action by causing simple anesthesia without serious systemic effects unless the dose is massive. They have a depressant action on the central nervous system. This group includes: aliphatic alcohols (ethyl, propyl, etc.); aliphatic ketones (acetone, methyl, ethyl, ketone, etc.); acetylene hydrocarbons; and ethers (ethyl, isopropyl, etc.).

Systemic poisons include toxic materials (particulates, gases and vapors) which may cause damage to various systems of the body. Examples of these systemic poisons include: toxic metals, such as lead, mercury, cadmium, manganese, etc.; toxic non-metals, such as compounds of arsenic, phosphorous, selenium, sulfur and fluorides; nerve poisons, such as carbon disulfide and methyl alcohol; materials which cause injury to internal organs, such as the majority of the halogenated hydrocarbons (carbon tetrachloride, etc.); and materials damaging to the blood system, such as benzene, phenols and, to some degree, toluene, xylene and naphthalene.

Particulate matter other than systemic poisons include: fibrosis- or pneumoconiosis-producing dust such as silica, asbestos, coal, etc.; inert dust such as carbon, calcium carbonate, limestone, marble, etc.; dust which causes allergic reactions, such as pollens, wood, resins, etc.; irritant dusts, such as acids, alkalies, chromates, etc.; and bacteria and fungi.

The President's Council on Environmental Quality has reported that about 2 million chemical compounds are known, and several thousand new chemicals are discovered each year. While most new compounds are laboratory curiosities which will never be produced commercially, several hundred are introduced into commercial use annually and are marketed for use in household products or in industrial processing.

Of particular concern are the metals, metallic compounds and synthetic organic compounds. These chemicals may enter the home in food preservatives, deodorants, cleaners, insecticides, etc.; and the user generally is unaware of, or pays little attention to, their potential hazards in this environment.

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While problems can arise in the industrial use of chemicals, industry has done a much better job of protecting workers than the general public – or workers themselves – are willing to admit. The fact is that any chemical hazard is preventable by the installation and maintenance of proper safeguards.

Effects of Exposure to Air Contaminants

The effects of over-exposure to air contaminants may be acute or chronic, local or systemic. The effect of a chemical hazard is considered acute when it appears with little time lag, such as within minutes or hours. For example, the effect of a direct exposure to blast furnace gas for a few seconds would result in an acute effect. On the other hand, chronic effects generally result from repetitive or continuous exposure over a period of months or years. They occur when the rate of detoxification in the body is less than the rate of accumulation of the harmful chemical. An effect is local in character if it harms only the part of the body in contact with it, as with an acid burn of the skin. A systemic effect is one which by the action upon one or more organs of the body changes the normal functioning of related organs that operate as a system. An example is the action of carbon monoxide upon the blood, or hydrogen cyanide upon tissue oxidation, and the ultimate effects of both upon the central nervous system.

Exposure to air contaminants can also be referred to in terms of acute and chronic exposure. The acute exposure generally has reference to exposure to very high concentrations over very short time periods, whereas chronic exposure involves repetitive or continuous exposure over long time periods (as in the case of chronic effects). Whether or not such chronic exposure is a potential health hazard generally depends upon the worker's time-weighted average exposure in relation to the TLV's. Usually, chronic exposure to materials at concentrations below the TLV's will not adversely affect the health of employees. However, at some concentrations in excess of the TLV's, it could be anticipated that chronic effects would begin to show. These effects might range from minor irritations to much more serious consequences, such as damage to the lungs or other internal organs, as a result of long-term exposure.

It should not be assumed that chronic effects of air contaminants are less serious than acute effects simply because they result from exposures to lower concentrations of toxic materials. In fact, the opposite may be true – although the onset of damage to health may be slow, the ultimate effect may be quite serious and irreversible.

The lung disease known as silicosis is a good example of a chronic effect. The inhalation of silica dust over a period of years can, if the concentrations are high enough, produce silicosis. Silicosis cannot be cured. It must be prevented. Fortunately, the damage from many substances is reversible and an employee removed from further exposure may recover his health completely. An example is chronic exposure to carbon monoxide.

Occupational Dermatitis

Occupational dermatitis (skin reactions) is a very common response to irritants in the work environment. This is because the skin is the largest organ of the body and the one most continuously exposed to chemical compounds. However, an equal opportunity for skin reactions occurs in the home environment because of the presence of many chemical compounds in aerosol sprays, deodorants, paints and solvents, and the like. The skin irritant and sensitizing potential of the environment influences, in large part, the severity of the skin reaction, but the level of personal hygiene practiced by workers is the major determinant of the frequency with which dermatitis occurs.

The causes of skin reactions can be classified into two general categories: (1) environmental factors, and (2) predisposing, or innate, factors.

Environmental Factors

The environmental agents of occupational skin reactions are primary irritants, sensitizers, and mechanical and physical agents (Figure 4.11). Chemicals are the most important of these, since they include the irritants and sensitizers, and are the materials potentially in more frequent contact with the skin. Petroleum and coal tar solvents, tar, pitch, greases, oils, paint thinners, epoxy formulations, acids, alkalies and maintenance cleaners, are among the common causes of skin reactions.

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The action of chemicals upon the skin is of two principal types: primary irritation, and sensitization. Primary irritation causes inflammation by reacting with the skin, or by dissolving or extracting from it the normal protective elements such as natural skin oils and the outer layer of the skin (keratin). Organic solvents and strong acids or alkalies are examples of chemicals which may cause primary irritation, if the duration of skin contact is sufficiently long. The resulting irritation is at the site of contact. Many strongly reactive chemicals can cause irritation after very short periods of contact as, for example, sulfuric and nitric acids, and caustic soda.

Sensitizers do not always cause demonstrable skin effects on first contact. Sometimes the effects may not appear until considerably later, even though the individual is in daily contact with the chemical. Examples of this group of chemicals are epoxy cements and phenolic plastics. Some chemicals such as pitch, tar, crude petroleum and petroleum waxes can, after years of exposure, cause skin growths which may become malignant in some persons who have not been provided with skin protection. Other chemicals are known as photosensitizers, i.e., they sensitize the skin to sunlight so that such persons more readily become sunburned. Coal tar pitch and crude petroleum are examples of photosensitizers.

Physical Factors

The physical agents that may cause skin reactions are radiation and abnormal heat or cold. Ionizing radiation emanating from radioactive materials and x-ray devices can cause skin burns. Similar effects can result from exposure to non-ionizing radiation, such as ultra-violet and infra-red, microwave and ultra-high frequency radiation. Exposure to abnormally cold temperatures can cause frost-

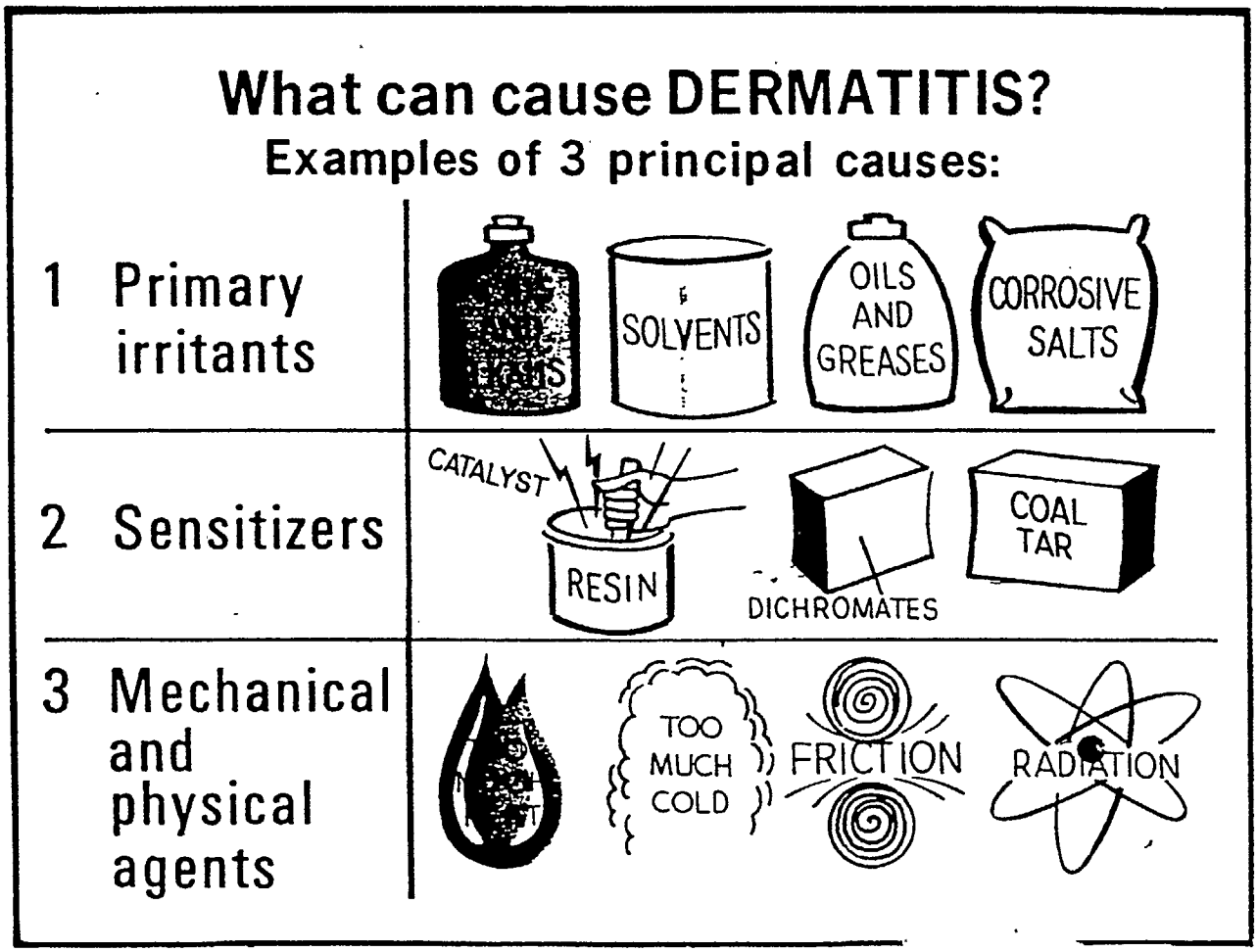


Figure 4.11

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bite, whereas over-exposure to heat or sunlight can cause excessive drying of the skin.

Mechanical Factors

Mechanical agents which can cause skin effects are friction, pressure and trauma. These effects take the form of abrasion, irritation, blisters, contusions or lacerations. The development of these conditions can also render the skin more susceptible to infection if the skin is broken.

Predisposing Factors

There are many innate factors which predispose an individual to greater-than-normal development of skin conditions of both occupational and non-occupational types. These factors are age, race, sex, skin texture, allergies and lack of cleanliness. Personal cleanliness is probably the most important of all factors. A dermatitis is related to the length of time the skin is in contact with a chemical or other agent. Persons who do not wash or bathe frequently, and do not wear clean work clothes, increase the duration of time during which the skin remains soiled.

Physical Agents and Conditions

Unlike air contaminants, the potential hazards due to physical agents and conditions in the environment cannot be classified as particulates or gaseous. They are best considered as residual energy being transmitted through the air or through a tool with which a worker is in contact. Some physical agents (such as noise, vibration, heat and illumination) may be detected by the senses, while others (such as ionizing and non-ionizing radiations) cannot.

Noise and vibration, heat and illumination are discussed in detail in subsequent chapters of this Manual. However, a brief introduction at this point may be helpful.

Noise

Noise is defined as unwanted sound. One reason it is unwanted is that excessive exposure to loud noise may cause hearing damage, depending upon the intensity of the noise and the duration of exposure. To prevent such occupational hearing loss, the Federal Occupational Safety and Health Administration has promulgated noise standards which limit employee exposure to a level of 90 dBA for an 8-hour-per-day exposure. Higher levels are permitted with a decrease in exposure time. Thus, for each halving of exposure time, the level of noise may be increased by 5 dBA, up to a maximum of 115 dBA. The term "dBA" is the intensity of noise, in decibels, as measured on the "A"-weighting network of a standard sound-level meter. Certain operations (Figure 4.12) are inherently noisy and should be evaluated periodically to determine if this standard is being exceeded. Noise instrumentation, measurement, sources and surveys will be discussed in detail in Chapter XI.

Vibration

Knowledge of the effects of vibration on workers is limited compared to knowledge of the effects of other physical agents and conditions. The information which does exist is derived mainly from research in aerospace medicine and from some studies on the effects of vibration on passengers and crews in commercial and military aviation. The vibration encountered in these areas is far greater than that associated with industrial exposures. It is partly because of the lack of sufficient knowledge that vibration standards for workers have not been developed. However, vibration is associated with noise, since noise is due to a vibrating source. Therefore, efforts to control vibration will also result in reducing noise.

Vibration may cause discomfort, decrease ability to perform tasks and, in some persons, cause motion sickness. Most research has been on the relationship of vibration to comfort in the frequency of 1-300 hertz (cycles per second). This range of vibration is above that which causes motion sickness. Resonances may develop in the body causing deformation of body tissues which can result in discomfort and, in the case of larger amplitudes, pain. Research into the effects on performance has included ability to respond to stimuli, ability to manually track a moving object on a screen by movement of a control stick, and ability to read numbers or dials. Intense vibration may cause neurovascular effects, or damage to bones and joints, or muscular numbness or pain.

Vibration criteria have long been in use by manufacturers in testing truck cabs and air-

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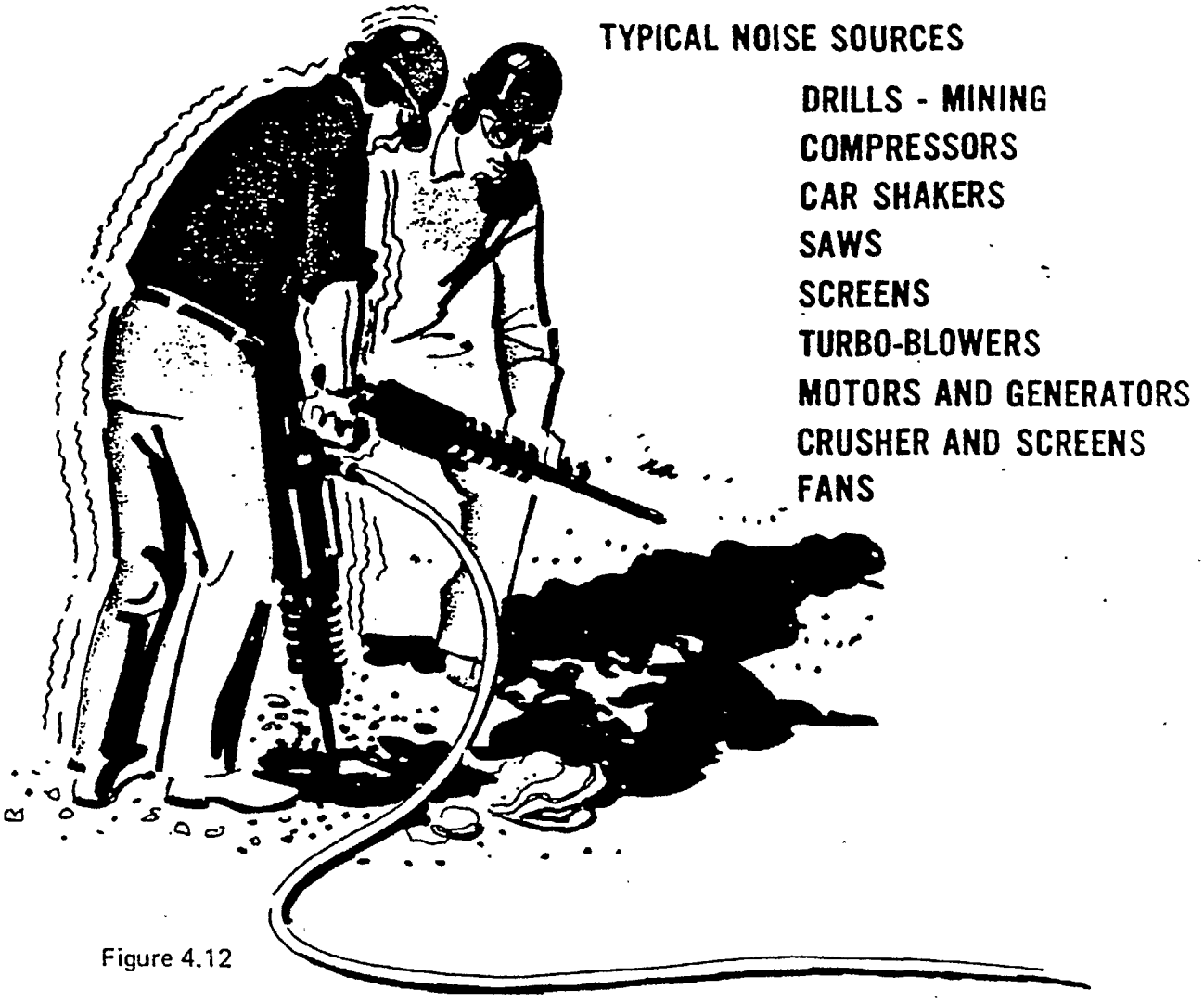


Figure 4.12

craft flight decks. They will be discussed in Chapter XI.

Heat

Without adequate protection, heat may adversely affect the efficiency and health of employees. Humans must maintain a body temperature of about 98.6°F. This body temperature is kept constant because heat produced by metabolism and heat absorbed from the environment are given off through radiation, convection or sweating. In extreme conditions of heat, the body is unable to give off excess heat, and the result is fatigue, loss of efficiency and sometimes physical collapse.

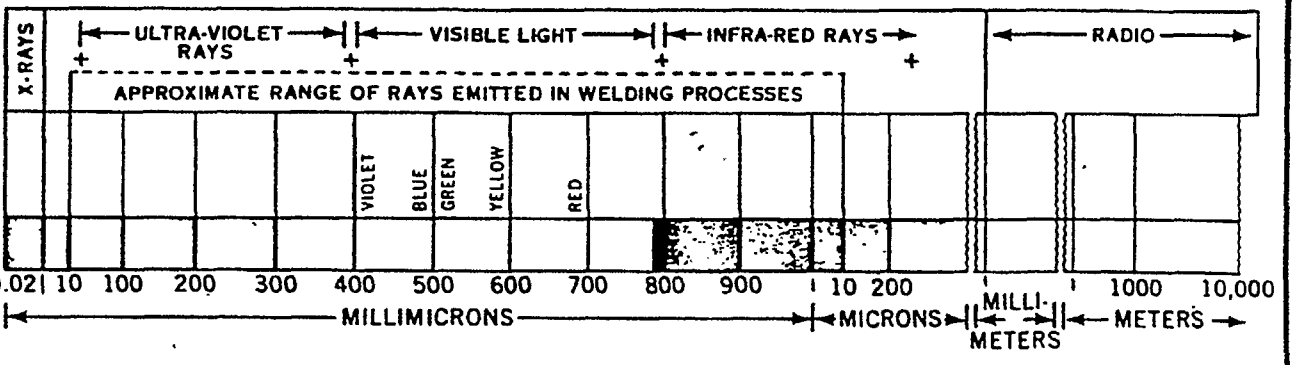
A good index of heat stress in hot areas is based upon effective temperature, which is determined by measuring the globe (radiant) temperature, velocity of air movement, and dry-and-wet bulb temperatures, and referring these measurements to appropriate charts. Recently, however, the ACGIH has published a proposed TLV applicable to heat stress. This is based upon the Wet-Bulb-Globe Temperature Index (WBGT). The WBGT is a function of natural wet-bulb temperature, dry-bulb temperature, and globe (radiant) temperature. The latter indices and the manner of making the necessary measurements will be discussed in Chapter XII.

Illumination

The task of seeing has become more demanding since the early days of mankind. Originally, man used his eyes almost entirely

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DIAGRAMMATIC CHART SHOWING RELATIONSHIPS OF WAVE LENGTHS OF VARIOUS FORMS OF RADIANT ENERGY TO VISIBLE LIGHT



NOTE: AS INDICATED BY THIS CHART. THE REGIONS OF RADIANT ENERGY OVERLAP AND THERE ARE NO SHARP BOUNDARIES BETWEEN THEM.

Figure 4.13

outdoors in bright daylight, and for simple long-range seeing tasks. Today, however, man generally lives and works indoors and very often is required to undertake close observations involving constant accommodation. Adequate illumination relieves the eyestrain which results from endeavoring to maintain good performance of varying visual tasks.

Adequate illumination is important in all industrial operations. While poor illumination is not generally considered a health hazard in the usual sense, it may be the cause of other problems. Faulty illumination may cause eyestrain and fatigue and in addition may create production and quality problems as well as adversely affecting safety conditions. Illumination levels, meters and surveys will be discussed in Chapter XIII.

Radiation

The term radiation as used in this chapter refers to a number of different types of energy of varying wave lengths which make up the electromagnetic spectrum (Figure 4.13). Non-ionizing radiation is part of this electromagnetic spectrum and includes, in addition to visible light, infra-red and ultra-violet light, lasers, microwaves, radio waves, etc. In general, the principle harmful effect of non-ionizing radiation is that it can cause burns to skin, eyes, and other organs.

Infra-red radiation lies just beyond the limit of the red portion of the visible spectrum; in other words, the wave lengths of the infra-red radiation are longer than those of visible light. The major problem associated with exposure to infra-red radiation is its heating effect. The effects of heat stress from infra-red radiation will also be discussed in Chapter XIII. Major sources of infra-red radiation include furnace operations, soaking pits, hot slabs and ingots, molten metal and kilns.

Ultra-violet radiations, in general, have shorter wave lengths than visible light, since ultra-violet light is in the range between violet

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light (400 millimicrons) and x-rays (150 millimicrons). The major problem areas associated with exposure to ultra-violet radiation are the eyes and skin. Excessive exposure of the eyes can produce serious damage, while sufficient skin exposure can result in "sunburn". Major sources of ultra-violet radiation in steel and related facilities are electrical and inert gas metal arc welding. Welding produces a wide range of radiant energy in both infra-red and ultra-violet areas.

Ionizing radiation is also part of the electromagnetic spectrum and refers to those wavelengths which produce electric charges in air or other matter with which they come in contact. The wavelengths of ionizing radiation lie below those of ultra-violet radiation. Although ionizing radiation is of extreme importance, it will not be dealt with in this Manual. The approval and control of devices which produce ionizing radiation are functions of the USS Radiation Committee which approves applications of this type of radiation, subject to adequate protective measures, and directs the monitoring of such devices through plant radiation committees.

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Chapter V
TLV's

TLV's - - LIMITS OF AIRBORNE CONTAMINANTS AND HARMFUL PHYSICAL AGENTS

On and off the job, everyone is exposed to a great variety of chemical and physical agents, most of which do no harm under ordinary circumstances, but all of which have the potential for being injurious at some level and under some conditions of exposure. How a material is used is the major determinant of the hazard potential. A gas line, for instance, may pose little hazard under designed conditions, but a ruptured gas line can create drastically altered conditions. A well known toxicologist has said:

> "Any substance contacting or entering the body will be injurious at some degree of exposure and will be tolerated without effect at some lower exposure."

The practice of industrial hygiene (environmental health) is based on the concept that for each substance there is a safe or tolerable lower level of exposure below which significant injury, illness or discomfort will not occur. The industrial hygienist protects the health of the worker by determining this safe limit of exposure for a substance and then controlling the environmental conditions so that exposure does not exceed that limit.

The Nature of Toxicity

The toxicity, or hazard properties, of a chemical refer generally to the capacity of the substance to injure an individual. Frequently the word poison is used to mean a substance with some capability of producing adverse reaction on the health or well-being of an individual. Whether or not any ill effects occur depends on: (1) the properties of the chemical, (2) the dose (the amount of the chemical acting on the body or system), (3) the route by which the substance enters the body, and (4) the susceptibility or resistance of the exposed individual.

There are four routes of entry or means by which a substance may enter or act on the body: (1) inhalation, (2) ingestion, (3) injection and (4) contact or absorption through the skin. Of these, inhalation is the most important insofar as serious and acute industrial poisoning is concerned, but contact of the skin with corrosive or irritating chemicals is the most frequently encountered. Ingestion of toxic materials occurs only through accidental or careless procedures in the industrial environment and, while it cannot be ignored, it is seldom a significant factor in exposure. However, there are multiple routes of entry to the body for some materials.

When a toxic chemical acts on the body or system, the nature and extent of the injurious response depends upon the dose received – that is, the amount of the chemical actually entering the body or system. This relationship of dose and response is shown in Figure 5.1. This is a generalized curve; an actual dose - response curve varies with the type of material and the response.

Response can vary widely and might be a cough, respiratory irritation, unconsciousness, or the death of an experimental animal. Typically, there would be no response up to a certain dose, then a gradually increasing response to an increasing dose. At the upper part of the curve, the increase in response to an increase in dose would diminish, and would gradually approach 100% response in all exposed animals or individuals. However, no such curve is precise, because there is great variation in the susceptibility or resistance of individuals to a fixed dose of any material and, in addition, the biological response covers a rather wide range of effects for any given dose.

In experimental work, some accidental exposures, or in the administration of medicine, the dose may be a certain quantity of the chemical administered at one time, such as in a pill, an injection, or an accidentally swallowed poison. In industry, time is a factor in most exposures, and *the dose* is the result of both the *concentration of the toxic agent* and the *duration of the exposure*. In exposures by inhalation of airborne materials, the dose is the concentration multiplied by the time (CT), and is roughly a constant for any given material and specified effect. The CT value can be used to provide a rough approximation of other combinations of concentration and time which would have about the same effect. Although this concept must be used very cautiously and cannot be applied at extreme conditions of either concentration or time, it is most important in setting limits

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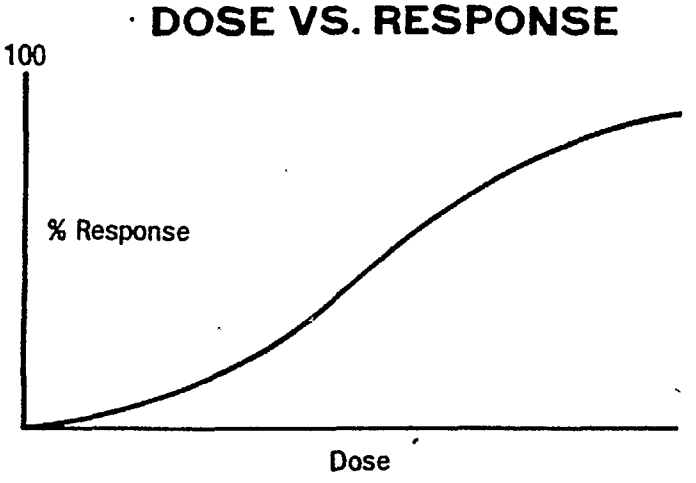


Figure 5.1

for airborne contaminants and physical agents in respect to environmental exposures. The worker is exposed for various periods of time, day after day, to the materials in his environment, and the safe limits are set so that the combinations of concentrations and durations are below the levels which will produce injury.

The concept of safe concentration limits, or standards for airborne contaminants, began almost sixty years ago when it was realized that the evaluation of environmental health hazards in industry required some knowledge of what constituted safe and unsafe conditions of exposure. Some work on the effects of various concentrations of different toxic materials had been done, particularly in Germany, since the late 1800's, but it was not until about 1920 that Patty compiled the first list of effects of exposures. His list contained information on concentrations which would produce death from exposures for periods ranging from several minutes to eight hours.

Over the next twenty years, various individuals proposed different limits, and some states, the U. S. Public Health Service, the American Standards Association (ASA), and the American Conference of Governmental Industrial Hygienists (ACGIH) began to develop limits or standards. In 1945, W. A. Cook compiled a list of concentration limits for 150 substances. The ACGIH adopted this list and developed an active program which continues to this day. The present list of chemicals for which the ACGIH has proposed limits of atmospheric contamination now includes about 500 chemicals.

The American National Standards Institute (ANSI, formerly ASA) is also active in the establishment of such limits. The American Industrial Hygiene Association (AIHA), and the Manufacturing Chemists Association (MCA) publish materials containing such proposed limits, but most of these are based on the limits proposed by one of the other organizations.

In the early development of such limits, they were generally known as Maximum Allowable Concentrations or MAC's, sometimes called Maximum Acceptable Concentrations, or Maximum Permissible Concentrations. The early concept was that these were values which must not be exceeded; in other words, they were truly maximum values. As the understanding of limits and the development of the philosophy for such limits grew, it was realized that short-term exposures to somewhat higher concentrations could be permitted without undue harm if the total exposure during the day was sufficiently below the maximum limit. This lead to the development of the concept of Threshold Limit Values (TLV's) by the ACGIH. The ANSI presently calls its standards Acceptable Concentrations (AC's) and in its definition it allows for some variability of exposure.

The TLV's, as recommended and published by the ACGIH, refer to concentrations of airborne contaminants or levels of physical agents, and represent the conditions to which it is believed nearly all workers may be repeatedly exposed day after day without

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adverse effects. TLV's are based on the results of animal experiments, limited human experiments, some industrial experience and, when possible, a combination of all three.

The basis on which the TLV's are set may differ from substance to substance. For some, such as levels for silica dust, a guiding factor is protection against impairment of health. For others, it is the comfort level of the individual, such as freedom from irritation, nuisance, or other forms of stress; for example, the TLV for sulfur dioxide is based on irritation and not on toxicity per se. The TLV list is reviewed annually resulting in some revisions in values and some additions to the list.

USE AND MISUSE OF TLV's

It is most important that TLV data be correctly used. Misuse can occur when uninformed individuals view these levels as magic numbers, below which workers are safe and above which they become ill. It should be remembered that there is wide variation in individual susceptibility to air contaminants and physical agents. Some workers may experience some discomfort from exposures at or below the TLV, and a much smaller number may be affected more seriously by aggravation of a pre-existing condition or by development of an occupational illness. Therefore, the TLV's as published were intended to be used only as guides in the control of health hazards and not as levels which separate safe from dangerous exposures. In addition, a TLV is not intended as a relative index of hazard or toxicity, nor to be mathematically manipulated by applying physical constants to derive a relative hazard.

Basically a TLV refers to a time-weighted averaged exposure for a 7 or 8-hour work day and a 40-hour work week. In other words, it is a level directed toward chronic (long-term) exposure and not toward acute (short-term) exposure. To date, very limited data has been published for acute exposures. Generally, toxicity data for acute exposures is obtainable only from animal experimentation, early medical data, and limited information from accidental exposures.

In the use of TLV's, it is important to recognize that the levels are generally developed for normal individuals doing normal work. Under conditions of high heat, unusual humidity, heavy exertion, abnormal pressure, or other work factors which may place added stress on the body, the effects from exposure to an air contaminant at its TLV may be altered. Generally, most of these stresses act adversely to increase the toxic response to a substance, and proper downward adjustment of the level should be made.

AIRBORNE CONTAMINANTS

The TLV's for airborne contaminants are based on the premise that although all chemical substances are toxic at some concentration for some period of time, a concentration exists for all substances from which no toxicity may be expected no matter how often the exposure is repeated. A similar premise holds for substances producing irritation, discomfort and nuisance. This premise differentiates chemical substances from ionizing radiation, which currently is considered to have no threshold for injury per se.

The present (1971) list published by the ACGIH (Figure 5.2) contains limit values for 400-500 substances. In using these limits, items such as excursion factors, ceiling values, "skin" notations, mixtures of substances, and inert material should be considered. All of these factors are discussed below.

Excursion Factors

Most TLV's refer to time-weighted average exposures for an 8-hour work day and a 40-hour work week. However, in calculating time-weighted average exposure, excursions above the limit are permitted provided they are compensated for by equivalent excursions below the limit during the same work day. The question here is: "How much of a fluctuation above the limit is permissible in developing the average?" These fluctuations above the limits are related to the magnitude of the TLV for the particular substance (Table 5.1).

Table 5.1

Permissible Excursions for Time-Weighted Average Limits

TLV (ppm or mg/m^3)	Excursion Factor
0-1	3
1-10	2
10-100	1.5
100-1000	1.25

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Some "Inert" or Nuisance Particulates

Alundum (Al_2O_3)	Kaolin
Calcium carbonate	Limestone
Cellulose (paper fiber)	Magnesite
Portland Cement	Marble
Corundum (Al_2O_3)	Pentaerythritol
Emery	Plaster of Paris
Glass, fibrous or dust	
Glycerin Mist	Rouge
Graphite (synthetic)	Silicon Carbide
Gypsum	Starch
Vegetable oil mists (except castor, cashew nut, or similar irritant oils)	Sucrose
	Tin Oxide
	Titanium Dioxide

Generally, these materials have a long history of little adverse effect on the lungs and do not produce significant organic disease or toxic effect when exposures are kept under reasonable control. However, excessive concentrations of "inert" or nuisance particulates in the work air may seriously reduce visibility (iron oxide), may cause unpleasant deposits in the eyes, ears and upper respiratory passages (Portland cement and limestone dust), or may cause injury to the skin or mucous membranes during rigorous cleaning or mechanical action. To control these effects, a TLV for particulates with less than 1% free silica has been set at 10 mg/m^3 or 30 mppcf (whichever is less) of total dust. The mg/m^3 refers to a gravimetric standard and the mppcf to a particle count standard, both of which will be discussed in Chapter VII. The limits do not apply to brief exposures to higher concentrations during a normal work day, nor do they apply to substances which may cause physiologic impairment at lower concentrations, for which no TLV has been indicated.

OSHA STANDARDS

The U. S. Department of Labor, under the Williams-Steiger Occupational Safety and Health Act (OSHA) has promulgated several interim health standards. These standards, pursuant to 29 CFR Part 1910, limit employee exposure to air contaminants, occupational noise, ionizing radiation and non-ionizing radiation. It is expected that these interim standards will be reviewed and revised to develop permanent standards, and that additional standards will be promulgated as national consenus standards.

Generally, the limits indicated for air contaminants and occupational noise in the present standards are the TLV's recommended and published as guidelines by the ACGIH, and these guidelines have become statutory limits. The standards for air contaminants, occupational noise exposure and nonionizing radiation were published in the Federal Register of May 29, 1971 and are contained in Sections 1910.93, 1910.95, 1910.97 of these standards.

Air Contaminants (Section 1910.93)

The standard contains three Tables -- G-1, G-2 and G-3. Generally, the levels listed in Tables G-1 and G-3 are ACGIH TLV's, except for some slight modifications and additions to Table G-3. As previously indicated, the levels for materials listed in Tables G-1 and G-3 are for time-weighted average exposures, except for materials designated with a ceiling "C" value. Table G-2 lists the consensus standards for 22 materials promulgated by the ANSI. These standards include, in addition to the 8-hour time-weighted averages, acceptable ceiling concentrations and maximum excursion levels for stated time periods during an 8-hour shift.

Employee exposure to any of the materials listed in Section 1910.93 shall be limited according to the following requirements:

1. For materials listed in Tables G-1 and G-3, the employee time-weighted average exposure to any material not designated with a "C", shall not exceed the indicated concentrations for any 8-hour work shift of a 40-hour week. In other words, there can be fluctuation above the indicated concentration during an 8-hour work period, but the 8-hour time-weighted average exposure must be within the indicated concentrations. Atmospheric concentrations for some of the mineral dusts must be calculated, based on the percentage of quartz (free silica SiO_2) as shown in the ACGIH list. For those materials designated "C", employee exposure shall at no time exceed the "C" value. As yet, the excursion factors developed by the TLV committee of ACGIH have not been included in the OSHA standard.
2. For materials listed in G-2, employees daily

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time-weighted average exposure is the same as in the ACGIH TLV's. However, for these materials, an acceptable ceiling concentration, and an excursion limit are also given. This means that during an 8-hour work shift, an employee's exposure should not exceed this acceptable ceiling concentration except for the time period and the concentration indicated in the last column (acceptable maximum peak above the acceptable ceiling concentrations for an 8-hour shift). In reality, the standards listed in Table G-2 are confusing by providing two excursion factors. For example: an employee's time-weighted average exposure to toluene is 200 ppm. However, the concentrations to which the employee is exposed may fluctuate up to 300 ppm any number of times provided the time-weighted average is not exceeded. In addition, the employee may be exposed to a concentration above 300 ppm but not above 500 ppm for a maximum period of 10 minutes. *However, such excursions above 200 ppm must be compensated for by exposures to concentrations below 200 ppm, so that the employee's time-weighted average exposure does not exceed 200 ppm.*

3. Time-weighted average exposures for an 8-hour work shift are calculated by the following formula which is similar to that in the ACGIH TLV list.

$$E = \frac{(C_1 T_1) + (C_2 T_2) + \ldots . (C_n T_n)}{\text{Daily hours of work (8)}}$$

where E = time-weighted average exposure,

C = concentration during any period of time the concentration remains constant, and

T = the duration in hours of the exposure at C.

As an example, several air samples collected during an 8-hour work shift for benzene (8-hour time-weighted average = 10 ppm) were 3 hours at 4 ppm, 1 hour at 15 ppm, 2 hours at 6 ppm and 2 hours at 9 ppm. The employee's time-weighted average exposure would be:

$$\frac{(3 \text{ hrs} \times 4 \text{ ppm}) + (1 \times 15) + (2 \times 6) + (2 \times 9)}{8 \text{ hours}} =$$

$$\frac{12 + 15 + 12 + 18}{8} = \frac{57}{8} = 7 \text{ ppm}$$

This exposure is not excessive since 7 ppm is below the 8-hour time-weighted average of 10 ppm.

4. Mixtures of air contaminants are additive and calculated in the manner described previously; that is, the fractions (concentration divided by limit for each material) are added together and if the sum does not exceed unity, the exposure is not excessive.

Occupational Noise Exposure (Section 1910.95)

This standard (Figure 5.3) limits employee exposure to noise on a daily basis to 90 dBA for an 8-hour per day exposure. For shorter exposure periods, the noise level in dBA may be increased for each halving of the time of the duration of exposure up to a maximum of 115 dBA. However, since a majority of noise exposures are composed of different levels (dBA) for varying periods of time, it might be well to discuss at this point how these exposures are handled.

As with mixtures of air contaminants, the effects of varying noise exposures are based on combined effects and, if the sum of the fraction $\frac{C_1}{T_1} + \frac{C_2}{T_2} + \ldots . \frac{C_n}{T_n}$ exceeds unity, then the mixed exposure is excessive. (Again, C is the duration of exposure for a specific noise level (dBA), and T is the allowable exposure time for the specific noise level.) For example:

An employee is exposed to the following noise levels for the indicated periods:

92 dBA	3.0 hrs.	(6 hrs. permissible)
95 dBA	2.0 hrs.	(4 hrs. permissible)
97 dBA	0.5 hrs.	(3 hrs. permissible)
85 dBA	2.5 hrs.	(no limit)

Since the duration of exposures below 90 dBA is not considered in calculating mixed exposures, the calculation to determine compliance with the standard would be:

$$\frac{3}{6} + \frac{2}{4} + \frac{0.5}{3} = 0.5 + 0.5 + 0.16 = 1.16$$

The sum of the fractions is greater than unity and the exposure, therefore, is excessive.

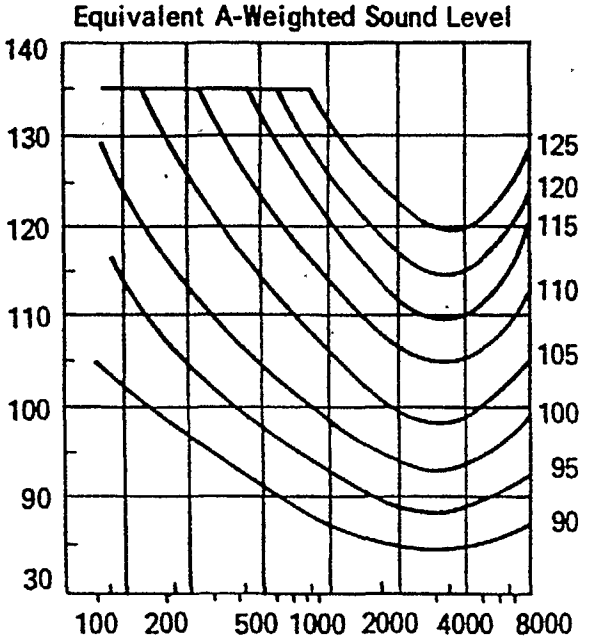
Non-Ionizing Radiation (1910.97)

This standard (Figure 5.4) limits employee exposure to electromagnetic radiations which are restricted to the portion of the spectrum

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OCCUPATIONAL NOISE EXPOSURE

(a) Protection against the effects of noise exposure shall be provided when the sound levels exceed those shown in Table G–16 when measured on the A scale of a standard sound level meter at slow response. When noise levels are determined by octave band analysis, the equivalent A-weighted sound level may be determined as follows:



Equivalent sound level contours. Octave band sound pressure levels may be converted to the equivalent A-weighted sound level by plotting them on this graph and noting the A-weighted sound level corresponding to the point of highest penetration into the sound level contours. This equivalent A-weighted sound level, which may differ from the actual A-weighted sound level of the noise, is used to determine exposure limits from Table G–16.

(b) (1) When employees are subjected to sound exceeding those listed in Table G–16, feasible administrative or engineering controls shall be utilized. If such controls fail to reduce sound levels within the levels of Table G–16, personal protective equipment shall be provided and used to reduce sound levels within the levels of the table.

(2) If the variations in noise level involve maxima at intervals of 1 second or less, it is to be considered continuous.

(3) In all cases where the sound levels exceed the values shown herein, a continuing, effective hearing conservation program shall be administered.

TABLE G–16–
PERMISSIBLE NOISE EXPOSURES[1]

Duration per day, hours	Sound level dBA slow response
8	90
6	92
4	95
3	97
2	100
1½	102
1	105
½	110
¼ or less	115

[1] When the daily noise exposure is composed of two or more periods of noise exposure of different levels, their combined effect should be considered, rather than the individual effect of each. If the sum of the following fractions: C1/T1 + C2/T2 Cn/Tn exceeds unity, then, the mixed exposure should be considered to exceed the limit value. Cn indicates the total time of exposure at a specified noise level, and Tn indicates the total time of exposure permitted at that level.

Exposure to impulsive or impact noise should not exceed 140 dB peak sound pressure level.

Figure 5.3

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NON-IONIZING RADIATION

1910.97 Nonionizing radiation.

(a) Electromagnetic radiation — (1) Definitions applicable to this paragraph. (i) The term "electromagnetic radiation" is restricted to that portion of the spectrum commonly defined as the radio frequency region, which for the purpose of this specification shall include the microwave frequency region.

(ii) Partial body irradiation. Pertains to the case in which part of the body is exposed to the incident electromagnetic energy.

(iii) Radiation protection guide. Radiation level which should not be exceeded without careful consideration of the reasons for doing so.

(iv) The word "symbol" as used in this specification refers to the overall design, shape, and coloring of the rf radiation sign shown in figure G-11.

(v) Whole body irradiation. Pertains to the case in which the entire body is exposed to the incident electromagnetic energy or in which the cross section of the body is smaller than the cross section of the incident radiation beam.

(2) Radiation protection guide. (i) For normal environmental conditions and for incident electromagnetic energy of frequencies from 10 MHz to 100 GHz, the radiation protection guide is 10 mW/cm.^{2} (milliwatt per square centimeter) as averaged over any possible 0.1-hour period. This means the following:

Power density: 10 mW./cm.^{2} for periods of 0.1-hour or more.

Energy density: 1 mW.-hr./cm.^{2} (milliwatt hour per square centimeter) during any 0.1-hour period.

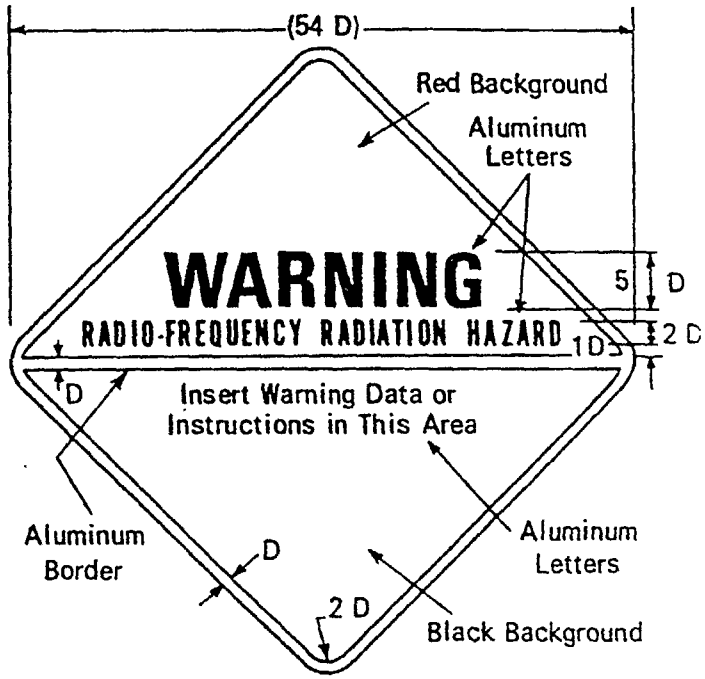
This guide applies whether the radiation is continuous or intermittent.

(ii) These formulated recommendations pertain to both whole body irradiation and partial body irradiation. Partial body irradiation must be included since it has been shown that some parts of the human body (e.g., eyes, testicles) may be harmed if exposed to incident radiation levels significantly in excess of the recommended levels.

(3) Warning symbol. (i) The warning symbol for radio frequency radiation hazards shall consist of a red isosceles triangle above an inverted black isosceles triangle, separated and outlined by an aluminum color border. The words "Warning — Radio-Frequency Radiation Hazard" shall appear in the upper triangle. See figure G-11.

(ii) American National Standard Safety Color Code for Marking Physical Hazards and the Identification of Certain Equipment, Z53.1-1953, shall be used for color specification. All lettering and the border shall be of aluminum color.

(iii) The inclusion and choice of warning information or precautionary instructions is at the discretion of the user. If such information is included it shall appear in the lower triangle of the warning symbol.



1. Place handling and mounting instructions on reverse side.
2. D = Scaling unit.
3. Lettering: Ratio of letter height to thickness of letter lines.

Upper triangle:	5 to 1 Large
	6 to 1 Medium
Lower triangle:	4 to 1 Small
	6 to 1 Medium

4. Symbol is square, triangles are right-angle isosceles.

Figure 5.4

commonly defined as the radio frequency region, or frequencies which range from 10 MH_3 to 100 MH_3. Exposure should be limited to 10 MW/CM^3 as averaged over any possible 0.1 hour period. This applies either to whole-body or to partial-body irradiation.

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Chapter VI
Strategy

Chapter VI

STRATEGY IN MONITORING THE ENVIRONMENT

The primary purpose of monitoring the air in the work environment is to determine the level of employee exposure to airborne contaminants and to protect his health. Generally, where employees may be over-exposed to potential health hazards, such sampling or measurements is performed on a routine basis. In addition to the above, sampling for air contaminants may be performed for one or more of the following reasons: (1) to determine the magnitude of employee exposure at the start-up of a new process or a change in a process or material used; (2) to determine the justification of employee grievances concerning an alleged health hazard; (3) to determine the performance or effectiveness of engineering control measures; (4) for research purposes, such as to determine the chemical and/or physical characteristics of contaminants, or (5) to investigate a potential health problem on a corporate wide basis. However, the majority of the sampling with which plant personnel will be concerned will be performed because of local or federal regulations. Those health standards promulgated under the Occupational Safety and Health Act (OSHA) will require monitoring, on a periodic basis, of all employees who are exposed to harmful materials.

While the concept of air sampling and the use of air monitoring devices may appear to be simple, the details of a good monitoring program may be misunderstood unless the person engaged in sampling is adequately trained and technical supervision is provided by a professional industrial hygienist. Consequently, misapplication of techniques, errors in instrument performance, and errors in interpretation of sampling data are common when monitoring is conducted by those individuals whose training is limited solely to undertaking the monitoring required by federal and state regulations without the essential professional guidance. The major problems arise from accepting an instrument reading as reliable without determining its calibration and the reproducibility of its response; and in not obtaining representative tests. Plant personnel must have some experience with and knowledge of the resolution of these problems. This knowledge is also important in order to determine if air tests conducted by OSHA compliance officers are valid. For example, if threshold limit value in the health standard is an 8-hour time-weighted average, the air sample should be obtained by sampling over the entire shift in the employee's breathing zone. It cannot be measured by a few short term samples, even if spaced over the full shift unless the worker is in a relatively fixed location with no variation in his work procedure or in the process. Such an event is generally the exception rather than the rule.

Unless established monitoring practices are conducted by plant personnel or the OSHA compliance officer, the results are of limited value in determining compliance with a standard, and what is more important, protecting the worker's health. The conduct of air monitoring by untrained, or poorly trained, persons relegates the program to a "numbers game" which serves no useful purpose.

General Principles of Air Sampling

A characteristic of the air contamination in most occupational environments is that there is most always a continual change in concentration with respect to time and location. This is particularly the case with respect to airborne particulates (dust, fumes and mists). Air currents within a room, process variations, changes in the work practice performed by an operator, and variation in the emission rate of contaminants are a few of the more significant factors resulting in this continual change in concentration throughout a work shift. This change in concentration will be less pronounced with gases and vapors than with particulates. However, generally speaking, marked concentration gradients can exist in most work areas which may be transient or relatively constant depending upon the contaminant sources and their number. Therefore, it is apparent that it would be most unrealistic to assume that the concentration of air contamination exists uniformly throughout a room or area.

The problem of determining the exposure of a worker to air contaminants is further complicated by the mobility of most workers who move about, in and out of, many areas of a workroom. This mobility is characteristic of many assigned jobs. Therefore, the concentration of contaminants in each work area, and

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the time spent in each must be considered in determining the full shift time-weighted average concentration to which each worker is exposed. Exposure is concentration averaged over a time period, which in the general case is a full 8-hour shift. However, several threshold limit values in the list published in the OSHA safety and health standards are peak concentrations or "ceiling values". Such standards indicate the maximum concentration which is allowed for any time period.

Although a single specific sampling strategy cannot be applicable for all air monitoring, general principles or considerations, which should be incorporated in such a strategy, can be developed.

Sampling Equipment

Air sampling instruments which have been approved by Headquarters Environmental Health will be discussed in detail in Chapters 7, 8 and 9. These are instruments which experience has indicated are applicable to the air sampling requirements of health hazard evaluation. New instruments will be developed due to the impact of OSHA and the need for more accurate, more portable and long-term sampling instruments. As these become available, Headquarters Environmental Health will evaluate them to determine whether or not they should be added to the list of approved devices.

As indicated previously in the discussion on the normal variability of the concentration of air contaminants and the mobility of workers, the average full-shift exposure of a worker is a composite of exposures to different concentrations during a workday. This can be ascertained by determining each concentration and exposure period, which is an extremely time-consuming and costly procedure; however, a more effective procedure involves the use of a personal sampling device worn by the worker during his full working shift, or any portion thereof which may be under inquiry. However, even this instrument has limitations and requires considerable care and maintenance as discussed in previous chapters of this manual. It is important to recognize that no perfect instrument exists nor can any be worn by a worker or placed in a location without periodic observation if for no other purpose than to note variation in process operating conditions or work practices. Both people and instruments malfunction and environmental conditions can readily depart from normality. It is such observations which must be noted if sampling data is to be properly evaluated.

Standard sampling instruments and procedures have been developed by OSHA with the assistance of the National Institute of Safety and Health (NIOSH). These are developed to have OSHA industrial hygienists and compliance officers operate under a necessary standardized practice to determine compliance with standards. A principal consideration in their selection has been simplicity in operation and direct-reading response. Both of these requirements are important for any inspectorate as these individuals must engage in considerable travel and desire to ascertain compliance status as soon as possible. However, these OSHA sampling instruments and practices are not necessarily the optimum for individual plant use to provide the most accurate data, but a number of them can be so categorized as they have been selected from those long accepted by the industrial hygiene profession. Some of them, notably those involving the use of charcoal (activated carbon) tubes can be so termed as they require considerably more field use before they can validly demonstrate sufficient accuracy for use for compliance determinations. Copies of these OSHA and NIOSH sampling data sheets will be shown later in this chapter. It would be prudent for any plant sampling program to obtain exposure information of employees utilizing both the instruments employed by OSHA personnel and instruments recommended by Headquarters Environmental Health, where different instrumentation is involved, to determine what differences may exist in the exposure data derived by both methods.

Type of Samples

Air samples to be obtained generally consist of breathing zone and fixed position samples. While both have application in hazard evaluation, the former is to be recommended for general use in determining compliance with standards. The exposure of a worker can be measured most accurately by determining the concentration of the contaminant in the air which he breathes. This does not imply that the sampling instrument must be located a few inches from his nose, as such a location would be impractical and unnecessary. The instrument should be held

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or located as close to an employee's nose and mouth without interferring with his freedom of movement in the normal conduct of his work. While some individuals have indicated sharp concentration gradients around a contaminant source, sample locations for exposure measurement located 1-2 feet from the nose is adequately representative. Of more significance is the need for more than one full-shift sample if representative exposure data is to be obtained. Unfortunately OSHA standards for air contaminants are based upon a single 8-hour time-weighted average except where "ceiling value" standards are involved. Such a basis of determining compliance with standards for materials such as pneumoconiosis-producing dusts do not recognize that these materials only produce long-term effects and hazard evaluation should be based on more than a single 8-hour sample. Such a single sample can be at considerable variance with the true exposure averaged over two or more days, nor is one rarely occurring excessive exposure hazardous to the employee. Nevertheless, the regulations require that samples must be based upon the sampling period prescribed in the standards.

Frequently is is desirable to obtain fixed position samples. For example, a worker may spend only a fraction of an hour in a job involving exposure to a contaminant and the remaining time in uncontaminated air. Such a breathing zone sample would collect such a small quantity of the contaminant that an accurate chemical analysis cannot be made. It would be preferable to locate a sampling instrument in a fixed position within the breathing zone of a worker when in the area and to sample for the entire shift. However, the concentration derived from such a sample must be time-weighted only for the actual time spent at the job to obtain the exposure of the worker involved. There are other instances when fixed position samples are desired, such as in control cabs, pulpits, etc., where the effectiveness of engineering controls or the contribution of this location to the total exposure is desired. Another application for fixed position samples is to determine whether employees located at distances from an operation should be sampled. This can be readily determined by locating several fixed position samplers at different distances from a source of contamination. Still another type of fixed position sampling, although not directly a measure of employee exposure is the use of continuous fixed position sampling stations, such as commonly used in blast furnace divisions for carbon monoxide. These types of samplers may be the sequential multiple point sampler type or the single point sampler. They are generally arranged so that the sampling point is located in close proximity to points where accidental release of high concentration of gases having an acute effect may develop. Their principal use is to warn employees by means of an audible alarm to immediately leave the area. Such instruments also can provide a continuous recorded measurement of some gases or vapors which may or may not be exposure related.

Number of Samples

A reliable estimate of an employee's exposure requires replicate samples irrespective of their duration. This is basic whether or not one is concerned with 8-hour time-weighted concentrations, operational exposures or areal contamination. Differences involving a factor of five or more are not rare. Therefore, a minimum of three samples should be obtained, until experience dictates an upward or downward revision, based upon the variability so determined. One cannot emphasize too greatly that the objective of a sampling program is worker protection and not the collection of numbers. An occasional exposure to a concentration which exceeds the threshold limit values in Section 1910.93 of Subpart G of OSHA regulations would result in a violation if the compliance officer is sampling on the day that such an exposure exists, even though the average of several daily samples obtained during the same week is within the standard. This demonstrates the difference between good evaluation techniques and the mere application of numbers which unfortunately is practiced because of the terminology in this section of the health standards.

In the development of a sampling schedule, one should remember that if an operation continues more than one shift, it may be prudent to collect samples during each shift, as exposure to airborne contaminants may be different for each shift. Furthermore, sampling should be performed during all seasons of the year (winter, spring, summer and fall). This is especially true for locations in areas where large temperature variations occur dur-

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ing the different seasons of the year. Generally, there is more natural ventilation in the warmer months with the buildings open, which tends to dilute air contaminants, than in the colder weather when natural ventilation may be limited due to closing of doors and windows.

In summary, the minimum number and type of samples is dictated by OSHA standards. However, it would be highly desirable to obtain more than this minimum number of samples.

Duration of Samples

For a practical viewpoint the duration of samples will be dictated by the requirements in the OSHA standards. These are continuous 8-hour samples or short-term samples when the standard has a "ceiling value" or peak concentration limit. Scientifically speaking, the minimum volume of air to be sampled, or the duration of sampling, is based on the following consideration: (1) the threshold limit value (TLV) or regulatory standard; (2) the sensitivity of the analytical procedure; or (3) the estimated air concentration. Thus, the volume of sample needed may vary from a few liters, where the estimated concentration is high to several cubic meters where low concentrations are expected. Then, knowing the sensitivity of the analytical procedure, the TLV and the sampling rate of the particular instrument in use, one can determine the minimum time necessary for an adequate sample. However, the collected sample should represent some identifiable period of time — usually a complete cycle of an operation or so many minutes out of each hour. This will enable the worker's exposure on a time-weighted average basis to be calculated.

Preparation for Sampling

The successful application of any sampling program requires that one be knowledgeable of the processes involved, the potential hazards and be able to recognize hazardous work conditions. Therefore, the first step in evaluating the occupational environment is to become familiar with the operations in the plant. This is best obtained by a preliminary, or "walk-thru", survey during which information is obtained on the job categories and the operations in each, the raw materials used, the process by-products, and the type of control measures afforded for the protection of the workers. This information should be recorded on an appropriate form following which the data is reviewed and the potential hazards indicated such as shown in Figure 6-1. Discussions should be held with supervisory personnel and industrial engineering personnel to obtain such details. It is imperative that plant personnel responsible for environmental health tests be considerably more knowledgeable of work practices and their environmental impact than one can expect from a regulatory official. Only by such experience can plant personnel determine if samples obtained by OSHA compliance officers are representative and accurate.

OSHA AND NIOSH SAMPLING PRACTICES

Early in this chapter, it was indicated that OSHA compliance officers are required to utilize instruments and procedures which have been standardized by this agency, with the assistance of NIOSH. These have been issued as directives to the various district offices as OSHA Sampling Data Sheets. A set of these are enclosed.

NIOSH has proposed to OSHA a number of additional sampling sheets which have not as yet been adopted by OSHA as the official method for compliance surveys. While NIOSH has authority under the Occupational Safety and Health Act to engage in its own surveys and conceivably use its own sampling techniques, it would appear that these two agencies will not engage in the utilization of different techniques particularly since NIOSH has the technical responsibility in health investigations. Therefore, a set of the additional sampling practices proposed by NIOSH is also enclosed as these will most likely become OSHA standard sampling practices. In view of the dynamic state of standards development in OSHA and an equal state of technical developments in NIOSH, it is expected that these sampling data sheets will undergo material revisions in the near future. When these are available, Headquarters Environmental Health will distribute copies to all recipients of this training manual.

