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Foreword

The 13 chapters of this well-constructed multiauthored volume contain a wealth of information not available in any other single contemporary publication, a fact readily verified by a review of the scientific and medical literature. There are various publications that address within their pages one or another of the topics covered in this book, but none discovered are as comprehensive.

If one were to take a basketball-sized globe and place a dot on it for each currently active airport, large, medium, or small, the outlines of the populated continents would be readily apparent. Today's airports are virtual reflectors of human progress and the associated demands for transport. Those numerous individuals in varying pursuits who work at these airports supporting the multifaceted requirements of aviation are the focus of this book.

It is a rare good fortune to have in hand one book of substance that remains on target, reads clearly, is prepared by experts, and addresses topics that physicians and aviation personnel throughout the world are finding of increasing importance. The economics and politics of aeronautical progress are requiring evermore attention to the occupational health of maintenance and support personnel, which is quite apart from the technical side of aviation developments. Within the covers of this book and its associated appendix, extensive guidance with respect to the health of aviation maintenance and support personnel is available, justifying its presence as a constant desk companion to those professional, administrative, and other persons associated with, or with an interest in, this field.

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Preface

The aviation industry employs thousands of workers throughout the world for the production, maintenance, and operation of civil as well as military aircraft. Regardless of the size or sophistication of an airplane, it must be serviced by ground personnel from a legion of flight line facilities. Cleaning, painting, soldering/welding, electroplating, and nondestructive inspection are but a few of the processes that workers perform. Consequently, workers are at risk of occupational illness and injury, albeit this risk can be minimized if a quality occupational health program is implemented.

Although a great deal has been written about the occupational hazards confronting the cockpit crew (hypoxia, acceleration, decompression sickness, and fatigue), there is very little published on the occupational hazards faced by ground support personnel. The major occupational medicine textbooks are almost entirely silent on the subject as are the medical journals.

The objective of the authors is to fill this void by providing the occupational health team a book that describes hazards found in the aviation industry as well as providing recommendations on remedial measures. In order to accomplish this, the early chapters provide a synopsis of the principles of occupational medicine and industrial hygiene. The middle chapters describe occupational hazards specific to aviation with the closing chapters dealing with the special problems of military aviation and the components of an airline occupational health program.

The intended audience is the occupational health team—physicians, nurses, engineers, industrial hygienists, and technicians—whether their affiliation is with general, civil, or military aviation. Although each sector has its own peculiar set of problems, there is clearly much common ground. It is the authors' sincere wish that the material contained herein will be useful. And if it prompts improvement even in one aviation industrial medicine program, our time and efforts will have been worthwhile.

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CHAPTER

1

Introduction

JOSEPH RIBAK

I. HISTORY

Occupational and environmental medicine has its roots in ancient history. It began in the era of Hippocrates and became a specialty due to the efforts of Georgius Agricula and the father of occupational medicine, Bernardino Ramazzini. In Ramazzini's famous book, "De Morbis Artificum," written in the 18th century, many diseases caused by exposures at work were described, including the occupational diseases of painters, potters, and glassmakers. In many instances his accurate descriptions of occupational diseases have undergone little revision over the past 250 years.

Aviation medicine, on the other hand, has only recently been established. The first manned motorized flight by the Wright brothers occurred at Kitty Hawk, North Carolina, in 1903. It did not take long to recognize that the effects of flight on man needed to be considered, and in 1907 a series of papers dealing with the physiological effects of flight were published in France. In 1910 several European countries were already considering instituting medical standards for flying. It was not until 1917, however, that the first aeromedical research laboratory was built in Mineola, New York, and criteria were established for the selection of aviators. From this laboratory came the first flight surgeons of the United States. As aviation technology advanced from the Spirit of St. Louis to the space shuttle of the present time, the physical and mental standards for airmen became more demanding.

An enormous amount of literature has been published on aviation physiology and aviation medicine, most of it dealing exclusively with aircrew. Only rarely are the occupational medical problems of ground personnel addressed despite the fact that in the aviation industry, pilots and other aircrew comprise only 10–15% of the total aviation industry workforce (DeHart, 1990; de Treville, 1985; DeHart and Gullett, 1985; Bruton, 1978), whereas ground personnel make up the remaining 85–90%. Furthermore, ground personnel are exposed to a variety of occupational hazards (physical, physicochemical, chemical, biological, and psychosocial) which demand special consideration.

II. PURPOSE

In the airline industry, both aviation and occupational medicine may be within the same department (DeHart and Gullett, 1985) or purchased from an outside contractor. In either case, this book is intended for flight surgeons and aviation medical examiners whose practice includes the care of ground personnel and for trained occupational health personnel and primary care physicians who may be employed by the aviation industry.

III. THE AIRPORT

The airport is actually a large factory with a myriad of tasks being performed as airplanes are serviced and prepared for flight. Airfield support services include control tower operators, fire brigade, security personnel, police, maintenance and repair, cargo services, ground transportation, aircraft sanitation and hygiene, food services, and baggage handling. Thousands of workers are on duty to keep the airport operating smoothly and safely 24 hours a day, 365 days a year.

The airport is an integrated unit with several overlapping spheres of authority and responsibility (Fig. 1). Circle 1 comprises airport services which are responsible for the smooth operation of the airfield and includes air traffic controllers, security personnel, and fire and emergency services. Circle 2 represents the airlines and includes maintenance which operates from the airport. Although minor repairs may be made easily, major problems require repair at the main maintenance facilities where a large number of workers with widely varying job descriptions are available. Circle 3 represents support facilities which are on the periphery of the airport, but are, nevertheless, very important since they provide essential services such as catering, sanitation, and ground transportation.

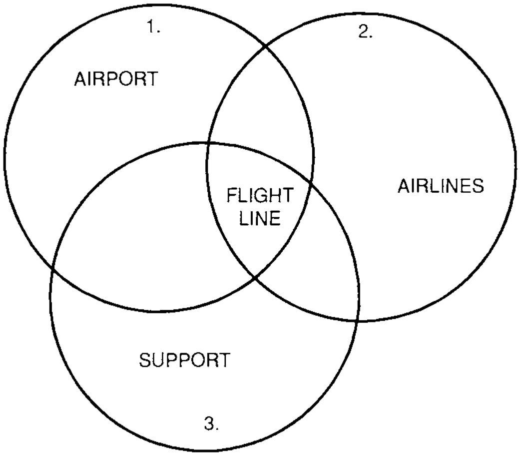

FIG. 1. Overlapping spheres of authority and responsibility at the airport.

These circles of authority must be coordinated and integrated in order to provide the public with safe and efficient service.

IV. CONTENT AND STRUCTURE

The material in this book will provide the physician, nurse, industrial hygienist, and technician with basic information on health care services at an airport, civil or military. There is also application to health care services in the aircraft manufacturing industry. Although this book is not intended to be a textbook in general occupational medicine, the first chapters provide the reader with basic information needed to understand subsequent chapters. Following this is an extensive overview of airport operations, essential information for occupational medicine personnel. Finally, the book closes with two chapters describing special aviation environments (military and agriculture) and a summary chapter with recommendations on how to manage an occupational health program.

We hope this book will provide the reader with the basic knowledge needed to properly run the health services at an airport.

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CHAPTER

2

Principles of Occupational Medicine

JOSEPH RIBAK *and* PAUL FROOM

I. INTRODUCTION

Occupational physicians have an extensive and varied task. In order to identify, treat, and prevent occupationally related diseases, they must determine if diseases present in the general population are associated with exposures in the workplace. Exploring the interface between the worker and the work environment requires epidemiological tools, as well as personal initiative. Finally, the occupational physician has to understand the rationale behind screening and how to interpret testing done in asymptomatic workers.

II. PREVENTION IN OCCUPATIONAL HEALTH

The occupational medicine physician depends upon preemployment and annual physical examinations, biological and environmental monitoring, work fitness evaluations, ergonomic assessment, first aid, and health promotion to prevent work-related diseases and injuries. Prevention of disease occurs at various levels defined as primary, secondary, and tertiary prevention.

A. Primary Prevention

Preventing toxic exposure in the workplace is the objective of primary prevention. Examples include substitution of a toxic substance for a less toxic one, provision of personal protective equipment such as masks and goggles, immunization, and health promotion programs. Another vital element of primary prevention is the selection of employees through preemployment screening in order to eliminate susceptible workers from stresses that are likely to result in work-related diseases or injuries.

B. Secondary Prevention

Secondary prevention is the detection of disease before the development of disability. Biological exposure and medical monitoring are essential components of secondary prevention of occupational disease. For example, a toxic exposure unknown to the worker might be detected by periodic biologic exposure monitoring. Restriction from the work area may be necessary and corrective action recommended.

C. Tertiary Prevention

Tertiary prevention is the early rehabilitation of the injured or diseased worker in order to limit disability and impairment. Gradual return to work after a myocardial infarction is an example of tertiary prevention.

Prevention of exposure to lead can be used as an example of the three levels of prevention. Proper ventilation and the provision of gloves and masks is part of primary prevention. Removing asymptomatic workers from exposure when blood lead levels are over 60 μg/100 ml is an example of secondary prevention. Finally, chelation therapy in those with symptomatic lead poisoning represents tertiary prevention. When primary prevention and secondary prevention fail, tertiary prevention becomes necessary. Thus, the occupational physician at the airport, in addition to providing acute care, is responsible for prevention of injury and disease by implementing biomedical, environmental, as well as health promotion programs.

III. WORK ACCIDENTS

In occupational health it is important to differentiate between acute events as opposed to chronic ones. Most acute events are due to accidents or incidents during work. A work accident is defined as an acute, sudden event usually due to trauma or a single exposure to high levels of an occupational risk factor and can range in severity from a minor scratch to death of the worker. It can take the form of a work injury when slips, trips, or falls occur, and includes road accidents to, from or during work. On the other hand, work accidents may be secondary to an acute exposure to high concentrations of various chemicals. For example, when an aircraft is not cleaned properly after aerial spraying of pesticides, the mechanic may be exposed to a high concentration of organophosphate pesticides. This may lead to acute poisoning which, if not immediately treated, may be fatal.

Work accidents including acute toxicological exposures are relatively easy to define. They usually occur at work and the time interval between the exposure and the demonstrated health effects is short (minutes to hours). Therefore, the problem of causality does not exist because the source and/or reason for exposure is known. Proper safety measures including a safe code of practice should be implemented in order to prevent such accidents from recurring.

IV. OCCUPATIONAL DISEASES

Occupational diseases are commonly chronic conditions caused by many years of exposure on the job to risk factors classified as physical, physicochemical, chemical, biologic, or psychosocial. It is extremely important to emphasize the major characteristics of occupational disease in order to help the occupational physician recognize the relationship between disease and work exposure, and to recognize the limitations when establishing such associations.

The signs and symptoms of most occupational diseases are indistinguishable from the same diseases due to nonoccupational causes. For example, lung cancer due to smoking or asbestos exposure may not be different in its clinical presentation or histological type. Similar neurobehavioral signs may be found in alcoholics, in patients with degenerative disease of the nervous system, or in those exposed to organic solvents.

There are, however, a few diseases which are caused almost exclusively by occupational exposure. For example, mesothelioma of the pleura or peritoneum is almost always caused by exposure to asbestos. Although it is a very rare disease in the general population, it is responsible for approximately 10% of total mortality in asbestos workers (Seidman *et al.*, 1979). Another disease is hemangiosarcoma of the liver which is almost exclusively caused by exposure to vinyl chloride monomer used in the production of polyvinyl chloride, although it can also be caused by exposure to arsenic and thorotrast (Neugut *et al.,* 1987).

Another important characteristic of occupational disease is a long latency period. It is unusual to diagnose an occupational disease in the first few years of employment unless the exposure is extreme. For most occupational cancers, the latency period ranges from 5 to 40 years. Understanding latency is very important since diseases diagnosed today are usually due to exposure many years ago. Therefore, acute disease is not always a sensitive indicator of a safe workplace.

The risk of disease after exposure usually demonstrates no threshold effect and generally increases over time. Even short exposures at work may lead to occupational disease if the follow-up period is long enough. This has been demonstrated in asbestos workers in whom a 1-month exposure resulted in mesothelioma 40 years later (Seidman *et al.*, 1979). Therefore, even brief periods of exposure require continued medical follow-up for potential disease since cessation of exposure does not eliminate the risk. Instead, the risk increases over time.

The etiology of occupational diseases is usually multifactorial. Very often the worker is exposed to a multitude of chemicals at the workplace and even to a combination of physical and chemical exposures. Furthermore, solutions may contain dozens of substances. Aviation gasoline, for example, contains close to 300 different chemicals including aliphatic and aromatic hydrocarbons. Therefore, it is often impossible to determine which of the compounds is responsible for the occupational disease and difficult to set up a model of interaction between the numerous chemicals. Self-imposed stresses, such as smoking and alcohol consumption, may further complicate the picture.

The interactions between the various factors can be additive or synergistic. Synergism is defined as an effect of two agents which is greater than the sum of the individual effect of each agent alone. A striking example of synergism is the relation between lung cancer due to asbestos exposure and smoking (Hammond *et al.*, 1979). The relative risk of a smoker to develop lung cancer is around 10. Hammond *et al.* (1979) reported a relative risk for lung cancer of 5 in nonsmoking asbestos-exposed workers, whereas the combined risk of smoking and asbestos exposure rose to 53.

Some exposures make existing nonoccupational diseases more severe. A worker, for example, who suffers from diabetes mellitus may have a more severe peripheral neuropathy if exposed to vibration at work. We have to remember that multifactorial etiology is the rule rather than the exception in occupational health.

Finally, not every disease outcome is the complete return to perfect health. There are cases when the outcome of disease leads to impairment, disability, or handicap. Impairment is an anatomical or functional abnormality or loss remaining after maximal rehabilitation. It may be total or partial but it is stable and nonprogressive. Disability is any temporary or long-term reduction of a person's activity as a result of an acute or chronic condition. A handicap limits or prevents an impaired or disabled person from performing normal tasks. In general, impairment refers to an organ dysfunction, disability concerns the inadequate functioning of the individual, and handicap refers to a person's difficulties in leading a normal life.

V. CAUSALITY

The causal connection between various exposures at work and occupational or work-related diseases is crucial in deciding whether or not the diseased worker deserves compensation. The establishment of causality can result in the removal of a toxic material from the work environment or the implementation of protective measures.

The determination of causality in occupational disease is difficult, however, due to the characteristics of such diseases as described above. Care is needed in order to ensure that there is actually an association between the disease and the exposure, since such associations have considerable medical and financial implications. If erroneous associations are made, the worker may be caused unwarranted concern and the factory undue expense in removing chemicals or providing additional protective equipment. Classical causality criteria were developed by Hill (Hill, 1986; Weed, 1965), and the generally accepted criteria are listed in Table I.

A. Strength

Is the association between exposure and the disease strong? The main measure of strength of an association is the relative risk (RR) which is defined as the disease incidence in those exposed to the risk factor divided by the disease incidence in those unexposed. When the disease incidence is not available, such as in case–control studies, the odds ratio (OR) is used to estimate the RR. It is defined as the odds of exposure in the diseased worker divided by the odds of exposure in the controls. In rare diseases the odds ratio is an accurate estimate of the relative risk. The higher the RR or OR, the higher is the strength of the association. The strength of an association may be influenced by confounding factors,

TABLE I
Criteria for Causality

Strength
Consistency
Specificity
Temporality
Dose–Response
Biological Plausibility

such as age, sex, or smoking, which can bias results. These and other factors can distort the apparent magnitude of the effect. Therefore, proper control of confounders is required in the design phase of a study and during analysis.

B. Consistency

Do other investigators constantly find the same results? Numerous studies showing consistent results are needed in order to accept a causal relationship.

C. Specificity

Is the association found limited to a single cause and a single effect? As mentioned above, specificity is generally lacking in occupational diseases which makes the establishment of causality more difficult.

D. Temporality

Does the cause of the disease precede the disease itself? This is important especially in cross-sectional studies. For example, blood lead levels have been associated with increases in blood pressure in the general population. In cross-sectional studies temporality, however, cannot be shown. That is, it cannot be demonstrated that high blood lead levels antedated the development of hypertension. To establish temporality, baseline blood pressure levels and blood lead levels must be determined with follow-up measurements for comparison.

E. Dose Response

Is there a relationship in which changes in amount, intensity, or duration of exposure are associated with a change (increase or decrease) in the risk of a specified outcome, i.e., dose response? For example, the incidence of lung cancer has been shown to increase as the degree of asbestos fiber exposure increases (often measured in fiber years).

F. Biological Plausibility

Can the association found be explained by known biological mechanisms? There is, for example, extensive literature showing the connection between asbestos fibers and lung fibrosis, due most probably to cytokines secreted by lung macrophages.

G. Difficulties in Proving a Causal Relationship

Temporality, strength, and consistency are the most important criteria in proving a causal relationship. The presence of other criteria support causality, while their absence does not refute it.

For a number of reasons, there are major difficulties in proving causal relationships in occupational health. As mentioned above, we are dealing with thousands of chemicals of which only a few have been thoroughly studied and their potential risks defined. New chemicals are produced every day and overwhelm our capacity to study their health effects on humans.

There are relatively few workers in a given vocation or profession in comparison to the general population. Therefore, even if there is an association between a given disease and a given vocational group, it may not be perceptible in national statistics, where the majority of cases are not associated with exposure. This is called the dilution effect, an example of which is asbestos exposure. Lung cancer is very common in the general population, so few of the patients will have a history of asbestos exposure. Therefore, associations are found often only after an alert physician or nurse mindful of occupational exposure detects an increase in the incidence of a given disease among workers.

There is often a large degree of turnover in the work force. This is especially true of high risk, high exposure jobs where workers tend to move to other jobs with less risk. Thus, they are often lost to follow-up and years later when disease develops due to the previous exposure, no one makes the causal inference.

Recall bias is another important factor which causes difficulties in determining causality. Many workers tend to forget previous jobs and do not pay attention to past exposures unless they become ill and an occupational history is taken by the managing physician.

Animal models are not always available for research on chemical exposures, and when they are, it is often tenuous to extrapolate findings from animal studies to humans. For example, exposure to arsenic causes occupational cancer of the lung, liver, and skin, but there is no animal model for arsenic-related cancer. On the other hand, aromatic amines, which cause bladder cancer in humans, were shown to be causally related to bladder cancer in an experimental dog model (Huper, 1969).

Presence of a documented dose–response relationship can help determine causality. However, we are often faced with exposures that cause occupational diseases but no clear dose–response relationship can be demonstrated because of the lack of sensitivity of the studies (too few cases and difficulties in determining the actual dose).

There are common measures used in epidemiological studies in occupational health which are important to understand (including their limitations) when assessing causality. Standard mortality ratio (SMR) is the ratio of the observed number of deaths in the study group to the expected number of deaths based on the incidence in a standard population. Standardized mortality ratios might be compared with one another, either across different studies or within a single study, in order to examine the effect of an occupational risk factor of interest (Halperin *et al.*, 1986). We have to remember that such a comparison sometimes may be misleading, especially when we deal with populations being compared which differ in respect to a factor that can modify the effect of the exposure (e.g., latency period).

Proportionate mortality ratio (PMR) is the ratio of the number of deaths from a specific cause in the exposed population as a proportion of the total number of deaths in that population to the number of deaths from that cause in the general population as a proportion of the deaths in the general population during the same time interval. The PMR is a good epidemiologic measure for the surveillance of occupational mortality. It can identify occupational groups with an increased risk from cause-specific mortality (Melius *et al.*, 1989).

An example of a mortality study on aircraft manufacturing workers in Southern California can be found in the work of Garabrant *et al.* (1988). They followed a cohort of 1406 aircraft manufacturing workers historically for a mean duration of 15.8 years from date of first employment. Standardized mortality rates were calculated based on United States national mortality rates and also on San Diego county mortality rates. They found that mortality due to all causes was significantly lower (SMR=75) than that of the general population as was the mortality due to all cancers (SMR=84), with no excess of specific cancers (an SMR or PMR which is identical to the control population equals 100). The authors mention the problem of latency which might be too short for some cancers which require 20–30 years to manifest themselves.

The low SMR observed in the aircraft manufacturing workers may have been due to the healthy worker effect. Occupational cohort studies usually compare morbidity or mortality rates of a cohort of workers with that of the general population. Employees usually undergo a preemployment screening which selects the fittest individuals for the job, excluding those who are unfit. Furthermore, those who are ill are likely to stop working or change to an easier job. Because the general population is composed of healthy and ill individuals, the working population will appear healthier than the general population. One way to overcome that bias is to compare disease or mortality rates between groups of workers.

VI. MONITORING IN OCCUPATIONAL HEALTH

A. Environmental Monitoring

Occupational health monitoring can be environmental, biological, and medical. Environmental monitoring is the first line of defense in preventing occupational injuries and diseases. It is the responsibility of the industrial hygienist who is professionally trained in the methods for evaluating the work environment. Measurements of exposure to physical, physicochemical, or chemical risks can be done in the general work environment or more specifically by personal monitoring of the worker. Detection of levels higher than the standard necessitates immediate corrective action to prevent further exposures. There are specific criteria for most physical and chemical exposures (see Chapter 3).

B. Biological Exposure Monitoring

Assuming that there are exposures which cannot be totally eliminated from the workplace, the second line of defense is biological exposure monitoring. Blood, urine, nails, hair, or other tissues of the body are analyzed in order to detect higher than normal exposure levels. Biological exposure indices (BEI) exist for many of the hazardous exposures at the workplace. Early detection of significant exposure (before there is any evidence of a disease) can point to areas where environmental monitoring was ineffective and can signal the need to remove the worker from the workplace. In cases in which the BEI is exceeded, active treatment may be indicated in order to rid the body of the offending agent and prevent or modify the course of the occupational disease or intoxication.

C. Medical Monitoring

The occupational physician deals with three primary types of examinations in the office setting: preemployment examinations, periodic statutory checkups, and fitness-for-work (i.e., disability) examinations. The purpose of preemployment examinations is to determine if the applicant is suitable for the proposed occupation. Two major questions must be answered in preemployment examinations: is the applicant at increased risk to develop job-related disorders because of preexisting diseases, and will certain preexisting conditions of the applicant affect safety in the workplace? Periodic checkups are often required by law and, therefore, are statutory, although physicians may still include such monitoring based upon their medical judgment. Biological exposure monitoring and/or testing for specific target organ damage are frequently part of such medical examinations. Finally, fitness-for-work examinations are those generally initiated by the worker in order to determine if a disease is compatible with continued employment in the present job.

1. Occupational Medical History Although the occupational history is important for each of the three types of examinations, it is particularly relevant for the statutory and fitness-for-work examinations. It is crucial for determining causality of occupational exposures and diseases, proper timing for removal of a worker from continued exposure, and for disposition as to whether an ill worker can continue in the present occupational setting.

Components of an occupational history include: current workplace, job title and description, duration of employment, work conditions, exposures at the workstation and nearby workstations, detailed description of work processes and work practices, past jobs and exposures, military service exposures, hobbies at home, and method of performance and work done at home or at a secondary job. Workers often do not volunteer such information. Therefore, it must be ascertained by proper history taking.

Although the basic history may be obtained at the medical facility, there is no substitute for visiting the work site. Only then can the physician properly define the work tasks and their concomitant risks. For example, surface cleaning may involve high concentrations of acids. Only in the workplace can the physician determine if such cleaning is done safely. Because work accidents are the most common cause of disability, the input of the physician at the work site is essential. Furthermore, understanding the work processes and the tasks is the only way to determine if an ill worker is able to continue a given job. Finally, such visits are likely to increase rapport between the worker and the occupational physician and increase the likelihood that an affected worker will report minor symptoms.

2. Physical Examination Preemployment physical examinations are sometimes useful in identifying applicants who are unfit for a particular job. Otherwise they are usually uninformative with the exception of blood pressure determinations. Mild increases in blood pressure (>140/90–160/95) occur in up to 15% of men in their twenties (Froom *et al.*, 1983). However, caution is advised in the job disposition of these applicants. For these individuals, the risk of future elevations of blood pressure over the subsequent 20 years is only double, and the incidence of frank hypertension requiring treatment is less than 2% until age 40. Thus, mild increases in blood pressure should not be a reason for rejecting the young applicant. Furthermore, the labeling of such workers as suffering from "borderline" hypertension can have negative consequences including an increased incidence of absenteeism.

On the other hand, increased blood pressure in the middle-aged applicant, especially with values of >160/100, is associated with significant morbidity and mortality. Also, hypertension is frequently associated with other cardiovascular risk factors such as obesity, smoking, and hypercholesterolemia. A combination of these risk factors may be synergistic in predicting morbidity and morality from diseases of the cardiovascular system. Therefore, the increased risk of morbidity and mortality in middle-aged men can be estimated and should be taken into consideration before accepting such applicants.

The physical examination may be much more informative on statutory and fitness-for-work examinations (see Chapters 7 and 11). For example, look for hand tremor in workers exposed to mercury, pulmonary disease for those exposed to dusts, and dermatitis for those workers exposed to various chemicals such as solvents. In fitness-for-work examinations, the physical examination, in general, is dictated by the complaints of the worker.

3. Testing Most preemployment examinations include a number of blood and urine tests for which caution must be exercised when ordering and interpreting them. The "normal" test is defined as the central 95% of values found on the distribution curve, whereas 5% of the values are automatically defined as "abnormal." If such tests results are independent, there is a 64% chance of at least one abnormal test if 20 tests are ordered. Furthermore, a positive test often leads to a follow-up battery of further tests with subsequent positive findings causing a number of negative consequences. First of all, positive tests may cause anxiety in the worker. Second, repeated testing with follow-up visits leads to an increase in medical costs and patient inconvenience. Such "fishing expeditions" are not recommended. Rather, specific testing (as opposed to battery testing) directed by the results of the history and physical examination is more likely to be productive.

As an example, the urinalysis has been regarded as an important marker of health and is often a routine test in preemployment examinations. The simplicity of both obtaining a specimen and performing the test (by reagent strip, microscopic examination, or both) may partially explain why it is so frequently ordered. In any event, the occupational medicine physician is often in the position of having to explain why a worker has hematuria or proteinuria.

Microscopic hematuria is generally defined as at least 2–4 RBCs/high-powered field (Froom *et al.*, 1984). It should be kept in mind that its prevalence probably increases with age, and after 60 normal values (95% of the population) may increase up to 8 RBCs per high-power field (Freni *et al.*, 1979). For young males, 5% have microscopic hematuria on single specimens, whereas if urinalysis is done yearly, a cumulative incidence of 38.7% has been reported in subjects tested for an average of 12.2 years (Froom *et al.*, 1984).

"Blood" in the urine causes anxiety to both the physician and the patient. Even though the finding is very common and the risk of significant urethral or nephrological disease is low, urologists often recommend a complete workup of patients with even one red cell per high-power field. These recommendations are based on their experience with patients referred to them. In most cases, patients seen by urologists are different from those seen by occupational medicine physicians. This is important when considering the proper approach to the young worker with incidental microscopic hematuria. Microscopic hematuria is a good example of a common finding which is rarely of significance. Urinalysis, therefore, should generally not be routinely ordered (if not required by law) in workers without potential exposure to nephrotoxic agents.

Proteinuria is usually tested by reagent strips. A positive reaction is indicated by a color change from yellow to either green or blue. The currently available dipstick methods react mainly to albumin; other proteins, such as gamma globulin, even in high concentrations, are usually not detected. Therefore, it may not be a sensitive test of nephrotoxic damage due to chemical exposure. Furthermore, false-positive results may be obtained in highly concentrated urine, after heavy exercise, in those with a high fever, after exposure to cold, and in highly alkaline urines. In fact, the prevalence of proteinuria may be as high as 5.8% in young men (Glassock, 1981). Generally, positive tests are trace positive only and transient. Therefore, like microscopic hematuria, such results rarely herald significant disease.

On the other hand, specific testing on preemployment examinations should be done to establish a baseline in workers who will be exposed to certain chemicals. Such a baseline is essential in order to compare it to subsequent tests should they be necessary. A list of recommended preemployment tests for the most common exposures is found in Chapter 11 (Table I).

Testing in periodic statutory examinations is dictated by potential damage due to the specific exposure. For example, a complete blood count is recommended in workers at increased risk for myelodysplasia due to exposure to benzene (see Chapter 7). Whereas testing in fitness-to-work examinations should be a function of specific complaints and the workplace environment.

In summary, testing should be kept at a minimum because general, nonspecific testing may cause more harm than good. Specific exposures or potential exposures and specific complaints should direct the physician in the choice of appropriate laboratory tests. Recommendations for appropriate testing in workers exposed to various chemicals can be found in Chapters 7 and 11.

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CHAPTER

3

Overview of Occupational Hygiene

ASHER PARDO

I. INTRODUCTION

Occupational health progressed greatly after the establishment of a clear cause and effect relationship between work and illness. Occupational health in the 19th century focused on the injured worker, legislating the right to compensation for occupational injuries. In the 20th century the emphasis changed to the long-term effects of the workplace environment on workers' health. Professionals started looking at the sources of exposure in order to prevent hazards, leading to the establishment of an independent science called industrial hygiene. Later, the field expanded to include occupations not necessarily industrial by nature. Hence, the broader term occupational hygiene evolved which encompasses the protection of worker health by control of the work environment.

Some important landmarks in the development of occupational hygiene in the United States may serve as an example of the worldwide progress in this field (Hansen, 1991). In 1905, Massachusetts became the first state to employ health inspectors who investigated health hazards in workplaces. The U.S. Department of Labor was established in 1913, and one of its sections was charged with collecting data on occupational accidents and health problems. In the same year the National Safety Council was established, originally called the National Council for Industrial Safety. During the second decade of the 20th century, concern for industrial hygiene and safety deepened with the establishment of the U.S. Office of Industrial Hygiene and Sanitation in 1914 and the American Society of Safety Engineers in 1915. An academic degree program in industrial hygiene was first established at Harvard Medical School in 1918. Health and safety requirements for government contractors were laid down by the Walsh Healy Public Contracts Act passed in 1936 and updated in 1970 in the Occupational Safety and Health Act.

National studies of occupational diseases and disasters as well as the reporting of incidents of occupational exposures and air pollution has led to the founding of federal and voluntary professional organizations and stricter health standards. For example, the "dusty trades" studies, begun in 1923, discovered a high incidence of silicosis among granite industry workers.

In 1938, the American Conference of Governmental Industrial Hygienists (ACGIH), one of the leading organizations in promoting industrial health standards, was formed. The ACGIH adopted the first list of threshold limit values (TLVs), then termed maximum allowable concentrations (MACs), with an expanded list of recommendations published in 1961. Many countries have adopted the ACGIH TLVs.

Dramatic progress in occupational health occurred in 1970 when the U.S. federal government passed the Occupational Safety and Health Act. Assuring safe working conditions is the fundamental principle underlying this act. It includes procedures for promulgation of regulations, for conducting investigations for compliance, and for maintenance of exposure records. The Occupational Safety and Health Administration (OSHA) and the National Institute of Safety and Health (NIOSH) were established through this act.

Occupational health rotates on an axis defined by the working person and the environment. This axis is characterized by a chain of action and reaction. An environmental change, such as development of a new industrial process or technology, results in new hazards to the worker. Health damage to the worker as well as aesthetic damage to the environment are reactions for which a solution is sought, often through additional changes in the environment.

II. DEFINITIONS AND GOALS

Industrial hygiene is defined by the American Industrial Hygiene Association as "the science and art devoted to the recognition, evaluation and control of those environmental factors or stresses arising in or from the workplace that may cause sickness, impaired health and well-being, or significant discomfort and inefficiency among workers or among the citizens of the community" (Plog, 1988). By definition, the practice of occupational hygiene (concerned with all workers and not just those in industry) requires three basic steps: recognition, evaluation, and control. First, the potential hazard is recognized in the workplace and its nature and properties are studied. Next, the evaluation of actual exposure to the hazard takes place, mainly by quantifying the intensity of the hazard using various monitoring techniques. The results are compared to accepted occupational health standards. Following the qualitative and quantitative characterization of the hazard, the third step involves short- and long-term control and preventive measures to minimize or eliminate the hazard.

The above sequence of steps may be erroneously interpreted to mean that an actual hazard has to exist before preventive action is taken. In fact, control measures should be incorporated in the workplace at the earliest possible stage of design or operation so as to prevent even the potential appearance of the hazard. Control of the hazard and prevention of exposure is defined as primary prevention (see Chapter 2) and is the major task of occupational hygiene.

Primary prevention is best applied at the stage of process planning and design. In practice, however, planning of industrial activities usually incorporates little or no involvement of appropriate health professionals or of adequate health and safety principles and guidelines. As a result, the occupational hygienist attempts to prevent exposure in existing facilities.

Occupational hygiene is a multidisciplinary science and is best applied in a workplace within the framework of a team, including occupational physicians and nurses, occupational hygienists, technicians, and safety professionals. The occupational hygienist provides the plant physician with information about work operations and industrial processes and their associated hazards and consults with safety professionals. In addition, the occupational hygienist is involved in the monitoring and assessment of workers' exposure, using sampling and analytical techniques, and in training and counseling employees and employers regarding health hazards and the necessary precautions to avoid adverse health effects.

III. OCCUPATIONAL HEALTH HAZARDS

Exposure is defined as a single or repeated contact of the body with an external factor in the environment. An agent capable of producing an adverse health or safety effect is defined as an occupational hazard, and any exposed worker may be considered to bear a potential health risk. As long as the worker is reasonably isolated from the hazard, or in contact with an agent too weak to produce adverse health effects, it may be considered as a potential hazard. Once the exposure reaches significant levels, the risk becomes actual.

Occupational hygiene deals with environmental hazards and stresses originating in chemical, physical, biological, and ergonomical factors. In addition, the occupational hygienist should be aware of environmental factors which may cause mental and social stresses, such as the isolation effects in control rooms or the overcrowding of workstations. A classification of health hazards is shown in Table I.

IV. CHEMICAL HAZARDS

Chemical agents may exist in the workplace in pure form or in mixtures. The number of chemicals used in industry, commerce, and services is enormous. Chemical agents appear in industrial processes as raw materials, intermediates, products, by-products, and wastes. Intermediates are those materials generated at some stage of production and used as precursors for the next stage or converted to more stable by-products. Sulfur trioxide (SO_3) is an example of an intermediate because it reacts in moist air to form sulfuric acid. Hot metals are also subject to further oxidation in the atmosphere and, therefore, appear mostly as their oxides in thermal processes. Hazardous by-products are a problem when emitted from

TABLE I
Classification of Sources of Health Hazards

Type	Examples
Chemical	Irritant gases and vapors, toxic metals, pesticides, organic solvents, corrosive acids, chemical carcinogens
Physical	Noise, vibration, heat and cold stress, pressure, radiation
Physicochemical	Pneumoconiotic dusts (silica, talc, asbestosis)
Biological	Bacteria, virus, fungi, parasites
Ergonomic	Musculoskeletal stress, repetitive motion, sensory overload
Psychosocial	Stress, anxiety, tension, overcrowding, isolation
Physical safety	Unguarded machines, electricity, flammability, explosiveness

an industrial process because workers may be exposed to them without being aware of their existence. Carbon monoxide, sulfur dioxide, and cyanides are good examples of by-products which have caused fatal accidents.

In general, potential chemical hazards exist in handling, preparation for processing (weighing, compounding, mixing), processing, transporting, as well as in laboratory operations, product disintegration, and waste treatment. The environmental vehicles of hazardous chemicals are air, water, and soil, although water and soil are less common sources of occupational exposure with most exposure situations involving airborne chemical substances. Direct contact with the agent is another common vehicle of exposure.

The recognition of a hazardous chemical substance requires familiarity with its nature and structure, physical state as airborne matter (solid, liquid, or gas), other physical and chemical properties, route of entry into the body, and mode of action and adverse health effects. In addition, the physical environment and the pattern of work and exposure at the workplace must be taken into consideration.

A. Physical States of Chemicals

The mechanism of penetration of chemicals into the respiratory system and subsequent absorption depend on the physical state of the chemical. The physical state of the chemical also affects the selection of method for sampling and analysis, the occupational exposure standard, and the planning and design of control measures. For example, generation of aluminum dust in metal machining and abrasive treatment processes and generation of aluminum fumes in welding are common in airline maintenance operations. Aluminum metal dust and aluminum welding fumes are retained in the lungs to different degrees because of different particle sizes. Thus, the ACGIH TLVs of aluminum are dependent on its physical state. Furthermore, if local ventilation is designed as a control method, the design of such a system as well as its air velocity may have to be different for the various particle sizes in order to effectively eliminate the hazard.

Chemical agents may appear in the air as gases, vapors, or as solid or liquid particulates. The latter two are dispersed in a gaseous phase and are hence defined as aerosols. When a substance's normal state at normal temperature and pressure is gaseous, it is considered a gas. The gaseous forms of substances that are liquids or solids at normal temperature and pressure are termed vapors. Thus, carbon monoxide is a gas, while trichloroethane produces a vapor at room temperature.

Reversible processes transform substances from one physical state to another. Fusion or melting converts a substance from its solid to its liquid state, while the reverse process is called crystallization. Processes of evaporation and condensation convert liquids to vapors and vapors to liquids, respectively. Less common are transformations between the solid and gaseous states. Iodine, dry ice, and naphthalene tend to sublime and become vapors. Metal vapors at very high temperatures condense and react with oxygen and other gases to form very small solid particles, termed fumes.

Airborne solid particulates may appear, in addition to fumes, as dusts and smoke. Suspended dust particles (e.g., crystalline silica) are formed by size reduction of solid matter through mechanical processes. The elongated thin, rod-shaped particles with a certain length to width ratio are called fibers (e.g., asbestos and glass fibers). Smoke is formed from the incomplete combination of carbonaceous material and sometimes contains droplets. The process of size reduction in liquids as well as condensation of vapors to the liquid state forms suspended droplets termed mists.

In the course of exposure, a chemical agent may enter the body via three major routes: inhalation, absorption, and ingestion. All hazardous chemicals in all physical states can enter the body through inhalation. However, absorption and retention of an agent in the lungs depend on its chemical nature and reactivity, the size of its particles, and the degree of its solubility in the respiratory tract. Reactive chemicals, such as acid and alkali mists, may be absorbed into the respiratory tract tissues by direct dissolution or chemical reaction. The efficiency of retention of solid particles in the lungs depends on the particle size. A high percentage of particles within a population having an aerodynamic diameter in the range of 1 to 5 μm is retained in the lungs; this is, therefore, termed the respirable fraction. Larger particles settle rapidly by gravitation and are not suspended long enough in air to be inhaled. Some of those entering the respiratory tract are trapped and removed by the action of the cilia. Particles of smaller mass are subject to the influence of turbulent air in the respiratory tract, being either removed from or impacted in the lungs. Fibers, due to their cylindrical structure, penetrate into the lungs better than particles of an equivalent aerodynamic diameter. Dust and fume particles vary greatly in size, but a significant portion of those produced in industrial processes are respirable. Fumes and smoke may be one or two orders of magnitude smaller than dust particles but may also be absorbed by dissolution.