Guideline No. 1 developed by the Headquarters OSHA Review Committee directs corporate facilities to notify the Director of Environmental Health — Pittsburgh if environmental health tests are to be conducted by an

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OSHA compliance officer. The purpose of this provision is to obtain guidance from Headquarters Environmental Health who will dispatch an industrial hygienist, if available, to conduct simultaneous samples and to generally review the sampling practices followed. In the event that Headquarters Environmental Health is unable to assign a person, the plant personnel accompanying the compliance officer should obtain the necessary information for completing the report form contained in Guideline No. 7. This guideline entitled, "Guideline For Environmental Health Tests During Inspections" should be followed if Headquarters Environmental Health is evaluating the inspection and undertake subsequent tests in the same locations and operations, and with the same testing equipment, as used by the OSHA compliance officer. This report form shown as Figure 6-2.

INDUSTRIAL HYGIENE SURVEY

WORK ROOM DATA

Name of Plant: *J. S. Davidson* Page *1* of *10*

Department: *Screw Machine*

Informant's Name: *C. Olka* Surveyed by: *C. S.* Work Room: *1* Date: 3-10-65

OCCUPATION	Number of Persons			NATURE OF JOB	RAW MATERIALS and BY PRODUCTS	CONTROL MEASURES							REMARKS & POTENTIAL HAZARDS
	M	F	T			Local Exh.	Isolation	Wet Method	Gas Mask	Respirator	Press Hel.	Other	
Machine Operators	20	–	20	Operate Screw Machines	Non-ferrous Metals Houghton #12 Oil							X Aprons	Dermatitis Oil Mist Noise
Salvage Men	3	–	3	Centrifuge and filter Spent Oil	Shavings – Non-ferrous Houghton Cutting Oil #12							X Aprons Gloves	Dermatitis Oil Mist Noise
Total:													

FORM # _____

Figure 6.1

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Federal Occupational Safety & Health Act

REPORT ON ENVIRONMENTAL TESTS CONDUCTED BY OSHA INSPECTOR

Plant	Eastern ☐	Divisions	UPD ☐	ACI ☐	USH ☐						Date(s) of Inspection		
	Western ☐		USD ☐	CEM ☐	ALS ☐						Time of Inspection: From		To
	O.L. & L.S. ☐		UAC ☐	ABD ☐	OWS ☐								
Name of Inspector		Title				Office Address							
Reason for Inspection	Routine ☐	Citation Made?	Yes ☐	Basis of Citation					Test Data ☐				
	Complaint ☐		No ☐						Visual ☐				

TEST DATA

| LOCATION | | | DATA ON ENVIRONMENTAL TESTS (Check Column unless Number is Requested) | | | | | | | | | | | | |

OSHA SAMPLING DATA SHEET #1

Substance:

Carbon monoxide.

Standard:

8-hour time-weighted average: 50 ppm (55 mg/m^3).

Sampling Equipment:

(1) CO meter. (Portable, Hopcalite — reagent type) — Follow directions. (Primary Method)

(2) Certified or NIOSH approved detector tubes and a hand operated pump (not squeeze bulb) may be used for compliance purposes. (Secondary Method)

Analytical Procedure:

(1) Direct reading instrument based on measurement of heat of reaction produced by oxidation of CO to CO_2. Follow instructions.

(2) Detector tubes are read for length of stain, strokes of pump are noted and appropriate corrections made for pressure (or altitude) above 5000 feet (1500 m). The tubes are not to be used when below 0°F (-18c) or above 125°F (52c).

Sampling Period:

(1) Hopcalite: maximum feasible number of readings should be averaged to determine average exposure. Time required dependent on variability and cyclical nature of exposures.

(2) Detector tubes: direct reading, length-of-stain detector tubes (certified or NIOSH approved) may be used for compliance purposes, if at least one sample per hour is taken per exposed worker or close group of workers. In an 8-hour day more frequent samplings per hour are preferred, especially for exposures over 50 ppm. Eight different samplings (one per hour is considered the minimum acceptable number).

Imminent Danger Situations:

Concentrations above 500 ppm (10 x TLV) for any length of time are considered to be an imminent danger.

Serious Violation:

Concentrations above 150 ppm (3 x TLV) for a total of 1 hour or more in an 8-hour workday are considered serious.

Nonserious Violation:

Concentrations above 50 ppm, but below 150 ppm for an 8-hour time-weighted average are considered nonserious violation.

De Minimis Violation:

Not applicable.

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OSHA SAMPLING DATA SHEET #2

Substance:

Asbestos.

Standard:

8-hour time-weighted average*: 5 fibers per milliliter greater than 5 microns in length.

Excursion limit*: 10 fibers per milliliter, up to 15 minutes in an hour for up to 5 hours per 8-hour day.

*Unprotected or improperly protected worker exposures.

Analytical Method:

Fibers counted at 400-450 magnification, using phase contrast illumination, with sample mounted in high-viscosity solution of membrane filter material.

Sampling Equipment:

Personal sampling pump plus Millipore type AA filter (37 mm, 0.8 μ pore size). Face cap is removed and filter used open face during sampling. Sampling rate: 2 l/m.

Sample Size:

Minimum period of 15 minutes for evaluation of excursion limit. Several samples of up to 4 hours for evaluation of 8-hour average. Samples with a visible deposit may be too heavy to count. Compare with a clean filter. Heavy concentrations of visible dust in the air (100 to 500 fibers/ml) may require short sampling periods of only 5 minutes, or less.

Blanks:

With each batch of samples submit two filters which are subjected to exactly the same handling as for the samples except that no air is drawn through them. Label these as blanks.

Shipping:

The cassettes in which the samples are collected should be shipped in a suitable container, designed to prevent damage in transit.

Imminent Danger Situations:

Generally not applicable.

Serious Violation:

5.1 or more fibers per ml, greater than 5 μ in length, for an unprotected or improperly protected worker, for an 8-hour time-weighted average, except for certain proven excursions as noted in the emergency standard, which may raise the 8-hour time-weighted average to 5.8 fibers per ml.

Nonserious Violation:

Not applicable.

De Minimis Violation:

Not applicable.

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OSHA SAMPLING DATA SHEET #3

Substance:

Crystalline silica.

Standard:

	Form
Quartz (respirable):	10 mg/m^3 %SiO_2+2

Cristobalite: One-half the value for quartz

Tridymite: One-half the value for quartz

Analytical Method:

Gravimetric personal samples for worker exposure should be tared and reweighed by DOL on a Cahn balance. The per cent of free silica is determined by NIOSH on the fixed location sample using a colorimetric wet chemical method, minimum detectable amount: 0.01 mg/filter.

Sampling Equipment:

For worker exposure:

Personal sampling pump plus preweighed MSA type FWS-B or Gelman type VM-1 filter, using 2-piece filter cassette and 10 mm nylon cyclone. Two filters should be subjected to the same handling as the samples except that no air is drawn through them, and these should be used as blanks. Sampling rate: 1.8 1/m.

For determining % quartz:

Collect at fixed locations near workers, using NIOSH preweighed MSA type FWS-B filters in 3-piece cassettes plus Gast 1531 pump with 9 1/m critical orifice and 1/2 inch steel cyclone. The vacuum release valve should be adjusted to 10-15 in. Hg. suction. Two blanks of the same filter type should be submitted with the sample. Sampling rate: 9 1/m.

Sample Size:

Minimum: 4 hours. Maximum: 8 hours.

Shipping:

The cassettes in which the samples for determining % quartz are collected should be shipped to NIOSH in a suitable container, designed to prevent damage in transit.

Imminent Danger Situations:

Generally not applicable.

Serious Violation:

Any 8-hour time-weighted average greater than 4 x stated TLV value.

Nonserious Violation:

Any 8-hour time-weighted average between the stated TLV and 4 x that value.

De Minimis Violation:

Not applicable.

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OSHA SAMPLING DATA SHEET #4

Substance:

Lead and its inorganic compounds (except lead arsenate).

Standard:

8-hour time-weighted average: 0.2 mg/m^3

Analytical Method:

Atomic absorption.

Detection Limit: 0.0003 mg/filter.

Sampling Equipment:

Personal sampling pump plus unweighted 37 mm Millipore type HA filter. Either 2- or 3-piece filter cassette may be used. Sampling rate: 1.5 l/m.

Sample Size:

A minimum sampling period of 60 minutes is recommended, and longer periods, up to full shift, are preferable. Care must be taken to prevent material from falling off heavily loaded filters during shipment. This may be done by placing another filter on top of the one with the sample, exercising care not to dislodge any of the sample in the process.

Blanks:

With each batch of samples, submit two filters which are subjected to exactly the same handling as for the samples except that no air is drawn through them. Label these as blanks.

Shipping:

The cassettes in which the samples are collected should be shipped in a suitable container, designed to prevent damage in transit.

Imminent Danger Situations:

Generally not applicable.

Serious Violation:

Anything above 0.6 mg/m^3 for an 8-hour time-weighted average.

Nonserious Violation:

Anything above 0.2 mg/m^3 and less than 0.6 mg/m^3 for an 8-hour time-weighted average.

De Minimis Violation:

Not applicable.

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OSHA SAMPLING DATA SHEET #5

Substance:

Cotton dust (raw).

Standard:

8-hour time-weighted average: 1 mg/m^3.

Analytical Method:

Net weight of gross airborne dust, using balance with sensitivity of 0.01 mg.

Sampling Equipment – Personal Samplers:

Cotton is to be determined primarily with the personal sampler attached to the workman's clothing with the face of the filter pointing down. The filter should not be covered. Our experience is that at least a 4- and preferably a 6-hour sample (at 1.5 1/m) is required in a textile plant opening or carding area to obtain reliable results. A preweighed filted (0.01 mg) should be used and reweighed to the same accuracy.

There is no ceiling or any limit on excursions.

Because of the nature of both the sampling method and the development of byssinosis, it is neither desirable nor possible to get grab samples.

Sampling Equipment – General Work Area:

Preweighed Gelman VM-1 or MSA type FWS-B 5 µ pore size filter in 3-piece cassette, located in the general work area with the cap removed and the filter facing down. Suction provided by Gast 1531 pump with a 7.4 1/m critical orifice. The vacuum relief valve should be adjusted to maintain 10-15 in.Hg suction. Sampling rate: 7.4 1/m for recommended minimum of 60 minutes. Longer period samples up to full shift are preferable. Filters should not be so heavily loaded that the sample is dislodged in transit.

Blanks:

With each batch of samples collected, two additional filters should be subjected to exactly the same handling except that no air is drawn through them. These should be used as blanks.

Shipping:

The cassettes in which samples are collected should be shipped in a suitable container, designed to prevent damage in transit.

Imminent Danger Situations:

Generally not applicable.

Serious Hazard:

An 8-hour time-weighted average above 3 mg/m^3 for identified worker. 3 x TLV.

Nonserious Hazard:

An 8-hour time-weighted average above 1 mg/m^3 and below 3 mg/m^3 for an identified worker.

De Minimis Violation:

Not applicable.

OSHA SAMPLING DATA SHEET #6

Substance:

Coal Tar Pitch Volatiles.

Standard:

8-hour time-weighted average: 0.2 mg/m^3 (benzene soluble fraction).

Analytical Method:

Weight of benzene soluble fraction of collected material.

Sampling Equipment:

Personal sampling pump plus cassette containing 0.8 μ pore size silver membrane filter preceded by Gelman glass fiber type-A filter. Preweighted and extracted cassette furnished by NIOSH.

Sampling Rate:

2 lpm. (liters per minute).

Sample Size:

Recommended minimum of 1 m^3 or an 8-hour sample at 2 lpm.

Minimum Concentration Measured:

0.1 mg/m^3.

Blank:

With each batch of samples submit one cassette which is subjected to exactly the same handling as for samples except that no air is drawn through it. Label this as a blank.

Shipping:

Keep samples in the dark and ship as promptly as possible. Stored samples should be kept refrigerated. The cassettes in which the samples are collected should be shipped in a suitable container, designed to prevent damage in transit.

Imminent Danger:

Generally not applicable.

Serious Violation:

Any 8-hour time-weighted average above 0.2 mg/m^3 (benzene soluble fraction) for an identified worker not wearing proper respiratory protective equipment is considered a serious violation (serious hazard).

Nonserious Violation:

If engineering controls have not been implemented, there may be a "nonserious" violation.

De Minimis Violation:

Does not apply.

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NIOSH SAMPLING DATA SHEET

Substance:

Solvent Vapors (sampled with charcoal tube)

Standard:

Substance	Standard 8-hour Average (ppm)	Excursion Standard (ppm)	Minimum to be Reported (ppm)	Sample Size (liters)
1. Benzene	10	25 (10 min)	0.5	10
2. Carbon tetrachloride	10	25 (5 min)	0.5	10
3. Chloroform	50	50 (15 min)	2.5	10
4. Dioxane	100	150 (15 min)	5	10
5. Ethylene dichloride	50	100 (5 min)	2.5	10
6. Methyl chloroform	350	450 (15 min)	20	5
7. Styrene	100	200 (5 min)	5	10
8. Tetrachloroethylene	100	200 (5 min)	5	10
9. Toluene	200	300 (10 min)	10	10
10. 1, 1, 2-Trichloroethane	10	20 (15 min)	0.5	10
11. Trichloroethylene	100	200 (5 min)	5	10
12. Xylene	100	150 (15 min)	5	10

Analytical Method:

These atmospheric solvent vapors can be collected efficiently on activated charcoal and desorbed with carbon disulfide prior to separation and analysis using a gas chromatograph with a flame ionization detector.

Sampling Equipment:

Personal sampling pump plus charcoal tube. Sampling rate: 1 1pm.

Sample Size:

As noted in table above.

Sampling Procedure:

1. Immediately before sampling, the ends of the tube should be broken so as to provide an opening approximately one-half the internal diameter of the tube.
2. The smaller section of charcoal is used as a back-up and should be positioned nearest the sampling pump. The charcoal tube should be placed in a vertical position during sampling.
3. Air being sampled should not be passed through any hose or tubing before entering the charcoal tube.
4. Care should be taken to position the middle of the rotameter ball to the 1 1pm calibration mark as exactly as possible.
5. The charcoal tubes should be capped with the supplied plastic caps immediately after sampling. Masking tape is the only suitable substitute for sealing the tubes. Under no circumstances should rubber caps be used.
6. One charcoal tube should be handled in the same manner as the sample tubes (break, seal, and transport), except for the taking of an air sample. This tube should be labeled as a blank.

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Special Considerations:

1. High humidity does not present problems in sampling by this method, but the presence of airborne water in liquid form does. Where two or more solvents are known or suspected to be present in the air, such information, including their suspected identities, should be transmitted with the sample, since, with differences in polarity, one may displace another from the charcoal.
2. Due to the high resistance of the charcoal tube, this sampling method places a heavy load on the sampling pump. Therefore, no more than ten charcoal tube samples should be taken without fully recharging the battery.

Bulk Samples:

Sample(s) of the suspected solvent(s) should be submitted to the laboratory in containers furnished for such purpose by NIOSH.

Shipping Instructions:

Never transport, mail, or ship the liquid bulk samples in the same container as the sample or blank tubes.

Application of Method:

The described procedure can be applied to each compound in the above list. Concentrations lower than those given in the column headed "minimum to be Reported" will customarily be reported merely as "less than". This will expedite rapid reporting of results. For compliance purposes, more precise information would usually not be necessary. If there are unusual circumstances requiring such information, special arrangements can be made for reporting smaller concentrations.

Accuracy:

Although the personal sampler pump is the preferred method of measuring worker exposure, the present pumps were not designed for use with charcoal tubes and a sample flow rate error of up to 15% may occur. Analytical error is typically a maximum of 10%. Compliance actions should therefore only be taken when the measured concentration exceeds the standard by at least 15%.

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NIOSH SAMPLING DATA SHEET

Substance:

Cadmium

Standard:

	8-Hour Time-Weighted Average	Ceiling
Dust	0.2 mg/m^3	0.6 mg/m^3
Fume	0.1 mg/m^3	0.3 mg/m^3

Analytical Method:

Atomic absorption

Sampling Equipment:

Personal sampling pump plus unweighed 37 mm Millipore filter, type HA. Either 2- or 3-piece filter cassette may be used. Sample at 1.5 lpm with cassette face cap on and small plug removed.

Sample Size:

Concentration to be Measured (mg/m^3)	Minimum Required Sample Size (liters)
0.1	100
0.2	50
0.3	34
0.6	17

Larger size samples are satisfactory provided the filter is not loaded so heavily that it becomes plugged or the material falls off.

Blank:

With each batch of samples submit one filter which is subjected to exactly the same handling as for the samples except that no air is drawn through it. Label this as a blank.

Shipping:

The cassettes in which samples are collected should be shipped in a suitable container, designed to prevent damage in transit. Loss of sample from heavy deposits on the filter may be prevented by mounting a clean filter in the cassette on top of the sample filter.

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NIOSH SAMPLING DATA SHEET

Substance:

Beryllium and beryllium compounds

Standard:

Ceiling: 5 $\mu g/m^3$ (30 min.)
Peak: 25 $\mu g/m^3$

Analytical Method:

Atomic absorption
Detection limit: 0.02 µg/filter

Sampling Equipment:

Personal sampling pump plus unweighed 37 mm Millipore type HA filter. Either 2- or 3-piece filter cassette may be used. Sample at 1.5 1pm with cassette face cap on and small plug removed.

Sample Size:

For ceiling limit evaluation, use 30 minute samples. Minimum of 60 minutes for measurement of 2 $\mu g/m^3$ limit. Longer samples up to full shift are preferred. Sampler battery recharge required after 4 hours.

Blank:

With each batch of samples submit one filter which is subjected to exactly the same handling as for the samples except that no air is drawn through it. Label this as a blank.

Shipping:

The cassettes in which the samples are collected should be shipped in a suitable container, designed to prevent damage in transit.

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NIOSH SAMPLING DATA SHEET

Substance:

Zinc oxide fume

Standard:

8-hour average: 5 mg/m^3
Excursion: 10 mg/m^3

Analytical Method:

Atomic absorption
Detection limit: 0.00002 mg/filter

Sampling Equipment:

Personal sampling pump plus unweighed 37 mm Millipore type HA filter. Either 2- or 3-piece filter cassette may be used. Sample at 1.5 lpm with cassette face cap on and small plug removed.

Sample Size:

A minimum sampling period of 15 minutes is required and longer periods, up to full shift, are preferred. Care must be taken to prevent material from falling off heavily loaded filters during shipment. This may be done by placing another filter on top of the one with the sample, exercising care not to dislodge any of the sample in the process.

Blank:

With each batch of samples submit one filter which is subjected to exactly the same handling as for the samples except that no air is drawn through it. Label this as a blank.

Shipping:

The cassettes in which the samples are collected should be shipped in a suitable container, designed to prevent damage in transit.

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NIOSH SAMPLING DATA SHEET

Substance:

Magnesium oxide fume

Standard:

8-hour average: 15 mg/m^3
Excursion: 22.5 mg/m^3

Analytical Method:

Atomic absorption
Detection limit: 0.00003 mg/filter

Sampling Equipment:

Personal sampling pump plus unweighed 37 mm Millipore type HA filter. Either 2- or 3-piece filter cassette may be used. Sample at 1.5 1pm with cassette face cap on and small plug removed.

Sample Size:

A minimum sampling period of 15 minutes is recommended. Longer periods of sampling are acceptable provided fume deposition is not too heavy. Care must be taken to prevent material from falling off heavily loaded filters during shipment. This may be done by placing another filter on top of the one with the sample, exercising care not to dislodge any of the sample in the process.

Blank:

With each batch of samples submit one filter which is subjected to exactly the same handling as for the samples except that no air is drawn through it. Label this as a blank.

Shipping:

The cassettes in which the samples are collected should be shipped in a suitable container, designed to prevent damage in transit.

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NIOSH SAMPLING DATA SHEET

Substance:

Cobalt, metal fume and dust.

Standard:

8-hour average: 0.1 mg/m^3
Excursion: 0.3 mg/m^3

Analytical Method:

Atomic absorption
Detection limit: 0.0001 mg/filter

Sampling Equipment:

Personal sampling pump plus unweighed 37 mm Millipore type HA filter. Either 2- or 3-piece filter cassette may be used. Sample at 1.5 1pm with cassette face cap on and small plug removed.

Sample Size:

A minimum sampling period of 15 minutes is required, and longer periods, up to full shift, are preferred. Care must be taken to prevent material from falling off heavily loaded filters during shipment. This may be done by placing another filter on top of the one with the sample, exercising care not to dislodge any of the sample in the process.

Blank:

With each batch of samples submit one filter which is subjected to exactly the same handling as for the samples except that no air is drawn through it. Label this as a blank.

Shipping:

The cassettes in which the samples are collected should be shipped in a suitable container, designed to prevent damage in transit.

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NIOSH SAMPLING DATA SHEET

Substance:

Copper

Standard:

Fume: 8-hour average: 0.1 mg/m^3
Excursion: 0.3 mg/m^3

Dusts and mists: 8-hour average: 1.0 mg/m^3
Excursion: 3.0 mg/m^3

Analytical Method:

Atomic absorption

Detection limit: 0.00005 mg/filter

Sampling Equipment:

Personal sampling pump plus unweighed 37 mm Millipore type HA filter. Either 2- or 3-piece filter cassette may be used. Sample at 1.5 lpm with cassette face cap on and small plug removed.

Sample Size:

A minimum sampling period of 15 minutes is required, and longer periods, up to full shift, are preferred. Care must be taken to prevent material from falling off heavily loaded filters during shipment. This may be done by placing another filter on top of the one with the sample, exercising care not to dislodge any of the sample in the process.

Blank:

With each batch of samples submit one filter which is subjected to exactly the same handling as for the samples except that no air is drawn through it. Label this as a blank.

Shipping:

The cassettes in which the samples are collected should be shipped in a suitable container, designed to prevent damage in transit.

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Determination of Compliance

The following procedure may be used to determine compliance with an eight hour average standard based on a small number of instantaneous (grab) or short period samples collected at random intervals during the workday.

Given the results of n samples with a mean m and a range (difference between least and greatest) r.

If, for from 3 to 10 samples, m is greater than the standard plus the % systematic instrument error times the standard plus $t_n r$, we are 95% confident that the true average concentration exceeds the standard. The value of t may be taken from the following table:

n	t
3	2.35
4	2.13
5	2.01
6	1.94
7	1.89
8	1.86
9	1.83
10	1.81

For larger size samples, the procedure given in Section 3-2.2.1 of NBS Handbook 91 should be followed.

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Chapter VII

SAMPLING EQUIPMENT

The objectives of this chapter are to (1) outline the equipment requirements for collecting air samples and for making noise, light and heat measurements in Corporation facilities, (2) to discuss from a general viewpoint some of the problems involved in making such test, and (3) to acquaint persons responsible for environmental health monitoring with sampling equipment which may be occasionally utilized, with assistance from Headquarters Environmental Health — Pittsburgh. Emphasis will be mostly on the types of equipment approved for Corporate use and those instrumental problems which a newcomer to the field of air sampling and the measurement of physical conditions in the environment will encounter and need to overcome, if meaningful data is to be acquired.

This chapter will not provide detailed sampling methods for each atmospheric contaminant, nor will it outline operational procedures for each type of testing equipment. It will present certain general principles to be employed in making such measurements. More specifically, it will discuss the selection and use of testing equipment.

The choice of instruments for collecting air samples and measuring physical conditions is usually a compromise among several desirable objectives, including high efficiency, reliability, reproducibility, ease of maintenance, and portability. Portable instruments which have been approved for sampling particulates, gases and vapors are listed in Guideline No. 8. This list will be updated periodically as new instruments become available and are approved by Headquarters Environmental Health.

AIR CONTAMINANTS

As discussed in Chapter IV, a basic knowledge of the physical and chemical characteristics of the air contaminant under investigation is one of the most important factors in the selection of an air sampling method. A collection device which may be highly efficient for a substance in one chemical or physical form might be totally unsuited to efficient collection of the same substance in another form. For instance, filter paper may be the correct choice for collecting dust and fume particulates, but would be a very poor choice for collecting solvent vapors. Similarly, combustible gas indicators or detector tubes are good choices for sampling gases and vapors, but unsuitable for sampling particulates.

Figure 7.1 shows the basic elements of an air sampling system, including arrangement of the component parts for sampling particulates, gases and vapors. These parts include: (1) a collection device, which can be a filter with filter holder, a detector tube, a fritted glass bubbler, an evacuated flask, etc.; (2) a flow meter or orifice to indicate the flow of air through the collecting device; and (3) a suction device, which can be a squeeze bulb or a pump. The pump may be manually operated as in the case of the MSA Universal Tester, or motor driven as in the case of the MSA Monitaire.

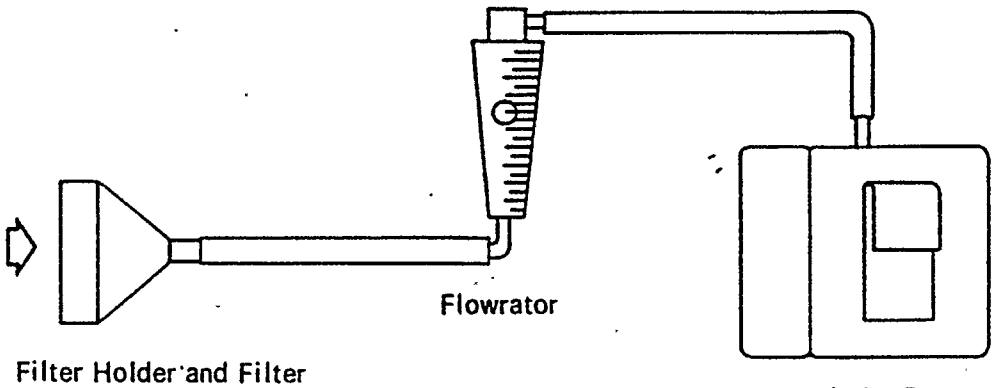
It should be noted that the collection device must be upstream of everything in the system, to insure collection of the total air contaminant. Otherwise, the contaminant may be deposited in the flow meter, the sampling lines, and/or the pump. The collection device should be as close as possible to the desired sampling point since wide variation in contaminant concentrations may occur even at short distances. It is also important to make sure that the sampling system is properly arranged and kept free of obstructions, if the correct flow rate through the collecting device is to be maintained. This will be discussed at more length in later chapters.

Air contaminants may represent a potential health hazard to the worker. Analysis of properly collected air samples can show both the nature and the magnitude of such exposures. In a sense, an air sampling system consisting of a suction device (pump or squeeze bulb) and a collecting device (filter paper, detector tube, etc.) substitutes for a human being as an air contaminant collector. By appropriate choice of air mover, sampling apparatus, and flow rates, almost any sample quantity can be collected in a given sampling interval. The instrument or sampling system of choice depends upon the type of information desired.

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BASIC ELEMENTS OF AN AIR SAMPLING SYSTEM

Arrangement for Particulates



Arrangement For Gases and Vapors

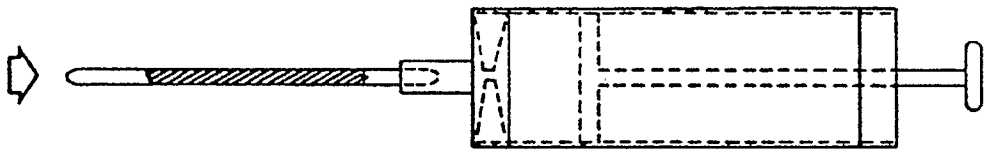


Figure 7.1

MSA Monitaire Pump

The portable pump recommended for Corporate use for taking air samples is a modified MSA Monitaire designated as Model S. It is shown in Figure 7.2 with its charger, and is available with a rotameter marked from 0-10 CFH or from 0-2 CFH. It has great flexibility since with the 0-10 CFH rotameter it can be used with filters, gravimetric samplers and midget impingers for collecting particulates, or with fritted glass bubblers for sampling gases and vapors. The 0-2 CFH rotameter with single or multiple indicating tube holders is used for collecting gases and vapors.

The Monitaire consists of a DC motor-drive diaphragm pump with a rotameter to indicate air flow and a valve to regulate air flow. A simple inlet fitting on the top center of the pump case accepts either 1/8" or 1/4" inside diameter tubing. The motor is driven by a rechargeable nickel-cadmium battery, and is designed to operate for a full 8-hour turn. The battery charger plugs directly into the charging jack on the front of the pump.

Gravimetric Sampling System

One type of gravimetric sampling system which separates respirable and nonrespirable dust consists of a portable pump with an elutriator and filter in which the dust is collected (Figure 7.3). The nonrespirable dust

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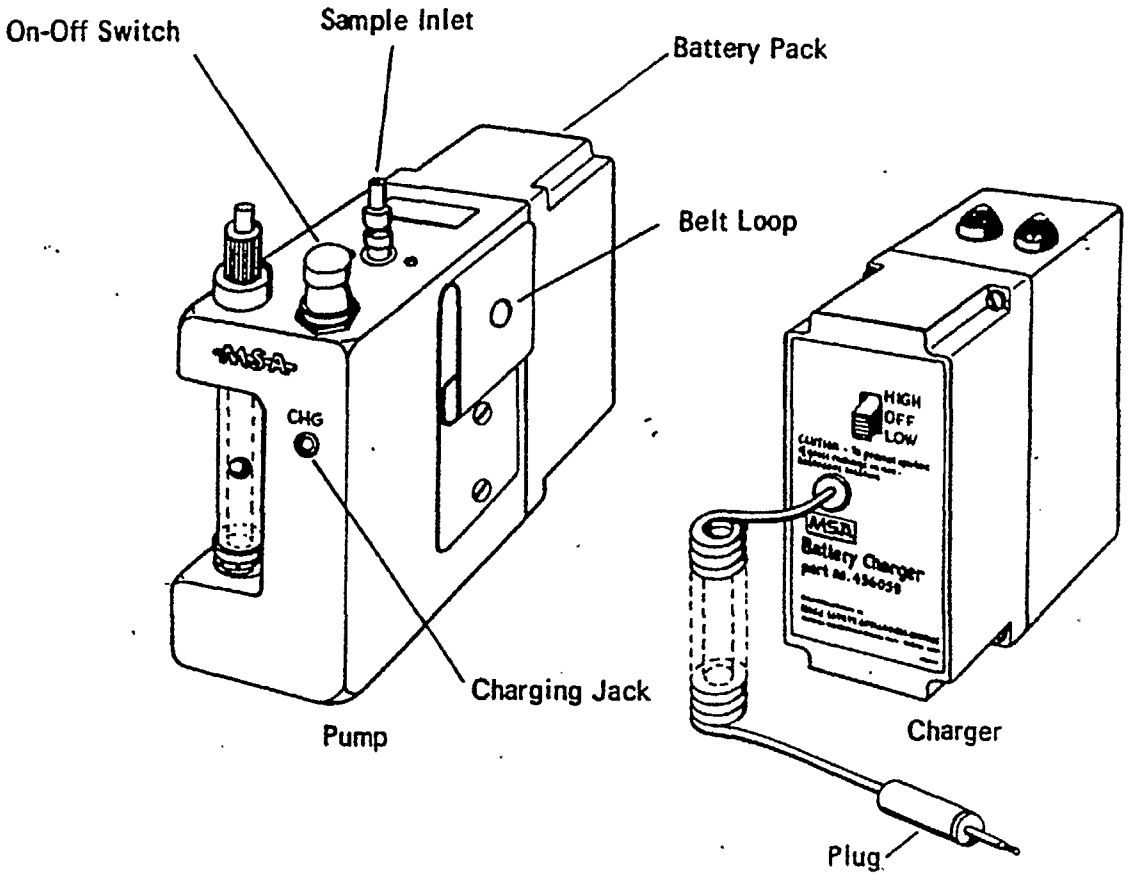


Figure 7.2

is collected in the cyclone (elutriator), and the respirable dust in the filter. Care must be taken to insure that there is no leakage in this kind of system; therefore, the filter holder must provide a positive seal, and a back-up support or screen is generally required to prevent rupture or displacement of the filter. The use of preweighed cassettes eliminates these problems since filter capsules are enclosed in the cassettes.

Filters

Many different types of filter media, with many different properties, have been designed for or adapted to air sampling requirements. Types of filters for specific particulate sampling applications are listed in Figure 8.6. They are available in preweighed cassettes, or as loose filters which require filter holders and must be weighed before use (tare weight).

GASES AND VAPORS

The same type of equipment is recommended for both gas sampling and vapor sampling in Corporation facilities. Portable instruments used to collect gas and vapors are generally classified as either direct reading instruments such as combustible gas indicators, which give an immediate indication of the gas or vapor concentration on a dial or other scale; or indirect instruments which remove the contaminant from a measured quantity of air for subsequent analysis.

Combustible Gas and Vapor Indicators

Two direct reading instruments approved for determining low concentrations of gases and vapors are the J&W Model SS-P and the MSA Model 40 shown in Figures 7.4 and 7.5. Each instrument has two scales. One scale, 0 to 100% LEL, is the same as that of a standard combustible gas indicator, and is not generally applicable to environmental health testing. The other scale, 0 to 10% LEL, has application in environmental health testing limited to gas and vapor concentrations in

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Cyclone/Filter Holder Assembly

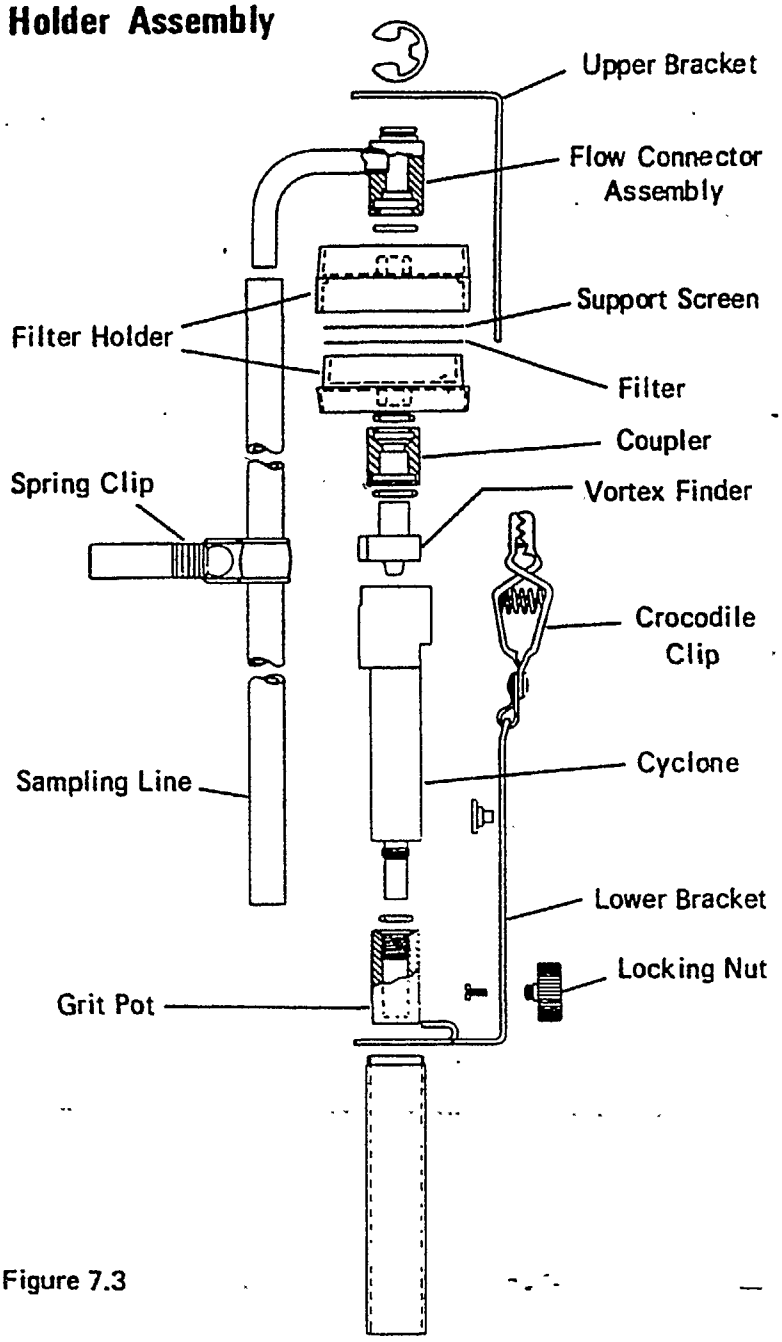


Figure 7.3

excess of 20-40 ppm. Because they lack specificity, it is practically impossible to use these instruments to determine the percentage of each component in a mixture. Nonetheless, if they are used judiciously, their portability and immediate availability of results make them useful.

Carbon Monoxide and Oxygen Instruments

The MSA Carbon Monoxide Indicator Model D with charger (Figure 7.6) is approved as a direct reading instrument for carbon monoxide measurements. It will detect 0 to 500 ppm carbon monoxide in the atmosphere and is useful for continuous monitoring over an 8-hour period. However, it has limitations which are characteristic of all catalytic indicators of this type – namely, the need for correction factors when used at elevated

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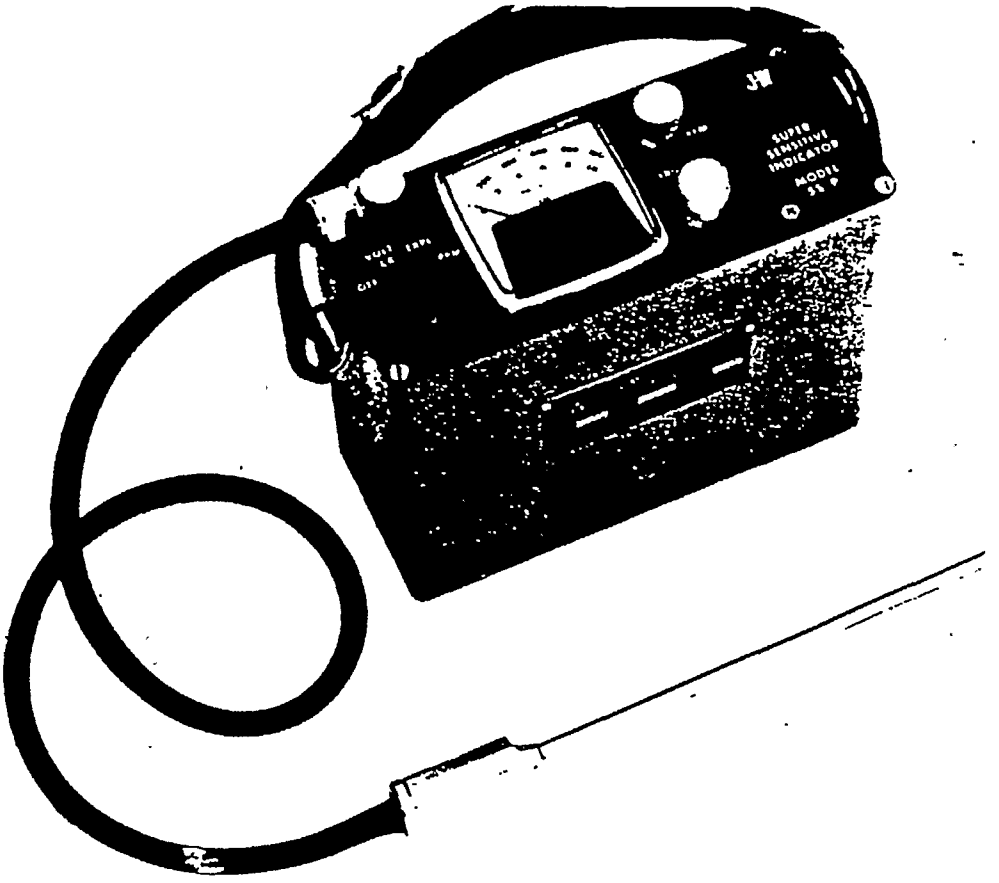


Figure 7.4

temperatures and/or in excessive humidity. therefore, the manufacturer's operating instructions should be reviewed carefully before the instrument is used.

The MSA Oxygen Indicator Model 244R, BioMarine Oxygen Analyzer No. OA222R, and Bacharach Fyrite Oxygen Analyzer No. 458-171 are shown in Figure 7.7. The MSA and BioMarine instruments give continuous direct readings of oxygen concentrations in the atmosphere, and do not require either warm-up or changing of chemicals. The Bacharach Fyrite Oxygen Analyzer requires the use of absorbing chemicals and, therefore, does not give an instantaneous reading. As with all instruments, operating instructions should be reviewed carefully.

Indicating Tubes

Indicating tubes are glass tubes containing chemically treated silica gel or activated charcoal which reacts to some chemicals by producing a stain, the length of which is proportional to the contaminant con-



Figure 7.5

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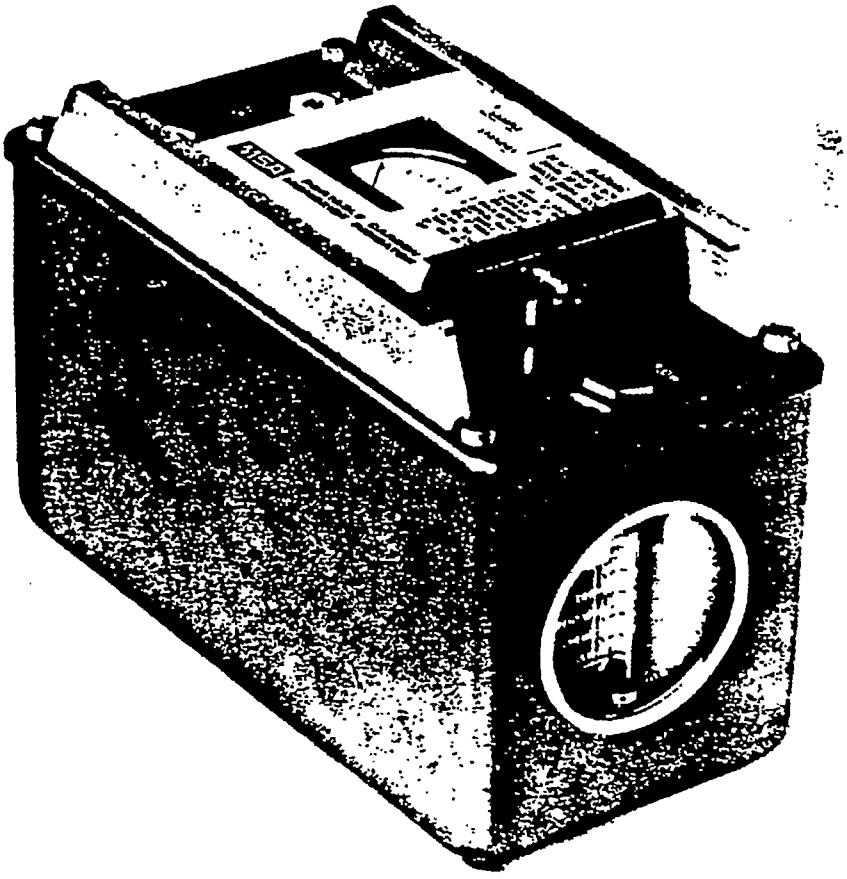


Figure 7.6

centration being measured. Their efficiency is dependent upon the rate of air flow through the tube, the packing and age of the chemicals, etc. They are used with either the MSA Model S pump (Figure 7.2) or the MSA Universal hand pump (Figure 7.8). Indicating tubes can be used for long-term sampling with the Model S pump and with a single or multiple tube holder (Figure 7.9). Detector tubes to be used with a hand pump (Figure 7.10) are also available from Bacharach Instrument Company.

The manufacturer's operating instructions must be closely followed in the use of indicating tubes. Their accuracy depends upon calibration of air flow, calibration of the tube with known gas concentrations, and the observer's visual interpretation of length of stain. In addition, their accuracy can be plus or minus 50%, and interference from other materials can affect or negate results.

Indicating tubes are used with a hand pump for grab samples, and with a battery-operated pump and tube holder for long-term samples. A carbon monoxide tube with a MSA Universal pump would only indicate the carbon monoxide concentration at the specific location of sampling for the short period of sampling (usually a few seconds). On the other hand, a carbon monoxide tube with a tube holder and a Monitaire pump can be used for up to 4 hours, with fluctuations in CO concentrations during that period being averaged automatically.

Other Instruments

Although there are several other commercially available instruments for sampling air contaminants, this Manual presents only those which have been approved and listed in Guideline No. 8. Other methods of collection may be used by an industrial hygienist. These include devices such as Hi Volume Samplers, electrostatic precipitators, and cascade impactors or impingers, for particulates; and charcoal tubes, evacuated flasks, and fritted glass bubblers for gases and vapors. Persons engaged in air sampling should be familiar

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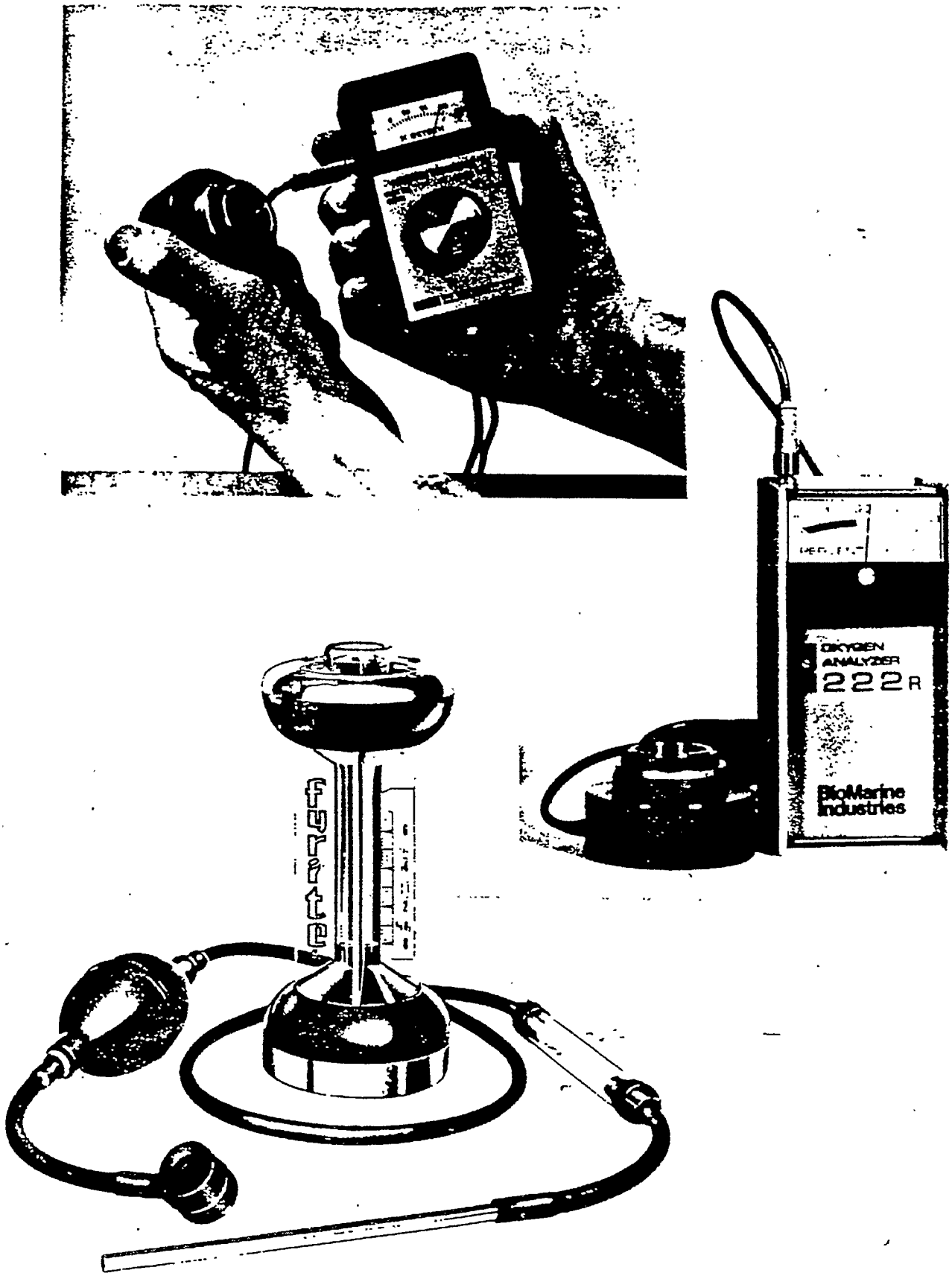


Figure 7.7

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MSA Universal Sampling Pump

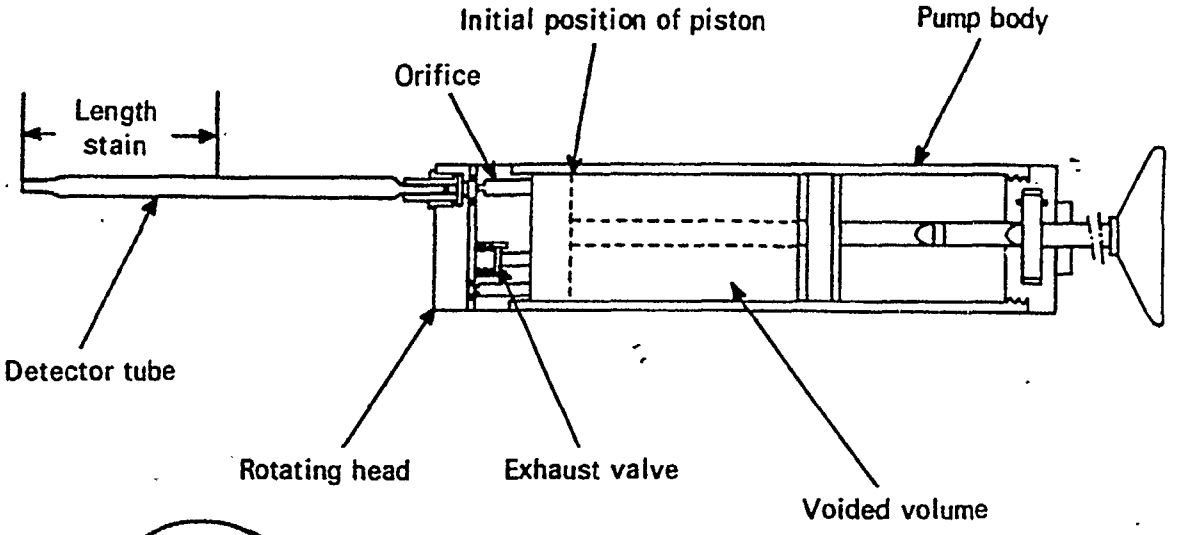
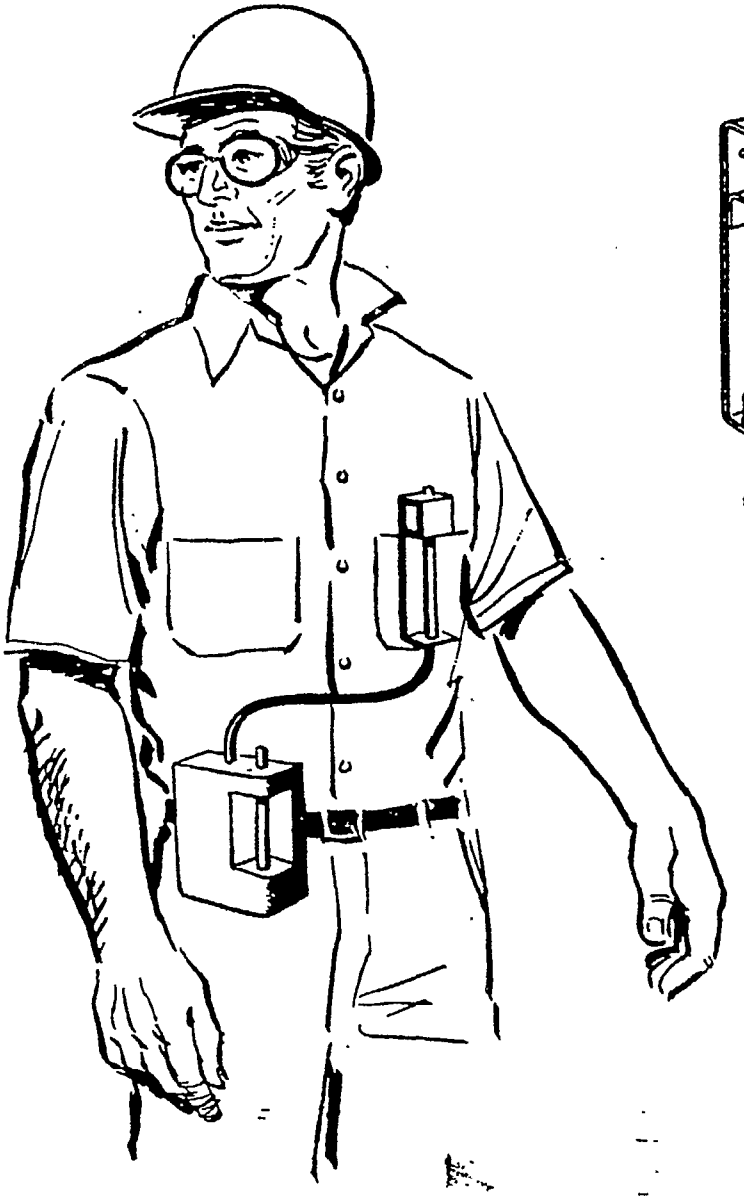
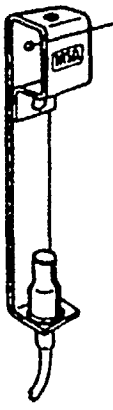
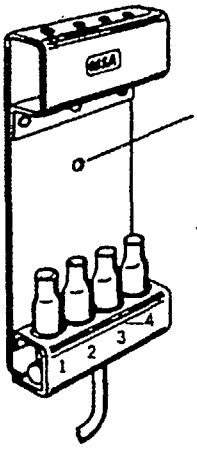


Figure 7.8





Single Tube Holder



Multiple Tube Holder

Figure 7.9

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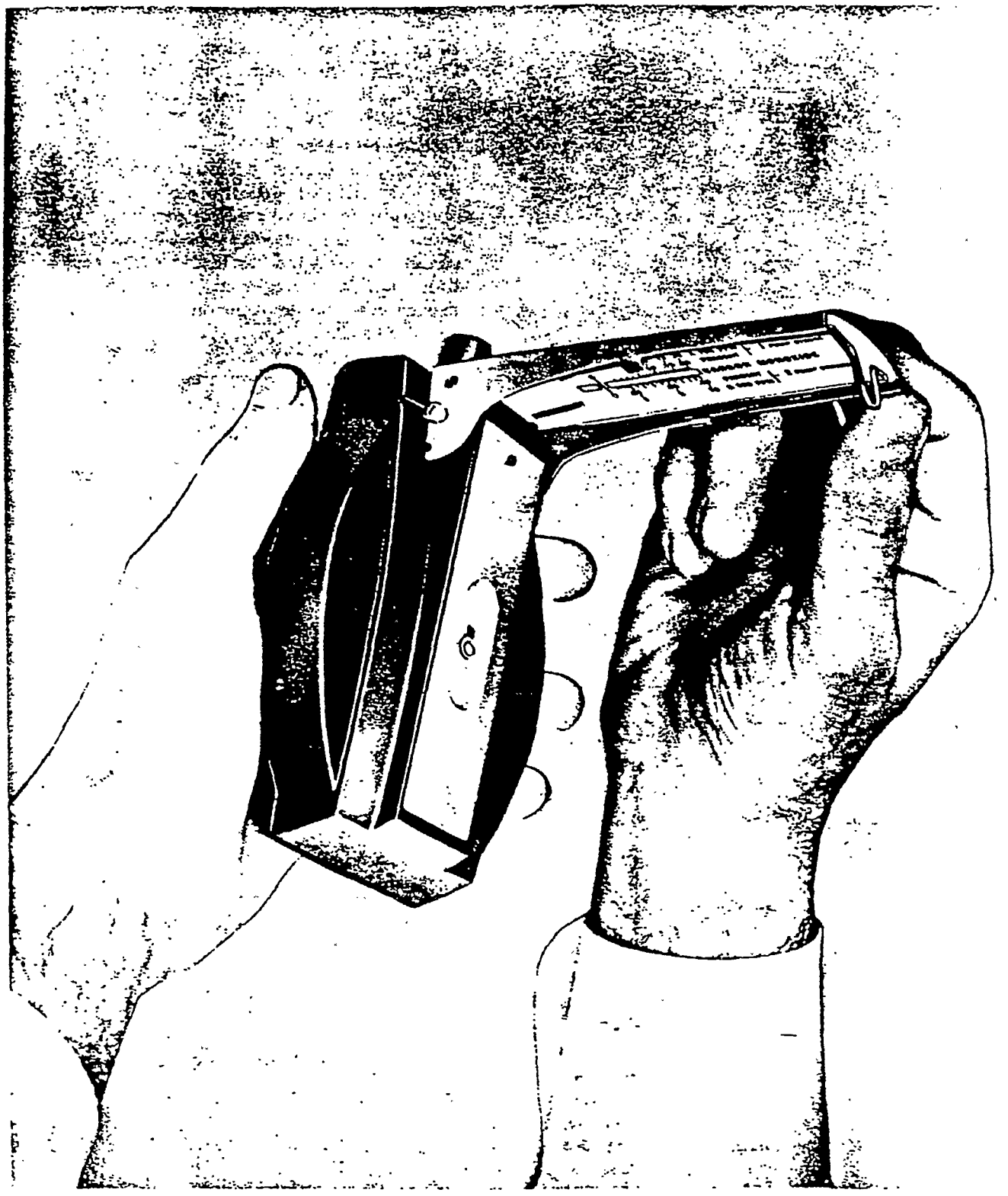


Figure 7.10

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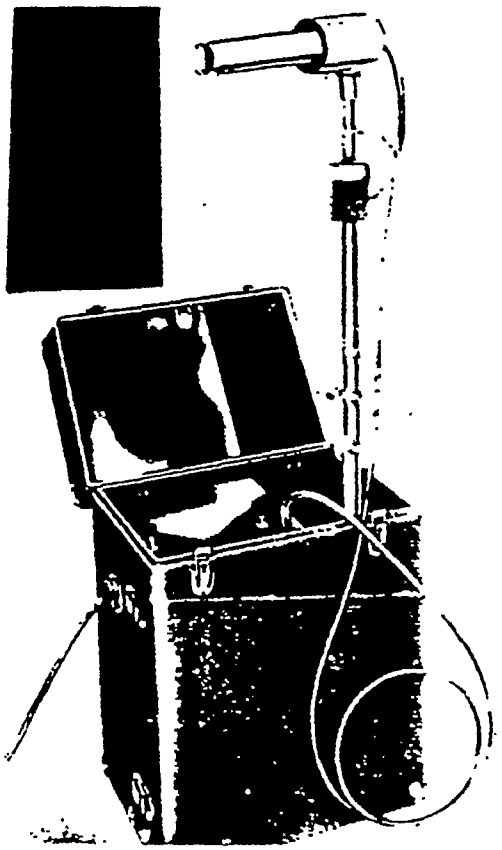


Figure 7.11

with their availability as well as their basic functions and limitations.