B. Absorption of Chemicals

The main mechanisms by which solid particles are deposited in the lungs are gravitation and impaction (Waldron and Harrington, 1980). Gravitation is dominant in the nose and pharynx where large inhalable but not respirable particles settle. Gravitation and diffusion are dominant in still air such as that in the fine bronchioles where the settling and diffusion rates depend on the particle size and density, the air viscosity, and the temperature. The impact mechanism comes into effect in the thoracic airways as a result of turbulent air motion in the bronchi and large bronchioles.

Gases and vapors migrate in the respiratory tract and lungs by diffusion and are absorbed by dissolution. The more soluble gases, such as sulfur dioxide and ozone, are absorbed in the upper respiratory tract where they also exert their irritating effects. The less soluble gases, such as carbon monoxide, penetrate deeper into the lungs. Vapors of lipophilic substances, such as chlorinated organic solvents, also reach the lungs and are absorbed into the blood. Substances retained in the lungs, if not soluble, may exert local toxic effects. Soluble substances enter into the bloodstream and are transported to target tissues and organs.

The second important route of entry is absorption through the skin and to a lesser extent through the eyes. Many organic solvents and pesticides permeate the skin easily, while the majority of inorganic materials and mineral dusts do not. The diffusion of airborne gases through the skin is poor, but dermal absorption is the main route of entry for directly contacted liquids and certain solid chemicals.

Ingestion is the third route of entry for chemical agents. In practice, this route is usually involved with accidental swallowing or inadequate personal hygiene. Smoking, eating, and drinking in work areas without adequate precautions are the main reasons for exposure through ingestion. This is particularly relevant in the case of heavy metal workers, as significant quantities of metals adhering to the hands may be ingested and later absorbed from the gastrointestinal tract into the blood.

C. Classification of Chemical Hazards

Chemical agents may be classified by several methods, one of which, the physical state of the airborne matter, has already been mentioned. The most widely used classification is by groups sharing common denominators as to function, chemical structure and nature, and/or mode of toxic action. Major groups are organic solvents, metals, inorganic substances (acids and bases), gases, organic compounds and polymers, mineral dusts and man-made fibers, and pesticides. Another common classification is used in safety engineering. Here, compounds and mixtures are classified flammable, explosive, corrosive, toxic, oxidizing agents, and dangerous gases. Chemical substances may also be classified by their toxicological and physiological properties. The various classifications of chemical hazards are combined in Table II.

D. Organic Solvents

Organic solvents are volatile and flammable liquids, many having flash points less than 38°C, and are capable of causing violent explosions as a result of rapid combustion. They serve mainly as solvents, diluents, degreasers, cleaners, and extractors. Structurally, organic solvents may be classified as aliphatic, alicyclic, or aromatic hydrocarbons, halogenated hydrocarbons, alcohols, ethers or glycol ethers, aldehydes, ketones, or esters, or belong to a miscellaneous group including substances such as carbon disulfide. Many of these substances have high vapor hazard ratios defined as the vapor concentration at equilibrium with the liquid phase at 25°C divided by the TLV.

Solvents appear in the work atmosphere as vapors and mists and enter the body by inhalation. Since they are lipophilic, however, they are also readily absorbed by the skin. In certain circumstances dermal exposure is more significant than respiratory absorption. Solvents cause adverse local and systemic effects in almost all systems of the human body.

It should be noted that halogenated solvents, although nonflammable, may decompose at high temperatures to produce toxic gases such as phosgene, fluorophosgene, hydrogen chloride, and hydrogen fluoride.

The use of solvents is widespread in airport maintenance and repair facilities. For example, halogenated hydrocarbons such as 1,1,1-trichloroethane and liquid freons are common in general maintenance and electronics workshops. Alcohol solutions are used in cleaning operations and nitro thinners are used in maintenance workshops. Aliphatic and aromatic hydrocarbons, such as mineral turpentine-based thinners and toluene, ketones (e.g., acetone, methylethyl ketone, and methylisobutyl ketone), and esters (e.g., butyl acetate) are used in aircraft maintenance and are contained in paints, adhesives, and lacquers.

E. Metals

Most of the metals which are considered as health hazards are heavy metals, chemically belonging to the transition elements. Light amphoteric elements such as beryllium, aluminum, and heavy metals like tin, lead, arsenic, and antimony are known toxins.

Production and processing of metals and their use as additives or catalysts may be sources of exposure in industry. Hot processes, such as melting, casting, welding, brazing, and soldering, emit mainly metal fumes, whereas cold processes, such as mining, grinding, machining, mixing, weighing, and assembly, are sources of metal dust. Soluble metal salts are dispersed as droplet aerosols in electroplating. Metal pigments dissolved in organic solvents and sprayed as liquid aerosols become solid particulate matter when the solvents evaporate. Contaminated surfaces and poor personal hygiene may also be significant sources of exposure to metals through ingestion. Skin is not considered to be a route of entry for metals, except for a few organometal compounds and salts. For a review of the toxic effects of specific metals found in the aviation industry, see Chapter 7.

Nickel, chromium, cadmium, and molybdenum are used in plating processes in aircraft repair departments. Steel alloys containing iron, manganese, aluminum, nickel, and chromium as well as other metals are used in main-

TABLE II
Various Classifications of Hazardous Chemical Substances

Classification	Subdivision	Examples
Physical	Dusts	Silica, talc, kaolin, asbestos, glass fibers
	Fumes	Metals, polyaromatic hydrocarbons
	Smoke	Soot
	Aerosol/droplet	Acid mists, oil mists
	Vapors	Toluene, styrene, acetone, butyl acetate
	Gases	Carbon monoxide, vinyl chloride, acetylene, argon
Chemical	Organic solvents	Benzene, toluene, hexanes, methanol, glycol ethers, 1,1,1-trichloroethane
	Organics, polymers	Formaldehyde, phenol, epoxy, polystyrene, polyvinyl chloride
	Metals	Lead, cadmium, nickel, chromium, mercury, beryllium
	Gases	Carbon monoxide, hydrogen sulfide, hydrogen cyanide, ammonia
	Inorganics	Nitric acid, sulfuric acid, hydrochloric acid, cyanides, nitrites, fluorides
	Pesticides	Organophosphates, carbamates, organochlorides
	Mineral dust	Silica, asbestos, portland cement
Physiological	Irritants	Strong mineral acids, phenol
	Asphyxiants	Simple: nitrogen, acetylene Chemical: carbon monoxide, hydrogen cyanide
	Narcotics	Organic solvents
	Hepatotoxics	Carbon tetrachloride
	Neurotoxics	Mercury, *n*-hexane, hydrogen, sulfide, organophosphates
	Hemotoxics	Lead, arsine, nitrobenzene
	Hemopoietics	Benzene
	Pneumotoxics	Asbestos, silica, beryllium
	Carcinogenics	Asbestos, benzene, arsenic, benzopyrene, nickel
	Mutagenics	Benzene, free radicals
	Teratogenics	Glycol ethers
Safety	Explosives	Nitroglycerine, methane
	Flammables	Organic solvents
	Corrosives	Mineral acids, hydrazine, ammonia
	Oxidants	Organic peroxides
	Toxics	Lead, benzene, cadmium, mercury
	Gases	Hydrogen, cyanide, hydrogen chloride
	Radioactive materials	Uranium, thorium

tenance and electronics workshops at the airport. Welding operations, a significant source of hazardous metallic fumes, are widespread in airport industrial shops.

F. Inorganic Substances

The hygienic concern regarding this group pertains to acids and bases and to soluble salts such as fluorides, cyanides, nitrites, nitrates, and phosphates. Inorganic peroxides are also included in this group. The main form of dispersion of acids and bases in the air is mists, while inorganic salts may be dispersed as dust and droplet aerosols.

Mineral acids, such as hydrochloric, hydrofluoric, nitric, and sulfuric acids, and alkali bases, such as sodium and potassium hydroxides, are corrosive. As such, they are local irritants and may cause chemical burns and acute damage to lungs and skin. In addition, some anions and salts, like those of fluorides and cyanides, are known to cause systemic effects. Ammonia is an irritant base known to cause chronic olfactory damage. Hydrazine, a very corrosive agent, and its derivatives are used in the aircraft industry as a fuel.

In airports, inorganic chemicals are used mainly in surface treatment and cleaning prior to plating and painting, as well as for etching and rust removal. Acids and bases attack metals, cement, and stone-based and organic materials and are corrosive to equipment as well as to human tissue.

G. Gases

It is convenient from a health point of view to classify gases either as biologically inert or as biologically active. Inert gases, though not considered toxic by themselves, may in high concentrations deplete atmospheric oxygen, causing oxygen deficiency in living tissues. The noble gases, nitrogen, hydrogen, methane, ethane, propane, butane, ethylene, and acetylene, are examples of biologically inert gases termed simple asphyxiants for their mode of action. On the other hand, biologically active gases exert their effects by chemical reactions with vital components of the cells. Among effects reported due to occupational exposure are primary irritation (ozone, sulfur dioxide, nitrogen oxides), chemical asphyxiation (carbon monoxide, hydrogen cyanide), corrosive action to tissues (chlorine), systemic neural effects (hydrogen sulfide, mercaptans), and hemolysis (arsine).

Inert gases in industry are used as fuels, for protection of the welding atmosphere from oxygen, as reagents in chemical reactions for specific purposes (thermal treatment), and as sources for light emission.

Many of the active gases are by-products of processes such as combustion (carbon monoxide, carbon dioxide, sulfur dioxide), oxidation (nitrogen oxides, phosgene, oxides of phosphorous), reduction (arsine, phosphine), disintegration of organic matter (hydrogen sulfide, mercaptans), and the interaction of radiation and matter (ozone).

Argon, carbon dioxide, helium, and nitrogen are used in airport hangars and workshops in welding processes. Hazardous by-products such as carbon monoxide, nitrogen oxides, and ozone are formed in these processes. The combustion of fuels results in the formation of carbon monoxide, sulfur dioxides, and nitrogen oxides, while arsine may be formed during metal alloy pickling as well as passivation and other acidic surface treatments carried out on airplane components.

H. Organic Substances and Polymers

The use of polymers has increased tremendously during the second half of the 20th century replacing metals, wood, glass, and ceramic minerals. Organic polymers are the heart of the plastic industry and comprise base materials in the production of resins, paints, adhesives and glues, lacquers, textile fibers, construction materials, and resins for metal casting molds. The production of polymers involves the use of small organic molecules, such as formaldehyde, phenol, isocyanates, epoxides, vinyl chloride, styrene, ethylene, and acrylates, which serve as monomers, together with a large variety of organic compounds which serve as additives. In addition, organic compounds are used as raw materials in the synthesis of various chemicals.

Organic compounds are dispersed in the atmosphere as dusts, droplet aerosols, fumes, smokes, gases, and vapors. All of them are inhalable but many are also absorbed readily through the skin or act on the skin itself. Potential exposure to polymers exists during their production as well as during their handling under extreme thermal conditions. Monomers and additives comprise a hazard during production while decomposition under extreme thermal conditions gives rise to noxious and toxic gases such as cyanides, carbon monoxide, and hydrogen chloride.

Organic polymers commonly used in repair and renewal of parts in electronics and airport general maintenance shops are epoxy resins, polyurethane-based paints and adhesives, polyester resins, vinyl-based paints and adhesives, and acrylic- and methacrylic-based glues. It is important to note the respiratory and skin sensitization effects of isocyanates and aliphatic amines which are basic components in the curing process of polyurethane and epoxy resins, respectively. Other sensitizing agents include organic peroxides which function as initiators and accelerators in free radical polymerization of polyester, PVC, acrylic resins, and epoxy. Some of these are also explosive. Skin irritants, such as cutting oils, are also present. Among the other fluids used, hydraulic fluids may contain tributyl phosphate, which is reportedly neurotoxic.

I. Mineral Dusts

Substances of mineral origin are commonly used in industry as fillers and bonding agents, abrasives, raw materials for construction and ceramics, parting agents (to prevent adhesion of the casted material to the mold), molding materials, and thermal insulators. Silica, asbestos, talc, diatomaceous earth, kaolin, mica, gypsum, marble, and portland cement are good examples of minerals which are dispersed as particles in the air. The route of entry for such substances is mainly inhalation with the respirable particles retained in the lungs where they exert their effects. Some mineral dusts (e.g., crystalline silica and asbestos) are fibrogenic in the lungs and warrant special precautions in handling. Others are defined as nuisance particles causing no fibrotic tissue or scars.

Several mineral dusts are found in airport industrial shops. For example, sand, mainly composed of quartz, is used in sand blasting for metal surface polishing, a hazardous operation requiring adequate worker protection. Also, asbestos may present a hazard where maintenance operations are performed on pipe insulation and brake bands.

The development of man-made mineral materials based on silicates and aluminum oxides as well as other combinations has partially replaced use of natural minerals. Examples are glass fibers, alumina, and silica carbide, which are now commonly found in workshops. Rock wool and ceramic fibers are other examples of man-made mineral fibers (MMMF). The risk of disease from exposure to MMMFs is controversial.

Some airplane components are composed of man-made fibers and organic polymers called composite materials which combine the hazards of both.

J. Pesticides

Because decontamination is sometimes necessary in aircraft and kitchen and food storage areas, there is a potential hazard for workers to be exposed to pesticides. Likewise, air and ground crews involved in aerial spraying face a similar hazard. Nevertheless, the danger can be minimal if workers follow established safety procedures in the handling of these toxic agents.

Pesticides may be classified according to their function (insecticides, rodentocides, herbicides, fungicides, etc.), but also according to the active functional chemical group in their molecules, the more common types being organophosphates, organochlorine, and carbamates. These substances are dispersed in air mainly as dusts and droplet aerosols, but those which are volatile release vapors. In addition to exposure by inhalation, dermal exposure may be substantial and under certain conditions even more significant than that by inhalation. Organophosphates and carbamates are cholinesterase inhibitors causing dysfunction of the parasympathetic nervous system. Organochlorine pesticides, which accumulate in soft tissues, are hepatotoxic and some are suspected carcinogens.

V. PHYSICAL HAZARDS

Physical hazards are characterized by properties which are quantitative rather than qualitative in nature. The property of concern is the energy transmitted to the human body by the hazard source.

The major sources of physical hazards encountered by workers in industry are noise, mechanical vibration, radiation (ionizing and nonionizing), and heat and cold stress. Exposure to abnormally low or high air pressure, although relevant for air crews, is less so for ground personnel.

Noise and vibration are characterized by mechanical energy, whereas the energy transmitted by nonionizing radiation and some forms of ionizing radiation is electromagnetic. Unbalanced exchange of thermal energy between the body and its environment may result in thermal stress.

A. Noise

In physical terms, sound is a wave phenomenon originating in a vibrating source in contact with a medium, the particles of which are disturbed as a result of the vibration. The propagation of a sound wave through air creates rapid changes in the atmospheric pressure which are terminated only when the wave encounters an absorbing surface (Zaner, 1991). When a sound wave encounters the human auditory system, it is converted to nerve impulses which are transmitted to the brain and perceived as sounds. The intensity of the acoustic energy transmitted to the ear may merely be perceived as unpleasant and annoying or may even damage the ear. In either case it is termed noise which, therefore, may be defined as "an audible acoustic energy that adversely affects the physiological or psychological well-being of people" (Kryter, 1985).

The pitch of noise is characterized by its frequency (expressed in Hertz, (Hz)). The conventional unit of noise intensity is the decibel (dB), which takes into account both acoustic pressure and the exponential nature of the human ear's subjective response.

Noise and its impact on man have been widely investigated. The average ear responds to frequencies between 100 and 10,000 Hz. The subjective response to a given intensity is not equal at all frequencies. In the occupational context, a time weighted average noise level exceeding 85 dB for 8 hr is accepted as being hazardous and potentially damaging to the inner ear. This value is generally considered the occupational threshold limit value–time weighted average (TLV–TWA) for 8 hr of exposure daily. Shorter durations of exposure to noise are allowed up to 115 dB in intensity. Exposures beyond these limits require ear protection.

Noise levels in various industrial processes are presented in Table III. Turbine or jet engine testing causes noise levels above 130 dB at the upper extreme of common industrial exposures. Jet engines create more intense noise than do propeller aircraft or helicopter turbine engines. Generally speaking, air and surface transportation have become a serious environmental noise source with universal impact.

Noise is defined as continuous, when emitted uninterruptedly over time, or impact, when having repeated peaks with a minimum of 1-sec intervals between them. Sonic booms created by aircraft exceeding the speed of sound fall into the category of impact noise. Impact noise may cause severe hearing loss, sometimes accompanied by mechanical damage to the ear resulting from shock waves (blasting). Noise which is high both in intensity and in frequency is the most hazardous.

Since high levels of occupational exposure to noise are common in industry, ear protection and programs for hearing conservation are essential. Laws and regulations have been promulgated to protect workers from noise-induced hear-

TABLE III
Noise Intensities

Source	Typical noise level (dBA)
Hearing threshold	0
Acoustically isolated room	10
Whispering	20–30
Quiet room	40
Conversation	50–60
Air conditioning unit	60–70
Average street	70–80
Milling machine, diesel truck	80–90
Subway	90
Newspaper press	90–100
Wood industry, rivetting	100–110
Textile loom	110
Large-size generator	120
Pneumatic chipping hammer	120
Rock-n-roll band	120
Cockpit propeller (aircraft)	120
Gunshot	130
Turbojet engine	140–160

ing loss (NIHL) and disability entitling compensation has been defined. NIHL may be detected by audiometry.

Nonauditory effects of noise have also been studied (Kryter, 1985). Cardiovascular effects including an increase in blood pressure, changes in blood flow, and an increase in pulse rate have been related to noise levels below 85 dB. Irritation, annoyance, and insomnia may result from the effects of noise on peripheral nerves. Gastrointestinal, neuroendocrine, and immunological effects have been reported as well as effects on the quality of task performance, learning ability, and cognitive development.

B. Vibration

A physical body is said to be vibrating if its particles oscillate about their equilibrium axis. Vibratory motion is depicted in a simple way as an harmonic oscillation, describing a sine wave in reference to the rest position of the vibrating particles. The different systems of the human body may be conceived of as continuous sequences of mass elements, each acting as an oscillating mechanical spring and attached to a damping element. Due to friction between the mass and damping elements followed by energy losses, the oscillations decay exponentially with time.

The natural oscillation of a system possesses a certain frequency and displacement. If an external force is introduced into the system, the mass elements will accelerate at a higher frequency and vibrate at a higher intensity. When the natural frequency of the system equals that of the external force exerted, the system obtains a resonant frequency which may cause a large displacement. The larger the displacement of a vertical vibration at a certain frequency, the more unpleasant and annoying the sensation it creates.

Vibrations are classified as whole body or segmental, depending on the surface of the body in contact with the source of vibration. A person sitting on a moving tractor or forklift experiences whole-body vibration, whereas electrical or pneumatic hand tools, such as saws, drills, and riveters, cause segmental vibration.

The resonant frequencies of the different parts of the body range between 3 and 60 Hz. Tolerance of whole-body vibration is low in the range of 3–14 Hz, and increases at higher frequencies. Low frequency vibration in the range of 2–20 Hz as produced by motorized vehicles and trains may cause musculoskeletal disorders and disturbances in the ocular nerve. Whole-body vibration of very low frequency (less than 2 Hz) has been observed to affect the central nervous system and the balance organ in the ear, causing nausea. Very low frequency vibration is experienced in aircraft during flight.

Whole-body vibration has been reported to induce mechanical changes in bones and muscles, endocrine and biochemical aberrations, increased pulse and oxygen-consumption rates, and acceleration of CNS electrical activity, as well as changes in the capability for complex task performance. Segmental vibration of high frequency, in the range of 20–2000 Hz, may lead to impairment of the peripheral nerves and the circulatory system in the hands and arms. Atrophy and weakness of muscles and decalcification of bones have also been reported. Workers especially affected are wood cutters, drillers, pneumatic hammer operators, and stone and diamond cutters. In the aviation industry mechanics using pneumatic tools are at risk for diseases associated with vibrational stress.

C. Heat and Cold Stress

The human body functions normally within a narrow range of body temperatures centered at 37°C and ranging about 1.5°C in either direction. The body can compensate for temperature increases up to 42°C and decreases down to 32°C before functioning is impaired or physiological or mental damage incurred. Even smaller changes in temperature, however, can result in a decrease in function resulting in an increased accident rate. It is essential to maintain the deep body temperature constant within the narrow normal range by control of the thermal energy exchanged with the surrounding environment. Physiological mechanisms prevent excessive heat loss and rid the body of excess heat generated or absorbed. The body can generate as much as 400 Kcal of thermal energy per hour (as measured by oxygen consumption rate) given an average to heavy work load. If not exchanged with the environment, this energy would raise the deep body temperature of a worker, of average weight, by 5 or 6°C.

In addition to self-generated heat, workers are exposed to environmental heat sources inherent in their jobs. Furnaces and ovens are standard equipment in foundry operations as well as in heat treatment of metals, glass and ceramics manufacturing, coal burning, and bakeries. Hot processes are also common in the plastics and rubber industries, and heat is generated in welding and steam operations. Outdoor workers in warm climates are exposed to high ambient temperatures and solar radiation. Excessive heat load on the body may cause physiological discomfort and even impair function. Chronic heat stress may induce heat exhaustion, heat cramps, electrolyte imbalance, dehydration, skin rashes, and decreasing physical and mental work capacity. Acute heat stress may cause heat stroke.

Heat is absorbed from the environment mainly via convection and radiation, the latter being more significant in still air. The same modes serve to exchange excess thermal energy accumulated by the body with the environment. Evaporation, mainly via sweat, is a third mode for exchange of excess heat. Evaporation of 1 liter of sweat is equivalent to a thermal energy loss of 600 Kcal. However, perspiration is efficient only when evaporation can take place from the surface of the skin.

Exchange of thermal energy between the body surface and its environment is affected by the environmental factors of temperature, humidity, air movement, and heat radiation. The higher the relative humidity, that is the percentage of atmospheric saturation by water vapor at a given temperature, the lower the capacity of that atmosphere to absorb water vapor from the skin surface and, hence, the lower the capacity of the body to cool itself. Air movement has a drying effect, hence, decreasing the humidity and increasing the capacity for evaporation.

Because measurement of deep body temperature of workers exposed to heat stress is not practical, heat stress indices have been developed. Heat stress is evaluated by simulation of the process through which thermal equilibrium is obtained between absorption and emission of thermal energy on the skin surface. Indices have been mathematically formulated to simulate the combined thermal effects produced by the different components of a given environment. The product of the formulation, expressed as a temperature, is termed the effective temperature. The index most widely used in occupational hygiene measurements is the wet bulb globe temperature (WBGT), combining the wet bulb temperature (WB, humidity and air movement effect) and the globe temperature (GT, thermal radiation effect) for indoor work environments, and the dry bulb (DB, ambient temperature), wet bulb, and globe temperatures for outdoor work environments. The formulas are: $\text{WBGT} = 0.7\ \text{NWB} + 0.3\ \text{GT}$ and $\text{WBGT} = 0.7\ \text{NWB} + 0.2\ \text{GT} + 0.1\ \text{DB}$ for indoor work and outdoor work, respectively (ACGIH, 1994).

Cold stress is as significant an occupational hazard as heat stress. Exposure of unprotected workers to low temperatures, such as those in refrigerator and deep-freeze storage rooms and in cold climates during the winter, must be avoided in order to prevent the decrease of the deep body temperature below 36°C.

The environmental factors considered for planning protection against cold stress are the temperature of the environment and the wind speed. At a given low temperature and wind speed, the combined cooling effect of these factors on exposed flesh is equivalent to an effect of lower temperature under calm conditions which is termed equivalent chill temperature (ECT). ECTs are shown in Table IV for various combinations of temperature and wind speed. Isocaloric lines can be drawn for equal loss of body heat in Kcal/m^{2}hr under various combinations of temperature and wind speed. Isocaloric lines of 1000 and 1200 Kcal/m^{2}hr reflect "very cold" and "bitterly cold" situations, respectively. Human flesh freezes within 20 min at a loss of 1400 Kcal/m^{2}hr and within 1 min at a loss of 2400 Kcal/m^{2}hr.

Extreme temperatures are significant hazards to outdoor airport workers. In cold climates, continuous work under very low ECTs requires work warm-up schedules where workers can warm up in heated shelters. The opposite is the case in warm climates, where cleaning and preparing an aircraft for its next flight

TABLE IV
Equivalent Chill Temperatures[a]

	Wind speed (estimated in kmph)				
	8	16	32	48	64
Actual temperature (°C)	Equivalent temperature (°C)[b]				
10	9	4.5	0	−2	−3
−1	−3	−9	−15.5	−19	−21
−12	−14	−23	−32	−36	−38
−23	−26	−36	−47	−53	−56
−29	−32	−43	−55	−62	−65
−40	−44	−57	−71	−78	−82

[a]Raw data from American Conference of Industrial Hygienists (1994).
[a]Exposed flesh under calm conditions.

is hardly bearable without air conditioning of the flight cabins. Maintenance workers on the flight line and loaders of cargo aircraft may be exposed for several hours at a time to solar heat and radiation.

D. Radiation

Radiation is classified as nonionizing or ionizing. Nonionizing radiation includes radio frequency, microwaves, infrared, and ultraviolet radiation (from welding) (see Chapters 7 and 10).

VI. BIOHAZARDS

Biohazardous agents are those from an animal or vegetative source capable of causing disease. Bacterial, viral, fungal, rickettsial, and parasitic agents are common biohazards (Plog, 1988). Recently, allergy-causing properties of bacteria and the cell walls of other microorganisms found in industrial plants and agricultural areas have been emphasized.

Hepatitis B and acquired immune deficiency syndrome are examples of diseases induced by viral agents to which laboratory workers and medical staff may be exposed through contaminated blood and body fluids. Needle sticks are a hazard to the medical staff at the airport outpatient clinic. Firefighters and emergency crews who administer first aid also have a potential risk of infection (Crutcher *et al.*, 1991).

Biohazardous agents may be transmitted through aerosols, contaminated food and water, biological fluids and feces, and contaminated items and equipment containing biological materials. Consequently, ground support personnel involved in waste disposal, interior cleaning of the aircraft, and animal transport may be at increased risk for disease.

VII. ERGONOMICS

Ergonomics, the study of the worker–work interaction, focuses on the compatibility between worker capabilities and limitations on the one hand, and job requirements and tasks on the other. This interaction is influenced by human factors, job definition, facilities and equipment, and physical and environmental factors at the workstation. Ergonomics is applied to design and control of the workstation and workplace in accordance with workers needs so as to eliminate potential stresses, health hazards, and trauma and to maintain high worker productivity. Ergonomics is an interdisciplinary field consisting of anthropometry, biomechanics, exercise and environmental physiology, and experimental and engineering psychology (Cralley and Cralley, 1985).

The designer of a workstation should consider a variety of details, sometimes unnoticed or taken for granted by the inexperienced eye. The design of the omnipresent video display terminal workstation, for example, must take into account anthropometric data regarding human dimensions. Entrances, exits, passageways should allow enough space for workers of different dimensions to move about freely. Space is needed for a sitting or standing worker to move the different parts of the body freely without musculoskeletal distortion or collision with obstacles. Postural factors should be considered in planning the heights of desks, chairs, keyboards, and monitors so as to avoid overexertion of the neck, shoulder, and back muscles, and with it fatigue and eventual musculoskeletal disorders. Similarly, the size of letters on the monitor, as well as the background color, glare, and background illumination can affect the worker's visual comfort and performance.

Applying ergonomic considerations to the design of workstations is complicated. For example, tools used in hard physical labor should be designed to meet the kinesiological capacity of the worker so as to prevent overexertion. Prolonged periods of repetitive motion should be minimized so as to prevent friction between the tendons and the median nerve in the forearm and hand. Such friction may lead to irritation and inflammation of tissues covering the tendons and nerve and cause the carpal tunnel syndrome.

Workers at control panels operate knobs and handles which should be quickly and easily accessible with no wasted effort. Besides operating knobs and handles, air traffic controllers are also faced with the perceptual and mental task of maintaining vigilance over prolonged periods. Continuous attention to several sensory modalities is essential to the maintenance of response speed and error-free performance. Such tasks may be stressful, and indeed psychosocial stress has been reported in air traffic controllers due to responsibility overload (see Chapter

5). Sensory overload should be avoided by proper selections between visual and auditory displays according to the job's conditions and requirements.

Environmental factors in the workplace are superimposed on the factors noted above. Such elements as environmental temperature, humidity, air quality, air flow, air conditioning, ventilation, and background noise may impose discomfort and stress on the worker if not properly controlled.

Special attention should be paid to illumination in jobs involving visual performance. Recommended values of light intensity for a certain task are usually given for the amount of light falling on the work surface. The reflectance (the ratio of the amount of light reflected from a surface to that falling on it) depends on the brightness of the surface. High reflectance may produce glare which should be controlled to maximize visual acuity and decrease eye fatigue. In order to emphasize objects, a proper contrast between the object and its surrounding should be designed with the aid of direct and indirect lighting.

In the future, ergonomists will have to take into account increasing automation, robotics, and computer use in industry and services. Ever larger numbers of workers will be involved in planning, design, programming, and quality control, tasks which require more sophisticated workstation design. The primacy afforded to worker health today can be expected to accelerate the development of the field of ergonomics.

VIII. EVALUATION OF EXPOSURE

A potential hazard previously recognized and defined qualitatively is given an actual, quantitative value when evaluating worker exposure. In this process, the industrial hygienist measures the magnitude of the exposure, compares the measured value with an occupational health standard, and interprets the significance of the assessed values in the context of overall exposure and worker activities in the workplace. Finally, decisions are made regarding a long-term monitoring strategy.

In addition to site evaluation, the industrial hygienist is involved in developing occupational exposure standards and methods for sampling and analyzing airborne contaminants, as well as in exposure assessments for research and survey purposes and risk assessment based on toxicological, medical, epidemiological, environmental, and other related data.

Sampling and analysis of the occupational environment must be performed to quantify exposure. The best mode is personal sampling during which a sampling unit is attached to the worker for a specified period. In addition, area sampling at fixed locations is beneficial in detecting hazardous agent dispersion to neighboring work sites or evaluating effectiveness of engineering control measures. Samples can be taken for laboratory analyses or direct reading instruments can be utilized to perform both sampling and analysis in real time. Each of these two methods has advantages and disadvantages which must be carefully weighed in light of the objectives of the environmental monitoring, the nature of the hazardous agent, the nature of the job, interferences from other agents in the same environment, and technical features of the instrumentation.

Results of measurements are validated and then compared with occupational health standards which serve as reference values in determining how much deviation exists from the standard. The intensity of the environmental exposure to a given occupational hazard is measured by a quantitative parameter. For chemical agents the parameter is air concentration, whereas for noise, it is acoustic power or pressure. Other physical agents are given different indices of exposure. The occupational health standards are expressed as threshold limit values of permitted exposure, each defined in units corresponding to those of the exposure parameter. Virtually no worker is believed to develop adverse health effects when repeatedly exposed to daily magnitudes of a hazardous agent below the threshold limit value. The TLV introduced by the ACGIH is one of the most widely used occupational exposure standards in the world (ACGIH, 1994). Other current standards are the permissible exposure limit used by OSHA and recommended exposure limit used by NIOSH in the United States, occupational exposure limit by the Health and Safety Executive in the United Kingdom, and MAC in the Federal Republic of Germany.

TLVs have been developed for environmental agents which comprise chemical and physical hazards and should be applied as guidelines as to the required air quality in workplaces and for control of potential health hazards. They do not reflect borderlines between "healthy" and "unhealthy" situations, nor can they be used as relative indices of toxicity.

Three categories are used in the application of TLVs for chemical substances (ACGIH, 1994). First, the TWA concentration, the most common, assumes an exposure over an 8-hr workday and is appropriate for substances for which toxic effects correlate with their long-term accumulation in the body. Second, the short-term exposure limit (STEL) defines the maximum level of exposure permitted for not longer than 15 min at a time, with additional provisions, that such exposure not occur more than four times per day, that there should be at least 60 min between successive exposures in this range, and that the daily TLV–TWA is not exceeded. STEL values are higher than the TLV–TWA values for any given substance. They have been established for toxic substances recognized for their possible acute effects, such as irritation, irreversible tissue damage, and narcosis, in addition to their chronic effects. Third, ceiling (TLV-C) concentrations are those that should not be exceeded at any time during the work day.

TLV values are presented in Table V for various toxic agents. In special cases, TLVs for mixtures of either organic solvents or mineral dusts can be calculated,

TABLE V
1994–1995 Time Weighted Average–Threshold Limit Values[a] of Selected Industrial Substances

Substance	TWA[b] mg/m^3 (ppm)	Carcinogenicity classification	Year adopted
Acetone	1780 (750)		1982
Acrolein	0.23 (0.1)		1976
Acrylonitrile	4.3 (2)	A2	1984
Aluminum welding fumes	5		1979
Ammonia	17 (25)		1976
Arsenic (inorganic compounds)	0.01	A1	1993
Asbestos-chrysotile	2 fibers/cc	A1	1980
n-Butyl acetate	713 (150)		1976
Carbon monoxide	29 (25)		1992
Cadmium	0.01	A2	1986
Chromium (VI) compounds	0.05	A1	1994
Cobalt	0.02	A3	1994
Ethanol	1880 (1000)		1977
2-Ethoxyethanol	18 (5)		1984
Ethylene oxide	1.8 (1)	A2	1984
Fibrous glass dust	10		1978
Formaldehyde	C[c] 0.37 (0.3)	A2	1992
n-Hexane	176 (50)		1982
Hydrazine	0.13 (0.1)	A2	1977
Hydrogen chloride	C 7.5 (5)		1977
Hydrogen fluoride	C 2.6 (3)		1986
Isopropyl alcohol	983 (400)		1976
Lead (inorganic)	0.15		1986
Mercury (metal)	0.025	A4	1994
Methanol	262 (200)		1976
Methylene chloride	174 (50)	A2	1988
Mineral wool fiber	10		1974
Nickel (soluble compounds)	0.1		1976
Oil mist (mineral)	5		1976
Perchloroethylene	170 (25)	A3	
Phenol	19 (5)		1987
Quartz	0.1		1986
Strontium chromate	0.0005	A2	1992
Styrene monomer	213 (50)		1981
Sulfuric acid	1		1989
Toluene	188 (50)		1992
Toluene diisocyanate (TDI)	0.036 (0.005)		1983
Tributyl phosphate	2.2 (0.2)		1986
Trichlorethylene	269 (50)	A5	1993
Turpentine	556 (100)		1987
Xylenes	434 (100)		1976

Note: A1, Confirmed human carcinogens; A2, suspected human carcinogens; A3, animal carcinogen; A4, not classifiable; A5, not suspected as human carcinogen.

[a]ACGIH (American Conference of Governmental Industrial Hygienists) (1994).

[b]Time weighted average.

[c]Ceiling values.

provided the composition of the mixture is known and each component has been assigned a TLV value.

In a few countries, an action level, usually one-half of the TLV–TWA value, has been set as a value above which monitoring of worker exposure as well as medical follow-up is required by law.

TLVs have been established for hundreds of industrial chemicals, among them carcinogens and suspected carcinogens as well as mutagens and teratogens. When new evidence concerning the toxicity of a substance is discovered, its TLV is usually lowered (or raised) accordingly. For substances having no established TLVs, exposure should be restricted to the minimum feasible levels.

Exposure to a chemical substance by inhalation is assessed by monitoring its concentration in the workplace atmosphere. However, biological exposure monitoring is a better approximation of exposure to substances which are absorbed through ingestion or skin (see Chapter 4).

Air and biological monitoring programs should be an integral part of any short- or long-term occupational health program. Such programs should include sampling strategies which define such parameters as sampling frequency, locations, and techniques.

TLVs have been developed for most physical agents encountered in industry. The TLV–TWA for continuous noise is termed the level equivalent; in addition, peak values have been established for impact noise. WBGT threshold limit values for heat stress are selected in accordance with the metabolic rate of heat generation and work–rest regimen for a given job. TLVs have been established for hand–arm vibration, ultrasonic acoustic radiation, cold stress, nonionizing radiation (ultraviolet, infrared, radiofrequency/microwave), lasers, and subradiofrequency electric and magnetic fields.

IX. PREVENTION AND CONTROL

The major objective of occupational hygiene is protection of worker health by identifying and eliminating hazards in the work environment. The major methods to achieve these objectives are engineering controls, administrative methods, and personal protection equipment.

Factors to be considered in selecting a control method include its efficiency, its effect on associated production systems, its effect on the worker, and the cost. The basic approaches to prevention and control of a hazard include control at its source, control of the pathway between the source and the worker, and control of the worker.

A. Control of Chemical Hazards at the Source

Effective methods used to control the source are substitution, isolation, automation and remote control, and local ventilation. Substitution of a nonhazardous chemical for one more hazardous allows complete elimination of the hazard (Goldschmidt, 1993). At present, however, there is a limited number of appropriate nonhazardous agents which can be substituted without compromising the quality of the final product. Availability and cost as well as environmental impact are other factors in the selection of a substitute. For example, chlorinated–fluorinated carbon (CFC) has been used as a substitute for carbon tetrachloride and trichloroethylene, suspected carcinogens. CFC compounds, however, are now banned in many areas because of their effects on the atmospheric ozone layer. Similarly, some man-made fibers used as substitutes for the carcinogen asbestos have themselves recently been found to induce adverse health effects.

Examples of effective substitutions are alkali compounds which have been used instead of chlorinated solvents in degreasing operations. Similarly, aromatic hydrocarbons, such as toluene and xylene, have been substituted for benzene, a leukemogenic agent.

Isolation does not eliminate a hazard but may reduce its potential to an insignificant level. Sealing or enclosing hazardous operations or isolating the worker in a special booth or control room creates a barrier between the worker and the hazard.

Technological developments offer increasing automation of processes, thus reducing potential exposure and improving hazard control. Control of emissions which affect both indoor and outdoor environments is carried out by dust collectors, electric precipitators, cyclones, scrubbers, precipitation chambers, baghouses, etc.

Local ventilation applied to the source of emission of a chemical can also be considered a method of controlling the hazard at the source. In principle, this method should be applied to any point source emission in the workplace regardless of the toxicity of the substance or the duration of exposure. However, in cases of scattered low emissions of substances of low toxicity (and hence high TLV) in which no more than the permitted concentrations are expected, dilution ventilation may suffice.

B. Control of the Pathway between the Source and the Worker

All forms of ventilation are the most prevalent method of controlling exposure to chemicals in the workplace. Another important example of such controls is adequate housekeeping in order to prevent the creation of a secondary source of exposure.

C. The Worker

Use of personal protective equipment (PPE) should be given lower priority than implementation of engineering controls and should be used only when the latter measures are not feasible or fail to supply full worker protection. Should a process begin operation before engineering controls are implemented, personal protection should be used until the control facilities are installed and tested for effectiveness. It should be realized that PPE may cause discomfort to the worker and reduce efficiency, mobility, and oral communication. The need to rely on worker responsibility and motivation is another significant disadvantage of PPE.

A distinction is made between respiratory and whole-body personal protection. The selection of respiratory protection equipment depends on the expected levels of exposure to a given chemical and on its toxicity as well as on the danger of accidental exposure to an oxygen-deficient atmosphere. Mechanical filters, air-purifying cartridges, canistered gas masks, and air line respirators are prohibited for oxygen-deficient atmospheres. In such cases oxygen needs to be supplied by fan-bearing hose masks or by a self-contained breathing apparatus. Each type of mask and filter is assigned a protection factor and a fit factor which designates its barrier capacity against the chemical agent; efficiency, however, is also affected by shelf life and maintenance.

Skin exposure is common in industry and many cases of dermatitis induced by such substances as solvents, mineral oils, irritants, and plastic additives are found among workers in machining, plastics production, and other processes. A large range of protective gloves and garments is available, but careful selection by trained personnel is essential based on features such as barrier properties (impermeability), flexibility, and comfort. Helmets, hats, goggles, aprons, sleeves, and shoes are part of safety equipment in factories as well as in airport facilities.

D. Administrative Control

Administrative means can be useful in the control and prevention of occupational health hazards, although they do not build a physical barrier between the worker and the hazardous agent. They reduce exposure mainly through surveillance, monitoring, and conservation programs as well as work schedules. Worker rotation during a shift or shortening of working hours is implemented in a certain workstation if duration of exposure must be reduced. Environmental and biological monitoring and medical surveillance when done routinely help to protect the worker from variations in exposure profiles.

E. Control of Physical Hazards

Principles and priorities for the prevention of chemical hazards are also applicable for physical hazards. For example, attenuation of noise at the source is preferred over earmuffs or plugs. If they must be used, the choice between earmuffs and plugs depends on their noise attenuation capacities and on the actual noise level in the workplace. A new and sophisticated noise attenuation method is active noise control. This approach, still in the experimental stage, employs destructive interference between noise waves, which literally cancel each other out. It has been applied to the attenuation of noise associated with aircraft propellers (Gordon and Vining, 1992).

Various methods of air cooling and radiation shielding, including personal cooling and insulating suits, are used to control hot areas to protect workers from heat stress. Successful methods are also available for protection against ionizing and nonionizing radiation.

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CHAPTER

4

Clinical Toxicology

PAUL FROOM

I. INTRODUCTION

Toxicology is the study of physical or chemical damage to living organisms. The clinical effect of the agent is dependent on absorption, distribution in various parts of the body, metabolism, excretion of the toxic substance, and toxicity, which also varies according to individual differences. Without an understanding of toxicology, the interpretation of blood and urine tests used to monitor toxic substances would be tenuous.

II. ABSORPTION OF TOXIC SUBSTANCES

Toxic substances may be absorbed through the gastrointestinal tract, the pulmonary epithelium, mucous membranes, and skin. Once absorbed, they are transported to various parts of the body, the distribution being dependent upon cell membrane permeability and binding. Biotransformation may then occur primarily in the liver with subsequent excretion into the bile or urine. It is important to remember that lipid solubility results in increased absorption through skin, increased storage in body fat, increased passage through the blood–brain barrier, and decreased excretion through the kidneys. Therefore, lipid-soluble agents are more likely to remain longer in the body.

III. THE HALF-LIFE

An important concept to understand is that of the half-life ($t_{1/2}$) which is the time it takes for the concentration of the chemical to be reduced by 50%. Substances that are eliminated linearly require about five times the half-life to reach a plateau and 3.5 half-lives to eliminate 90% of the absorbed substance. Thus, monitoring of blood levels of a substance with a short half-life (e.g., 1 hr) should take place at the end of the work day. Estimating exposure by obtaining samples the next morning, 16 half-lives after cessation of the exposure, may lead to the erroneous impression that exposure was limited. On the other hand, blood levels can be determined anytime with substances with very long half-lives (e.g., lead plasma levels of 30 days) in a chronically exposed individual.

It should be stressed that blood levels do not necessarily reflect body stores. Some elements (e.g., lead, cadmium) accumulate in bone with half-lives measured in years.

IV. THRESHOLD DOSES

The estimation of potential damage is often difficult. Most toxic substances have defined levels at which damaging effects do not occur. The level which separates no effect to a possible effect is called the threshold dose. For carcinogenic substances, however, no threshold can be assumed; consequently, risk assessment is controversial.

One of the criteria for proof of causality is the presence of a dose–response curve: in other words, the higher the exposure, the more the effect. In determining the margin of safety of toxic substances one needs to define both the effective dose (ED) and the lethal dose (LD) curves. The effective dose in this case is the dose needed for the worker to be aware that an exposure has taken place (e.g., smell). The LD_{50} minus ED_{50} equals the margin of safety, where 50 signifies the effect occurring in 50% of the cohort.

V. BIOLOGICAL MONITORING

A. Introduction

Blood, urine, hair, nails, or exhaled air may be used to measure chemicals (or their metabolites) to which the worker is exposed. Chapters 3 and 5 discuss environmental monitoring which provides information about potential exposures. On the other hand, biological monitoring provides a measure of the amount of chemical absorbed. Since the amount of chemical absorbed depends on work practices, protective equipment, route of absorption, and individual variations in absorption and excretion, there may be a poor correlation between environmental measurements and biological monitoring. Furthermore, environmental measurements may not be representative of actual environmental exposure since only limited areas are tested. The reliability of the measurements is to a great extent dependent on the expertise of the industrial hygienist. Therefore, properly timed biological specimens, when available, sent for specific chemical testing are preferable to environmental measurements in assessing the risk of toxicological effects.

The timing of the sampling is of utmost importance. Chemicals with very long half-lives (e.g., Cd, $t_{1/2}$ = 10–15 years) can be tested anytime, and those with intermediate half-lives (e.g., trichloroethylene, $t_{1/2}$ = 30 hr) should be tested at the end of the workweek since they will accumulate. Chemicals with short half-lives (e.g., toluene, $t_{1/2}$ = 1 or 2 hr) accumulate during the workday and can be tested for at the end of the work shift (see Table I).

It is important to consult with the laboratory in order to choose the appropriate container and to send the sample to the laboratory in time to be processed. Blood and urine should be sent in plastic containers with plastic tops. They should generally be sent immediately to the laboratory or kept refrigerated for not longer than 2 days.

TABLE I
Biological Monitoring

Chemical	Test[a]	Terminal t (half-life)	Appropriate time to sample
Acetone	b/u	4 hr (blood)	During shift
Benzene	u[b]	28 hr	End of shift
Cadmium	b/u	10–30 Years	Not important
Carbon monoxide	b[b]	6 hr	End of shift
Chromium	u	15–40 hr	End of workweek
Lead	b	30 Days	Not important
Mercury	b	60 Days	End of workweek
	u		Preshift
Methylene chloride	b[b]	10–12 hr	End of shift
Nickel	u	17–39 hr	End of shift
Phenol	u	3.5 hr	End of shift
TCE[c]	u[b]	50–100 hr	End of workweek
Toluene	u[b]	1 or 2 hr	End of shift
Xylene	u[b]	30 hr	End of shift

[a]b, Blood; u, urine.
[b]The chemicals and their associated tests are as follows: TCE, trichloracetic acid; toluene, hippuric acid; xylene, methylhippuric acid; benzene, phenol; CO and methylene chloride, carboxyhemoglobin.
[c]Trichloroethylene

B. Selected Chemicals

1. Benzene Benzene is absorbed readily in the respiratory tract: 40% is exhaled unchanged, whereas 60% is converted to over 13 potential genotoxic metabolites including hydroquinol and benzene hypoxide. Benzene itself is not genotoxic.

2. Beryllium Beryllium is poorly absorbed. It may be retained in the lung or deposited in the bone, liver, or spleen. Renal excretion is slow and urine is used only to confirm that there was an exposure. Levels of over 0.02 mg/liter confirm significant exposure.

3. Cadmium Cadmium is mostly absorbed through inhalation (10–40%). Ten percent of an ingested dose is absorbed but may be increased if there is concomitant iron deficiency. It is bound to plasma proteins and enters the red blood cells bound to hemoglobin or metallothione in the plasma and stored mainly in the kidney and liver. The half-life is approximately 30 years. Blood levels reflect recent exposure, whereas urine reflects total body burden (Kido *et al.*, 1992). Urine levels, however, increase when there is proximal tubular kidney damage and then do not reflect total body stores. Cadmium also increases with age and smoking (Kahan *et al.*, 1992).

4. Chromium Chromium is absorbed primarily in the gastrointestinal tract where it is bound to transferrin and taken up by red blood cells. After a rapid phase of redistribution, the terminal half-life of chromium is between 2 and 3 days, although in chromeplaters the final phase has been shown to have a half-life of approximately a month (Lindberg and Vesterberg, 1989). It is excreted into the urine and does not accumulate in body tissues. Urine collection must be done in special containers which are acid washed in order to prevent leaching out of the chromium. Blood levels also represent recent exposure.

5. Cyanide Cyanide is absorbed through the lungs, GI tract, and skin. It is rapidly distributed throughout the body combining the ferric iron in cytochrome oxidase thereby inhibiting cellular oxygen utilization which leads to metabolic lactic acidosis. In the liver it is metabolized to thiocyanate which is excreted into the urine. Blood cyanide levels are difficult to measure because of the instability of collected samples. Furthermore, whole blood thiocyanate correlates poorly with blood cyanide levels.

6. Lead Lead is absorbed both in the respiratory tract (40% of inhaled lead oxide fumes) and in the gastrointestinal tract (5–10%). There is increased gastrointestinal absorption with concomitant iron deficiency. Lead is widely distributed with varied half-lives in the brain, kidney, liver, skin, skeleton, and muscle. The usual half-life varies between 5 and 10 years. Blood lead levels may vary somewhat with recent exposure, whereas blood zinc protoporphyrin levels in the red blood cells may reflect long-term exposure.

7. Mercury Inorganic mercury is not well absorbed in the gastrointestinal tract, whereas organic mercury is absorbed by inhalation, ingestion, and through skin contact. Mercury is distributed primarily to the brain and kidney. Because alkyl mercury is not excreted into the urine, high blood levels and low urinary levels suggest organic mercury exposure, often from seafood. Alkyl mercury is found primarily in the red blood cells. Therefore, a higher whole blood level compared to a plasma level also suggests organic mercury exposure. Industrial exposure is primarily inorganic mercury. Blood levels reflect recent exposure, whereas urine excretion reflects chronic exposure.

8. Methylene Chloride Methylene chloride is readily absorbed through the lungs and the gastrointestinal tract and slowly absorbed through the skin. It is distributed mainly to the liver, brain, and subcutaneous adipose tissue. It is metabolized to carbon monoxide, formaldehyde, and formic acid. Subsequently, the carbon monoxide is bound to hemoglobin resulting in carboxyhemoglobin (Ratney *et al.*, 1974) and is excreted primarily through the lungs.

9. Nickel Nickel is poorly absorbed by ingestion, but well absorbed by inhalation. It is bound to albumin and other plasma proteins and can cross the placental barrier. Insoluble nickel may accumulate in the respiratory tract, but otherwise does not accumulate in the body tissues.

10. Toluene The main route of entry into the body is through the respiratory system. Skin absorption is not clinically significant and ingestion is rare. Of the absorbed dose, 80% is metabolized to hippuric acid which appears in the urine; 20% is exhaled unchanged.

11. Trichloroethylene Trichloroethylene is mostly absorbed by inhalation. Dermal absorption occurs but is usually not significant. It is highly lipid soluble and is, therefore, rapidly cleared to fatty tissues including the brain, adrenals, and ovaries. Ninety percent of the inhaled dose is metabolized in the liver, 30–50% as trichloroethanol with a $t_{1/2}$ of 10 hr, and 10–30% as trichloroacetate with a $t_{1/2}$ of approximately 50 hr.

12. Xylene Xylene is mostly absorbed by inhalation but may be absorbed through the skin or after ingestion. Pulmonary retention is about 60%. It is complexed with serum proteins and distributed to tissues proportional to the fat content. Ninety-five percent of absorbed xylene undergoes biotransformation to methylhippuric acid.

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CHAPTER

5

Stress in Ground Support Personnel

TALMA KUSHNIR

I. INTRODUCTION

Physiological and psychological components involved in the stress experience are "built-in," programmed within the human system, as mechanisms for dealing with life-threatening situations. Although such situations are rare, successful coping with less stressful sources still requires taking over from the automatic pilot and investing deliberate efforts to land on stress-reduced terrain.

Much has been written about stress in pilots. In contrast, airport and airline ground personnel (except for air traffic controllers) have been studied only infrequently. Yet there are indications that occupational stress levels in ground crews may be as high as, and sometimes exceed those in pilots (Fitzpatrick and Shannon, 1992). Stress and burnout among employees involved in the numerous occupational categories related to ground support and airport facilities is common. The highest levels are found in flight line service and maintenance crews, air operations personnel, including air traffic controllers, and customer service employees. Individuals responsible for the physical and emotional well being of airport personnel can play an important role in stress control.

A. The Cost of Stress

Occupational stress is a condition that employees around the world have in common and it is recognized today as a major risk to workers' well being. The National Institute for Occupational Safety and Health has suggested that stress-related conditions are among the 10 most important occupational health problems of the 1990s, costing an estimated 150 billion dollars annually in the United States alone. The cost is manifested in many forms including health insurance claims and lost productivity.

The severity of workplace stress has been documented in several recent surveys. For example, the New York Business Group on Health commissioned the Gallup Organization to survey a national sample of medical directors, personnel directors, and directors of employee assistance programs (Warshaw, 1990) and estimated that the proportion of employees experiencing stress-related problems in the workplace averaged 25%. Kearns (1986) reported that about 60% of absenteeism from work is caused by stress-related disorders. Cooper *et al.* (1988) have estimated that the cost of stress to British industry amounts to over 10% of the GNP.

Stress is also being increasingly implicated as a cause of disease and reduced well being in workers' compensation claims. In the 1980s, stress-related illnesses comprised more than 14% of all such claims (Raymond, 1988). One of the fastest growing types of mental stress claims (a recent 700% increase in California) is termed "mental–mental" indicating cases where the worker is subjected to some form of workplace stress, the outcome of which is psychiatric rather than physical symptoms (Earnshaw and Cooper, 1991).

Unfortunately, this epidemic is unlikely to disappear. Elkin and Rosch from the American Institute of Stress claim that stress is a growing problem which is becoming more "pervasive, prevalent and pernicious" (Elkin and Rosch, 1990).

B. Definition of Stress

Stress is a diffuse and global negative experience accompanied by other negative emotions such as anxiety, frustration, dissatisfaction, and depression. Although there is general agreement among researchers, health professionals, and lay people that we are in the midst of an epidemic of stress, there is disagreement about the meaning of the term. Engineers may view stress as a state of a physical body which has been subjected to pressure or forces close to, or beyond its tolerance. Sociologists tend to equate it with demanding conditions, placing the problem on the environment, while psychologists tend to view stress as a psychological response dependent on internal factors. The most comprehensive approach is to view stress as a combination of several interacting biological, psychological, and social factors having mutual or reciprocal effects.

The everyday use of the term stress implies that it is negative. However, stress may have positive consequences. In 1908 it was found that there is an optimum level of stress which will elicit the best performance and that too little stress may be as bad as too much stress (Fig. 1). This principle is known today as the Yerkes–Dodson law (Yerkes and Dodson, 1908), named after the two scientists who studied the effect of noxious stimuli (electric shocks) on the level of performance of mice. A moderate level of stress may keep the individual alert to both challenging and threatening environmental stimuli. It is only when the level of stress deviates greatly from the optimum that dysfunctional consequences occur.

C. Signs of Stress

It is important to recognize the signs of stress so that action can be initiated to control it. Examples of stress symptoms occurring at the physical, behavioral, and mental/emotional levels are listed in Table I. The signs are not specific, but the occurrence of several of these symptoms simultaneously in a worker may indicate the presence of excess stress.

Such symptoms may be signs of stress in personal life and/or in the workplace. There is also a variety of stress indicators specific to the workplace including arriving late and leaving work early, low involvement with the workplace and co-workers, frequent and/or unjustified absences, feeling dissatisfied with work, and conflicts with fellow employees or supervisors.

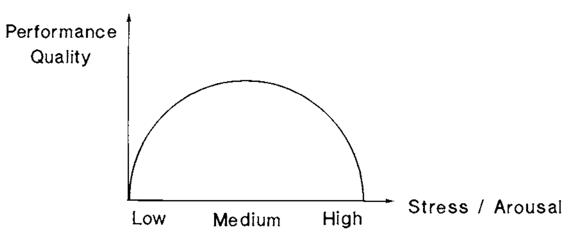

FIG. 1. The relationships between stress level and performance quality according to the Yerkes–Dodson law.

TABLE I
Common Signs of Stress

Physical	Mental/emotional	Behavioral
Headaches	Worrying	Increased smoking
Insomnia	Forgetfulness	Increased alcohol drinking
Dry throat and mouth	Depression	Impulsiveness
Muscle tension	Helplessness	Aggressive antagonism
	Anxiety	

D. Model of the Stress Process

Figure 2 integrates several current approaches and outlines a schematic description of the stress process, starting from its antecedent conditions and ending with long-term consequences.

The model suggests that the main effect of stressors is to induce short- and long-term stress responses, which may involve a variety of psychological, behavioral, and physiological reactions. However, the main process is influenced at several stages by interacting variables, each of which is hypothesized to moderate the process so that the end result is different from the net effect of stressors alone.

1. Stressors The process begins with the perceived presence of a stressor. A stressor refers to something in the external or internal environment which makes a demand on us or requires adaptation. It should be emphasized that not all demands instigate a stress response. Only excessive ones do. At the airport, aircraft mechanics are required to repair mechanical faults within a specified time limit before the plane is scheduled for takeoff. Ground agents are expected to treat rude customers politely. Fire fighters must spring into action within seconds of an alarm regardless of the time of day. These are examples of stressors that may result in a stress reaction.

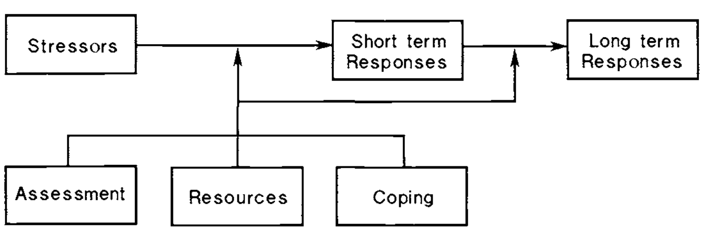

FIG. 2. An integrative model of the stress process.

There are numerous stressors and various classifications have been suggested. They include the environment, the employing organization, the content and context of the job, the work–home interface, and the home environment. Apart from external demands, there are internal stressors which arise from self-imposed needs (such as the need to excel). In fact, everything in life is potentially stressful.

Generally, the basic sources of occupational stress can be divided into two broad categories: physical–chemical conditions and psychosocial conditions. Physical–chemical conditions are easily defined and potentially amenable to change (e.g., heat, noise, and chemical exposure). On the other hand, psychosocial conditions, such as qualitative overload and unstimulating jobs, are less easily defined by the employees and not amenable to simple solutions. The term psychosocial usually involves the social environment at work, organizational aspects of the job, and the content and certain operational factors of the tasks performed.

2. Assessment Assessment refers to the way one evaluates the severity of demands against one's own coping abilities. This is a crucial component since it determines whether or not a stress response will occur. A demand considered excessive may initiate a stress response, whereas a demand thought to be a challenge will not. Assessment occurs in two almost simultaneous stages: primary and secondary appraisals.

Primary appraisal refers to the assessment of the implication of the demand to well being ("Is it serious?"). A demand that is appraised as involving harm, loss, or threat induces stress. For example, a crew that fails to prepare the plane in time for a scheduled flight is reprimanded and may be stressed by the possible consequences. It is important to understand that when a demand is perceived as threatening, a stress response is initiated even if the assessment is irrational.

Secondary assessment refers to the evaluation of one's ability to successfully cope with a threatening demand/stressor by using one's resources ("How can I overcome this situation?"). Stress occurs as a consequence of the realization that the available resources are probably or definitely insufficient for complying with the demands. It can be seen from Fig. 2 that assessment occurs at various stages throughout the stress process and at each point it may change the course of events.

3. Coping Resources Coping resources are all the material (e.g., money), physical (e.g., health), social (e.g., support from colleagues), psychological (e.g., self-confidence), and various other resources at one's disposal for coping with life demands/stressors and their impact. Actual as well as perceived or imagined threats of resource loss also may induce a stress response. The main object of many stress management interventions is developing and reinforcing coping resources. Psychological interventions may use techniques such as relaxation, rational problem solving, and assertiveness training to augment such skills. Health promotion activities strive to improve physical resources.

Two important types of psychosocial resources are control and social support. Control refers to the person's belief in self-determination and his or her ability to use coping strategies and resources in order to alter or limit negative consequences from outside stresses. Control over task demands is the critical factor in determining the health consequences of employment. In other words, the excess of demands over personal control may have negative health consequences. Social support includes practical informational and emotional assistance from others.

4. Short-Term Stress Responses The next stage in the process involves a variety of reactions to a perceived stressor. The integrative model of stress suggests that stressors activate a large variety of reactions: physiological, psychological (cognitive + emotional), and behavioral. Most reactions are automatic or habitual because they occur often or because they are innate.

Any demand interpreted as a threat to something we value or a challenge requiring effort initiates physiological responses to deal with the situation. These are innate, patterned, and unconscious responses over which one has little control and which lead to the mobilization of the body's energetic resources for coping with the demand. The perception of the demand initiates signals from the brain cortex to the hypothalamus, and through the autonomic nervous system to the adrenal medulla which responds by secreting adrenaline and noradrenaline. These two catecholamines, often referred to as stress hormones, mobilize bodily resources to make one ready for "fight or flight." In the short run, these hormones facilitate both mental and physical coping with demands and help adjustment. On the other hand, if the situation causes feelings of distress and helplessness (as when the events are unpredictable and uncontrollable), the brain sends messages to the adrenal cortex which secretes cortisol, another stress hormone which plays an important part in the immune system. In the long run, excessive secretion of stress hormones may damage health by effecting structural changes in the blood vessels which may lead to cardiovascular diseases. A suppressed immune system may also result.

The patterned response includes three stages as defined in the General Adaptation Syndrome by Hans Selye (1950). The first stage is alarm, a psychophysiological (mind–body) reaction which is rooted in the human evolutionary development since it was essential for survival in the physical environment of prehistoric times. It is characterized by pallor, sweating, increased heart rate, and redistribution of blood to the muscles. It is normally short in duration (a few seconds to a few days) and readies the body for fight or flight.

The second stage, resistance, occurs when the threat persists and physical adaptation begins. The body's reactions appear to have returned to normal but its resources are being taxed for the task of coping. Finally, Selye suggested that in the third stage, exhaustion, the body's resources are depleted due to prolonged stress. Endocrine activity is increased and high levels of cortisol are excreted producing damaging effects on the immune, digestive, circulatory, and other bodily systems.

The most meaningful physical and emotional experience in the development of the stress response may be labeled arousal. This is the short-term reaction in which energetic resources are mobilized through the combined action of the sympathetic nervous system and the endocrine system. Among other things, arousal is manifested physiologically by constriction of blood vessels in the skin (pallor), by increased heart rate and blood pressure, increased sweating, and reduced salivation. It is accompanied by emotional arousal, the nature of which depends on the specific stressor in question. For example, an interpersonal conflict may arouse anger or fear, while failing a test may produce disappointment and/or anxiety. Stress is manifested simultaneously in several channels although it is possible to distinguish between various categories of response (physiological, emotional, cognitive, and behavioral).

Cognitive reactions to stressors include restriction of the scope of attention and the ability to concentrate as attention becomes focused on the stressor and the threat it poses. If the level of general arousal increases adequately in the response to the stress, cognitive abilities may actually improve. However, in line with the Yerkes–Dodson law, beyond a certain level of arousal, the ability to make adequate decisions becomes impaired. Another cognitive reaction is the tendency to think irrationally in stressful situations. Under stress the "automatic pilot" often takes charge. Instead of deploying extra resources to choose a strategy of response which is particularly appropriate for the situation, there is an economical tendency to adopt automatic reactions.

Emotional reactions are an integral part of emotional arousal during stress and include anxiety and depression which are a part of everyday experience. There are other common negative reactions varying in strength from mild (sadness, frustration) to very strong (rage). Anger, irritability, and tension are very common reactions. Short- and long-term negative reactions tend to impair subjective well being and reduce the quality of life. Stress management and preventive interventions attempt to reduce emotional reactions in order to help employees feel better.

Behavioral reactions in stress situations vary according to the person and the nature of the situation. Common behavioral reactions to occupational stress are conflicts with co-workers due to irritability and tension and self-prescribed drugs such as nicotine and alcohol. Absenteeism is also a common outcome. Frequent, one-day absences, sometimes labeled "mental health days," are used to take one's mind off stressful occupational situations.

5. Long-Term Consequences of Stress Psychophysiological disorders are physical symptoms that have psychological origins. Temporary stress may be manifested by bodily symptoms, and prolonged stress may result in disease. Common symptoms found among workers exposed to stressful situations include: respiratory (hyperventilation and shortness of breath), cardiac (palpitations and arrhythmias), genital (impotence and dysmenorrhoea), muscular (muscle tension or pain), gastrointestinal (heartburn, indigestion, vomiting), and central nervous system (sleep disorders, anxiety, and headaches).

Psychophysiological diseases are not an inevitable result of psychosocial stress. Although there are many known psychophysiological reactions to stress, compensatory psychological and physiological processes exist which moderate extreme or dysfunctional reactions to stressful conditions. Individuals with inadequate stress-resistance mechanisms may have an increased risk of developing psychophysiological diseases. The health of other individuals, however, may not be affected by stressful conditions (Suls and Rittenhouse, 1990).

There are a variety of models linking behavior in stressful situations to disease outcomes. Three prominent models will serve as examples (Suls and Rittenhouse, 1990). One model postulates that physical illnesses are due to a structural weakness or underlying abnormality that creates a risk of illness by increasing susceptibility to external pathogens and/or degenerative organ damage.

Another model suggests that physical diseases are the result of acute or chronic exaggerated physiological reactivity to stress. For example, various diseases of the muscles, tendons, and joints (e.g., occupational neck–shoulder–arm syndrome) may be due to a chronic increase in isometric muscle tension. This model associates certain personality traits with heightened reactivity. For example, certain personality styles tend to appraise situations as more stressful and, therefore, react more often with exaggerated responses. A popular example is Type A behavior pattern ("coronary-prone personality") which is thought to characterize individuals who display intense hostile reactions in frustrating interpersonal situations as opposed to Type B persons who react more mildly.

A third model suggests that stressful situations are associated with bad or risky behavior leading to disease. In certain individuals with specific personality dispositions, stressful situations may induce lack of care for health and risky behavior styles such as smoking, alcohol consumption, overeating, and drug abuse.

E. Burnout

A discussion of occupational stress cannot avoid touching upon psychological burnout. Although the term was first coined in the early 1970s, there remains disagreement as to its exact definition.

Shirom (1989) has recently suggested a definition which encompasses the core meaning of many existing conceptualizations of burnout. He stated that burnout is a syndrome characterized by emotional exhaustion, chronic fatigue, and cognitive weariness usually with symptoms of tension and listlessness. It signifies the chronic depletion of coping resources following prolonged exposure to emotional demands. Recent evidence indicates that burnout may also be implicated in a variety of physical conditions as mild as upper respiratory infections and as serious as myocardial infarction and sudden death (Kushnir and Melamed, 1992).

F. Vulnerability and Resistance Factors

There is a host of personality factors which have been found to increase vulnerability to stressful events. For example, vulnerability may be influenced by Type A (coronary-prone) behavior pattern, noise annoyance, hostility, low self-esteem, and neuroticism. Other factors which are not personality variables, such as negative life events, also increase vulnerability because adaptation to frequent changes taxes human resistance resources and thus decreases the resistance to stress.

Stress resistors serve to make individuals less vulnerable to stress. People who display commitment or involvement in daily activities and who perceive control over life events are likely to view unexpected change or a potential threat as a positive challenge rather than as a negative event ("hardy" personalities). High levels of social support from family, friends, and/or co-workers, high levels of self-confidence, a Type B behavior pattern, and optimism are other stress resistors.

II. MAJOR OCCUPATIONAL STRESSORS AMONG AIRPORT EMPLOYEES

Analyzing stress and burnout among airport personnel can be approached in different ways. One way is to evaluate specific jobs in terms of the amount of stress they engender. For example, air traffic control has been singled out as one of the most stressful occupations. The main stressors are high and variable work loads, responsibility for people's lives, job complexity, and the demands for concentration (Cooper, 1987). Classical studies from the 1960s involving air traffic controllers (ATCs) at O'Hare Airport in Chicago (Hale *et al.*, 1971) have highlighted the stressful nature of this profession leading to the unprecedented amount of cases of psychophysiological illnesses and an increased incidence of myocardial infarction (Hammar *et al.*, 1992). Other than the reports on airline reservation agents (Saxton *et al.*, 1991), airport baggage handlers and airplane mechanics (Theorell *et al.*, 1988), and "non flight personnel" (Fitzpatrick and Shannon, 1992), little is to be found in the literature regarding stress in other aviation support occupations.

An approach which may be useful for learning about stress in airport and airline personnel would be epidemiological surveys in which various occupations are ranked in terms of the stressfulness of the job or of the risk or incidence of illnesses. The data indicate that several specific ground support occupations, such as air traffic control, aircraft repair, freight handlers, and forklift operators, are highly stressful jobs with characteristics associated with an increased risk for cardiovascular disease (Murphy, 1991; Theorell *et al.*, 1988). Furthermore, it is possible to extrapolate from epidemiological studies of related but nonaviation occupations. For example, the stresses in risky occupations, such as industrial engineering technicians, motor vehicle drivers, mechanical engineers, and catering supervisors, are similar to those found in the aviation environment and have been reported to cause an increased risk for myocardial infarction (Hammar *et al.*, 1992).

Another approach to understanding occupational stress is to analyze specific job components and environmental conditions. This strategy represents the need expressed by several stress researchers to shift attention from high-stress jobs toward the study of the stressfulness of job demands that may exist in varying degrees in many occupations. It is a practical approach in the sense that it pinpoints targets for intervention and cautions us that stressful conditions may be found in almost any occupation.

The focus on stressful conditions rather than on occupations reveals that all jobs have nonstressful aspects as well. For example, not all components of air traffic control are inherently stressful. In fact, there are various attractive components that, according to ATC reports, are stress reducing such as the challenge and the constantly changing nature of the work (Smith, 1980).

A. Shift Work

Shift work is a well-known source of occupational stress and dissatisfaction. The world is becoming a 24-hr society and increasingly air traffic is carried on around the clock. This entails shift work for many operators of airport facilities and ground crews including ATCs, flight line mechanics, freight warehouse workers, porters, catering, sanitation personnel, drivers, and security personnel, as well as customs officials.

Shift work involves employees who, on a regular or rotating basis, work nonstandard hours. This arrangement creates a problem for many employees since nearly all bodily functions, including metabolism and patterns of wakefulness and sleepiness, follow natural rhythms regulated by a roughly 24-hr biological clock. Because the endogenous rhythms in humans do not correspond exactly to the 24-hr solar day, the circadian rhythms must be reset daily. They are synchronized to the 24-hr day by time cues such as light/dark cycles, social factors, eating schedules, and environmental noises. For most people, physical and social time cues are complementary. Thus, daylight means going to work or to school and darkness at night means leisure or sleep.

However, for the shift worker, time cues tend to conflict and, therefore, slow the rate of adjustment to a new shift. Internal desynchronization of the various biological rhythms may occur which is often associated with a variety of physical and emotional symptoms such as sleeping problems, irritability, and depression. These are common symptoms among travelers experiencing jet lag after a time zone change of several hours.

Accumulated experience and research have shown that the optimum work routine (in terms of productivity and health) involves an 8-hr day, in a 40- to 50-hr week (Fraser, 1987). Although high output can be maintained with prolonged hours (up to 16 hr a day), this can only be achieved for a limited period of several weeks, given appropriate motivation and rewards. Highest productivity is achieved during daytime. Daylight is a powerful cue for activity–rest patterns and society expects people to work during the day and rest at night. Furthermore, night work is often associated with increases in accidents due to human error. For example, both the Chernobyl and Bhopal catastrophes are reputed to have occurred because of human error on the night shifts.

One of the most common complaints associated with shift work is sleeping problems which are due to daytime noise disturbances as well as to the disruption of the normal sleep/wake rhythms. In addition, night work regularly shortens sleep length on workdays by up to 4 hr causing chronic sleep deprivation. Dement and Mitler (1992) report from the Stanford University Sleep Disorders Center that shift workers are two to five times more likely to fall asleep on the job than day workers. Complaints of sleepiness and fatigue can be expected when sleep time is reduced to less than 5 or 6 hr per day. On the job fatigue, drowsiness, and diminished ability to concentrate in shift workers can result in serious performance errors and increased accident rates.

Additionally, increased irritability and stress associated with shift work may cause interpersonal difficulties, particularly among family members. When only one spouse is a shift worker or when both spouses work on different shifts, difficulties in fulfilling familial roles may occur, evidenced by reports of increased divorce or marital conflict rates among such families (Scott and Ladou, 1990).

Shift workers have an increased prevalence of sleep disturbances, fatigue, and associated stress symptoms. In fact, 5–20% of employees cannot adjust to shift work and suffer from shift maladaption syndrome which includes sleep disturbances, chronic fatigue, gastrointestinal complaints, drug abuse, higher rates of accidents, mood disturbances, and interpersonal relationship difficulties (Scott and Ladou, 1990). Mothers and pregnant women tend to suffer more from cumulative sleep loss and tiredness on night shifts, and individuals older than 50 are also especially prone to maladaption (Scott and Ladou, 1990).

Finally, sleep complaints are associated with morbidity and mortality (Dement and Mitler, 1992) such as increased prevalence of gastrointestinal symptoms and increased risk for ischemic heart disease.

Shift work is thus associated with increased costs to employers due to reduced capacity to perform at work, increased absenteeism, and increased incidence of serious diseases. Thus, it is important to identify and utilize strategies that will enhance well being and improve alertness and performance of night-shift workers. Two common short-term strategies are napping and coffee consumption, which tend to attenuate the sharp decline in alertness and performance, but do not counter the strong circadian effects of night work. Recent studies have resulted in various recommendations for arranging shifts to be more compatible with psychophysiological and social considerations.

The best shift-work system has not been clearly defined. However, strategies must be dependent on a variety of factors including the nature of the task and individual vulnerability and preference (Knauth, 1993). There are currently three basic systems. Permanent systems are those where individuals work regularly on the same day, evening, or night shift. Weekly rotating systems are those with slowly rotating shifts. Rapidly rotating systems are those where individuals work night shifts for 2 or 3 days, have 2 days of rest, and then work two or three afternoon shifts followed by an additional 2 days of rest. The permanent shift is not recommended for most people due to social isolation, although it may be preferable when safety is paramount. The rapidly rotating system involves the least disruption of circadian rhythms, least sleep disturbances, and avoidance of social isolation.

In a recent report of Italian ATCs (Costa, 1992), it was found that tolerance of shift and night work may be improved by several interventions. Costa recommended adopting a rapidly rotating shift system (one afternoon, one morning, one night) to reduce disturbance of normal circadian rhythm and performance at work; scheduling one night shift followed by 2 days of rest to minimize sleep deficit and fatigue, allowing an immediate recovery of lost sleep; adjusting the length of the shifts according to the workload (5 to 6 hr on a morning shift, 7 hr on an afternoon shift, and 11 to 12 hr on a night shift); providing the possibility of a short nap during the night shift; delaying the start of the morning shift to 7:00 or even 8:00 AM to allow a normal sleep pattern; keeping the shift rotation as regular as possible in order to allow better organization of personal, family, and social life; arranging a sufficiently long break (45 to 60 min) for a meal during the work shift; providing hot meals; and arranging for ATCs who commute for long distances to get comfortable hotel bedrooms for the night between afternoon and morning shifts.

B. Responsibility for People's Lives

Responsibility, especially responsibility for the work of other people, has long been recognized as a major stressor in managers. Managers in lower-level positions with little latitude in decision making yet having a high level of responsibility are especially under stress. Above all, responsibility for the life and well being of others has been singled out as one of the strongest occupational stressors.

In the aviation environment there are several occupations in which the main stressor is minimal tolerance for errors because of responsibility for lives—this includes pilots, ATCs, firemen and rescue personnel. Grout (1980) suggested that job responsibilities of ATCs compare to those of personnel in intensive care units in terms of tasks which are crucial to the life of others. Watkins (1983) colorfully described adrenaline "punches" experienced by ATCs during "air occurrences" ("almost" air disaster) including their recovery from frightening memories and the need for psychiatric treatment of those who cannot forget. Spring (1991) described modern air traffic control as a system functioning with a near-zero tolerance for error, and where the "subliminal message hour after hour, day after day, week after week, month after month, year after year, is always that the lives of hundreds of people depend on the air traffic controllers handling every situation correctly."

Fire fighting is another occupation which is widely recognized as a high stress job in the community because of responsibility for people. There is also a variety of other stressors such as the emergency nature of the work, repeated exposure to injury and death, and personal safety risks. In fact, in the United States, fire fighting is considered as the most stressful job. Nevertheless, the job of airport fire fighter is quite different in the sense that the frequency of emergency calls is relatively low.

Paradoxically, one of the main stressors of airport fire fighters is low utilization of skills (and boredom) while waiting to be summoned in case of a fire or an emergency. In fact, underload may be a chronic stressor for airport fire fighters compounded by the rare exposure to fire, injury, and trauma.

In summary, both ATCs and fire fighters are responsible for other people. In addition, fire fighters are also physically at high risk because of the nature of the job. Thus, both groups may be faced with a variety of stressors: high intensity and dangerous events, the low frequency of events, the unexpected nature of the event, and underload and low skill utilization.