Sampling Devices for Particulates

1. *Electrostatic Precipitator*
   The electrostatic precipitator (Figure 7.11) can pass a relatively high air flow (3 CFM) through a high voltage electric field with a collection efficiency of nearly 100% for all size particles. It consists of a grounded metal tube about 1.5" in diameter and 6" in length, which serves as a collecting electrode. In the center of this tube is a stiff wire electrode which is maintained at a potential of about 12,000 volts. Particulates passing through this electric field become highly charged and are attracted to the cylinder wall where they are collected. The precipitator can be used to collect air samples to determine total weight, or for microscopic or chemical analysis. It has several major disadvantages: weight (about 40 pounds), power requirements (60 cycle, 110 volts), calibration of air flow, and the fact that it cannot be used in areas containing combustibles.
2. *Cascade Impactor*
   The Cascade Impactor is used to determine the size range of airborne particulates. Its operation is based on the principle that when a high velocity dust-ladened air stream strikes a flat surface at a 90° angle, the sudden change in direction and momentum causes the dust to separate from the air.
   The Cascade Impactor (Figure 7.12) consists of 4 impingement slits of decreasing width mounted in a series at decreasing distances above the collecting plates. The largest particles are collected on the first plate and the smallest on the last plate. Particle size separation is dependent upon air flow, usually 18 liters/minute. With

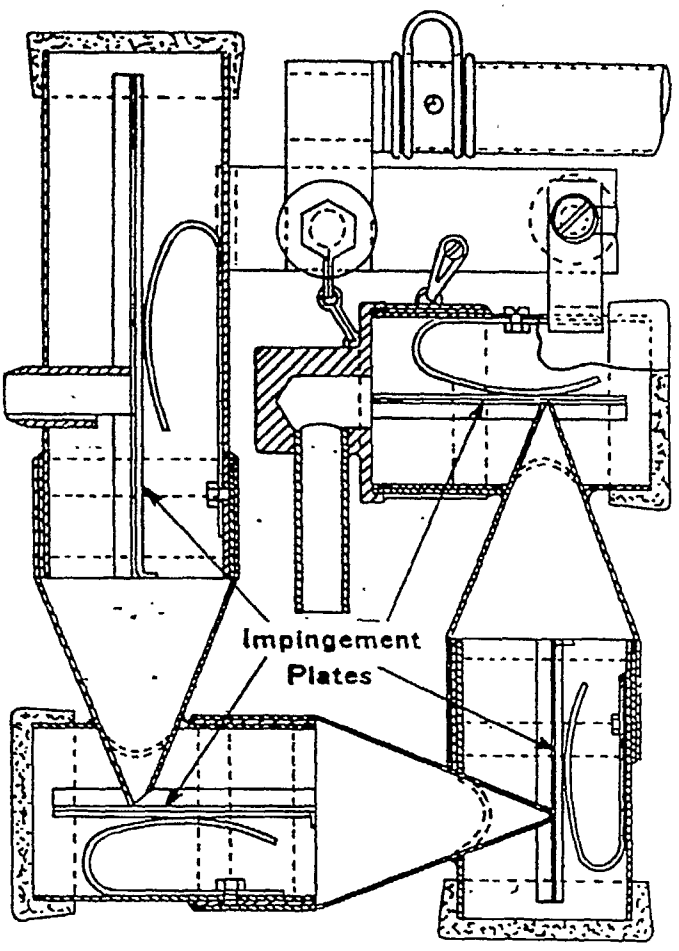


Figure 7.12

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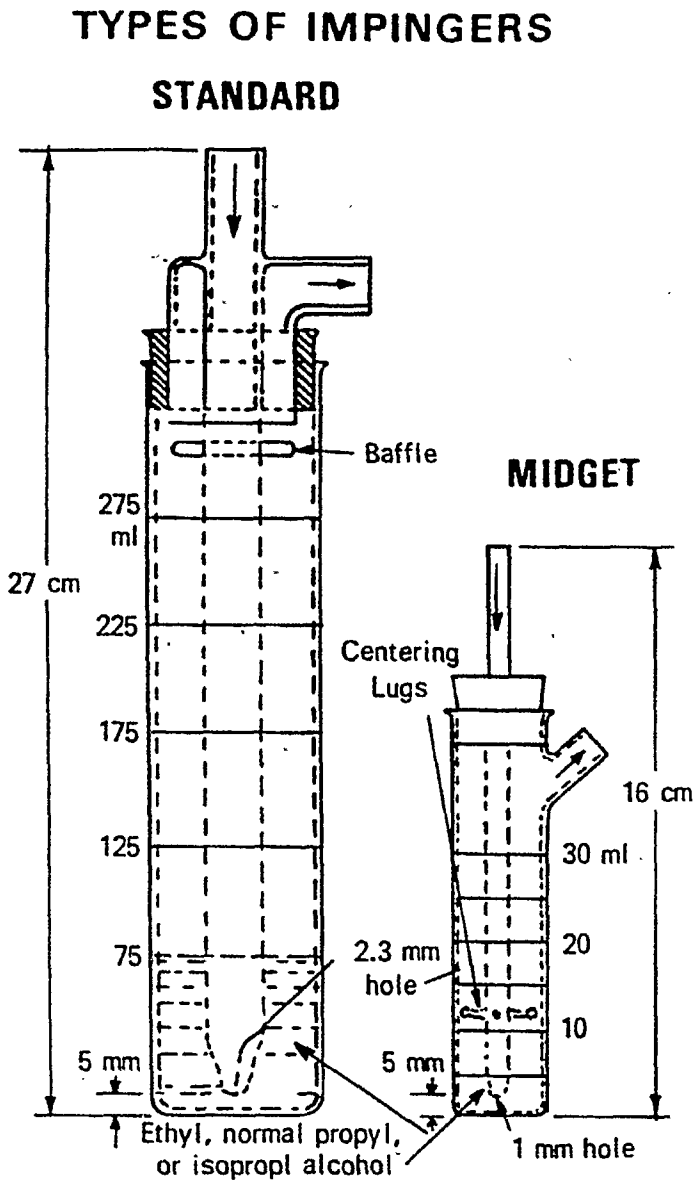


Figure 7.13

constant air flow, the particle size range at each collecting plate is constant. Thus, the particles on each plate can be analyzed for total weight, particle count, chemical composition, or further size determination. The disadvantages of this instrument are that its air flow requirements are high and that its efficiency for very small particles is low because their momentum is not sufficient to cause them to impact or collect on the plate.

3. *Impingers*

The impinger (Figure 7.13) is an apparatus through which air is sampled at high velocity and impinged from a jet onto a plate which is immersed in a liquid collection medium. Particulates are impinged on the plate, lose their high velocity, are wetted by the liquid, and remain trapped. Gases soluble in the collection medium are also collected.

Monitor and Midget Impinger Unit

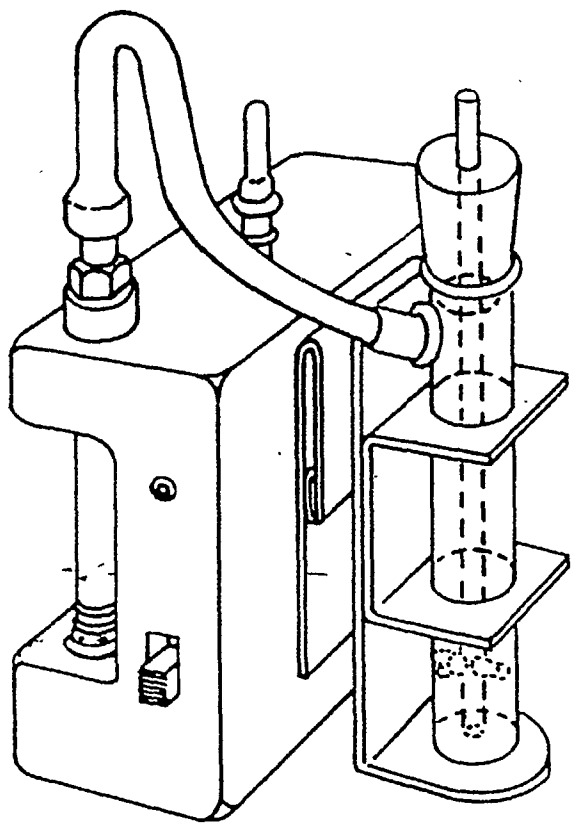


Figure 7.14

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The impinger had a long history of use in this country before the advent of gravimetric samplers, and it is still the standard dust sampling instrument in the United States for dust assessment on a particle count basis.

As discussed previously, OSHA dust standards are either on a weight basis (mg/m^3) or on a particle count basis (mppcf). To use the count standard, dust samples are generally collected with a midget impinger, at a sampling rate of 0.1 CFM utilizing a Monitaire pump as the source of suction (Figure 7.14). The resulting sample is counted by a standard microscopic technique.

4. *Hi-Volume Samplers*

As the name implies, these devices are designed to sample high volumes of air at rates of 50-75 CFM to collect large quantities of airborne particulate matter on filter papers for subsequent mineralogical (principally quartz) analysis. Several units are commercially available, including the one shown in Figure 7.15, which is described in Chapter VIII.

Sampling Devices for Gases and Vapors

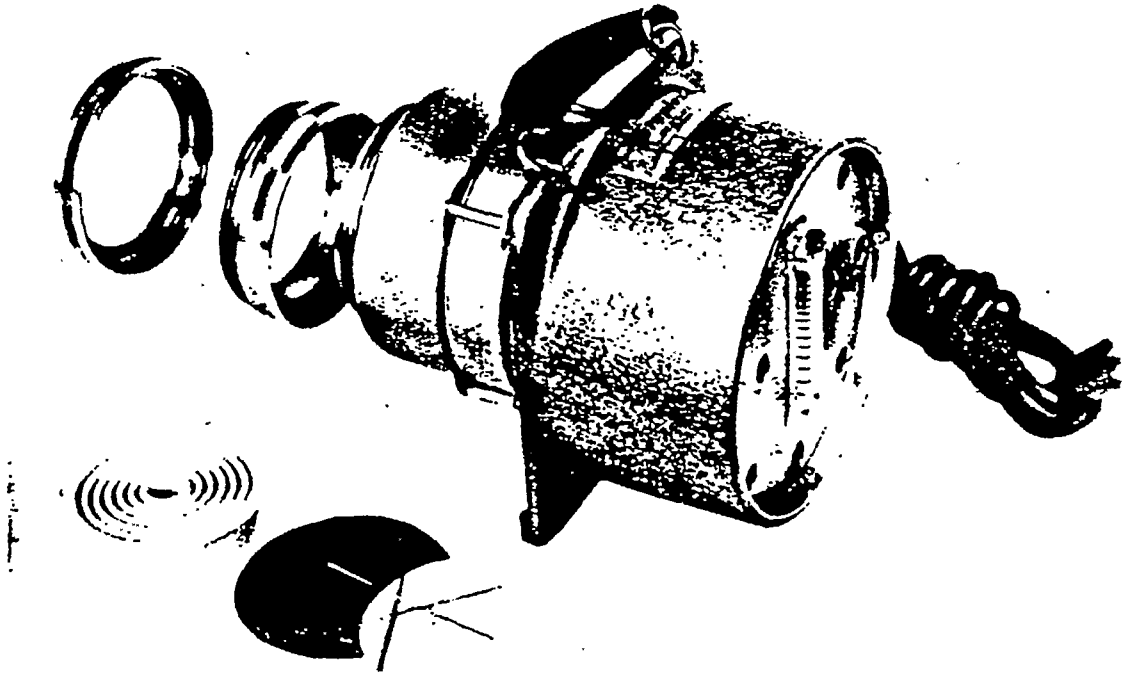


Figure 7.15

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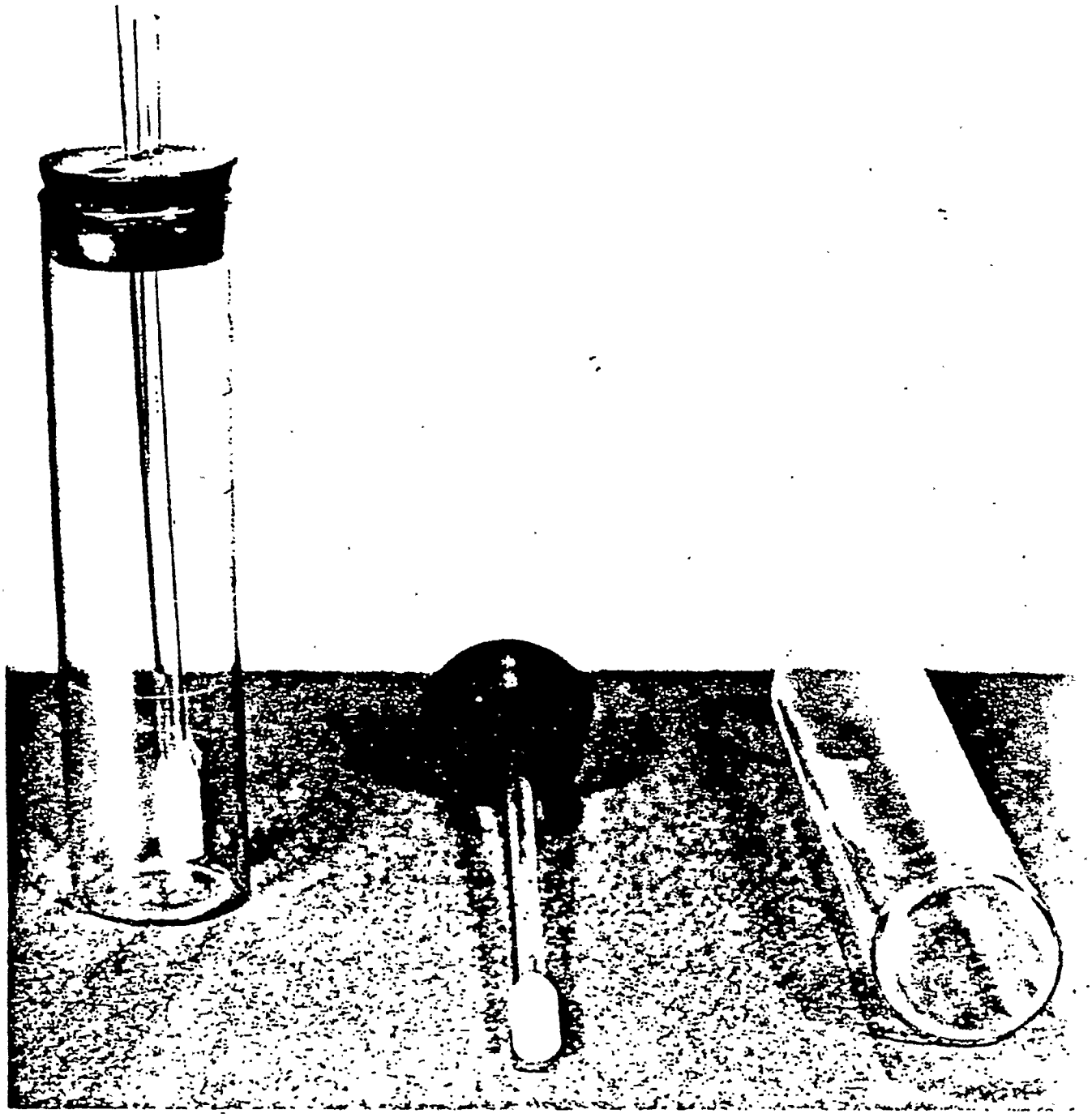


Figure 7.16

Indirect reading devices are used to sample for gases or solvent vapors for which there may be no commercially available detector tubes, or to sample for gas or vapor mixtures which cannot be separated by the direct reading instruments described earlier. They include fritted glass bubblers, charcoal tubes and plastic bags (Figures 7.16, 7.17 and 7.18 respectively), and are discussed in Chapter IX.

Instruments for Measurements of Physical Conditions

Equipment requirements for noise, illumination and heat measurements are listed in Guideline No. 8, Appendix B.

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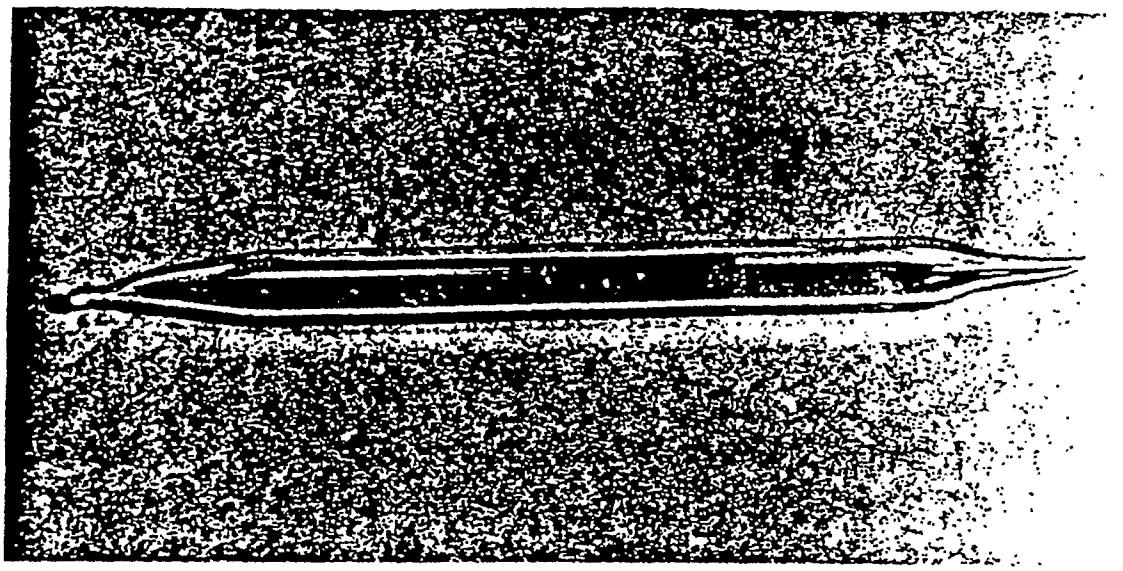


Figure 7.17

Noise

Two measurements are normally made during surveys for compliance with OSHA. One is the sound pressure level on the A-weighted network of the sound level meter (dBA) and the other is the length of time a worker is exposed to various sound levels during the work day.

The recommended sound level meters and calibrators are shown in Figures 7.19 and 7.20. The meter is a small compact instrument which includes a nondirectional microphone, a continuously-adjustable calibrated attenuator, an amplifier with three weighting networks and an indicating meter. The sound pressure level is the sum of the attenuator setting and the reading from the indicating meter. These instruments can serve no useful purpose unless they are properly calibrated and their calibrations are maintained. Acoustic calibrators made by the meter manufacturers provide a simple method of checking sound level meters, including microphones. The calibrator consists of a small loud-speaker mounted in an enclosure which fits over the microphone and is so designed that measurements can be repeated with a high degree of accuracy.

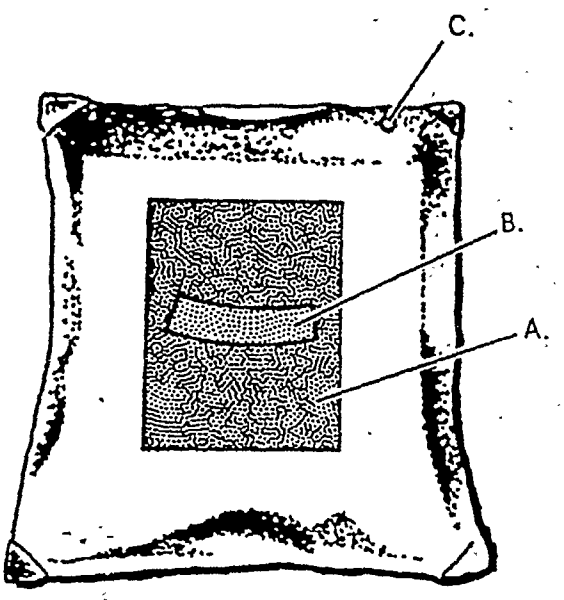


Figure 1. 13-3/4 x 16 inches bag of Flex-o-foil
A. 8 x 10 inches piece of hardboard
B. 1¼ x 10 inches handle, made of ribbon
C. 1/8 inch I. D. nipple, made of Teflon

Figure 7.18

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Figure 7.19

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B&K Sound Level Meter & Calibrator

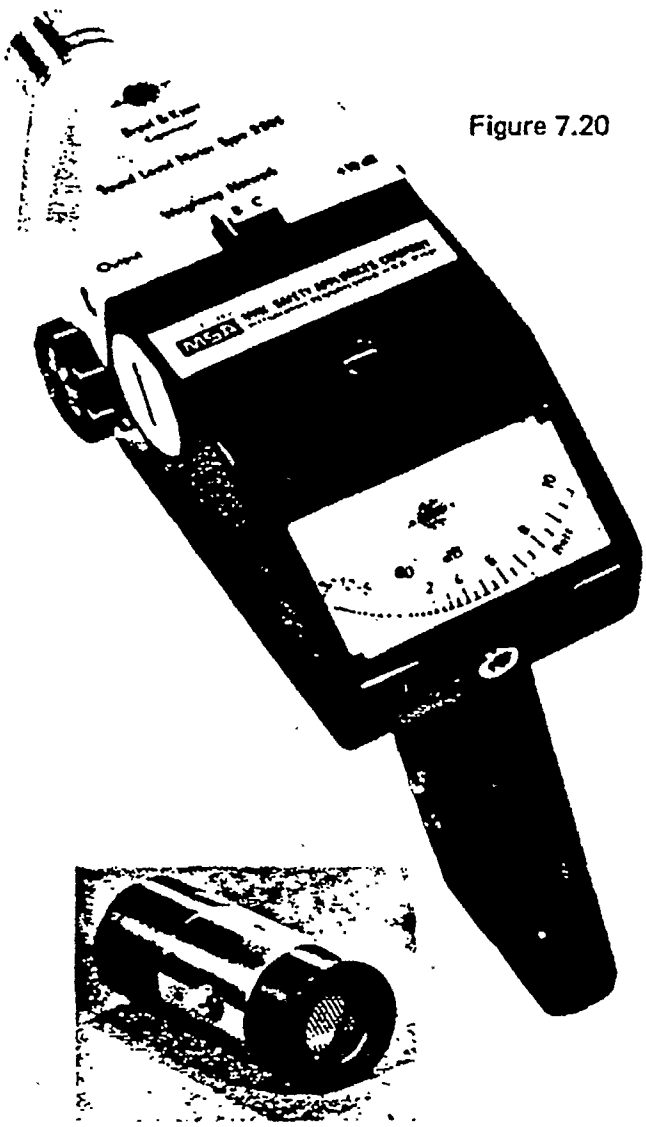


Figure 7.20

General Radio Noise Exposure Meter

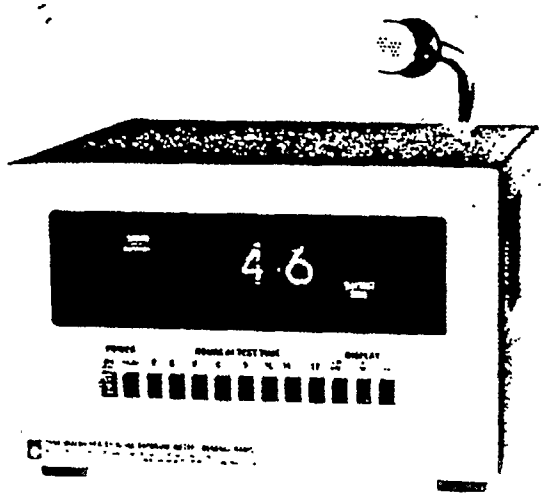


Figure 7.21

Personal Noise Dosimeter



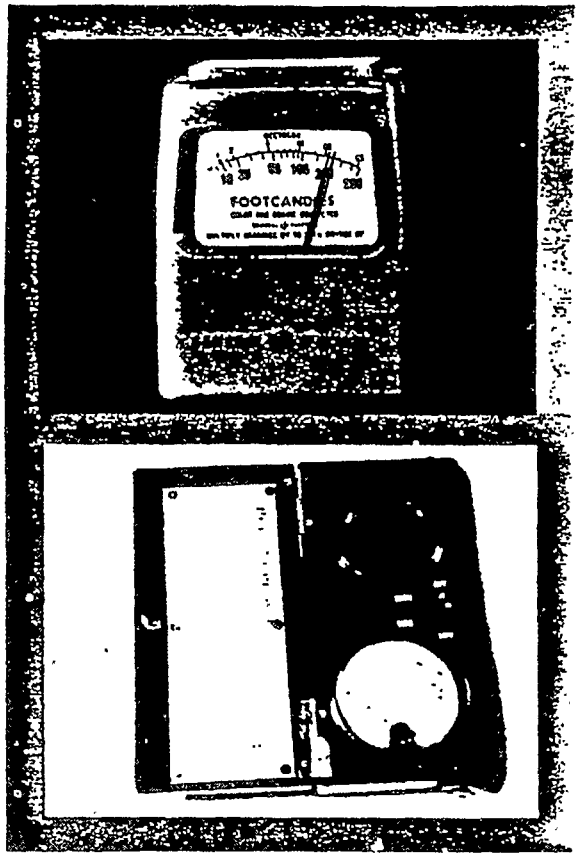
Figure 7.22

A noise exposure meter (Figure 7.21) provides accurate information on exposure by automatically integrating sound pressure level (dBA) with exposure time to indicate compliance or non-compliance with the noise standard. A personal noise exposure meter (Figure 7.22) is also available, which similarly integrates the time factors with noise intensity.

Light

Light meters recommended for illumination surveys (Figure 7.23) are the G. E. Pocket Size Meter Type 213, G. E. Type DR

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Light Meters

200 and Weston Hinged Cell Meter Model 614. All are color- and cosine-corrected light indicating devices. The G. E. Meters are capable of reading 500 footcandles on their basic scales and to 5,000 footcandles with the use of built-in multiplying switches. The Weston Hinged Cell Meters have wider ranges than the G. E. Pocket Size Meters, but are more expensive. The color-correcting filter permits evaluation of any color of light essentially the way the eye sees it, while the cosine correction makes the meter respond equally to illumination from all directions.

Heat

Heat stress is a complex and difficult problem to evaluate and the related measurements involve more than determination of air temperature. But the instruments used for

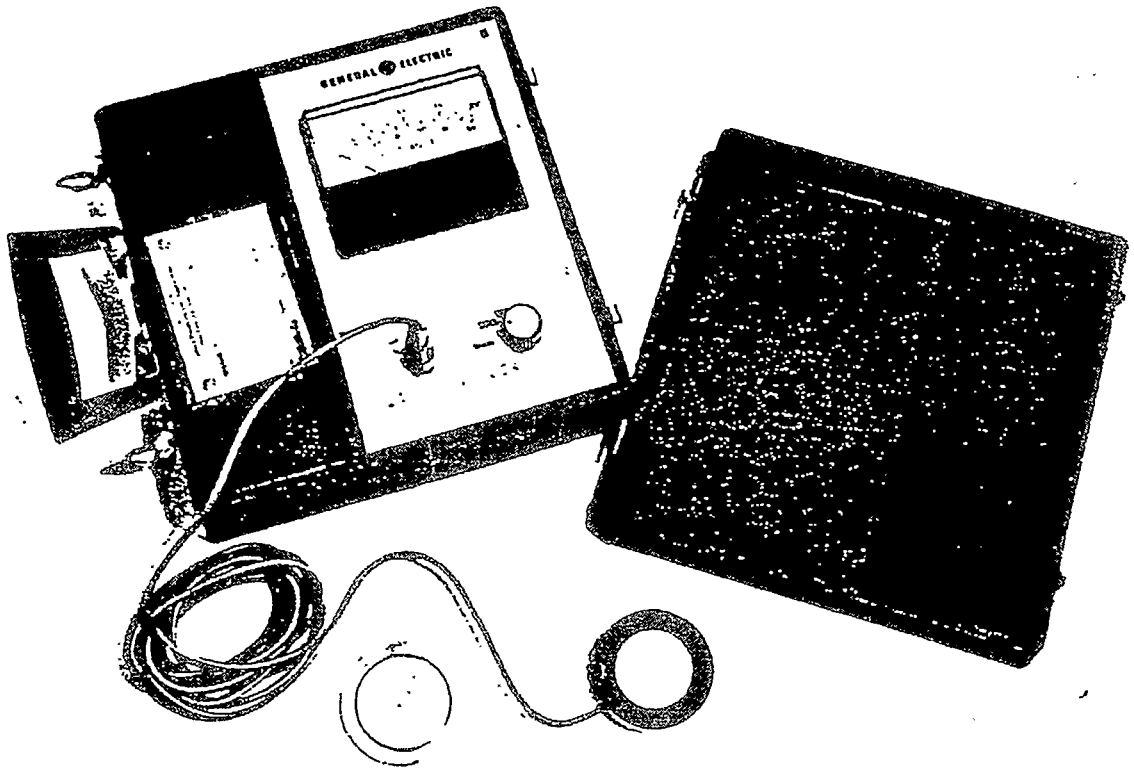


Figure 7.23

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this purpose are simple and almost trouble-free.

The Wet Globe Thermometer from Howard Engineering Company (Figure 7.24) is a new instrument that combines air temperature, humidity, wind and thermal radiation into a single reading related to human response. It consists of a 2-3/8" hollow copper sphere that is painted black and covered with a double layer of black cloth. The cloth is continuously moistened by water seeping from an attached reservoir tube. The stem of a dial thermometer passes along the centerline of the water reservoir tube and into the globe, where it senses changes in air temperature, humidity, wind, or thermal radiation.

Other instruments which measure air temperature, humidity and thermal radiation are listed in Guideline No. 8, Appendix B, Sections 3-b and 3-c and are discussed in Chapter XII.

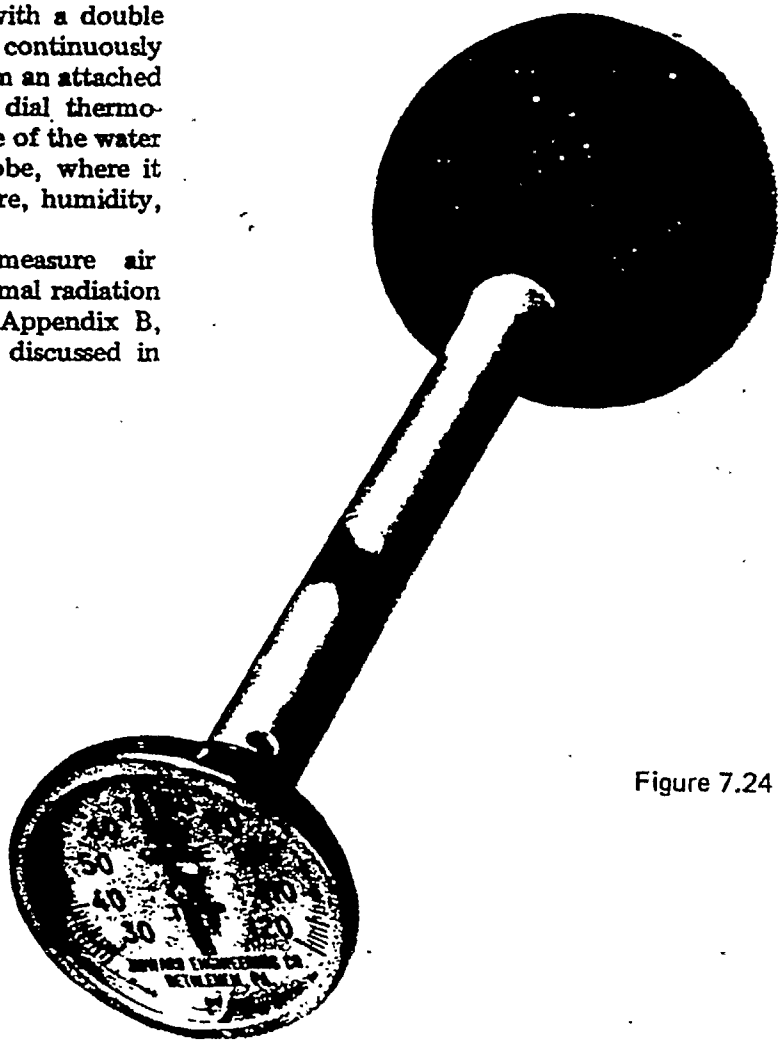


Figure 7.24

A Wet Globe Thermometer

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SAMPLING FOR PARTICULATES

For many years, industrial hygiene (environmental health) engineers have monitored air contaminants as one step toward insuring healthful working environments for employees. Air sampling (monitoring) data is used to determine the nature and magnitude of potential health hazards, to identify air contaminant sources, and to evaluate the effectiveness of engineering controls. With the advent of OSHA, air sampling is now required to document compliance with health standards.

Airborne particulates (aerosols), as defined in Chapter IV, are any solid particles or liquid droplets dispersed in the air. Dusts, fumes and smokes are solids, while mists and fogs are liquids. Particulates can range in size from visible to sub-microscopic, but in air sampling for health considerations the primary concern is with those aerosols smaller than 10 microns (μ).

Particulates may be sampled for total quantity, for the respirable fraction, or for chemical analysis for such substances as lead, chromium, zinc, acids, etc. In certain cases, samples are taken for microscopic study of the size, shape or number of airborne particles or for other special analysis or examination. Figure 8.1 shows a set-up for, and Figures 8.2 and 8.3 the type of data resulting from, microscopic study.

The method of sampling particulates depends upon the reason for sampling. Since most samples are collected to determine total weight and/or to analyze for one or more specific contaminants (metals, acids, organic compounds, etc.), passing the air through a suitable filter is usually the method of choice (Figure 8.4). Since the worker's actual exposure to airborne contaminants is of primary concern, a "personal sampler" which can be attached to the employee's clothing and will

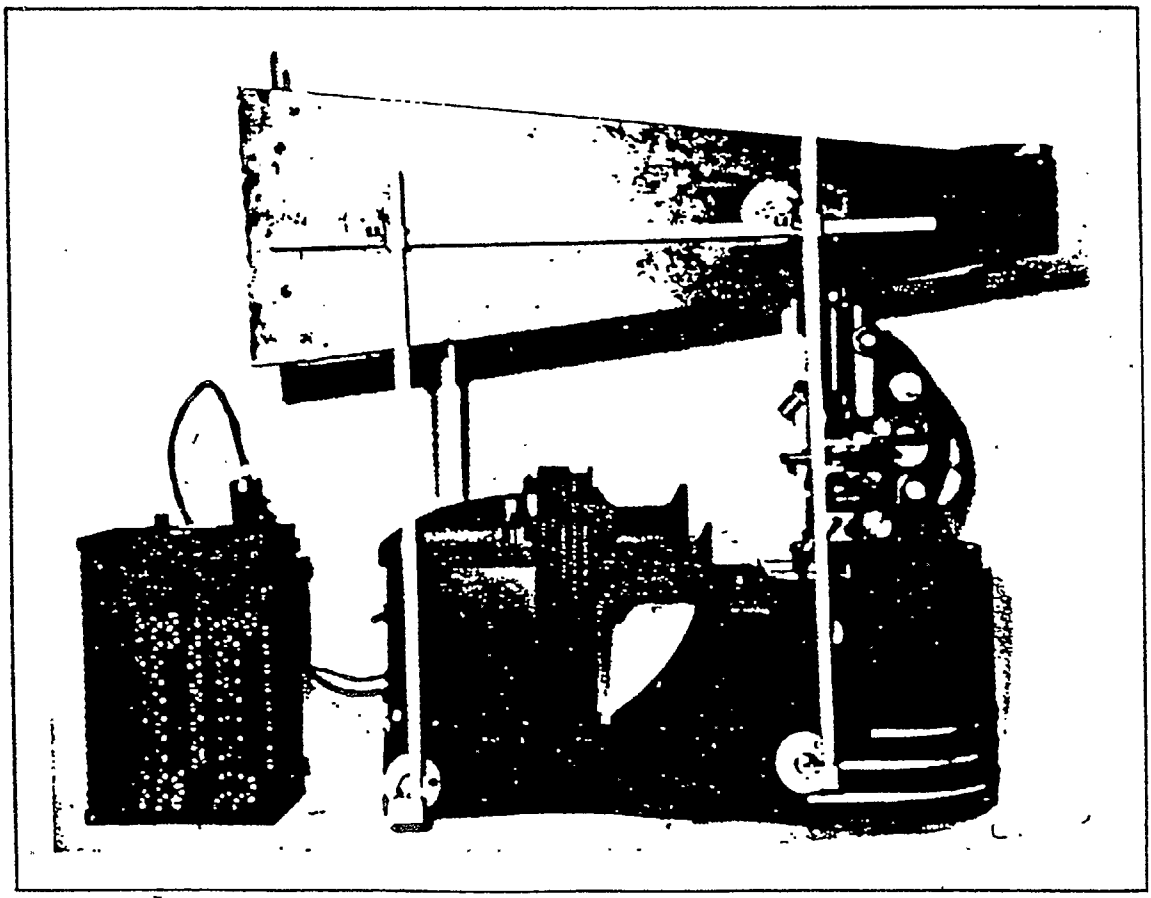


Figure 8.1

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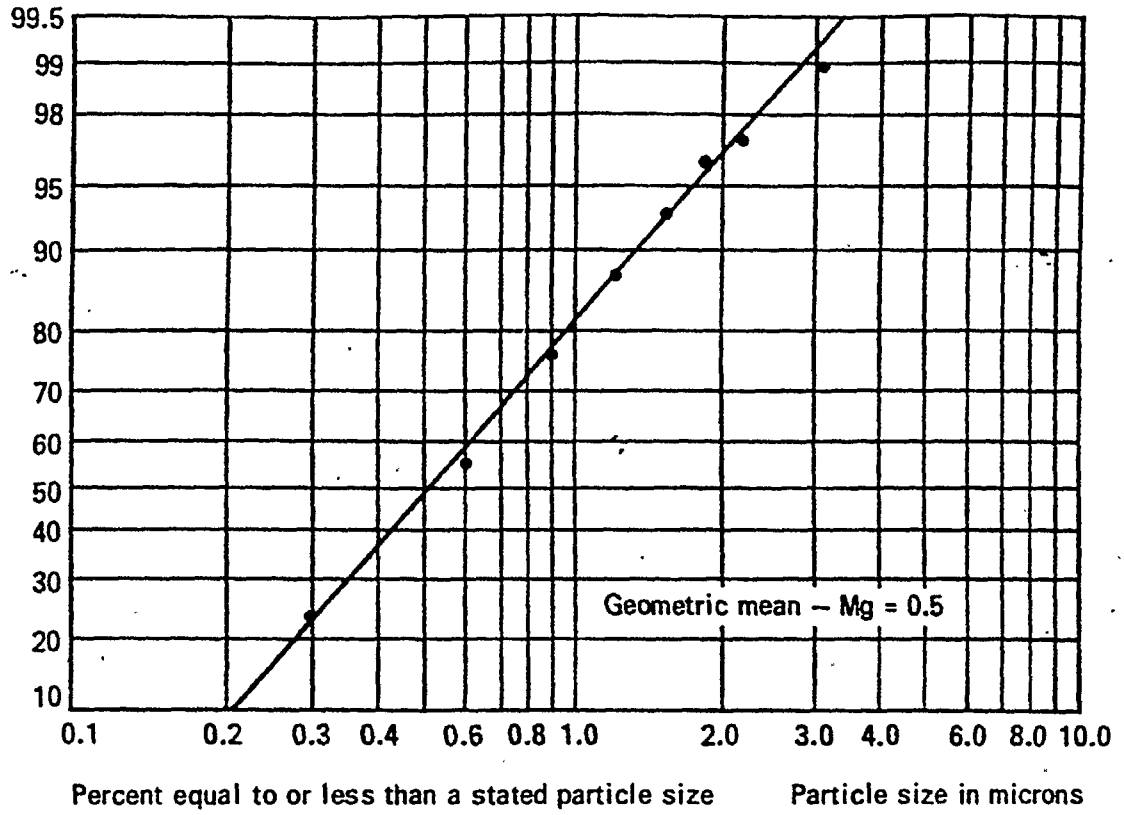


Figure 8.2

PARTICLE SIZE DISTRIBUTION

Study	Total Percentage of Particles below Stated Size				Median Size
	0.5 μ	1.5 μ	4.0 μ	5.0 μ	μ
USPH Anthracite Survey – Penna., 1934	8.0	88.0	99	99	0.9
USPHS Bituminous Survey – Utah, 1941	2.8	40.3	71.8	83	1.94
USS – CM Mining (Augur Type) – Penna., 1963		1 μ	4 μ	5 μ	
		39.1	84.8	88.7	
Great Britain – South Wales 1943	0.4 μ	1.2 μ	4 μ	5 μ	
Longwall Stalls	27.3	60.5	89.6	94.3	
Narrow Workings	27.8	66.6	93.1	97.0	

Figure 8.3

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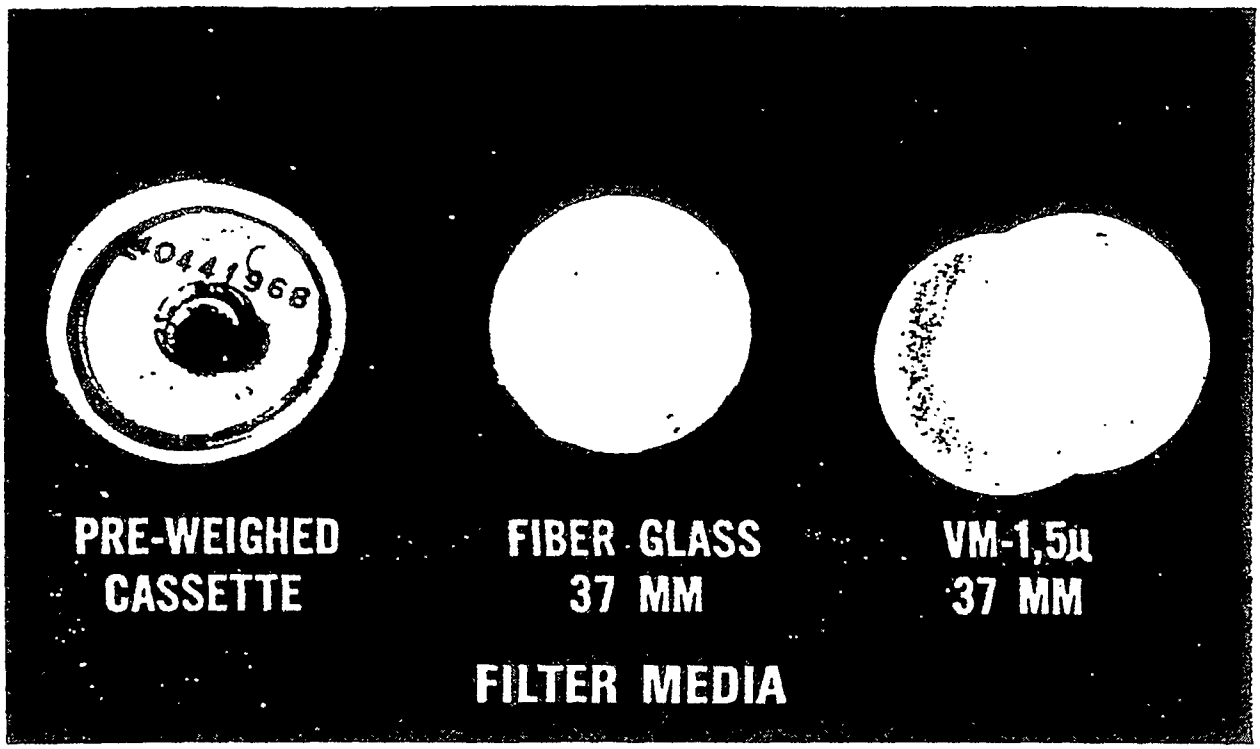


Figure 8.4

collect breathing zone air samples throughout a full work shift is generally preferred.

Other methods of air sampling which are used in special cases include the electrostatic precipitator, the cascade impactor, the impinger and the hi-volume sampler, which are also briefly discussed in Chapter VII. However, none of the devices are suitable for personal sampling. The electrostatic precipitator can be used to sample most particulates, but its size and power requirements are limiting factors. The impactor, impinger, and hi-volume sampler are useful only for dust, and only the impinger should be used to determine employee exposure. In general, therefore, these devices are not used in USS sampling programs, although a hi-volume sampler may be used for special studies as will be discussed.

Air in the work environment can appear quite dirty to the eye, and still contain, on a weight basis, relatively small amounts of particulates. Generally, it is not possible to obtain enough sample for accurate weighing or for chemical analysis unless long-term (4 to 8 hour) personal samples or hi-volume samples are collected.

WITHIN THE CORPORATION, ROUTINE SAMPLING FOR PARTICULATES, i.e., DUST, FUME, SMOKE, MIST, ETC., IS BY LONG-TERM LOW VOLUME SAMPLING DEVICES WHICH CAN BE WORN BY A WORKER AND WILL INDICATE HIS FULL-SHIFT EXPOSURE.

These devices can also be used to collect long-term samples in fixed areas.

Sampling System

The sampling system (sampler) consists of a pump, a flow indicating device, a valve for controlling the amount of air sampled, and a device for collecting the particulates (Figure 8.5).

A filter is the most widely used collection device for particulate sampling, since full-shift personal samples can be taken and a gravimetric sample (for direct weighing and, when necessary, chemical analysis) does not require microscopic study. In addition, OSHA lists air standards for pneumoconiosis-producing (mineral) dusts on both weight and particle count bases. Although collection of particulates by the impinger (utilizing light field

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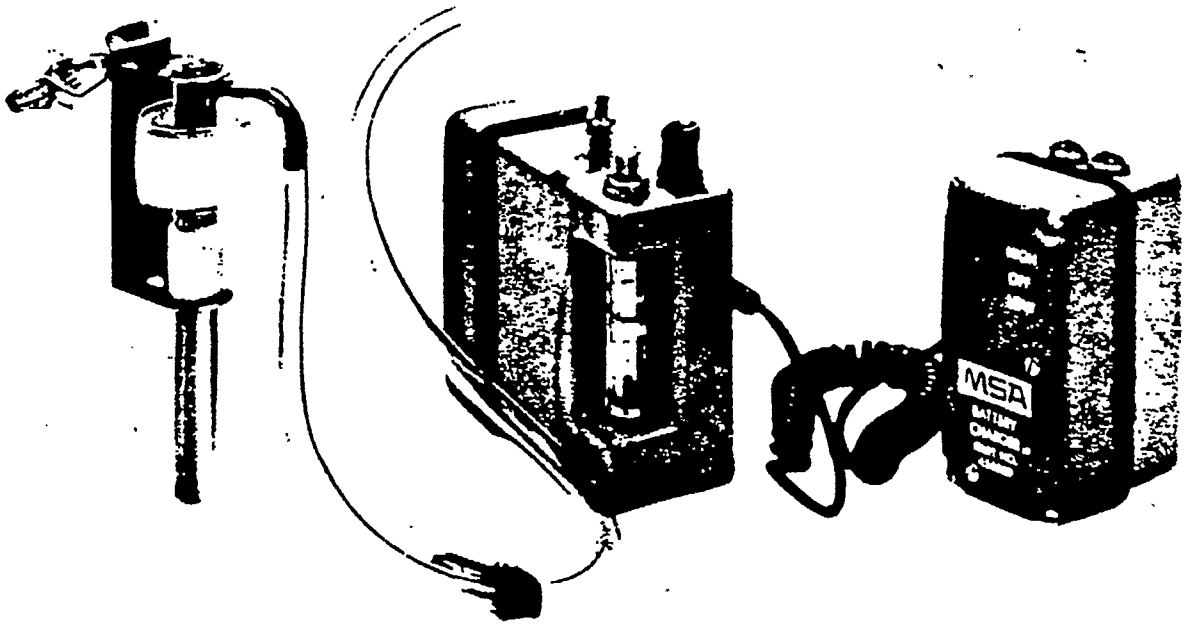


Figure 8.5

microscopic techniques for counting dusts) is still an accepted method of evaluating worker exposures to airborne dust, gravimetric sampling is usually much simpler and, as indicated earlier, is used for routine particulate sampling. Equipment to be used for particulate sampling is listed in Figure 8.6.

Pumps

There are many different kinds of pumps used in sampling systems to collect air samples. They range from very small devices which sample at rates of only a few milliliters per minute (ml/min) to hi-volume samplers which sample at rates of 50 to 75 CFM (50 CFM equal 1.41×10^6 ml/min).

Pumps may be hand-operated, battery-operated or powered by 120V ac/dc or 240V ac/dc. Several companies manufacture relatively light-weight battery-operated pumps which can be attached to a worker's belt and can sample up to 3 liters/min (lpm) of air through a collection device for periods of 8 hours. These pumps in general are ruggedly constructed and sufficiently stable so that a given airflow (1 to 3 liters/min) can be maintained throughout a full shift.

Headquarters Environmental Health has evaluated commercially available personal samplers with the following results:

1. The devices manufactured by the Bendix Company (Unico) and supplied by National Environmental Instruments, Inc. (NEII) are not presently recommended (Figures 8.7 and 8.8). The early model Unico long-term sampler (Figure 8.7) is too large for general use and needs frequent maintenance. The present Bendix model (Figure 8.8) uses a small piston type pump and a dc motor powered by a 3.75V battery. This pump is unacceptable because it samples at a flow rate of 2.0-2.5 liters/min against a static pressure of only 4.0 inches of water.
2. The recommended sampler, as indicated in Guideline No. 8, Appendix B, is the unit manufactured by Mine Safety Appliance

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AIR SAMPLING EQUIPMENT FOR PARTICULATES

Contaminant	Type of Sample	Sampling Apparatus	Supplier	Collection Device	Supplier	Sampling Rate
Total Dust	Personal or Area	Monitaire Pump	MSA	No. 3600-101 Type VM-1 Filter Holder No. 625412	NE11 MSA	2.0-2.8L/M
	Personal or Area	Monitaire Pump	MSA	Filter Disc No. 625413 and Holder No. 625412	MSA	2.0-2.8L/M
Respirable Dust	Personal or Area	Monitaire Pump with Holder 456243	MSA	Pre-weighed Cassette with 10MM Cyclone	MSA	1.8L/M
	Personal or Area	Monitaire Pump with Holder 456243	MSA	VM-1 Filter with 10 MM Cyclone	NE11 MSA	1.8L/M 1.8L/M
	Personal or Area	Monitaire Pump with Holder 456243	MSA	Disc Filter No. 625413 and Cyclone	MSA	1.8L/M 1.8L/M
Coke Oven Fumes	Personal or Area	Monitaire Pump	MSA	Extracted Fiber Glass Filter	USS	2.0-2.8L/M
Other Fumes	Personal or Area	Monitaire Pump	MSA	Glass Fiber Filter Type A	Gelmar	2.0-2.8L/M
Acid Mists	Personal or Area	Monitaire Pump	MSA	Treated Glass Fiber Filters	USS	2.0-2.8L/M
Oil Mists	Personal or Area	Monitaire Pump	MSA	Extracted Glass Fiber Filters	USS	2.0-2.8L/M
Asbestos	Personal or Area	Monitaire Pump	MSA	Millipore Type AA	Millipore Co.	1.5-2.0L/M

Figure 8.6

Company (Figure 8.5), which samples at a flow rate of 2.8 liters/min against a static pressure of 12.0 inches of water. The pump, its charging unit and all accessories are described in detail in the Appendix.

The recommended MSA sampling unit is simple to operate. It is activated with an off-on switch, and the flow rate is adjusted until the correct airflow is obtained. The adjustment device consists of two valves. The larger valve stem controls the airflow directly, while the smaller valve stem controls the by-pass air system. For particulate sampling, the by-pass valve is completely closed, and the larger valve is adjusted until the indicator ball shows the desired airflow. Although the unit is quite stable after the initial adjustments are made, there may be some decrease in airflow due to battery usage, pressure drop, or other factors. Therefore, the airflow (rotameter) settings should be checked about once every hour and adjusted if necessary.

This unit is designed to sample continuously



Figure 8.7

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for 8 hours. After full-shift use, the battery requires a 14 to 16 hour charge with the switch of the charger (Figure 8.9) set on the high position. After shorter periods of use, each battery should, as a rule of thumb, be charged 2 hours for each hour of use. A voltmeter should always be used to determine full charge (6.8 - 7.2V). When pumps are not in use, or are used intermittently, they should be stored with fully charged batteries and with the charger switch set to low or "trickle" charge. Malfunctions, repairs, etc. are discussed in Chapter X.

Figure 8.8

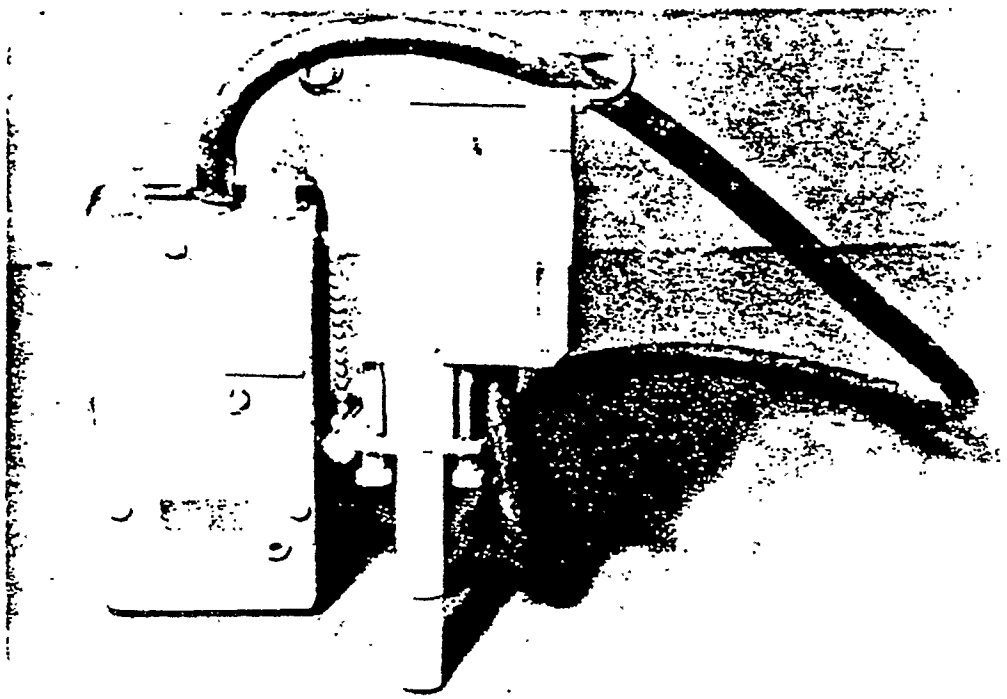
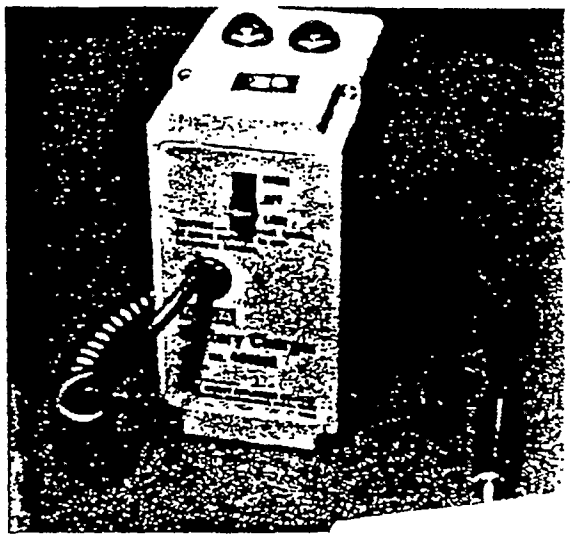


Figure 8.9



As mentioned earlier, if a large air sample is required for a special application, a hi-volume sampler will be needed. The most common type of hi-volume sampler (Figure 8.10) is essentially a stripped-down vacuum cleaner pump. It can sample through a 4-inch filter or be fitted with a special frame which holds an 8 x 10-inch filter (Figure 8.11). Like many other hi-volume samplers, this one cannot be operated at a constant rate. Initial sampling will be at high airflow, but the airflow will gradually decrease as the particulates build up on the filter. The usual (but not the best) practice is to record the flow rate at the beginning and end of the sampling period, and to assume that the airflow decreased uniformly during that time. This assumption is

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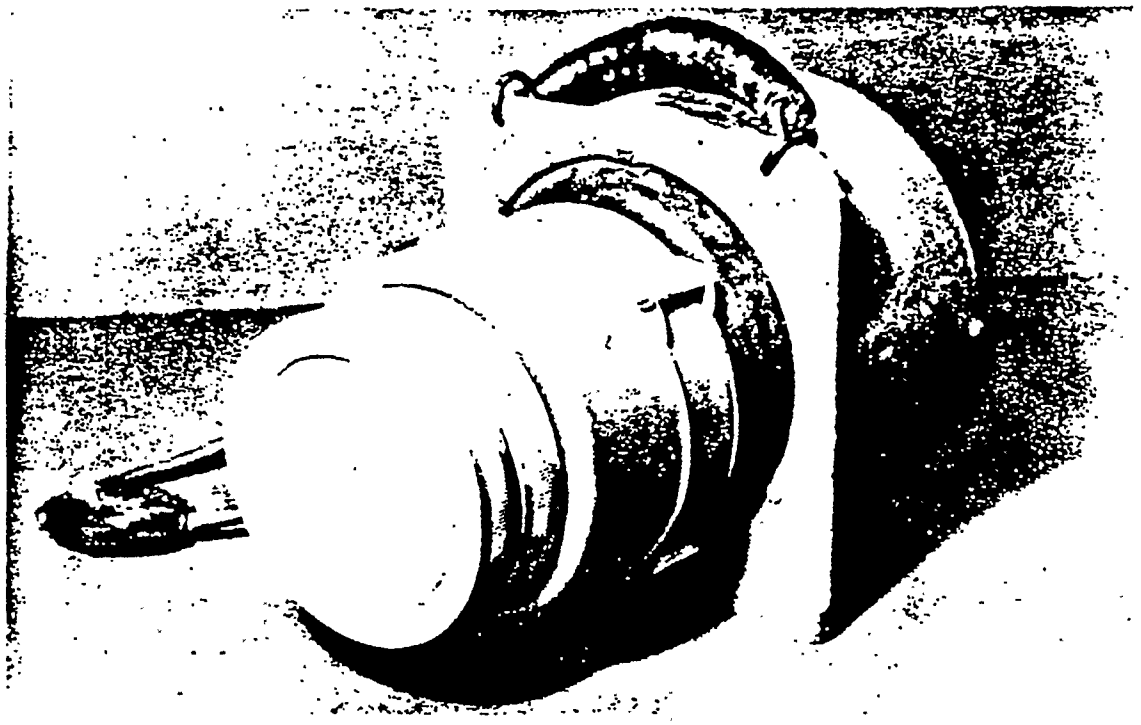


Figure 8.10

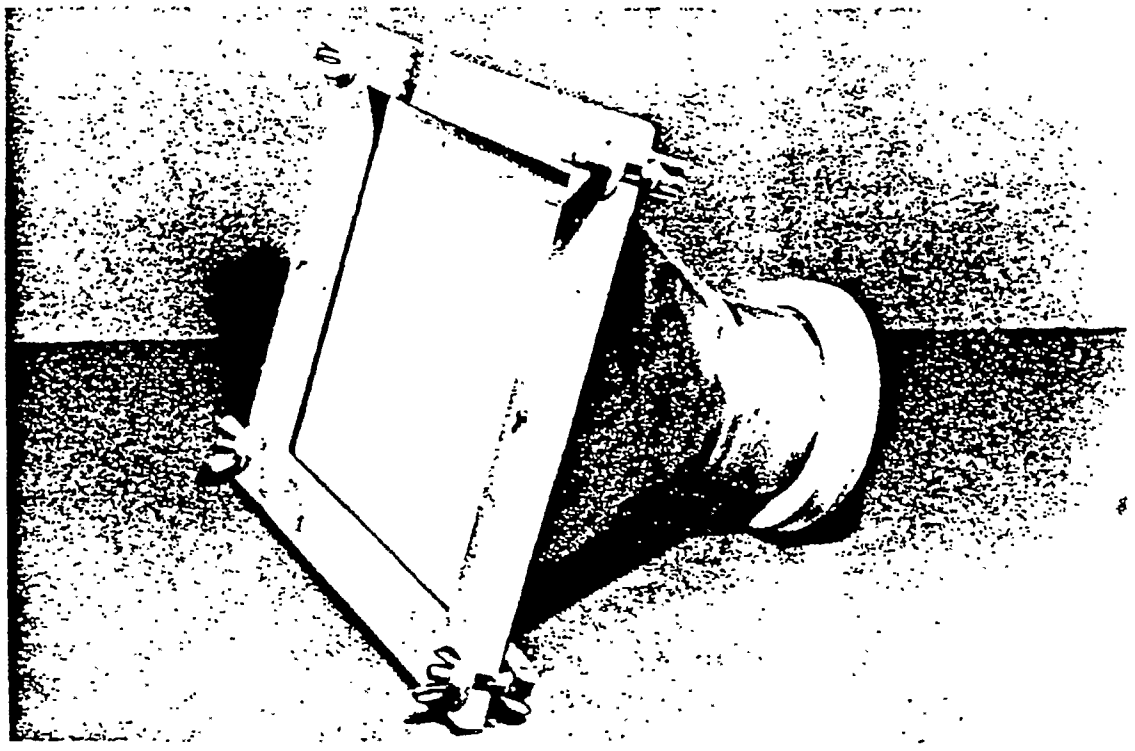


Figure 8.11

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not valid, however, and this type of hi-volume sampler must be monitored continuously to insure an accurate indication of the total volume of air sampled. In addition, it is difficult to calibrate hi-volume samplers, and the handling of their large filters may present problems. Therefore, before a hi-volume sampler is considered for use, the application, type of filter, calibration and other considerations should be discussed with Headquarters Environmental Health - Pittsburgh.