C. Time Pressures and Deadlines

The main business of air transportation is to fly travellers safely with undue delay. Thus, many employees, especially those in dense transport facilities, often function under heavy time pressures which tend to increase as traffic expands.

Time pressures set the pace of work. The shorter the available time for servicing an aircraft before takeoff, the faster the pace of work. This affects all flight line service and maintenance personnel, flight operations personnel, employees involved in customer services, baggage and cargo handlers, and dispatchers. A fast pace has been shown repeatedly to be one of the most common causes of stress and mental strain because of two factors: the demands for speed and the fact that it is the deadline, or the clock, which controls the pace of work. External control of time constraints is threatening, whereas self-determination or perceived control over the environment reduces stress.

D. Overload

Whereas time pressure refers to the distribution of activities, work load is a broad index of the amount of task demands. Overload may be viewed subjectively as quantitative overload (too many tasks or too little time) or qualitative overload as when the individual lacks required skills, abilities, knowledge, or competencies to accomplish a job.

The experience of overload is manifested by a variety of symptoms including psychophysiological symptoms such as headaches, sweating and palpitations, inability to unwind after a hard day's work leading to irritability, and sleep difficulties. High work loads were also found to be related to social withdrawal among ATCs as a mechanism of reducing arousal.

Overload and time pressure are often synergistic, with both being exacerbated by other stressors such as responsibility for life. The situation can be made even worse when airlines, due to economic pressures, do not employ a sufficient number of employees. Shortages in personnel, therefore, may cause enough stress as to compromise aviation safety. There are many reports of overload among ATCs caused by such factors as high traffic density and personnel shortages. Indeed, ATCs are often regarded as a high risk group for stress-related diseases, injuries, and psychological burnout (Mohler, 1983).

E. Routine Jobs and Monotony

Too little a load associated with repetitive, routine, boring work is a potential stressor as much as high overload (Yerkes–Dodson law). Repetitive and simple tasks, such as those performed by airplane refuelers, cleaners, and ramp personnel, are such examples. In all cases of underload, the common factor is low utilization of skills. Especially stressful is the combination of quantitative overload (too much to do) and qualitative underload (monotonous and boring work) which has been labeled "hectic work." This combination may be lethal judging by its association with an increased risk of myocardial infarction (Alfredsson *et al.*, 1982). Paradoxically, in many highly stressful jobs (ATCs, fire fighters), periods of boredom must be tolerated. Although occasional short periods of inactivity may be welcome, Mohler (1983) has suggested that dedicated ATCs prefer to be kept busy. However, in aviation, one must not be lulled into a false sense of security by periods of low activity because there is always the possibility of sudden disruption by an emergency situation. Airport fire fighters must be prepared within a few seconds to sprint from inaction, even sleep, to be fully involved in fire fighting and rescue. Underload and periods of inactivity tend to reduce the rate of response to emergency situations because of lack of attention, boredom, and disinterest. Underload and boredom can be alleviated by enlarging the employees job duties, such as adding additional and varied components, and by enriching the job by increasing complexity and responsibility.

F. Poor Working Conditions

In the aviation environment, outdoor ground crews may be exposed to unpleasant and even hazardous working conditions. Those servicing airplanes, such as refuelers, technicians, and freight and baggage handlers, are exposed to all weather conditions. In many locations wide seasonal variations may include unpleasantly high or low temperatures, humidity, precipitation, winds, and dust. Extreme temperatures with ice and snow may interfere with work and cause accidents.

Another factor related to poor working conditions in ground crew and airport personnel is high levels of noise, especially in large airports with dense traffic. Besides hearing loss, loud noise can cause physiological stress responses induced by annoyance, interference with normal auditory function, sleep deprivation, and fear.

According to Kryter (1990) there is considerable evidence of a positive relation between exposure to aircraft noise in residential environments and various health disorders. For example, several research studies found an association between the presence of intense aircraft noise and an increase in admission rates to psychiatric hospitals. It could be argued that if noise from airport activity is a causative factor in increasing the rate of mental health problems of people living in communities around airports, then one should expect even greater effects on mental health of airport employees.

It appears that noise acts as a nonspecific stressor which induces a general stress response. The primary stimulation leads to changes in the reticular activating system of the higher cortical centers, the sympathetic nervous system, the adrenal medulla and cortex, and the limbic system. This pattern suggests that noise may influence cardiovascular function and blood pressure (although the evidence is inconsistent) and produce changes in emotion, mood, and sleep patterns.

The detrimental effects of noise intensity and duration may be compounded by other occupational stressors. For example, shift workers are very noise sensitive. Other detrimental combinations are aircraft noise and mental load, and the combined effects of noise, total body vibration, and physical activity.

G. Airline Fare Wars and Job Future Ambiguity and Insecurity

Work is often a prerequisite for survival and for most of the great religions and philosophies, working is a virtue. For most workers, gainful employment involves at least a third of daily life and preoccupies them emotionally and mentally for even more time. Moreover, employment defines to a large extent the person's socioeconomic status or social "worth." Naturally, any threat to employment, especially under conditions of scarce jobs, is bound to create an alarming sense of insecurity and uncertainty, particularly among older or unskilled individuals and those whose jobs became obsolete due to technological advances. Such individuals may find it harder to reestablish themselves in the occupational market place.

A growing number of airlines has been experiencing financial difficulties in recent years. Increased competition for routes and passengers has led to various drastic organizational changes involving loss of job security and organizational stability. A surge of takeovers, mergers, acquisitions, and downsizing since deregulation in the United States has caused many airline employees from all ranks to find themselves out of jobs or demoted. Just the uncertainty about the ability to hold a job can be a source of great stress. Additionally, survivors are known to suffer low levels of well being and guilt. The resulting physical, emotional, and social symptoms of stress include family problems and alcohol and substance abuse.

Two detrimental effects of job insecurity are especially disturbing. First, the ripple effect causing individuals to be increasingly upset and insecure as they see unemployed colleagues having difficulty finding new jobs. Second, survivors of organizational changes exhibit reduced levels of work commitment and effort which may accelerate organizational decline as performance is reduced.

Following layoffs, the employing company's interests would be best served by reinforcing the self-esteem of its employees so as to restore motivation and commitment to the workplace. This is best achieved by open communication with survivors so that they fully understand why, when, and how organizational changes will occur.

H. Disaster and Trauma

Major disasters in the aviation environment are infrequent and unexpected, but of high intensity. Exposure to death and the task of recovering and handling dead bodies is frequently a part of the trauma experience and is a risk to the health of the rescue workers (Ursano *et al.*, 1990). Even the role of providing practical assistance and emotional support to bereaved family members may induce a variety of somatic symptoms, such as sleep disturbances, muscle tension, and fatigue, as found in a study of rescue workers in the Dallas/Ft. Worth Delta Airline crash (Keating *et al.*, 1987). Exposure to disastrous events may cause post-traumatic stress which involves intrusive thoughts about the event, flashbacks, and heightened levels of arousal, particularly in individuals who have to handle bodies or assist in their identification. Thus, helpers and rescuers may be the hidden victims of a disaster. Sometimes the reactions have a delayed onset and may become chronic in which case the symptoms are classified as part of the post-traumatic stress disorder (PTSD).

Because of potential psychological damage to firemen and rescue workers from accidents and disasters, those responsible for the planning of rescue operations should consider recommendations issued by various authorities to alleviate post-traumatic stress. First, the training of such personnel is of utmost importance for better coping with high-stress conditions and disasters. In this regard, active training exercises are better than theoretical knowledge and familiarity alone. Theoretical knowledge taught along with practical skills induces feelings of control which are essential for coping with stress. Relevant and frequent training is essential for preventing severe psychiatric sequelae.

Second, once a disaster has occurred, it is important to prevent the development of chronic disorders by providing counseling and support for those in need. Several methods of psychological debriefing of rescue teams have been developed for the purpose of primary prevention of stress disorders (Raphael, 1986; Mitchell, 1983; Wagner, 1979). Since it has only recently been realized that traumatic events may affect the well being of employees, few companies have developed comprehensive crisis readiness plans to cope with short- and long-term effects of traumatic events in the workplace.

I. Serving Passengers

It is well known that intensive contact with the public, as in customer service, may be stressful. With increased competition among airlines, there is an increased pressure on all personnel working with the public or customers to provide high-quality service. This includes positive facial expressions, smiles, politeness, and prompt replies. Such demands often create a dissonance between the true feeling of the provider of service and the feeling displayed to the customer by voice, facial expression, and body language. This discrepancy is especially great when facing a particularly demanding or difficult customer. This challenges customer service personnel to fully control their emotions, particularly anger, which is a widespread job requirement nowadays. To a certain extent, everybody who works with and among people may face a dissonance between outward expression and internal feelings. Yet there are certain occupations in the aviation environment, such as ground attendants, airline agents, waiters and catering personnel, and security and police personnel, who are especially subjected to such stressors.

J. Physical Work

There are several occupations in the aviation environment which are held by physical laborers such as freight and baggage handlers, airplane cleaners, sanitation workers, and ramp personnel. These are low status occupations in terms of the tasks carried out and of the economic rewards.

Physical demands of work have traditionally been viewed as causal factors of diseases in many occupational health and safety research projects. It is now established that various psychophysiological illnesses as well as cardiovascular pathology are influenced by the effects of physical exertion. However, the most important point in the stress process is not the sheer amount of physical exertion, but rather the interaction between physical exertion and psychosocial demands. Physical exertion alone is not a stressor or risk factor for heart diseases. However, in combination with hectic work with little control over pace, it may become a stressor and a risk factor.

K. Stressful Aspects in Human Relationships

Interpersonal conflicts are a common experience in life and exert a dominant effect on mood and behavior. Recent studies indicate that interpersonal conflicts are by far the most upsetting of all daily stressors, especially if they involve nonfamily conflicts. In fact, people do not have the capacity to habituate emotionally to such conflicts.

Despite the fact that interpersonal demands are acknowledged as one of the most important stressors in the workplace (and in life), this topic has not been discussed directly in the literature with regard to airport personnel. Yet two comments were made recently concerning ATCs. Spring (1991) noted the uncomfortable feelings created by differences in the role of ATCs and airport personnel. He suggested that ATCs entertain a sense of elitism and "condescending arrogance," encouraged by their managers and supervisors, because they have always been perceived as a special group requiring special qualities. Other airport employees are often envious of the privileges controllers seem to enjoy, such as pay differentials, work break periods, etc. Conversely, ATCs often lack appreciation of the important contribution of airport facilities personnel in keeping the system working smoothly and reliably. The importance of interpersonal relations to functioning was emphasized in an experimental study on ATC teams (Herschler and Gilson, 1991) which found that successful teams enjoyed good team coordination, willingness to attend to each other's comments, and receptivity to the concerns surfaced by partners, as well as ability to overcome personal differences. The opposite occurred among unsuccessful teams.

III. STRESS MANAGEMENT AND PREVENTION

There are two paradigms or approaches to understanding stress. The clinical approach focuses on factors in the individual (history, personality, perceptions, and susceptibility). The public health approach views the origins of occupational stress mainly in environmental and psychosocial conditions which affect the individual.

The two approaches reflect two distinct ideologies and suggest different strategies for preventing occupational stress and burnout. The first is closely in line with traditional medical thinking and singles out the employee as a target of change. This individual-level focus considers the conditions of work as immutable from the employee's point of view, since they are considered primarily a management responsibility. Thus, prevention means reducing the employee's vulnerability by the modification of maladaptive lifestyles (smoking, overeating) and workers' tendency to react to job demands in a dysfunctional, stressful manner. The work environment should be accepted more easily or at least tolerated. Accordingly, a variety of person-oriented worksite-based interventions have been developed, such as stress inoculation, assertiveness training, relaxation techniques, "talking cures," and a variety of health promotion educational strategies. For example, to reduce the risk of cardiovascular disease, employees are offered programs for reducing blood lipids, smoking cessation, and physical exercise.

One example of the clinical approach is employees assistance programs (EAPs) which originated in the 1940s in the United States and which have developed as part of benefit packages for the staffs of companies, including the airlines. The main aim of such programs is to identify and provide help for employees with any kind of problem, including those related to health. The majority of the EAPs in North America and Western Europe refer the employee to specialist treatment agencies as required.

As the "stress industry" has proliferated, the preferred interventions are usually those that are theory based, tailored specifically to the employees' needs and providing follow-up activities and assessment. Effective interventions take time and require much perseverance over multiple sessions (Elkin and Rosch, 1990). Critics of this approach have rightfully argued that it is often impractical, or at least insufficient, to implement clinical-type strategies as the sole solutions to workplace stress. For example, stress management interventions offered to individuals or small groups are inadequate for an entire work force in large organizations; also, they are costly because they require highly trained professionals.

According to proponents of the public health approach, individual and organizational health are interdependent. Unlike the clinical focus, it relies upon labor–management negotiations for improving workplace conditions dealing with causes rather than symptoms.

The public health paradigm of stress prevention is dominant in Sweden where the conditions and the organization of work are considered a shared responsibility of labor and management, and the emphasis is on corporate changes, i.e., the modification of working conditions thought to be implicated in stress processes. This approach attempts to tackle the basic conflict between conditions required for employee health and the constraints and exposures occurring at work. It is based on the concept of increased worker self-determination and participation, flexible work schedules, more complex work roles, and more social support. Aided by legislation, it strives at adapting the work and the working environment to the worker's abilities, needs, and expectations.

A rapprochement between these two perspectives is needed in which both structural and personal factors are considered and in which stress prevention and management become a multidisciplinary effort. A multilevel approach taking into account the organization, the task, and the worker has been suggested (Elkin and Rosch, 1990). Some recommend that such modification efforts should be done in steps starting from individual awareness, through individual skill learning and coping capacities, to organizational-directed strategies.

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CHAPTER

6

Walk-Through Survey

ASHER PARDO

I. INTRODUCTION

The purpose of a walk-through survey is to recognize and identify potential health and safety hazards in the workplace. The information gathered should serve as a solid basis for the quantitative evaluation of health hazards and the design of their control measures. A comprehensive preparatory survey consists of the following elements: examination of industrial processes, identification of hazardous agents, examination of the work environment, work practice, and worker–work interactions.

Investigation of the industrial processes and their sequence assists in determining the source and nature of the exposure and hazards. The information sought at this point is: "where is the hazard generated?" Production operations as well as maintenance, storage, cleaning, and waste disposal should be considered.

Identification of hazardous agents is the second basic element of the walk-through survey. Examination of raw materials, end products, intermediates, and by-products is essential in the identification of toxic chemicals. Information is collected on physical and chemical properties, toxicity, route of entry into the body, physical state in the atmosphere, and possible interactions with other chemical state in the atmosphere, and possible interactions with other chemical agents. Physical agents (noise, vibration, radiation, temperature extremes) as well as biological agents and ergonomic factors are also identified at this stage.

Examination of the work environment, including neighboring areas, is another important part of the walk-through survey. Factors such as the layout of work areas, environmental temperature, pressure and temperature of the industrial process, lighting, ventilation, and engineering control measures should be examined.

The information base of any walk-through should include information about workers' activities, work practices and methods, the degree of physical effort involved in each activity, duration of exposure, and personal protective equipment used. Workers can be classified into homogeneous groups of individuals bearing similar direct and indirect exposures.

Observations on worker–work interactions, such as those between job requirements and work station design, are needed as background for evaluation of ergonomic hazards.

Keeping the above elements of an industrial hygiene walk-through survey in mind, all maintenance shops (divided into three levels) and airport service facilities should be periodically visited by the occupational health team. Level I maintenance is on the flight line or ramp area where minor repairs, system checkups, aircraft interior cleaning, fueling, and replenishing of supplies take place. Level II maintenance is in large hangars where more extensive repairs and overhaul are performed on aircraft systems, usually without their disassembly. Level III maintenance is done in independent shops where basic maintenance and overhaul work is performed on disassembled systems, components, and equipment. These shops are equipped with facilities which enable them to carry out typical industrial processes of production and maintenance.

The division of the airport facilities into maintenance levels and their corresponding functions is according to internationally accepted practice. For the readers convenience, a comprehensive summary of the potential hazards in airport facilities can be found in Table III.

II. FLIGHT LINE—LEVEL I MAINTENANCE

A. Aircraft Maintenance

Soon after passengers disembark the incoming airplane, first level maintenance is performed in preparation for the next takeoff. A brief checkup and inspection of systems and, if necessary, small scale mechanical, electrical, and avionic repairs are performed. Minor periodic maintenance as well as repair of system failures reported by the pilot can also be accomplished on the flight line, as long as they are not too complex. The technical crews involved include aircraft interior workers, ground equipment operators, oil and fuel systems technicians, and various inspectors.

The work, performed in shifts and outdoors under all weather conditions, is mainly manual. Potential hazards include noise and vibration, radio frequency (RF) radiation, ionizing radiation, inclement weather conditions, toxic substances, and ergonomic and psychosocial factors. To cite a few examples, pneumatic tools operated by mechanics are a source of noise and hand–arm vibration. In addition, aircraft engine noise on most airport flight lines is considerable. Workers may also be accidentally exposed to RF radiation while activating aircraft radar systems. Because radioactive materials are utilized in the determination of changes in fuel density, exposure is a possibility. This system includes radioactive units which are dismantled during maintenance work. Though the units are usually well protected, they should be carefully handled and checked for radiation leaks.

Mechanics and avionic technicians handle a number of toxic substances including engine oils, hydraulic oil (containing tributyl phosphate), greases, polysulfide-based sealants, and solvents. It should be noted that the small quantities of these materials, the short time required per job, and the partial execution in the open air lower worker motivation to use personal protective equipment against respiratory and dermal exposure. Large quantities of detergents and soaps are used for spray cleaning of the outside of the aircraft with potential dermal irritation.

Maintenance of the fuel system is usually performed during level II or III operations. However, when minor maintenance is required, workers may need to enter the fuel tanks during level I operations. These are confined spaces, which, when not properly ventilated, may result in exposure to high concentrations of fuel vapors containing narcotic hydrocarbons. Workers entering such spaces should be adequately protected against the oxygen-deficient and hydrocarbon-saturated atmosphere.

Musculoskeletal contortions, muscular exertion, and uncomfortable postures are an integral part of work on the flight line. Due to the tight scheduling of aircraft takeoffs, the maintenance work is very strenuous and stressful in this respect, unlike that done in hangars and workshops (levels II and III).

B. Fueling

In general, the fueling of an aircraft is conducted through a permanent pipe network, reducing worker–fuel contact (Fig. 1). However, vapor overpressure released during the fuel feeding and splashes of liquid fuel are sources of exposure for both refuelers and bystanders. The fuel consists of one of the petroleum fractions containing low and medium boiling point aliphatic hydrocarbons. Because large quantities of fuel are stored in the wing base, maintenance work in this area is almost as hazardous as work in a confined space saturated with fuel vapors.

C. Aircraft Interior Cleaning

Because the aircraft interior is cleaned in the brief period between its landing and next takeoff, workers must be fast and efficient. Their duties include vacuum cleaning, carpet washing, disposal of wastes (food, trash, and toilet), and replacement of headsets and blankets. It is also necessary to replenish the aircraft with food, drinking water, toilet water, and accessories. At the same time, a

FIG. 1. Aircraft fueling at the flight line.

technical crew performs small-scale maintenance work including minor repairs inside the aircraft.

Seats, cushions, upholstery, and carpets are cleaned using detergents and other cleaning materials approved by national bureaus of standards and the chief engineer of the airline. Although the potential for respiratory exposure to chemicals is limited in this type of work, direct contact with detergents may result in dermatitis (Fig. 2).

Food residues are loaded on trucks and centrally disposed of at the Food Services Department. The kitchen cabin is cleaned often utilizing acetic acid to remove lime from kitchenware and sodium hydroxide solution as a fat degreaser in ovens.

Solid trash is collected in large bags and transported to a facility where, in a special chamber, it is ground up before being transported to a waste disposal site (Fig. 3).

Liquid and toilet sewage is pumped into tanker trucks and transported to a central sewage pit which should have access to a sewage treatment facility. Potential exposure to biohazards exists during disposal of personal and toilet waste. Airlines should provide workers with disposable gloves and plastic bags in order to avoid contact. Common disinfectants used to clean the aircraft toilets contain formaldehyde (in a solution up to 30% concentration) or alkyl ammonium salts (e.g., alkyl dimethyl ammonium chloride).

After a shipment of plants and animals, cargo aircraft are treated for pest control by authorized personnel. Formulations of chlororganic and organophosphate compounds are used for this purpose.

Like level I aircraft maintenance workers, those who do aircraft interior cleaning are also subjected to the physical stresses of inclement weather, engine noise, and hard labor, as well as the mental stress of meeting tight schedules.

III. OVERHAUL HANGAR—LEVEL II MAINTENANCE

Level II maintenance is carried out on the entire aircraft in hangars large enough to accommodate even the largest size airplanes (such as the Boeing 747). Overhauls lasting up to 3 weeks are scheduled based on flight hours, landings, manufacturer instructions, and planned periodic maintenance.

At this level of maintenance, systems and accessories of the aircraft are also removed, inspected, and overhauled in nearby small workshops. The aircraft systems, including mechanics, avionics, hydraulics, fuels and oxygen, engine units, and composite structures, are treated in their entirety by the appropriate technical crews. Other crews responsible for painting, machining, welding, nondestructive testing, and cleaning also take part in the overhaul. If disassembly of systems is required, the parts are taken to the peripheral shops in the airport for level III maintenance.

Precise planning and scheduling of the overhaul process takes place prior to

FIG. 2. Hand spraying of a detergent during cleaning of the aircraft interior.

the aircraft's arrival in the hangar. It should be emphasized that the various jobs are performed simultaneously with large numbers of employees working inside and outside the aircraft, each crew engaged in a different assignment. The crowding requires precise coordination so as to prevent interference and accidents (Fig. 4). Workers climb on wings and external surfaces to reach inaccessible areas, thus increasing the risk of an accident. Also, electric cables and hydraulic pipelines spread on the aircraft floor obstruct free movement which can cause tripping and falling.

The processes and potential hazards found in level II shops are similar to those of level III. Therefore, they will be discussed jointly under Sections IV and V of this chapter. Here the description will be confined to the entire aircraft structure: washing, cleaning of fuel tanks, paint removal, painting and corrosion prevention, nondestructive inspection, and noise.

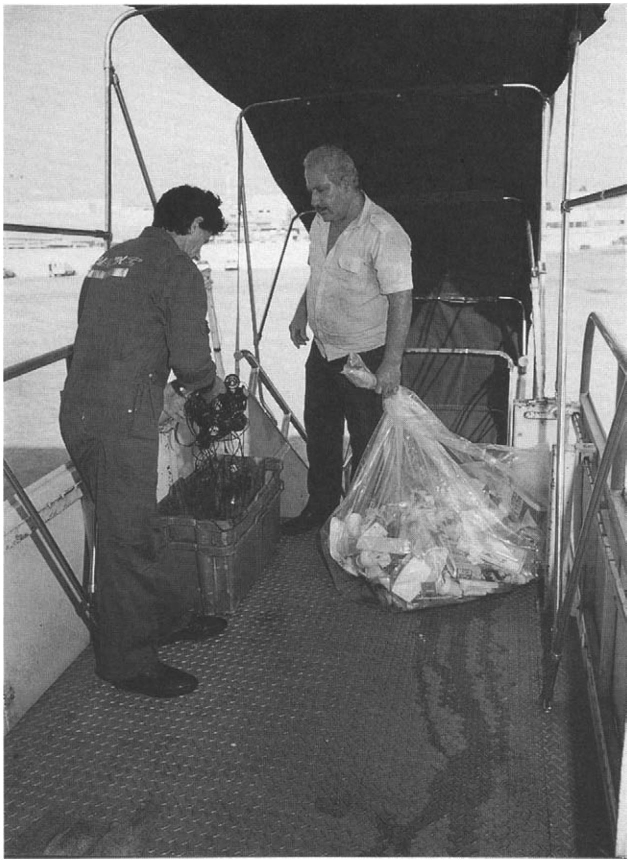

FIG. 3. Trash disposal and collection of headsets during cleaning of the aircraft interior.

Prior to the overhaul, the aircraft is cleaned externally and internally. It is spray washed using mainly steam and detergents but jet fuels and washing oils are used locally to remove greasy dirt. If the floor drainage is not properly designed, there will be spills and puddles emitting bothersome odors which may be a nuisance especially in hot climates. Cleaning operations in the aircraft usually require removal of glues and plastics utilizing petroleum distillates, white spirits, and detergents.

The fuel tanks in the wing bases must be periodically inspected, cleaned, and repaired. Although they are emptied of excess fuel and ventilated before workers

FIG. 4. Aircraft maintenance in the overhaul hangar.

enter them, there is always the danger of residual fuels and vapors. Fatal accidents of unprotected workers who had entered into such confined spaces have occurred. This operation, therefore, requires special protective clothing and a hose mask/oxygen supply. It is also extremely important that the buddy system be used.

Cracked paint is removed from the aircraft structure by either mechanical (abrasive discs) or chemical means. With the former method, exposure to paint and metal dust may be significant if local ventilation and bag filtering are not applied. The chemical removal of paint is done by phenol and methylene chloride stripping as well as by the digestive action of hydraulic oil containing tributyl phosphate. These substances have systemic effects as well as corrosive and irritating effects on the skin.

The majority of the painting work is performed on small areas of the aircraft structure (although on rare occasions a wing or the whole body is painted). The surface is first cleaned with solutions usually containing nitric and phosphoric acids which are corrosive to the skin and the respiratory tract and chromate and fluoride salts. The part is then sprayed by a primer containing water-insoluble chromate after which the paint is applied.

Some of the paints used are based on polyurethane containing isocyanate dimers. Recently, water-soluble paints have been introduced to be used inside the pilot cabin. A variety of organic solvents are used as thinners in the painting process. Among them are toluene, xylene, butyl acetate, amyl acetate, and acetone. Sometimes, painting is carried out after pretreatment with polyester paste thinned with styrene. Respiratory irritation may result from excessive exposure to organic solvents, many of which are also narcotic. Painters exposed to solvents may experience headache, dizziness, and fatigue. Respiratory and skin protection should be used in order to avoid contact with residues of free isocyanates and epoxy hardeners since these agents are potent allergens.

Special oils are applied to prevent corrosion and rust in spaces where contact with humidity and water is possible. Such oils contain aromatic hydrocarbons, petroleum oil, and dipropylene glycol monoethyl ether. Excess oil is removed by terpene solvent, the active ingredient of which is usually *d*-limonene, a skin irritant.

There are two possible sources of radiation exposure: uranium weights and nondestructive inspection. Depleted uranium weights in the aircraft by which dynamic balance is maintained during the flight may be a source of ionizing radiation. X-rays are used in nondestructive inspection (NDI) to detect cracks and metal fatigue in the aircraft structure. Disassembled parts undergo inspection in specially designed rooms and a cathode tube is generally used as a generator of x-rays with typical energies ranging from 40 to 420 KeV. However, mobile units supplying energies of 40–50 KeV are used for NDI of the aircraft body and wings and inside the aircraft. Workers should follow strict guidelines and rules to ensure protection against accidental exposure to ionizing radiation in such units.

Finally, noise is addressed here to complete the discussion on potential hazards in the overhaul hangar. While test runs of the engine are usually done outside the hangar to reduce the excessive noise level, the auxiliary power unit and partial running of the engine without ignition is done inside the hangar creating a source of noise.

IV. AIRCRAFT STRUCTURE SHOPS—LEVEL III MAINTENANCE

A. General

Structural aircraft parts and components are mainly repaired and overhauled at level III shops (similar but less extensive work may also be done at level II). At both levels, therefore, workers are involved in a multitude of processes including aircraft body repair, metal machining, welding and soldering, electroplating, and painting. Occupational exposure is comparable to that in similar facilities in industry, though on a smaller scale. Small-scale processes are usually less technologically advanced and, therefore, employ less automation and robotics. Hence, many workers are likely to be involved in manual operations. In addition, unlike assembly line workers in industry who are usually assigned to the production of specific parts, the parts being repaired in the structure shops in the airport are heterogeneous. For example, brake drums may be handled together with food containers, heaters, and hydraulic tubing. For these reasons, airport workers are potentially exposed to a wider range of chemical and physical hazards.

B. Aircraft Body Repair Shop

In this shop, aircraft body and skin parts together with items belonging to the aircraft interior equipment are renewed, repaired, or modified. Common operations are cutting, bending, riveting, plumbing (tubes, pipes), and sealing.

Pneumatic tools used in the above operations are sources of high noise levels and segmental vibration. If source isolation cannot be achieved, personal protection, including ear muffs, ear plugs, and heavy gloves, is mandatory.

Workbenches are usually covered with soft fabric to prevent scratching of the repaired parts. This fabric may become a secondary source of dust emission if accumulated fine metal particles are not occasionally removed by cleaning. In addition, floors should be vacuumed to keep the area as free as possible from airborne particles.

In order to increase the resistance of the aircraft body and other parts to the corrosive action of the atmosphere and the weather (solar radiation, temperature, and moisture) as well as to hot hydraulic fluids, the metal surface is protected by high-quality coating systems. This coating is obtained by a combined application of an inorganic coating layer and a protective paint layer. While the inorganic coating is applied in baths containing mineral acids and salts, the paint coating is usually applied by spraying, creating a high potential for occupational exposure.

Two coats of paint are normally applied: the first, a primer based on epoxy formulations and anticorrosive pigments; the second, a topcoat based on polyurethane products (civil aircraft) or thermoplastic acrylic resins (military aircraft). Amine hardeners of epoxy resins and aliphatic isocyanates as curing agents of polyurethane-based paints are sensitizing agents as mentioned previously. Anticorrosive pigments, such as zinc chromate and strontium chromate, are human carcinogens and have very low threshold limit values (TLV). Even with normal engineering control, personal protective equipment may be needed during their use.

In order to seal connections, sealants are utilized which contain reactive solvents and organic peroxides. Both substances are skin and respiratory sensitizers.

NDI for cracks and surface imperfections is done with special dyes spread on the surface of the metal. Once the dyes have penetrated into cracks, the surface is rinsed, leaving dye only in the cracks. An adsorbent powder is then spread on the surface so the dye can be detected visually or by special lighting. Organic solvents including 1,1,1-trichloroethane, chlorodifluromethane, kerosene, and mineral oils are used in this process. Other additives, such as methylal and methyl isopropanol, may be present.

Another NDI technique to detect metal fatigue or cracks is based on radiography. This technique utilizes radioactive sources, such as cobalt 60 and iridium 192, or cathode tubes to generate gamma rays or x-rays, respectively. The radiation is absorbed or attenuated by the object to a degree which depends on its thickness, density, and the atomic number of its elements. Any change in the density of the metal tested (compared to a standard) is detected and the inconsistency located. Workers must be protected by specially designed shielded rooms.

Much of the work in the aircraft body repair shop requires prolonged standing, bending, and repetitive motion. There is, therefore, a potential for musculoskeletal disorders.

C. Welding and Brazing Shop

Welding and brazing are techniques for coalescing metals by heat using filler metal alloys similar in composition and metallurgical properties to the components to be joined. The two processes differ in the temperature required: welding is performed at very high temperatures (above 800°C) on metals having high melting points so that the welded parts melt before the joint is formed; brazing is performed on softer metal alloys, usually at temperatures ranging from between 400 and 800°C, where only the filler metal is fused between the brazed metal pieces.

There are several techniques for welding depending upon the base metal alloy being treated. Most techniques use electric arc or spark to obtain high temperatures. In others, the necessary heat is provided by combustion of fuel gas enriched with oxygen.

The more common welding techniques applied in airport welding shops are gas metal arc (GMA) (also called manual inert gas), shielded metal arc (SMA), and gas welding. In the former two, a high voltage arc is generated between the metal workpiece and a specific electrode most kinds of which contain the filler metal. The GMA technique requires a constant supply of inert gas, mostly argon and carbon dioxide, onto the point being welded to protect it from atmospheric oxygen interference. Gas welding utilizes the combustion of acetylene and oxygen mixture to generate the required heat.

The items that are welded in the shop come from different parts of the aircraft. Examples are engine parts (exhaust box, tail cone, heat exchange units), tubes and pipes, and brake drums and discs of the aircraft wheels.

The sequence of operations in the welding shop follows including brief remarks of potential health hazards.

Items brought to the shop are first stored in a special location and subsequently dismantled and cleansed of soil and protective grease with detergents and solvents. If the base metal is not cleaned from protective grease prior to welding, the thermal decomposition of the grease may release irritating aldehydes. Even during cleaning and degreasing of parts being prepared for welding, there is a risk of exposure to solvent vapors with attendant respiratory or CNS symptoms. When detergent solutions are used, dermal irritation is the potential hazard.

After cleaning, the parts are dry ground and filed (to allow detection of cracks) before they are ready for welding. However, the potential of exposure to significant amounts of metal dust released in the grinding and filing stage is very low.

The welding technique most frequently used in the shop is the GMA utilizing a tungsten electrode and argon gas. It is performed on stainless steel, mild steel, and aluminum—magnesium (Fig. 5). The SMA technique applying coated electrodes is used for spot welding of mild steel.

There are a number of health risks associated with welding, among them possible interactions of the various chemical and physical agents involved (Table I). (The hazard is increased in the airport shop because the operation is usually done manually rather than by robotics.) One of the risks is exposure to chromium and nickel found in stainless-steel alloys. The former, in its Cr(VI) state, and the latter in all its states are definite human carcinogens. Another hazard is carbon monoxide which forms when the carbon in the steel reacts with oxygen at high temperatures. And finally, ozone is generated by the reaction of uv radiation with atmospheric oxygen.

The coating of the electrodes, consisting of organics and inorganics, turns into a flux that cleans the welded surface and prevents its oxidation. Alternatively, paste flux may be applied. Some fluxes, depending upon their composition, emit hydrogen fluoride and airborne particulates of fluorides at high temperatures.

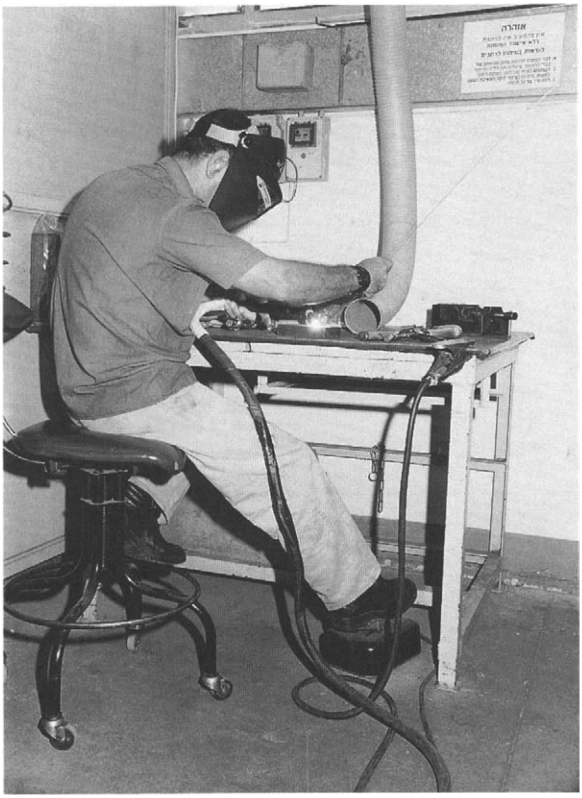

FIG. 5. Tungsten-inert gas (TIG) welding in the welding shop: An example of a variety of chemical and physical hazards encountered in one job.

Significant levels of electromagnetic energy are produced by the electric arc during GMA operations and by the flame in gas welding. The latter is a substantial source of ir radiation. In addition, a wide range of uv wavelengths is encountered by the welder, exposure to which may result in photokeratitis and dermal erythema.

When the welding is carried out intermittently during the workday the noise level may be bothersome but is unlikely to exceed the 8-hr Leq threshold. Heat generated by the high temperatures in the welding zone is not sufficient to induce heat stress, but may cause discomfort.

The degree of potential exposure to chemical and physical agents varies depending on the welding technique used. High levels of metal fumes are produced during both SMA and GMA welding. The latter can also generate

TABLE I
Health Hazards Associated with Welding Processes

	Chemical Hazards
Metal fumes	Iron oxide, manganese, chromium, nickel, molybdenum, vanadium, aluminum, titanium, beryllium, zirconium, cobalt, tin, tungsten, lead, zinc, copper, arsenic, cadmium
Gases	Carbon monoxide, ozone, oxides of nitrogen, hydrogen fluoride, hydrogen chloride, phosgene, phosphine
Inorganics	Fluorides, zinc chloride, silica, borax magnesium oxide
Particulates	NOC[a]
	Physical Hazards
	uv and ir radiation
	Noise
	Heat
	Burns
	Electric shock

[a]NOC, not otherwise classified.

significant levels of ozone and uv radiation. The existence of high DC voltages (10–50 V) and thousands of amperes in the arc welding poses an electric shock or electrocution hazard.

The control of gases and fumes generated during welding requires local or general exhaust ventilation. The effectiveness of the local exhaust system depends on the distance between the welding spot and the face of the duct inlet. The use of exhaust ventilation is not always possible (e.g., when the air currents interfere with the masking gas in the GMA technique). Therefore, airline respirators equipped with built-in protective windows against nonionizing radiation should be employed. Leather or special plastic aprons are also used as protection against radiation. In addition to protection against chemical and optical hazards, workers should be protected against noise, heat, and electric shocks.

As in the aircraft body repair shop, postural considerations are also relevant to welding. Welders stand for long periods often in uncomfortable positions which can cause musculoskeletal disorders such as low back pain.

Engine parts and brake discs are tempered in an oven immediately after welding. Tempering ovens are electrically heated and thermally insulated by layers of synthetic ceramic fibers which may be released into the shop space when the insulation layer is exposed.

NDI for cracks, the final step in the welding process, follows using a specific dye which penetrates into the cracks and fluoresces under uv light. Another technique utilizes a ferromagnetic powder, the particles of which are magnetized to the surface of the part forming visually distinct lines along the cracks. Hydrocarbon solvents (white spirits) are used in this technique.

Brazing, the technique most commonly used in airports, employs gas where combustion of gas mixtures, such as butane and acetylene, generates high temperatures. The filler metal used in this technique consists of metal alloys softer than steel such as copper, zinc, lead, silver, and cadmium.

Lower levels of exposure are encountered in brazing due to the lower temperature of the process. However, with cadmium alloys, toxic cadmium fumes are generated. In aircraft, this toxic metal is incorporated into bearings, gears, electrical wires, and electronic components of radar. Fumes of other metals, such as silver, copper, tin, and lead, may also be present. The flux is based on borax.

D. Machining

Typical machining operations include drilling, sawing, grinding, milling, and lathing. Potential hazards are cooling fluids, additives, metal dusts, and noise.

In some machining operations, cooling fluids are continuously sprayed over the interface between the tool and the piece being worked to reduce heat generated by friction between the piece and the rapidly spinning blades, drills, grinding stones, or discs (Fig. 6). The fluids consist mainly of synthetic mineral oils and soluble oils emulsified in water. The sprayed emulsions release oil mist into the air and throughout the work area if the machines are not properly shielded. Dermal exposure and contact dermatitis of the eczematous eruption type may occur especially among workers not wearing protective clothing and gloves.

Various compounds are added to the oil–water mixture as emulsifiers, surfactants, bactericides, rust inhibitors, soaps, and deodorizers. Included in this group of additives are numerous chemicals (see Table III) which can affect the CNS and skin.

Therefore, it is imperative to protect skin from oils and their additives. Since no universal glove exists, the selection of gloves and other protective clothing must be target specific.

Although oil–water emulsions may cause dermal problems, they are useful in that they reduce the release of metal dusts during the machining process. However, when cooling fluids are not used, as in dry processing, dust is the major hazard present, the type of which released depending upon the composition of the material being ground, drilled, or polished.

Noise is the physical hazard present in all machining operations. Be-

FIG. 6. The lathing process: Oil mist is produced by a constant flow of oil–water emulsion which reduces heat generated by friction. (Note that the worker is not wearing protective gloves.)

cause these machines produce high-frequency, high-intensity (dB) noise, ear protection is mandatory.

E. Plating Shop

The purpose of plating is to improve the metal resistance against corrosion. Electroplating and chemical plating are composite processes which require special facilities. Prior to the plating process the metal must undergo surface treatment to remove dirt, grease, and rust in order to prepare the surface for quality adherence of the plating layer. Surface treatment is carried out in a series of bathing tanks, each of which is assigned a different operation: acid and alkali cleaning, surface passivation, and solvent degreasing.

A number of hazardous substances, including mineral acids, inorganic bases, cyanides, and hydrocarbons, are found in the bathing tanks during the cleaning process (Table III). Acid and base mists, together with vapors of organic solvents and droplet aerosols of soluble metals, are released into the atmosphere from the baths. Another class of inhibiting compounds, aliphatic amines, pyridine derivatives, and salts of arsenic and molybden, added to the baths to prevent excessive corrosion of the metal surface poses minimal risk to the worker.

Once the metal is cleaned, it can then proceed to the electroplating process. When direct electric current is applied between two electrodes immersed in a bath filled with an electrolyte solution, electrolysis will occur with positive ions migrating toward the cathode and negative ions toward the anode. If the part to be plated serves as a cathode and the electrolyte solution contains the plating metal, the part will be coated by that metal. This is the principle of simple electroplating. (Other newer techniques, called electroless or chemical plating, utilize electrochemical reactions to produce the coating without requiring electrolysis.)

Not all the energy of the electric current in the plating bath is invested in the electroreduction of the metal; part is wasted in the dissociation of water into hydrogen and oxygen. These gasses migrate to the bath surface and escape into the atmosphere, transporting with them fine droplet aerosols of the bath content. (Plating efficiency is measured by that part of the electrical energy consumed for electroreduction.) For example, in chromium plating, most of the energy (80%) is wasted in water dissociation, causing substantial amounts of chromic acid to escape the solution. In contrast, nickel and cadmium have very high plating efficiencies.

Such factors as the current intensity and temperature of the plating bath also affect the concentrations of the airborne pollutants, and with them the potential for worker exposure. Clearly, the electroplating process requires proper ventilation and the availability of protective clothing to ensure worker safety.

F. Paint Shop

Most painting operations are confined to the paint shop although in some cases painting is done in other areas of the airport. Paints are applied mainly for protection against corrosion, for decoration, for electric insulation, and for camouflage. Spray painting, usually using air-compressed spray, is the most common technique. A paint can is attached to a spray gun with high air pressure applied so that the paint solution is nebulized and sprayed through the gun. Depending on the item painted, the excess paint solution sprayed by air compression can reach 50–80% of the amount used. (Less excess paint is used in other painting techniques such as airless and electrostatic spray, and dip and roller painting.) For small repairs, spot painting brushes are usually used.

Paints consist of substances which can be classified in four main groups: pigments and extenders, film-forming agents for volume and texture, solvents as diluents, and additives to improve the properties of the paint (Tables II and III).

Painters are potentially exposed to paint aerosol and vapors, particularly with spray gun operations, if protective measures are not taken. Although the inhalation of these paints is always of concern, so also is skin exposure, especially when workers pour and mix paints and solvents.

The standard facility for spray painting should be a painting booth equipped

TABLE II
Components of Paints

Classification	Function	Example of components
Pigments	Coloring, corrosion resistance	Metal powders, metal oxides, chromates, sulfides, titanates, organometal, ultramarine, azo pigments, polycyclic compounds
Extenders and fillers	Technical and optical properties, volume modification	Minerals, carbonates, barium salts, kaolin
Film-forming agents	Film formation, gloss, texture	Vinyl coatings, acrylic coatings, alkyd coatings polyurethane coatings, epoxy coatings
Solvents	Dissolution, dilution, suspension, vehicle	Aliphatic hydrocarbons, aromatic hydrocarbons, alcohols, ketones, esters, glycol ethers, water, oils
Additives	Stabilizers	Organotin compounds
	Plasticizers	Phthalates, oleates
	Wetting and dispersing	Detergents
	Inhibitors	Quinones, aromatic amines
	Antioxidants	Polyphenols, quinones
	Antiskinning	Oximes
	Preservatives	Organotin compounds, chlorinated phenols
	Defoamers	Mineral oils
	Driers and catalysts	Organometallic compounds
	Light stabilizers	Hydroxyphenyl triazines
	Rheology additives	Castor oils
	Surface additives	Alkyl polysiloxanes
	Curing agents	Toluenesulonic acid
	Flame retardants	Antimony compounds, polybrominated biphenyls

with a ventilating hood and a water curtain (Fig. 7). The painter stands inside the booth and is protected from the excess spray which is trapped by the hood and the water. In practice, however, workers are often exposed to the paint solution either because of carelessness or because of poor ventilation. In some cases workers may require whole-body protective equipment.

Potential hazards have been reduced since the introduction of water-based paints as substitutes for those diluted in organic solvents.

G. Silk Screening

Silk screening is a technique used to prepare aircraft signs, e.g., the name of the airline printed on the fuselage or tail. A computer-designed prototype of the

TABLE III
Summary of Potential Hazards in Airport Premises and Facilities

Facility/work	Process/operation	Types of hazards
Flight line	Maintenance	Chemical: engine oils, hydraulic oils (tributyl phosphate), greases, MEK, freons, white spirits, petroleum distillates, jet fuel, detergents and soaps Physical: noise, vibration, heat and cold stress, RF radiation Ergonomic: musculoskeletal contortions, uncomfortable postures Psychosocial: stress, tension
	Fueling	Chemical: aliphatic hydrocarbons
	Cleaning	Chemical: detergents, formaldehyde, acetic acid, sodium hydroxide Physical: noise, heat Biological: bacteria, fungus, virus Ergonomic: musculoskeletal contortions Psychosocial: tension, stress
	Waste disposal	Biological: bacteria, virus, etc.
	Loading and unloading	Ergonomic: muscle exertion, musculoskeletal stress
Aircraft body repair shop	Cutting, bending, riveting, routing, plumbing, rigging, burnishing	Chemical: metal dust Physical: noise, hand–arm vibration Ergonomic: postural factors, musculoskeletal stress
	Corrosion protection	Chemical: nitric acid, phosphoric acid, chromates, fluorides, epoxy resins, amine hardeners, isocyanates
	Sealing	Chemical: methacrylic resins, organic peroxides, petroleum distillates, white spirits
	Nondestructive testing	Chemical: chlorinated hydrocarbons, methyl isopropanol, methylal, kerosene, mineral oils
Welding and brazing shop	Cleaning and degreasing	Chemical: detergents, chlorinated hydrocarbons
	Welding	Chemical: iron oxide, manganese, chromium III, chromium VI, nickel, molybdenum, vanadium, aluminum, titanium, beryllium, zirconium, carbon monoxide, ozone, nitrogen oxides, hydrogen chloride, hydrogen fluoride, fluoride, zinc chloride, silicon dioxide, borax, unclassified particulates Physical: uv and ir radiation, noise, heat, burns, electric shock Ergonomic: postural factors
	Brazing	Chemical: cadmium, lead, tin, silver, copper, borax

(continues)

TABLE III—*Continued*

Facility/work	Process/operation	Types of hazards
Welding and brazing shop (*cont.*)	Nondestructive testing	Chemical: petroleum distillates Physical: ionizing radiation
Metal machining	Grinding, drilling, sawing, lathing (dry)	Chemical: metal dust, nuisance dust of abrasive materials (silicon carbide, silicates, alumina) Physical: noise
	Grinding, milling, lathing (wet)	Chemical: cooling fluids and cutting oils, diamines, triamines, triazines, triethanolamine, formaldehyde, chlorinated phenols, sodium nitrite, quaternary ammonium compounds Physical: noise
	Cleaning	Chemical: white spirits, petroleum distillates, 1,1,1-trichlorethane
	Cable wiping	Chemical: freon TF
Plating shop	Acid cleaning, pickling, passivation	Chemical: acids: nitric, hydrochloric, hydrofluoric, chromic, sulfuric, phosphoric
	Alkali cleaning	Chemical: alkali hydroxides, sodium meta-silicate
	Solvent degreasing	Chemical: 1,1,1-trichloroethane, trichloroethylene, perchloroethylene
	Plating	Chemical: chromic acid, nickel, cadmium, copper, silver, cyanides, fluoborates
Paint shop	Painting	Chemical: metal oxides (zinc, iron, antimony, titanium, chromium, copper), zinc chromate, strontium chromate, lead molybdate, nickel titanate, aluminum powder, barium borate, cadmium sulphoselenide, carbon black, toluidine red, talc, amorphos silica, kaolin, diatomaceous earth, alkyd resins, phenol resins, PVC, PVA, epoxy resins, polystyrene, polyurethane, polyester, linseed oil, turpentine, white spirits, petroleum ethers, toluene, xylene, ethyl benzene, methylene chloride, methanol, ethanol, isopropanol, butanol, acetone, MEK, MIBK, isophorone, cyclohexanone, ethyl acetate, butyl acetate, glycol ethers (cellosolves)
	Silk screening	Chemical: epoxy- and polyurethane-based paints, amine hardeners, uncured isocyanates, methyl acrylate, methyl methacrylate, toluene, xylene glycol ethers
	Etching	Chemical: chromic acid, sulfuric acid, hydrogen peroxide, hypochlorites Physical: uv radiation
Composite structure shop	Carpentry	Chemical: soft and hard wood dust, contact adhesives, toluene, xylene Physical: noise

TABLE III—*Continued*

Facility/work	Process/operation	Types of hazards
Composite structure shop (*cont.*)	Vacuum forming (molding)	None
	Layers bonding	Chemical: glass fiber, graphite fiber, aramide fiber, epoxy resin, amine hardener
Seats and upholstery shop	Washing and cleaning	Chemical: detergents
	Drilling, nailing, grinding, polishing	Chemical: metal dust, plastic polymers dust Physical: noise
	Painting	(see under paint shop)
	Glue removal	Chemical: detergents, methyl ethyl ketone
	Gluing	Chemical: epoxy resin, amine hardener, isocyanates, acetic acid, toluene, silicone rubber, ethyl silicate
	Sewing	Ergonomic: uncomfortable posture, long sitting
Life-saving equipment repair	Lifeboats and jackets	Chemical: petroleum naphtha, toluene, *n*-hexane, talc, zinc oxide, amine catalyst
Engine buildup shop	Washing	Physical: hot water burns
	Cleaning and degreasing	Chemical: 1,1,1-trichloroethane, freons, methanol, ethanol, gasoline, white spirits, kerosene
	Engine lubrication	Chemical: engine oils (diesters, polyalcohol esters, hydraulic oil, tributyl phosphate, tricresyl phosphates, mineral oils
	General maintenance	Chemical: asbestos Physical: noise Ergonomic: long standing, fatigue, musculoskeletal contortion, muscles overexertion, postural factors
Wheel and brakes shop	Mechanics	Chemical: oils Physical: noise
Treatment of metal surface (hydraulics shop)	Solvent degreasing	Chemical: chlorinated hydrocarbons, freons
	Alkaline cleaning and degreasing	Chemical: sodium hydroxide, potassium hydroxide, sodium metasilicate
	Acid treatment	Chemical: mineral acids: nitric, chromic, sulfuric, phosphoric, hydrochloric, hydrofluoric
	Carbon removal	Chemical: phenol, methylene chloride
	Paint removal	Chemical: toluene, methylene chloride, phenol
Maintenance and units inspection (hydraulics shops)	Control speed drive (CSD) and hydraulic systems inspection	Chemical: engine oils, hydraulic oil (tributyl phosphate), white spirits, naphtha, petroleum distillates, chlorinated diphenyls, chlorinated paraffins, acetic acid, ethyl silicate, organotin compounds, zinc cobalt aluminate

(continues)

TABLE III—*Continued*

Facility/work	Process/operation	Types of hazards
Electronics shop	Hand soldering and inspection and testing of electronic systems	Chemical: colophony (decomposition products of resin acids), acetone, methanol, 1,1,1-trichloroethane, freons, white spirits, mercury, cadmium, silver, toluene, MEK, alcohols, epoxy resins, amine hardener, methacrylic polymers Physical: noise, RF microwave radiation, ELF electromagnetic fields
Overhaul hangar	General	Physical: noise Safety: slip, trip, fall Ergonomic: postural discomfort Psychosocial: overcrowding
	Aircraft wash	Chemical: detergents, oils, jet fuel
	Fuel system inspection	Chemical: fuel hydrocarbons
	Cleaning and degreasing	Chemical: petroleum distillates, white spirits, caustic soda, 1,1,1-trichloroethane, terpens (*d*-limonene)
	Paint removal	Chemical: dry paint dust, phenol, methylene chloride, hydraulic oil
	Painting	Chemical: nitric acid, phosphoric acid, fluorides, zinc chromate, strontium chromate, toluene, xylene, butyl acetate, amyl acetate, acetone, styrene, isocyanates, epoxy hardeners
	Rust prevention	Chemical: petroleum oils, aromatic hydrocarbons, dipropylene glycol monoethyl ether
	Nondestructive testing	Physical: X rays
Food services	Cooking	Chemical: decomposition products of edible oil (acrolein, aldehydes) Physical: heat load
	Storage	Physical: cold stress
	Food packing	Sanitation: pathogens Ergonomic: musculoskeletal stress
	Dish washing	Chemical: detergents Physical: heat load, noise Ergonomic: musculoskeletal stress
Cargo terminal	Miscellaneous	Chemical: diesel exhaust Physical: noise, temperature extremes Mechanical: slip, trip, fall Ergonomic: musculoskeletal stress, body contortions, muscle exertion, fatigue Psychosocial: stress, strain, tension

TABLE III—*Continued*

Facility/work	Process/operation	Types of hazards
Ancillary services	Air conditioning maintenance	Chemical: freons (gas), rock wool fiber
	Plumbing	Chemical: hydrogen sulfide, methane, mercaptans
	Gardening	Chemical: pesticides, insecticides, herbicides
	Fire fighting	Chemicals: halons, extinguishing powders, thermal decomposition products
	Security personnel	Physical: x rays

desired wording is photographed on a special adhesive tape coated with a photosensitive material. Areas of the photosensitive tape comprising the background of the lettering are cured under uv light losing their absorbency for paint. The tape is then laid under a special screen on which paint is poured, absorbed only by the uncured lettering areas of the sign. The excess paint on the tape is washed away with solvents after which the painted tape is dried in an oven.

A potential hazard results during the application of the epoxy and polyurethane-based paints containing residues of uncured epoxy and isocyanates, respectively. Both are known to be sensitizers which can cause allergic reactions. The solvents used contain chemicals which can cause CNS, respiratory, and dermal symptoms. Therefore, silk screening should be performed under a ventilating hood and adequate skin protection and protective clothing should be provided.

H. Etching

Etching is also used to prepare signs. It involves imprinting a prototype image on a photosensitive layer of a coated anodized aluminum plate. Selective exposure of the background areas of the lettering to uv light provides them with a protective coating against etching. The plate is immersed in an etching solution containing strong mineral acids and the unprotected areas which comprise the lettering on the plate are etched. The protected areas of the sign are washed with a bleach and wash solution to remove the hardened photosensitive agent. Glowing signs or signs for illumination boards are made by a combination of etching and silk screening with the occasional use of a pentograph for fine grooving.

Splashes and spills during the above operations may generate droplet aerosols of etching solution containing chromic and sulfuric acids which are corrosive to unprotected skin.

FIG. 7. **Spray painting inside a paint booth.**

I. Composite Structures Shop

A composite structure is one containing a combination of materials of different origins. The materials are layered one on top of the other and bonded with special glues to form one composite structure which is lightweight yet has high physical strength and resistance to mechanical forces.

The construction of composite layered structures is done under thermal control by two independent methods. In the first, thin layers of the composite structure components are pressed together and softened by heat allowing them to adhere. In the second process, glass fibers, polyimides, aramide fibers (kevlar), and graphite fabric sheets are impregnated in epoxy glue and put one on top of the other to form layered reinforced composite structures (Fig. 8). The epoxy glue (base and hardener) is a potential hazard in this process mainly due to dermal exposure. In addition, graphite fibers are a respiratory hazard requiring respiratory protection.

One part of the composite structures shop functions as a carpentry where wooden models of aircraft parts are made. Various operations, such as sawing, drilling, lathing, planing, filing, and sanding, are performed on chipboard, plywood, and hard beech wood. The potential hazard in these operations is wood dust, especially that of hard wood. Either isolation or local exhaust ventilation is

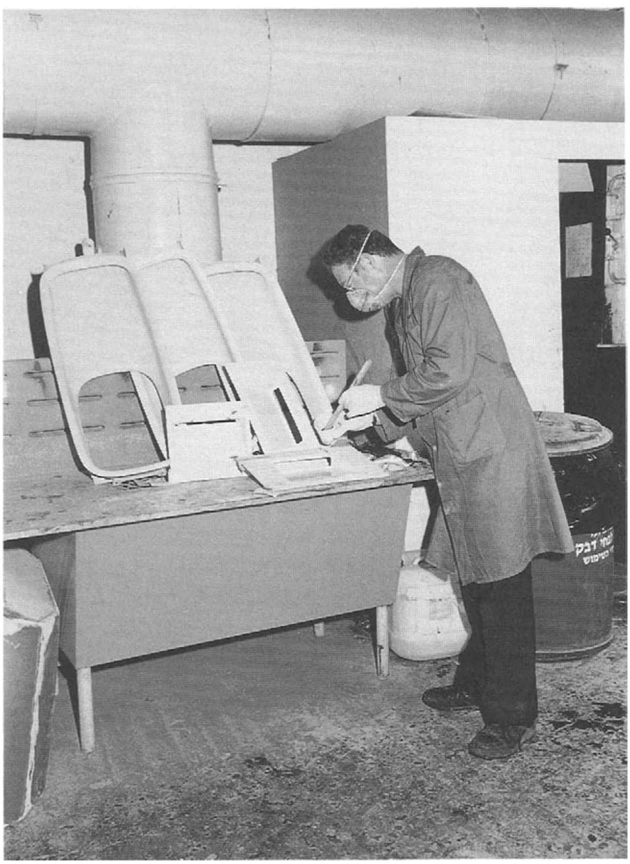

FIG. 8. Epoxy gluing during preparation of a composite structure.

required in such operations. Where preventive engineering is not adequate, personal respiratory protection should be provided. Because the use of glues and lacquers in wood work is limited, the potential exposure to such compounds and their organic solvents is low.

In another part of the shop, plastic molds are manufactured for the composite structures using various techniques such as injection molding, extrusion, and vacuum forming. The technique of vacuum forming (Fig. 9) utilizes plastic sheets made of thermoplastic polymers which are placed over wooden models in a heating box and softened by heating to 130°C. A vacuum is applied under the plastic sheet causing it to be drawn into the wooden model to obtain its shape. The shaped plastic is allowed to cool, regaining its original hard consistency. Finishing operations, such as cutting and smoothing edges, are performed on the molded plastic. Exposure to toxic chemicals is unlikely to occur during this process, but the heat involved may cause discomfort and add to the heat load present on hot days.

FIG. 9. Vacuum forming in the composite structure shop: A softened plastic sheet takes the shape of a wooden model under vacuum.

J. Aircraft Interior Shop

Aircraft seats require occasional repair and rework. The four main operations involved are: metal work on the seat skeleton, repair of plastic parts, upholstery replacement, and seat cover sewing.

The seat cover and electronic items are removed and the seat is washed, following which small repairs using pneumatic tools, drilling, and riveting are performed. The seat is then painted followed by final finishing operations before it is reinstalled in the aircraft.

The seat is usually washed with water, detergents, and occasionally organic solvents. Minor maintenance activities involve the use of contact cement and sealants containing organic solvents and silicon rubber products, respectively. Spray painting must be performed in a paint booth with proper ventilation to avoid exposure to dry paint particulates and organic solvents (Fig. 10). Loud noise can occur during drilling and riveting requiring ear protection.

Plastic parts of seats may require repair or replacement. They are first softened by heating and then glued onto the metal parts of the seat with epoxy and furan adhesives. Grinding and polishing are the final steps. Epoxy glue contains two components, a base and a hardener, which are mixed just prior to gluing. Of these, the hardener, usually containing aliphatic or aromatic amines, is known to be a sensitizing agent especially through dermal exposure. The mechanical operations (polishing and grinding) involved are noisy and may lead to noise-induced hearing loss if ear plugs or ear muffs are not used.

Old upholstery in the aircraft interior is occasionally removed to be replaced by new upholstery. After removal, the bare surfaces are cleaned with detergents and solvents such as methyl ethyl ketone. The new upholstery is then glued to the cleaned metal parts using adhesives containing polyurethane and toluene. The removal of old and fitting of new upholstery is usually done manually, increasing the potential for inhalation and dermal exposure to organic solvents, detergents, and prepolymers.

Sewing operations performed on seat covers and fabrics do not pose specific hazards. Lint dust may spread in the air but can be easily controlled. Adhesive tapes are ironed before use between carpet layers, but the release of vapors from the adhesive material, if any, is insignificant. Ergonomic defects are often present, however, if workbenches and chairs are improperly designed.

K. Life-Saving Equipment Repair Shop

The repair of lifeboats and life jackets is limited to the patching and covering of cuts and tears. Adhesive glue is applied on a patch which is then pressed to the surface being repaired. Patches can also be heat ironed to the rubber surface.

Organic solvents and other components of the contact glue (catalysts, accelerators, and preservatives) are potentially hazardous substances found in this

FIG. 10. Spray painting of a seat carried out in a paint booth.

process (Table III). Therefore, respiratory and skin protection should be provided.

L. Renewal and Filling of Cylinders

Fire extinguishers are periodically inspected and recharged with halons (fluoro-chloro-bromo carbon), nitrogen, and carbon dioxide. Likewise, cylinders for inflating lifeboats must be refilled with air. Because these processes are carried out in closed systems, there should be little danger to workers as long as proper safety measures are taken. However, because some compounds contained in fire extinguishers contribute to depletion of the ozone layer in the stratosphere, they are being phased out in favor of new chemicals which are less destructive.

V. PRODUCTION, OVERHAUL, AND MATERIAL CONTROL—LEVEL III MAINTENANCE

This section addresses the renewal and overhaul of central parts and systems of the aircraft. The work is extremely detailed and precise, ranging in nature from routine maintenance to production-type operations. The section includes: engine buildup shop, the wheel and brakes shop, hydraulics shop, and the electronics shop.

A. Engine Buildup Shop

The engine is brought into a special hangar (EBU) where dismantling or assembly is performed. The nature of the work is mechanical and electrical usually

entailing no significant chemical processes. Engines of aircraft of the various airlines are generally maintained at their home bases, but in the absence of adequate facilities, such processes as assembly and engine testing may be done by outside contractors. Several technicians may be working on the engine simultaneously performing different duties and, therefore, may be bystanders in shared exposures.

The engine is first washed with hot water and soap necessitating care to prevent burns from hot water splashes. After disassembly and washing, solvents, such as trichloroethane, freons, and alcohols, are used for cleaning and degreasing. Each has its own toxicity although there is little health risk if they are properly handled. The safest procedure is the use of closed systems. Otherwise, protective clothing should suffice. Of particular concern is dermal exposure for which the use of hand protection, such as gloves and barrier creams, is necessary.

Besides possible exposure to solvents, workers may also come into contact with residues of oils, lubricants, and greases on aircraft parts as well as in pipes and tubes. Aviation oils used for engines, gears, and hydraulics contain a number of organic chemicals including antioxidants, anticorrosives, and antifriction and pressure-resistant substances. Tricresol phosphate and tributyl phosphate are additives of particular concern because of their neurotoxicity.

Noise is another major hazard in the hangar due to the use of pneumatic tools on the engine and manual hammering. Therefore, a robust hearing conservation program is mandatory.

The workers in the shop maintain the external and internal surfaces of the engine. Since the engine is of large size, there is much climbing, standing on ladders and benches, bending, twisting, and sitting. Therefore, proper ergonomics is important in order to prevent incorrect posture, overexertion of muscles (neck, shoulders, back), musculoskeletal distortion, and continuous standing which can cause repetitive trauma. In addition, there is the risk of slips, trips, falls, and electrocution.

Finally, if transportation inside the EBU spare parts store is by fuel-operated forklifts, good ventilation is necessary to prevent the buildup of noxious exhaust gases such as carbon monoxide, oxides of nitrogen, and irritating aldehydes.

B. Wheel and Brakes Shop

Renewal of the metal drum of the aircraft wheel takes place in this shop. The nature of the work is mainly mechanical although oils and silicon grease are used for lubrication. Skin contact with these substances is possible, but with sufficient care exposure is insignificant. As in so many other aircraft maintenance processes, workers may be exposed to high levels of noise.

C. Hydraulics Shop: Treatment of Metal Surfaces

Parts of hydraulic systems require cleaning before overhauling and renewal and before finishing operations such as electroplating. Depending on the requirements, the cleaning operations done on the part's surface include solvent degreasing, alkali cleaning and degreasing, carbon removal, acid treatment, paint removal, and steam cleaning. Each process is carried out in a similar manner with the part being dipped into the appropriate cleaning bath containing the solution specified for the required treatment (Fig. 11). The conveyance of parts from one bath to another along the line is generally by means of levers and cranes, but manual cleaning is sometimes done in different baths using petroleum distillates as degreasing agents.

The more commonly used degreasing agents are halogenated hydrocarbons such as liquid freons and 1,1,1-trichloroethane. Vapors of these organic solvents are the main source of exposure although potential dermal exposure also exists. Due to the depletion of atmospheric ozone, the use of freons and trichloroethane is being banned in some countries, resulting in the renewed use of degreasing agents such as trichloroethylene, which is more toxic.

An alternative is the use of alkali cleaning; techniques available are simple degreasing of parts in an alkali bath or electrolytic reactions. Both types of cleaning remove oils as well as soils and paints. Alkali cleaning baths usually contain caustic agents such as hydroxides of sodium and potassium, carbonates and phosphates of sodium, and sodium metasilicate. The solution in the bath also contains surfactants and salts of metals which produce a foam layer and modify the etching effect of the caustic environment. The potential hazard in such operations is alkali mists, which are respiratory irritants. Bare skin contact with caustic materials may result in serious burns. Electrolytic alkaline cleaning has similar characteristics as in the electroplating process in that water dissociates

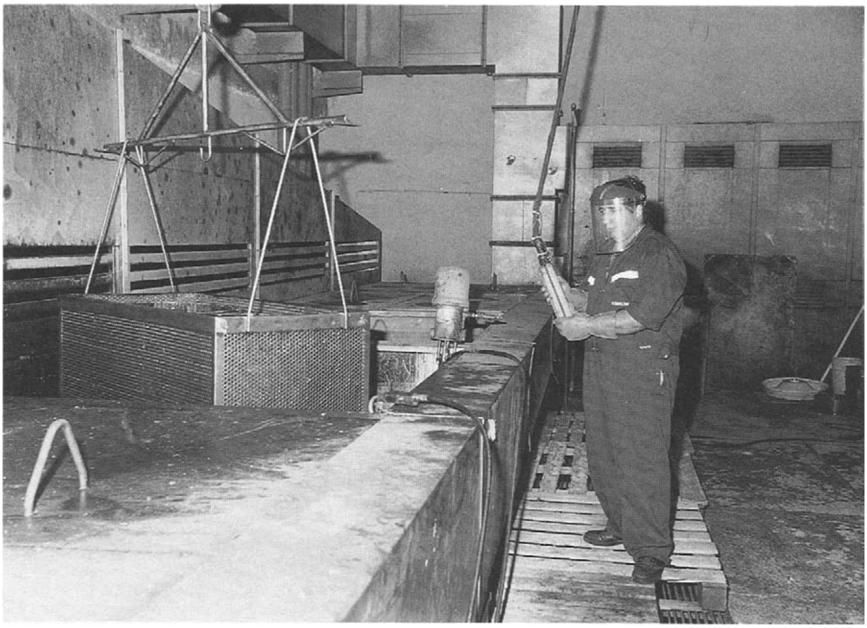

FIG. 11. Treatment of metal surface in the hydraulics shop; The slot hood is seen along the line of baths.

to oxygen and hydrogen. It is worth noting that increasing amounts of gas escape with an inclusion of alkaline mist if the foam layer at the bath surface area is too thin. On the other hand, if the foam layer is too thick it traps hydrogen and oxygen creating an explosion hazard.

Combustion residues of carbon and soot require aggressive cleaning known as stripping. Such an effect is achieved by the combination of a chlorinated solvent, usually methylene chloride, and phenol. The former has recently been reported as a suspected carcinogen, while the latter is a strong corrosive agent. Both are systemic toxicants.

Rust, scale, and oxide stains are removed by acid treatment termed pickling. Strong mineral acids including nitric, chromic, sulfuric, phosphoric, and hydrochloric acids are used, the combinations and concentrations of which depend on the type of alloy treated. For example, the more common acids used in treatment of chromium and stainless-steel alloys are nitric, hydrochloric, and sulfuric, with the addition of hydrofluoric acid. The latter is extremely corrosive when its concentration in the solution is high. Nitric and hydrofluoric acids in a mixture are used for aluminum and titanium, while a chromic and hydrofluoric mixture is applied to magnesium alloys. If brightening of the metal surface is needed, the part is dipped in a mixture of nitric and sulfuric acids, and if corrosion resistance is required for stainless steel, the part is dipped in nitric acid and undergoes passivation.

Acid mists and vapors emitted from this process are significant respiratory hazards. Exposure potential is higher if the solutions are heated and/or the ventilation is poor. Skin contact with the solutions may cause irritation and burns. Amine and urea compounds, added to the bath as inhibitors to modify the aggressive action of the acids, are completely dissolved and are, therefore, nonhazardous.

Paint removers used are based on phenol, methylene chloride, toluene, and other mixtures of organic solvents. In view of the possible additive adverse health effect of mixtures of organic solvents, the occupational exposure to the mixture, rather than to each separate component, should be assessed.

The final step is a steam bath or a pressurized spray used to clean soiled and greasy spots adhered to the metal surface, burns being a potential hazard.

The line of baths in the shop should be provided with local ventilation which reduces emissions of mists and vapors, thus reducing respiratory exposure. However, manual or lever-aided transportation of parts from one bath to another increases the possibility of splashes and spills. The baths are supplied, whenever necessary, with fresh cleaning solutions stored in barrels and drums. The discharge of drums is a source of exposure if not conducted through a closed system of pipelines. Also, controlled drainage of the baths is required to prevent additional exposure.

D. Hydraulics Shop: Maintenance and Units Inspection

Hydraulic units of different systems of the aircraft are treated in this shop. Examples of such units are hydraulic pumps, brakes, servo mechanisms, constant speed drives, and their generators and cylinders. The units undergo routine maintenance and are repaired or renovated, depending on their condition.

Brakes arrive at the shop soiled and covered with soot. Their components are taken apart for cleaning and possible metal work. Likewise, detailed inspection is performed on every part of the servo-control units (Fig. 12) which are sealed in order to prevent oil leakage and trapping of moisture in the inner spaces. Constant speed of the engine is controlled by a constant speed drive (CSD), of which a basic unit is a generator turning at a constant speed. In the aircraft, this hydraulic unit is immersed in fine engine oil. In the shop, the drive is inspected on a test bench after being washed with organic solvents sprayed manually (Fig. 13) or by air pressure. The drive may need brazing, the required temperature for which is maintained by electrical induction. Sanding of the hydraulic cylinders of the CSD is done with abrasive silicon carbide paper or sanding paste. The generator of the CSD is also dismantled for routine inspection, maintenance, and lubrication as required.

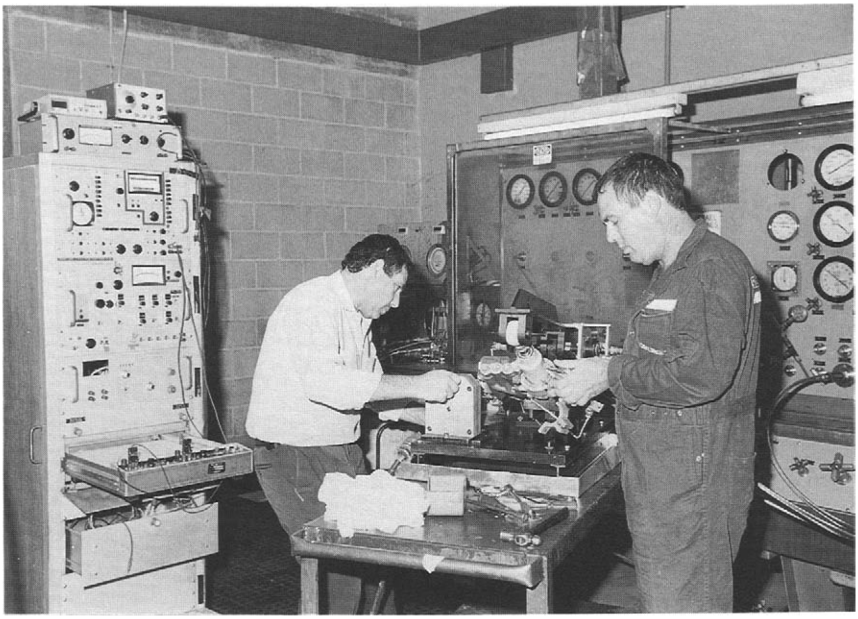

FIG. 12. Careful examination of electrohydraulic systems of the aircraft.

Hydraulic oil is the lubricant primarily used in aircraft hydraulic systems. Since resistance to high pressure is required, extreme pressure agents, such as organophosphate compounds, chlorinated paraffins, and chlorinated diphenyls, are added to the oil. Other additives are tributyl phosphate and tricresyl phosphates which are neurotoxic. Contact with significant amounts of the lubricant may occur during dismantling of systems in the aircraft itself and also during operations such as filling containers, lubrication, and feeding of test systems.

Sealing agents used for servo-control mechanisms are based on plastic resins and may contain acetic acid. The major filling metals used in the brazing of the CSD are copper, silver, and gold. Although low airborne concentrations of metal fumes are formed in this technique, adequate ventilation should be used.

Noise is a physical hazard encountered in the various operations of the shop. It is especially prevalent in the test room where the CSD is inspected and near electrohydraulic test benches, where the normal operation of the hydraulic units is tested upon completion of their maintenance (Fig. 14).

E. Electronics Shop

The electronics shop is organized according to an international protocol which requires specific licenses for electricity, instrumentation, communication,

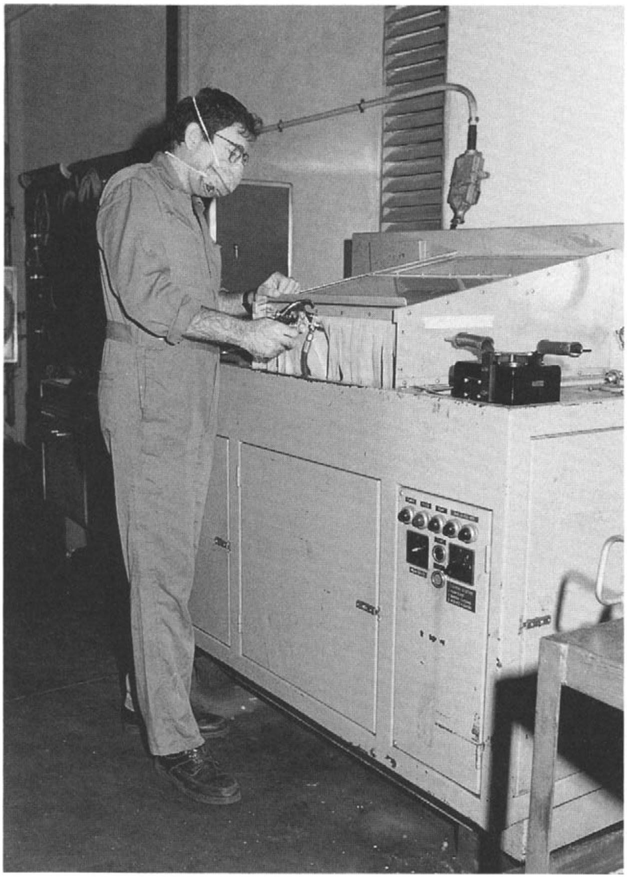

FIG. 13. Manual cleaning of the constant speed drive (CSD) in the hydraulics shop.

navigation, and radar in order to conduct work on electronic aircraft systems. The four internationally designated and licensed workshops are electronics 1–4: 1, automatic pilot systems; 2, instrumentation (electromechanics and gauges); 3, radio communication, navigation, and radar; and 4, inertial navigation and standards.

The health hazards which exist in the electronics shop are those characteristic of the electronics industry. Hand soldering is performed occasionally in many work stations, but the concentration of lead fumes released from the solder is usually well below the TLV. More sensitive individuals may suffer irritation of the upper respiratory tract as a result of the rosin core solder (organic resins used as flux) and its thermal decomposition products as resin acids—colophony.

FIG. 14. A setup for testing hydraulic aircraft parts (hydraulics shop).

Where small-scale brazing is done to join metal parts, workers may be exposed to low concentrations of metal fumes of cadmium, zinc, silver, and tin. Cleaning materials, including organic solvents such as freons, acetone, methanol, white spirits, and 1,1,1-trichloroethane, are used locally to clean electronic components. The quantities used are low, although small cans and jars containing the solvents, if left open when not in use, increase the risk of exposure by solvent evaporation.