Flow Rate

There are numerous devices for measuring airflow but most are not sufficiently lightweight, rugged or reliable for use on a personal sampler. The flow measuring device most widely used on these units is a rotameter – a short length of transparent plastic or glass tubing with a ball or other float to indicate the amount of air passing through the tube (Figure 8.12). The rotameter and its calibration are discussed in detail in Chapter X.

The rate of flow is used to calculate the total volume of air sampled. For example, a pump operating at 1 liter/min will sample a total of 480 liters in 8 hours (1 liter/min x 60 min/hr. x 8 hr.) or a total of 0.48 m^3 (1,000 liters = 1 m^3). The total volume of air sampled must be known so that atmospheric concentrations or exposures can be calculated as discussed in Chapter III.

In some cases, the operation of the collection device is dependent upon a prescribed flow rate. In dust sampling, for instance, respirable and non-respirable dusts are separated in an elutriator or size-selecting device (Figure 8.13) ahead of the filter, and this device will not function properly unless the prescribed airflow is maintained (elutriators are discussed later in this Chapter). In sampling with open face filters for total particulates, the flow rate is not critical for collecting the airborne dust but must be known so that the total volume of air sampled can be computed.

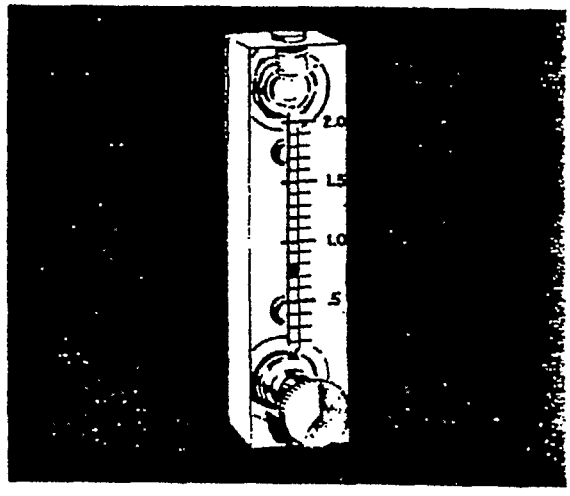


Figure 8.12

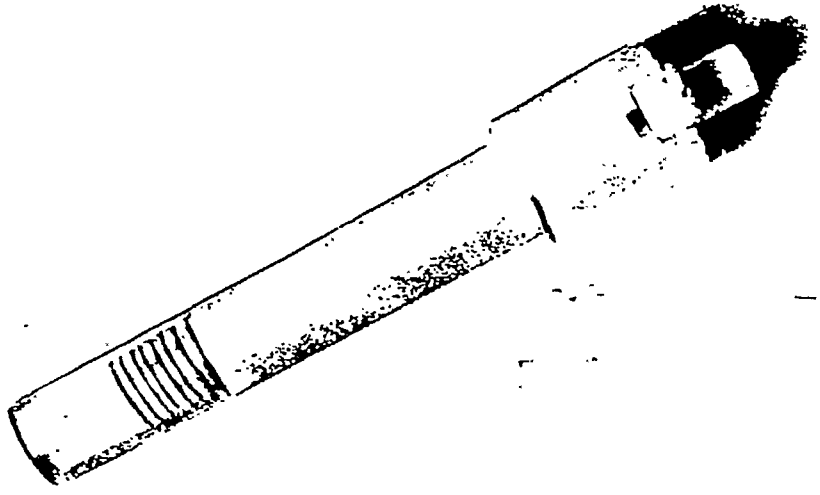


Figure 8.13

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In U. S. Steel, the airflow rates now used are:

1. For respirable dust sampling using the recommended elutriator – 1.8 liter/min.
2. For all other particulates, including total dust, and using an open face filter – 1.5 to 2.8 liter/min. Generally, the sampling rate for open face filters depends upon the type of filter media used. Calibration for this type of sample is with the float at the 9.0 mark on the rotameter of the Monitaire (usually 2.4 to 2.6 liter/min).

Each sampling set-up must be individually calibrated (for respirable-non-respirable dust, total particulates, different types of filters, etc.) as discussed in Chapter X.

Filters

Filters can be made of such widely different substances as paper, asbestos, or a variety of synthetic materials. Technically, the principal factor which determines the type of filter required is the use to which it will be put. However, NIOSH is responsible for specifying sampling devices and methods in the criteria packages they will recommend to OSHA for promulgation.

For dust sampling, the filter most appropriate for determining the total amount of dust may not be suitable for collecting dust or fume to be analyzed for lead, zinc, etc. For example, filters used only for total dust determinations need not be chemically pure, but they must be capable of collecting small particles and of being weighed accurately. Weighing techniques and the most common weighing errors are discussed more fully later in this Chapter.

When sampling for toxic metals or other substances for laboratory analysis, it is very important that the filter does not contain appreciable quantities of the substance for which the tests are to be made. In the absence of specific information about such contaminants, it is advisable to include one or two unused filters as blanks to determine what, if any, contamination was present in the original filter. Such unused filters should be taken from the same package as those on which the air samples were collected.

A filter is often described by the name of the material from which it is made and the average size of the pore openings – 5 μ, 2.0 μ, 0.8 μ, etc. Figure 8.14 shows a box of 37 mm. VM-1 filters with a pore size of 5 μ. Theoretically, particles slightly smaller than the stated pore size could pass through the filter. But in practice very few particles of such size will pass through any of the recommended filters because the pore openings are not straight through and the direction of airflow through the filter is tortuous. In addition, the pore openings quickly become wholly or partially clogged as particulates are collected. As a result, a filter which is designated as having a 5 μ pore size will retain particles as small as 2 μ with very high efficiency during the initial phase of sampling and may quickly thereafter retain much smaller particles. Pre-weighed MSA No. 457193

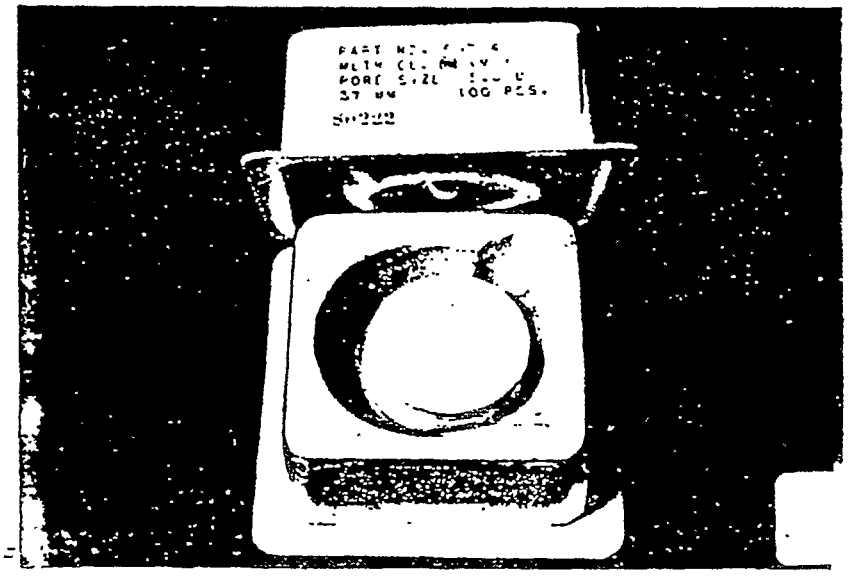


Figure 8.14

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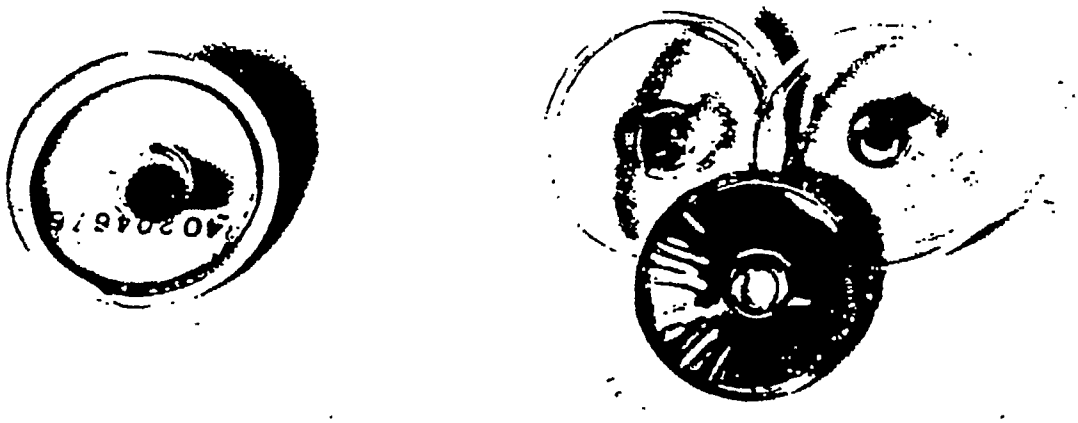


Figure 8.15

cassettes (Figure 8.15) and regular MSA No. 625413 and NEII No. 3600-11 Type VM-1 filters are of this type. They are made of Vinyl Metracel and have a stated pore size of 5.0 μ. The pre-weighed cassette to be used with the Bendix pump and assembly is shown in Figure 8.16.

For other filter types, the designation DOP may be used to indicate efficiency in collecting small particles. DOP refers to Dioctyl Phthalate, a substance which can be vaporized and condensed to form very uniform droplets of any desired size. Generally, however, the efficiency of a filter is referred to as a percentage of removal of particles larger than 0.3 DOP. The Gelman Instrument Company's Glass Fiber Type A filter, recommended for metal fumes, mist, etc., is of this type (Figure 8.17). Its efficiency is listed as 99.7% for particles larger than 0.3 μ as measured by the DOP test. It is presumed that other particulates (dusts, mists, fumes, etc.) will behave in a manner similar to DOP. It is also stated that the efficiency of these filters (glass fiber Type A) is said to be greater than 98% for particles as small as 0.05 μ.

Filters which have been found to be best suited for their intended purposes are listed in Guideline No. 8 (Appendix B) and in Figure 8.6. The MSA No. 457193 pre-weighed cassette is to be used specifically for respirable dust sampling. The 37 mm MSA No. 625413 and the NEII No. 3600-11 Type VM-1 filters can be used for either respirable or total dust.

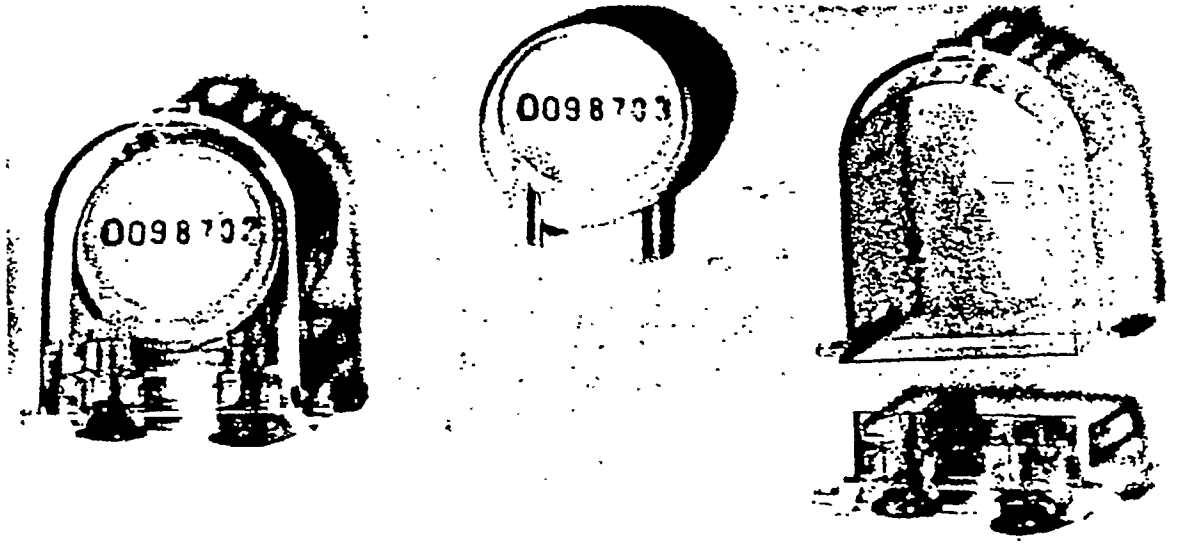


Figure 8.16

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Figure 8.17

These filters are thin membranes of cellulose ester and are combustible. Consequently, they should not be used for collecting fumes because hot sparks may puncture them, thus negating their efficiency. The recommended glass fiber filters should be used for fumes and smoke since these are noncombustible, nonhygroscopic, and have high collection efficiencies.

Except for the MSA No. 457193 preweighed cassette, the filters listed in Figure 8.6 must be weighed prior to sampling. In addition, all filters must be weighed after sampling and before any laboratory analysis, to determine the total weight of particulates collected from the atmosphere.

Filters for special applications, such as collecting oil mists, coke oven fumes, acid mists, etc., are also available. Since these filters generally require laboratory treatment, Headquarters Environmental Health - Pittsburgh should be consulted for guidance in their selection and use.

Respirable and Non-Respirable Dust Samplers

As previously mentioned (Chapter IV), dust particles and particulates in general are classified as respirable or non-respirable. Those which are deposited in the lung are said to be respirable, while those which are so large they cannot enter the lung, and are removed in the upper respiratory passages, are considered non-respirable. Non-respirable particles may enter the nose, mouth or windpipe (trachea) but do not go substantially deeper into the respiratory system (Figure 8.18). They are usually trapped in the trachea and moved upward into the throat area with the movements of the hairlike filaments (cilia) where they are swallowed or expectorated. Respirable particles that are breathed in, reach the lower portions of the windpipe (bronchi) and enter the small air spaces (alveoli) of the lung. Some of the very smallest particles which enter the alveoli also

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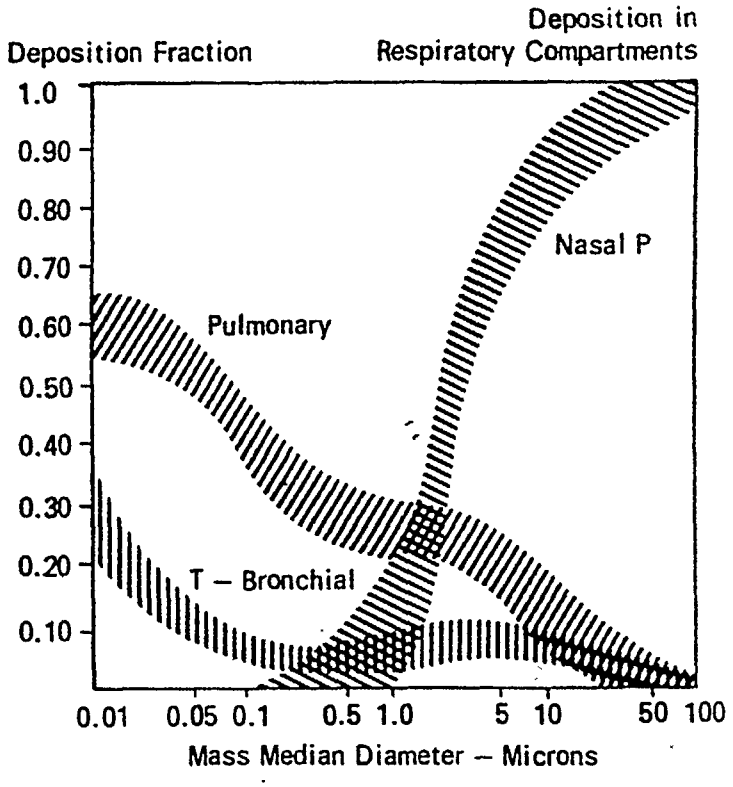


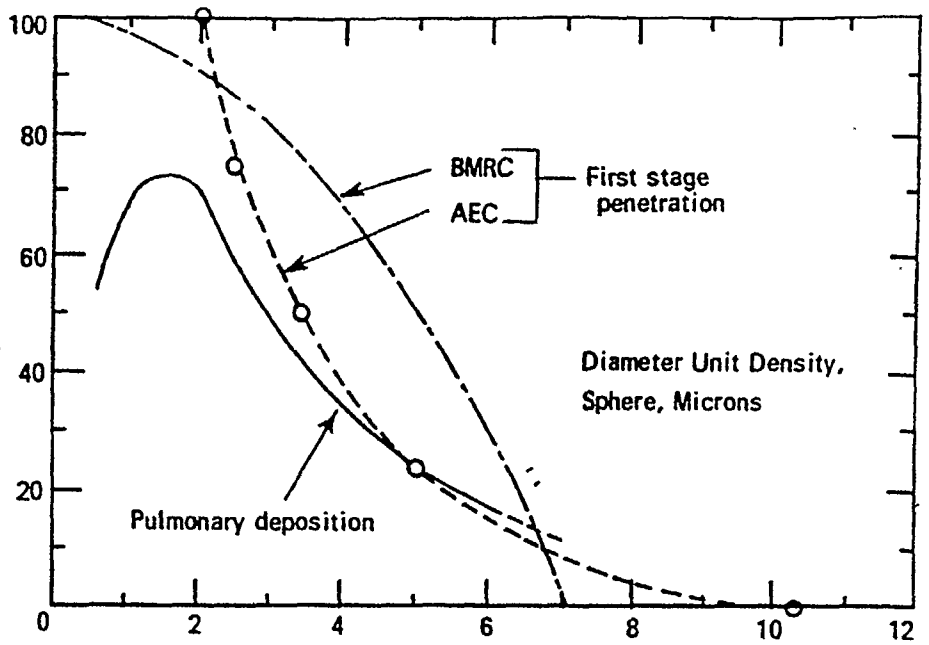
Figure 8.18

leave when air is exhaled.

In considering respirable and non-respirable dust, the environmental health engineer is usually interested only in those particles which are associated with pneumoconioses (dust diseases of the lung). Therefore, an air sampler used to distinguish between respirable and non-respirable particles should perform in somewhat the same fashion as the human respiratory system. Figure 8.19 is a graph based on studies made by medical and environmental health scientists from England and the United States working in similar research areas. The BMRC line shows the percentage of particles of any given size which, when inhaled, remain in the lung. Obviously, most of the large particles (greater than 7 μ on this graph) are removed by the nose, mouth, throat and trachea, and only a small percentage of them enter the lung. As the particles become smaller, the curve rises, indicating an increasing percentage of particles entering the lung and reaching a maximum of nearly 100% at approximately 2 μ. Thereafter, the percentage of particles retained in the lung falls off somewhat, showing that some of the extremely fine particles leave the alveoli when air is exhaled. The AEC line on the graph describes the size-selecting characteristics of unit density particles of the first stage of a respirable dust sampler. This first stage, an elutriator, is supposed to remove the non-respirable, or large, particles. The second stage (filter) collects only the small particles which remain. The AEC and BMRC curves indicate the performance of the elutriators used by each agency to sample respirable dust. The lines are quite similar and show that the filter does not collect particles larger than 5 μ, thus approximating the behavior of the lung. The size referred to is the aerodynamic size.

Some respirable dust samplers are simply long, narrow boxes in which larger particles fall out (Figure 8.20). The sampler approved for use in United States Steel is constructed quite differently. It is a cyclone and is shown in Figure 8.21 with a filter attached. It is made of nylon and is small and lightweight. Air enters an opening on the side of the cyclone (Figure 8.22) where it immediately swirls around inside the tube and is drawn upward through the filter. The result of the

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Comparison of Recommended Respirable Size Criteria with Pulmonary Deposition Curve.

Figure 8.19

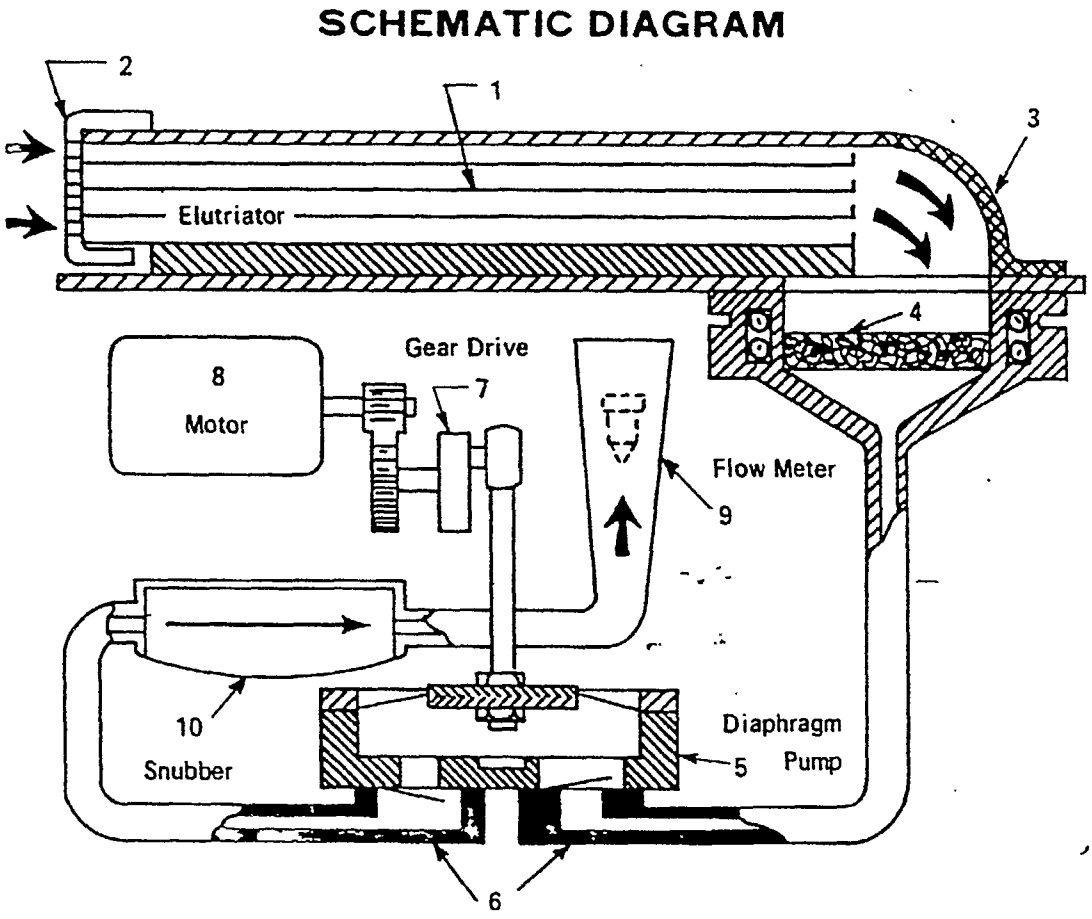


Figure 8.20

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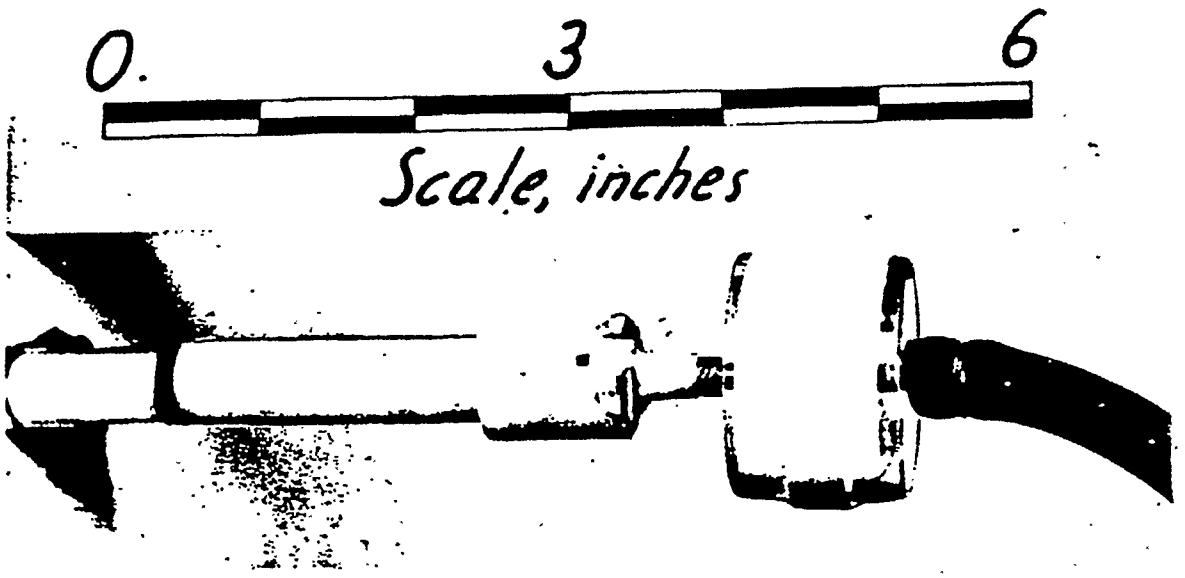


Figure 8.21

swirling (centrifugal) motion is to cause the heavier particles to be deposited in the bottom of the tube while the lighter particles remain with the airstream and are collected when the air passes through the filter. This method of separating fine and coarse particles has been used for many years. Generally, the cyclone-filter will be used in the MSA Holder assembly.

The effectiveness of the size selector used for respirable dust sampling depends upon the flow rate through the system. When the flow rate is high, the weight of respirable dust collected on the filter will be lower than when the flow rate is low, when sampling in the same dust cloud. This is because the efficiency of the cyclone as an elutriator depends upon the velocity of the air. The higher the air velocity through the cyclone, the higher its separating efficiency (Figure 8.23). Therefore, to insure representative sampling for respirable dust, the correct flow rate (1.8 liter/min) should be maintained and all long-term respirable dust samplers should be observed at least once every hour to verify proper airflow.

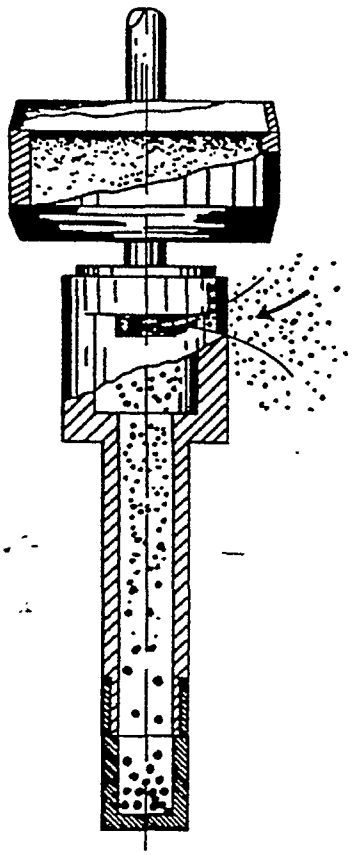


Figure 8.22

Total Particulate

An open face filter (Figure 8.24) is used to collect total particulate samples. With this type of collecting device, no distinction is

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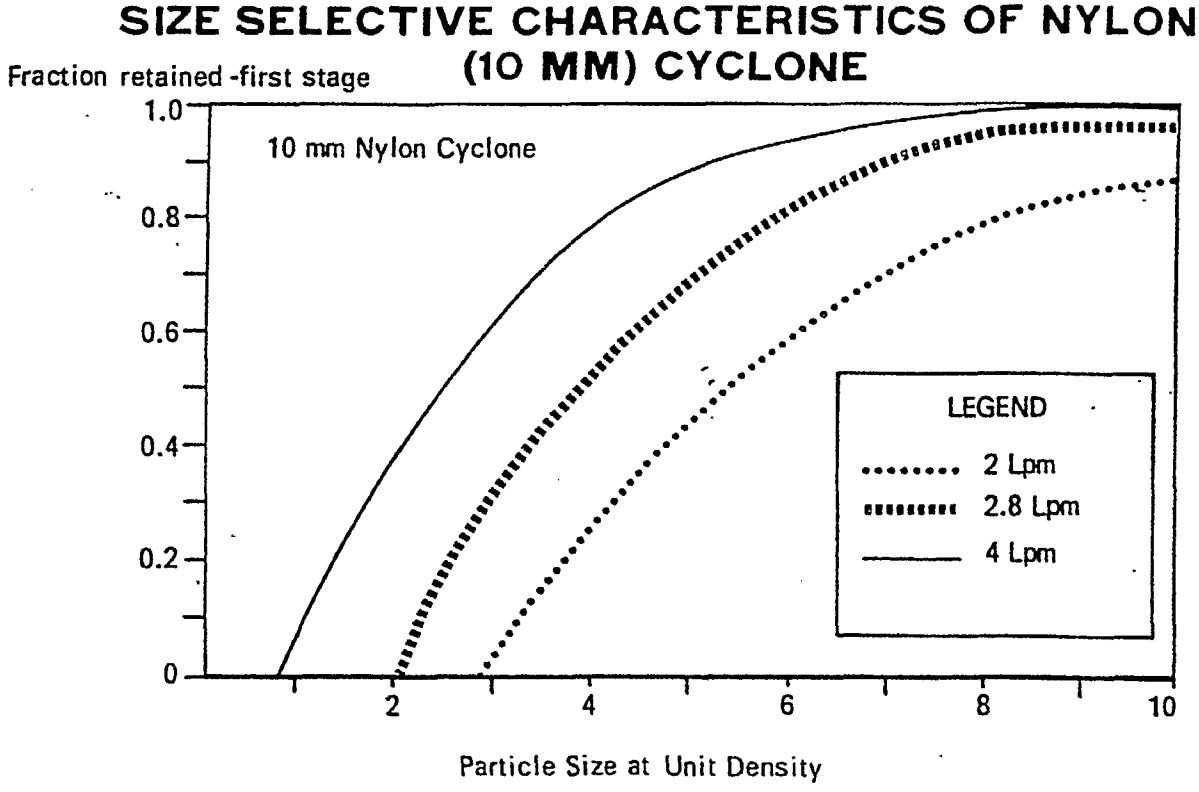


Figure 8.23

made in particle size and both respirable and non-respirable particulates are collected. As mentioned previously, the effectiveness of this system does not depend upon a specific airflow. The efficiency of the filters is the same whether the sampling rate is 1.5 liter/min or 2.8 liter/min, the range recommended earlier. Sampling for total particulates with open face filters may appear to be simpler than sampling for respirable and non-respirable dust. Actually, both require the same attention to flow rate, so that the total volume of air sampled and the concentration of air contaminants can be calculated accurately. Therefore, open face filter samplers should be monitored at least once every hour, just as respirable dust filters are.

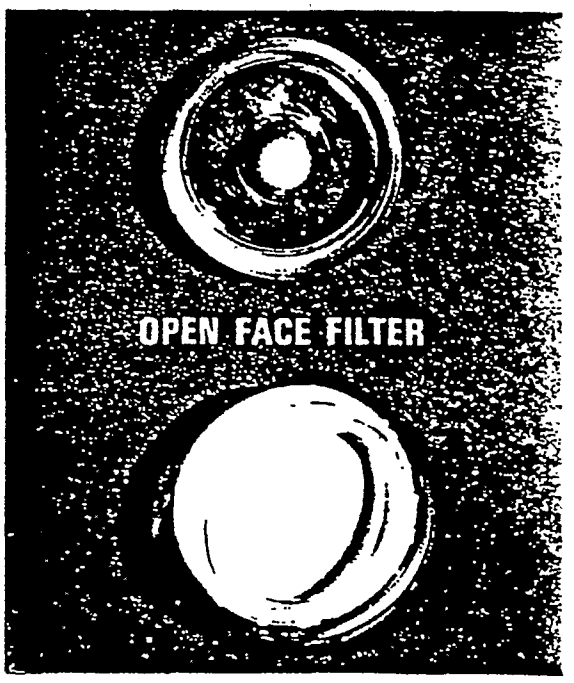


Figure 8.24

Personal Sampling

Personal sampling requires the worker to wear a sampling system (MSA pump and suitable collection device - Figure 8.25) while performing his normal duties during the work shift. The sample, collected in the worker's breathing zone, integrates the concentration(s) of particulates to which he is exposed

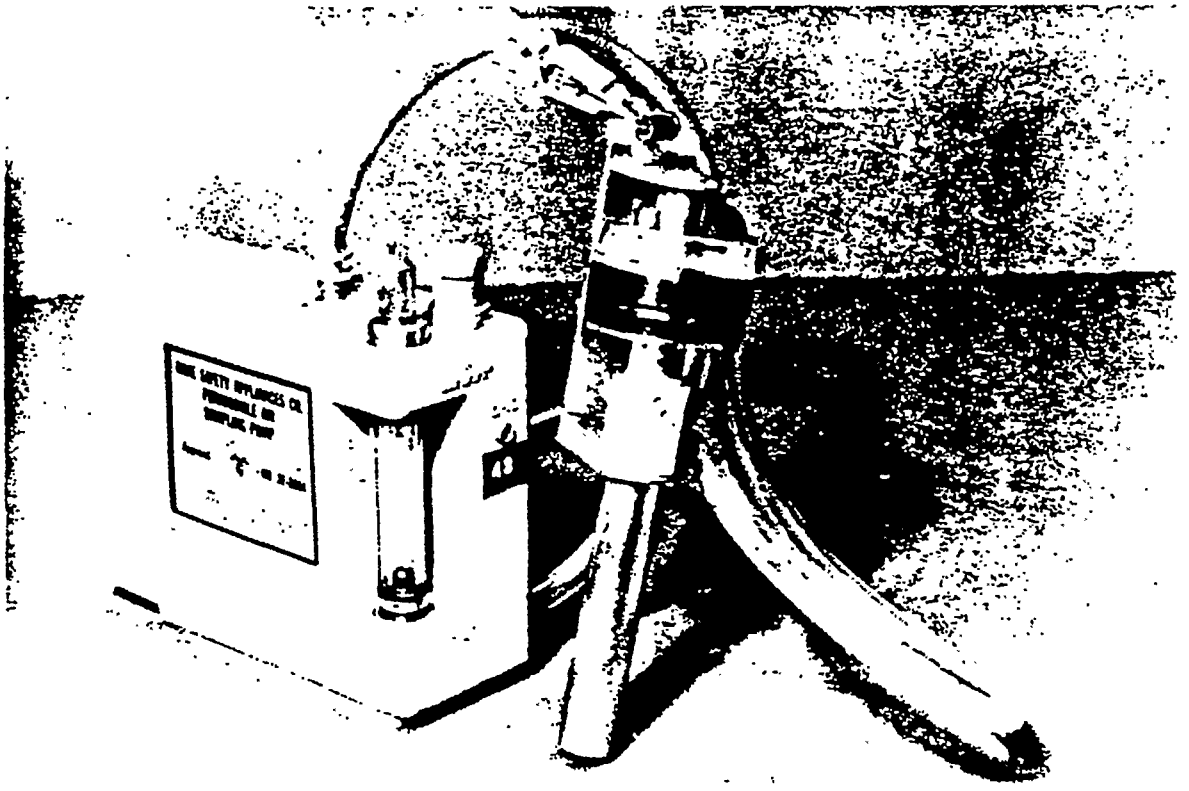


Figure 8.25

during his normal work routine. Whether the sample is for respirable and non-respirable dust, or for total particulates, the way the equipment is placed on the worker, the data recorded, and the periodic surveillance required are the same.

The purpose of the test should be explained and the worker's cooperation secured before the sampling begins. The pump is then fastened to his belt, either to one side or at his back, wherever it will be most comfortable for him. The sample holder (filter) is attached to his lapel by the clip which is part of the respirable dust sample holder, or by a pin if an open face filter is being used (Figure 8.26). The tubing between the pump and the filter holder should be pinned to his clothing to prevent it from catching on equipment, etc., during his normal movements. In placing the sampling equipment, care should be taken to insure that the tubing will not be pinched, thus restricting or cutting off the airflow, and that, when sampling for respirable dust, the cyclone hangs perpendicular to the floor.

In preparation for sampling, the following steps should be taken:

1. The pump should be fully charged. This means that the battery should show a minimum of 6.8 - 7.2V dc.
2. The pump should be calibrated at 1.8 liter/min for respirable dust samples and 1.5 to 2.6 liter/min for open face samples.
3. For respirable dust sampling, care must be taken that the filter-cyclone assembly does not leak. This is best done by assembling the unit, covering the inlet to the cyclone, and drawing a vacuum on the assembly.
4. For other than pre-weighed cassettes, the filters must be weighed (tared) and a backup disc inserted in the holder, followed by the filter and a retaining device (Figure 8.27). Unless a backup disc is used, the filter may rupture or break during sampling.
5. Assemble the entire sampling system, i.e., pump, tubing, and filter holder. Turn on the pump and close the inlet opening (of the cyclone or filter) to insure that the system does not leak. The pump should not operate unless there is a leak. If there are no leaks, the sampler is ready for use.
6. After sampling, the sample should be in-

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spected to insure that there has been no tampering or contamination. It is usually possible to detect contamination by the presence of loose material and/or large particles on the filter.

For each sample, the following basic information should be recorded: date, department, location, worker's name, pump number, filter number, type of sample, time the sampler was started, and time the sampler was turned off. In addition, data on the operation, production, type of contaminant, controls, outside weather conditions, etc., should be noted.

Area Samples

Generally, a personal sample is preferable to an area sample, since the personal sample measures actual exposure. In some instances, however, where the employee works in a fixed location (on mobile equipment or in a crane cab or operating pulpit, for example) it may be necessary or more convenient to collect an area sample.

Either respirable dust or total particulates may be collected with an area sampling system (Figure 8.5). The general procedures and precautions are the same as those described for personal sampling. The sampler should be placed in a position which is representative of the air the worker breathes. Care should be taken to prevent contami-

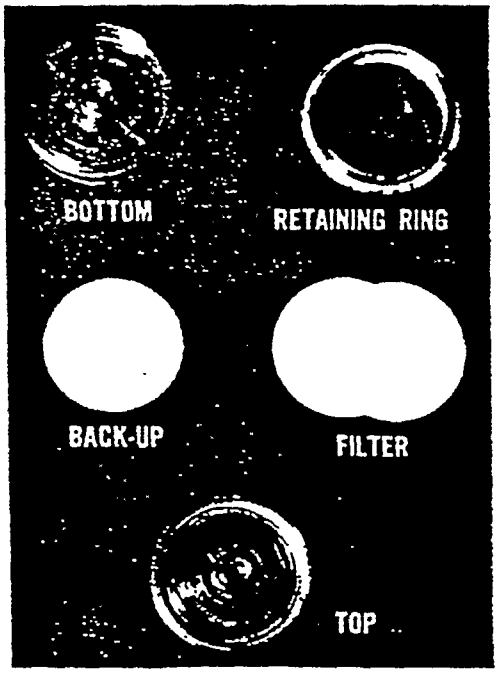


Figure 8.27

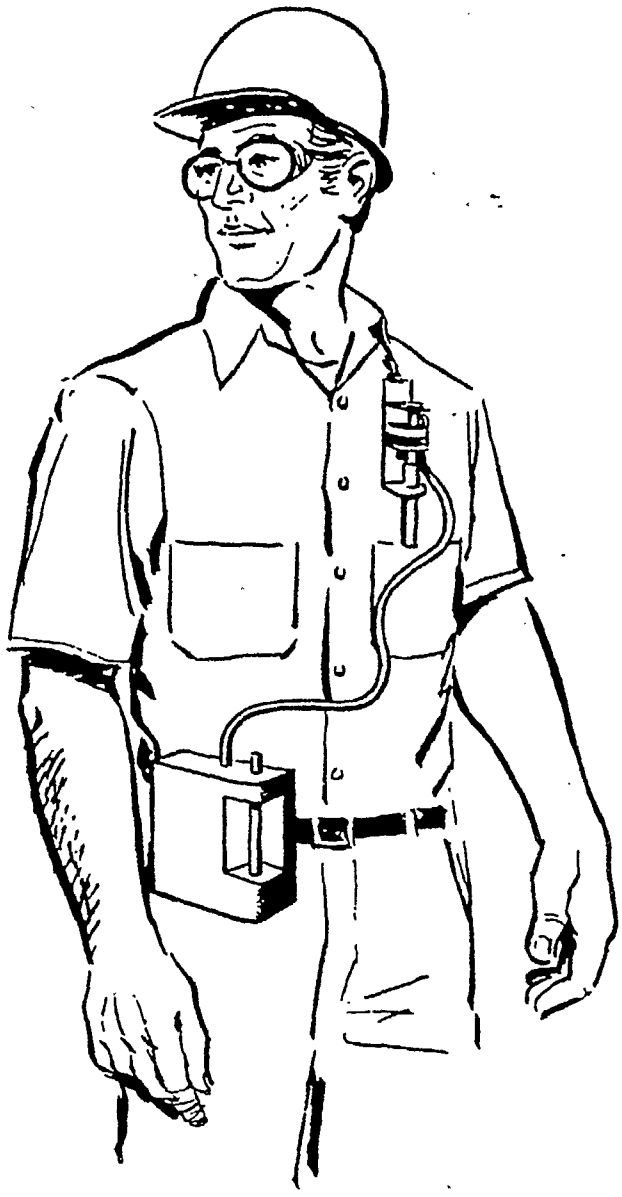


Figure 8.26

OPEN FACE FILTER

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nation from extraneous sources, such as spillage from overhead, splashes from the process, and tampering.

The same information should be recorded for an area sample as for a personal sample, and the filter should be inspected for contamination or tampering when the sampling is completed.

Weighing of Filters

In many industrial situations, only a small amount of airborne contamination, whether respirable dust or total particulate, will be collected on the filter. The weight of the air contaminant may be only a few milligrams (often less than one milligram) even after a full 8-hour sampling period. Accuracy is very important when weighing such small amounts, and considerable care must be taken to minimize errors.

All filters, except the pre-weighed cassettes, must be weighed (tared) before use. After sampling, and independent of further analysis, the filter should be weighed again to determine the total weight of particulate collected. If further analysis is needed, the filter should be replaced in the holder and sent to the laboratory.

The analytical balance necessary for weighing filters is of the semi-micro type, such as the Mettler Model H-20 or equivalent (Figure 8.28). This type of balance is best used in a laboratory and the actual weighing should be done by personnel familiar with the use of such sensitive equipment.

Headquarters Environmental Health staff has found that weighing errors are common and can be most significant; in some cases, the error may be greater than the weight of the particulate collected on the filter. Generally, such errors result from moisture, improper handling, or poor balance technique. However, weighing filters is subject to a normal error of 0.1 - 0.5 milligrams.

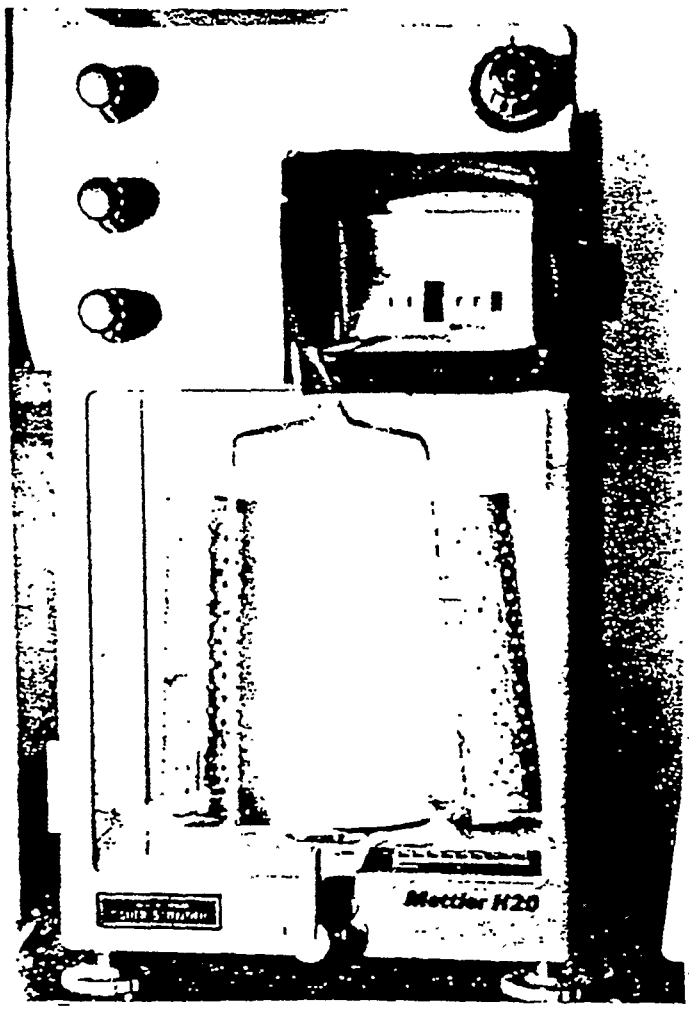


Figure 8.28

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Many filters, including most paper filters, absorb water from the atmosphere so readily that special techniques must be used in handling them before and during weighing. Even filters which are described as non-hygroscopic can have a moisture error because of atmospheric moisture absorbed by the material collected.

To overcome such errors, a filter handling and weighing procedure should be developed, and followed without exception. As a minimum, the procedure should include:

1. Each filter weight, both tare and final, must be made by the same individual and on the same balance.
2. Filters should never be touched with the hands, since moisture and oil from the skin will cause weighing errors. The filter should always be handled with bone-tipped tweezers.
3. Prior to tare weighing, all filters should be stored in a desiccant (drying) cabinet (Figure 8.29). This is an air-tight cabinet provided with a desiccant such as silica gel or Drierite, which absorbs moisture from the filter.
4. The filters to be used for sampling should be removed, one at a time, from the storage cabinet to the balance, using tweezers, for tare weighing. The balance must also be provided with drying cylinders to minimize moisture errors during weighing.
5. After its number and tare weight are recorded, the filter should be placed in the proper holder (using tweezers) and properly sealed.
6. After sampling, the filter holder cover (top) should be removed and the exposed filter placed in the desiccant cabinet to remove excess moisture (usually 16 to 24 hours). Note: the filter must be free from the backup disc before drying.
7. After drying, the filters should be removed, one at a time, from the storage cabinet to the balance (using tweezers) for final weighing.
8. The final weight should be recorded and, if further analysis is necessary, the filter should be replaced in the holder (using tweezers) and sealed for shipment to the laboratory.
9. At all times, care must be taken to insure that the filter is not damaged, since any loss of filter substance will result in erroneous weight calculation.

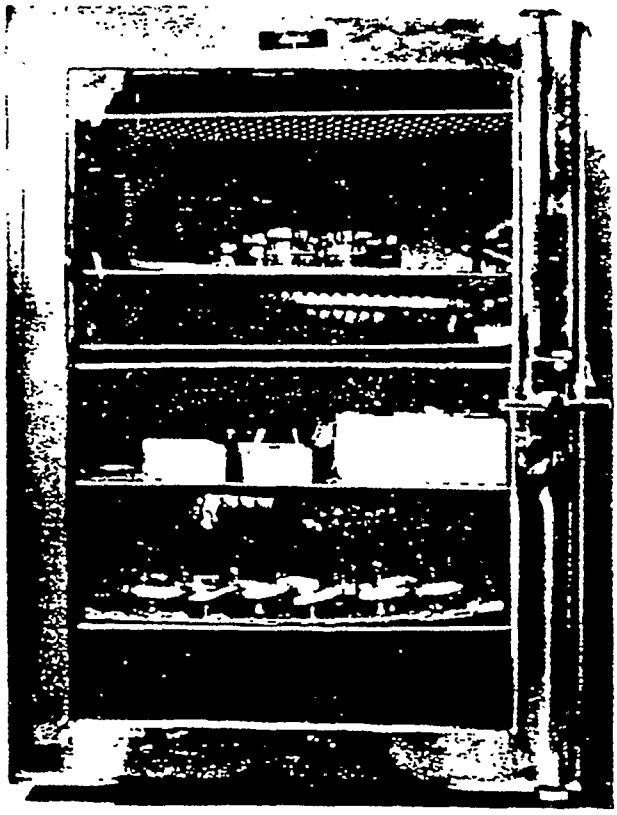


Figure 8.29

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SAMPLING FOR GASES AND VAPORS

Many gases and vapors can be sampled by devices which indicate the concentration of the substance during sampling or shortly thereafter, without the necessity for chemical analysis. These *direct reading devices* are convenient and useful when properly calibrated. Other substances cannot be sampled by this method, usually because no appropriate instrument is available, and indirect methods which require laboratory analysis of the sample must therefore be used. Such analyses are often delayed by days, or even weeks, depending upon laboratory schedules.

Direct reading samplers include simple devices such as colorimetric indicating tubes in which a color change indicates the presence of the contaminant in air passed through the tube, or instruments which are more or less specific for a particular substance. In the latter category are carbon monoxide indicators, combustible gas indicators (explosimeters) and mercury vapor meters, as well as a number of instruments too specialized for discussion in this Manual.

All instruments for sampling gases or vapors must be calibrated before use and their limitations and possible sources of error must be fully understood. Every instrument has a lower limit of sensitivity which can be too high, making the instrument useless for health hazard evaluation. For example, some explosimeters are so insensitive that they show only the presence of nearly explosive mixtures of some solvent vapors, and give no response of levels which may be harmful to health. To be useful for environmental health purposes, an instrument should give a substantial reading at or near the TLV concentration and preferably should accurately indicate the presence of air contaminants as low as 10% of this concentration. Most direct reading instruments and many colorimetric indicating tubes are not sufficiently sensitive for this kind of sampling. The manufacturer's specifications should, of course, be reviewed before a sampling device is selected. But it should be remembered that specifications may be optimistic, and that it may not be possible to detect with certainty the concentration which is listed as the lower limit of detection.

Since no device is completely specific for the substances of interest, care must be taken that interferences do not invalidate the sampling results. Many common gases and vapors react with the same chemicals, or have similar physical properties, so that the instrument may give falsely high or low readings for the substance being sampled. The manufacturer's data for colorimetric indicating tubes lists those substances which may interfere with the desired determination as indicated in the following example:

> "Interferences — Other common gases in the range of their allowable limits do not interfere with accurate measurements. Some acid gases in high concentrations may give a positive indication. Hydrogen Sulfide does not interfere with accurate measurements."

If there is reason to think that interfering substances may be present, it is advisable to sample for them to determine whether their concentrations are sufficiently high to actually constitute an interference.

As mentioned in Chapter VII, it is very important to establish that an instrument responds properly to the substance it is designed to sample. This is generally done by calibration procedures with standard concentrations of the substance of interest. It is also desirable to spot test the instrument's response between calibrations. For this purpose, several suppliers of compressed gas prepare cylinders containing almost any desired concentration of the gas or vapor of interest. If it is not practical to keep such cylinders on hand, other procedures may be used. For example, a carbon monoxide meter can usually be checked by exposing it to a small amount of diluted automobile exhaust; a mercury meter can be checked by holding it above an open bottle of mercury; a combustible gas indicator (explosimeter) can be checked by exposing it to a solvent mixture such as gasoline, lighter fluid, or paint thinner. Although such rough checks are not quantitative, they indicate whether the meter is responding to the substance for which it is to be used. Indicating tubes cannot be tested in this way, since they are usually designed for one-time use. If there is any doubt about the response of indicating tubes, it is advisable to sacrifice one tube from the box, to be sure that the tubes in the particular batch are, in

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fact, responsive to the substance being sampled. In any case, it is desirable to check one tube from each batch with a calibrating gas of known concentration.

Principles of Sampling Devices

A sampling device may use one of three basic methods for collecting gaseous air contaminants. The first involves passing air through a direct reading instrument which indicates, without further analysis, the actual concentration of the substance at the time the sample is taken. The second method involves passing a known volume of air through an *absorbing* solution (a liquid which takes up and retains the gas or vapor), or an *adsorbing* medium (a solid substance which mechanically holds a solvent or vapor on its surface), to remove the desired contaminant or contaminants from the air. The absorbing solution may be a weak alkali solution (0.01% normal sodium hydroxide) in a fritted glass bubbler and the adsorbing medium may be chemically treated silica gel or activated charcoal sealed in a glass tube. In the third method, an air sample of definite volume at known temperature and pressure is collected in a container (an evacuated flask, a bottle, or a plastic bag) which is resealed immediately to prevent sample loss. It should be noted that samples collected by the second and third methods must be sent to a laboratory for analysis.

All three sampling methods should:

1. Provide an acceptable efficiency of collection for the air contaminant involved;
2. Maintain this efficiency at a specified air flow;
3. Have a high degree of reproducibility;
4. Require minimal manipulation in the field;
5. Avoid, if possible, the use of corrosive or otherwise hazardous sampling media; and
6. Be approved for use by the Director of Environmental Health - Pittsburgh.

The first (direct reading) method is fairly simple and results are available immediately. However, the instruments have limited sensitivity and must be recalibrated periodically. At present, these direct reading instruments are commonly used in USS plants.

The second (absorption in a liquid or adsorption on a medium) and third (gas container) methods are generally considered more sensitive and more accurate because of recent development in laboratory techniques for trace analysis by gas chromatographs, infra-red spectrophotometers, and similar instruments. However, because of their sophistication, both of these methods required careful handling to insure representative tests. At this time, therefore, they are not considered applicable except under special circumstances when no other method is available (although they are used by Headquarters Environmental Health - Pittsburgh).

It should be evident from these comments that instruments for gas and vapor sampling for health hazard evaluations leave much to be desired in meeting the requirements of good field instrumentation.

Direct reading instruments enable the operator to obtain immediate indications of gas or vapor concentration by reading a meter dial or by noting the length of stain on an indicator tube. This does not mean, however, that the mere reading of a meter implies a valid test. On the contrary, the operator must be thoroughly familiar with the use and limitations of the instruments and devices listed in Figure 9.1 (which are the approved instruments also listed in Guideline No. 8, Appendix B). Although these were discussed briefly in Chapter VII, more complete information is given below.