Various types of adhesives and bonding agents are used in the shop. Among them are epoxy and silicone rubber-based adhesives, anaerobic sealants based on methacrylic polymers, and contact adhesives based on chloroprene rubber. In addition, coatings based on acrylic resins are used to protect bare metal surfaces. Care should be taken to avoid contact with the hardening agents of epoxy resins which contain amines known to cause sensitization and allergies. Most of the glues are mixed with organic solvents (toluene, ketones, alcohols) which evaporate upon application and, subsequently, diffuse into workers' breathing zones. The local and sporadic use of these materials does not usually lead to significant respiratory or dermal exposure.

Elemental mercury is found in manometers throughout the electronics shop. This metal has high vapor pressure causing the release of mercury vapors from open surfaces. The potential for exposure stems from accidental mercury spills in the event of instrument breakage. Mercury drops on the floor or on horizontal surfaces constantly release vapors if not collected and properly disposed of.

System testing can cause loud, high-frequency noise. In the event that test run facilities are not acoustically isolated, ear protection is essential.

The electromagnetic energy associated with radar operations falls within the microwave and RF spectrum. Despite strict safety instructions and rules in places where RF and microwave radar systems are operated, accidental exposures do occur (e.g., touchdown control systems during the landing of aircraft). Depending on the intensity of the radiation, distance, and its duration, direct exposure may result in some degree of hyperthermia.

The abundance of video display units (VDUs) and personal computer terminals in the workshops makes ergonomic factors of central importance (Fig. 15) particularly since workstations are often poorly designed. The more important factors to be considered are the workbench, the chair, postural and orthopedic factors, the VDU dimensions, screen and background illumination, position of VDU relative to windows and daylight glare, environmental conditions (air conditioning), and background noise.

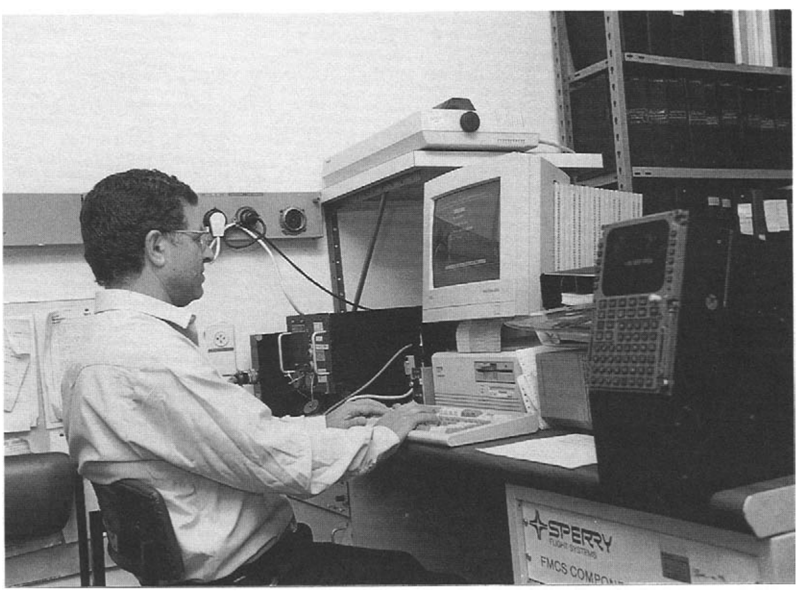

FIG. 15. A video display terminal in the electronics shop.

VI. GROUND OPERATIONS AND AIRPORT SERVICES

A. Food Services

The facilities and nature of the work in the food services section at the airport resemble those of a hotel combined with catering services. Major hazards to workers include thermal stress and dermal irritation due to soaps and detergents.

Because raw ingredients and fresh foods are stored in refrigeration rooms where workers may have to spend up to 15 min at a time, protective clothing against cold should be available. In the kitchen, cooks are exposed to oven and stove heat which can be very uncomfortable. Those who work near baking ovens and grills may suffer physiological heat load if the ventilation and cooling systems are inadequate. The recommended air exchange rate above a large oven is 34 M^3/min, while that above a grill is only 18 M^3/min. Such rates will also prevent the accumulation of thermal decomposition products of cooking oil (such as acrolein) and thus potential irritation of the respiratory tract.

The meals are packed manually (Fig. 16) and the trays are heat sealed in plastic film although the temperature applied for sealing does not induce thermal decomposition of the plastics. Because workers at this station stand for long periods of time, there is potential for development of musculoskeletal disorders as well as exacerbation of varicosities.

Dish washing rooms may be warm and highly humid and the floors wet and slippery so as to pose a safety hazard requiring workers to wear rubber boots. While this is adequate protection against the wet floor, prolonged use of rubber boots may cause development of fungi and eczematous eruptions on the feet.

Large containers and pots are washed separately and often by hand, posing potential skin exposure to detergents and other cleaning materials. As a result, sensitive individuals may develop contact dermatitis. (In this context, it should be noted that skin irritation may also be caused by food ingredients such as vinegar and spices.)

Food services encompass sanitary biohazard considerations pertaining to personal hygiene and sanitation control in kitchens, storage rooms, food packing areas, and other facilities. While the population at risk for this particular health hazard is mainly that of the passengers, such hazards can also affect the food service staff.

B. Cargo Terminal

Freight is loaded and unloaded at the cargo terminal. Although this is done mainly by diesel forklifts, it is not uncommon for workers to move loads manually (Fig. 17). Therefore, many suffer from muscle overexertion and musculoskeletal disorders, particularly low back pain (Fig. 18). In this context, it is noteworthy that luggage porters (who are not part of the cargo terminal crew) also experience similar problems due to bending and lifting (Fig. 19).

FIG. 16. Food services. Note the continuous work in standing position.

Frequently, freight containing chemical substances passes through the cargo terminal. These substances are classified under nine coding groups according to an internationally recognized coding system. Each group is transported separately to a special area where they are stored in accordance with compatibility regulations. For example, there are separate areas for storage of items under low temperatures and for radioactive materials. Exposure to chemicals in the terminal is unlikely although accidents involving leakage or breakage of packages have occurred. Radioactive sources are frequently monitored for leaks.

Workers and carriers are exposed to noise inside the cargo terminal (diesel forklifts) as well as to intense background noise caused by the aircraft engines. In small areas, the use of diesel-operated forklifts also creates a potential exposure to exhaust gases and particulate matter.

FIG. 17. Transportation of cargo by diesel forklift inside the cargo terminal.

FIG. 18. Unloading of cargo in the cargo terminal.

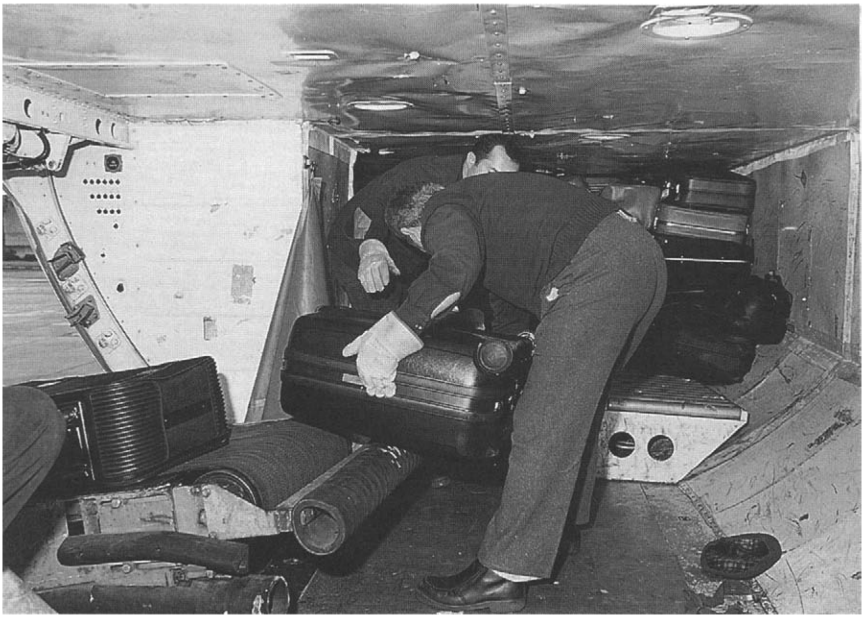

FIG. 19. Loading of passengers' luggage into the aircraft. Note the potential musculoskeletal stress.

Other factors in the terminal are uncomfortable weather conditions, poor illumination, and the danger of slips, trips, and falls.

There is a high degree of stress and pressure in the jobs performed in the terminal. Workers as well as managers have to meet precise, tight time schedules and work according to the priorities dictated by air companies. The work load is high and the rate of work is rapid. Additionally, shift work is common and extended work hours are often required. Because of rapid burnout and fatigue, the workforce has a high turnover.

C. Ancillary Services

Some occupations in the airport are not directly associated with the aircraft itself, but are worth mentioning from an occupational hygiene point of view. These include maintenance of air conditioning, plumbing, gardening, fire fighting, and security.

During the maintenance of air conditioning systems, workers may be exposed to cooling gasses and to fibers of the insulation materials such as rock wool. Accidental exposure to high concentrations of cooling gas such as ammonia may be fatal, while rock wool may cause respiratory irritation. Evidence as to the carcinogenicity of rock wool is inconclusive.

Plumbers may be exposed to decomposition products of disintegrating organic waste. Dangerous levels of gaseous hydrogen sulfide, methane, and mercaptans may accumulate in sewage pits and in central junctions of drainage systems. Fatal accidents have been reported of plumbers who ignored safety regulations requiring them to measure gas levels before entering pits and confined spaces.

Gardeners maintaining the airfield landscape use a variety of pesticides, insecticides, and herbicides. While each gardener is generally authorized to handle such substances, neglect of safety rules may result in accidental exposure.

Firemen may be exposed to fire extinguishing gasses and powders and to musculoskeletal injuries during training exercises. They may also be exposed to noxious and toxic substances emitted as gasses and smoke during the burning or thermal decomposition of chemicals.

Security check of baggage and cargo is performed by spot x-rays inside special chambers. The intensity of the radiation in use is usually less than 0.1 mR and the machine operates on 80–100 KVP and 5 mA. From time to time security personnel move suitcases and other baggage by putting bare hands into the chamber while the machine is in operation, thereby risking exposure. However, significant exposure to x-rays during hand luggage monitoring (Fig. 20) is unlikely.

There are other job assignments pertaining to airport facilities and services such as civil engineers, ground operation crews, and power supply controllers. See Table IV for potential hazards.

FIG. 20. X-ray examination of hand luggage.

TABLE IV
The Chemical, Physical, Biological, Ergonomical, and Psychosocial Risks in the Various Occupations

	Chemical						Physical						
Occupation	Solvents	Oils	Inorganic	Metals	Gasses	Organic/ polymers	Noise	Vibration	Radiation	Heat/cold	Biological	Ergonomical	Psychosocial
Aircraft body/skin repairer fitter, metal bonder	+	+		+	+	+	+	+	+	+		+	
Aircraft cleaning, worker/ supervisor/inspector	+				+	+	+				+	+	+
Aircraft mechanics, electricians (body shop), radio operators	+	+		+	+	+	+		+	+		+	+
Airframe/power plant, mechanic, inspector, assembler	+	+		+	+	+	+	+	+			+	+
Airline security					+		+			+		+	+
Airplane inspector							+	+					+
Airplane painter/coverer/ painter of transportation equipment	+			+	+	+	+					+	
Bonded structure repairer, plastic bench inspector	+				+	+	+					+	
Electrician—flight line	+	+				+		+					
Electronics repairer, equipment tester/ inspector/supervisor, electronics system mechanic/technicians/ electrician (electronics													

shop), field service	+					+	+			+		+	+
Engine tester	+	+			+		+	+		+			
Field service engineer/ mechanic					+		+			+			+
Fire fighters					+		+			+		+	+
Fluoroscope operator	+	+				+			+				
Food services					+	+	+			+	+	+	+
Inspecto r—aircraft launching/arresting systems	+												
Inspector—assembly/ instal lations							+						
Installer fuel bay lining	+				+	+				+		+	+
Mechanic—heating/ ventilation	+				+								
Mechanic—rig ging and control testing and plumbing of pneumatic/hydraulic systems	+	+		+	+	+	+	+	+			+	
Oil filter inspector	+	+		+		+							
Operations/perso nnel												+	+
Pattern maker/plasterer	+		+										
Porter/baggage checker							+					+	+
Precision assembler	+	+				+	+		+			+	
Riveter				+									
Sanitation services						+	+			+	+	+	
Service liason representative							+						+
Shipping processor	+				+		+			+	+	+	+
Surface processing, inspector	+		+	+		+							
Tank Processor	+		+	+	+	+	+			+		+	
Upho lsterer	+			+		+	+					+	

CHAPTER

7

The Electromagnetic Spectrum and Chemical Hazards

RUSSELL B. RAYMAN

Occupational Health in Aviation:
Maintenance and Support Personnel

I. INTRODUCTION

This section describes the electromagnetic spectrum (EMS) and some of the toxic chemicals found in aircraft maintenance operations. Because hundreds of chemicals are in use by various companies, it would be impractical to describe them all. Therefore, the most common ones or those representative of a class found in civil and military aviation are included. Descriptions were intentionally kept abbreviated with emphasis given to medical considerations rather than to physical or chemical properties, information of which is readily available in standard references. Additionally, because various regulatory agencies in the world publish differing exposure limits, and because they are always subject to change, only general ranges are given without assigning them to any particular country or agency. For current exposure limits, practitioners of occupational medicine should refer to those regulatory agencies under whose jurisdiction they fall.

II. ELECTROMAGNETIC SPECTRUM

The electromagnetic spectrum consists of ionizing and nonionizing radiation of varying frequencies and wavelengths. That portion of the spectrum of industrial consequence includes x-rays, ultraviolet, visible light, infrared, and microwave. Their respective frequencies and wavelengths, in part, determine their biomedical effects on human beings.

The nondestructive testing and inspection (NDI) of metal castings or welded metals is done by x-ray units adapted for aircraft maintenance. It is a very effective and convenient way to ensure the integrity of any aircraft part. For example, if cracks are suspected in a wing due to metal fatigue, the defect can be identified by radiography as a bone fracture might be diagnosed by medical x-ray.

The long-term effects of exposure to ionizing radiation are well known and include cancer, cataracts, birth defects, and sterility. The availability of well-designed x-ray units which minimize leakage and scatter and the provision of proper shielding have limited such adverse effects in industry today. According to one survey, the mean annual radiation dose in industry is 0.290 rems, well below the 5 rem/year standard for workers in occupations with potential radiation exposure (Voelz, 1988). Workers run into difficulty only through carelessness, improper shielding, and the use of faulty x-ray units.

Although the safety record in aviation maintenance is excellent, industrial hygiene programs should never be relaxed. X-ray machines must undergo periodic inspection and workers must be protected by shielding, usually lead or concrete of proper thickness. Special precautions are necessary for portable equipment because they might be utilized in open spaces affording little or no shielding. Particular care must be given to avoid exposures to unwary individuals in proximity of the field unit. For biomedical monitoring, workers should wear dosimetry badges and have a periodic complete blood count (CBC). It would also be wise to obtain an occupational and medical history of workers before assigning them to NDI operations. Special care and judgment are necessary if a worker has a history of ionizing radiation exposure or preexisting disease such as a blood dyscrasia or leukemia. Likewise, it might be best for pregnant workers to avoid work areas with a potential for radiation exposure. With proper workplace surveillance and biomedical monitoring, injury from ionizing radiation should continue to be a very rare event.

Further down the EMS is laser which is amplified light mainly in the visible light range. It is used in aviation for radar and communication devices. In the military, it has application as a range finder and an illuminator for offensive weapons. Laser beams are of such high thermal intensity that they can cause serious burns to the skin and eye. Although they can damage the cornea and lens, the retina is particularly vulnerable. Vision can be temporarily or permanently lost depending upon the severity of the retinal burn (Fowler, 1983). The degree of impairment depends upon several factors including the power of the laser and the proximity of the lesion to the fovea. Therefore, an extra-foveal injury may cause a visual field defect, while blindness might result from a direct hit on the fovea.

In one study of 23 cases of occupational laser retinal injury, 19 reported immediate visual disturbances from blurring to complete loss of vision (Wolfe, 1985). Several also reported pain. In several cases, oral or parenteral steroids were prescribed and in others, no medication was given. The period of recovery lasted from several days to several months with most cases having complete or partial clearing. Although laser injury in industry is rare, there is always the potential risk of serious retinal injury with partial or complete loss of vision.

If laser equipment is handled properly, workers should be able to engage safely in laser operations. This would include proper positioning of the beam source. Taking into account that laser beams can be reflected from smooth or shiny surfaces appropriate eye wear should be available. Different types of goggles are necessary depending upon the wavelength of the laser in operation.

The microwave portion of the EMS is utilized in aviation for radar, navigation, tracking, and communications. Like laser, it can damage tissue by its heating effects and by the tissue's inability to dissipate the heat buildup before damage occurs. The eyes and the testes are particularly vulnerable precisely because they do not dissipate heat well. Although many experimental studies on animals as well as observations on human beings exposed to microwave have been published, potential hazards require more definition. Laboratory animals exposed to microwave of different power densities have demonstrated teratogenic effects and cataracts as well as gonadal, chromosome, neuroendocrine, and hematological changes, but the clinical significance of such findings is not well defined (Michaelson, 1982). Several military studies including one with 40,000 U.S. Naval personnel demonstrated no harmful effects from microwave exposure (radar) during the course of duty (Michaelson, 1982). Furthermore, there has been no evidence that microwaves are carcinogenic in animals or human beings (Michaelson, 1982; Mosely, 1988a).

On the other hand, a number of studies published in the former Soviet Union and in Eastern Europe described a syndrome called radiowave sickness due to exposure to microwave. Workers complained of a broad range of symptoms including headache, fatigue, poor appetite, and changes in mentation. Although this syndrome is well recognized in the East, it has not yet been demonstrated in the West (Michaelson, 1982).

Based on our knowledge of microwave and its heat-generating effects on laboratory animal tissue, there is a clear potential for damage to human tissue causing, for example, cataract formation or abnormal spermatogenesis. Since tissue damage appears to be dependent upon power density and duration of exposure, proper industrial controls should provide effective protection of workers. It has been recommended that microwave power densities should not exceed 10 $Mwcm^{-2}$ since man tolerates well heat generated up to this level (Mosely, 1988; Erwin, 1983). It is important to periodically inspect microwave equipment and measure field strength of the beam to ensure that standards are not exceeded. To date, there is no evidence that exposure to this standard over an 8-hr day is harmful although the effects of chronic exposure have not yet been determined. For biomedical monitoring it might be advisable to do periodic eye examinations for cataract formation and semen analysis.

Ultraviolet (uv) and infrared (ir) exposure may occur with welding operations. The former can cause damage to the skin and eyes causing burning and keratoconjunctivitis. A mild form of these effects often occurs with excessive sun exposure or with sun light reflection from a snowy landscape. Likewise, infrared can burn the skin but it has a propensity to affect the lens causing cataract formation. In either case, the use of proper eye wear with a proper glass which filters uv and ir should afford full protection for those engaged in welding.

III. CHEMICAL EXPOSURES

A. Acetone

Acetone is classified as a ketone and may be found in solvents and related cleaning compounds. Although it is not particularly toxic, it can affect the central nervous system (CNS), lungs, skin, and mucous membranes (Craft, 1983). Excessive exposure to fumes can cause headache, dizziness, lack of coordination, sedation, and coma. In addition, fumes can irritate the mucous membranes of the mouth, nose, throat, and respiratory tract as well as the conjunctivae. With skin contact, drying, scaling, and fissuring may occur. In any event, there have been few, if any, cases reported of prolonged or permanent effects, whether the exposure to acetone was acute or chronic.

However, one study of 137 workers exposed to acetone found a performance decrement (Dick *et al.*, 1989). Vigilance, visual, dual task, reaction time, and memory testing were done before, during, and after exposure with small but statistically significant differences noted in some performance parameters. Even though these were only temporary decrements without great clinical significance, this study supports keeping exposures within the recommended standards of 250–750 ppm.

Shop surveillance might include air samples as well as testing the blood or urine of workers for acetone. In the event of exposure, treatment is symptomatic.

B. Alcohols

Many types of alcohols are used in aviation as cleaning agents, diluents, and solvents. Inhalation of fumes can cause upper respiratory irritation with attendant symptoms of cough and sore throat. There may also be anesthetic-like effects of CNS depression and possible loss of consciousness if the exposure is extreme. With chronic exposure the skin may become dry and cracked although this is easily preventable by utilizing protective clothing.

In general, the alcohols should cause no significant harm to workers particularly if used in small amounts and if workers observe relatively simple rules of prevention. One exception is methyl alcohol which can cause blindness by the toxic effects of its metabolite, formic acid, on the optic nerve. Although this is almost always due to ingestion, some cases have purportedly occurred as a result of occupational inhalation (Rosenberg, 1990). The TLV ranges from 50 to 1000 ppm depending upon the type of alcohol.

C. Ammonia

Ammonia is a very noxious substance found in coolants, plastics, and explosives. In the aircraft industry it is chiefly used as a cleaning agent, particularly in fuel cell maintenance. Ammonia causes injury to tissue similar to a corrosive alkali with the severity of injury directly related to the concentration of the ammonia and the duration of exposure. Tissues that are particularly vulnerable are the mucous membranes, eyes, respiratory tract, and skin. Fortunately, the vapors of ammonia are so pungent that workers are forewarned in most cases before excessive exposure occurs.

The vapor readily dissolves in moisture on skin and the mucous membranes, and hydroxyl ions form causing thermal and chemical injury. Although most exposures result in minor and temporary symptoms, extreme exposure results in serious burns with the liquefaction of tissue and deep penetration. The inhalation of fumes can cause mild, moderate, or severe symptoms. In the case of minor exposure, there might be coughing due to mucous membrane irritation. However, with a more serious exposure, workers develop a cough, bronchospasm, wheezing, and dyspnea, and in some cases respiratory distress with pulmonary edema carrying a mortality rate approaching 100% (Arwood *et al.*, 1985). Others might develop a toxic pneumonitis with its attendant signs and symptoms. Cases have been reported in which the initial symptoms remitted only to recur with much greater severity followed by the onset of respiratory failure (Arwood *et al.*, 1985). In others who appeared to have recovered, chronic obstructive pulmonary disease manifested itself as a late sequela (Close *et al.*, 1980).

Contact of liquid with the skin can cause mild to severe burns depending upon the concentration of the solution, the moisture content of the exposed area, and the speed with which the skin is flushed. The same principles apply to the conjunctivae which are vulnerable to vapors as well as to a liquid splash.

In the event of a moderate or severe exposure, treatment includes the removal of clothing and flushing of the skin and/or eyes with water. Hospitalization may be necessary in some cases in order to provide respiratory support: intubation or tracheotomy may even become necessary. Although steroids have been advocated by some, their efficacy remains questionable (Close *et al.*, 1980).

Although ammonia readily announces itself by its pungent and penetrating odor, shop surveillance should ensure proper use of ammonia especially in closed areas where cleaning operations are performed. The presence of ammonia can be easily determined by utilizing small amounts of hydrochloric acid which, in combination with ammonia, form ammonium chloride fumes. Protective clothing and equipment should be available for eye, skin, and respiratory protection if exposure is anticipated. Likewise, showers and eye washes must be in the proximity of the workplace.

Recommended standards for exposure to ammonia range from 25 to 50 ppm. In one study it was found that subjects could tolerate 100 ppm for several hours with eye irritation beginning at 140 ppm, throat irritation at 408 ppm, and laryngospasm at 1700 ppm (Arwood, 1985).

D. Asbestos

Of all toxic substances in the workplace, asbestos probably has the most notoriety. It is a generic term for fibrous forms of several mineral silicates, each of which can be harmful to human beings. In the aviation industry, this substance may be found in electrical insulation, brake lining, and friction components.

The most significant effect of asbestos is pulmonary and pleural pathology caused by the inhalation and entrapment of fibers in the airways. This results in progressive dyspnea, cough, and chest pain due to pulmonary fibrosis. Usually there is a latency period of 20–30 years before the fibrotic process becomes clinically perceptible. Not only may there be pulmonary symptoms, but also abnormal pulmonary function tests consistent with obstructive and restrictive disease. In addition, it has long been recognized that cigarette smoking contributes to the risk of asbestosis (NIOSH, 1980).

The diagnosis of asbestosis can be readily made by occupational history, respiratory symptoms, abnormal pulmonary function tests (PFTs), and chest x-ray. PFTs may show a decrease in vital capacity and FEV-1. Chest x-ray often shows irregular opacities, thickening and calcification of the pleura, and ultimately fibrosis.

There is little dispute that asbestos is carcinogenic causing lung cancer as well as mesothelioma. The latency period is usually long (20–30 years) (Rom, 1983). In various autopsy series of individuals with asbestosis, 12–50% had bronchial cancer (Cremer-Sluis, 1980). Other studies substantiate this association and an increased mortality rate due to lung cancer among workers exposed to asbestos (Dement *et al.*, 1986). Likewise, 80–90% of cases of malignant mesothelioma are associated with asbestos exposure (Dement *et al.*, 1986). Smoking increases the risk for lung cancer but not for mesothelioma. Other cancers, possibly asbestos related, occur in the buccal cavity, pharynx, gastrointestinal tract, and kidney.

Every effort must be made to avoid the use of asbestos. If it is used, a system of biomedical and workplace surveillance, as well as effective preventive measures are cardinal. A good program might include a preemployment examination of the respiratory system including chest x-ray and pulmonary function tests, periodic examinations during employment, focusing on the respiratory system with pulmonary function testing and repeat chest x-ray examinations if indicated. Similarly, an examination should be done at the termination of employment and filed permanently because of the 20–30 year latency period for asbestos-related disease. Finally, arrangements should be made for follow-up examinations after cessation of employment.

Periodic sampling and analysis for airborne asbestos in the workplace should be done every 3–6 months (Dement *et al.*, 1986). Protective clothing should be provided as well as showers. Double lockers are needed so that work clothes can be kept separate from street clothes. The former should never be worn out of the workplace in order to avoid transferring fibers to the home. (This requires laundry facilities at work.) In the event of high levels of fibers, approved respirators (by the Mine Safety and Health Administration in the United States) should be available. Finally, eating and smoking should be prohibited in the workplace. Rather, special rooms should be provided for such activities.

In summary, asbestos primarily affects the lungs, causing asbestosis, lung cancer, and mesothelioma. Although this substance occurs in a number of different fibrous forms, all should be considered hazardous. Consequently, effective surveillance and prevention programs must be implemented.

E. Benzene

Although benzene is a component of some solvents and aviation fuels, it is not a major hazard because it is not ubiquitous in the aviation industry and where it is found, it is in low concentrations. Nevertheless, aviation medicine practitioners must be mindful of its presence because of its toxicity, most notably its carcinogenicity.

The primary route of exposure is by the inhalation of fumes although skin contact can also cause harm. The inhalation of toxic levels of benzene will affect the CNS causing narcosis, drowsiness and dizziness, progressing to convulsions, loss of consciousness, and possible death due to respiratory paralysis. It can also cause drying and fissuring of the skin with absorption and penetration which can lead to systemic effects (Blank and McAuliff, 1985). Other reported effects include cough and hoarseness due to irritation of the respiratory tract, cardiac arrhythmias, and hepatotoxicity.

Although these acute effects can be significant, benzene's notoriety is mainly due to its association with aplastic anemia and leukemia. Marrow suppression is heralded by a myelodysplastic syndrome. Leukemia may develop after months to years of exposure. Aplastic anemia is particularly serious having a 30% 5-year survival rate (Kilian, 1988). Other malignancies attributed to benzene are lymphoma, multiple myeloma, and lung cancer (Aksoy, 1985).

Consequently, every effort should be made to either eliminate benzene from the workplace or ensure workers are not exposed to toxic levels by implementing a strict industrial hygiene program. The first step would be to review substances in the workplace for benzene content and concentration. If any risk exists, the air must be monitored. Furthermore, biomedical monitoring should include periodic CBCs and liver function tests. Because benzene is metabolized to phenol and excreted via the kidneys, urine phenol determinations are also advisable. In addition, benzene fumes can be detected by breath analysis as they are detectable for 16–24 hr postexposure. The recommended TWA exposure standard is 1 ppm (Kilian, 1988).

The treatment of an acute exposure to high levels of benzene is mainly supportive with monitoring for cardiopulmonary dysfunction and seizures. Flushing with water should be adequate for skin or eye contact.

F. Beryllium

In the aerospace industry, beryllium is found in brakes, electrical insulation, heat shields, inertial systems, and jet engine blades. Beryllium is a strong irritant primarily affecting the lungs and skin. Although some workers have manifested its acute effects of chemical pneumonitis and contact dermatitis, these are rare occurrences today because of effective industrial hygiene programs. Although most patients will recover after an acute exposure to toxic levels, about 17% will develop chronic beryllium disease or berylliosis (Kriebel *et al.*, 1988). Others may develop chronic disease due to long-term exposure to unsafe levels of this substance without manifesting an acute reaction. The disease can be fatal if the exposure is severe enough.

Although the long-term inhalation of beryllium in the workplace can affect most organ systems, the primary target is the lung. Frequently, there is a latency period as long as 20 years during which time fibrotic and granulomatous lesions develop in the pulmonary tissue (Williams, 1988). This results in progressive exertional dyspnea, cough, and chest pain. A routine chest x-ray may reveal hilar adenopathy and infiltrates which, along with the symptoms, mimic sarcoidosis. Indeed, sarcoid must always be at the top of the differential diagnosis list whenever a patient presents with suspected berylliosis.

In addition to pulmonary disease, contact dermatitis may occur resulting in ulcerations and granuloma formation. Very little, if any, beryllium is absorbed through intact skin.

Interestingly, there is considerable evidence that chronic beryllium disease, pulmonary or dermal, is due to an undefined immunological mechanism.

The diagnosis of berylliosis can usually be made by occupational history and its attendant pulmonary and dermal manifestations along with chest x-ray, urine beryllium levels, and a positive lymphoblast transformation test (an *in vitro* test of hypersensitivity). Suggested criteria for the diagnosis are (Kriebel, 1988): (1) a history of beryllium exposure; (2) the presence of beryllium in lung tissue, lymph nodes, and urine; (3) a clinical course consistent with the disease; (4) radiological evidence; (5) a restrictive or obstructive pulmonary defect; and (6) pathological changes in the lung or lymph nodes.

The association of beryllium with cancer in human beings is tenuous although cancer has been induced in exposed laboratory animals (Groth, 1980). The literature is replete with studies which support and disclaim the carcinogenicity of beryllium. In one study of 3658 beryllium-exposed workers, there was a higher mortality from lung cancer when compared to controls (Mancuso, 1980). Others refute those findings. It would probably be prudent to consider beryllium as a potential carcinogen. There is no convincing evidence, however, for teratogenicity (Preuss, 1988a).

There is no specific treatment for beryllium disease. Chelating agents are not effective although steroids sometimes provide symptomatic improvement (Williams, 1988; Preuss, 1988a).

Workplace surveillance should be conducted periodically with air sample analyses. In addition, workers should be examined with particular attention given to the pulmonary system and skin. Periodic chest x rays and pulmonary function tests might be considered as well as urine beryllium levels which, if positive, indicate exposure. Exposure limits to beryllium in the workplace are contentious although differences, in general, range from 0.5 to 2 μg/m^3 (8-hr day TWA).

G. Cadmium

In aircraft maintenance, cadmium exposure may occur with electroplating, soldering, welding, and painting. This metal is also found in battery shops. Of particular danger is the heating or melting of cadmium without adequate ventilation. Although cadmium fumes are well absorbed from the alveoli, there is practically no absorption through the skin. Once in the blood stream, it is transported to the liver where it is detoxified by combining with a protein, metallothionine (Preuss, 1988b). The latter is subsequently excreted in the urine with some stored in various organs such as the liver, kidney, pancreas, and thyroid gland.

The acute effects of exposure to a high concentration of cadmium fumes are generally confined to the pulmonary system. There is irritation of the respiratory tree which could lead to pneumonitis and even pulmonary edema if severe enough. There are three phases to this respiratory insult (Dunphy, 1967). An initial edematous phase with irritation and extravasation of fluid into the alveoli followed by a proliferative phase at about 72 hr with alveolar thickening, alveolar proliferation, and chemical pneumonitis. The final or third stage is fibrogenic which can result in some degree of pulmonary disability. If the exposure is severe enough, pulmonary edema, with a fatality rate of 15–20%, can occur after a latent period of up to 12 hr (Preuss, 1988b). Therefore, even if a worker appears well following an acute exposure, the patient should be hospitalized if estimated exposure levels are significant.

Workers exposed to cadmium may complain of cough, chest pain, and dyspnea all of which worsen if the disease process progresses to pulmonary edema. Some have the flu-like symptoms of metal fume fever with fever, chills, and headache which classically worsen on Monday after a weekend away from the job. Another peculiarity of cadmium is a metallic taste imparted when workers are overexposed.

Long-term exposure to low concentrations of cadmium can affect multiple organ systems resulting in serious sequelae. For example, pulmonary emphysema may develop. In one study of 101 men working with cadmium for at least 1 year, there was an excess of abnormal pulmonary function tests and radiological evidence of emphysema when compared to controls (Davison *et al.*, 1988).

Tubular and glomerular damage with proteinuria is an indication of excessive amounts of accumulated cadmium in the kidney. The appearance of proteinuria is an early sign of chronic exposure. Although this may be an indication of renal pathology with some cases reported of nephritis and nephrosis, the long-term health risk is not well defined (Armstrong and Kazanzis, 1985). In any event, managing physicians should be mindful of the potential for renal damage.

Of considerable conjecture is the association of cadmium with the development of hypertension. It would not be unreasonable to cite cadmium-induced renal pathology to support this hypothesis. Furthermore, it has been demonstrated that small laboratory animals will develop high blood pressure after exposure to cadmium (Bernard and Lauwerys, 1984). In one retrospective study, 311 male workers in a battery shop were exposed to cadmium oxide for at least 1 year. It was demonstrated that the incidence of hypertension correlated positively with the duration of employment (Engvall and Perk, 1985). Hence, there is some evidence to suspect cadmium as a causal factor for hypertension.

Other long-term effects include hypochromic anemia due to bone marrow depression, the demineralization of bone with osteomalacia and osteoporosis, renal calculus formation, and hepatotoxicity.

Always of concern is the carcinogenic potential of any substance in the workplace. Like so many other compounds, the association is steeped in controversy. Although cancers have been induced in animals, the evidence in humans is not so clear cut. Nevertheless, prostatic, lung, and renal carcinoma have been held suspect by some investigators (Preuss, 1988b; Armstrong and Kazantzis, 1985; Bernard and Lauwerys, 1984; Hallenbeck, 1984) and, consequently, cadmium has been considered by several U.S. Federal agencies as a potential occupational carcinogen (NIOSH, 1984). Teratogenic effects have been observed in cadmium-exposed rats, but not in the offspring of female workers who have been exposed in the workplace (Preuss, 1988b).

Because cadmium primarily affects the lungs and kidneys, biomedical surveillance (and the preemployment physical examination) should include urinalysis, looking particularly for proteinuria, pulmonary function tests, and chest x-ray, the latter showing patchy infiltrates if there are abnormalities due to cadmium. Other studies to consider would be liver function tests and a complete blood count. Urine cadmium or metallothionine is a sensitive indicator of cadmium exposure and body burden and should be monitored (Shaikh *et al.*, 1990).

Shop surveillance by periodic visits is also a vital part of ensuring a safe workplace. Local exhaust and good ventilation are critical in the avoidance of unsafe levels of cadmium in the air. It would also be wise to obtain air samples for periodic analysis. Regulatory agencies in the United States have established permissible exposure limits for cadmium in recent years between 40 and 100 $\mu g/m^3$ (NIOSH, 1984). In the event of high levels or if workers must operate in a closed space, approved respirators and protective clothing are mandatory.

In the event of an acute exposure to cadmium in which there are signs and symptoms, the individual should be immediately removed from the workplace. Oxygen should be administered and the patient hospitalized if there is pulmonary involvement at least for observation because of the chances of pulmonary edema after a 12-hr latent period. Renal, hepatic, and hematological function should also be followed. Treatment is supportive although chelating agents (BAL and EDTA) may be necessary in selected cases. If it is prescribed, it should be with considerable caution in that there is some evidence that chelating agents, in the presence of cadmium, are nephrotoxic (Preuss, 1988b; Anderson, 1984).

H. Carbon Monoxide

Carbon monoxide (CO) is a by-product of the incomplete combustion of carbon-containing materials and is, therefore, an ubiquitous hazard in industry. In aviation, for example, it can be found in the exhaust of jet and propeller-driven engines. CO is particularly dangerous because it has neither color nor odor, making it virtually undetectable by the senses.

The affinity of CO for hemoglobin is 200 times that of oxygen. Carboxyhemoglobin is readily formed as CO is inhaled and absorbed into the systemic circulation. Consequently, the body's oxygen supply is significantly reduced. Furthermore, the presence of carboxyhemoglobin causes a shift of the oxyhemoglobin dissociation curve to the left making it more difficult for hemoglobin to release oxygen at the tissue level. As a result, workers exposed to hazardous levels of CO will develop a myriad of symptoms, particularly CNS and cardiac, including headache, weakness, visual disturbances, and light headedness. With continued exposure, cardiac arrhythmias may occur as well as convulsions, coma, and death (Marzella and Myers, 1986).

Although the effects of acute exposure to CO are well defined, those of low-dose, long-duration exposure are not. Hence, it would be prudent to keep the environmental concentration of the gas as low as possible. Cigarette smoke, another source of CO, can drive carboxyhemoglobin levels as high as 10%. Since symptoms begin at carboxyhemoglobin levels of about 15%, it is apparent that smokers are at increased risk from CO toxicity.

If excessive CO exposure is suspected in a worker, immediate and rapid removal of the worker from the area of exposure is critical. In mild cases, simply breathing room air will suffice, while in others, 100% oxygen or hyperbaric therapy at three atmospheres may be necessary. If CO-free room air is breathed, half of the accumulated body CO is eliminated in 4 or 5 hr; for 100% oxygen and hyperbaric therapy, the half-life of CO decreases to 45–80 and 20 min, respectively (Marzella and Myers, 1986). Therefore, it is prudent to have arrangements with a hyperbaric facility if a risk of serious poisoning is present.

Shop surveillance should include periodic air analysis for CO particularly in high risk areas where, for example, there are welding or engine runup operations. If an exposure is suspected, a blood carboxyhemoglobin level should be ordered.