EQUIPMENT FOR SAMPLING GASES AND VAPORS

Direct Reading Instruments — Combustible Gas Explosimeters

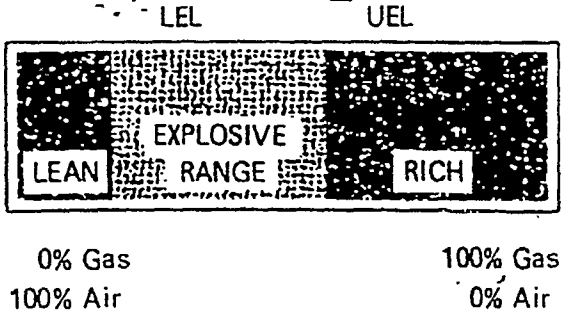


Figure 9.2

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AIR SAMPLING EQUIPMENT FOR GASES AND VAPORS

Contaminant	Type of Sample	Sampling Apparatus	Supplier	Detection Method	Supplier	Sampling Rate
Carbon Monoxide	Area	Model D	MSA	Catalytic Combusion Hopcalite Cell	MSA	Approx. 1.5 LPM
	Area	Universal Pump No. 83500 Model 1	MSA	Detector Tubes No. 91229	MSA	Per Instructions Supplied
	Area	Test Pump No. 19-0246	Bacharach Inst. Co.	Detector Tubes 19-5010	Bacharach Inst. Co.	Per Instructions Supplied
	Personal	Monitaire Pump with Tube Holders 92943 or 93481	MSA	Detector Tubes No. 91229	MSA	Per Instructions Supplied
Oxygen	Area	Model 244R	MSA	Fuel Cell	---	Diffusion Head
	Area	Fyrite Oxygen Indicator No. 10-5011	Bacharach Inst. Co.	Chemical Absorbing Media	Bacharach Inst. Co.	Squeeze bulb Total volume 900 CC
	Area	OA-222R	Bio Marine	Fuel Cell	---	Diffusion Head
Combustible Gases or Vapors	Area	Model SS-P No. 503-001	Bacharach Inst. Co.	Combustion Cell	JW Bacharach Inst. Co.	Approx. 1.5 LPM
	Area	Model 40 No. 08-74711	MSA	Combustion Cell	MSA	Approx. 1.0 LPM
Others	Personal (Long Term)	Monitaire Pump with Tube Holders No. 92943 or 93481	MSA	Various Detector Tubes	MSA	Per Instructions Supplied
	Area (Short Term)	Universal Pump No. 83500 Model 1	MSA	Various Detector Tubes	MSA	Per Instructions Supplied
		Test Pump No. 19-0246	Bacharach Inst. Co.	Various Detector Tubes	Bacharach Inst. Co.	Per Instructions Supplied

Figure 9.1

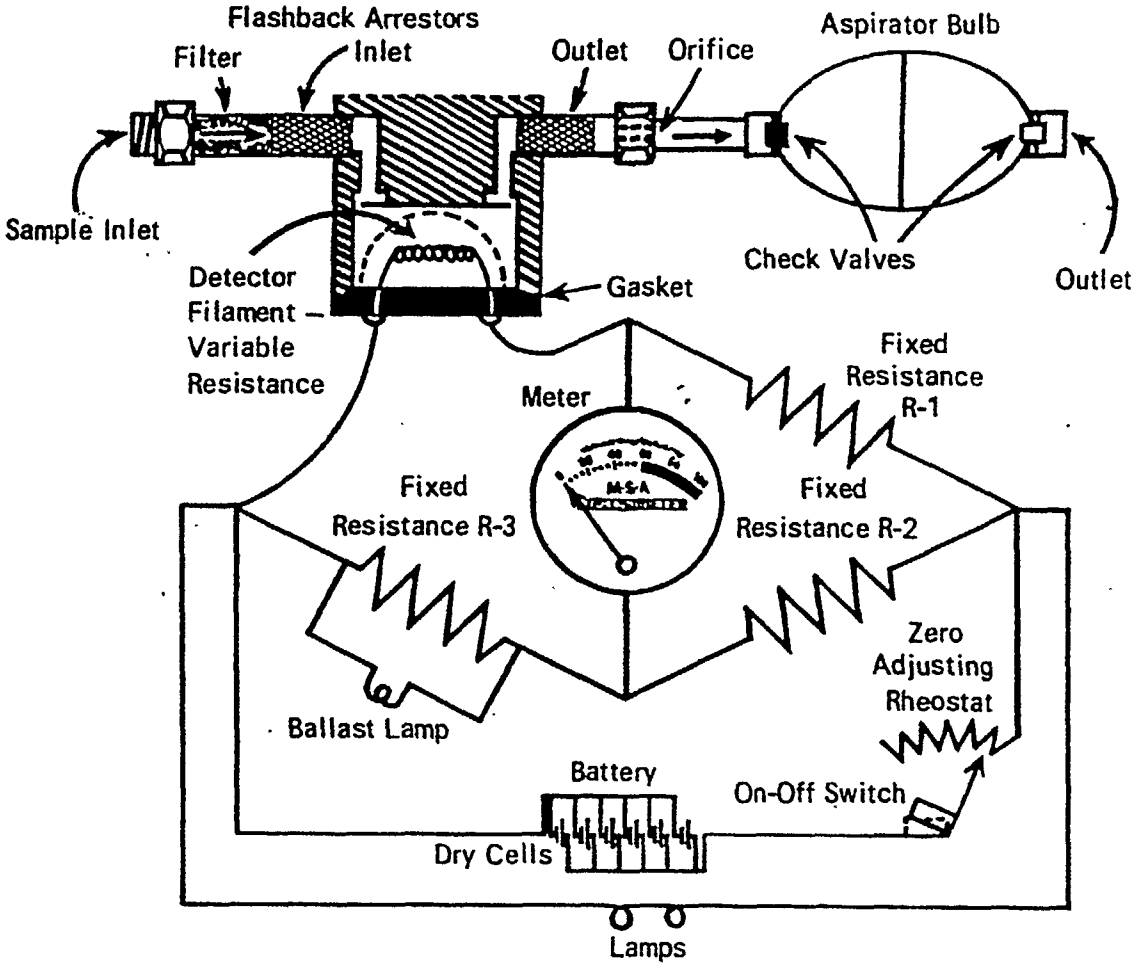


Figure 9.3

One of the most useful instruments of the direct reading type is the explosimeter, or combustible gas indicator. As the names suggest, instruments of this type were designed to detect the presence of explosive or combustible gases in the air. Safety checking is still their principal application, and many of them are suitable only for this purpose.

To understand the principle on which these instruments operate, the terms lower and upper explosive limits must be defined. When certain proportions of combustible vapor are mixed with air, ignition will produce an explosion. The range of concentrations over which this will occur is called the explosive range. It includes all concentrations in which a flash will occur or a flame will travel if the mixture is ignited. The lowest percentage at which this occurs is the lower explosive limit (LEL), and the highest percentage is the upper explosive limit (UEL). Mixtures below the LEL are too lean to ignite, and mixtures above the UEL are too rich. The relationship of gas and vapor mixtures to explosibility is shown in Figure 9.2.

Explosive limits are expressed in per cent by volume of vapor in air. LEL's and UEL's have been determined in fire and safety, and health laboratories for all substances likely to be found in industry, and tables are included in many reference books. One table of such values for many solvents and gases is shown in Table 9.1.

Several manufacturers make explosimeters or combustible gas indicators. Although they differ somewhat in design and operating features, their operation is based on the fact that a measurable amount of heat is released when a combustible gas or vapor is burned. Most meters contain a battery-operated elec-

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PROPERTIES OF FLAMMABLE LIQUIDS

Name	Flash Point °F		Explosive Limits in air % by Volume		Autoignition Temperature °F.	Vapor Density
	Closed Cup	Open Cup	Lower	Upper		Air = 1.0
Acetaldehyde	−36	—	4.0	55.0	365	1.52
Acetone	0	15	2.1	13.0	1000	2.00
Ammonia (Anhydrous)	Gas	Gas	15	28	1204	0.596
Amyl Acetate-n	76	80	1.1	7.5	714	4.49
Amyl Alcohol-n	91	120	1.2	—	572	3.04
Benzene	12	—	1.4	7.1	1044	2.77
Benzine	<0	—	1.4	5.9	550	2.50
Butyl Acetate-n	72	90	1.4	7.6	790	4.00
Butyl Alcohol-n	84	110	1.4	11.2	693	2.55
Camphor	150	200	—	—	871	5.24
Carbon Disulfide	−22	—	1.0	50	257	2.64
Carbon Tetrachloride	None	None	—	—	—	—
Cellosolve	104	120	2.6	15.7	460	3.10
Chloroform	None	None	—	—	—	4.13
Coal Tar Oil	80-160	—	—	—	—	—
Coal Tar Pitch	405	490	—	—	—	—
O-Cresol	178	—	1.3 at 300° F.	—	1038	3.72
Cyclohexanol	154	—	—	—	572	3.45
Denatured Alcohol — 95%	60	—	—	—	750	1.60
Ethyl Acetate	24	30	2.2	11	800	3.04
Ethyl Alcohol	55	70	3.5	19	737	1.59
Ethylene Glycol	232	240	3.2	—	775	2.14
Ethyl n-propyl ether	—	—	1.9	24	—	—
Formaldehyde, 37% in water	130	200	—	—	795	1.03
Fuel oil No. 1	114-185	—	0.6	5.6	445-560	—
Fuel oil No. 1-D	100 min	—	1.3	6	350-625	—
Fuel oil No. 2	126-230	—	—	—	500-705	—
Fuel oil No. 2-D	100 min	—	1.3	6	490-545	—
Fuel oil No. 4	154-240	—	1	5	505	—
Fuel oil No. 5	130-310	—	1	5	—	—
Fuel oil No. 6	150-430	—	1	5	765	—
Gasoline Automotive premium	−50±	—	1.3-1.4	6.0-7.6	770	3.0-4.0
Gasoline Automotive regular	−50±	—	1.3-1.4	6.0-7.6	700	3.0-4.0
Gasoline Aviation, commercial	−50±	—	1	6.0-7.6	800-880	3.0-4.0
Gasoline Aviation military	−50±	—	1	6.0-7.6	800-880	3.0-4.0
Hexane-n	−7	—	1.2	7.5	453	2.91
Hexane-iso	<−20	—	1	7	—	3.00
Hydrogen sulfide	Gas	Gas	4.3	45.5	500	1.18
Jet fuel JP-1	110-125	—	0.6	5.6	442-560	—
Jet fuel JP-4	26-36	—	0.8	6.2	468	—
Kerosene	110-130	—	0.6	5.6	440-560	4.5
Lacquer	0-80	—	—	—	—	—
Maleic Anhydride	218	240	—	—	890	3.38
Methyl Acetate	15	20	3.1	16	935	2.56
Methyl Alcohol	54	60	5.5	36.5	878	1.11
Methyl Ethyl Ketone	30	—	1.8	10	960	2.48
Mineral spirits	100 min	110	0.77@212°F	—	475	3.9
Naphtha	100-110	—	0.8	5	440-500	—
Naphtha VM&P	20-45	—	0.9	6.0	450-500	3.75
Naphthalene	174	190	0.9	5.9	979	4.42
Petroleum crude	20-90	—	—	—	—	—
Petroleum ether	<0	—	1.4	5.9	550	2.50
Phenol	175	185	—	—	1319	3.24
Phthalic Anhydride	305	330	1.7	10.5	1083	5.10
Pine oil	172	175	—	—	—	—
Propane	<−100	Gas	2.2	9.6	871	1.56
Propyl Acetate-n	58	70	1.7	8.0	842	3.52
Propyl Alcohol-ISO	53	60	2.5	12	750	2.07
Quenching oil	365	405	—	—	—	—
Stoddard solvent	100-110	—	0.8	5	440-500	—
Styrene	90	—	1.1	6.1	914	3.60
Sulfur	405	440	—	—	450	—
Toluene	40	45	1.3	7.0	997	3.14
Trichloroethylene	Weakly Flammable		10 in O_2	65 in O_2	—	4.53
Turpentine	95	—	0.8	—	488	4.84
p-Xylene	77	—	1.1	7.0	984	3.66

Table 9.1

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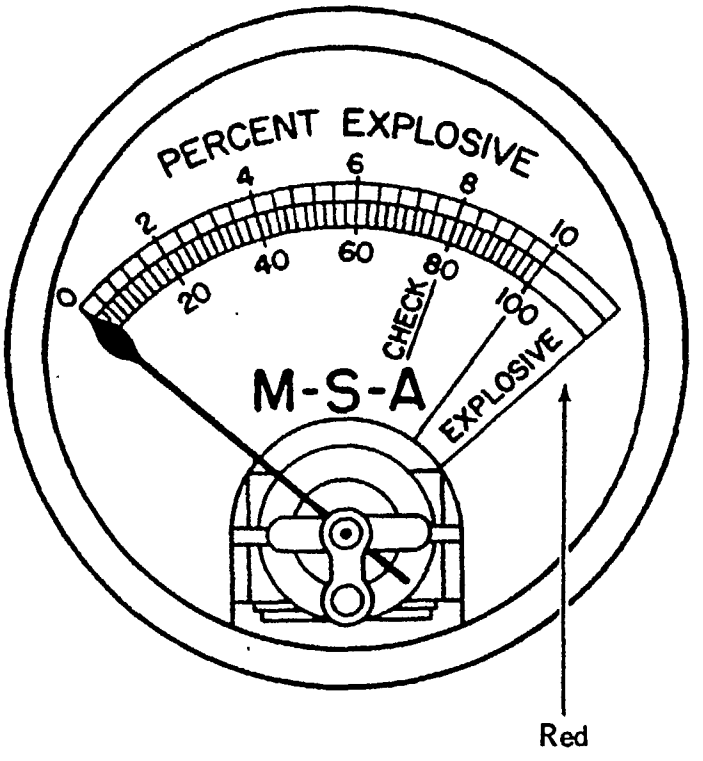


Figure 9.4

trical circuit known as a Wheatstone bridge, which is balanced by means of controls on the outside of the instrument. A schematic illustration of the basic flow system and wiring diagram are shown in Figure 9.3. In one part of the bridge, the air being sampled is passed over filaments which have been brought to white heat. If the air contains a combustible gas or vapor, the heated filaments cause combustion and additional heat is released, changing the electrical resistance of the filaments. Another part of the bridge contains similar filaments which are heated in identical fashion to those in the air stream; these cancel out all changes and resistance due to temperature variations or to characteristics of the instrument itself. The net effect is that the resistance of the filaments in the air stream changes due to the presence of combustible gases. These changes are converted into a small electrical current which is registered as "per cent LEL" on the instrument's meter.

On the simplest type of instrument (an explosimeter) only one scale is provided, usually with readings from 0 to 100% LEL. However, the detectable changes produced by combustion are too small to be measured accurately in the presence of the low concentrations of contaminants usually encountered in evaluating potential health hazards. For example, the LEL of even the most explosive gas is of the order of 1%, or 10,000 ppm, which is well in excess of the toxic limit for any gas. Therefore, explosimeters or combustible gas indicators which have only a 0-to-100% LEL explosive scale are not suitable for environmental health testing in the ppm range.

More sensitive instruments, including the type used in sampling for environmental health purposes, have a dual scale, in which the second, more sensitive scale, expands the 0-to-10% LEL part of the instrument's response to full-scale reading (Figure 9.4). While this permits more sensitive and accurate reading of concentrations in the 0-to-10% range, this type of instrument is not sufficiently sensitive to give precise indications of concentrations at the TLV of many toxic gases and vapors. In addition, they lack specificity, do not read directly in TLV units (ppm), and are subject to interferences.

All combustible gas and vapor indicators are calibrated by the manufacturer using one specific gas or vapor such as methane, and a calibration curve is provided, in per cent LEL, for the calibration gas only. Obviously, accurate concentrations of other gases or vapors cannot be indicated unless the instrument has been appropriately calibrated for each of these gases. Furthermore, the manufacturer's calibration may not be sufficiently accurate and a correction may be required.

For example, a meter reading of 2.0 on the 0-to-10% LEL scale of one instrument would indicate, for a solvent having an LEL of 1.4%, a concentration of 280 ppm (0.02 x 14,000 ppm). Benzene, methyl isobutyl ketone (MIBK) and toluene all have LEL's of 1.4%, but actual concentrations at a meter reading of 2.0 would be 294 ppm for benzene, 350 ppm for MIBK and 231 ppm for toluene. Therefore, unless the scale reading is corrected according to a calibration chart (Figure 9.5), to indicate actual ppm values, the reading can be seriously in error.

The manufacturer's instructions for operating a combustible gas indicator should be carefully reviewed before the device is used. In general, all explosimeters require a brief initial warm-up period so that the batteries can heat the filaments. Then battery strength

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A TYPICAL CALIBRATION CHART (MSA)

L.E.L. = % by Volume (U.S.B.M. Bulletin #503)
T.L.V. = Threshold Limit Values (A.C.G.I.H. 196-4) (P.P.M.)

PARTS PER MILLION (in squares)
10% L.E.L. Switch Setting
Meter Reading:

METER READING (in squares)
% L.E.L. Switch Setting
O.S. = OFF SCALE

No.	Name	L.E.L.	T.L.V.	1	2	3	4	5	6	7	8	9	10	2X T.L.V.	3X T.L.V.	5X T.L.V.	5% L.E.L.	10% L.E.L.	20% L.E.L.	50% L.E.L.	75% L.E.L.	No.	Formula
1	Acetone	2.6	1000	338	676	1026	1376	1716	2055	2418	2756	3133	3432	7	11	18	5	9	19	48	72	1	CH_3COCH_3
2	Acetaldehyde	4.1	200	328	697	1025	1394	1722	2091	2419	2788	3116	3414		2.5	4.5	8	15	30	75	OS	2	CH_3CHO
3	Acrylonitrile	3.0	20	240	480	720	960	1200	1410	1650	1860	2070	2280				8	16	32	78	OS	3	C_2H_3CN
4	Allyl Alcohol	2.5	2	225	450	650	875	1100	1325	1525	1750	1975	2175				8	15	28	61	83	4	C_3H_5OH
5	Amyl Alcohol	1.2	100	180	216	504	660	804	948	1092	1224	1344	1452			4	5	10	18	37	60	5	$C_5H_{11}OH$
6	Benzene	1.4	25	140	294	434	574	728	868	1008	1162	1302	1442				6	12	24	58	83	6	C_6H_6
7	Butyl Acetate	1.7	200	170	340	527	697	884	1071	1275	1496	1720	1955		1.5	4	2.5	5	11	28	42	7	$CH_3COOC_4H_9$
8	Butyl Alcohol	1.4	100	210	406	602	798	980	1148	1316	1456	1568	1666	1	2	3	4	8	15	33	46	8	C_4H_9OH
9	Carbon Disulfide	1.25	20	275	625	1000	1375	1750									2.5	5	10	24	35	9	CS_2
10	Carbon Monoxide	12.5	100	750	1500	2250	3000	3750	4500	5250	6000	6750	7500				10	22	42	100	OS	10	CO
11	Cyclohexane	1.3	400	143	286	429	572	715	845	988	1118	1261	1404	7	10	18	6	11	23	57	83	11	C_6H_{12}
12	Dimazine (UDMH)	2.5	0.5	200	450	725	1000	1325	1675	2025	2375	2750	3100				5.5	11	21	53	77	12	$(CH_3)_2N_2H_2$
13	Ethyl Acetate	2.5	400	325	675	1025	1400	1775	2175	2625	3050	3450	4000	3	5	8	5	10	20	50	75	13	$CH_3COOC_2H_5$
14	Ethyl Alcohol	4.3	1000	215	473	774	1075	1419	1763	2107	2494	2871	3311	8.5	12	18	9	17	31	70	101	14	C_2H_5OH
15	Ethyl Ether	1.9	400	114	247	399	570	741	931	1021	1311	1520	1729	5	7.5	12.5	6	12	23	56	82	15	$C_2H_5OC_2H_5$
16	Ethylene Chloride	6.2	50	496	1054	1590	2140	2666	3224	3720	4250	4774	5270				7	14	28	68	98	16	CH_2ClCH_2Cl
17	Ethylene Oxide	3.0	50	405	780	1155	1530	1890	2265	2640	3000	3345	3705				5.5	11	21	54.5	90	17	C_2H_4O
18	Gasoline (leaded – with inhibitor)	1.4	500	140	294	448	608	770	924	1085	1246	1400	1580	8	12	20	5	11	22	55	82	18	
19	Heptane	1.2	500	132	270	402	540	672	804	936	1068	1200	1332	9	13.5	21	6	11	21	50	73	19	C_7H_{16}
20	Hexane	1.2	500	144	288	444	600	750	900	1056	1212	1368	1512	8	11.5	19.5	5	9.5	18.5	47	69.5	20	C_6H_{14}
21	Hydrogen Sulfide	4.3	10	516	1011	1485	1935	2387	2838	3290	3741	4171	4622				6	12	24	56	79	21	H_2S
22	Iso-Propyl Acetate	1.8	200	252	504	738	990	1224	1478	1728	1962	2214	2468	1.5	2.5	5	4.5	9.5	18.5	47	70.5	22	$(CH_3)_2CHOOCCH_3$
23	Iso-Propyl Alcohol	2.0	400	280	550	810	1100	1380	1660	1950	2230	2510	2790	3.5	5	8.5	4.5	8.5	17.5	45	67	23	$(CH_3)_2CHOH$
24	Iso-Butyl Methyl Ketone (MIBK)	1.4	100	182	350	512	665	826	980	1141	1288	1442	1596	1.4	2.1	3.6	5	10	22	50	73	24	$CH_3COC_4H_9$
25	Methyl Acetate	3.1	200	465	930	1395	1891	2372	2853	3317	3813	4278	4743			2	4.5	8.5	17	43	65	25	CH_3COOCH_3
26	Methyl Alcohol	6.7	200	402	838	1273	1740	2210	2700	3200	3680	4180	4690		2	3	9	18.5	36.5	88	OS	26	CH_3OH
27	Methyl Ethyl Ketone (MEK)	1.8	200	180	378	585	837	1080	1350	1620	1908	2180	2448	2	3	5	5	10.5	21	47.5	71	27	$CH_3COC_2H_5$
28	Octane	1.0	500	130	255	380	510	640	770	915	1060	1210	1365	9.5	14	23	5	9.5	18.5	44	64	28	C_8H_{10}
29	Pentane	1.4	1000	140	294	448	608	770	924	1085	1246	1400	1580	16	24	39	5	11	22	55	82	29	C_5H_{12}
30	Styrene	1.1	100	66	143	242	341	457	583	715	847	990	1133	2	3	4.5	5	10.5	21	52.5	75	30	$C_6H_5CHCH_2$
31	Tetrahydrofuran	2.0	200	200	400	630	840	1050	1260	1480	1700	1930	2160	2	4	6	6	12	25	60	88	31	C_4H_8O
32	Toluene	1.4	200	112	231	350	476	602	728	846	973	1099	1218	3.5	5.5	9	6.5	13	25	60	87.5	32	$C_6H_5CH_3$
33	Xylene	1.0	200	110	220	330	450	560	680	800	920	1055	1200	5	7.5	12.5	6	12	23	42	52	33	$C_6H_4(CH_3)_2$
53	Chlorobenzene	1.3	75	130	267	409	546	682	822	962	1105	1248	1391	1	2	2.5	4.5	8.5	16.5	39	55.5	53	C_6H_5Cl
55	1, 4 Dioxane	2.0	100	280	560	830	1100	1370	1640	1910	2180	2450	2720	1	1.5	2.5	5	10	20	50	75	55	$C_2H_4OC_2H_4O$

Figure 9.5

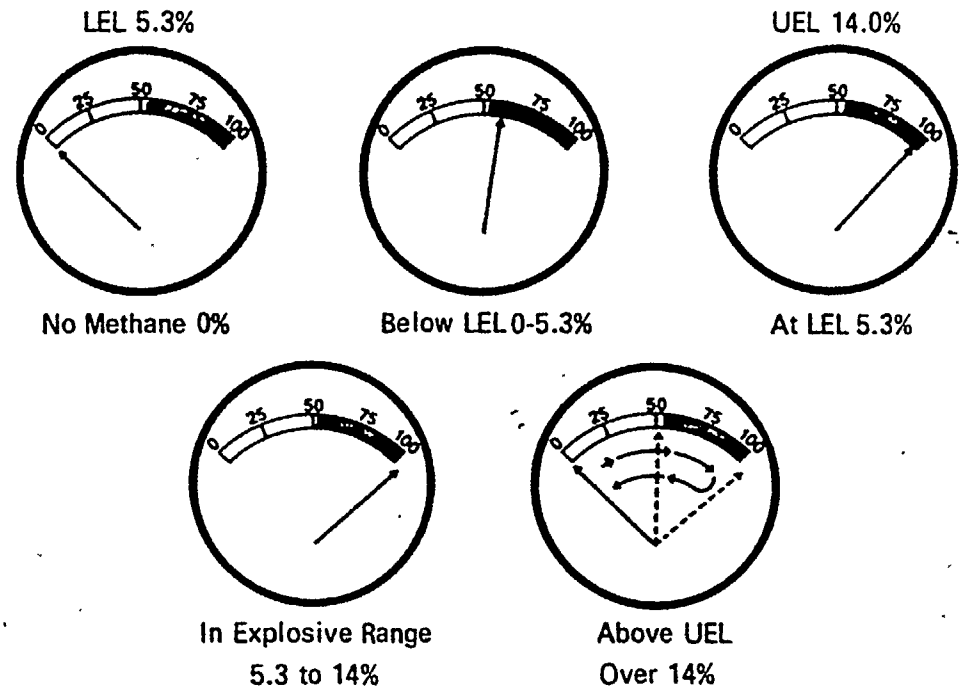


Figure 9.6

should be checked, and the zero scale adjusted. When zero is established and the indicating needle is stable, the instrument is ready for use.

The zero adjustment must be made by taking the instrument to a source of air which does not contain combustible gases or vapors, or by passing air into it through an activated carbon filter which will remove combustible vapors and gases except methane. Since methane is not removed by activated charcoal filters, extra caution is required if the presence of methane is suspected. In addition, the filter should be changed periodically because it tends to become saturated during prolonged use and will no longer remove many of the combustible gases and vapors. If the zero adjustments are made in fresh air, care must be taken that no combustible gas or vapor is present in an amount which would influence the instrument's response.

Most combustible gas indicators are equipped with a length of sampling tubing with a metal probe at the end. The probe is held at the sampling point (usually near the breathing zone of the worker) and, a few seconds later, the response can be read on the meter. Generally, the air is drawn through the probe and meter by means of a hand-operated rubber squeeze bulb. In some instances, however, a small electrically-operated pump in the instrument case is used for this purpose. In most work areas, the concentration of combustible gas or vapor fluctuates constantly, and it is necessary to observe the instrument carefully and to make a judgment concerning average and peak readings.

Sometimes the probe of a combustible gas indicator or explosimeter is placed in a manhole or other space not normally occupied by people, to determine if there is a potentially explosive or dangerous concentration of gas present. When the instrument is used in this way, it may show a zero response for several different reasons. Assuming that the batteries are working and the instrument is functional, the absence of meter response can mean either that there is little or no combustible gas in the space being tested, or that the concentration is so high that it is above the UEL and combustion cannot occur because of lack of oxygen. A very high concentration can be identified by carefully watching the needle as the probe is moved into and withdrawn from the space being tested. At some point during entry and withdrawal, the probe must pass through the LEL concentration and enter the flammable

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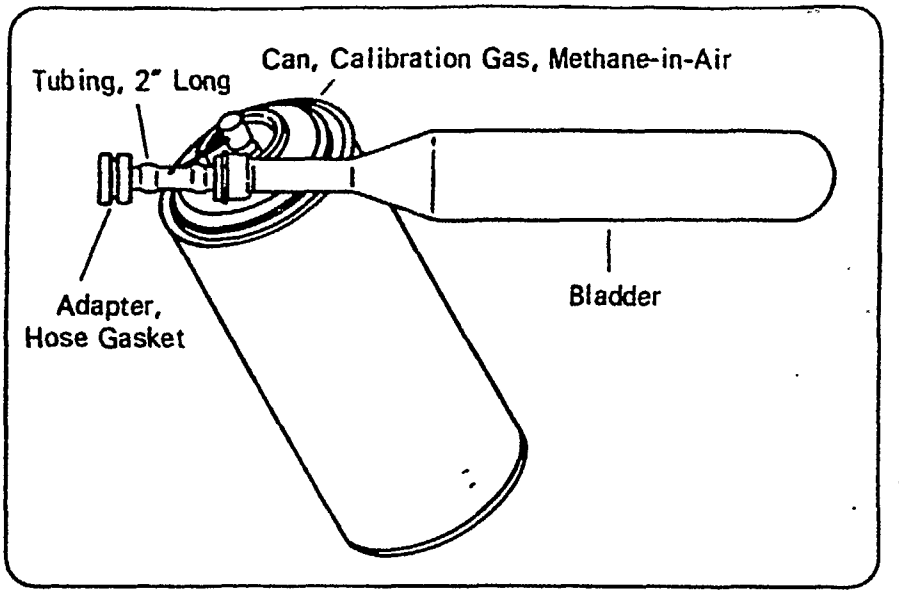


Figure 9.7

range. At this point, the needle will jump briefly, then settle back to zero. This "chink" or jump is a clear indication that a high concentration is present.

Dual scale combustible gas indicators are rugged, relatively lightweight, and portable so they are widely used for checking work operations like solvent cleaning or painting, or locations such as coal chemical areas where organic solvents are emitted. Their limitations must be realized, however, and where there is a possibility that benzene or an unknown and possibly toxic solvent may be present, they cannot be relied upon. In such cases, sampling must be performed by other means.

The dual-scale combustible gas indicators which Environmental Health - Pittsburgh has approved for evaluating health hazard potentials have scales on their meters similar to those shown in Figure 9.4.

PRECAUTIONS, INTERFERENCE, FIELD CALIBRATION

The user of any instrument should be thoroughly familiar with precautions to be taken in its operation; users of combustible gas indicators must also be aware of interfering gases and vapors which can create major aberrations in instrument response. One such precaution is that the 0-to-100% scale should be used first, to determine whether an explosive atmosphere exists and to prevent overloading to 0-to-10% LEL scale. For example, note the typical meter responses to methane gas shown in Figure 9.6, particularly those at the LEL, in the explosive range, and above the UEL. If the pointer of the meter travels into the red portion of the scale and remains there, an explosive concentration is present. However, if the pointer climbs rapidly to the red area and then falls back to zero, there is either a concentration above the UEL or a gas mixture which lacks sufficient oxygen to support combustion. Whatever the reason, if the pointer touches the red portion of the scale, the gas tester should leave the area immediately.

Interfering gases and vapors can seriously affect instrument response, and an experienced tester recognizes the indications of their presence. The manufacturer's instructions should be thoroughly understood. For example, high concentrations of chlorinated hydrocarbons (i.e., trichloroethylene) or of an acid gas (sulfur dioxide) may cause depressed meter readings when high concentrations of combustibles are also present. Trace amounts of these interferences may not affect the readings directly, but can corrode the sensitive detector elements. High molecular alcohols in the atmosphere may burn out the filaments, making the instrument inoperative. If such limitations are understood, the tester can obtain sufficiently valid results.

For calibration of the 0-to-100% LEL scale, test kits (Figure 9.7) containing known concentrations of combustible gases (usually either 2.5% methane or 2.5% natural gas) are available from the instrument manufacturers.

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interfering materials also influence the accuracy of the readings. Therefore, indicating tubes came to be considered as semi-quantitative devices whose use was limited to screening or preliminary surveys to locate areas which required more accurate monitoring.

In view of all this, the Bureau of Occupational Health of the U. S. Public Health Service (now NIOSH) undertook another evaluation at the request of the ACGIH-AIHA Joint Committee on Direct Reading Chemical Indicator Tube Systems. The initial results of this study were reported at the 32nd (1970) Annual Meeting of ACGIH. They showed that the carbon monoxide tubes manufactured by four leading suppliers, for ranges of 25 to 100 ppm, were ±50% accurate at the 95% Confidence Level, but no better than ±25%. The sulfur dioxide tubes of three manufacturers, tested at concentrations ranging from 2.5 to 25 ppm, were found to be ±25% accurate at the 95% Confidence Level at the higher concentrations. The Committee then published its recommended specifications for performance standards for colorimetric gas detecting devices in the January 1971 issue of the Journal of the AIHA (Appendix A). The recommendations take on increased significance since OSHA has accepted the use of indicating tubes for regulatory purposes.

The specifications are intended primarily for the manufacturers of tubes, since the user's control is limited to checking the manufacturer's claims and specifications. Particular attention is directed to Specification 5 which states that the tubes are required to be accurate within 25% of the stated concentration. As an example of how this specification is being met, another recent NIOSH publication ("The Evaluation of Gas Detector Tube Systems: Benzene") states that, of those tubes tested, none met the 25% criterion, and only three were found to be within ±50% of the stated value. It is probable that many, if not most, tubes are equally inaccurate and, as suggested earlier, they should be used with caution. Whenever accurate information is needed concerning the concentration of a given gas or vapor, the tubes may be useful for range-finding purposes, but sampling should then be performed with a more suitable (and reliable) device.

Specification 7 indicates that the batch number and expiration date of the tubes must be noted on the box. This information should always be checked before the tubes are used, and those which are outdated should be discarded unless evidence based on calibration indicates that they are still reliable. As noted in Specifications 9 and 10, the flow rate must be indicated and should be accurate to within ±5%. For this reason, the air moving device or squeeze bulb should be calibrated periodically.

Obviously, making reliable tests with indicating tubes requires thorough knowledge of their limitations and care in their use. Experience has shown that the following measures help to minimize some errors:

1. Test each batch of tubes with a known gas concentration.
2. Read the length of stain in a well-lighted area.
3. Read the longest length of stain if stain development is not sharp or even.
4. Observe the manufacturer's expiration date closely, and discard outdated tubes.
5. Keep detector tubes in a shirt pocket or other warm place until time to start the test.
6. Refer to the manufacturer's data for a list of interfering materials.
7. Calibrate for the proper flow rate, as discussed elsewhere in this Chapter.

Mine Safety Appliances Company (MSA) recommendations for use of detector tubes with their Universal Sampling Pump, or with a single- or multiple-tube holder for long-term sampling, are outlined in the operating instructions supplied with each box of tubes, as well as in the MSA Monitaire Sampler booklet. In reviewing these instructions, the following information should be noted carefully:

1. Operating instructions for Universal and Monitaire sampling pumps are not the same, although both use the same detector tube (Part No. 91229).
2. When using the Universal pump to sample for CO:
   a. Use the No. 1 orifice on the rotating head;
   b. Use the prescribed volume of air. Either 25 cc (1/4 pump stroke), 100 cc (1 pump stroke) or 500 cc (5 pump strokes) must be taken;
   c. After each pump stroke, allow the specified length of time (70 seconds) for the evacuated pump to fill; and
   d. Compare the length of stain with the

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Figure 9.8

volume of sample taken.

Note that these instructions (in this item 2) are specific for CO testing. For other gases or vapors, the rotating head setting (Figure 9.8), the volume of air collected (Figure 9.9) and the length of time required for the chemicals in the tube to react with the contaminant, may be different.

3. When using the Monitaire pump with single or multiple tube holders:
   a. Position the bypass valve on the Monitaire as determined by air flow calibrations;
   b. When using the multiple-tube holder, insert a tube in each position, as determined by air flow calibrations;
   c. Make frequent observations (at least every half hour) during testing, to insure that the entire length of the detector tube does not become stained; and
   d. Use a calibration chart (Figure 9.10) to determine the concentration of the contaminant sampled. The concentration depends upon the length of stain and the sampling time. For example, a stain development of 10 mm for a 1-hour sample would indicate a concentration of 150 ppm.



Figure 9.9

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CALIBRATION CHART - INDICATING TUBES (Carbon Monoxide)

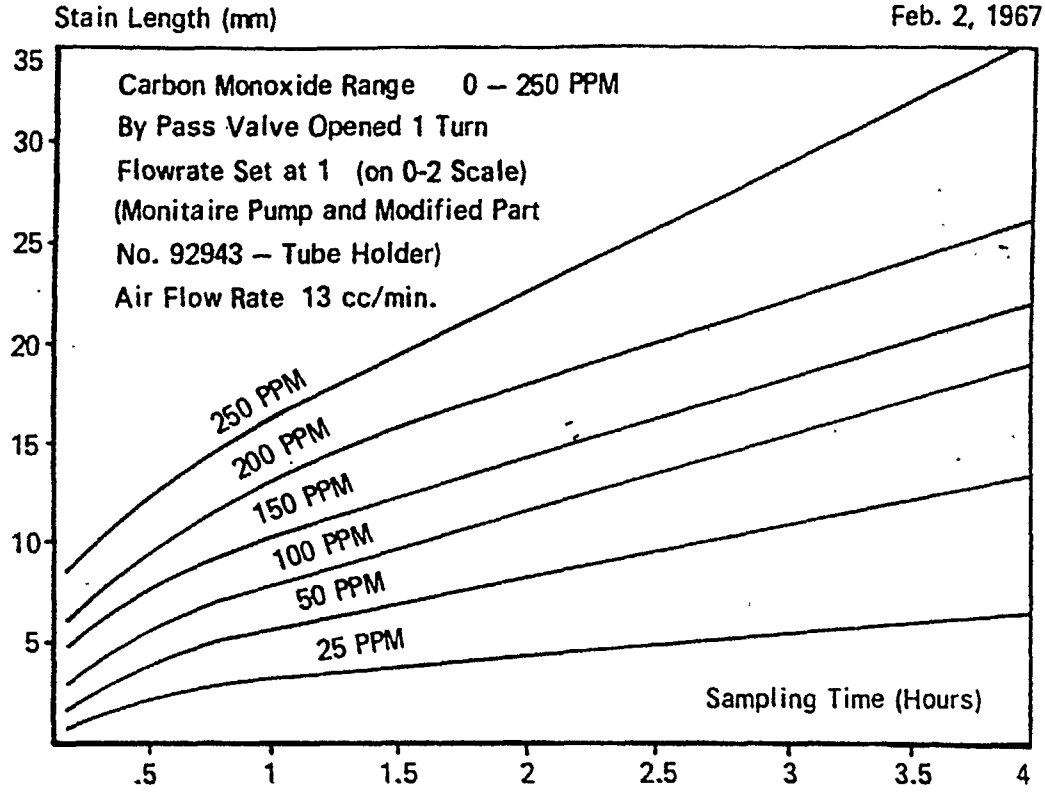


Figure 9.10

Calibration

For accurate measurements, sampling instruments must be calibrated against a known concentration of gas or vapor. Various-sized cylinders of compressed gases or vapors in the TLV ranges can be purchased from specialty gas and equipment manufacturers, or can be prepared in the laboratory. The purchased cylinders are more adaptable for plant use.

Gas mixtures are available from Air Products & Chemicals, Inc.; Matheson Gas Products; Scientific Gas Products, Inc.; and other suppliers, or they may be purchased from local companies which specialize in this type of product. Generally, these mixtures are available only in No. 3 cylinders (32 ft^3) and require the purchase of a regulator and payment of a cylinder deposit and a demurrage charge. Some manufacturers, such as Scientific Gas Products, Inc., also provide gas mixtures in low-cost non-returnable "mini" containers of 4- and 24-liter sizes. The 4-liter container is similar to a 6-ounce pushbutton aerosol can (Figure 9.7).

To calibrate the sampling device:

1. Prepare the sampling instrument for use, i.e., a combustible gas indicator must be allowed to warm up and be properly zeroed;
2. Attach the calibration assembly (gum rubber tubing and inflatable bladder) to the inlet valve;
3. Exhaust all air from the bladder by actually operating the sampling instrument;
4. Inject the calibration gas into the bladder through the tubing, using the needle arrangement on the gas container;
5. Draw a sample through the instrument; and
6. Compare the instrument reading with the gas concentration used.

A 24-liter container is similar in size to the propane torch gas containers which are currently popular for home use. It must be equipped with a discharge valve and suitable fittings for transferring the gas into the bladder. Calibration procedures are conducted as shown in Figure 9.11.

Preparing TLV range mixtures of some gases and vapors can be quite difficult, while others are relatively easy. There are a number of ways to make known mixtures, but some are practical only in a laboratory and cannot be used for field calibrations. For example,

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24 LITER GAS CONTAINER CALIBRATION SET-UP

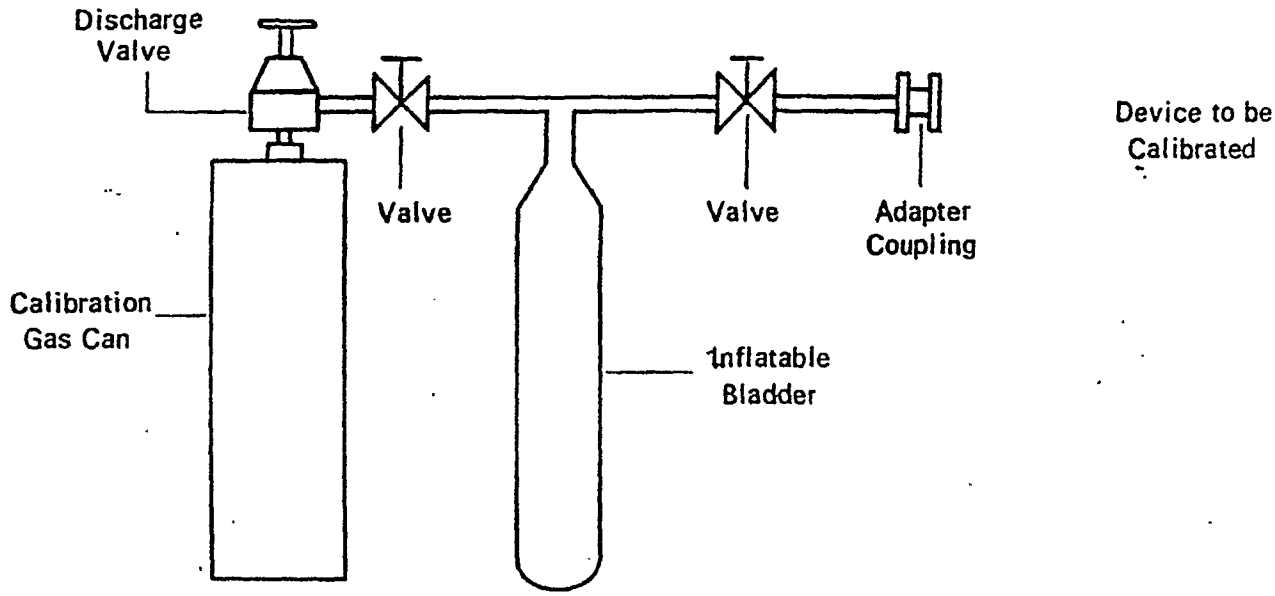


Figure 9.11

the so-called dynamic method of mixing gases and air requires continuous and very precise metering of the contaminant and air to obtain a mixture of known proportions. In contrast, the static method involves preparing a mixture of fixed volume and sampling it for a limited period of time. Although mixtures can be made up in bottles, tanks, or other containers, it is generally more convenient to use plastic bags.

Several important factors must be considered in making any calibration mixture:

1. For gases, it is essential to use pure gas or, preferably, a dilute air/gas mixture whose exact concentration is known. For vapors, it is essential to have a sample of the pure liquid which is to be vaporized.
2. The air source (compressed or not) must be completely free from all contaminants, especially the contaminant which is to be measured.
3. The plastic bag must be appropriate for the intended mixture, and must not alter the calibration mixture.

Small pressurized cylinders (lecture bottles) of pure gases such as ammonia, sulfur dioxide, hydrogen sulfide and carbon monoxide are commercially available and can be diluted to known concentrations for calibration purposes. Some gases in TLV ranges may be available in such containers, but these can stratify and should be used with care. The Director of Environmental Health should be consulted for further instructions.

The preparation of gas mixtures for calibration requires calculations based on container volume, actual concentration of gas in the cylinder, and desired concentration in the bag. If the gas concentration in the cylinder is known in terms of per cent by volume, and if the desired concentration is also expressed in volume/volume units (such as ppm), the calculations are quite simple.

For example, if the cylinder contains exactly 0.1% gas by volume (1,000 ppm), and a mixture containing 100 ppm is needed, this will require a simple 1-to-10 dilution, expressed in volume/volume units. Therefore, it is necessary only to measure 1 liter of calibrating gas and add 9 liters of air, to obtain a total volume of 10 liters of mixture with 100 ppm of gas.

In practice, it is probable that the starting mixture will be some other less simple concentration and a calculation will be required. The following formula can be used:

$$V_1 \times C_1 = V_2 \times C_2$$

where V_1 = volume of concentrated gas in bottle,

C_1 = concentration of gas in bottle,

V_2 = volume of gas mixture in bag, and

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C_2 = desired concentration of gas mixture in bag.

For example, find V_1 (volume of concentrated gas in bottle) where

C_1 = 0.15% (1,500 ppm),

V_2 = 20 liters, and

C_2 = 50 ppm.

$$V_1 \times 1{,}500 = 20 \times 50$$

$$V_1 = \frac{1{,}000}{1{,}500}$$

$$V_1 = 0.67 \text{ liter}$$

When the concentration of gas in the bottle, or in the desired calibration mixture, is not expressed in volume/volume units, the calculations become more lengthy, since they require conversion to common units.

Vapor mixtures can be made in the laboratory by injecting a small quantity, usually microliters, of the given solvent into a plastic bag containing a known amount of air. When the solvent evaporates, the desired concentration results. However, the molecular weight of the solvent and its density must be known in order to make the proper calculations, and these can be quite difficult when they involve only small amounts of liquid solvent. Assistance in the mathematics related to preparing known gas or vapor mixtures can be requested from Headquarters Environmental Health - Pittsburgh.

INDIRECT SAMPLING DEVICES FOR GASES AND VAPORS

As stated earlier in this Chapter, not every contaminant can be sampled by a direct reading device. In such cases (or even in some situations involving contaminants which can be measured with direct reading devices) an indirect reading sampler must be used when the sample must be sent to a laboratory for analysis of the components. For this purpose, a number of glass or plastic bubblers are available, containing water or some other liquid to capture gases or dusts when air is drawn through them. Occasionally, filter papers are used, but since ordinary filter paper cannot trap gas or vapor, the paper must be treated with chemicals which will react with the substance of interest and retain it on the paper. For many purposes, gases and vapors can also be collected in bottles, in plastic bags, or in tubes which contain activated charcoal or some other adsorbent. Each of these methods is discussed below, since the person responsible for monitoring in each plant will be required to use them at some time.

BUBBLERS

Bubblers are ordinarily made of glass, although some are made of clear plastic. A stated amount of absorbing liquid is placed in a sample bottle which also contains the bubbler. When air is drawn through the bubbler, the contaminant is retained in the absorbing solution. The most efficient unit for sampling gases and vapors is a fritted bubbler, which is a piece of glass with thousands of small holes which disperse the air as it bubbles through the solution.

The choice of absorbing solution, the strength (normality or pH) of the solution, the sampling rate (generally 1 to 3 liters per minute), and the size of the bottle (20 cc, 50 cc, or 125 cc), are some of the variables which must be considered in using bubblers.

It should also be emphasized that the air flow calibration of bubblers should be done before field use. The calibration should be done with the same type and amount of absorbing solution as will be used in the actual testing, since absorbing solutions vary in viscosity and can directly affect the pressure drop in the sampling system. The pressure drop is also directly affected when the pores of the fritted bubbler become clogged thus lowering the efficiency of the bubbler and materially influencing the collection rate. To avoid such clogging, a filter must be used ahead of the bubbler.

CHARCOAL TUBES

Reference has been made earlier to adsorption, which is the property of some solid materials, such as activated charcoal, to physically retain solvent vapors on their surfaces. In environmental health testing, the adsorbed vapors are removed, generally with a solvent, in a laboratory. The solvent is then analyzed by physical methods (gas chromatography, etc.) to determine the individual compounds whose vapors, such as benzene, were present in the sampled air.

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Currently, industrial atmospheric samples are collected in small glass tubes (4 mm ID) packed with two sections of activated charcoal, separated and retained with fiberglass plugs. To obtain an air sample, the sealed ends of the tube are broken off, and air is drawn through the charcoal at the rate of 1 liter per minute by means of a personal sampler. After sampling, the tubes are resealed and sent to a laboratory for analysis.

Four precautions must be observed when this type of collection device is used:

1. The shorter (backup, or second) section of the charcoal tube should be inserted into the sampling line so that the air is drawn through the longer section first. When analyzed, the backup section should be void of solvent vapors - in other words, there should have been no carry-over from the first section.
2. The sampling rate must be maintained at 1 liter per minute. Sampling at a higher rate may elutriate the solvent vapors from the first section, in which case they may be adsorbed in, or even elutriated from, the second section.
3. Because of the limited adsorption capacity of the tube, the sampling period should not exceed 15 to 30 minutes. The time will depend to some degree on the expertise of the observer, since high concentrations of solvent vapors could saturate the first charcoal section in a few minutes.
4. The tubes should be carefully resealed, with the caps provided for that purpose, immediately after use.

PLASTIC BAGS

Sometimes it is possible to sample simply by filling a bag, bottle, or other container with air from the working area and sending the container to a laboratory. Plastic bags have several advantages over bottles for this purpose. First, of course, they require little storage space and can be kept on hand at all times. In addition, they are available in relatively large sizes so that a much larger volume of air can be sampled than might be practical with a bottle. Finally, they are lightweight even when filled.

Among the materials used for these bags are Myler, Saran, and a laminated material called Scotch Pak. These bags are, in general, strong and impermeable, do not react with many of the common vapors which must be sampled, and do not themselves add contaminants to the air after it is collected. Commercially available bags come in various sizes ranging upward from 1 liter, and have built-in tubes for sampling purposes.

There are several ways to fill a sampling bag. The most common is to attach to the bag inlet a rubber bulb containing two valves, one to draw air in, the other to blow air out. If the bulb is squeezed rapidly, the bag can be filled in a very short time. If a rubber bulb is not suitable for the vapors of interest, some other means must be used to fill the bag. As for all other special sampling techniques, instructions can be obtained from the Director of Environmental Health - Pittsburgh.

INSTRUMENT LIMITATIONS

Every instrument has certain limitations which must be recognized. A number of these have already been discussed, and it is very important that they be kept in mind at all times. Otherwise, serious errors can result, rendering the tests meaningless or misleading. Following is a brief summary of limitations common to many instruments, but it must be emphasized that any given instrument may not be susceptible to any particular error:

1. All instruments are limited in specificity of response to the contaminant they are supposed to measure. Interferences may cause false readings and, as pointed out earlier, care must be taken to identify (and, if possible, compensate for) these interferences.
2. Any instrument is suitable for only a given range of contaminant concentration. This means that at certain very low levels, the instrument will not respond while, at very high levels, the reading may be grossly inaccurate or even meaningless. As discussed earlier, combustible gas indicators can even register zero in the presence of very high concentrations of vapors or gases.
3. Every instrument is likely to have a slight error, and the magnitude of this error, if it exists, must be known. It is meaningless, for example, to record an instrument reading as 51.3 ppm when in fact there is a known instrument error of $\pm 5\%$. It is also meaningless to report the average of several readings by a number which cannot be read on the instrument itself.

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4. Every instrument which requires that air be passed through it, must be operated at a specific flow rate, or within a certain range of flow. Failure to sample at the correct flow rate can produce inaccurate or meaningless results.
5. A number of limitations are imposed by the construction of the instrument and its operating parts, including such factors as fully charged or new dry cell batteries, replacement of drying agents or other chemicals and, of course, how well the moving or consumable parts such as filaments have been maintained. Most instrument failures from these causes can be prevented by routine care and maintenance, and by periodic calibrations as described in Chapter X.
6. *CAUTION! Most motors are NOT explosion-proof.* A battery-operated or electrically-driven instrument should NEVER be used in a potentially flammable or potentially explosive atmosphere, unless it is specifically designed and approved for such use.

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Chapter X
Calibration

Chapter X

CALIBRATION AND MAINTENANCE OF AIR SAMPLING INSTRUMENTS

The exposure of workers to potential health hazards in the working environment can be properly evaluated only by qualitative and quantitative measurements. The validity of such measurements depends upon the accuracy of the sampling and upon the skill and experience of the user. It would be unscientific, and possibly dangerous, to base hazard evaluation on measurements taken with unreliable instruments or by inexperienced persons. It is essential that each sampling device be accurately calibrated and properly maintained to insure its precision and its continued availability for use.

Calibration of instrument response has been discussed in connection with sampling gases and vapors, and sampling particulates. This chapter deals with calibration of air flow or sampling rate, equipment performance and maintenance, and trouble-shooting procedures for identifying and correcting equipment malfunctions. In addition, information is provided on the care and maintenance of batteries, Monitaire pumps, and the sampling instruments listed in Figures 8.6 and 9.1.

Errors in sampling rate can materially affect the performance of a testing instrument. Since gas volumes or flow rates can be accurately measured, calibration procedures should be developed, and used regularly, to eliminate errors in the determination of the volume of the sample obtained with any sampling instrument. Likewise, a good maintenance program will insure that the equipment operates without fail at the calibrated flow rate during any sampling period.

Air Flow Calibration

Air volume or flow calibration is defined as the determination, within given limits, of the true value of the air flow scale reading on the sampling device. On instruments approved for collecting air samples in USS, this flow indicator is usually an orifice meter or a rotameter.

A specialized application of the orifice meter is the limiting or critical orifice. When the pressure drop across the orifice is greater than the critical pressure, the flow rate through the orifice is constant. These units are best adapted for use with collection devices with fixed or constant pressure drops, e.g., Standard Impinger, Universal Pump, and Indicating Tube Holders.

The rotameter or variable area meter is perhaps the most popular type of flow indicator, and is used in such sampling instruments as the MSA Monitaire. The rotameter consists of a tapered tube, mounted vertically with the small end down, through which air flows from the bottom to the top. An obstruction, called a float, creates a variable ring orifice or annulus between its outer surface and the inner wall of the tube. The float rises to the level at which the upward force of the air balances the weight of the float. Thus, the flow rate determines the position of the float in the tube. While there is some question as to where the float level should be read, the general rule is that its highest-widest point should be used (Figure 10.1).

Orifices and rotameters used as flow indicators should be calibrated under the same conditions of pressure, temperature, and density as those in which they are to be used, to avoid errors in determining the sample volume due to changes in these conditions. Care should also be taken to clean the float and tapered tube periodically since contamination may accumulate on them.

The frequency of calibration depends upon the use, care, and handling of the instrument. All sampling instruments should be calibrated after they are received from the manufacturers and before they are used in the field. They should also be calibrated following repair or replacement of any element, after mishandling, or in case of inability to zero or otherwise properly regulate the flow indicator during sampling. Generally, the manufacturer's instructions should be followed regarding volume or air flow rates to be used. With routine operation, instruments should be calibrated periodically, as discussed later. A log or schedule should be maintained for each instrument and should include date, calibration, and servicing information (Figure 10.2).

Before establishing air flow calibration procedures for any instrument, it is necessary for the user to:

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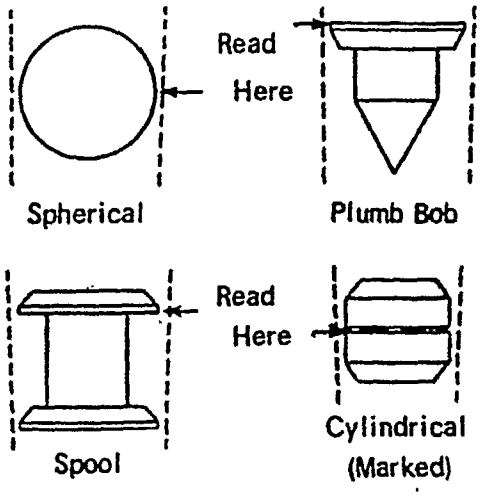


Figure 10.1

1. Understand the operation of the instrument by familiarizing oneself with the manufacturer's operation and calibration instructions;
2. Understand how the instrument is to be used;
3. Know what calibration procedures are appropriate and understand how they should be performed; and
4. Be familiar with the gas laws and necessary calculations (Chapters III and IX).

Since this Manual cannot deal with the calibration equipment and procedures for all air sampling devices, discussion will be confined to the equipment and procedures applicable to USS-approved air sampling instruments.

Calibration Equipment

Approved air sampling instruments are calibrated with volume measuring devices in which the volume under consideration is measured by a direct physical method independent of the air or gas involved, such as the physical dimensions of the containing vessel.

For instruments which sample at a low flow rate (milliliters per minute) or which require a small air volume, a burette can be used to make a bubble meter for calibration purposes (Figure 10.3). Usually a burette with a capacity of 100 milliliters is adequate. A solution of detergent and water is used to form a bubble and a stopwatch is used to time the bubble's movement through a given length of the burette.

Instruments which sample at moderate flow rates are calibrated with either a wet test meter or a dry gas meter (Figure 10.4). A wet test meter consists of a partitioned drum half submerged in a liquid (usually water) with openings at the center and periphery of each radial chamber. Air or gas is drawn through the instrument being tested, enters the drum at the center, and flows into an individual compartment. This causes the compartment to rise and the drum to rotate, which is

A TYPICAL LOG OR SCHEDULE FOR EQUIPMENT

SAMPLER (Mfgr.)	Repairs		CALIBRATION – AIR FLOW											
	Date	Type	Date	Out	In	Date	Out	In	Date	Out	In	Date	In	Out
MODEL														
SERIAL OR COMPANY NUMBER														
DATE OF PURCHASE														
REMARKS														

Figure 10.2

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BUBBLE METER FOR CALIBRATION

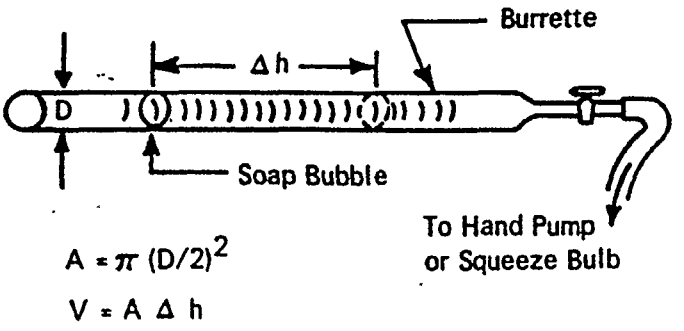


Figure 10.3

indicated on a dial on the face of the meter. Since liquid is being displaced by air, the volume measured depends upon the height of the fluid in the meter. A sight gauge for determining fluid height is provided, along with a gas pressure gauge and a thermometer. A bubble gauge and two screws in the base are used to keep the meter in a level position. There are errors inherent with the use of wet test meters. Since the drum and other moving parts are subject to corrosion, only distilled water should be used, and it should be changed at least every three months. The meter is accurate to within ±1% when new, and it should be recalibrated by the manufacturer if it has been grossly misused.

A dry gas meter, similar to a domestic gas meter, consists of two bags connected by mechanical valves and a counting device. As the air or gas fills one bag, it mechanically empties the other. Any such device has the disadvantages of mechanical drag, pressure drop, and leakage. The user should follow the manufacturer's instructions.

WET TEST AND DRY GAS METERS

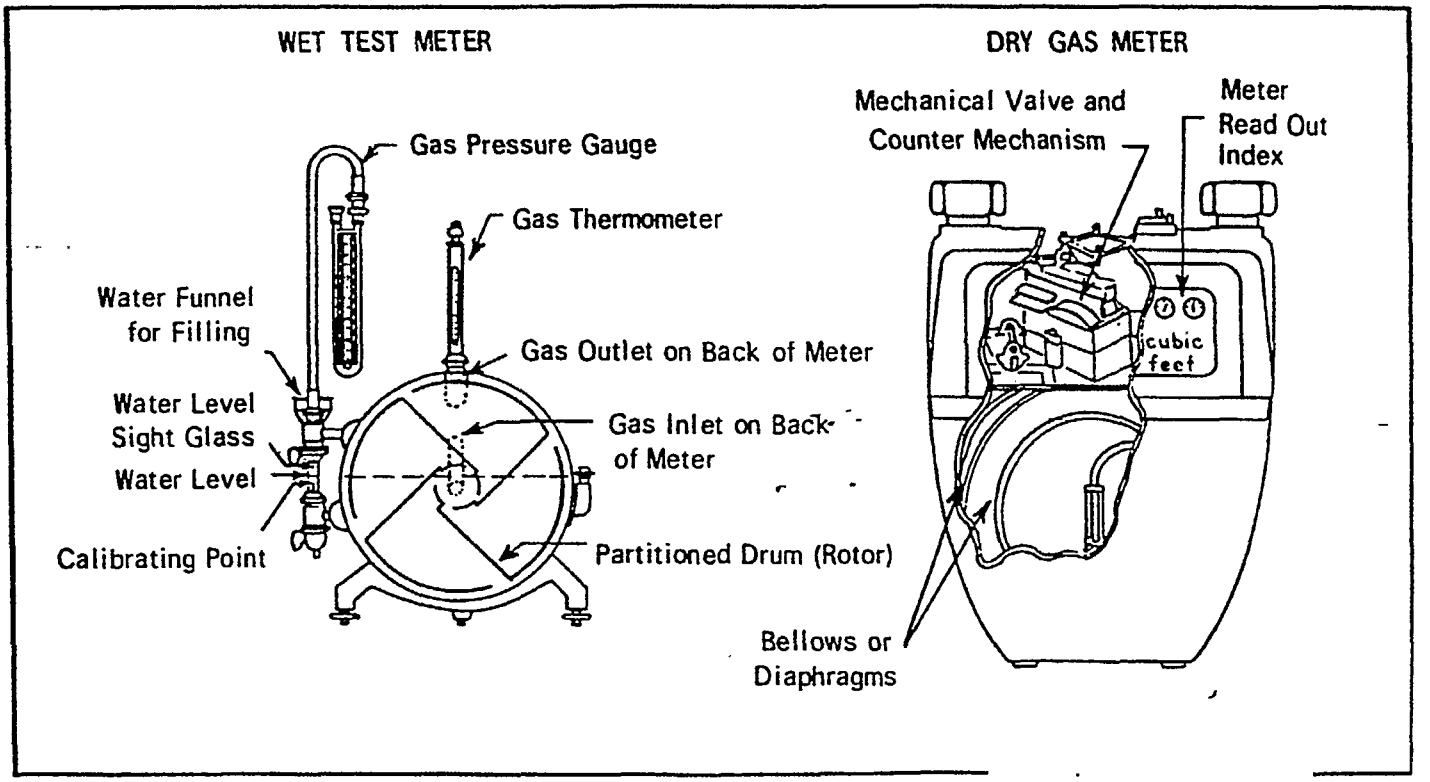


Figure 10.4

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Procedure for Calibrating MSA Type S Monitaire for Filters and Bubblers

Both wet and dry gas meters come in a variety of sizes and should be selected for the flow rate range of the sampling systems to be calibrated. Both types should be recalibrated periodically; generally, the manufacturer will provide this service.

The MSA Monitaire is a miniature battery-operated device which aspirates air through a collector, at a flow rate which is metered through a small rotameter. This unit may be worn by an individual for an 8-hour shift, or it may be mounted in an appropriate location near an exposed worker. With the bypass valve (small knurled knob) completely closed, the indicated air flow rate range of the scale on the rotameter is 0-to-10 cfh (0-to-0.167 cfm). However, the actual (true) flow rate through the sampling or collecting device must be determined by calibration. The preferred instruments for such calibration are a wet or dry test meter with a capacity of 0.1 cubic feet or 3 liters per revolution. The outlet of the test meter is connected to the inlet of the sampling system and the inlet of the meter is open to atmosphere. A typical calibration setup is shown in Figure 10.5, and illustrates the calibration system for respirable dust sampling.

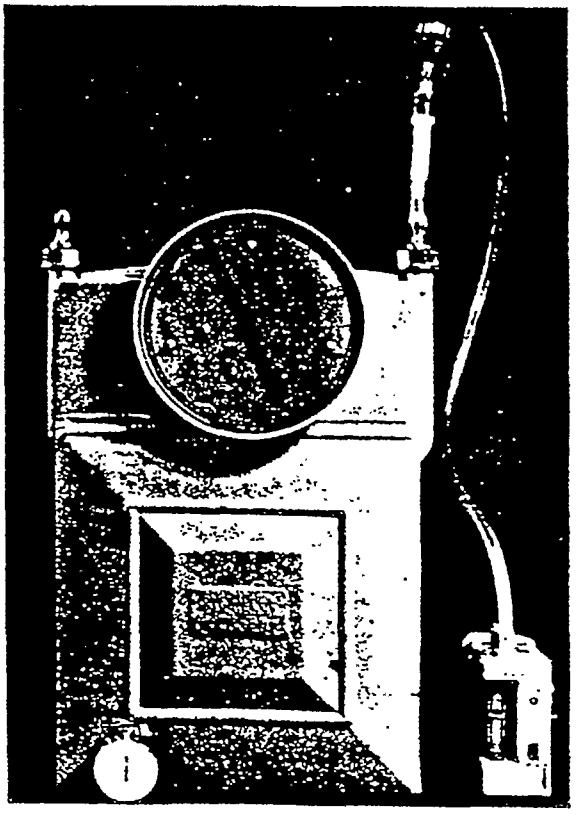


Figure 10.5

The inlet of a 37 mm filter holder is connected to the outlet of a 10-mm-diameter nylon cyclone with a short piece of tubing. The inlet of the cyclone is carefully sealed

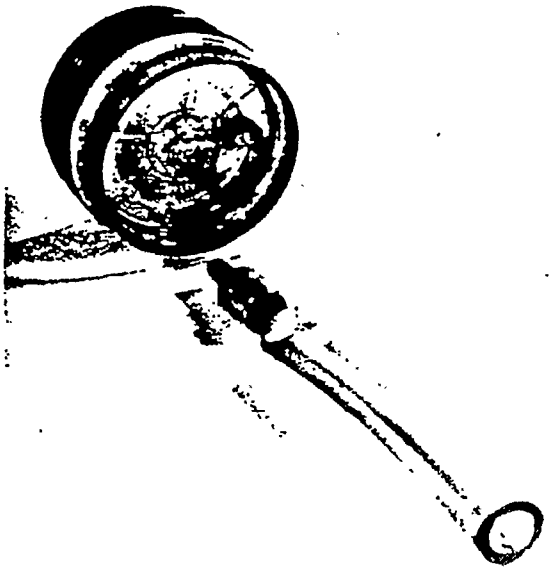


Figure 10.6

with vinyl electrical tape. The end of the cyclone, also shown in Figure 10.5, is connected by tubing to the outlet port of the test meter. The outlet of the filter holder is then attached by tubing to the pump inlet. A special metal adapter, or Luer fitting (Figure 10.6) permits attachment of tubing to one end while the other end is inserted into the filter holder. An alternate arrangement involves the use of the MSA cyclone-filter holder assembly. As before, tubing connects the cyclone to the outlet of the test meter, and the filter outlet to the pump.

The MSA Monitaire draws air through the test meter and collecting device when activated by a switch. The flow rate through the test meter is determined by using a stopwatch to determine the number of revolutions per unit of time indicated by the dial on the front of the meter. The flow rate, calculated from the meter reading and the measured time, is the actual (true) flow rate

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at the particular rotameter setting (position of the float in the tapered measuring tube). With the bypass valve (small knurled knob) completely closed, the large knurled knob on top of the instrument permits adjustment of air flow through the system. For respirable dust collection, a flow rate of 1.8 liters per minute must be maintained over the sampling period. The height of the center of the float, indicating 1.8 liters per minute, may be marked (with 1/32" Chart-Pak or similar adhesive tape) on the outside surface of the rotameter marked 0-10.

With a dry test meter rated at 0.1 cubic foot per revolution, one revolution of the dial in 94 seconds calculates to 1.8 liters per minute. For a wet test meter rated at 3 liters per revolution, one revolution of the dial in 100 seconds gives 1.8 liters per minute.

Each MSA Monitaire should be calibrated after a maximum of 40 hours of operations, and after any repairs to the pump, severe mishandling in the field, or any change in filter media. A log should be kept for each instrument, listing calibration, repairs, battery changes, etc.

The calibration for a "total particulate" sampling system which collects both respirable and nonrespirable particles on a filter is similar to that shown in Figure 10.5, except that the 10 mm cyclone is removed. For calibration, a 37 mm filter in a holder is used with the MSA Monitaire and test meter. The holder with filter is again connected by adapters (Luer fittings) and tubing to the outlet of the test meter and the inlet of the pump. The rotameter has markings from 0 to 10. The procedure involves calibration of the rotameter at the 10, 9, 8, and 7 markings. The actual (true) flow rate is calculated by dividing the volume of air (number of revolutions) by the elapsed time for each setting. The actual flow rate will be in liters per minute or cubic feet per minute, depending upon the scale of the test meter. A graph of actual flow rate (lpm or cfm) can then be plotted against rotameter markings (10, 9, 8, 7). Again, total particulate samplers should be calibrated after a maximum of 40 hours of operation, and after repairs, mishandling, or changes in filter types.

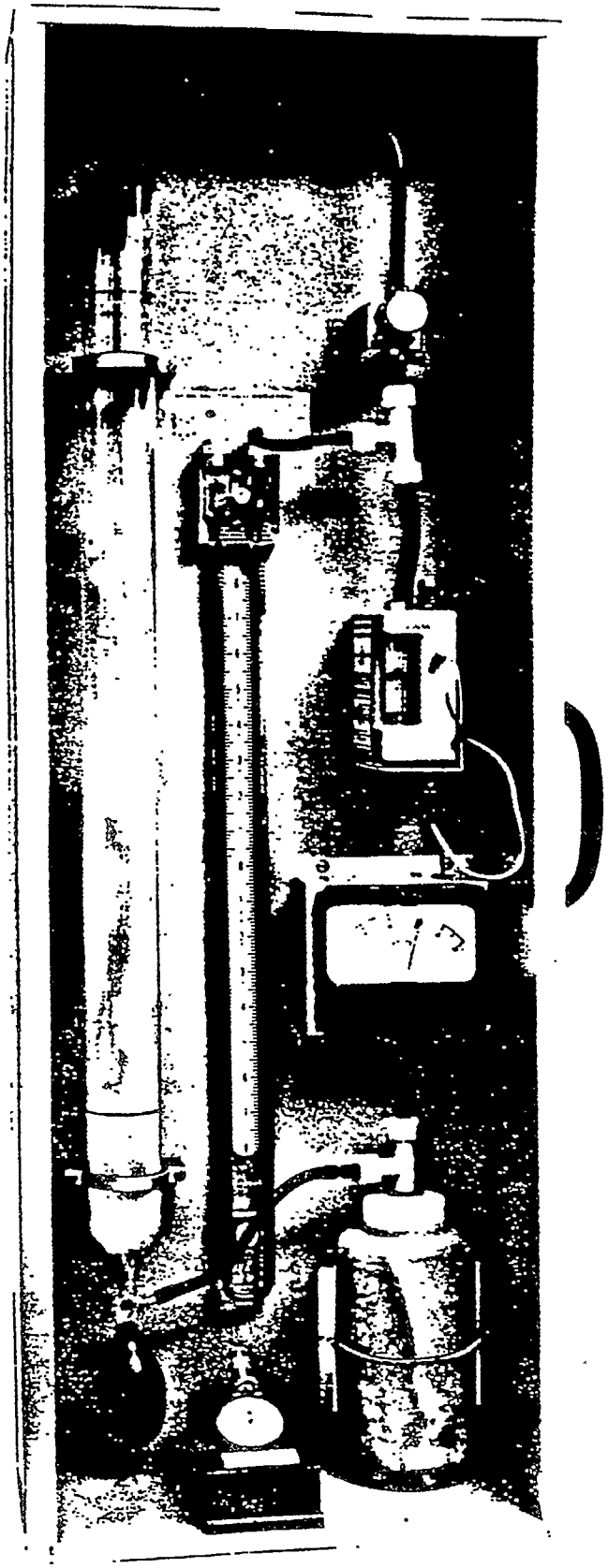
The system used to calibrate the MSA Monitaire with a fritted glass bubbler is also similar to that shown in Figure 10.5 except that the cyclone and filter are replaced with a bubbler. The bubbler inlet should be connected to the test meter and the bubbler outlet to the pump. Calibration should follow the procedures as described for the total particulate sampling system; i.e., the actual flow rate should be calibrated for rotameter settings of 10, 9, 8, and 7 with each collection media (solution) to be used. Great care must be taken in cleaning the rotameter and pump after calibration and sampling, since moisture, or chemicals used as collection media, can corrode or otherwise damage the pump unit. Maintenance, cleaning, and calibration should be performed after each investigation.

Between calibrations of actual flow rates with a wet or dry test meter, an MSA bubble calibrator (Figure 10.7) can be used to monitor the flow rate of an MSA Monitaire for respirable dust sampling. The calibration unit consists of a 1-liter glass tube, a "soap" solution with a saturator, a stopwatch, and a nonbreakable U-tube with a ruled scale. Detailed operating instructions are supplied when the equipment is purchased.

In actual operation, the pump is attached to the unit and operated against a fixed resistance of 2 inches of water gauge. This approximates the pressure drop across the 10 mm cyclone and filter medium at 1.8 liters per minute flow, which is the prescribed air flow rate for the respirable dust sampling system. The resistance is applied by a valve located between the pump and the bubble chamber. Detergent ("soap") solution is introduced into the base of the glass tube with an aspirator bulb and the pump draws the bubble up through the tube by means of a special valve. The bubble is timed as it passes two etched lines, one at the bottom and the other at the top of the tube. The time required for the pump to move one liter of air is read by stopwatch and compared to a chart to obtain the actual flow rate. The position of the float at the 1.8 liter per minute flow rate can be marked on the outside of the rotameter.

This bubble calibrator can be adapted to check air flow rates for other sampling systems using MSA Monitaire. The pressure drop (resistance) across the collection device such as a bubbler is measured for a desired flow rate with a simple U-tube containing water. The resistance in inches of water is then applied to the MSA bubble unit and the air flow test proceeds as described above.

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MSA Bubble Calibrator

Figure 10.7

Procedure for Calibrating MSA Monitaire with Indicating Tubes

The MSA battery-powered pump with 0-2 range rotameter is available for use with a single or multiple tube holder. As described in Chapter IX, with the tube(s) inserted in the holder and connected to the pump inlet, the bypass valve is opened by turning the small knurled knob counterclockwise exactly one turn. The flow regulating valve (large knurled knob) is then adjusted to raise the float in the rotameter to the 1 mark. Instead of calibrating the rotameter, the established flow rate of each tube should be checked using a burette.

This is done by making a solution of synthetic detergent (such as Joy) and water, allowing the resultant foam to subside, and then pouring the solution into a 100 cc burette, taking care not to raise additional foam. The burette is then emptied (into a beaker) in such a way that its inside walls retain a thin film of "soapy" water. The open end of the burette is placed momentarily in contact with the surface of the detergent solution (in the beaker) so that a film adheres to the mouth of the burette. When suction is applied, the resulting bubble is pulled up through the length of the burette.

The calibration setup for a single tube holder is shown in Figure 10.8. The sealed ends of the tube are broken and one end is inserted through the grommet into the indicating tube holder. The holder in turn is connected with tubing to the pump inlet, the pump is turned on and the float is adjusted, as described above, to the indicated flow rate. A piece of tubing is then used to connect the open end of the indicating tube in the holder with the tapered end of the burette. The petcock of the burette is opened and the rise of the bubble through the burette is timed with a stopwatch. Chart-Pak tape may be used to mark the burette for the respective volumes. The prescribed air flow rates for various types of indicating tubes are listed in Figure 10.9.

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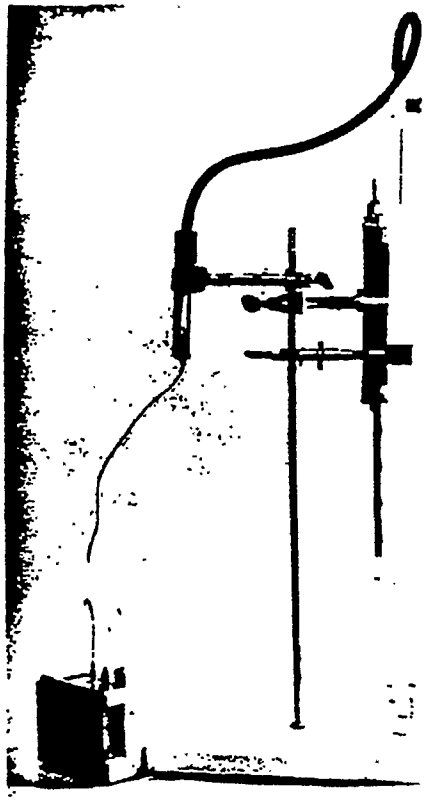


Figure 10.8

If the prescribed flow rate is not attained, the bypass valve should be readjusted and the test repeated until the desired flow is achieved. During the calibration, the float in the rotameter should remain fixed at the prescribed mark of 1. When the recommended flow rate is attained, the screw in the bypass valve should be marked to identify its correct setting for each particular type of tube.

With the multiple tube holder, an open indicating tube must be inserted in each position, and the air flow through each tube determined as with the single tube holder. Indicating tubes may have to be interchanged to achieve correct flow rate, since all orifices may not provide the desired flow for each type of tube. The flow rate for each of the indicating tubes to be used in the multiple tube holder is the same as those listed for single tubes (Figure 10.9).

The bypass valve of the pump should be cleaned frequently, especially when air samples are collected in dusty atmospheres.

Air Flow Rates — MSA Indicating Tubes

Gas or Vapor	Air Flow Rate, cc/min.
Carbon Monoxide, CO	40
Hydrogen Chloride, HC_1	20
Hydrogen Sulfide, H_2S	75
Hydrogen Cyanide, HCN	25
Sulfur Dioxide, SO_2	15

Figure 10.9

Procedure for Calibrating MSA Universal (Hand) Pump

The MSA Universal Pump is a calibrated piston-type pump with variable orifices, which is used with indicating tubes to obtain instantaneous (grab) air samples.

For calibration, the MSA Hand Pump is connected by tubing to the tapered end of a burette (Figure 10.8). The piston is withdrawn and locked in the 100 cc position. The petcock of the burette is opened, the bubble rises through the burette, and a volume of 80 cc is timed with a stopwatch. Marking tape can again be used to aid the observer in timing the bubble as it moves through the burette. If the flow rates for the orifices do not conform to the manufacturer's recommendations (Figure 10.10), the pump should be repaired in accordance with the manufacturer's maintenance instructions.

Air Flow Rate Through MSA Universal Hand Pump Orifices

Orifice No.	Time (Seconds) for 80 cc
1	44-48
2	24-26
3	12-14
4	1-2

Figure 10.10

Equipment Performance

When sampling for air contaminants, there are certain tests, checks, or procedures which should be used before, during, and after sampling, to insure that the equipment is performing satisfactorily. The following are general items which are recommended, as a minimum, to insure satisfactory performance.

Before Sampling

It cannot be emphasized too often that the very first step is to become familiar with the

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operation of the instrument. The best way to do this is to read the manufacturer's operating instructions carefully, and become thoroughly familiar with the principles of operation outlined.

For instruments which have a battery check position, which allows the charge condition of the battery to be read directly on the meter, this is the first test that should be made. If the battery does not come up to the check position, it should be replaced. For instruments which do not have a battery check position, it will be necessary to use a voltmeter to determine if the battery is fully charged (6.8 to 7.2 volts for the MSA Monitaire). If the voltage is lower than that recommended by the manufacturers, the battery should be replaced and the cause for the degradation should be ascertained.

Finally, the instrument should be calibrated for air flow as already discussed. In addition, instruments used for sampling gases and vapors should be calibrated with known concentrations of the contaminants of interest, as explained in Chapter IX.

During Sampling

As detailed in Chapter VIII, care should be taken when placing a sampling unit on a worker, to insure that the pump is fastened to his belt in a position that is comfortable to him. The collection device (filter, filter-cyclone, or tube holder) should be in his breathing zone. For example, when sampling for welding fumes, the filter holder assembly should be inside the welder's helmet. When collecting respirable dust samples, the filter-cyclone assembly must hang in a vertical position to prevent the possibility of sample contamination.

The rotameter on the MSA Monitaire should be checked after the first 30 minutes of operation. There is an initial excess charge on a fully charged battery which is usually dissipated during the first 30-45 minutes of operation. Unless the rotameter is reset at the end of this period, the pump will sample at a low flow rate because of the lower battery voltage.

Pump units should be checked every hour or so to insure continued operation at the proper flow rate. The MSA Monitaire, for instance, can be turned off inadvertently if it is placed in the wrong position, such as at the front of a worker who normally sits while operating his equipment. A low air flow may be caused by a pinched hose, by partial clogging of the system, by a weak battery, by excessive loading of the collection device, and/or by internal pump problems.

Potential leaks in the sampling system are a problem that requires constant attention. Separation of the cyclone and filter in a gravimetric sampler can lead to sample contamination. Separation of a connecting hose, in which case dust would be pulled directly into the sampling pump, can lead to operational problems. Pinching of the connecting hose can result in low or no flow. If any condition which affects air flow is not corrected immediately, the sample will not be indicative of the worker's actual exposure and, as emphasized earlier, errors in the sampling rate can result in erroneous evaluation of the potential hazard.

At frequent intervals, other battery-operated equipment, such as combustible gas indicators, should be given electrical checks and should be re-zeroed in uncontaminated air or with an activated charcoal filter placed on the inlet.

After Use

When sampling has been completed, the collection device for particulates, or the indirect reading device for gases and vapors, should be carefully separated from the sampling system to prevent breakage, spillage, or contamination. Samples requiring chemical analysis should be sealed and prepared for shipment to the laboratory. Indicating tubes can be prepared for measuring length of stain, after which a determination of atmospheric concentration can be made.

All equipment should be cleaned, recalibrated, and the batteries recharged. Any equipment malfunction noted during the survey should be repaired at this time. For example, if the pump failed to operate for a full turn, it should be repaired immediately.

Routine maintenance is essential to insure that the sampling instruments are in good condition. Some individuals may believe that equipment which "checks out" before use can be expected to perform satisfactorily throughout a survey. This is not necessarily true. Consider, for example, a respirable dust sampler which was properly calibrated before field use, but due to poor maintenance, failed to maintain the correct flow rate for the

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desired sampling period.

A respirable dust sample collected by this sampler would not be indicative of the worker's actual exposure because the efficiency of the cyclone elutriator would have been affected by the incorrect flow rate. The sample would have to be discarded and the employee resampled on another day. This is a waste of time and money. Proper care and maintenance of equipment minimize such problems.

The manufacturer's instructions generally contain a section on maintenance. The directions are usually explicit, and sufficient for minor instrument repair. For such repairs, it is necessary to stock an assortment of spare parts. Items which have a limited shelf life, such as batteries, should not be stocked in abundance. But it is advisable to stock an ample supply of parts which do not deteriorate, such as lamp bulbs for chargers, "O" rings for couplers, flapper valves for pumps, etc.

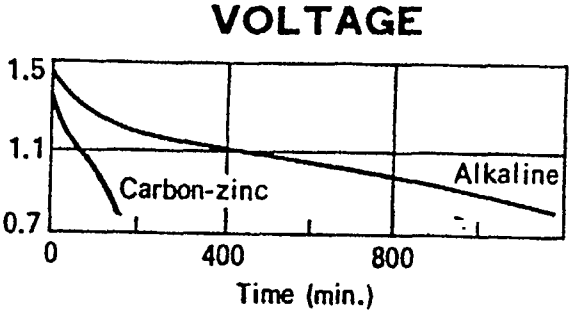
Instruments requiring major repairs should be returned to the manufacturer with a letter outlining the equipment malfunction and requesting an estimate of cost of repair. In some instances, it may be just as cheap to purchase a new instrument as to repair the old. Remember that any instrument that has been repaired, whether by the manufacturer or locally, should be recalibrated.

It is not the intent of this Chapter to present a maintenance checklist for every piece of equipment itemized in Figures 8.6 and 9.1 but the following guides should be helpful.

Batteries

Batteries used in USS-approved sampling equipment are of two basic types: rechargeable and non-rechargeable. Instruments such as MSA Model 40 Explosimeters, Sound Level Meters, Sound Level Meter Calibrators, and Noise Dosimeters use non-rechargeable batteries, while J&W Model SS-P Explosimeters, MSA Type S Monitaire pumps, and Model D Carbon Monoxide indicator use rechargeable batteries.

Non-rechargeable batteries are either carbon-zinc or alkaline-manganese cells. Alkaline-manganese cells outperform conventional carbon-zinc cells, as shown by the discharge characteristics in Figure 10.11.



Comparison of Discharge Characteristics of Alkaline–Manganese and Carbon–Zinc D-Size Cells for 500 MA Continuous Drain at 70° F.

Figure 10.11

Their higher cost compared to carbon-zinc cells is usually offset by their longer life. Most sampling instruments which use non-rechargeable batteries have a battery test (BAT) position on the meter dial which indicates battery condition. If the battery fails this check, it should be replaced with a new battery of the same rating.

Nickel-cadmium batteries such as those used in MSA Type S Monitaire pumps can be recharged many times, have a relatively constant potential during discharge (Figure 10.11), and have excellent charge retention properties. They are ideal for operating DC motor driven pumps provided, of course, they are properly maintained. Based on several thousand hours of sampling experience, the following procedures have proved to be most helpful in insuring maximum useful life in these rechargeable batteries.

1. Charge immediately after use with the selector switch on high. After intermittent use (less than 6 hours), 2 hours of charging time is required for each hour of operation. For continuous use (6 to 8 hours), overnight charging (14 to 16 hours) is required. A fully charged battery should indicate in excess of 6.8 volts.
2. After a battery has been fully charged, it should be kept on a trickle charge (selector switch on low) until the pump is used again. The recommended trickle charge rate is 8 to 10 milliamps per hour.
3. A pump which is stored and maintained on trickle charge should be operated for 6 to 8 hours each week. The battery should then

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be recharged in accordance with the above procedures. This will insure that the battery will accept and keep a full charge, i.e., 2000 milliamps at 6.8 volts DC. Unless nickel-cadmium batteries are either maintained at full charge, or are completely discharged, their charging characteristics and capacity to accept a full charge will deteriorate.

4. Batteries which fail to provide 8 hours of continuous operation can be rejuvenated, providing their voltage is not below 1.1 volts per cell, or a total of 5.5 volts (Figure 10.11). To accomplish this, the battery must be discharged and recharged repeatedly until it has the capacity to accept a full charge, i.e., above 6.8 volts. If the voltage is below 5.5 volts, the battery should be discarded.

(dipole plug – Figure 10.12A). One end of this plug is inserted in the charging jack of the instrument and the other end is connected to the appropriate terminals of a voltmeter. The Monitaire should have 6.8 to 7.2 volts, and the Model D CO Indicator should have 7.5 volts.

Chargers

The battery chargers for the MSA Monitaire and the MSA Model D CO Indicator are shown in Figures 7.2 and 7.6; the charger for the J&W Combustible Gas Indicator Model SS-P is incorporated in the instrument. All of these have indicator lamps (bulbs) which light when the battery is being charged. The MSA Type S Monitaire charger has two lamps – red to indicate high charge and amber to indicate low charge. The MSA Model D CO instrument

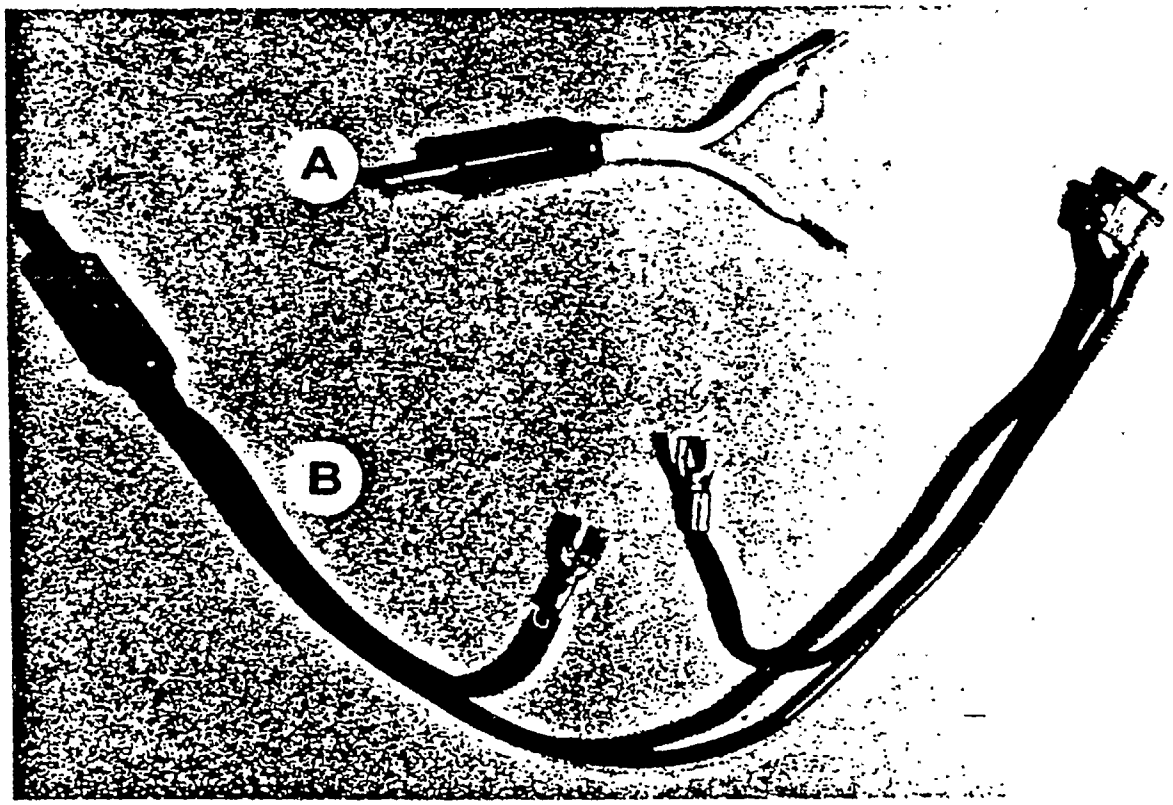


Figure 10.12

5. Always check battery voltage before use. The J&W Combustible Gas Indicator has a Min Voltage Test position on the meter. The MSA Type Monitaire Pump and the Model D Carbon Monoxide Indicator require a voltmeter and a special adapter has a lamp to indicate the high charge rate. However, for low charge, the switch must be placed in the high position until the lamp lights indicating that a positive electrical connection has been made, after which the switch is placed on low for trickle charging.

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The most common problems encountered with chargers involve indicating lamps and fuses. Indicator lamps are wired in series and must be lighted before the charger can operate. Therefore, burned-out bulbs must be replaced immediately. Burned-out fuses, of course, must also be replaced if the charger is to function. The replacement of lamps and fuses is discussed in the manufacturer's instructions.

Occasionally, a charger may develop an electric short due to a pinched wire, or may burn out a diode. Repairs of this kind should be done in an electrical shop by someone familiar with basic electronic circuits.

The charging rate for the MSA charger (Type S Monitaire) is 200 MA with the selector switch on high, and 10 MA with the selector switch on low. The output of the charger can be checked with a special adapter (Figure 10.12B). The male plug of the adapter is inserted in the charging jack of the instrument and the male plug of the charger is inserted in the female plug of the adapter. To complete the circuit, the open connections of the adapter are connected to the appropriate terminals of an ammeter. The milliamp output of both the high and low charging circuits can then be read on the ammeter.

MAINTENANCE REQUIREMENTS

Monitaire Pump

Of all the equipment listed in Figures 8.6 and 9.1, the MSA Type S Monitaire will probably require the most maintenance. At the end of each sampling day, these pumps must be inspected, tested, and repaired if malfunctions are noted. The exterior of the Monitaire pump should be inspected for physical damage, and for loose or missing parts. For example, the belt clip may be loose, the on-off switch may be stuck because the dust cover is improperly positioned, a rotameter may be dirty or have been jarred loose, etc. Such problems should be corrected immediately. In addition, these pumps must be maintained (cleaned, repaired as necessary, and calibrated) on a routine basis, usually after each 40 hours of use. Such routine maintenance should, as a minimum, include:

1. Inspection, cleaning, and resealing the rotameter. The float and tapered tube should be thoroughly cleaned of accumulated dirt and/or condensation. The end seals (rubber gaskets) should be inspected for deterioration or wear, and replaced as necessary.
2. Clean the flow rate adjustment valve and inspect the "O" ring for the bypass valve. The orifices for both valves should be cleaned.
3. Open the pump and clean the interior. Inspect the wiring, hose connections, and motor-pump unit. The bearings should be cleaned and relubricated.
4. Remove the pump diaphragm and clean the interior of the pump hosing. The inlet and discharge flapper valves should be inspected and replaced as necessary (a special tool is needed to remove and replace the flapper valve retaining ring). Replace the pump diaphragm and tighten securely. Check the inlet and outlet valves by operating the pump. If the valves are clean and properly installed, the motor will stall if either the inlet or outlet valve of the pump is closed.
5. Reassemble leaving the battery cover off, turn the pump on, and check for leaks. Leakage may be due to a loosely positioned rotameter, an open bypass adjustment valve, improperly seated inlet or outlet flapper valves, a loose hose connection, etc.
6. Check the battery voltage with a voltmeter and dipole plug adapter as described earlier. Check the current drain on the battery during actual pump operation by placing a milliammeter in series between the battery and the motor. When current requirements exceed 200 milliamps, the cause for the excess current drain should be determined. It may be a dirty motor, a faulty bearing, an unseated bushing, a pinched hose, or some other problem which requires cleaning or repair.
7. Replace the battery pack cover.
8. Calibrate the unit for air flow as described previously.

Sample Holders

Although seemingly simple, holder assemblies for respirable dust sampling, filter holders for total particulate sampling, and single or multiple tube holders for sampling gases and vapors are all subject to leaks and obstructions.

In gravimetric samplers, it is necessary to check the cyclone to make sure the vortex finder (top) is correctly seated and the grid

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pod (bottom) is properly sealed. It is then necessary to check for leaks as discussed in Chapter VIII. Leakage may be due to deteriorated O rings in the coupler or holder assembly, a loose assembly, etc.

Filter holders used for total particulates should also be checked to make sure that the filter is properly seated against the supporting screen or pad, and that the support ring over the filter is also firmly seated. The outlet of the holder should be checked for cracks to make sure that the Luer makes a tight seal.

The orifices and/or screens on single or multiple tube holders frequently become clogged with particles. They must be clean and kept free of obstructions if required air flow rates are to be maintained.

MSA Universal Sampling Pump

There are certain pump performance tests which should be made before actual air flow calibration with detector tubes. These tests are recommended by the manufacturers to insure against leakage between the piston and cylinder or at the inlet of the rotating head, and to indicate whether any of the four flow regulating orifices are clogged. The tests are outlined in the instructions supplied by the manufacturer and should be followed.

The main causes for leakage or clogging are usually either a cracked (rubber) tube holder, an improperly seated tube holder bushing, or a filter disc clogged with glass particles because of uneven detector tube breakage. The parts in question are shown in Figure 10.13.

MSA Model D Carbon Monoxide Indicator

A photograph of the MSA Model D CO Indicator, with bottom cover subpanel removed, is shown in Figure 10.14. The battery pack, hopcalite (detector) cell, drier canisters, and rotameter can be easily identified.

The manufacturer's instructions for maintenance of this instrument are explicit and should be followed exactly. Instructions are given for replacing the drier, removing water vapor from a water-contaminated hopcalite cell, stabilizing the indicating cell, etc. Procedures are also outlined for checking the flow system tightness to insure that proper air flow is maintained through the cell. A low flow could indicate, among other things, a low battery charge (this instrument does not have a battery check position), a blocked sample probe, a dirty cotton filter, or a stuck sample valve.

Oxygen Indicators

The MSA and BioMarine Oxygen Indicators are basically trouble-free. They automatically compensate for temperatures between 32° and 104°F, and are insensitive to carbon

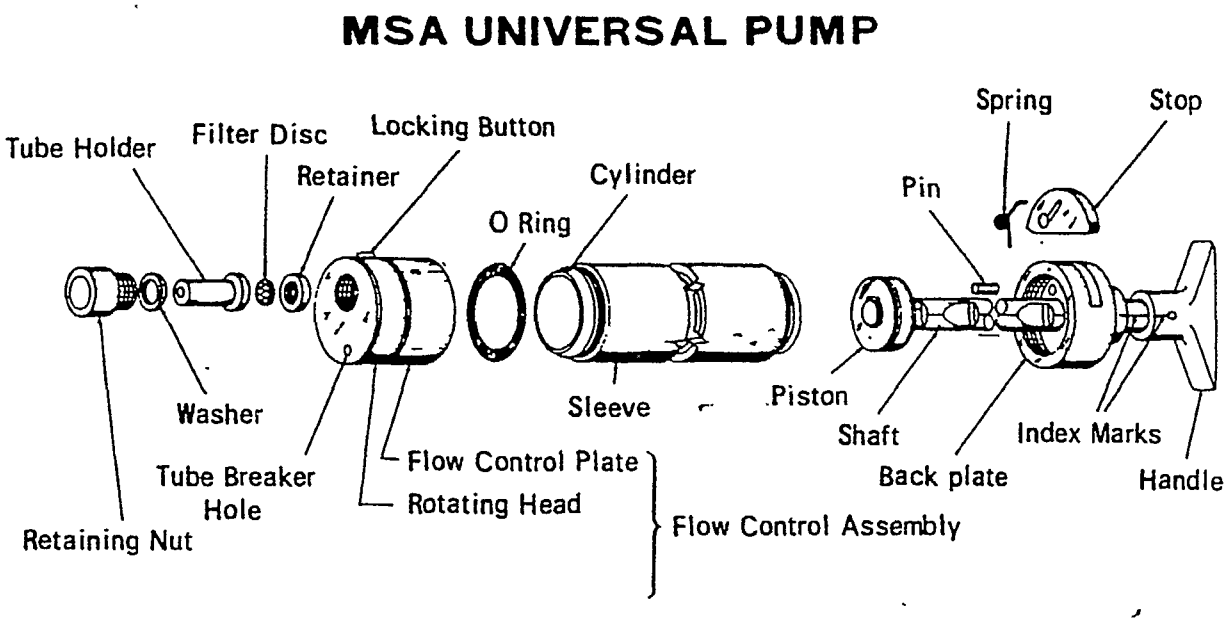


Figure 10.13

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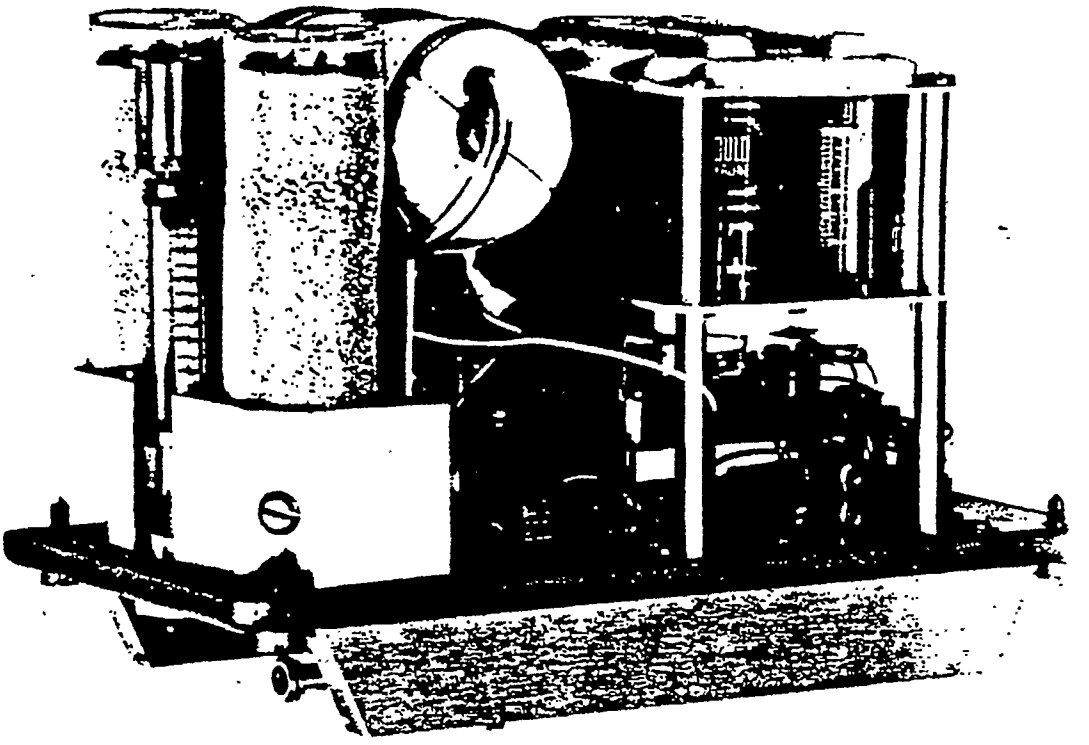


Figure 10.14

dioxide and humidity. The only two problems usually encountered with this instrument are an electrical short between the sensing head and the instrument, and failure of the oxygen cell. A short can be traced through electrical continuity checks, while a bad oxygen cell will require replacement.

The Bacharach Fyrite Oxygen Indicator is also very rugged and should require little maintenance. However, the device should not be stored, for long periods, while filled with absorbing solution. This solution is corrosive and will cause the gaskets and diaphragm to deteriorate. The refill kit contains a new diaphragm and gaskets which should be inserted each time the absorbing solution is changed. The filtering material in the line should be kept clean. When changing the absorbing solution (reagent) as specified in the manufacturer's instructions, care should be taken to:

1. Avoid spillage since this is a corrosive chemical mixture;
2. Clean the analyzer with soap and water, and rinse thoroughly before refilling; and
3. Replace the gaskets and diaphragm to be sure that a positive seal is provided for the refill.

Combustible Gas Indicator

Most maintenance for the J&W and MSA Combustible Gas Indicators is minimal, e.g., replacing the D cells on the MSA Model 40 or recharging the nickel-cadmium battery on the J&W Model SS-P. The electrical power for these instruments is provided by batteries, and both have a battery check position. This is indicated on the MSA Model 40 as "Check", and on the J&W Model SS-P as "Minimum Voltage". If the batteries on the Model 40 fail this test, all cells should be replaced. As mentioned earlier, the battery on the J&W Model SS-P is rechargeable and should have a full charge before use. When not in use, this instrument should be stored with the battery being charged. If the battery cannot be recharged, it should be replaced.

After the batteries have been checked and the instrument properly zeroed, expose the instrument to a combustible solvent mixture such as lighter fluid, paint thinner, etc., to be sure it is operating. This check will not

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indicate whether the instrument is accurate, however, and calibration with known gas or vapor concentrations is required to assure accurate measurements.

More extensive maintenance is required if the instrument cannot be zeroed. The following steps should be helpful in isolating the cause(s) of such malfunctions.

1. *Air Flow* – It should be remembered that these instruments, like detector tubes, are dependent on the rate of air flow through the detector cell. The rate of flow recommended for the J&W Model SS-P is 0.05 cubic feet per minute (1.4 liters per minute) while that for the MSA Model 40 is 0.03 to 0.05 cfm (0.8 to 1.4 lpm). Low flow rates may indicate that the flow regulating orifice, flame arrester, or cotton filter is clogged; that there is leakage in the flow system; that the rubber bulb aspirator on the MSA Model 40 is cracked; that there is a pump malfunction in the Model SS-P, etc.
2. *Detector Cells* – After several hours of operation, particularly in areas with high gas or vapor concentrations, the detector cell may burn out. It may also burn out or become coated when used in areas containing leaded gasoline, high molecular alcohols, acid gases, etc. In any case, the cell must be replaced and, while it is not absolutely necessary, it is highly advisable to replace the reference cell at the same time. In other words, replace the cells in pairs.
3. *Electrical Malfunctions* – If the above checks fail to rectify a zero drift, it is necessary to check for loose battery connections, examine for poorly soldered electrical connections, or loose terminals, etc.

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Chapter XI
Noise

Chapter XI

NOISE AND ITS MEASUREMENT

Noise is generally defined as "unwanted sound". This very general definition is due to the variety of reasons why sound may be unwanted, and thus becomes noise. Industry interest in noise may be grouped into three areas of concern, each of which involves some differences in measurement technique and data evaluation. These major areas of concern are as follows: (1) annoyance of workers due principally to their inability to converse in a normal voice, (2) community response to interference with sleep and leisure activities and (3) hearing loss among workers exposed to high noise levels. However, the main noise measurement effort by plant personnel will be directed to determining the status of the work environment with respect to the noise standards promulgated under the Federal Occupational Safety and Health Act. The objective of this standard is to prevent hearing loss among workers exposed to noise. It is a basic requirement in noise measurement work that the person so engaged have some elementary knowledge of the physics of sound.

PHYSICS OF SOUND

Sound is produced by any vibrating body regardless of its size or shape. Sound is mechanical energy in the form of pressure waves. Any vibrating body, whether it be a violin string, a loudspeaker, or a machine sets up in the surrounding air a corresponding series of pressure changes in the form of waves of alternating compressions and rarefications. When these pressure waves strike the ear, they may be heard as sound, depending upon the amplitude of the wave (sound pressure) and how rapidly the source is vibrating (frequency). A physical picture of this phenomena are the waves propagated out from the point at which a stone is dropped into a pond. Wave motion in sound propagation is longitudinal, that is along an axis parallel to the direction of propagation. Sound waves may be reflected, refracted (bent around corners) and undergo interference, such as by acoustic materials.

The quantity normally measured when dealing with noise is "sound pressure". An understanding of this term, together with the meaning of "frequency" and "decibel" is necessary if one is to undertake noise measurements.

Decibel:

The range of sound pressures generally encountered is extremely large. For example, the weakest sound pressure heard by a young person with good hearing, at a frequency of 1,000 cycles per second, is about 0.0002 microbars (μ bar). On the other hand, the highest sound pressure perceived without pain is about 1,000 μ bar (as a reference, one-bar is atmospheric pressure and a μ bar would be one-millionth of atmospheric pressure). Therefore, the scale of sound pressures normally encountered covers a range of 1:1,000,000. This range of more than a million microbars cannot be scaled linearly with a practical instrument, because such a scale might be miles in length in order to obtain the desired accuracy at various pressure levels. In order to cover this extreme range of sound pressures with a reasonable number of scale divisions and to provide a means to obtain the required measurement accuracy at extreme pressure levels, the logarithmic decibel (db) scale was selected. In addition, the hearing mechanism responds to changes in sound pressure in a relative manner, rather than in an absolute way. Therefore, it is obviously more convenient to use a relative scale of sound pressure and such a scale is the decibel scale. By definition, the decibel is a dimensionless unit related to the logarithm of the ratio of a measured quantity to a reference quantity. The decibel (db) is commonly used to describe levels of acoustic energy, power and pressure, as well as hearing thresholds. However, it has no meaning unless a specific reference quantity is specified.

Frequency (Hz)

The frequency of a sound source is the number of vibrations (rapid pressure variations of the surrounding air) indicated as "hertz" (Hz), or cycles per second. In simple terms, when sound waves arrive at the ear at regular intervals, the frequency is the number of waves arriving each second. When the frequency is small, one hears a low-pitch sound and when it is high, one hears a

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high-pitch note. We generally hear sounds between about 20 to 15,000 Hz if the amplitude (pressure) of the wave is of sufficient magnitude. Noise sources in industry do not generally produce a completely regular series of waves, but a complex mixture of many frequencies. However, the most complicated waves can be regarded as being made up of a number of simple waves, each at a different frequency. In industry, equipment noise contains low, intermediate and high frequencies, each of which can have a different amplitude or sound pressure.

Sound Pressure and Sound-Pressure Level

Most sound-measuring instruments are calibrated to provide a reading of root-mean-square (rms) sound pressures on a logarithmic scale in decibels. The reading taken from the instrument is called a sound-pressure level (Lp). The term "level" is used because the pressure measured is at a level about a given pressure reference. For sound measurements in air, 0.0002 microbar (2×10^{-5} N/m^2)* commonly serves as the reference sound pressure. This reference is an arbitrary pressure chosen many years ago because it was thought to approximate the normal threshold of human hearing at 1,000 Hz. The mathematical form of the L_p is written as:

$$L_p = 20 \log \frac{p}{p_o} \text{ dB} \qquad (2)$$

where p is the measured sound pressure, p_o is

* — The newer acoustical term is Newton's (N) per square meter.

Sound pressure in bar	Sound level in dB		Environmental conditions
		140	
1	134		Threshold of pain
mbar		130	
			Pneumatic chipper
		120	
100	114		Loud automobile horn (dist. 1 m)
μbar		110	
		100	
10	94		Inside subway train (New York)
μbar		90	
			Inside motor bus
		80	
1	74		Average traffic on street corner
μbar		70	
			Conversational speech
		60	
0.1	54		Typical business office
μbar		50	
			Living room, suburban area
		40	
0.01	34		Library
μbar		30	
			Bedroom at night
		20	
0.001	14		Broadcasting studio
μbar		10	
			Threshold of hearing
0.0002 μbar		0	

Some commonly encountered noise levels (sound pressure levels).

Figure 11.1

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the reference sound pressure, and the logarithm (log) is to the base 10. Thus, L_p should be written in terms of decibels referenced to a specified pressure level. For example, in air, the notation for L_p is commonly abbreviated as "dB re 0.0002 μ bar" or "dB re 2 x 10-5 N/m^2".

Figure 11.1 shows the relationship between sound pressure in μ bar and sound pressure level in dB re 0.0002 bar, and illustrates the advantage of using the dB scale, rather than the wide range of direct pressure measurements. For example, the scale of sound pressure levels of 1:1,000,000 is reduced to 0-120 dB.

Combining Sound Levels

Often it is necessary to combine or add sound pressure levels. An example would be to determine the total sound pressure level which would result if two sound sources of known noise characteristics were operated instead of one. One should note that it is not possible to add individual dB levels arithmetically since they are logarithmic values and adding logarithms is multiplication. Therefore, the addition of two noise sources each producing 90 dBA does not produce a total noise level of 180 dBA. Rather, the addition of two noise sources each producing 90 dBA would result in a total noise level (sound pressure level) of 93 dBA. The most convenient way to combine or add sound pressure levels is to use the chart shown in Figure 11.2.

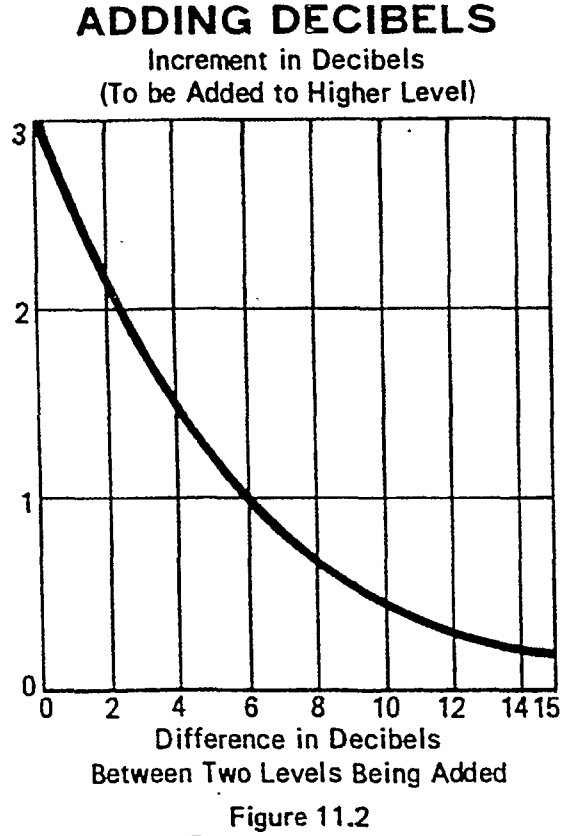


Figure 11.2

THE MECHANISM OF HEARING

One of the most amazing body organs and functions is the human ear and the sense of hearing. Few organs accomplish as much in so little space. Within about one cubic inch is created what is truly a miracle of electronic miniaturization encompassing an acoustic energy analyzer, energy conversion and a system of delicate hydraulic balance. The ear's performance is probably unequalled by any body organ or mechanical device. It can distinguish various sounds in the presence of others. It functions during sleep with incredible efficiency. For example, because the brain can interpret and select signals passed to it by the ear, a man can sleep soundly through noisy traffic and the noise from a neighbor's television set and then awaken at the sound from a chime or an alarm clock.

For the purpose of description, the ear consists of three sections called (1) the outer ear, (2) the middle ear and (3) the inner ear, which are shown in Figure 11.3. Airborne sound waves reach only as far as the middle ear. The functions of the outer ear is to collect the sound, while the function of the middle ear is to convert and transmit sound stimuli to the inner ear where the sensory receptors (hair cells) for sound sensation are located. When the sound waves reach the eardrum, they set this taut membrane into vibration similarly as they do to the diaphragm of a telephone. The eardrum transmits these vibrations through a lever system of three small bones, which amplify the force produced by the conversion of acoustic energy into mechanical energy, to the inner ear by causing the oval window to vibrate. Within the middle ear are muscles. These muscles provide some protection of the ear against intense sound. In such instance, they contract and thereby reduce the amount of energy which is conducted through the middle ear by the lever system.

The oval window is a membrane covering an opening in the bony case of the cochlea

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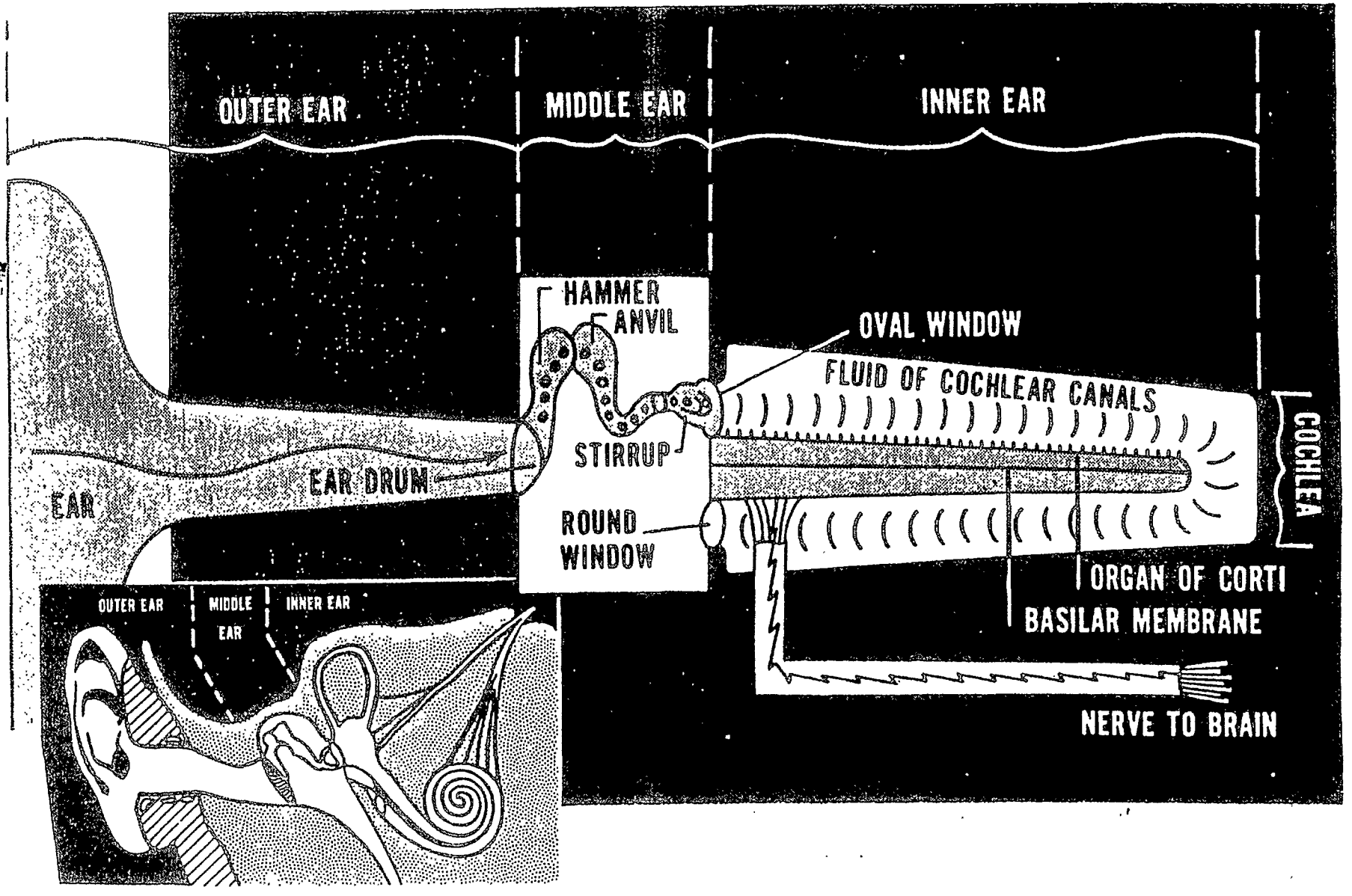
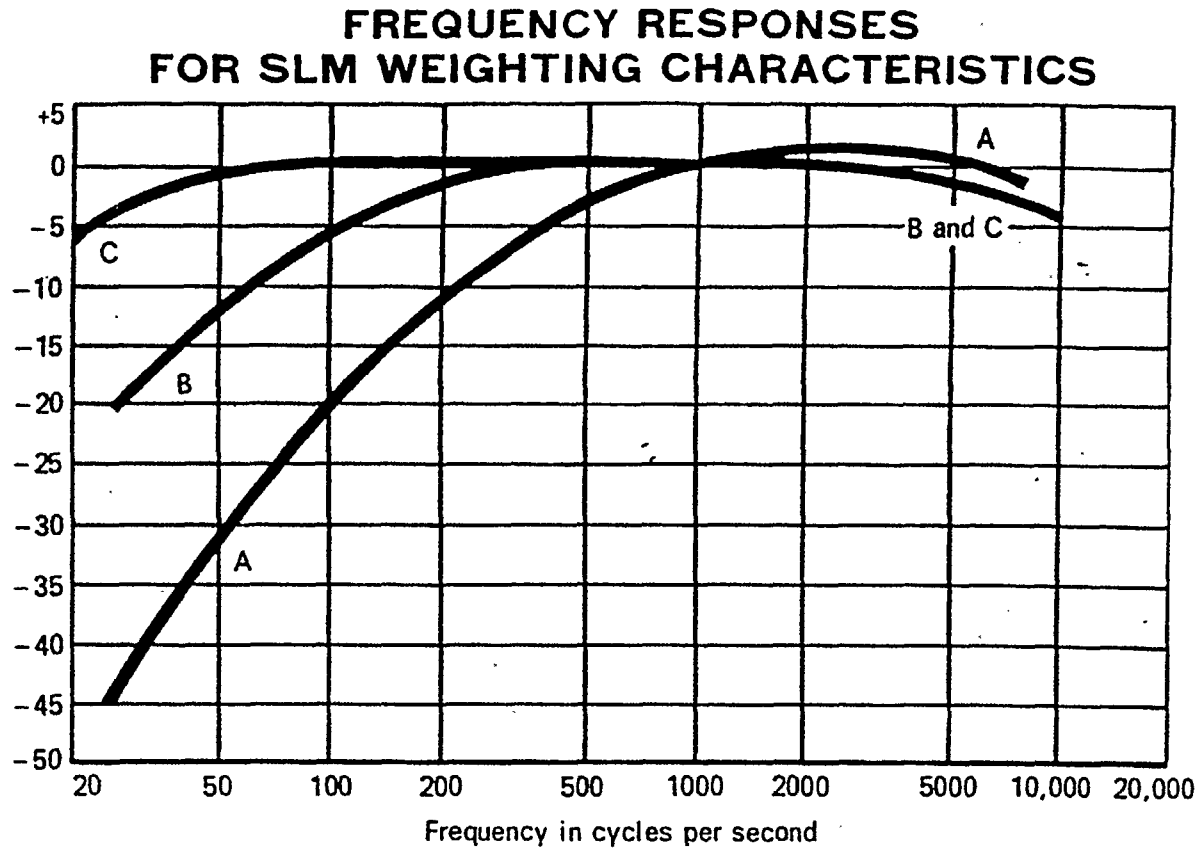


Figure 11.3

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CHARACTERISTICS IN THE USA STANDARD FOR SOUND-LEVEL METERS, S1.4, 1961.