I. Chromium

Chromium is an important metal in industry because of its excellent corrosion-resistance properties. Hence, it is frequently found in aviation corrosion-control facilities posing a particular hazard to workers engaged in welding and electroplating operations. Its two major forms are trivalent (e.g., chromic oxide, chromic sulfate) and hexavalent (e.g., chromic acid), the latter being more toxic than the former. The major medical conditions associated with chromium are chemical pneumonitis, perforation of the nasal septum, dermatitis, and cancer of the respiratory tract.

Workers who inhale fumes or mist may develop coughing, wheezing, and chest pain due to irritation of the mucosa of the respiratory tract. These symptoms are self-limited once the patient is removed from the work area although with continued or severe exposure, chemical pneumonitis can result. Chromium's irritative effects also explain the occasional occurrence of nasal septum perforation. Although chromium is not well absorbed through intact skin, physical contact may cause irritative or allergic dermatitis with eczematous lesions and ulceration. The most serious hazard of chromium is its carcinogenicity, particularly of the lung. A number of studies have documented an excess incidence of respiratory tract cancer among workers (Franchini *et al.*, 1983; Norseth, 1986). In one study, workers in the proximity of chromium were dying of respiratory system cancer at 20 times the rate of a control group (Enterline, 1974). The latency period is 10 years or longer.

In the event of an acute exposure, treatment is mainly supportive in that chelating agents are not effective. Prevention of toxic exposure, therefore, is paramount in the form of protective clothing, eye protection, and the availability of respirators. This, in concert with periodic workplace inspections and biomedical monitoring, should keep workers out of harms way. Standards for chromium in the workplace have ranged from 0.1 to 1 mg/m^3 (Sawyer, 1988). Biomedical surveillance should include inspection of the skin, nasopharynx, and lungs. A baseline chest film for new workers is advisable with follow-up x-rays along with pulmonary function tests as indicated. Urine chromium levels can also be ordered in the event of suspected acute or chronic exposure.

J. Cobalt

Cobalt is a metal found in alloys used in the manufacture of aircraft engines. Because engines require repair and servicing by grinding or welding, cobalt dust or fumes are released into the workplace and inhaled by workers. Asthma, hypersensitivity pneumonitis with alveolitis, and interstitial fibrosis can occur with exposure (Cugell, 1990).

Asthmatic-like symptoms of wheezing, coughing, and shortness of breath are an allergic response to this metal. Workers typically note symptoms 4–6 hr postexposure thereby feeling worse in the evening after work but showing improvement on weekends or when away from the job. It takes approximately 6–48 months for sensitization to occur.

Hypersensitivity pneumonitis is a serious sequela of cobalt inhalation causing fever, cough, and shortness of breath. Like occupational asthma, it remits when the worker is not in the workplace. Chest x-ray may reveal a reticulonodular pattern. If exposures are chronic, there may be permanent pulmonary changes including interstitial fibrosis. Eventually, pulmonary function tests will become abnormal manifesting a restrictive defect. It takes 10–12 years of exposure to cobalt for this end stage to be reached.

In addition to pulmonary damage, cobalt can also cause an allergic erythematous papular eruption of the skin called the cobalt itch, as well as conjunctivitis, if fumes or dust contact the eye. Although this is much less serious than the problems of inhalation, it can make the patient very uncomfortable.

In the event of significant exposure and pulmonary disease, the worker should be removed from the workplace permanently in order to prevent progressive alveolitis or interstitial fibrosis. Treatment of acute exposures is supportive with oxygen, corticosteroids, bronchodilators, and sympathomimetics possible modalities. The efficacy of chelating agents, BAL and EDTA, is unclear.

Contact with the skin or eyes should be treated by washing the skin with soap and water and irrigating the eyes with tepid water for 15 min. Every effort must be made to prevent exposure by good ventilation and protective clothing.

Periodic shop surveillance and air analysis is recommended. Biomedical monitoring should include pulmonary function tests, chest x-ray, and blood or urine cobalt levels if significant exposure is suspected. The recommended TLV standard is 0.05 mgm/m^3 (Cugell, 1990).

K. Composites

A composite is a material composed of a number of components which give it added strength, light weight, and thermal resistance—attractive properties for the design and manufacture of aircraft. Although the exact components may vary somewhat, in general, they can be classified as resins, fibers, and solvents. Workers are at risk mainly from dermal exposure or inhalation resulting from grinding or sanding operations as well as vaporization from heating.

The most commonly used resin, epoxy resin, forms a matrix to bind carbon or graphite fibers. Several ingredients of epoxy resins can cause irritation of the skin, eye, and mucous membranes. In addition, epichlorohydrin, utilized in its production, has been classified by the International Agency for Research on Cancer as a probable human carcinogen (Dennis, 1992). If a polyurethane resin is part of the composite, an additional potential hazard is toluene diisocyanate (reviewed elsewhere in this chapter), the fumes of which commonly cause sensitization and asthmatic symptoms upon reexposure.

Hardeners, such as methylene dianiline (MDA), are usually added to the resin. MDA can cause irritation to the skin and mucous membranes; hepatotoxicity and nephrotoxicity have also been reported due to dermal absorption from chronic skin exposure (Walter, 1992). Another hazard is the formation of methemoglobin which compromises the oxygen carrying capacity of the blood.

Another class of chemicals which are additives to composites is solvents. These may include a wide variety of substances, such as ketones and halogenated hydrocarbons, each of which to some degree can cause defatting of the skin and dermatitis. In addition, the inhalation of fumes can result in a broad spectrum of pulmonary and CNS symptoms (respiratory irritation, cough, shortness of breath, pulmonary edema) and CNS depression, narcosis, unconsciousness, and death with severe exposures. Some halogenated hydrocarbons are also suspected of causing liver and kidney damage.

The third component of composites is fibers, usually carbon, graphite, or fiberglass, to add strength to the final product. With grinding or sanding processes, there may be airborne particles that result in skin contact or inhalation of the fibers. How far down the respiratory tract the fibers reach depends upon their size. Generally, those less than 3.5 μm can reach the deep lung, whereas other larger fibers may be deposited on the bronchial walls or trapped in the nasal hairs (Dennis, 1992). These fibers might cause skin irritation and minor irritation to the respiratory tree, but studies have not confirmed other effects such as pulmonary scarring or cancer. Hence, they are considered more of a nuisance dust than a substance with significant toxicity.

There are many potential hazards associated with composites if they are not handled properly. In general, composites contain resins, solvents, and fibers which can damage or cause dysfunction of various organ systems including the skin, lungs, CNS, liver, and kidney. The organ systems affected and the extent of injury vary according to the chemical components in the composite as well as the usual variables of type, concentration, and duration of exposure. There is no solid evidence that composites are teratogenic or carcinogenic although some components are considered probable carcinogens.

Because composites consist of many components, there is no single recommended exposure limit. Rather, attention must be given to exposure limits of each substance as recommended by regulatory and advisory bodies which, for several of the major components, are: MDA, 0.1 ppm; epichlorohydrin, 2 ppm; graphite fibers, 10 mg/m^3 (Dennis, 1992).

Unsafe exposure to composite materials can occur during aircraft production but also during the maintenance of operational aircraft, particularly when patching procedures are necessary. During this process, fibers and the resin are heated which can cause vaporization. Hence, proper industrial hygiene demands good ventilation and local exhaust. In the event of machine work, workers must use protective clothing, gloves, and goggles; in addition, a vacuum cleaning system is necessary to remove any fibers left behind in the shop environment after machining. Surveillance systems should include periodic shop inspections and biomedical monitoring with attention given to the skin, respiratory system, liver function tests, and urinalysis for protein.

L. Cyanide

Cyanide is one of the most lethal substances known. In the aircraft industry, it may be found as a by-product of electroplating or as a by-product of fires, especially of cockpit/cabin interiors containing cyanide-releasing chemicals such as urethanes. Its extreme lethality is attributed to its propensity to poison the cytochrome oxidase system causing a histotoxic hypoxia. Although any tissue of the body could be affected, the brain is a particularly sensitive target. Consequently, acute exposures will cause CNS symptoms including dizziness, convulsions, loss of consciousness, and death. Chronic exposure to low levels of cyanide may be possible in some industries, such as synthetic rubber manufacturing, but would probably be rare in aviation. Therefore, industrial hygiene programs should focus on the avoidance of cyanide-releasing chemicals or, if this is not practical, monitoring the workplace frequently to ensure that workers are properly protected and that air quality standards are not exceeded. Regulatory and advisory agency standards are 5 mg/m^3 TWA (Becker, 1990).

The diagnosis of cyanide poisoning can be readily made by occupational history, the worker's signs and symptoms, and blood cyanide levels. Besides immediate removal from the area, antidotes must be readily available for expeditious administration. Among them are nitrites and sodium thiosulfate. Because cyanide has a higher affinity for methemoglobin than for oxyhemoglobin, nitrites are given for the purpose of forming methemoglobin which, in turn, binds the cyanide rendering it less harmful. Thiosulfates are also useful in that they facilitate the metabolism of cyanide to less toxic products (Becker, 1990). Although there are other antidotes of varying efficacy, the mainstay of treatment is the nitrite–thiosulfate combination and supportive therapy.

M. Ethylene Glycol

In aviation, ethylene glycol is mainly used as a coolant and a deicing agent although it may be found in paints and hydraulic fluids. Because of its coolant properties, it has been utilized in spacecraft systems and in aviator protective clothing. Ethylene glycol is not likely to be an inhalation hazard in the workplace unless there is the unlikely presence of heated vapors. Very few such cases of occupational exposure have been reported and those that were had nystagmus or loss of consciousness (U.S. Department of Health and Human Services, 1992). Rather, the major danger is accidental or purposeful ingestion. Therefore, practically all exposures are acute with chronicity an extremely rare event.

Ethylene glycol itself is not toxic. As it is metabolized in the liver, aldehydes, lactic acid, and oxalates are formed which may cause toxicity to several organ systems. Three clinical stages have been described following a toxic exposure, the extent and severity depending upon the amount of chemical which enters the body (Factor and Lava, 1987). Stage I occurs within .5–12 hr, the main target being the central nervous system. The worker may appear inebriated (without the odor of alcohol) with dizziness, ataxia, and somnolence. Other CNS manifestations may include cranial nerve dysfunction, encephalopathy, convulsions, coma, and death. Stage II occurs 12–24 hr postexposure involving the cardiopulmonary system. The patient may develop tachypnea, tachycardia, and hypertension eventually progressing to congestive heart failure. In addition, cardiac conduction disturbances and arrhythmias are common. Renal involvement is the hallmark of Stage III becoming manifest after 24 hr. As ethylene glycol metabolites accumulate, there is an increasing BUN as well as metabolic acidosis. In addition, oliguric renal failure develops due to the precipitation of oxalates in the renal tubules.

Therefore, poisoning by this chemical, if severe enough, causes CNS dysfunction, cardiopulmonary changes, metabolic disturbances, and nephrotoxicity. However, there have been no convincing studies indicating that ethylene glycol is either carcinogenic or teratogenic. Regarding skin contact, very little if any of this substance is absorbed as long as the skin is intact. The worst that will happen is a mild dermatitis or irritation that can be obviated by prompt rinsing with soap and water.

The diagnosis of poisoning can be made by history of exposure and the presence of ethylene glycol in the serum. Furthermore, patients may have a very high concentration of oxalate crystals in the urine.

Ethyl alcohol is a specific antidote for the treatment of ethylene glycol poisoning which should be given iv within 8 hr (Winek *et al.*, 1978; Parry and Wallach, 1974). In addition, supportive care including correction of acidosis and electrolyte disturbance is essential.

In some cases the administration of vitamins, thiamine and pyridoxine, has been helpful. In the event of poisoning by ingestion, gastric lavage and induced emesis is recommended. For severe cases, hemodialysis should be considered.

In general, serious exposure to ethylene glycol in the workplace is not very common. Nevertheless, as with any chemical, there is always the potential. Hence, adherence to workplace standards with proper surveillance and biomedical monitoring is essential. The recommended 8-hr TWA has ranged from 50 to 100 ppm; if the chemical is ingested, approximately 100 ml is lethal. Biomedical monitoring of workers might include periodic examination of the skin and nervous system, blood pressure determinations, urinalysis, and BUN.

Serum ethylene glycol level would be advisable if there was strong suspicion of a toxic exposure.

N. Fiberglass

Fiberglass is a chemically inert substance found in plastics and thermal insulation of aircraft. Although inert, particles can cause dermal irritation with pruritus and possible secondary infection. Interestingly, reactions decrease with repetitive exposure indicating an acclimatization process. Likewise, the eye can become irritated if airborne particles gain entrance although there is rarely significant sequelae. To prevent even mild albeit annoying symptoms, exposed surfaces of the body should be rinsed off and on during the workday with showering after work. Clothing should be changed and washed regularly and goggles or glasses worn.

Inhalation of fiberglass particles usually causes no more than tickling of the throat although there have been cases of possible bronchitis due to chronic exposure. Although some investigators believe there is no association with serious long-term effects such as pulmonary fibrosis or cancer (Gross, 1986), the issue remains controversial. The recommended TLV is 10 mgm/m^3.

O. Freon

Freon is a trademark for a number of fluorocarbons which are used as refrigerants, aerosol propellants, fire extinguishers, and industrial solvents. The potential for injury demands caution in the handling of these substances. The skin, respiratory tract, CNS, and heart are organ systems at particular risk in event of an unsafe level of exposure. Contact with the skin can result in drying, cracking, fissuring, and possible secondary infection. Hence, it is advisable to wash the involved area well with soap and water. Likewise, if the eyes are splashed, flush well with copious amounts of water for 15 min. Of greater potential danger is the inhalation of Freon vapors which can cause mild or severe pulmonary or CNS symptoms. Exposed workers might develop irritation of the respiratory tree with complaints of cough and shortness of breath, whereas more serious exposures, although rare, could go on to pulmonary edema and its attendant sequelae. In addition to pulmonary symptoms, CNS involvement can cause transient headache, dizziness, and a narcosis-like effect; on occasion, coma and even death have been reported.

An uncommon but potentially lethal effect of inhaled Freons is the induction of cardiac arrhythmias, most notably ventricular fibrillation. It is believed that fluorocarbons sensitize the myocardium to endogenous catecholamines occasionally causing sudden death. When this occurs, it is usually due to the inhalation of a high concentration such as might occur in a closed space where there has been a vapor buildup following a spill. Although not of industrial relevance, the same could occur if fumes were intentionally inhaled, for example, from a bag. In either case, the fumes can displace oxygen which can cause asphyxiation and possibly have an additive effect on the induction of ventricular fibrillation (Hulka, 1992).

Freon 113 (trichlorotrifluoroethane) has been used in industrial shops aboard U.S. Navy aircraft carriers for a number of years. In a study of Navy seamen during a 7-year period, it was found that 38 Freon-related mishaps had occurred: 16 chemical burns and 22 inhalation injuries (Voge, 1989). Most of these exposures resulted from the unauthorized use of Freon 113 as a degreaser in closed spaces where vapor buildup had occurred. Had it been used for this purpose in an open or well-ventilated area, the workers most likely would not have been affected at all.

In the event of Freon exposure, there is no known specific antidote. Therefore, supportive care is the hallmark of therapy. Besides the use of cardiopulmonary resuscitation and supplementary oxygen, there should be cardiac monitoring to detect arrhythmias. Preventative measures should include the provision of local exhaust and ventilation in areas where Freon is utilized. As a corollary, avoid its use in closed spaces. In addition, protective clothing and goggles should be available to workers as well as emergency showers and eyewash fountains. Another caveat is to avoid high temperatures in an area where there is Freon in that phosgene, a highly toxic substance which can cause acute pulmonary edema, is a thermodegradation product.

In the event of exposure, there are no particular laboratory tests that would be useful in the diagnosis. Rather, reliance must be placed on shop surveillance, history of Freon exposure, and physical examination.

Regulatory agencies recommend exposure limits of 1000 ppm under which there are generally no effects (Hulka, 1992). At present, there have been no studies on the long-term effects of exposure to Freon nor on cancer or reproductive hazards.

P. Fuels

There are several types of fuels used in aviation for jet and propeller aircraft. In general, they consist of aliphatic and aromatic hydrocarbons as well as various additives. Jet fuel, or JP-4, as it is commonly called, is primarily kerosene which distinguishes it from aviation gasoline or avgas utilized for propeller-driven airplanes. The latter also contains tetraethyl lead (TEL). Other dangerous ingredients in aviation fuel include *n*-hexane and benzene. Workers are most likely to be exposed during refueling of aircraft, servicing engines, and cleaning of fuel tanks.

Fuel contact with the skin may occur anytime there are aircraft servicing operations. Although workers so exposed may experience burning, erythema, and blister formation, this is relatively rare due to good industrial hygiene as well as the use of closed systems during fueling operations. Should fuel splash the skin, washing with soap and water would suffice to prevent a dermatitis reaction.

On the other hand, dangerous exposures can result from the inhalation of fumes during the cleaning of fuel tanks. The major effect is on the nervous system causing CNS dysfunction, headache, drowsiness, dizziness, and possible coma and death. Hazardous ingredients, such as *n*-hexane, benzene, and TEL, which can cause peripheral neuropathy, leukemia, and CNS damage, respectively, are much more of a risk in the production and manufacture of fuels than in aircraft operations and maintenance. Of lesser consequence is irritation of the conjunctivae and mucous membranes of the nose and throat. Fuel tank cleaning operations are particularly hazardous in a closed space where fumes accumulate and cannot be purged by adequate ventilation. For this reason it is imperative that workers wear protective clothing, utilize approved respirators, and work in pairs in case one of them becomes incapacitated.

Several studies have been published on the experiences of jet fuel handlers. In one, exposures were determined among workers in three flying units of the Swedish Air Force (Holm, 1987). It was found that fumes, as well as *n*-hexane and benzene levels, in outdoor refueling areas were well below 8-hr TWA standards. Furthermore, skin contact was a rare problem. However, it was cautioned that these determinations were made outdoors and that indoor refueling would clearly require good ventilation and local exhaust.

As with any chemical, the question of aviation fuels and carcinogenicity has received much attention. A cohort of Swedish Armed Forces personnel working with fuels was followed prospectively for 9 years (Seldon, 1991). No evidence was found that indicated an association between military aircraft fuel and the occurrence of malignant lymphomas or any other malignancies among 2176 exposed men. Similarly, in a joint U.S. Air Force–Navy study, laboratory animals exposed to JP-4 jet fuel fumes showed no significant hematological or bone marrow changes (MacNaughton, 1983). However, the follow-up period may have been too short since the latency period may be 20 years or more. Therefore, further follow-up is warranted.

Although carcinogenicity does not appear to be a risk factor, other long-term effects of chronic exposure are a possibility. Workers with long-term exposure were compared with a control group and were found to have a higher incidence of fatigue, anxiety, mood disturbances, memory dysfunction, and psychosomatic symptoms (Knave, 1979). Even though it may be tenuous to attribute these maladies to aviation fuels, it cannot be dismissed.

In summary, aviation fuel exposure is probably not a major occupational medical problem. With proper handling during refueling and the use of protective clothing and approved respirators during fuel tank cleaning operations the risk of dermatitis and CNS dysfunction can be avoided.

Q. Hydrazine

For certain military aircraft, such as the F-16 fighter, the interruption or loss of electrical or hydraulic power or engine failure in flight can be disastrous. Therefore, there must be a quick response, backup source of emergency power to quickly restore normal operation of the aircraft. One such system is an emergency power unit, fueled by hydrazine, which is installed in the aircraft and which can be activated by the pilot at the first indication of an in-flight emergency. While hydrazine is an extremely potent and effective fuel not only for emergency power units, but also for missiles, it is also extremely toxic for workers who might be exposed during maintenance operations or in the event of a spill.

Major exposure in the workplace is by skin contact or by inhalation of fumes. Because hydrazine is so caustic, it can cause severe burns of the skin as well as serious eye damage if the cornea or conjunctivae are splashed. If so exposed, the worker's clothes must be immediately removed and the involved skin area washed thoroughly with water. Copious use of water is necessary not only to protect the skin from injury, but also to prevent or minimize absorption. If there is delay in treatment, absorption through the skin may result in systemic effects similar to those caused by the inhalation of fumes. Likewise, if the eyes are splashed, flushing with water for at least 15 min should be done immediately.

The fumes of hydrazine can cause irritation of the upper respiratory tract with its attendant symptoms of cough and shortness of breath. More severe exposures often lead to pneumonitis or pulmonary edema which can be lethal. With absorption through the alveoli or skin into the systemic circulation, the liver and kidneys may be damaged. There may also be CNS depression and at very high concentrations convulsions can occur. Hydrazine also affects the blood causing hemolytic anemia. Therefore, the systemic toxicity of hydrazine is significant with adverse effects upon the liver, kidney, CNS, and blood. The treatment is supportive.

Although acute exposure to hydrazine is a recognized threat with well-defined sequelae, the implications of long-term exposure to lower concentrations are unclear. Animal studies have shown that hydrazine is moderately genotoxic and oncogenic, causing primarily cancer of the lung and liver. Based on such studies, U.S. advisory bodies recommend that hydrazine be considered a potential human carcinogen in the workplace and that exposure be minimized to the lowest feasible limit (Keller, 1988). Likewise, there may be embryotoxic effects, although there are no reports of U.S. Air Force personnel with occupational exposures who have been so affected (NIOSH, 1988a).

Because of the significant toxicity of hydrazine, workers who are at risk of exposure must be provided with chemical protective equipment including gloves and goggles. Periodic shop surveys should ensure that this equipment is available and that the chemical is safely handled. Biomedical monitoring might include examination of the skin and eyes as well as laboratory tests: CBC, liver function tests, renal function tests, and pulmonary function tests. Advisory and regulatory bodies publish exposure limit standards between 0.1 and 1 ppm.

R. Hydrofluoric Acid

Hydrofluoric acid is an extremely corrosive substance found in electroplating, stripping, and derusting operations. The skin and eyes are particularly vulnerable as well as the lungs if fumes are inhaled. Skin lesions can be severe with erythema, blister formation, and necrosis with sloughing. With deeper penetrations of the skin, fluoride ions will form salts with tissue calcium; also, cell membrane permeability will increase, upsetting extracellular/intracellular potassium balance, resulting in intense pain as well as possible hypocalcemia (Upfal, 1990). Likewise, the eyes can be extensively damaged if splashed with hydrofluoric acid. The cornea and conjunctiva can be inflamed with residual scar formation should the exposure be severe enough, causing partial or complete blindness.

In the event of the inhalation of fumes, workers may complain of mild upper airway irritation with cough. However, hydrofluoric acid fumes can be much more serious causing pulmonary edema and death. Other systemic effects reported include liver and renal dysfunction, bone loss, and cardiac rhythm disturbances.

In the event of skin exposure, the worker's clothes should be immediately removed and the involved area flushed with copious amounts of water—a safety shower in the vicinity would be most effective. Likewise, if the eyes were splashed, flush well with water for at least 15 min. Speed is of the essence in treating these burns as delay can result in more serious injury. Because the fluoride ion can deplete tissue calcium, various calcium-containing medications have been recommended after first-aid measures have been completed: for example, calcium gluconate gel for local skin care and 1% calcium gluconate in saline for flushing of the eyes; and for deep wounds, 10% calcium gluconate solution for injection at the site (Trevino *et al.*, 1983). These medications should replace tissue calcium and at the same time reduce pain. With inhalation injury, treatment is supportive with the addition of the administration of a calcium gluconate solution through a nebulizer.

Because of the serious nature of hydrofluoric acid injury, it is vital that first aid and definitive medical treatment begin as soon as possible for the best possible therapeutic outcome. In addition, patients must be closely monitored because there is often a delay before signs and symptoms of exposure become apparent. Studies should include pulmonary, renal, and hepatic function as well as electrocardiogram and serum electrolytes including especially calcium.

Although there is great potential in industry for exposure to hydrofluoric acid, very few injuries have been reported (Clayton and Clayton, 1981a). Nevertheless, the great toxicity of this substance mandates impeccable industrial hygiene to include periodic shop visits and air sample analysis, proper ventilation, and the availability of protective clothing and respiratory protection. Furthermore, safety showers and eye flushers should be in the workplace to ensure expeditious first aid. Regulatory and advisory agency air standards are 3 ppm (NIOSH, 1979a).

Biomedical monitoring should include examination of the skin, eyes, and lungs. X-rays of the chest and bones could be ordered if indicated. Urinalysis, liver function tests, pulmonary function tests, and urine fluoride levels are other options to be considered.

S. Insecticides

One particular form of flying operations fraught with hazards is aerial spraying or crop dusting very much due to the high degree of toxicity of the pesticide cargo. Likewise, ground personnel are at risk of exposure during the handling and loading of these chemicals as well as during aircraft cleaning and maintenance operations. It is not uncommon for chemical residue to be found on loading tanks, nozzles, and on the aircraft itself due to splashing or leaking in flight. A number of incidents and even deaths have been reported due to exposure (Rayman, 1990).

There are four classes of insecticides: nitrophenols, chlorinated cyclic hydrocarbons (DDT, chlordane, lindane), carbamates, and organophosphates. The former two are rarely used today in aerial spraying because of their toxicity and adverse effects upon the environment. Carbamates and organophosphates are in use today although they must be handled with a great deal of respect because of their anticholinesterase activity.

Nerve impulses are transmitted to target organs by acetylcholine at cholinergic nerve endings. The enzyme, acetylcholinesterase, serves to terminate this transmitter action of acetylcholine. Without the enzyme, acetyl choline continues to accumulate at the nerve ending site causing continuous discharge of the nerve impulse which results in abnormal function of the receptor organ. The carbamate and organophosphate pesticides do just that by binding cholinesterase thereby allowing unrestrained acetylcholine activity. Exposed workers will, consequently, develop multisystem signs and symptoms (the effects are similar to those associated with some chemical warfare agents).

The primary route of entrance into the body is by skin absorption although systemic effects can also occur after inhalation of mist. In any event, one of the first signs of poisoning is visual disturbances with meiosis and loss of accommodation. The cardiopulmonary effects include coughing, wheezing, and bradycardia. Workers may also complain of headache, rhinorrhea, vomiting, diarrhea, and uncontrollable muscle twitching. All of these signs and symptoms can be explained physiologically by the anticholinesterase activity of these pesticides.

The carbamates (e.g., tetraethyl pyrophosphate or TEPP) and the organophosphates (e.g., parathion, malathion) cause similar signs and symptoms although their reaction with acetylcholinesterase is slightly different. While the organophosphates form an irreversible or persistent bond with the enzyme, the carbamate-enzyme bond is reversible or nonpersistent (Quantick and Perry, 1981). The implication of this difference is in the treatment of exposed workers. Although parenteral atropine is given for both classes in order to block the action of excess acetyl choline accumulating at the cholinergic nerve ending, pralidoxine or 2-PAM must be added to the therapeutic regimen of patients suffering from organophosphate poisoning. Its action is to break the persistent bond in order to restore the body's supply of acetylcholinesterase. Whether exposure is to a carbamate or organophosphate, it is imperative to immediately remove the workers clothing and wash down the involved area with soap and water to prevent or minimize absorption through the skin, since that route of entry poses the greatest danger.

Prevention of exposure to these dangerous chemicals cannot be overemphasized. Workers at risk must wear full-body impervious protective clothing. Furthermore, regular workplace inspections must include not only the shop, but also the aircraft itself and attendant insecticide equipment for evidence of leaks. Immediate remedial action is mandatory if any discrepancies are found.

Because carbamate and organophosphate bind acetylcholinesterase, exposure lowers the levels of the enzyme in the blood. Therefore, the cornerstone of biomedical monitoring is the periodic determination of erythrocyte cholinesterase activity. Because of the high interindividual variation of activity, all employees should have preemployment baseline determinations with which to compare with subsequent values. The results are then expressed as the percentage of baseline. During the period of aerial spraying activities, every worker should have repeat erythrocyte cholinesterase studies every 1–4 weeks depending upon the risk of exposure (NIOSH, 1979b). If abnormal levels are noted, the worker should be immediately removed from the work area until it is fully inspected, the source of the exposure identified, and remedial action completed. Also as part of a biomedical program, workers must be periodically questioned for subtle cholinergic signs and symptoms resulting from chronic, low-dose exposure.

T. Lead (Inorganic)

Although lead has gained most of its notoriety from its effects on children, it is also a potential hazard in the workplace. In the aviation industry, inorganic lead can be found in batteries, some paints and pigments, and alloys. (Organic lead is more commonly found in automobile than in aviation fuels as an antiknock additive.) There is a particular risk of exposure to fumes if lead-containing substances are subjected to high temperatures such as with welding and soldering. In addition, metal cutting, sanding or scraping, and spray painting cause airborne dusts which might be inhaled. Therefore, the major route of entry is by inhalation although ingestion can occur from hand–mouth contamination.

Once lead enters the body, it has a predilection for bone although multiple organ systems can be adversely affected causing a myriad of signs and symptoms. Organ systems particularly vulnerable are the nervous system, blood, kidneys, and gastrointestinal tract (Lewis, 1990a). With acute intoxication workers may complain of severe abdominal cramps with nausea and vomiting accompanied by headache, lethargy, weakness, and fatigue, all of which are reversible after removal from the workplace.

On the other hand, if exposure is chronic with a buildup of blood lead levels, encephalopathy with changes in mentation, stupor, seizures, and coma might occur. Many studies have demonstrated that chronic, low-level exposure can cause behavioral changes, memory impairment, increased reaction time, and changes in intellectual function (Feldman *et al.*, 1980). There may also be peripheral neuropathy often manifested by asymmetric motor damage, most commonly leading to wrist drop. Lead can also cause anemia by inhibiting the activity of certain enzymes necessary for hemoglobin synthesis. The effect of this inhibition is a microcytic–hypochromic anemia, with basophilic stippling, and increased blood zinc protoporphyrin. Pathological changes indicative of nephropathy have been reported with impaired proximal tubular function resulting in aminoaciduria, glycosuria, and hyperphosphaturia. Severe exposures may progress to extensive renal damage and failure although this is very rare in industry. There is also evidence that chronic exposure to lead may cause hypertension most likely associated with nephropathy (NIOSH, 1990).

Because lead crosses the placenta, there is the possibility of fetotoxicity (premature birth, reduced birth weight, and neurological disorders) should a pregnant worker be exposed to unsafe levels of lead (NIOSH, 1990, 1988b). However, it is uncertain whether or not lead is carcinogenic (Putnam, 1986).

The diagnosis of lead poisoning can be made by the occupational history, the patient's medical history, physical examination, and laboratory studies. Although exposed workers may demonstrate anemia, proteinuria, glycosuria, and other chemical aberrations which support the diagnosis, the abnormalities are not specific for lead poisoning. More specific tests are blood lead levels and blood zinc protoporphyrin. The latter test, however, may also be elevated in iron deficiency.

Fortunately, in adults, most of the effects of lead poisoning are reversible if the exposure is caught early enough and the worker is removed from the workplace. However, for those patients with significant manifestations of poisoning, particularly encephalopathy, chelating agents such as EDTA or BAL must be considered. But even with treatment, there is often residual nervous system impairment.

To prevent hazardous exposures to inorganic lead, regular shop inspections must be scheduled. No eating or smoking should be permitted in the work area and protective clothing must be available. If there is the potential for the release of fumes, either the process must be enclosed or local exhaust ventilation provided. Periodic air analysis for lead is also advisable.

Biomedical monitoring should focus on signs and symptoms referable to the nervous system, gastrointestinal tract, kidneys, and blood with periodic laboratory studies as indicated to include: CBC, blood zinc protoporphyrin, urinalysis, BUN and serum creatinine, blood lead levels, and possibly nerve conduction velocities.

Regulatory and advisory agencies recommend exposure limits ranging from 50 to 150 $\mu g/m^3$ (NIOSH, 1988b). Although whole blood levels in nonexposed individuals range from 5 to 15 μg/dl, one regulatory agency requires that the blood level be maintained below 40 μg/dl (Lewis, 1990a; NIOSH, 1990).

Interestingly, a survey of 291 workers in a U.S. aircraft plant revealed an average blood level of 19 μg/100 ml (WHO, 1977), well above the average blood lead level in the U.S. population of 10 μg/dl (NIOSH, 1990). Although one cannot draw sweeping conclusions from this survey, it does signal a message that vigilance in the aircraft industry cannot be relaxed.

U. Mercury

Although mercury's reputation as a toxic agent is well known mainly because of ingestion of contaminated fish in polluted waters, it is also a potential hazard in the workplace. Areas of particular concern are shops engaged with batteries, calibration, electroplating, metal work, explosives, paints, and dyes. In an industrial setting, the greatest threat is the inhalation of mercury fumes which, in high enough concentration, can cause central nervous system and renal dysfunction. Workers may be exposed to the metallic, inorganic, or organic forms of mercury each with a different affinity and distribution in body tissues. The organ affected and the extent of dysfunction is dependent upon the type of exposure.

The major point of entry is by inhalation with rapid absorption into the blood stream and distribution throughout the body. Organic mercury can also be absorbed through the skin although it is a secondary point of entry in an industrial setting. The primary route of excretion is through the kidneys.

The acute effects of inhalation, particularly the metallic or elemental form, are pulmonary with coughing, shortness of breath, and chest pain (Knight, 1988). If severe enough, chemical pneumonitis will develop.

Long-term effects or chronic exposure involve the central nervous system. Patients will demonstrate an intention tremor with characteristic changes in handwriting as well as ataxia, incoordination, and dysarthria (Goldfrank, 1980). In addition to neurological dysfunction, erethism or psychic disturbance can occur with its attendant symptoms of anxiety, depression, and emotional lability. Memory loss is a particular hallmark of long-term exposure to high concentrations of mercury.

In one study of 502 subjects exposed to elemental mercury for 20–35 years, there was an increased incidence of tremor as well as poorer performance testing when compared to controls (Albers, 1988). Furthermore, workers exposed to higher concentrations of mercury were at greater risk of developing polyneuropathy. Other studies have clearly demonstrated that mercury poisoning can cause impaired mental function, disturbance in cognitive abilities, loss of short-term memory, and performance decrements in psychomotor skills (Piikivi, 1984).

Another long-term effect is renal pathology with tubular necrosis, uremia, and the nephrotic syndrome. Glomerulonephritis has also been reported. The occurrence of proteinuria should be an early warning of damage to the kidneys. If the patient is removed from the area of exposure, there should be remission with full return of normal renal function.

Other symptoms associated with acute or chronic mercury exposure are contact dermatitis, either as a primary irritant or hypersensitivity reaction, and gingivitis or stomatitis due to mucous membrane sensitivity.

There is no evidence that mercury is carcinogenic (Agency for Toxic Substances and Disease Registry, 1989a). However, it has been established that it can be transferred across the placenta to the fetus resulting in psychomotor signs of brain damage during infancy (NIOSH, 1978a; Messite, 1988). Hence, pregnant women should not be in a workplace where there is danger of mercury exposure.

In the event of worker exposure, the individual should be removed from the workplace and examined for CNS, pulmonary, and renal dysfunction in particular. Besides symptomatic treatment, chelating agents have been effective against mercury poisoning. These include dimercaprol (BAL) and penicillamine with two provisos: chelating agents should not be prescribed if the exposure was to alkyl compounds, and if EDTA is to be given, there is the danger of nephrotoxicity (Goldfrank, 1980).

Problems can best be avoided with a good workplace and biomedical surveillance system. Periodic shop inspections to ensure good ventilation, cleanliness, and the availability of proper respirators in the event the TLV is exceeded or if work must be done in a closed space. In addition, the work area should be sloped to facilitate collection of spillage. Vacuuming is also an effective way to clean up mercury spills. There should be no eating or smoking in the workplace and if mercury comes in contact with the skin, it should be removed with soap and water. Periodically, air samples should be collected and analyzed for mercury.

Biomedical surveillance includes preemployment and periodic physical examination. For the former, it would be advisable to rule out pulmonary, CNS, and renal disease. For the latter, examination of the skin, mucous membranes, nervous system, lungs, and kidneys should be done annually. Urinalysis for proteinuria is highly recommended as is urine mercury levels. Pulmonary function tests and a chest film might be useful as a baseline to compare with later studies in the event of significant exposure. U.S. regulatory agencies have recommended in recent years a TLV for mercury ranging from 0.01 to 0.05 mg/m^3.

V. Methylene Chloride

Methylene chloride is a chlorinated hydrocarbon commonly found in enamels, lacquers, paints, paint strippers, and degreasing agents. Exposure in the aircraft industrial setting occurs with inhalation of vapors or contact with the skin. In high enough concentrations, methylene chloride vapors can cause irritation of the respiratory tract and by its anesthetic-like properties, it can also cause dizziness, incoordination, confusion, lethargy, and loss of consciousness. In rare cases of extreme exposures, death has been reported. In human experiments, behavioral changes and performance decrements with psychomotor testing have also been demonstrated (NIOSH, 1976).

An added hazard of methylene chloride is its metabolism to carbon monoxide which has an additive effect on the CNS. Therefore, smokers with elevated baseline carboxyhemoglobin levels are at increased risk if exposed to methylene chloride. Even nonsmokers exposed for 1–7.5 hr can develop carboxyhemoglobin levels as high as 10% (NIOSH, 1976).

Significant effects of methylene chloride on other organs, such as the liver and kidney, have not been demonstrated although pathological changes have been noted on exposed laboratory animals.

Skin contact can cause minor, local irritation but there is also some degree of absorption. In one experiment, methylene chloride was detected in the breath of subjects who had immersed their thumbs in a solution of the chemical. Although skin absorption in this experiment caused no systemic effects, one cannot presume that long-term skin contact would be so innocuous.

Laboratory animals exposed to methylene chloride by inhalation developed cancers of the lung and liver. However, epidemiologic studies of workers have been inconclusive. Based on the animal studies, the United States National Institute for Occupational Safety and Health (NIOSH) expressed concern about potential carcinogenicity and, consequently, recommended that exposure to the chemical should be controlled to the lowest feasible limit (NIOSH, 1986; Agency for Toxic Substance and Disease Registry and U.S. Environmental Protection Agency, 1989b).

An industrial hygiene program to minimize the risk of adverse effects of methylene chloride should include the following features (NIOSH, 1986; Agency for Toxic Substances and Disease Registry, 1989b): control worker exposure to the lowest feasible limit, provide adequate ventilation, provide protective clothing, discourage smoking and prohibit it in the work area, provide suitable respiratory equipment in case of emergency, monitor the work area periodically for methylene chloride, and provide a medical monitoring program which includes periodic urine methylene chloride and blood carboxyhemoglobin levels. Workers must also be questioned regarding known signs and symptoms associated with exposure.