Figure 11.4

Figure 11.4. For measurements in USS facilities, the instrument should measure sound on the "A" weighting network, slow response.

Microphone

The type of microphone provided with the sound survey meter is generally a piezoelectric. The basic characteristics of this are: (1) it has a good response to the frequencies in which we are interested, i.e., 20 to 8,000 H_z; (2) it is suited for the sound levels in which we are interested, i.e., from about 20 to 140 dB; and (3) it is generally not affected by the temperature and humidity found in USS facilities. (Extreme temperatures can affect piezoelectric microphones.)

Special Instruments

Recently, there has been a new development in the evaluation of worker exposure to noise. This is a personal noise dosimeter which is available from several manufacturers such as those shown in Figure 11.5. These personal units which can integrate a worker exposure over a full work shift are generally small enough to be worn in a worker's pocket or on his belt similarly as the personal sampling pump. The device automatically computes the time and noise, where the worker has been exposed to noise in excess of the present level. A 4-digit read-out indicates whether or not the worker's exposure is within the present standard. The device incorporates an "A" weighting network for measurement. However, to date, the American National Standards Institute has not published a specification for noise dosimeters. Therefore, only those approved by the Director-Environmental Health-Pittsburgh should be used for noise monitoring. The suppliers of noise dosimeters as known at present are the following:

1. No. 1944 Noise Dosimeter; General Radio, Concord, Mass.
2. Audio Dosimeter; E.I. duPont de Nemours & Co.,(Inc.),Wilmington, N.C.

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3. Quest M-6 Sound Hazard Integrator; Quest Electronics, Oconomowac, Wisc.
4. SPL-104A Dosimeter; Columbia Research Laboratories, Inc., Woodlyn, Penna.
5. Bendix Noise Exposure System; Environmental Science Division, Bendix Corporation, Baltimore, Md.
6. Sound Consultant System, Willson Products, Reading, Penna.

Operation of the Instruments

Evaluation of a noise problem depends upon accurate and meaningful measurements. Even though the equipment is electronic and may appear simple to operate, one must use it with caution and be on the alert to detect errors in the operation of the sound level meter or the acoustic calibrator and the influence of the environment.

In general, the instruments which will be used for noise surveys in USS facilities are the Bruel & Kjaer (B&K) Type 2205 Sound Level Meter (Figure 11.6) and Type 4230 Calibrator, and the General Radio Company (GR) Type 1565B Sound Level Meter and Type 1562A Calibrator (Figure 11.7).

In addition to the above sound level meters, any device which measures sound pressure level as a single number through an "A" weighting network (dBA), on slow response and is manufactured according to the present ANSI standard S1.4-1971 for sound level

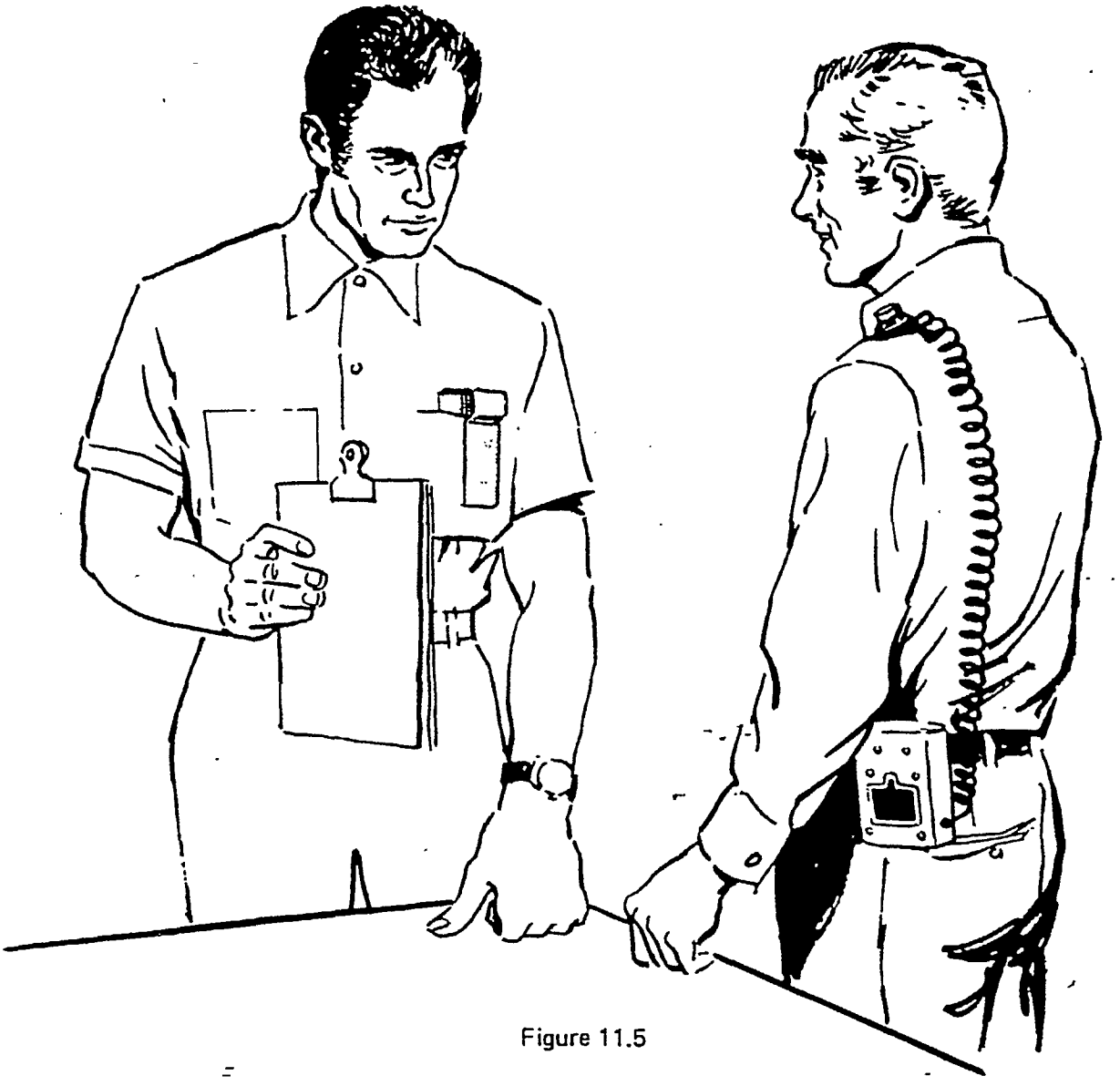


Figure 11.5

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Plant-Noise Survey Form

DATE:
METER # :

LOCATION: S&T. CONTINUOUS PICKLE LINE - FEEDERMAN

NUMBER OF PERSONNEL EXPOSED: 1

WEARING EAR PROTECTION? ☑ yes ☐ no

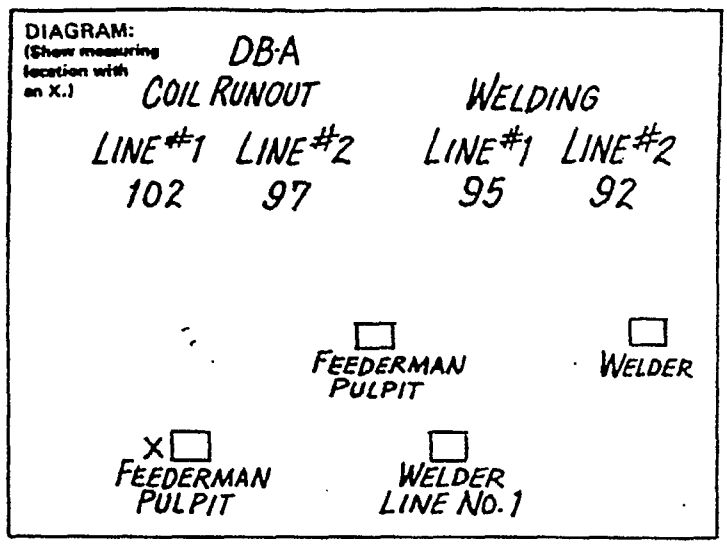
OPERATOR:

SIGNED:

1565-A PROCEDURE CHECK LIST

1. REMOVE WHITE CAP.
2. TURN MODE SWITCH TO "A_S" (OR "C_F" FOR IMPACT NOISE).
3. TURN ATTENUATOR KNOB TO GET SCALE READING (OR TO 130 FOR IMPACT NOISE).
4. ADD READING TO KNOB SETTING TO GET TOTAL dB.

DIAGRAM: (Show measuring location with an X.)



NOTES: NOISE AT OPERATOR FROM STRIP RUNOUT AND BUTT WELD FROM BOTH NOS 1 AND 2 LINES. LINE NO. 1 - 90 COILS PER DAY --- LINE NO. 2 - 120 COILS PER DAY.

	dB(A) MAX LEVEL	EXPOSURE TIME If necessary, note time of day	D TOTAL DURATION IN HOURS PER DAY	P PERMISSIBLE HOURS PER DAY	D/P
MAXIMUM LEVELS AS MEASURED ON THE "A_S" SCALE OF THE SOUND LEVEL METER. IF THE READING IS BETWEEN LEVELS SPECIFIED, USE THE HIGHER LEVEL.	OVER 115			NONE	
	115			¼	
	110			½	
	105			1	
	102	90 TIMES A DAY (LINE NO. 1) @ 50 SEC'S EA. - STRIP RUNOUT	1.25	1½	.83
	100			2	
	97	120 TIMES A DAY (LINE NO. 2) @ 40 SEC'S EA. - STRIP RUNOUT	1.33	3	.44
	95	95 TIMES A DAY (LINE NO. 1) @ 30 SEC'S EACH - WELD	.75	4	.19
	92	120 TIMES A DAY (LINE NO. 2) @ 30 SEC'S EACH - WELD	.60	6	.10
	90			8	
	UNDER 90	COIL SET UP. LUNCH. BREAK. DOWNTIME, ETC.		ANY	0
				TOTAL	1.56

To comply with regulations, total cannot be more than 1.

RECOMMENDATIONS: CONTINUE EAR PROTECTION - DEVELOP ENGINEERING CONTROL FOR NOISE.

GENERAL RADIO WEST CONCORD, MASSACHUSETTS 01781

Form No. 3227-A
PRINTED IN U.S.A.

Figure 11.8

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as possible without interfering with his work. However, care should be taken to insure that neither the worker nor the person conducting the survey shields the microphone. Several measurements should be made in the immediate area of the worker to insure the sound pressure level is relatively uniform and to make certain the dBA levels recorded are representative for each period of the worker's exposure.

One of the most important items in a sound survey is the recording of sufficient data. The date, name of the person conducting the survey, time of day, operation, operator's name, and sound level meter and serial number identify the measurement conditions. The noise levels (maximum, minimum and average) and the time for each exposure should also be recorded. In addition, a description of the noise source and secondary noise sources should be included. A typical survey form is shown in Figure 11.8. It is important to note that, not only is the measurement of the sound pressure (dBA) important, but equally vital is the exposure time. This must be obtained in order to determine compliance with OSHA.

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Chapter XII
Heat

Chapter XII

HEAT STRESS -- ITS EVALUATION

The human body is a heat-producing machine with a complex thermoregulatory system which maintains a balance between heat gain by, and heat loss from, the body within a relatively narrow range of internal body temperatures, under normal conditions. Depending upon one's physical activity, between 250 and 4800 BTU per hour is generated. To keep the normal internal (core, or deep body) temperature at about 99°F, it is necessary to cool the body at a controlled rate which is dependent upon the temperature, moisture content, and velocity of the surrounding air. Not only must these factors be controlled to meet the requirements for heat balance, but the body must be shielded from high levels of radiant heat energy.

The amount of heat involved in maintaining the thermoequilibrium can vary considerably, depending upon energy expenditure and the environmental conditions. Ultimately, the amount of heat exchanged between the body and its environment depends upon the differences of temperature and of vapor pressure existing between the skin and its surroundings. Three mechanisms are involved in this thermobalance:

1. Heat is lost from, or gained by, the body by convection, depending upon whether the air temperature is lower or higher than the skin temperature. As air movement increases, so does the rate of convective heat exchange.
2. When the surface temperature of the surroundings is above or below the skin temperature, radiant heat is gained or lost by the body.
3. Evaporation of sweat results in the loss of heat from the body and is a major means of cooling it. The amount of sweat that can be evaporated, and hence the efficiency of sweating for cooling, depends upon the difference between the vapor pressures of the environment and of the skin, and increases as air movement increases.

Hard physical work or exercise in hot surroundings is considered hazardous because the total heat load on the body is the sum of environmental and metabolic heat. Since large amounts of thermal energy are released in steelmaking and related operations, workers in many work areas are exposed to significant heat. Technological changes have intensified heat conditions in some operations, but have drastically reduced the numbers of employees so exposed. Air-conditioned enclosures, thermal protective clothing (including ventilated suits), radiant heat shielding, relief periods, etc., have been adopted to reduce thermal stress. However, heat exposures still exist, especially in warm weather when the temperature and humidity of the ambient air can compound the heat stress factors.

The terms "stress" and "strain" are used here in the conventional engineering sense. Heat stress is the burden or load of heat that must be dissipated if the body is to remain in thermal equilibrium, and is represented by the sum of metabolic rate (minus external work), and gain or loss by convection or radiation. Heat strain is the physiological change resulting from heat stress; e.g., increase in heart rate and body temperature, sweating, or water and salt imbalance.

Only infrequent and limited studies have been made to correlate heat stress with heat strain among industrial workers. Hence, reliable heat stress criteria are not readily available for accurate appraisal of thermal exposures. Much of the investigative work in this area has been done in laboratories where physically fit students were studied. Consequently, such factors as clothing, age, acclimatization, physical condition, etc., have not been extensively probed. Despite these deficiencies, heat stress standards are now being developed for promulgation under OSHA, and tentative heat stress threshold limit values have been adopted and published by NIOSH. Nevertheless, there is still a need to develop adequate investigative procedures for the evaluation of heat exposures.

Heat Stress

An internal body (core) temperature of 99°F is usually considered "normal". However, body temperature varies during the day and with physical activity, and body temperatures of 97° to 101°F are frequently and normally recorded. In a healthy person, body temperature in excess of 101°F may be viewed with some concern, and a temperature of over 105°F is always serious. Consequently, the regulation of body temperature is an

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important physiological function, and the ease with which it can be achieved is determined by the individual's ambient conditions -- the temperature, humidity and movement of the air, and the radiant temperature.

Heat Exchange

As mentioned earlier, there are two sources of heat: internally generated metabolic heat, and externally imposed environmental heat. In the maintenance of thermal equilibrium in the body, metabolic heat is exchanged with the ambient environment by the processes of convection-conduction, radiation, and evaporation. The net heat exchange between the body and its ambient environment can be expressed by the following equation:

$$H = M \pm C \pm R - E,$$

Where H = net heat gain or loss by the body,
M = metabolic heat production,
C = heat exchanged by convection-conduction,
R = heat exchanged by radiation, and
E = heat loss by evaporation.

Metabolic heat (M) is a by-product of chemical processes occurring within the body. Under resting conditions, the metabolic heat production of an adult is about 300 BTU/hr. During hard physical work involving muscular activity, heat production may reach 2400-3000 BTU/hr. This metabolic heat must be removed if an increase in body temperature is to be prevented. Environmental heat influences the rate at which body heat can be exchanged with the environment, and consequently the ease with which the body can regulate and maintain its normal temperature.

Nearly all transfer of "sensible" heat (C) between skin and air is by the combined process of conduction-convection, in which the latter plays by far the greater part.

Heat may also be lost from the body surface to the air by evaporation (E) of water diffusing through the skin from deeper tissues or produced by sweat glands. Basically, the rate of evaporative heat loss is determined by differences between the effective vapor pressure of water on the skin and in the air, although air movement accelerates this rate of loss. Vapor pressure of water on skin is taken at an assumed skin temperature of 95°F. The vapor pressure of air is determined largely by humidity.

Heat is exchanged by radiation (R) between the surface of the body and all the surfaces in its surroundings which are at temperatures different from its own. The net rate of this heat exchange by radiation is proportional to the difference in the fourth powers of the absolute temperatures of the body and of the surrounding surfaces, and to emissivity. Emissivity is determined by the physical nature of the surface, i.e., a perfectly black object has an emissivity of 1.0.

If the surrounding atmosphere is at a lower temperature than the skin (94°F), heat is lost from the body. Conversely, if the environment is at a higher temperature, heat is gained. The rate by which heat is lost or gained is a function of the differences in temperature. Movement of air over the body accelerates the transfer.

If the body temperature is to remain near normal, then its net heat gain or loss (H) must be zero. Since M represents the heat gain by metabolism, the environmental factors of C and R will add to the heat burden as they increase above 95°F. The heat loss by evaporation (E) may balance this gain. But as the net heat gain by M, C, and R exceed the loss by E, the core temperature of the body rises (Figure 12.1).

Responses to Heat

Since radiant energy exchange, air temperature, humidity and air movement all affect, quantitatively, the heat balance of the body, these effects are largely interchangeable. An alteration in one can be duplicated, or compensated for, by an appropriate change in another. The effect of a rise in radiant heat gain can be duplicated by a rise in air temperature; a rise in humidity may be offset by an increase in air movement, and so on.

At air temperatures below 70°F, sweating is not called into play. As air temperature rises, sweating increases and humidity becomes increasingly important. As long as the air temperature is below skin temperature (95°F), air movement facilitates heat loss by both convection and evaporation.

When air temperature exceeds 95°F, a mixed situation is created. Air movement increases heat loss by evaporation but now it also increases heat gain by convection. The higher the air temperature, the more important the heat gain becomes, until it may actually override the heat loss. For example: a man-cooling fan blows air at 95°F, 50%

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PHYSIOLOGICAL EFFECTS OF HEAT STRESS

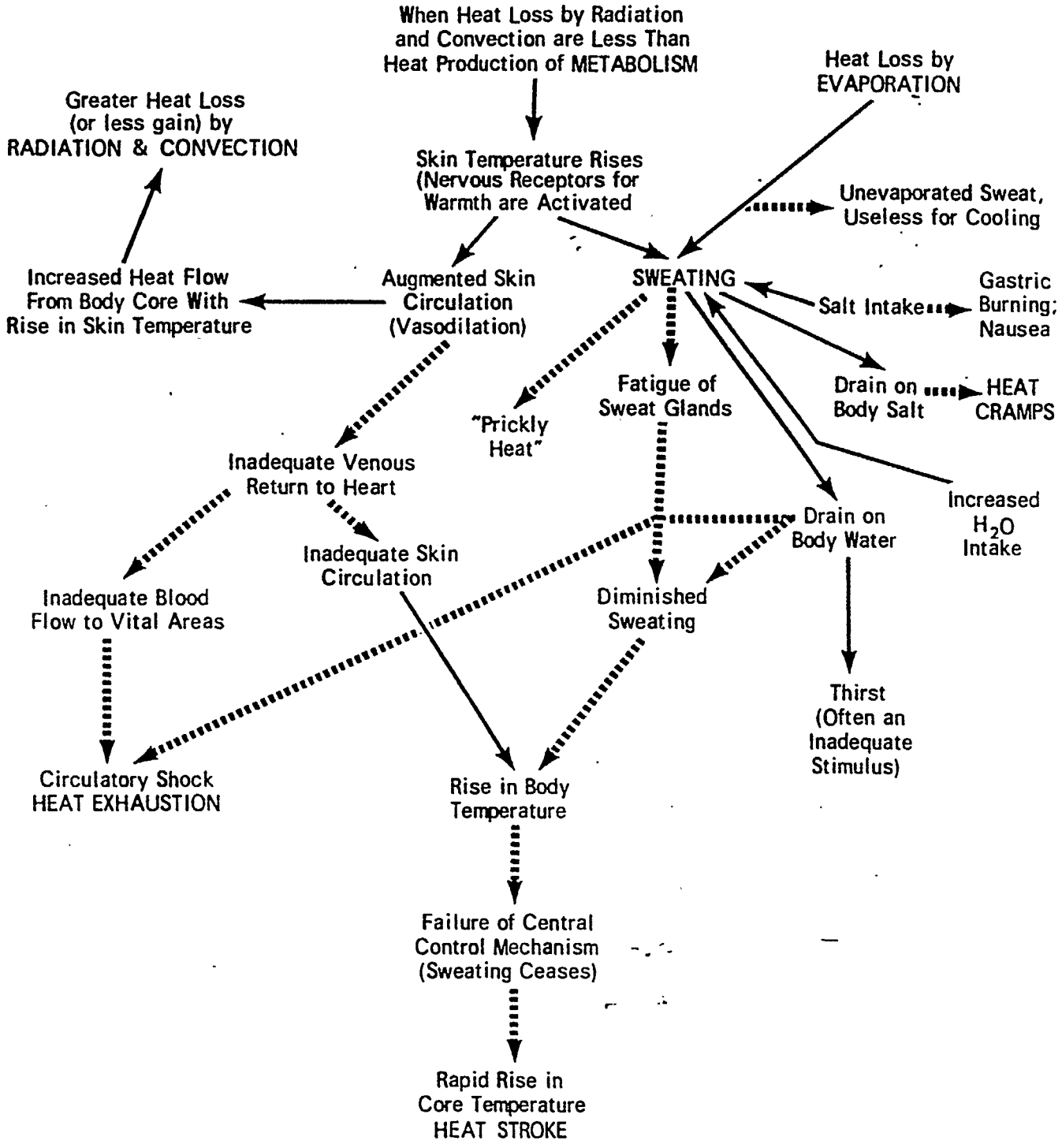


Figure 12.2

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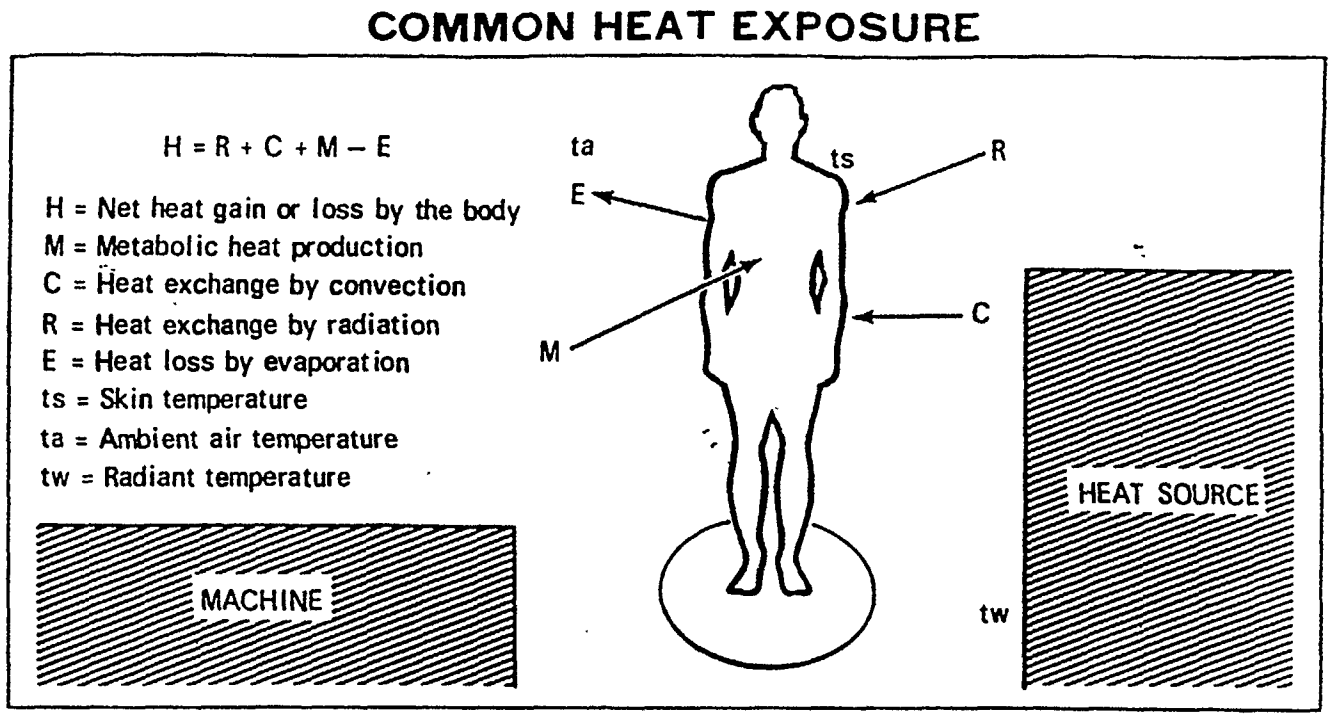


Figure 12.1

humidity, and 500 fpm over an employee. Under these conditions, convection (C) calculates as zero, while the maximum available evaporative loss (E) is 3500 BTU/hr. However, if the air is at 110°F, with the same speed and humidity, E remains at 3500 BTU/hr. but C is +680 BTU/hr. so that the net heat loss is 2820 BTU/hr.

For each set of conditions in which air temperature exceeds skin temperature, there is an optimal air movement. Lower rates of air movement result in sweat accumulations. High rates result in additional heating and place a bigger burden on compensatory sweating.

Figure 12.2 shows the nature and causes of overstrains, together with the bodily responses to heat. The solid lines indicate normal responses, the broken lines the courses of physiological breakdown. In hot environments, heat cramps (painful muscular spasms which result directly from salt depletion) are much more prevalent than heat exhaustion or heat stroke.

The acclimatized individual develops an increased ability to maintain adequate cardiovascular function in the face of a high heat load, although some increase in sweat production may occur. He can work in the heat with lower body temperature, lower heat rate, and more stable blood pressure than the individual who is not acclimated to these conditions. The fully heat-acclimatized individual shows no important decrease in capacity to do physical work in the heat, compared to the amount he can do under comfortable conditions. This does not mean that he is insensitive to heat, merely that he is acclimatized to it. The fact of acclimatization is well documented by both experience and scientific observation, and while some of its features are known, many of its basic mechanisms are still elusive.

Instrumentation and Techniques for Measuring the Thermal Environment

Heat stress is influenced by:

1. Ambient air temperature (dry bulb),
2. Wet bulb temperature,
3. Mean radiant temperature (globe), and
4. Air velocity.

All of these factors may affect human comfort, but the wet bulb and globe temperatures are required to evaluate exposures according to the proposed heat stress criteria. For ambient air measurements, the dry bulb temperature is needed.

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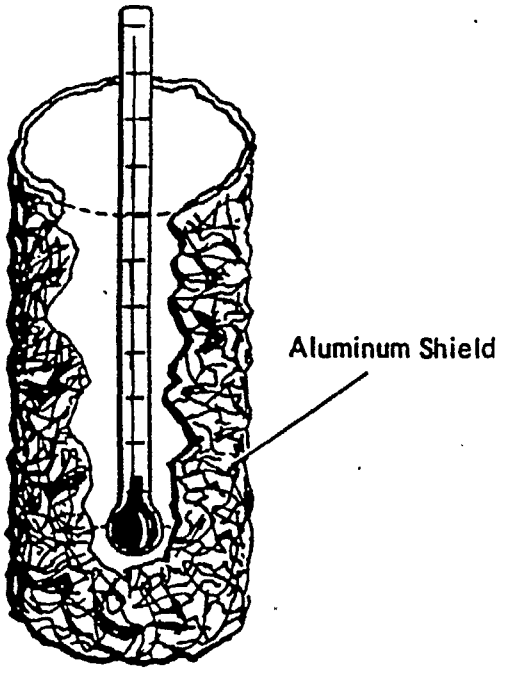


Figure 12.3

Measurement of Dry Bulb Temperature

Dry bulb temperature usually is measured with an ordinary laboratory thermometer, although a thermocouple or a thermistor can also be used. A minimum temperature range of 0° to 125°F with an accuracy of ±1°F is sufficient. When used outdoors or in areas of direct sunlight or radiant energy, the bulb and part of the stem should be shielded from radiation without restricting the airflow around the bulb. A simple shield can be made with an aluminum tube which is fastened around the bulb end of the thermometer (Figure 12.3).

Measurement of Natural (Static) Wet Bulb Temperature

An ordinary laboratory thermometer with a scale range of 0° to 125°F and an accuracy of ±1°F is adequate. A highly absorbent cotton wick should be fastened around the bulb and about one bulb-length of the stem.

Care should be taken to assure that the wick is completely wet at all times, and at least 30 minutes should elapse after wetting before a reading is taken. A long wick, with one end wrapped around the bulb and the other end immersed in a water reservoir, can be used. The reservoir should be kept at least three-quarters filled at all times. Since merely waiting until the entire wick becomes wet by capillary action does not produce correct readings, a small squeeze bottle filled with water (preferably distilled) should be carried in the field, and the exposed wick should be completely wetted by direct application of water from the bottle. The wick must be clean and in good contact with the bulb. New wicks should be washed before they are used.

In areas of high radiant heat, a shield, as previously described, should be mounted at the bulb end of the thermometer, so arranged that air circulates through the annular area between the shield and the thermometer.

Measurement of Globe Temperature

An ordinary laboratory thermometer with a range of 0° to 220°F, with an accuracy of ±1°F, is adequate. Thermocouples or thermistors are well adapted to use with globes, as are any other temperature sensors, provided they give identical readings to mercury thermometers under the same conditions.

The globe is a six-inch-diameter copper sphere painted matte black. A hole is drilled in the globe and 1/2-inch copper tubing is soldered on as a neck through which a one-hole rubber stopper may be inserted. A 3/16-inch bolt may be used opposite the stopper for support.

The thermometer is inserted through the rubber stopper, with its bulb approximately in the center of the globe. Regardless of the heat-sensing instrument used, the globe must be airtight. At least 25 minutes should be allowed for the globe temperature to reach equilibrium with the ambient air. Equilibrium is reached when the heat loss or gain by convection balances the gain or loss by radiation.

Environmental Measurement Setup

To measure environmental heat, two thermometers - a natural wet bulb (NWB) and a globe thermometer (GT) – are mounted on a tripod and placed in the position normally occupied by the worker (Figure 12.4). When this is not possible, approximations should be made by averaging the readings taken at several points near the worker. The tripod should be adjusted so the thermometers are

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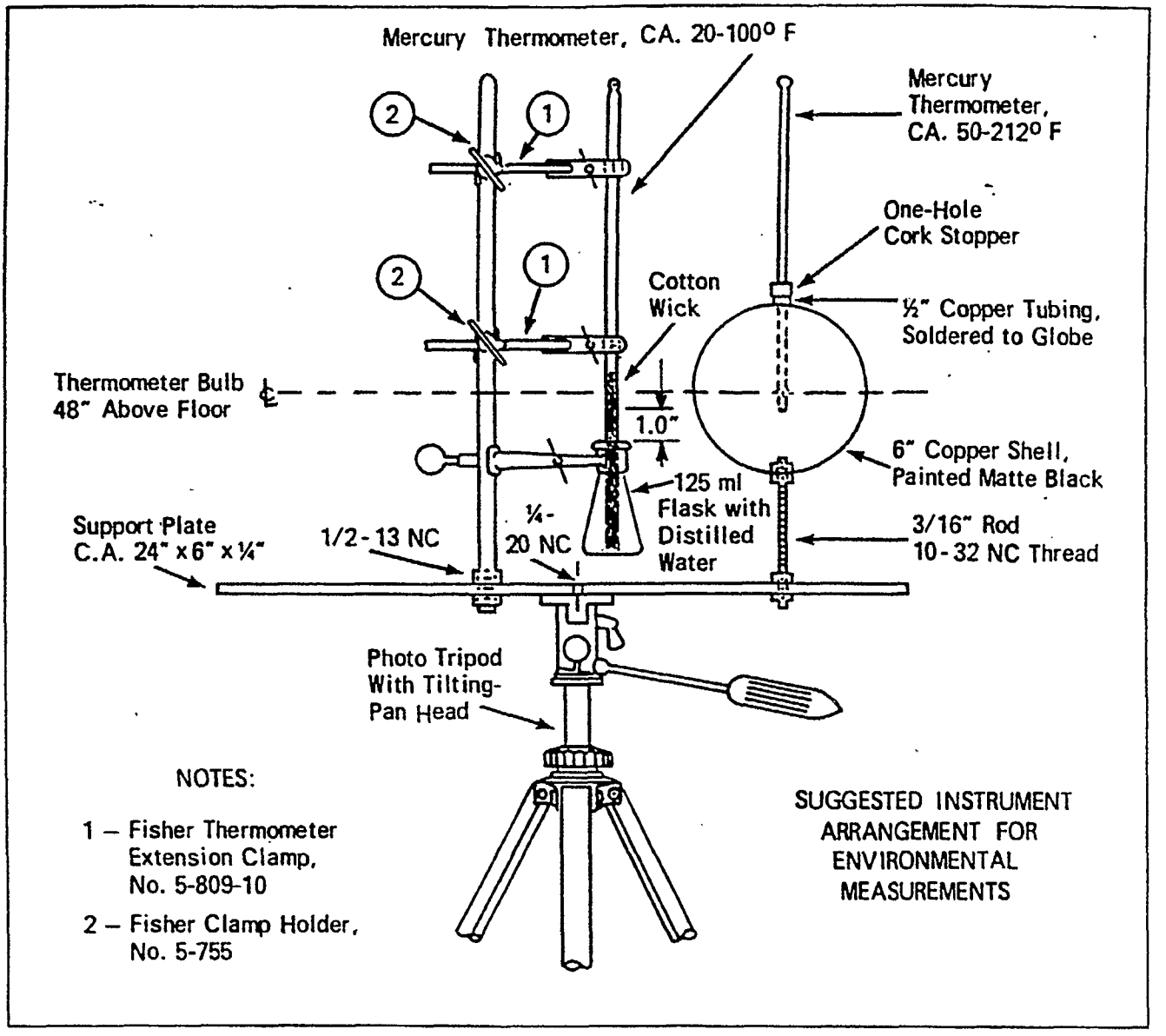


Figure 12.4

four to five feet above floor level. At present, at least 30 minutes of elapsed time are required for GT and NWB temperatures to reach equilibrium. The following items should be checked:

1. Care should be taken that the globe is not shielded from radiant heat sources;
2. The wick on the wet bulb thermometer should be examined frequently for wetness; and
3. A radiant shield should be placed on the wet bulb thermometer where such heat sources exist.

Temperature should be read and recorded at intervals of several minutes. At the time the measurements are recorded, notes should also be made on prevailing weather and local work conditions, time of exposure, protective equipment provided, localized heat controls, etc. A data sheet pertaining to evaluation of heat stress is shown in Figure 12.5.

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Department _____

Job Title _____ Employee No. _____

Date _____ Time _____ AM _____ PM _____ Observer _____

Time Started _____ Time Finished _____

Duration of Exposure for a Cycle (Min.) _____ No. of Cycles per Shift _____

Workload _____ Light _____ Moderate _____ Heavy _____

Work-Rest Regiment _____ Work Time (min.) _____ Rest Time (min.) _____

Location of Rest Area _____

Rest Area Temperature _____ NWB _____ GT _____

Clothing (work) _____

HEAT STRESS DATA

Temperatures (^{o}F) _____ NWB _____ GT _____ DBT _____

Indoor Conditions _____ Rel. Humidity _____ Air Velocity _____

WBGT Calculations (Indoors) WBGT = _____ 0.7 NWB + 0.3 GT _____

_____ (Outdoors) WBGT = _____ 0.7 NWB + 0.2 GT + 0.1 DBT _____

Estimated Head Exposure Level (From Figure 11.6): _____

Control Measures (Radiant Shield, Ventilation, Clothing, Cooling, Air, etc.) _____

Outdoor Conditions: Rel. Humidity _____ Wind Direction _____ Speed _____

SKETCH

Indicate:

Rad. Heat Sources

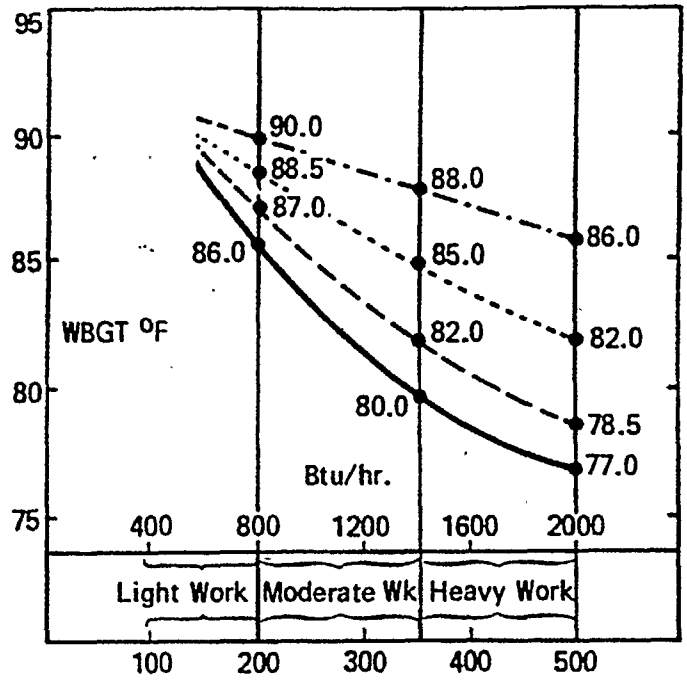
Operator's Position

Testing Point

Remarks:

Figure 12.5

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LEGEND:
8 Hr. Continuous Work
75% Work 25% Rest Each Hr.
50% Work 50% Rest Each Hr.
25% Work 75% Rest Each Hr.
K cal/hr.

PERMISSIBLE HEAT EXPOSURE LIMITS FOR WORKING IN SURFACE MINING OPERATIONS.

Figure 12.6

Thermal Criteria

Since measurement of deep body (core) temperature is impractical for monitoring the worker's heat load, measurements are made of the environmental factors which most nearly correlate with core temperature and other physiological responses to heat. At the present time, the wet bulb globe temperature index (WBGT) is the proposed standard.

The proposed threshold limit values (Table 12.1, derived from Figure 12.6), where applicable, refer to heat stress conditions to which it is believed that nearly all workers may be repeatedly exposed without adverse health effects. The proposed TLV's are based on the assumption that nearly all acclimatized, fully clothed workers with adequate water and salt intakes should be able to function effectively under the given working conditions without exceeding a deep body temperature of 100.4°F. WBGT values are calculated by the following equations:

1. Outdoors with solar load (direct sunlight),
   WBGT = 0.7 NWB + 0.2 GT + 0.1 DB
   or
2. Indoors or outdoors with no solar load
   WBGT = 0.7 NWB + 0.3 GT

Where; WBGT = wet bulb globe temperature index,
NWB = natural wet bulb temperature,
GT = globe temperature, and
DB = dry bulb temperature

The determination of WBGT requires the use of a black globe thermometer, a natural (static) wet-bulb thermometer, and a dry-bulb thermometer for outdoor situations, as previously described.

Permissible Heat Exposure Threshold Limit Values (in degrees F WBGT)

	Work Load		
Work-Rest Regimen	Light	Moderate	Heavy
Continuous	86.0	80.0	77.0
75% work - 25% rest/hour	87.0	82.0	78.5
50% work - 50% rest/hour	88.5	85.0	82.0
25% work - 75% rest/hour	90.0	88.0	86.0

Higher heat exposures than shown in Table 12.1 are permissible if the workers have been under medical surveillance and it has been established that they are more tolerant than average workers to work in heat. A worker should not be permitted to continue work when his deep body temperature exceeds 100.4°F.

Table 12.1

Work Categories

The work load category is established by ranking each job as:

1. Light Work— sitting or standing to control machines, performing light hand or arm work, pulpit and crane operations, etc.
2. Moderate Work — moderate lifting or pushing, machining, bricklaying, etc.
3. Heavy Work — pick and shovel work, railroad track laying, digging, forging, etc. Instruments and procedures have been

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developed for measuring an individual's metabolic rate. Much of the related work in this field has been undertaken in cardiac projects. While not all occupations have been assessed, any particular job or operation may be ranked with a similar type of activity for which an energy requirement has been assigned.

Work-Rest Regimen

The permissible exposure limits presented in Table 12.1 are based on the assumption that the WBGT value of the resting place is the same or very close to that of the work place. If the resting place is air-conditioned and its WBGT is maintained at or below 75°F, the allowable rest time may be reduced by 25%. The permissible exposure limits for continuous work are applicable for a five-day work week and an eight-hour shift, with a half-hour lunch period and morning and afternoon breaks of about 15 minutes each. Higher exposure limits are permitted if additional rest time is allowed. All breaks, including unscheduled downtimes and operational waiting periods during work, may be counted as rest time in situations where additional rest time must be allowed because of high environmental temperatures.

It is a common experience that, when the work on a job is self-paced, a worker will spontaneously limit his hourly work load to 30-50% of his maximum physical performance capacity. He does this either by setting an appropriate work speed or by interspersing unscheduled breaks. Thus, the daily average of the worker's metabolic rate seldom exceeds 330 Kgal./hr. (1320 BTU/hr.). However, within an eight-hour work shift, there may be periods when his hourly average metabolic rate is higher.

Other Considerations

The permissible heat exposure limits are valid for the summer-weight clothing customarily worn by employees working under hot environmental conditions. Flame retardant clothing, when worn in areas where molten metal is handled, may generally be classified as summer clothing. If special clothing, such as aluminized coats, jackets, pants, etc., is required for performing a particular task, and if this clothing is considerably heavier than summer clothing, or impedes sweat evaporation, or has higher insulation value, the worker's heat tolerance is reduced and the proposed TLV's are not applicable. With the use of such protective clothing, a microclimatic condition prevails under the garment, and this is not determinable from environmental measurements. As a rule, these garments are worn for relatively short periods, and are removed when the hot job is completed. For each job category where special clothing is required, the permissible heat exposure limits should be established by a qualified expert.

During hot weather or when workers are exposed to job-imposed heat, reasonably cool drinking water (50° to 60°F) should be made available in such a way that they are encouraged to drink adequate amounts of it. Water should be located close to (within 200 feet of) the job site. The use of salt supplement should be stimulated.

Heat Stress Evaluation

When evaluating a heat exposure at a given job site, the natural wet bulb and globe temperatures should be measured, together with the dry bult temperature for outdoor exposure with solar load (direct sunlight). The WBGT should then be calculated using the appropriate equation. The work load category must be estimated or assigned for the particular task, and the work-rest regimen established. The investigator may then compare the calculated WBGT for the specific task against the standard for that work load and work rest regimen (Table 12.1 or Figure 12.6). For example:

> A craneman works in an area where measured NWB and GT are 75°F and 110°F respectively, in his crane cab. The calculated WBGT is (0.7 x 75°F) + (0.3 x 110°F), which equals 52.5 + 33, or 85.5°F. For light work load and continuous work, the TLB in Table 12.1 is 86°F. Comparing 85.5° with TLV of 86°F indicates that the craneman's heat exposure is below the TLV.

Outdoor conditions of temperature and humidity (described below) should be measured or obtained from the local weather report. Other factors should be noted: air velocity, shielding and clothing provided, time of sampling, duration or frequency of task, location of instruments with respect to the operator, and productivity (normal or other).

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PSYCHROMETRIC CHART

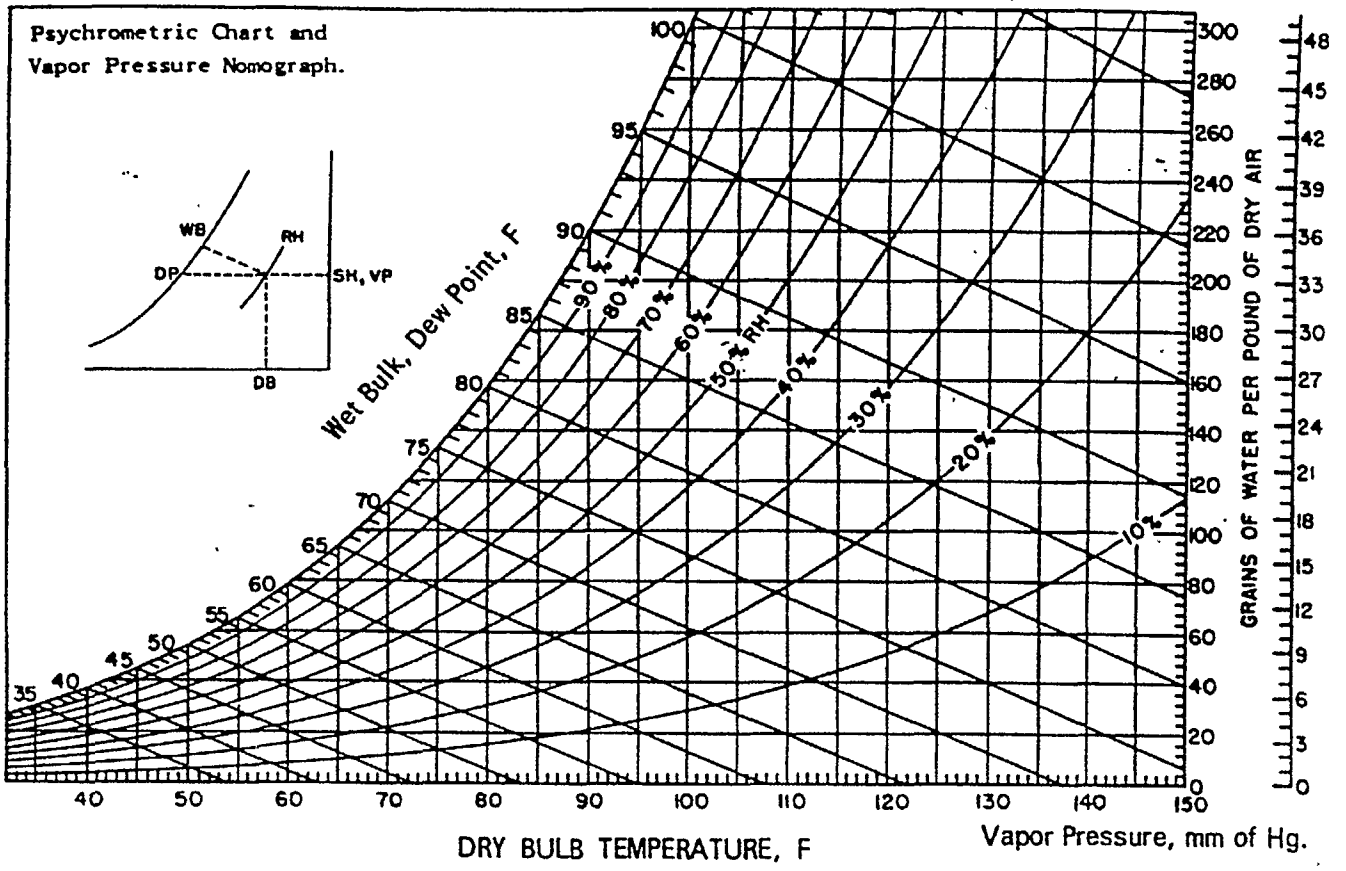


Figure 12.8

When abnormal conditions prevail, sampling should be repeated to determine average situations.

Measurement of Humidity

The simplest and most common instrument used to determine the humidity (moisture content) of air is the sling psychrometer (Figure 12.7). The device consists of a frame on which two matched thermometers are mounted. The bulb of one thermometer is exposed to the air, while the bulb of the other is covered with a wetted wick. The frame is connected to a handle which is hand-held and rotated vigorously for about one-half minute. The differential between the temperature on the wet bulb from that on the dry bulb is a function of the amount of moisture in the air. Whirling is resumed and interrupted at intervals to take additional readings until both thermometer readings are constant. A psychrometric chart (Figure 12.8) is used to calculate relative humidity. For example: If DBT is 90°F and WBT is 75°F, enter the chart at 90°F on the horizontal axis and follow this line vertically until it intersects the 75°F wet bulb line. This point indicates 50% relative humidity or 108 grains of water vapor per pound of dry air.

In areas of high radiant temperature, however, errors result from using this method, and a properly shielded aspirated psychrometer is recommended.

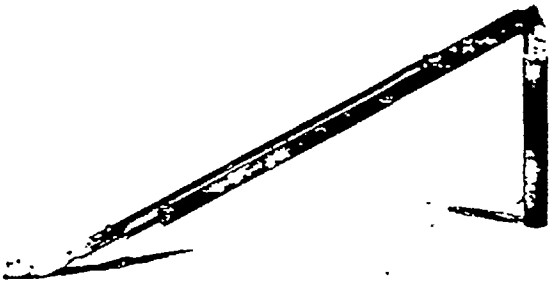


Figure 12.7

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Chapter XIII
Illumination

Chapter XIII

ILLUMINATION AND ITS MEASUREMENT

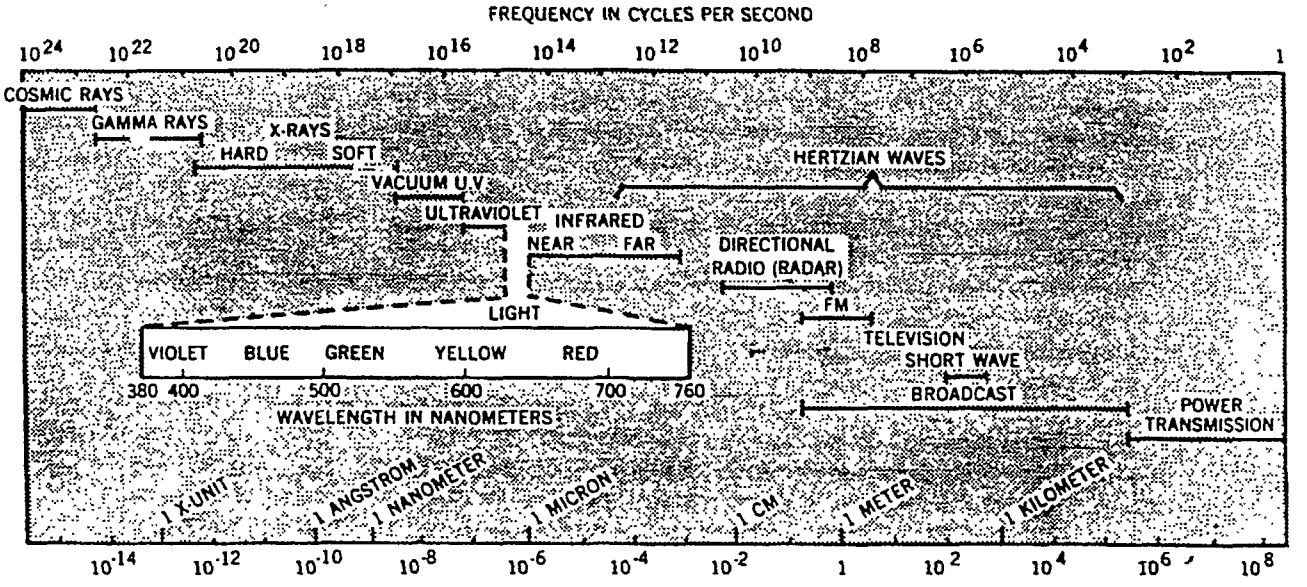
At present, illumination standards have not been promulgated by OSHA. However, some citations have occurred under the general duty provisions of the Act. So it is realistic to anticipate such standards at a later time. While the role of illumination as a health factor is questionable, good vision is a factor in accident prevention.

Visual demands have increased materially from the period of early man who spent most of his time out of doors in daylight where the visual tasks were relatively simple. Today, man lives and works mostly indoors where the visual demands require close observation of details under conditions of constant visual accommodation for long periods of time. Good illumination considerably improves the environment under which the eyes must work. Such improvement relieves stress on the eyes and improves their performance when functioning under difficult visual demands. This improvement is greater for older eyes than for young eyes with normal visual activity.

Illumination is a factor of primary importance which affects the environment in every establishment. Among the advantages of proper illumination: (1) greater accuracy of workmanship, resulting in improved product quality with less rejection and rework; (2) increased production and decreased costs; (3) better utilization of floor space; (4) greater ease of seeing especially among older employees; (5) less eyestrain among employees; (6) improved morale among employees resulting in less turnover in the work force; (7) improved safety performance; and (8) improved housekeeping.

Visible Light

Light is radiant energy evaluated in terms of its capacity for producing the sensation of sight. This is produced by the very small visible energy portion of the electromagnetic spectrum which comprises a tremendous range of radiant energy. These radiations travel through space in the form of electromagnetic waves, and all of these radiations are similar in nature and in the speed at which they travel (186,300 miles per second). They differ only in wavelength and frequency, and in the ways they manifest themselves. The presently known electromagnetic spectrum ranges from a wavelength of 1×10^{-15} cm (cosmic rays) to 60 cycle alternating current waves which are 3100 miles long (Figure 13.1). However, the human eye can respond only to radiations within the visible spectrum, which have a range of wavelengths between 380 to 760 nanometers (nm). The nanometer



The radiant energy (electromagnetic) spectrum.

Figure 13.1

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is a unit of wavelength equal to 10^{-9} (one one-billionth) meter. Another unit of wavelength is the angstrom (A^{o}) which is one-tenth of a nanometer.

Factors in Seeing

The seeing process depends upon four primary variables which are associated with the visual object; its *size*, its *luminance* (brightness), the luminance *contrast* between the object and its immediate background and the *time* available for seeing. These factors are mutually interrelated and interdependent. Within limits, a deficiency in one can be compensated for by an adjustment in one or more of the others. Since size is generally fixed, the adjustment is generally limited to the other factors. Of these, luminance and contrast provide the greatest degree of control by illumination. Luminance depends on both the intensity of light striking the object and the proportion of that light reflected in the direction of the eye.

Factors in Good Illumination

The design of a lighting installation involves the consideration of many factors. Therefore, such an installation should be developed only by one knowledgeable in the design of illumination systems. There are certain basic requirements governing adequate quantity and good quality of lighting discussed in this chapter.

Quantity of Light

The term quantity applied to lighting refers to the amount of illumination to produce necessary brightness of the task and surroundings. Lighting engineers have consistently increased their recommended illumination levels for industrial lighting since about 1900. Part of this increase is due to the greater visual demands required by modern technological development in which information must be visually obtained within a short time increment.

The desirable quantity of light for any particular installation depends primarily upon the work being done. The degree of accuracy required, the fineness of detail to be observed, the color and the reflectivity of the work, as well as the immediate surroundings, materially affect the brightness requirements which will produce maximum seeing conditions. Investigations in the field and laboratory have indicated that as the illumination of the task (and hence its brightness) is increased, the ease, speed and accuracy with which the task can be accomplished are increased. Illumination level is only one characteristic of a lighting system and many other important considerations enter into a well-designed system such as glare, distribution, diffusion and color. However, quantity is a basic requirement of adequate illumination. The quantitative requirement varies with the nature of the activity and is principally a function of the difficulty of the visual task in terms of size of detail, brightness or color contrast and speed required.

Recommended illumination levels have been developed by the Illuminating Engineering Society for a variety of representative industrial operations. They have been published by the American National Standards Institute (ANSI) as American National Standard Practice for Industrial Lighting, A11.1-1965 (R1970). While some research has been done in the development of a method of evaluating actual work situations in terms of the laboratory test results, a sound basis for the recommended definite levels of illumination is still lacking, particularly in their application for regulatory purposes. The illumination levels in the ANSI publication, of interest to U. S. Steel operations, are shown in Table 13.1.

Quality of Lighting

The factors involved in quality of lighting are many and variable. Glare, diffusion, direction and uniformity of distribution, color, brightness and brightness ratios have a significant effect upon visibility and ability to see easily, accurately and quickly. Certain seeing tasks require higher lighting quality than others. Areas where the seeing tasks are casual or relatively infrequent require less high quality lighting than those where the seeing tasks are severe and are performed over long periods of time. The quality factors are not discussed in detail in this manual. These factors determine the effectiveness of a design and are considerations of the illumination engineer.

Light colored surfaces are of particular value because they reflect more light toward the working areas. Also bright openings and artificial light sources are less uncomfortable to the eye when viewed against light back-

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Table 13.1

	Recommended Minimum Footcandles
COAL TIPPLES AND CLEANING PLANTS	
Breaking, screening and cleaning	10
Picking [1]	300
ELECTRICAL EQUIPMENT MANUFACTURING	
Impregnating	50
Insulating: coil winding	100
Testing	100
EXTERIOR AREAS	
Entrances	
Active (pedestrian and/or conveyance)	5
Inactive (normally locked, infrequently used)	1
Storage areas – inactive	1
Loading and unloading platforms	20
FLOUR MILLS	
Rolling, sifting; purifying	50
Packing [2]	50
Product control	100
Cleaning, screens, man lifts, aisleways and walkways, bin checking	30
FORGE SHOPS	50
CHEMICAL WORKS	
Hand furnaces, boiling tanks, stationary driers, stationary and gravity crystallizers	30
FOUNDRIES	
Annealing (furnaces)	30
Cleaning	30
Core making (fine)	100
Core making (medium)	50
Grinding and chipping [1]	100
Inspection (fine) [1]	500
Inspection (medium)	100
Molding (medium)	100
Molding (large)	50
Pouring	50
Sorting	50
Cupola [3]	30
Shakeout	30
GARAGES – AUTOMOBILE AND TRUCK	
Service garages	
Repairs	100
Active traffic areas	20
Parking garages	
Entrance	50
Traffic lanes [3]	20
Storage [3]	10
INSPECTION	
Ordinary	50
Difficult	100
Highly difficult [1]	200
Very difficult [1]	500
Most difficult [1]	1000
IRON AND STEEL MANUFACTURING	
Open hearth	
Stock yard	10
Charging floor	20
Pouring slide	
Slag pits	20
Control platforms	30
Mold yard	5
Hot top	30
Hot top storage	10
Checker cellar	10
Buggy and door repair	30
Stripping yard	20
Scrap stockyard	10
Mixer building	30
Calcining building	10
Skull cracker	10
Cinder dump	0.1
Rolling Mills	
Blooming, slabbing, hot strip, hot sheet	30
Cold strip, plate	30
Pipe, rod, tube, wire drawing	50
Merchant and sheared plate	30
Tin plate mills	
Tinning and galvanizing	50
Cold strip rolling	50
Motor room, machine room	30
Inspection	
Black, plate, bloom and billet chipping	100
Tinplate, other bright surfaces [5]	100
LOCKER ROOMS [3]	30
MACHINE SHOPS	
Rough bench and machine work	50
Medium bench and machine work, ordinary automatic machines, rough grinding, medium buffing and polishing	100
Fine bench and machine work, fine automatic machines, medium grinding, fine buffing and polishing [1]	500
Extra fine bench and machine work, grinding—fine work [1]	1000
MATERIALS HANDLING	
Wrapping, packing, labeling	50
Picking stock, classifying	30
Loading, trucking [3]	30
Inside truck bodies and freight cars [3]	30

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PAINT MANUFACTURING	
General [3]	50
Comparing mix and standard [5]	200
PAINT SHOPS	
Dipping, simple spraying, firing	50
Rubbing, ordinary hand painting and finishing art, stencil and special spraying	50
Fine hand painting and finishing	100
Extra fine hand painting and finishing (automobile bodies, piano cases, etc.) [1]	300
SHEET METAL WORKS	
Miscellaneous machines, ordinary bench work	50
Presses, shears, stamps, spinning, medium bench work	50
Punches	50
Tin plate inspection, galvanized [4]	200
Scribing [4]	200
SHIPYARDS	
General	5
Ways	10
Fabricating areas	30
STONE CRUSHING AND SCREENING	
Belt conveyor tubes, main line shafting spaces, chute rooms inside of bins	10
Primary breaker room, auxiliary breakers under bins	10
Screens	20
STORAGE ROOMS OR WAREHOUSES	
Inactive [3]	10
Active	
Rough bulky [3]	30
Medium [3]	50
Fine [3]	100
STRUCTURAL STEEL FABRICATION	50
SUGAR REFINING	
Grading	50
Color inspection	200
TESTING	
General	50
Extra fine instruments, scales, etc. [1]	200
WELDING	
General illumination	50
Precision manual arc welding [1] [2]	2000
WOODWORKING	
Rough sawing and bench work [2]	50
Sizing, planing, rough sanding, medium quality machine and bench work, glueing, veneering, cooperage [2]	100
Fine bench and machine work, fine sanding and finishing [2]	200

grounds. Many plants are painting machines in such colors that they present a harmonious color picture with the interior. It is desirable that the background be slightly darker than the seeing task. Also, the painting of the stationary and moving parts of machines in contrasting colors can reduce accident hazards by aiding identification. Contrasting colors can also be employed on walkways, handrails, etc., to aid identification.

Glare is defined as any brightness within the field of vision of such character as to cause discomfort, annoyance, interference with vision or eye fatigue. Glare is objectionable because: (1) when continued, it tends to injure the eye and disturb the nervous system; (2) it causes discomfort and fatigue and reduces the efficiency of the worker; and (3) it interferes with and often prevents clear vision and thus reduces efficiency and can increase the risk of accidents or injury to workers.

The two common forms of glare are *direct* and *reflected*. Direct glare is caused by excessive brightness or brightness contrast within the visual field, i.e. unshielded lamp or high brightness surface of luminaries, unshaded windows or openings. Proper mounting of fixtures above the normal line of vision, proper shielding of fixtures and shading of openings or windows will reduce glare. Also, employment of artificial lighting luminaries which are too bright for the environment in which they are located should be avoided. Reflected glare is caused by high brightness images or brightness contrasts reflected from shiny ceilings, walls, desk tops, materials, machines or surfaces within the visual field. Reflected glare is frequently more annoying than direct glare because it is so close to the line of vision that the eye cannot avoid it. The effect of reflected glare can be abated by

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increasing the general level of illumination, changing the character of the offending surface, repositioning the lighting equipment or the task, or reducing the light source by shielding or diffusing the luminaries. Some directional and shadow effects are desirable in general illumination for accentuating the depth and form of solid objects, but harsh shadows should be avoided. Shadows are softer and less pronounced when diffusing units and units having a wide distribution of light are used, since then the object is illuminated from many sources. Alternate light and dark areas in strong contrast are undesirable because the eye has difficulty in adjusting itself to the two levels of illumination and seeing becomes tiring. For this reason, purely local lighting restricted to a small work area is unsatisfactory unless there is adequate general illumination in the area. Clearly defined shadows, without excessive contrast, are a distinct aid in certain types of operations. When such shadowing is desired, it is best obtained with supplementary directional lighting combined with diffused illumination of ample intensity.

The ability to see detail depends upon the brightness difference between the detail and its background. The greater the difference in brightness, the more readily the seeing task is performed. However, the eye functions most comfortably and efficiently when the brightness within the remainder of the environment is relatively uniform. Often brightnesses within the field of view vary greatly, and all brightnesses contribute, either favorably or unfavorably, to the seeing conditions. The recommended maximum brightness ratios are shown below but lower values may be desirable.

Importance of Maintenance in Lighting

There should be a regular program of cleaning and repairing skylights, windows, lighting equipment, lamps and room surfaces. Luminaires should be kept in proper adjustment and in good repair. Even when this is done, illumination levels will drop about 25 to 35% less than the original under normal operating conditions. The useful output of some lamps decreases with age before they burn out. Therefore, it is important that a regular maintenance program be established whereby the lamp and fixture are cleaned routinely, and dim and burned-out lamps are replaced.

MEASUREMENT OF ILLUMINATION

The conduct of illumination measurements involves an understanding of the units used in illumination, the type of available field instruments and the use of instruments in field measurements.

Units

The basic terms and units used in the conduct of lighting surveys are defined below in Table 13.2.

Light Meters

Several kinds of light meters are commercially available. In principle, a voltage is generated when radiant energy (light) strikes the light sensitized surface of a cell which in turn activates a microammeter calibrated directly in footcandles. Among the more popular types are the GE pocket-sized meter and the Weston Hinged Cell Meter (See Figures 13.2 and 13.3). Both types are available with color and cosine correction. With cosine correction, a light meter responds equally to illumination from all directions

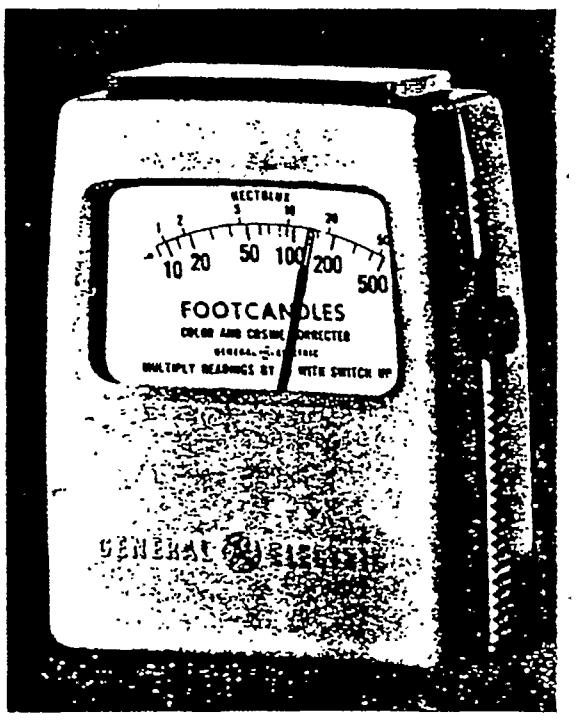


Figure 13.2

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Term	Unit	Definition	Use
Luminous Intensity (candlepower)	Candela (cd)	The international basic physical quantity in all light measurements from which all other units are derived.	Indicates luminous intensity of a source in one particular direction.
	Candle-Power (cp)	The luminous intensity of a source expressed in candelas is its candlepower.	Provides information regarding luminous flux at its origin and is always a property of the light source.
Luminous Flux	Lumen (lm)	A lumen is the light flux falling on a surface one square foot in area, every part of which is one foot from a point source having a luminous intensity of one candela in all directions.	Used to express a quantity of light flux as for example, total output of a source, amount of light reflected, absorbed or transmitted by an object amount of light incident on a surface, etc.
Illumination	Foot-candle (fc)	The illumination at a point on a surface which is one foot from and perpendicular to a uniform point source of one candela. The density of luminous flux on a surface.	Used to indicate the illumination at a specified point, or the average illumination on a surface.
Luminance (Photometric Brightness)	Candela per sq. in. (cd/in.) or Footlambert (fl)	The brightness of an illuminated surface, expressed in candelas per unit area or lumens per unit area. A surface emitting or reflecting light in a given direction at the rate of one Candela per sq. in. of projected area has a luminance in that direction of one candela per sq. in.	A convenient unit to express the luminance of illuminated surfaces.

Table 13.2

instead of primarily to vertically incident radiation. The Weston device has wider ranges with multiplying scales than the GE units, but is more expensive. Prolonged exposure to heat above 120°F will permanently damage the cell. Instruments of this type have no provisions for field calibration other than a zero reading correction. With normal usage periodic calibrations, about every two to three years, is recommended. Under severe handling or abuse, more frequent calibrations may be needed. Consult the manufacturer relative to calibration.

The light intensity meter is used to check illumination levels with the standards that have been proposed. More sophisticated measurements may be required by the expert analyzing a lighting problem. However, for our purposes, additional instruments other than the light meter are not warranted.

All light-sensitive cells exhibit a tendency

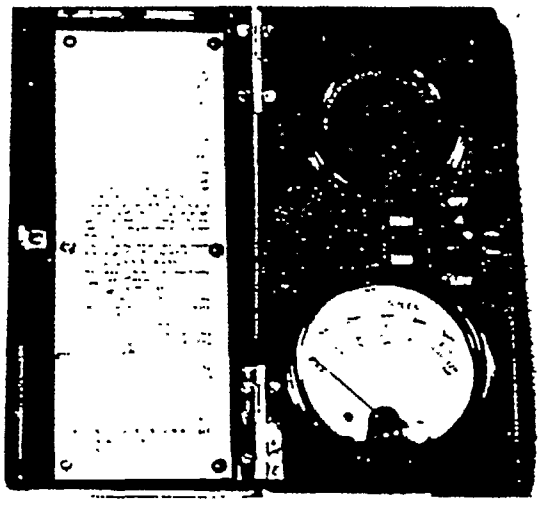


Figure 13.3

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for the meter indication to drop off over a period of minutes, until a constant reading is reached. This effect is most noticeable at high illumination levels, particularly if the meter has been in the dark or exposed to a much lower level of illumination. Therefore, an adaptation period may be necessary before conducting measurements.

Field Measurement

In measuring illumination, the type of instrument embodying a light-sensitive cell, as described earlier, should be used. This instrument is fairly rugged and easy to use. A switch on the instrument panel permits the observer to change from one scale to others. There is no warm-up period for the device. The user should be careful to avoid casting a shadow on the light sensitive cell while reading the instrument. A mercury or fluorescent system should be lighted at least one hour before measurements are taken to be sure that normal operating output has been attained.

In determining the average footcandles on a horizontal plane from general lighting, the measuring instrument should be positioned so that when readings are taken, the surface of the light sensitive cell is in a horizontal plane and thirty inches above the floor. This can be facilitated by means of a small portable stand that will support the cell at the correct height in the proper plane, or the meter may be held at this location.

When measuring the light intensity at a specific seeing task, i.e., inspection table, grinder, lathe, etc., the illumination at the point of work should be measured with the employe in the normal working position. The light meter should be positioned so that when readings are recorded, the surface of the light sensitive cell is in the plane of the work or of that portion of the work on which the critical visual task is performed - horizontal, vertical, or inclined.

If much light is contributed by daylight conditions, the survey should be repeated at night as we are also interested in measuring the adequacy of artificial light.

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Chapter XIV

RECORDKEEPING

The recording of data obtained in any activity necessitates the development of necessary forms and their orderly completion in a neat and efficient manner if the data is to serve the purposes for which it is obtained. The Federal Occupational Safety and Health Act (OSH-Act), and the various standards promulgated thereunder, requires the collection and recording of considerable data on the exposures of employees to toxic materials and hazardous physical conditions for review by the OSHA compliance officers and the employees so exposed. The neatness and thoroughness with which such records are maintained not only reflects upon the quality of the industrial hygiene or environmental health program, but allows plant personnel to readily review the test data and establish conclusions relative to compliance with OSHA standards. The maintenance of these records is specifically provided for under the OSH-Act in Sections 8 (c) and 20 (a) (5). However, in developing a recordkeeping program, it is desirable to go beyond the mere statutory requirements and to anticipate future needs which may be for plant use or for possible proposed standards in the future. Therefore, the necessity for maintaining thorough accurate records on the work environment should be quite clear to all plant personnel responsible for environmental health tests.

Records to be of value must be accurate, complete, appropriate, and at the same time as concise as possible. There are many reasons for keeping records applicable to industrial hygiene or environmental health activities. The most important reason is to periodically document an employee's (or group of employees) exposure to known atmospheric contaminants or physical conditions. Such records do not only determine whether or not an exposure of an employee is in conjunction with OSHA standards but can provide data and the potential influence, if any, of his working environment upon him during his total employment period. From the Corporation's viewpoint, environmental health records can also be beneficial in grievances, arbitrations and compensation cases. All of these aspects point up the great need for concise and accurate records.

Good records require, among other factors, good measurements. The need for accurate samples, when monitoring the worker's environment, has been emphasized in previous chapters. Unless this is done, the data derived from the sample has little value. Accurate sampling involves more than good instrumentation. It necessitates recording data on the operations under scrutiny, whether or not the conditions observed are representative, the operating rate of the instrumentation, the location and duration of the sample and other information. In other words, it is just as important to record all the data pertinent to a sample as it is to collect the sample. Good instrumentation is only one phase of collecting good environmental data.

Environmental Health Inventory

Before an industrial hygiene (environmental health) sampling program can be effectively undertaken, knowledge must be developed on where potentially toxic materials and harmful physical conditions are or may be present. This requires a walk-thru type of survey by an industrial hygienist or one adequately trained in associating work conditions and materials with potential health hazards, to determine for each job classification (1) a brief job description; (2) the materials used, by-products and products formed and equipment used; and (3) measures afforded for health protection. An appropriate form on which to record this data is shown in Figure 14-1. In completing this form, it is vital to be brief in recording the pertinent information. Excessive wordage should be avoided. The most important information in this form is recorded in Columns (3) and (4) which relate to the materials used and control measures. The potential health hazards will be derived from Column (3). The control measures which are to be recorded in Column (4) are indicated by merely checking the appropriate space and noting in the spaces afforded other pertinent information relative to the control measures. For example, if respirators are provided, it would be pertinent to note the manufacturer and type, such as "MSA Dustfoe-66."

Upon completion of Figure 14-1 for any division, department or room, the last column is completed by indicating the exposures in each job category utilizing a code consisting of the material abbreviations and materials shown in Figure 14-2. This should be done by a professional industrial hygienist at the start of the program. Therefore, Environmental

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INDUSTRIAL HYGIENE SURVEY

WORKROOM DATA

Facility: _____ Page _____ of _____

Division: _____ Department: _____ Building: _____

Data Source: _____ Surveyed by: _____ Date: _____

OCCUPATION (1)	NATURE OF JOB (2)	RAW MATERIALS AND BY-PRODUCTS (3)	CONTROL MEASURES (4)							REMARKS (5)	ENVIRON. CODE
			LOCAL EXH.	MECHANICAL VENTILATION	WET METHODS	PROTECTIVE EQUIPMENT	RESPIRATOR				

Figure 14-1

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EXPOSURES, CLASSIFIED BY OCCUPATION AND TYPE

Facility:_____ Division: _____ Dept.: _____ Date: _____

DEPT.	OCCUPATION	DUSTS – FUMES							GASES – VAPORS – MISTS									PHYSICAL CONDITIONS						
		SiO_2	Mn	Lime		Lead	CR_2O_3		HCN	NO	Cl	BTX	Chro-mates	Pitch	H_2SO_4			IR	Noise	Heat				
		FeO	Coke	Ore		Fluor	NIO		N H3	H2S	SO2	HCL	CO	Tar	Alk.			UV	Vib.					

Figure 14-2

Health — Pittsburgh should be contacted when the form is completed. Figure 14-2 is a form for summarizing the exposures by department, occupation and type. From this form one can readily review the location of the exposures to air contaminants and physical conditions. The presence of these exposures is denoted by merely an "x" mark in the appropriate box. After thoroughly reviewing the data recorded on these forms, one can establish the sampling or testing program.

Sampling Data

It has been previously stated that the adequacy and accuracy of the sampling data largely determine the validity of the evaluation derived from the test results. Therefore, such data should be as complete as possible and obtained during sampling. The data collected in the field during testing should be recorded for each test on an appropriate form such as the one shown in Figure 14-3 or logged in a field notebook. Certain basic information is required in all sample data or measurements of physical conditions, and in addition, notes should be made regarding special situations which may influence the sample or the interpretation of the analytical results. The data recorded, as a minimum, should include (1) where the sample was taken, (2) when it was taken, and (3) the volume of air that was sampled, (4) the name of the sampling instrument, (5) the type of sample (breathing zone or fixed position), and (6) the operating conditions. Sample location should be specified first by noting the plant name and geographical location; next, the department, and finally the specific location in that department. Most samples will be collected by a worker wearing a personal sampling device. In such cases, the employee's name and/or identification number, as well as his occupation should be recorded. For area samples, it is possible to describe the sampling location by reference to numbers on the building columns or other designations used within a given plant. The records should be sufficiently detailed that another individual would be able to locate the sampling area without the assistance of the person recording the data. When there are a number of singular work stations, machines or jobs in a given department and only one is sampled, then reference should be made to that one location.

The date on which the sample was taken must be recorded, as well as the time the sampling period began and the time sampling ended. If for some reasons sampling is performed discontinuously the individual times at which the sampling started and stopped should be noted. Finally the total number of hours and/or minutes during which the sample was taken should be recorded. Summarizing the following information regarding the sample itself should be recorded: (1) the type and manufacturer of the sampling device, such as MSA Monitaire Model S, MSA Universal Tester, General Radio Model 1565-B sound level meter, etc.; (2) the number or identification of a filter, indicator tube or other collection device; (3) the type of contaminant, i.e., fume, respirable dust, gas, etc.; (4) the type of sample, i.e. breathing zone or fixed position; and (5) the sampling rate at the start and at each check period during the shift.

Finally, a brief description of the work operation being sampled, making special reference to any features of the job which relate directly to the production of air contaminants for which sampling was being performed. This description should include reference to local exhaust or mechanical general ventilation or its absence. For example, are there windows and if so, are they opened or closed? Is there an overhead ventilator or a roof monitor? Are there roof exhaust fans? Is the point of contaminant generation enclosed and provided with exhaust ventilation and does the system appear to be effective? Under remarks, it will usually be useful to make some notation about the presence or absence of visible dustiness in the air, of an odor or irritation to the eyes, nose or throat. Figure 14-3 is an example of a useful form. Others may be developed for each plant's use but it would be desirable to standardize.

Analytical Records

Air samples require analysis of the collected material and/or weighing. These should be placed in an appropriate container together with the form requesting analysis and mailed to ARL-Environmental Health Laboratory, Monroeville. The form requesting laboratory analysis (Figure 14-4) should be completed in full. To insure accurate records, it is imperative that the sample number, location or

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FIELD SAMPLING DATA

Division: _____ Bldg.: _____ Date: _____

Sampling Instrument: _____ Sampling Rate: _____

Contaminants: - Principal: _____ Other: _____

Processes in Area: _____

Type of Contaminant Control: _____

SAMPLE NO.	TYPE OF SAMPLE		FILTER WEIGHT		TIME OF SAMPLING	DURATION OF SAMPLE	SAMPLE VOLUME	OPERATING CONDITIONS
	BZ	Fixed	Tare	Final				

Sampled By: _____

Figure 14-3

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USS ENVIRONMENTAL HEALTH
SAMPLES FOR ANALYSIS

Date Submitted _____

Facility: _____ By _____ Ext. _____

Location: _____ Date Reported _____ Lab.# _____

Dept.: _____ OSHA Insp. _____ Complaint _____ By _____

SAMPLE DATA									ANALYTICAL RESULTS					
NO. (1)	DIVISION DEPARTMENT (2)	JOB, OPERATION or LOCATION (3)	DATE (4)	TIME MIN. (5)	RATE LPM (6)	FINAL WEIGHT (7)	INITIAL WEIGHT (8)	ANALYSIS DESIRED (9)						

Figure 14-4

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operation involved, date, flow rate, sampling time, initial filter weight and the analysis required be indicated. All of this information is necessary to insure complete and accurate records regarding potential exposure to toxic materials.

Many gas and vapor samplers and instruments which measure physical agents are direct reading devices. In the use of these instruments it is necessary to gather most of the previous data and in addition, record the reading. As indicated earlier, when using a direct reading instrument, such as a combustible gas analyzer or a sound level meter, the needle or indicating device generally fluctuates constantly. In general, the intent is to record the average reading along with the range (maximum and minimum).

In addition to records of samples taken as just described, it is important to keep good records concerning the case and maintenance of sampling equipment. Every instrument ought to have a log sheet (a sample was shown in Chapter X, Figure 10-2) on which is recorded the date that instrument was acquired and dates on which calibrations, battery charges or maintenance were performed. A separate sheet should be maintained for the purpose of recording the actual calibration data when it is obtained. Reference should always be made to this sheet when sampling so that suitable corrections for sampling rate or interpretation of instrument readings can be made. Frequently it is desirable to construct a small calibration chart or curve and attach it to the instrument for convenience, but the primary reference should be in the log book.

Exposure Record (Permanent)

The previously noted forms are employed to obtain data from which the exposures of workers, to toxic material and harmful physical conditions, may be determined. Accordingly, it is necessary to compile exposures on an appropriate form. The one used by Headquarters Environmental Health is shown in Figure 14-5. Only the data on this form needs to be revealed to an OSHA or NIOSH representative or to the employee. An exposed employee is entitled to be informed only on the extent of his exposure and not on that of other employees.

Figure 14-5 is used to record only time-weighted average concentrations (TWAC), derived from breathing zone samples, or mean average concentrations of air in plant areas. The former represent exposure while the latter represent data from which exposure may be calculated. This information must be derived from a 4-hour sample, as a minimum, and preferably over the full 8-hour shift. The duration of the sample must be determined from knowledge of the variability of the contaminant concentration over a full-shift and the mobility of the employee. The exposure information is recorded by department and job involved.

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USS – ENVIRONMENTAL HEALTH
INDUSTRIAL HYGIENE SURVEY REPORT

Plant _____
Dates of Survey _____
Project No. _____
Survey Eng. _____

TEST LOCATION		JOB EXPOSURE – FULL SHIFT (mg/m³)												AREA CONCENTRATION – (mg/m³)									
		DUST		FUME										DUST		FUME							
Dept.	Job	No.	$\bar{X}$	No.	$\bar{X}$	No.	$\bar{X}$	No.	$\bar{X}$	No.	$\bar{X}$	No.	$\bar{X}$	No.	$\bar{X}$	No.	$\bar{X}$	No.	$\bar{X}$	No.	$\bar{X}$	No.	$\bar{X}$

Federal Stds.:

Notes:
No. _____ Number of Tests
X _____ Mean Avg. Value

Date of Report: _____

Figure 14-5

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Direct Reading Gas Detecting Tube Systems

A Report of the Joint American Conference of Governmental Industrial Hygienists-American Industrial Hygiene Association Committee on Direct Reading Gas Detecting Systems

Preamble

The Joint Committee recognizes that gas detecting tube systems are widely used by industrial hygienists and by others, and that proper use of such systems can be both desirable and beneficial to industrial hygiene activities. However, it is apparent also that a great deal of the usage of these devices has been by individuals unfamiliar with the limitations of such detecting tube systems. Errors in analyses of workroom atmospheres and unwarranted interpretations of data obtained with the use of such detecting tube systems have resulted from the lack of knowledge on the part of the users and from variations in performance inherent in the specific tube systems. The Committee believes that a reasonable uniformity of performance is necessary, if use of a gas detecting tube system is to be acceptable, and that such uniformity can be fostered by the recommendation of performance specifications for these tubes.

The specifications recommended by this Committee are designed to assure that gas detecting tube systems which conform will yield results which are reliable and uniform within recognized, acceptable, and specified limits of performance. These are performance specifications without regard to design features, production techniques, reagent systems, and mode of operation, which are considered to be the prerogatives of the manufacturers. Nothing in this report and the specifications is intended or is to be construed as an attempt to dictate or to infringe on the prerogatives of the manufacturers in matters of design and production.

The Committee also recognizes that no attempt is being made to ascribe to these tube systems a precision and accuracy which cannot be attained.

Recommended Specifications

These specifications cover the performance standards of colorimetric gas detecting devices for the determination of low concentrations of gases and vapors in ambient air. This does not include usage in stack, process line, or similar sampling procedures. Procedures for testing and calibration are not covered in these specifications.

1. Each tube or batch of tubes supplied by a manufacturer shall be accompanied by a calibration chart or curve showing those concentrations of gas, as volumes of contaminant gas per million volumes of air (ppm), which correspond to changes in length of stain or in color of the reagent under specified conditions of usage.
2. Where indicating tubes of essentially equivalent reliability are available with different modes of reading the color change, the order of preference is: (a) length-of-stain, (b) change in color (hue) or in color intensity.
3. Each batch of detecting tubes supplied shall have been calibrated by the manufacturer against test concentrations at least at one-half, one, two, and five times the Threshold Limit Value (TLV) for the specific gas or vapor. The TLV will correspond to the value printed in the latest list as promulgated by the Threshold Limits Committee of the American Conference of Governmental Industrial Hygienists.
4. Each manufacturer shall specify the methods of tests used in establishing the calibration concentrations. Two independent methods shall be used in checking the calibrations. Examples of methods or sys-

tems for establishing known concentrations are: (a) dynamic flow gas-mixing, (b) vapor pressure, (c) static concentrations, (d) gas diffusion, and (e) independent chemical or physical instrumental analysis of test concentration.

5. At each calibration point listed by the manufacturer, the gas detecting tube shall read correctly to within ±25% of the stated concentration over the working range of the tube. Standard statistical quality control methods should be used by the manufacturer to assure that the ±25% criterion can be met within 95% confidence limits.

6. The temperature, pressure and humidity ranges for which the tube has been calibrated shall be stated by the manufacturer. Variations in calibration or performance of a tube due to temperature, pressure or humidity differences or to tube diameter shall be indicated by the manufacturer and correction data shall be supplied with each box of tubes for use under such conditions.

7. Each box of tubes shall be labeled with the manufacturer's batch number, and the expected month and year of expiration of the tubes. Any explicit instructions for storage shall be printed on each box of tubes.

8. Other gases or vapors which may interfere with the tube's performance shall be listed on each box of tubes, and the amount of interfering substance which may be tolerated without causing variations in excess of the recommended limits over the working range of concentrations shall be stated.

9. The flow rate shall be indicated for each type of tube. Any air-moving device or pump supplied by the manufacturer shall be calibrated by him for volume and flow rate and shall be correct to within ±5%.

10. Where auxiliary air-moving devices are needed to provide suitable flow rate for the use of a tube to detect or to measure extremely low concentrations, the manufacturer shall specify the flow rate necessary and shall supply a calibration curve or data suitable for the low ranges of concentrations.

Further Comment

The Joint Committee recommends that a central agency be established to act as a certifying body to assure that the performance specifications are met. This agency would have to be responsive to the needs of both the users and the manufacturers.

Gas detecting tube systems may be used as an approximate method or screening procedure for the indication of conformity or lack thereof with accepted standards for gases and/or vapors in ambient air when performance of the given tube system has been shown to meet the criteria of uniformity and reliability as set forth in the recommended specifications. Interpretation and utilization of results of measurements made with gas detecting tubes always must take into consideration the analytical limitations of such tube systems.

APPENDIX B

GUIDELINES FOR SELECTION AND USE OF ENVIRONMENTAL HEALTH TEST EQUIPMENT OCCUPATIONAL SAFETY AND HEALTH ACT OF 1970

A. Scope and Application

1. These guidelines shall be used for the selection, purchase, and use by United States Steel personnel of environmental health test equipment to monitor work areas and to conduct environmental health tests during a federal inspection.
2. The Director of Environmental Health shall investigate, test, and approve test equipment which is available for measuring environmental health conditions.
3. The Director of Environmental Health will distribute pertinent information on such equipment after it has been tested and approved.
4. Any equipment presently available but not included in the approved list must be approved by the Director of Environmental Health before purchase and/or use.
5. Environmental health test equipment is to be used only by personnel who have been trained in the calibration, use, and maintenance of the equipment in accordance with instructions and procedures issued or approved by the Director of Environmental Health.

B. Divisions and Associated Subsidiaries

1. Procedures shall be established for the selection, purchase, and use of environmental health test equipment for corresponding Division or Subsidiary plant and headquarters responsibilities after consultation with the Corporation Director of Environmental Health.

C. Equipment Requirements

1. Each plant or operating facility shall purchase test equipment necessary to undertake tests for determining exposures to toxic materials and hazardous physical conditions as required under the Act.
2. As a minimum, each facility should purchase the following equipment:
   a. Particulates — Dust, Fumes, and Mists
      (1) Six long-term personal samplers with indicated accessories.
   b. Gases and Vapors
      (1) One long-term personal sampler for indicating tubes with indicated accessories.
      (2) One combustible gas indicator. 0-100% LEL & 0-10% LEL Scales.
      (3) One carbon monoxide indicator.
      (4) One oxygen indicator.
      (5) One hand pump for indicating tubes.
   c. Noise
      (1) One sound survey meter and calibrator.
   d. Illumination
      (1) One illumination (foot-candle) meter.
   e. Heat
      (1) A dry bulb, a natural wet bulb and a globe thermometer.
3. Each facility should consult with the Director of Environmental Health as to their requirements on the number of testing devices.

D. Approved List of Equipment

1. Personal Samplers (Long-Term)
   a. Particulates - Dust, Fumes, and Mists
      (1) Mine Safety Appliances Company
         (a) No. 458475 - Pump Assembly, 0-10 CFH (similar to No. 92814 except with No. 456275 Battery Pack).
         (b) No. 456059 - Battery Charger Assembly.
         (c) No. 456243 - Holder Assembly complete with Cyclone Plastic Coupler and Sampling Line Assemblies.
         (d) No. 457392 - Coupler, Assembly, Stainless Steel with "0" Rings.

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(e) No. 625412 - Holder, Filter, Package of 12 (Millipore Field Monitor).
(f) No. 456246 - Kit, Supplementary Parts with 3 No. 456224 Support Screens; 1 No. 625417 Tweezer and 1 No. 625416 Brush.
(g) Set of Instructions.
(h) No. 456275 - Replacement Battery.

b. Filters for Personal Samplers
(1) Preweighed cassettes (filters) (for dust only).
(a) Mine Safety Appliances Company No. 457193 - Cassette, Preweighed (used in conjunction with No. 456243 Holder).
(2) Regular Filters (used in conjunction with Mine Safety Appliances Company No. 625412 Holder and No. 456224 Support Screen). These filters *are not preweighed* and must be weighed before and after use on a Mettler H2O or equivalent type balance:
(a) National Environmental Instruments, Inc. (NEII) — (for dust only) No. 3600-101, Type VM-1, 37 mm box of 100.
(b) Mine Safety Appliances Company (for dust only) No. 625413 Filter Disc (membrane type) package of 50.
(c) Gelman Instrument Company (for metal fume, paint-mist, etc.), Glass Fiber, Type A, 37 mm box of 500.
(d) Special filters for acid mists, coke oven fumes, etc. Contact the Director of Environmental Health.

c. Gases and Vapors - Colorimetric (Length of Stain) - Personal Type
(1) Mine Safety Appliances Company
(a) No. 458474 - Pump Assembly, O-2CFH (similar to No. 92813 except with a No. 456275 Battery Pack).
(b) No. 456059 - Battery Charger Assembly.
(c) No. 92943 - Single Tube Holder.
(d) No. 93481 - Multiple Tube Holder.
(e) Set of Instructions.
(f) No. 456275 - Replacement Battery.
(2) Mine Safety Appliances Company Indicating Tubes (used in conjunction with No. 458474 Pump Assembly and No. 92943 Single Tube Holder or No. 93481 Multiple Tube Holder) - Note the accuracy of indicating tubes can be ± 50% and interference from other materials can affect or negate results.
(a) No. 92115 - Ammonia 10-1500 ppm.
(b) No. 91229 - Carbon Monoxide 10-3000 ppm.
(c) No. 91636 - Hydrogen Chloride 2-500 ppm.
(d) No. 87414 - Hydrogen Sulfide 1-800 ppm.
(e) No. 92623 - Sulfur Dioxide 1-400 ppm.

2. Nonpersonal Samplers, Area or Short-Term Samples
a. Indicating Tubes - Colorimetric (length of stain) - As indicated above, the accuracy of indicating tubes can be ± 50% and interference from other materials can affect or negate results.
(1) Mine Safety Appliances Company
(a) No. 83500 - Universal Testing Kit, Model 1.
(b) No. 92115 - Ammonia 10-1500 ppm.
(c) No. 93074 - Aromatic Hydrocarbons (BTX), 5-200 ppm Benzene and/or 10-800 ppm Toluene and/or 10-800 ppm Xylene.
(d) No. 91229 - Carbon Monoxide 10-3000 ppm.
(e) No. 91636 - Hydrogen Chloride 2-500 ppm.
(f) No. 93262 - Hydrogen Cyanide 1-65 ppm.
(g) No. 87414 - Hydrogen Sulfide - 1-800 ppm.
(h) No. 88536 - Methyl Chloroform 100-700 ppm.
(i) No. 92623 - Sulfur Dioxide 1-400 ppm.
(j) No. 85833 - Trichloroethylene 25-600 ppm and/or Perchloroethylene 10-400 ppm.

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(2) Johnson-Williams Products - Bacharach Instrument Company
(a) No. 19-0246 - Test Pump with scales.
(b) No. 19-5010 - 0.2% carbon monoxide - 5-2000 ppm with scale No. 19-014, 0.2% carbon monoxide and orifice A, No. 19-0175.
(c) No. 19-5030 - Hydrogen Sulfide, 1-650 ppm with scale No. 19-0088.
(d) No. 19-5071 - Sulfur Dioxide, 1-600 ppm with scale No. 19-0092.

b. Gas and Vapors - Direct Reading Instruments
(1) Erdco Engineering Corporation
(a) Model 01 HCS, Portable Combustible Gas Indicator with integral pump, dual scale, with calibration curves.
(b) No. OISC Battery Charger.
(2) Johnson-Williams Products
(a) No. 503-001, Model SS-P Super Sensitive Indicator with integral pump and built-in 115 VAC battery charger. Short probe with nonabsorbing hose, filter-dryer cartridges, and charger cord.
(b) No. 340-101 Carrying Case.
(3) Mine Safety Appliances Company
(a) No. 08-74711, Model 40, dual scale, complete with calibration curves, conversion chart and special 5 ft. humidity stabilizing sampling line.

c. Carbon Monoxide Indicator
(1) Mine Safety Appliances Company
(a) No. 08-96300, Model D Portable CO Indicator.
(b) No. 08-96383, Battery Charger.

d. Oxygen Indicators
(1) BioMarine Industries, Inc.
(a) No. OA 222R, Oxygen Analyzer, 0-40%, for use with remote sensor.
(2) Johnson-Williams Products - Bacharach Instrument Company
(a) No. 10-5011, Fyrite Oxygen Analyzer, 0-21% with carrying case.
(3) Mine Safety Appliances Company
(a) No. 458-171, Oxygen Indicator, Model 244R, 0-25% with remote sensor.

3. Physical Measurements
a. Noise Instruments
(1) Bruel & Kjaer Instruments, Inc.
(a) No. 2205, Miniature Sound Level Meter with 4117 (1") Piezoelectric Microphone.
(b) No. 4230, Sound Level Calibrator.
(c) No. KE-0811 Carrying Case.
(2) General Radio
(a) No. 1565-9701, 1565A Sound Level Meter.
(b) No. 1565-9601, 1565-Pl Leather Carrying Case.
(c) No. 1562-9701, 1562A Sound Level Calibrator.
(d) Type 1934 Walsh-Healey Noise Exposure Meter.

b. Illumination Instruments
(1) General Electric Company
(a) Type 213 Light Meter with carrying case (single scale).
(b) Type DR 200 Light Meter, dual range, 0-100/200 foot candles.
(2) Weston Instruments, Inc.
(a) Model 614 Illumination Meter, 0-60/120/600 foot candles.

c. Heat
(1) Howard Engineering Company
(a) Wet Globe Thermometer Kit
(2) Fisher Scientific Company
(a) No. 11-666 Hydrometer, Sling Psychrometer.
(b) No. 11-688 Wet Bulb Thermometer.
(c) No. 11-673 Wicks.

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(3) Black Globe Thermometer (no supplier - should be made at plant)
(a) One thermometer 0°-200° F. with tip centered in a 6" copper toilet float painted with a flat black.

E. Suppliers of Approved Environmental Health Test Equipment

1. Bruel & Kjaer
5111 West 164th Street
Cleveland, Ohio 44142
2. BioMarine Industries, Inc.
303 West Lancaster Avenue
Devon, Pennsylvania 19333
3. Erdco Engineering Corporation
136 Official Road
Addison, Illinois 60101
4. Gelman Instrument Company
P.O. Box 1448
600 South Wagner Road
Ann Arbor, Michigan 48106
5. General Electric Company
Large Lamp Department
Noble Road
Nela Park
Cleveland, Ohio 44112
6. General Radio Company
300 Baker Avenue
Concord, Massachusetts 01742
7. Johnson-Williams Products
Bacharach Instrument Company
625 Alpha Drive
RICD Industrial Park
Pittsburgh, Pennsylvania 15238
8. Mine Safety Appliances Company
201 North Braddock Avenue
Pittsburgh, Pennsylvania 15208
9. National Environmental Instruments, Inc.
P.O. Box 590
Fall River, Massachusetts 02722
10. Western Instruments, Inc.
614 Frelinghuysen Avenue
Newark, New Jersey 07114
11. Howard Engineering Company
P.O. Box 3164
Bethlehem, Pennsylvania 18017
12. Fisher Scientific Company
585 Alpha Drive
Pittsburgh, Pennsylvania 15238

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GLOSSARY

A

Acid. A compound which reacts with an alkali to form a salt and water. It turns litmus paper red.

Activated Carbon (activated charcoal). Activated carbon or charcoal is commonly used in gas-adsorption.

Acuity. Pertains to the sensitivity of a bodily organ to perform its function.

Acute. Severe, often dangerous effect. Also used to denote an exposure to high concentrations of a contaminant for short duration.

Aerodynamic diameter. The diameter of a unit density sphere having the same settling velocity as the particle in question of whatever shape and density.

Aerosols. Liquid droplets or solid particles dispersed in air, that are of fine enough particle size to remain so dispersed for a period of time.

Air conduction. Air conduction is the process by which sound is transmitted through air from one point to another.

Air monitoring. The sampling for and measuring of contaminants in the air.

Aliphatic. Usually applied to petroleum products derived from a paraffin base and having a straight or branched chain, saturated or unsaturated molecular structure.

Alkali (Base, caustic). A compound that has the ability to neutralize an acid and form a salt. Turns litmus paper blue.

Allergy. A response of a hypersensitive person to chemical and physical stimuli.

Alveoli. Tiny air sacs of the lungs at the end of a bronchiole, through which gas exchange takes place by which the blood takes in oxygen and gives up its carbon dioxide in the process of respiration.

Ambient noise (Background). Ambient noise is the total noise within a given environment, being usually a composite of sounds from many sources near and far.

Angstrom (A). Unit of measure of wavelength equal to 10^{-10} meters or 0.1 nanometers (millimicrons).

Aromatic. Applied to a group of hydrocarbons and their derivatives characterized by a molecular ring structure.

Asphyxia. Suffocation from lack of oxygen. Chemical asphyxia is produced by a substance, such as carbon monoxide, that combines with hemoglobin to reduce the blood's capacity to transport oxygen. Simple asphyxia is the result of exposure to a substance, such as carbon dioxide, that displaces oxygen.

Atom. Smallest particle of an element which is capable of entering into a chemical reaction.

Attenuation (sound). The reduction, expressed in decibels, of the sound intensity at a designated first location as compared with sound intensity at a second location, which is acoustically farther from the source.

Audible range. The frequency range over which normal ears hear – approximately 20 Hz through 20,000 Hz. Above the range of 20,000 Hz, the term ultrasonic is used. Below 20 Hz, the term subsonic is used.

Audiogram. A record of hearing loss or hearing level measured at several different frequencies–usually 500 to 6000 Hz. The audiogram may be presented graphically or numerically.

Audiologist. A person trained in the specialized problems of hearing and deafness.

Audiometer. A signal generator or instrument which can be operated manually or automatically for measuring objectively the sensitivity of hearing in decibels referred to audiometric zero. Pure tone audiometers are standard instruments for industrial use.

Auditory. Pertaining to, or involving, the organs of hearing or the sense of hearing.

Auto-ignition temperature. The lowest temperature at which a flammable gas- or vapor-air mixture will ignite from its own heat source or a contacted heated surface without necessity of spark or flame. Vapors and gases will spontaneously ignite at a lower temperature in oxygen than in air, and their auto-ignition temperature may be influenced by the presence of catalytic substances.

B

Bacteria. Small, relatively simple organisms found in soil, water, and alimentary tract of animals and man. Some cause diseases in man.

Band pressure level. The sound pressure level for the sound contained within a specified frequency band. The reference pressure must be specified.

Bandwidth (Acoustic). The range between the low and high cutoff frequencies of an acoustic filter. For measurement of sound the bandwidths generally utilized are octaves, 1/3 and 1/10 octaves.

Boiling point. The temperature at which the vapor pressure of a liquid equals atmospheric pressure.

Bronchial tubes (bronchioles). Branches or subdivisions of the trachea (windpipe) which carry air into and out of the lungs.

Buffer. Any substance in a liquid which tends to resist the change in pH when acid or alkali is added.

C

Carcinogenic. A substance or material capable of producing cancer.

Catalyst. A substance which changes the speed of a chemical reaction but undergoes no permanent change itself.

Chromatograph. An instrument which can separate and analyze mixtures of chemical substances.

Chronic. Applies to persistent, prolonged, repeated exposures and their effects.

Cilia. Tiny hair-like "whips" in the bronchi and other respiratory passages that normally aid in the removal of dust trapped on these moist surfaces.

Cochlea. The auditory part of the inner ear which contains the nerve cells which when damaged results in hearing impairment.

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Compound. A substance composed of two or more elements joined according to the laws of chemical combination. Each compound has its own characteristic properties different from those of its constituent elements.

Concentration. The amount of a given substance in a stated unit of measure. Common methods of stating concentration are percent by weight or by volume, weight per unit volume, normality, etc.

Condensation. Act or process of reducing from one form to another denser form such as steam to water.

Conjunctivitis. Inflammation of the membrane (conjunctiva) that lines the eyelids and covers the front of the eyeball.

Contaminant (Air). A harmful, irritating, or nuisance material that is foreign to the normal atmosphere.

Convection. The motion resulting in a fluid from the differences in density and the action of gravity.

Critical temperature. The temperature above which a gas cannot be liquified by pressure alone.

Cyanosis. Blue appearance of the skin, especially on the face and extremities, indicating a lack of sufficient oxygen in the arterial blood.

D

Damage risk criterion. The suggested base line of noise tolerance. A damage risk criterion may include in its statement a specification of such factors as time of exposure, noise level, and frequency, amount of hearing loss that is considered significant, percentage of the population to be protected, and method of measuring the noise.

Decibel (dB). A dimensionless unit used to express a logarithmic ratio between a measured quantity and a preference quantity. It is commonly used to describe the levels of acoustic intensity, acoustic power sound pressure levels, and hearing threshold when a reference quantity is specified.

Density. The ratio of the mass of a specimen of a substance to its volume.

Dermatitis. Inflammation of the skin from any cause. There are two general types of skin reaction: primary irritation dermatitis and sensitization dermatitis.

Desicant. Material which absorbs moisture.

Dose. A term used interchangeably with "dosage" to express the amount of energy or substance absorbed in a unit volume of an organ or individual. Dose rate is the dose delivered per unit of time.

Dosimeter (dose meter). An instrument which measures the accumulated energy to which one may be exposed, i.e., noise, radiation, etc.

Dry bulb temperature. Temperature of air as determined by a standard thermometer.

Dusts. Solid particles (particulates) of matter which have become airborne.

E

Ear. The entire hearing apparatus, consisting of three parts: the external ear, the middle ear, and the inner ear.

Ear protectors. Plugs or muffs designed to keep noise from the ear to preserve hearing acuity.

Effective temperature. The sensation of warmth or cold felt by the human body.

Electromagnetic radiation: The propagation of varying electric and magnetic fields through space at the speed of light, exhibiting the characteristics of wave motion.

Element. Solid, liquid or gaseous matter which cannot be further decomposed into simpler substances by chemical means.

Elutriator. A device used to separate respirable and non-respirable particulates such as the cyclone or horizontal types.

Emphysema. A lung disease resulting from the enlargement of the alveoli accompanied by destruction of normal tissue.

Epidemiology. A science that deals with the incidence distribution and control of disease in a population.

Esters. Organic compounds which may be made by interaction between an alcohol and an acid, and by other means and includes solvents and natural fats.

Etiology. The study or knowledge of the causes of disease.

Evaporation rate. The ratio of the time required to evaporate a measured volume of a liquid to the time required to evaporate the same volume of a reference liquid under ideal test conditions. The higher the ratio, the slower the evaporation rate.

Excursion. Deviation from a definite path. A movement above or below a norm.

Explosive Limit. See flammable limit.

Exposure. As it pertains to air contaminants, it is the state of being exposed to a concentration of a contaminant.

F

Far Field (free field). In noise measurement, this refers to the distance from the noise source where the sound pressure level decreases 6 dB for each doubling of distance (inverse square law).

Fibrosis. The formation of fibrous tissue usually as a reparative or reactive process.

Flammable (explosive) Limits. The range of flammable vapor or gas-air mixture between the upper and lower flammable limits.

Flash point. The lowest temperature at which a liquid gives off enough vapor to form an ignitable mixture with air and produce a flame when a source of ignition is present.

Foot candle. A unit of illumination. The illumination at a point on a surface which is one foot from, and perpendicular to, a uniform point source of one candle.

Frequency (cps or Hz). The time rate of repetition of a periodic phenomena. The frequency is the reciprocal of the period and is sometimes called pitch.

Fume. Minute solid particles formed by the condensation of a metal vapor.

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G

Gas. Normally formless fluids which occupy the space of enclosure and which can be changed to the liquid or solid state only by combined effect of increased pressure and decreased temperature.

Gravimetric. Of or pertaining to measurement by weight.

H

Hearing conservation. The program for preventing or minimizing noise-induced deafness through audiometric testing, measurement of noise, engineering control and ear protection.

Hearing level. A measurement of hearing acuity. The deviation in decibels of an individual's threshold from the zero reference of the audiometer.

Hearing loss. The deviation of hearing acuity from normal.

Heat stress. The burden, or load of heat, that must be dissipated if the body is to remain in thermal equilibrium.

Hemoglobin. The red coloring matter of the blood which carries the oxygen.

Hydrocarbons. The basic building blocks of all organic chemicals which are composed solely of carbon and hydrogen.

Hygroscopic. Readily absorbing or retaining moisture.

I

Inert (chemical). Not having active properties.

Infrared. The region of the electromagnetic spectrum including wave lengths from 0.78 microns to about 300 microns.

Inorganic. Term used to designate compounds that generally do not contain carbon.

Inverse square law. The propagation of energy through space is inversely proportional to the square of the distance it must travel. An object 3 feet away from an energy source receives 1/9 the energy as an object 1 foot away.

K

Kelvin scale (absolute). The fundamental temperature scale, also called the absolute or thermodynamic scale, in which the temperature measure is based on the average kinetic energy per molecule of a perfect gas. The zero of the Kelvin scale is -273 degrees centigrade.

L

Laser. Light amplification through stimulated emission of radiation resulting when the rate at which energy is added to a monochromatic beam is greater than that at which it is extracted and light amplification results.

Latent period. The time which elapses between exposure and the first manifestation of damage.

LC_{50}. The airborne concentration of a given substance that when inhaled over a period of time will kill 50% of the animals under test.

LD_{50}. The oral dose which is required to produce death in 50 per cent of the exposed species, usually within the first 30 days.

Liquid. A state of matter in which the substance is a formless fluid that flows in accord with the law of gravity.

Lumen. The light flux on one square foot of an area, every part of which is one foot from a point source having a luminous intensity of one candle.

M

Manometer. Instrument for measuring pressure; essentially a U-tube partially filled with a liquid (usually water, mercury, or a light oil), so constructed that the amount of displacement of the liquid indicates the pressure being exerted on the instrument.

Maser. Microwave amplification by stimulated emission of radiation. When used in the term optical maser, it is often interpreted as molecular amplification by stimulated emission of radiation.

Metabolism (Heat). Energy resulting from physical and chemical changes which are constantly occurring in the body. Term used for heat stress evaluation.

Microbar. A unit of pressure, commonly used in acoustics which equals 1 dyne per square centimeter or one newton. A reference point for the decibel, is 0.0002 dyne per square centimeter, or 20 Newtons/M^2.

Micron. A unit of length equal to 10^{-4} centimeter, approximately 1/25,000 of an inch.

Mists. Suspended liquid droplets in air generated by condensation from the gaseous to the liquid state or by breaking up a liquid into a dispersed state, such as by splashing, foaming, or atomizing.

Molecule. Generally the smallest particle of an element or a compound capable of retaining chemical identity with the substance in mass.

Monitor. The measurement of the environmental factors which may adversely affect health.

N

Narcosis. Stupor or unconsciousness produced by chemical substances.

Near field. In noise measurement this refers to a field in the immediate vicinity of the noise source where the sound pressure level does not follow the inverse square law.

Noise. Unwanted sound. Unwanted because it can cause annoyance, interfere with speech or communication, and/or cause hearing impairment.

Noise level. For airborne sound, unless specified to the contrary, noise level is the weighted sound pressure level called sound level; the weighting must be indicated.

Noise reduction. See Attenuation.

Nuisance dust. Generally innocuous dust, not recognized as the direct cause of a serious pathological condition.

O

Octave Band. A frequency range in which the ratio of upper to lower frequency is 2 to 1.

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Organic. Term used to designate chemicals that contain carbon. To date nearly one million organic compounds have been synthesized or isolated. Many occur in nature; others are produced by chemical synthesis.

Otologist. A physician who specializes in diseases of the ear.

Oxygen deficiency. An atmosphere having less than the percentage of oxygen found in normal air. Normally, air contains about 21 per cent oxygen at sea level. When the oxygen concentration in air is reduced to approximately 16 per cent, many individuals become dizzy, experience a buzzing in the ears, and have a rapid heartbeat. OSHA indicates 19.5% as the lower limit of oxygen acceptable in industry.

P

pH. Means used to express the degree of acidity or alkalinity of a solution with neutrality indicated as 7.

Physiology. The science and study of the functions or actions of living organisms.

Pitch. (See Frequency)

Pneumoconiosis. A chronic disease of the lungs resulting from the inhalation of various kinds of dusts. The pneumoconioses which include siderosis (iron oxide), silicosis (free silica), asbestosis (asbestos), etc., generally require a period of years for development.

Pneumonitis (Chemical). Inflammation of the lungs resulting from inhalation of chemical vapors and characterized by an outpouring of fluid in the lungs.

ppm. Parts of vapor or gas or other contaminant per million parts of air by volume.

Presbycusis. The hearing loss normally occurring due to age because of the degeneration of the nerve cells due to the ordinary wear and tear of the aging process.

Psychometer. An instrument consisting of wet and dry bulb thermometers for measuring relative humidity.

Pure Tone. The sound energy which is characterized by its singleness of frequency.

Q

Quartz (free silica). Chrystalline silicone dioxide. The main constituent in sandstone and some igneous rocks.

R

Radiant temperature. The temperature resulting from the body absorbing radiant energy.

Random noise. Random noise is an oscillation whose instantaneous magnitude is not specified for any given instant of time.

Relative humidity. The ratio of the quantity of water vapor present in the air to the quantity which would saturate it at any specific temperature.

Respirable (dust). Term used to indicate particulate matter which can be inhaled. Generally considered to be 5 microns or less in aerodynamic diameter.

Rotameter. A flowmeter, consisting of a precision-bored, tapered, transparent tube with a solid float inside.

S

Sensorineural (hearing loss). The type of hearing loss which affects the inner ear.

Silica gel. A regenerative absorbent consisting of the amorphous silica. Used in dehydrating and in drying and as a catalyst carrier.

Solution. Mixture in which the components lose their identities and are uniformly dispersed. All solutions are composed of a solvent (water or other fluid) and the substance dissolved called the "solute". Air is a solution of oxygen and nitrogen. A true solution is homogeneous as salt in water.

Solvent. A substance which dissolves other substances, most commonly water but often an organic compound.

Sound analyzer. A device for measuring the band pressure or pressure-spectrum level of a sound as a function of frequency.

Sound pressure level, SPL. The level, in decibels, of a sound is 20 times the logarithm to the base 10 of the ratio of the measured pressure of this sound to the reference pressure. The reference pressure is 0.0002 dynes/cm^2.

Specific gravity. The ratio of the mass of a unit volume of a substance to the mass of the same volume of a standard substance at a standard temperature. Water at 39.2°F (4°C) is the standard usually referred to for liquids; for gases, dry air (at the same temperature and pressure as the gas) is often taken as the standard substance.

Spectrum (Noise). The distribution in frequency of the magnitudes (and sometimes phases) of the components of the wave. Spectrum also is used to signify a continuous range of frequencies, usually wide in extent, within which waves have some specified common characteristics.

Speed Interference Level (SIL or PSIL). The speech interference level of a noise is the arithmetic average, in decibels, of the sound pressure levels of the noise in the three octave bands of frequency 600-1200, 1200-2400, 2400-4800 Hz for SIL and the preferred center frequencies of 500, 1000 & 2000 Hz for PSIL.

Spectrophotometer. An instrument used for comparing the relative intensities of the corresponding colors produced by chemical reactions.

Standard temperature and pressure. Measured volumes of gases are generally recalculated to 0° Centigrade and 760 mm pressure.

Static pressure. The potential pressure exerted in all directions by a fluid at rest. For a fluid in motion, it is measured in a direction normal (at right angles) to the direction of flow, thus it shows the tendency to burst or collapse the pipe. When added to velocity pressure, it gives total pressure.

Synergism. Cooperative action of substances whose total effects is greater than the sum of their separate effects.

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Systemic. Spread throughout the body, affecting all body systems and organs, not localized in one spot or area.

T

Tare. A deduction of weight, made in allowance for the weight of a container or medium. The initial weight of a filter, for example.

Temporary threshold shift (TTS). The hearing loss suffered as the result of noise exposure, all of which is recovered during an arbitrary period of time. (The loss which is not recovered is called PTS - Permanent Threshold Shift.)

Time Weighted Average Concentration. Refers to concentrations of contaminants which have been weighted for the time duration of sample. A sufficient number of samples are needed to permit a time-weighted average concentration throughout a complete cycle of operations or throughout the work shift.

TLV. Threshold Limit Value. An exposure level under which most people can work consistently for 8 hours a day, day after day, with no harmful effects. A table of these values and accompanying precautions are published annually by the American Conference of Governmental Industrial Hygienists.

Toxicity. A relative property of a chemical agent and refers to a harmful effect on some biologic mechanism and the condition under which this effect occurs.

Transducer. A device such as a microphone capable of being actuated by waves from one or more transmission systems or media and of supplying related waves to one or more other transmission systems or media.

Transmission loss. The ratio, expressed in decibels, of the sound energy incident on a structure to the sound energy that is transmitted. The term is applied both to building structures (walls, floors, etc.) and to air passages (muffler, ducts, etc.).

U

Ultrasonics. The technology of sound at frequencies above the audio range.

Ultraviolet (black light). Those wavelengths of the electromagnetic spectrum which are shorter than those of visible light and larger than X-rays, 10^{-5} cm to 10^{-6} cm wavelength.

V

Vapor pressure. The pressure characteristic at any given temperature of a vapor in equilibrium with its liquid or solid form.

Vapors. The gaseous form of substances which are normally in the solid or liquid state and which can be changed to these states either by increasing the pressure or decreasing the temperature alone.

Visible radiation. The wavelengths of the electromagnetic spectrum between 10^{-4} cm to 10^{-5} cm.

Volatility. The tendency or ability of a liquid to vaporize. Such liquids as alcohol and gasoline, because of their well-known tendency to evaporate rapidly, are called volatile liquids.

W

Wavelength. The distance in the line of advance of a wave from any point to a like point on the next wave. It is usually measured in Angstroms, microns or nanometers.

Weighting Network (Sound). Electrical networks (A, B, C) which are associated with sound level meters. The C network provides a flat response over the frequency range 20-10,000 Hz of interest while the B and A networks selectively discriminate against low (below 1 KC) frequencies.

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TRAINING PROGRAM

Of major importance to a successful program of corporate compliance with the Occupational Safety and Health Act, but not required by law, is the training of personnel to perform environmental health monitoring. The management team at every employing location must be familiar with its responsibilities and also the rights of employees. In addition, however, the responsible monitoring manager at each employing facility must be adequately trained and prepared to monitor the work place to assure compliance with the law.

The following training outline provides reasonable classroom time devoted to each important phase of OSHAct, and is developed around a two-week schedule of related classroom experiences, plant visits, and lab-type vestibule training. Each user should modify the training program based on his particular requirements and the emphasis of his potential occupational hazards.

Purpose: To train environmental health monitors for in-plant compliance with the OSHA 70 law.

First day:	Introduction, purpose, and background	60 Min.
	Definition & description of OSHAct	90 Min.
	Mathematics & units of industrial hygiene	90 Min.
	Air Contaminants in the industry	90 Min.
	Physical agents in the industry	90 Min.
Second day:	OSHA standards on air contaminants and physical agents	60 Min.
	Monitoring equipment available	60 Min.
	Selection & application of monitoring equipment —	90 Min.
	Monitoring strategy	60 Min.
	Plant visit to relate instrument selection to monitoring requirements	90 Min.
	Discussion of instrument needs for observed areas	60 Min.
Third day:	Use of monitoring instruments for particulates	90 Min.
	Use of monitoring instruments for gases & vapors	90 Min.
	Filter for air sampling — selection and weighing	90 Min.
	Monitoring instrument laboratory session	150 Min.

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Fourth day:	The physics of sound	60 Min.
	Hearing & the effects of sound	60 Min.
	Sound survey instruments	60 Min.
	Noise dosimeters	30 Min.
	OSHA noise standards	30 Min.
	Procedures in noise survey	90 Min.
	Plant visit for noise measurement	90 Min.
Fifth day:	Heat stress	30 Min.
	Heat stress monitoring	60 Min.
	Illumination and vision	60 Min.
	Illumination monitoring	60 Min.
	Non-ionizing radiation	90 Min.
	Ionizing radiation	120 Min.
Sixth day:	Calibration, use and maintenance of monitoring equipment	60 Min.
	Calibration of air monitoring equipment	240 Min.
	Calibration of physical agent monitoring equipment	120 Min.
Seventh day:	Maintenance & repair of equipment	210 Min.
	Weighing filters	120 Min.
	Handling & analysis of samples	90 Min.
Eighth day:	Data collection — visual survey	150 Min.
	Plant visit — visual survey	60 Min.
	Data Collection — monitoring	120 Min.
	OSHA records	90 Min.
Ninth day:	Plant visit — collecting air contaminant samples	210 Min.
	Processing samples and recording data	210 Min.
Tenth day:	Sources of information to environmental monitors	120 Min.
	General review	90 Min.

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