Advisory and regulatory agencies have set exposure standards ranging from 14 to 707 ppm (NIOSH, 1976). Because of the additive effects of carbon monoxide, a metabolite of methylene chloride, a more conservative permissible exposure level of 75 ppm is advisable (NIOSH, 1976).

W. Methylethyl Ketone

A broad class of solvents found in aviation maintenance is ketones, and within this group one of the most utilized is methyl ethyl ketone (MEK). In general, MEK is not particularly toxic unless there is exposure to very high concentrations for a prolonged period of time. With skin contact, it can cause contact dermatitis with drying, scaling, and fissuring, as well as irritation to the conjunctivae and mucous membranes of the nose, mouth, and throat. Washing the skin with copious amounts of soap and water should obviate any significant sequelae. Likewise, immediate flushing of the eyes with water should suffice to prevent serious injury.

The major potential hazard in aircraft maintenance is the inhalation of fumes. Like most hydrocarbons, MEK affects the CNS causing CNS depression, narcosis, coma, and even death in extreme cases. Milder exposures, which are more common, might include headache, dizziness, incoordination, nausea, and vomiting. Because there is the possibility of skin absorption, there could feasibly be CNS sequelae in the event of severe dermal exposure. This was demonstrated in one experiment when subjects who had MEK affixed to their skin had detectable amounts of MEK in their expired air (Clayton and Clayton, 1981b).

Preplacement as well as periodic physical examinations should focus on the skin and respiratory system. If, in the course of shop inspections a hazard is suspected, air samples can be analyzed and urine glucuronic acid determinations made on workers. Although minimal toxic or lethal doses are not well defined in the literature, the TLV of ketones ranges from 25 to 200 ppm.

X. Nickel

Nickel can be found in jet engine parts, electronic components, and nickel–cadmium batteries as well as in electroplating or welding operations. One of its properties particularly attractive to aviation is corrosion resistance. Although oxides and sulfides of this metal can be found in industry, nickel carbonyl is most frequently encountered and is the most toxic. The major target organs are the lung by inhalation and the skin by contact.

The effects of nickel inhalation can be divided into an initial phase and a delayed phase. Early symptoms, which can occur as late as 12 hr after exposure, mimic flu-like syndrome with headache, weakness, dizziness, nausea, and vomiting. There may follow a period of remission for several days to a week after which the delayed phase begins. Because of irritation of the respiratory tract, asthmatic symptoms and a chemical pneumonitis may develop causing cough, wheezing, dyspnea, and chest pain. Eventually pulmonary edema and fibrosis may occur. If the exposure is severe enough, the patient may die of pulmonary insufficiency due to hemorrhage, atelectasis, and pulmonary tissue necrosis.

Other organs which may be affected are the liver and kidney, the latter evidenced by proteinuria, although the clinical significance of such a finding has not been well defined. Nickel dermatitis following skin contact is frequently reported due to either irritation or an allergic hypersensitivity reaction. Not uncommonly, erythema and nodular eruptions causing burning and pruritus will develop at the point of contact.

Numerous studies have been published on the effects of nickel exposure in workers. In one study, 100 workmen suffering from an acute exposure to nickel carbonyl fumes were followed (Sunderman and Kincaid, 1954). Most of them had some degree of initial and delayed symptoms with 21 requiring hospitalization; 2 patients died. Interestingly, a majority of the workers complained of protracted weakness and fatigue for months after the incident. In another study of 179 workers who were exposed as long as several hours, most complained of tightness of the chest, cough, headache, and dizziness (Zhicheng, 1986). A number also developed chemical pneumonitis and pulmonary edema. Like the former study, many of the patients even after recovery from the acute effects continued to have weakness and fatigue weeks to months later.

There is solid evidence that nickel is carcinogenic in animals and man, affecting in particular the nasal passageways and the lungs. In most cases there is a 20–30 year latency period (Sunderman and Kincaid, 1954; Smith *et al.*, 1983). However, there is little evidence of teratogenic effects. The experience of several hundred women working in a nickel refinery in Wales over a period of 50 years did not reveal abnormalities of their offspring attributable to nickel (Smith *et al.*, 1983).

Because nickel affects the skin and respiratory tract primarily, preemployment and periodic employment examinations should focus on these organ systems. Therefore, the skin should be inspected and the worker questioned about previous skin disease, allergy to nickel in particular. Examination of the nasal passageways, oropharynx, and lungs must be included as well as chest x-ray and pulmonary function tests if indicated. It is always wise to consider a baseline chest x-ray for new employees. In the event of suspected exposure to toxic levels of nickel, blood and urine levels can be measured.

The most effective therapy for acute inhalation is sodium diethyl dithiocarbamate or dithiocarb, a chelating agent (Sunderman, 1981). Other chelating agents, such as EDTA, BAL, or *d*-penicillamine, either have low effectiveness or unacceptable side effects. If there is skin contact, wash thoroughly with soap and water. Dithiocarb and disulfiram (antabuse) are effective medications if needed.

If there is potential for significant exposure to nickel in the workplace, goggles and protective clothing must be available as well as respirators. Barrier creams are effective in the prevention of skin sensitization. The workplace should be periodically inspected with air samples analyzed particularly if there is evidence of acute or chronic exposure. Standards for nickel levels based on an 8-hr TWA have ranged from 0.1 to 1 mg/m^3 (Mastromatteo, 1988).

Y. Phenol

Phenol is a relatively toxic substance found in plastics, solvents, and paint strippers. Its route of entry is inhalation or absorption through the skin. Because phenol spreads ubiquitously throughout the body, many systems can be adversely affected. The inhalation of fumes can cause respiratory tract irritation, pulmonary edema, and possible respiratory arrest. The CNS is sensitive to exposure with workers complaining of headache, lethargy, and dizziness; in more serious cases, seizures, coma, and death have been reported. Liver function tests may become abnormal causing jaundice on occasion with more serious sequelae due to hepatic necrosis. The kidney is also not immune to the ravages of phenol. Serious injury with renal papillary necrosis can lead to renal dysfunction and failure. If the myocardium is affected, arrhythmias, including supraventricular and ventricular tachycardia, might occur. With such widespread effects, it is clear why phenol must be handled very carefully in the work area.

Besides its systemic effects, phenol acts as an allergen or irritant if there is skin contact. Mild dermatitis can occur as well as more serious lesions with ulceration due to its corrosive properties. Likewise, splashing of the eyes can cause damage to the cornea with partial or total loss of vision if the exposure is extensive. Of particular concern is the propensity of phenol to be absorbed through the skin. In the event of serious skin contact, systemic effects can occur.

The treatment of phenol exposure in general is supportive depending upon which organ system has been affected. With skin contact the exposed area should be washed with copious amounts of water. If polyethylene glycol 300 or 400 is immediately available, flush the skin first with this solvent cleaner before water irrigation. Likewise, flush the eyes with tepid water for at least 15 min if they were splashed. In the event of a serious exposure to phenol, it may be necessary to hospitalize the patient to observe for systemic effects. Monitoring should include ECG, pulmonary function, and liver and renal function.

Because phenol has such toxic potential, the workplace and the workers must be closely monitored. Ensure that the chemical is handled safely and that protective clothing and goggles are available if there is a risk of worker exposure. In addition, an eye wash basin should be in the immediate area. It is advisable to take occasional air samples for analysis and to monitor workers by exposure history as well as urinalysis, ECG, and liver function tests. Urinary phenol determinations should also be done periodically. The recommended exposure limit (TLV) is 5 ppm (Lewis, 1990b).

Z. Phosphoric Acid

Phosphoric acid may be used in cleaning, electroplating, and rustproofing operations. It is a weak acid but can cause irritation to the skin, eyes, and upper respiratory tract. Therefore, workers who are exposed may complain of burning of the skin, eye discomfort, cough, and sore throat. These symptoms are usually self-limiting with no sequelae. Treatment is symptomatic and includes washing of the skin with soap and water and eye irrigation with tepid water for 15 min. For inhalation injury, remove the worker from the area and administer 100% oxygen if necessary. Although the great majority of exposures cause only mild illness, the infrequent severe exposure may result in life-threatening pulmonary edema. The recommended TLV is 1 mgm/m^3.

AA. Sulfuric Acid

Sulfuric acid can be found in aircraft battery shops since it is a component of lead storage batteries. Because it is so corrosive, it can cause severe burns to whatever tissue it comes into contact. Of particular concern is liquid contact with the skin and conjunctivae and the inhalation of fumes.

The degree of injury to the skin depends very much upon the concentration of the acid. While lower concentrations result in dermatitis, the corrosiveness of higher concentration solutions causes extensive damage with burns, ulceration, and scarring. Likewise, the eyes are very vulnerable to injury from sulfuric acid splashing with necrosis and ulceration of the cornea and blindness a possible sequelae. Hence, after exposure, immediate flushing of the skin and eyes with copious amounts of water is mandatory. Eye wash fountains and showers must be in the area of the workplace to ensure expeditious treatment.

The corrosive fumes of sulfuric acid will also wreak havoc on the mucous membranes of the respiratory tract causing not only irritation, coughing, and shortness of breath, but also bronchospasm and pulmonary edema in more serious cases. In the event of chronic exposure to more diluted solutions, the signs and symptoms may be subtle. Patients will complain only of throat irritation, tickling, and sneezing, while others may develop frequent respiratory infections or chronic bronchitis. In one study of 225 workers, the incidence of acute pulmonary symptoms was very low with exposures less than 1 mg/m^3

(Gamble *et al.*, 1984a). In another study of the effects of chronic exposure, an interesting finding was tooth erosion and etching after 1–4 months (Gamble *et al.*, 1984b).

In any event, workers exposed to sulfuric acid fumes should be removed from the area until remedial action is completed. This may be all that is necessary. However, for more serious exposures, oxygen may be necessary with hospitalization for appropriate diagnostic and therapeutic modalities should pulmonary edema be suspected.

There is much conjecture regarding carcinogenicity. Some studies purport an association with lung cancer although there may have been other confounding environmental factors. In other studies there is some evidence to suggest that there is an increased risk of laryngeal cancer in workers exposed to sulfuric acid (Soskolne *et al.*, 1984; Steenland *et al.*, 1988). Clearly, proper precautions must be taken for any substance even suspected of being a carcinogen.

Biomedical surveillance might include periodic pulmonary function tests, examination of the eyes, skin, and teeth, and chest x-ray. Furthermore, the workplace should be periodically visited to ensure proper handling of the acid and the availability of protective clothing and goggles should there be a potential for exposure. Air samples can also be analyzed if chronic exposure is suspected. An exposure standard of 1 mg/m^3 is recommended (NIOSH, 1974).

AB. Tetrachloroethylene

Tetrachloroethylene or perchloroethylene is a solvent and degreaser with effects very similar to trichloroethylene (TCE). Its fumes are readily absorbed through the lungs causing injury to several organ systems. Because it is an agent with anesthetic properties, CNS depression, coma, and even death due to respiratory depression can occur. It can also cause less serious, but nonetheless, significant neurological dysfunction such as dizziness, incoordination, and peripheral neuropathy. Liver and kidney damage has also been reported manifested by abnormal liver function tests consistent with hepatitis as well as proteinuria, hematuria, and in rare instances, renal failure. The lungs themselves can be irritated causing coughing and shortness of breath with more severe exposures progressing to pulmonary edema.

Although the inhalation of fumes is the primary route of entry into the body, small amounts may enter through the skin. However, the major danger of skin contact is fissuring and blister formation. Likewise, splashing of the eyes or mucous membranes can be very irritating.

Carcinogenicity and teratogenicity have been reported in laboratory animals but there is inadequate evidence that tetrachloroethylene is a human carcinogen.

In the event of exposure, the worker should be removed from the area and the skin thoroughly washed wherever there was contact. Likewise, the eyes should be irrigated with water for 15 min. Medical treatment is supportive.

The work area should be periodically inspected to ensure the availability and use of protective clothing and goggles should the operation pose a potential threat of exposure. Containers with the solvent should be covered. In addition, adequate ventilation is essential. Medical surveillance might include periodic skin examination as well as liver and renal function tests. Blood or serum levels of tetrachloroethylene should be ordered if exposure was suspected.

Regulatory agencies in the United States and abroad mandate variable TLV standards ranging from 1.5 to 200 ppm.

AC. Titanium

Titanium is a corrosion-resistant metal utilized in the construction of some commercial and military aircraft as well as certain aircraft parts and avionics equipment. One of its compounds, titanium dioxide (TiO_2), is a frequent ingredient of paints, lacquers, and coatings found in maintenance facilities. TiO_2, called rutile or anatase, is a white powder considered more of a nuisance dust than a highly toxic substance (NIOSH, 1978b). Either metallic titanium or TiO_2, when inhaled, can be a mild pulmonary irritant. There are only rare cases reported linking them with significant sequelae, such as pulmonary fibrosis and bronchitis, in workers chronically exposed during the production process (NIOSH, 1978b; Mogilevskaja). And even in these cases, the cause–effect role is very tenuous because of other possible confounding variables.

Because workers in the aircraft industry are not exposed to the same extent as those in the manufacture of titanium and its compounds, serious pulmonary pathology is unlikely. Despite the apparent benign nature of titanium, care must be taken because pulmonary pathology, albeit rare, may still occur. In addition, individuals with underlying disease, such as asthma or bronchitis, might experience exacerbations when exposed to the dusts of titanium. If there are processes which might release these dusts into the work area, air samples should be periodically analyzed and appropriate ventilation provided should permissible levels be exceeded. Likewise, workers should be monitored particularly for respiratory symptoms with chest films taken before and during employment.

Advisory and regulatory bodies recommend exposure limits of metallic titanium and TiO_2 ranging from 10 to 15 mg/m^3 (NIOSH, 1978b; Mogilevskaja). There has been no evidence of adverse health effects if the concentration of TiO_2 is kept below 10 mg/m^3 (U.S. Department of Labor, Occupational Safety and Health Administration, 1989).

AD. Toluene

Toluene is a hydrocarbon utilized as a solvent or degreaser and is also found in paints. Because it is a chemical relative of trichloroethylene, the effects on man are somewhat similar. Its main route or entry to the body is the respiratory system with minimal absorption through the skin. Fumes may be inhaled inadvertently in the workplace or intentionally by sniffing glue which contains toluene. Direct contact on the skin and mucous membrane, or in the eyes by accidental splashing, can cause minimal to severe irritation. Likewise, ingestion of toluene can be lethal but this should not be viewed as an occupational hazard in that ingestion is usually intentional.

Although the literature is replete with studies on toluene and its effect on man, they are difficult to interpret because they are fraught with bias. For example, toluene is frequently used with other substances, such as xylene and benzene, making it impossible to determine which ingredient (or possibly the synergistic activity of all the ingredients) is causing the adverse effects. In addition, there are other confounding factors, such as cigarette smoking and alcohol consumption, which, like toluene, can affect the lungs and liver. Therefore, in any study with such confounding factors, it is virtually impossible to be certain if the pathology is due to toluene alone. Finally, many studies in the literature report the effects of toluene among glue sniffers including encephalopathy hepatic–renal toxicity, cardiac arrhythmias, and death (De Leon et al., 1988). Although this does provide much useful information on its potential toxicity, it probably has less relevance to the workplace in that a worker's inadvertent inhalation of fumes would probably be less than that of a glue sniffer.

In any event, the predominant effect of toluene fumes is its effect on the CNS by inhalation. It can cause a broad spectrum of symptoms including headache, drowsiness, incoordination, unsteady gait, coma, and death (De Leon *et al.*, 1988). This should not be surprising for any agent with anesthetic-like properties. Other studies have also demonstrated neurobehavioral changes when exposed to high concentrations of fumes possibly due to a resultant encephalopathy (Echeverria *et al.*, 1989). With chronic exposure to fumes, there are changes in the white matter as detected by MRI which can lead to cognitive difficulty, performance decrement, and even organic brain syndrome (Filley *et al.*, 1990; Carlton *et al.*, 1989; Larson and Leira, 1988).

The inhalation of fumes will also cause irritation to some extent of the respiratory tract resulting in coughing, shortness of breath, and pneumonitis. Pulmonary edema and respiratory failure occur in more severe cases.

Although not very common, there are reports of hepatic and renal damage due to toluene inhalation (Guzelian *et al.*, 1988; Streicher *et al.*, 1981). It is very difficult to determine exactly how hepatorenal toxic toluene is to human beings in the workplace because many reports describe single cases, are anecdotal, or include long-term glue sniffers. There are also contradictions in that in one study of workers exposed for many years to 80–300 ppm toluene fumes, there was no clinical or laboratory evidence of liver damage (NIOSH, 1978c). Nevertheless, one should be mindful of the possibility of hepatorenal toxicity and take precautions accordingly. Likewise, there are isolated reports, mainly in glue sniffers, of myocardial infarction/ventricular fibrillation and macrocytic anemia (De Leon *et al.*, 1988; Wiseman, 1987).

If toluene comes into direct contact with the skin, it can cause irritation, drying, and cracking with fissure formation. This can best be avoided by wearing protective clothing and by ensuring that there is no exposed skin, particularly of the arms, hands, and legs. Likewise, toluene is very irritating to the eye and inadvertent splashing can lead to keratoconjunctivitis. Careful handling of the fluid and the use of goggles should minimize or avoid all such exposures.

Neoplasia does not occur in laboratory animals exposed to toluene (Agency for Toxic Substances and Disease Registry, 1989c). Although some studies have revealed chromatid changes with long-term exposure, there is no substantive evidence that toluene is carcinogenic in man. It is also unclear whether or not unborn children are affected if the mother inhales fumes in the workplace. Only a few anecdotal reports purporting physical and CNS anomalies have been reported. However, it has been demonstrated in the laboratory that unborn animals have been affected with skeletal anomalies if the mother was exposed (Agency for Toxic Substances and Disease Registry, 1989c).

Because of the effects of toluene, workers should undergo preemployment and periodic employment physical examinations with special attention given to the skin, CNS, lungs, liver, and kidney. The main reason for a preemployment physical examination is not only to detect a preexisting condition that puts the worker at increased risk if exposed to toluene, but also to establish baseline values with which to compare with subsequent examinations should they become necessary. Laboratory studies to consider might include a complete blood count, urinalysis, liver function tests, and possibly a chest x ray. Toluene is metabolized in the liver to hippuric acid and excreted in the urine in which it can be measured.

The workplace should also be inspected periodically to ensure that operations are conducted safely. Workers should wear protective clothing and goggles if necessary to avoid direct contact with the fluid. Safety showers and eye wash facilities must be located in the general vicinity. Air samples should be analyzed for toluene periodically or if an unsafe concentration in the workplace air is suspected. It is also advisable to have available proper respirators should there be toxic levels in the workplace or should it be necessary to conduct operations in a closed space such as a tank.

In the event of exposure including skin and eye contact, the worker should be taken from the workplace and clothing removed. The skin should be washed with soap and water and the eyes flushed with water for 15 min if they were splashed. If there was a more serious acute exposure, hospitalization may be necessary with monitoring of liver and renal function, blood gases, electrolytes, electrocardiogram, and chest film. There is no specific antidote for toluene exposure. Therefore, treatment is supportive.

Regulatory agencies in the United States have, in recent years, recommended exposure limits of 100–200 ppm (8-hr day TWA) (De Leon, 1988; NIOSH, 1979c). In one study of subjects exposed to toluene 8 hr per day for 14 days, the effects were (Agency For Toxic Substances and Disease Registry, 1989c): 100 ppm, moderate fatigue; 300 ppm, severe fatigue and headache; and 600 ppm, extreme fatigue, confusion, dizziness, and behavioral changes. This and other studies seem to indicate that some workers may be adversely affected once levels reach 100 ppm.

AE. Toluene Diisocyanate

Toluene diisocyanate (TDI) is an additive to paints, foams, and various coatings and adhesives. In aviation, it can be a hazard to workers engaged in spray painting or the application of coatings. The major danger is the inhalation of vapors or aerosols. Other toxicity includes contact with the skin and eyes causing redness/blistering and keratoconjunctivitis, respectively. An acute exposure can affect the respiratory tract with irritation to the mucous membranes of the nose, throat, and upper airways causing cough, chest discomfort, and shortness of breath (WHO, 1987). If the lungs are affected, the patient could develop pulmonary edema with signs and symptoms becoming manifest as long as 8 hr postexposure.

Interestingly, TDI is a sensitizing agent which will cause symptoms of classical asthma—wheezing, shortness of breath, and abnormal pulmonary function tests (FEV_1 and FVC)—in a sensitized individual. Sensitization may occur at any time after just a few exposures or even years later. Therefore, vigilance in the workplace as well as worker protection is extremely important. Although there is no way to identify healthy workers who are prone to develop asthma, keeping exposure as low as possible minimizes the danger of sensitization. For example, with exposures between 0 and 0.02 ppm, there is little danger of reaction; at 0.02 to 0.1 ppm, there is potential; and at levels greater than 0.1 ppm, the risk becomes significant (Woolrich, 1982). Once an individual becomes sensitized to TDI, asthma-like symptoms can be induced at very low concentrations. Therefore, these workers should never be employed in an area where there is the risk of further TDI exposure.

The treatment for skin contact is to remove clothing and wipe the involved area with rubbing alcohol before washing with soap and water. Although the major consideration is the prevention of dermatitis, repeated skin contact with TDI can also induce pulmonary sensitization. In the event of splashing of the eye, flushing with water should be done as soon as possible.

The TLV prescribed by some regulatory agencies is 0.02 ppm which should never be exceeded primarily to avoid sensitization (Woolrich, 1982). Levels below this appear to be safe as illustrated by a study in which 107 workers who were chronically exposed to low concentration of TDI (0.001 ppm) were followed for 5 years (Musk and Peters, 1982). During this time, there were no changes in pulmonary function testing nor respiratory symptoms attributable to TDI exposure. Therefore, there should be adequate ventilation of the workplace with periodic analysis of air samples. Workers should be examined periodically for a history of asthmatic symptoms and pulmonary function testing. Individuals with pulmonary disease, such as chronic bronchitis or emphysema, should be restricted in that TDI exposure could exacerbate preexisting disease.

AF. Trichloroethylene

TCE, a halogenated hydrocarbon, is a clear fluid with a sweet odor commonly used in aircraft maintenance as a solvent or degreasing agent for metals. It was first used for this purpose in World War I at which time its effects on workers were noted. Today, it is frequently used in closed automatic degreasers, which affords excellent protection, although open vats in which aircraft parts are placed are also utilized. Workers in degreasing operations, therefore, are at risk for the inhalation of TCE fumes as well as for skin and eye contact with the fluid itself. However, with properly implemented industrial hygiene procedures, this potentially toxic substance can be employed with no harm to workers and handlers.

TCE is readily absorbed by inhalation and ingestion although ingestion should not be a problem in the workplace unless it is intentional. Although TCE can damage the skin, it is very poorly absorbed as long as the skin is intact. Metabolism occurs primarily in the liver, the products of which are urochloralic acid, trichloroethanol, trichloroacetic acid, chloroform, and monochloroacetic acid, most of which is excreted in the urine (Barceloux and Rosenberg, 1990).

Although TCE has the potential to adversely affect most systems of the body, the most compelling are the lungs, skin, and CNS. Fumes can be readily inhaled by workers, particularly near open vats. This can cause irritation of the respiratory tract causing cough, shortness of breath, and even pulmonary edema if the exposure is great enough. An important precaution is to avoid high temperatures, such as those caused by welding, in the vicinity of TCE because one of its thermal decomposition products is phosgene, an even more potent pulmonary irritant than TCE itself. In one case study, a worker so exposed developed pulmonary edema within 12 hr and recurring dyspnea for 10 days (Sjogren *et al.*, 1991).

Although intact skin is practically impermeable to TCE, direct effects from contact are not infrequently found among workers. Because it is a fat solvent, TCE acts as a primary irritant causing drying and fissuring which can lead to secondary infection. In some cases it has also acted as a sensitizer causing generalized dermatitis including papular/vesicular lesions and exfoliation (Bauer and Rabens, 1974). Another cutaneous manifestation of TCE exposure is degreaser flush in which there is a redness and pruritus of the skin particularly in the face, neck, and back (Barceloux and Rosenberg, 1990). There appears to be an association between the severity of symptoms and ethanol intake. In any event, the condition will remit spontaneously with avoidance of the precipitating factors.

Interestingly, TCE was once used as a general anesthetic and it is those very CNS effects of such anesthetics that lend TCE some of its toxic potential. If fumes are inhaled in large enough amounts, loss of consciousness and even death may occur (Beliczky and Zenz, 1988). In less serious exposures, workers may complain of a host of CNS symptoms including headache, dizziness, giddiness, drowsiness, ataxia, and tremors. In addition, a number of patients have reported symptoms consistent with cranial nerve palsies including anosmia (olfactory nerve), visual disturbances including blindness (optic nerve), and facial hypesthesia (sensory portion of the trigeminal nerve) (Buxton and Hayward, 1967).

As might be expected in an agent that affects the CNS, there have been reports of emotional and mood changes as well as a change in psychomotor skills. In one study, subjects were given perception, memory, and reaction time tests before and after exposure to TCE vapors at 110 ppm for 8 hr. The subjects had a statistically significant degradation in performance scores after vapor exposure (Salvini *et al.*, 1971).

Other organs that might be affected by TCE are the liver, kidney, and heart. Although hepatotoxicity is believed to be rare, workers occasionally have abnormal liver function tests. Only a few cases of hepatitis and massive necrosis have been reported (Schattner and Malnick, 1990; Smith, 1966). It can only be concluded that although hepatic damage due to TCE exposure is extremely rare, it cannot be entirely dismissed and care should be taken accordingly when working with TCE. Likewise, renal involvement is uncommon with only rare cases of acute tubular necrosis and renal failure reported (Barceloux and Rosenberg, 1990; Smith, 1966; Gutch *et al.*, 1965; David *et al.*, 1989). In most cases, exposure has been by inhalation with full recovery after the patient was removed from the workplace and given symptomatic therapy. Cardiac arrhythmias have also been reported on occasion including ventricular ectopy and fibrillation as well as minor conduction disturbances (Feldman, 1979; Anonymous, 1974). It is believed that death following acute exposures is probably due to ventricular fibrillation.

Of particular interest in exposure to a toxic substance is the potential for carcinogenicity and mutagenicity. Hepatocellular and renal cancer have been found in rodents exposed to TCE but there is no solid evidence that it causes cancer in man (Tola *et al.*, 1980; Kimbrough *et al.*, 1985). In one study, 2117 workers exposed to TCE were followed for 13 years. In males, 5 neoplasms occurred (6.3 expected) and in females there were 4 neoplasms (6 expected)

(Tola *et al.*, 1980). In addition, no malformed babies were found with 3 expected. These and other studies support the noncarcinogenicity and nonmutagenicity of TCE in man (Barceloux and Rosenberg, 1990; Axelson and Hogstedt, 1988).

There should be a system of shop surveillance and worker surveillance to ensure that appropriate precautions are taken in areas where TCE is being used. Periodic visits, scheduled and unscheduled, to ensure workers are utilizing protective wear, such as gloves, aprons, and long sleeves, are recommended. If open vats are being utilized for degreasing operations, there should be a good ventilation system and no welding should be done in the same area. It is also advisable to cover all vats when not in use. If there are operations in closed tanks, workers should be wearing masks and conducting operations with the buddy system. Periodic air samples may be analyzed for TCE concentration to ensure that TLVs are not exceeded. The American Conference of Government Industrial Hygienists recommends a TLV of 50 ppm (ACGIH, 1991).

Besides the workplace, the workers should be clinically evaluated periodically. Enquiries about respiratory symptoms or skin lesions can be helpful in determining if there was TCE exposure. Furthermore, urine specimens should be analyzed for trichloroacetic acid and trichloroethanol, metabolic products of TCE. With proper workplace and biomedical monitoring, the risk of toxic exposure can be reduced.

In the event of exposure to TCE, treatment must be supportive in that there are no known antidotes. For an acute exposure, removal from the workplace and removal of clothing is mandatory. The skin should be washed with soap and water and the eyes irrigated for 15 min if they are splashed. (Eye wash facilities should be in the immediate work area.) In some cases supplementary O_2 may be useful if there are respiratory symptoms. If the exposure was severe or chronic, hospitalization may be necessary with monitoring by ECG, chest film, liver function studies, urinalysis, and vital signs. The managing physician must be particularly alert for cardiac arrhythmias, pulmonary edema, and hepatic or renal damage.

AG. Tricresyl Phosphate

Tricresyl phosphate (TCP) gained notoriety in past decades when large numbers of innocent people were poisoned by ingesting adulterated food substances, notably cooking oil. Although this is not a direct occupational hazard, a potential hazard still exists because TCP is an additive in various fluids found in industry, namely hydraulic fluid and some oils.

Workers can be adversely affected by the inhalation of heated vapors or by skin contact. The nervous system is particularly vulnerable should an individual be exposed to toxic levels of the vapor. Flaccid paralysis, convulsions, polyneuropathy, and a broad spectrum of neurological deficits can result, some of which may be permanent or transitory taking weeks to months for full recovery (Clayton and Clayton, 1981c). Less serious exposures may serve only as a warning causing headache, nausea and vomiting, and upper respiratory irritation which remit upon removal from the work area (Proctor *et al.*, 1988).

Contact dermatitis due to irritation can occur if TCP-containing fluids splash the skin. Although TCP is not well absorbed, a case has been reported of percutaneous absorption in which the worker developed pyramidal signs and polyneuropathy (WHO, 1990). Therefore, washing the skin and removing clothing is highly advisable in the event of skin contact.

Although TCP is an extremely toxic substance, adverse effects are rarely reported in industry. Illustrative of this is a U.S. Navy study of maintenance personnel on board aircraft carriers where TCP-containing substances were frequently used (Withers, 1981). No illness or cases of neurotoxicity occurred on U.S. aircraft carriers despite extensive use of TCP-containing compounds and even in the case of spills. Nevertheless, despite such assurances, every precaution must be taken with this or any substance which has the potential to cause permanent neurological sequelae.

Skin contact can be avoided by careful handling of TCP-containing fluids and by wearing protective clothing. Periodic air sampling for analysis is advisable to be sure vapor levels, especially if there are heating processes in proximity, do not exceed regulatory agency recommended standards (5 ppm TWA). Currently, there is no reported evidence that TCP is carcinogenic or mutagenic (Clayton and Clayton, 1981c).

AH. Xylene

Xylene is a hydrocarbon found in solvents, paints, adhesives, and various cleaning fluids. It often contains small amounts of toluene, phenol, benzene, and other contaminants. As a result, some studies of its effects on human beings have been confounded, since it is difficult to ascertain whether observed adverse effects are due to xylene, its adulterates, or both.

In general, inhaled xylene fumes cause a narcotic-like effect on the CNS with patients complaining of headache, giddiness, and a feeling of drunkenness. With severe exposures, there will eventually be loss of consciousness and death. Fumes can also cause irritation of the nose, throat, conjunctivae, and respiratory tract which is more of an annoyance and almost always reversible. However, a high-concentration exposure can be much more serious resulting in pneumonitis or pulmonary edema. Studies of workers as well as laboratory animals exposed to xylene indicate that the chemical may be hepatotoxic and nephrotoxic although these changes are usually reversible (NIOSH, 1975). At one time xylene was thought to be toxic to the hematopoietic cells in that some workers were found to have bone marrow suppression. However, it is now believed that these effects were due primarily to adulterates, most notably benzene.

Skin absorption of xylene is considered to be minimal and not enough to cause systemic poisoning (De Leon, 1988). However, it is a dermal irritant and, consequently, can cause erythema, fissuring, and secondary infection of the skin. Therefore, if skin contact occurs, thorough washing of the involved area is advisable.

At the present time, there is no evidence that xylene is carcinogenic or teratogenic.

Periodic shop surveillance should include air analysis of fumes if worker exposure is suspected. In addition, an effective industrial hygiene program must ensure proper handling and use of the chemical. Because xylene could affect several organ systems, biomedical monitoring might include CBC, liver function tests, and urinalysis. In the event of suspected exposure, the best test for the presence of xylene in the body is a urine methylhippuric acid determination. It is a metabolic product of xylene easily detectable. In addition, workers can be surveyed for signs and symptoms associated with exposures to unsafe levels of xylene. Particular attention should be given to the skin and CNS. Regulatory and advisory agencies have published standards ranging from 12 to 230 ppm (NIOSH, 1975).

AI. Zinc

Exposure to zinc can result from galvanizing, electroplating, and welding–soldering operations with most cases due to inhalation of zinc oxide and zinc chloride. The major occupational hazard of zinc oxide is metal fume fever which usually occurs up to 12 hr after exposure causing fever, chills, cough, and myalgias/arthralgias similar to a viral syndrome. The illness is self-limiting with remission within 24 hr. It is most often associated with welding or soldering in an area with poor ventilation. Zinc chloride is more dangerous than the oxide because it can damage the respiratory tract causing respiratory failure. It can also cause severe burns to the cornea as well as the skin with possible exfoliation.

Metal fume fever can be treated symptomatically with bedrest and antipyretics the mainstay of therapy. In the event of corneal or skin contact, treat with irrigation and washing, respectively. Pulmonary damage usually due to zinc chloride requires hospitalization because of its potential seriousness.

Preventive measures include good ventilation and the use of protective clothing and goggles. If exposure is suspected, the eyes and skin should be examined and CBC and PFTs ordered. Routine periodic screening of workers might include skin examination and PFTs. Recommended TLV range is 1–10 mgm/m^3 depending on the compound (Lewis, 1990c).

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CHAPTER

8

Biological Hazards

JOSEPH RIBAK

I. INTRODUCTION

The health and sanitation aspects of international travel have been of concern to the World Health Organization (WHO). In 1951, the Fourth World Assembly recommended that all countries should "improve sanitary and environmental conditions especially in and around ports and airports." We can find airport sanitary requirements in the International Health Regulations. Furthermore, the WHO has established an expert committee on hygiene and sanitation in aviation. In 1960, the first Report and Guide to Hygiene and Sanitation in Aviation was published (WHO, 1960a,b).

Air transportation is steadily increasing with new routes established everyday and tourists traveling to places with marginal sanitary standards infrequently visited before. Transportation of food, drink, and animals is of special biological concern. Since biological risk factors carry a potential for harm to a significant number of people, the International Civil Aviation Organization, the International Air-Transport Association, and the Airport Associations Coordinating Council all published specific recommended practice codes and specific procedures for monitoring sanitary standards. Possible sources for biological exposure on aircraft are (a) food, either prepared on board or imported (especially when unprocessed); (b) water; (c) waste to which ground personnel can be exposed by cleaning toilets and water basins and working on the plumbing system; (d) biologically active materials which can be inadvertently released in the event of damage to containers during handling; and (e) transported animals and vectors such as flies, fleas, mosquitos, rats, etc., which may disseminate a number of infectious diseases of major public health concern (Table I). Therefore, it is important to prevent such exposures in order to protect ground personnel specifically and the public in general.

II. GENERAL RECOMMENDATIONS

General recommendations can be found in Bailey's Guide to Hygiene and Sanitation in Aviation (Bailey, 1977). However, it should be kept in mind that these are only the minimum criteria. Every organization should strive for the highest possible standards by adopting the most comprehensive program possible. Food, water, utensils, and cooking equipment must be as free as possible from pathogenic organisms and toxic substances. Furthermore, persons must not be in contact with infected wastes, particularly those of human origin. Finally, disease vectors must be kept under control.

In order to comply with Bailey's criteria, every airport should have a robust sanitation program. This includes the availability of a clean water supply, proper food handling, pest and vector control, and collection and disposal of all types of waste. Furthermore, there is a need for disinfection, disinfestation, and disinsecting of aircraft to keep potential vectors under control. Ground personnel

TABLE I
Diseases That Can Be Transmitted through Airline Operations

Vector transmitted	Foodborne diseases
Yellow fever	Cholera
Typhus	Salmonellosis
Relapsing fever	Typhoid fever
Plague	Paratyphoid fever
Malaria	Shigellosis
Dengue	
Encephalitis	Clostridium
Leishmaniasis	Staphyloccal intoxication
Trypanosomiasis	Vibrio parahemolyticus
Hepatitis virus	Amebiasis
	Campylobacter
	Bacillus Cereus

are responsible for these activities during the servicing of aircraft when loading food and water, removing excreta and dry wastes, and cleaning the interior.

III. FOOD

Food may be responsible for infection from various bacterial, viral, protozoal, and parasitic diseases. Furthermore, other risks include chemical poisoning, plant and animal toxins, and radioactive contamination.

In order to prevent foodborne diseases, there should be quality control along the chain of the food flow line (Bailey, 1977). Food supplies must be of the highest quality, fresh, clean, and under environmental inspection to prevent cross-contamination. There are specific WHO guidelines for airport catering establishments, flight catering kitchens, and inflight catering premises. Special attention must be given to food handlers and food preparation since time of preparation and the temperature may be crucial in foodborne diseases (Bailey, 1977). Food handlers must be free of any contagious diseases, especially those which can be transferred by the food chain. Periodic examinations (including stool) for general health and personal hygiene should be scheduled. Special attention should be paid when catering premises are situated in developing countries which lack basic services (Kelly, 1993).

IV. WATER

Water is an important source of diseases (e.g., cholera, dysentery, and enteric infections). Since airlines operate in different parts of the world where they have to replenish aircraft from the local water supply, special care should be taken. Airport water supply must be subjected to continuous monitoring and sampling to ensure its acceptability. Personnel who supply water to the aircraft must be medically fit and not be involved in aircraft waste handling. If water is not supplied from an approved public service, water treatment must be carried out by chlorination before flight. British Airways, for example, treats the aircraft water supply by adding chloramine-T at a rate of 16 mg per liter to all water uplifts (Bailey, 1978), a procedure done by line maintenance. The water on board aircraft is usually stored in fiberglass or stainless-steel tanks built into the aircraft structure (Bailey, 1978). It is supplied to the aircraft via a feeding hose in the belly of the aircraft and then fed to all outlets, galleys, and hand basins.

V. WASTE DISPOSAL

Toilets on board aircraft have to be serviced, emptied, and repaired by ground personnel. Because intestinal organisms in feces can cause harm to workers who service the aircraft, it is good practice to add an aromatic colorful bactericidal chemical to the retention tank. Such chemicals have a dual purpose: they kill pathogenic organisms within minutes, and they have a cleansing action in the toilet on emptying.

When servicing aircraft toilets, the retention tank should be removed and discharged into a main sewage system and then washed and disinfected. When returned to the aircraft, the system should be charged with germicidal chemicals.

Personnel involved in toilet cleaning and servicing must always wear protective clothing and gloves. They should not be involved with water supply to the aircraft and they should remove protective gear and wash before eating.

Solid wastes are removed from the aircraft in containers made of strong plastic material. After removal, the containers are washed and disinfected. If the problem of special hazardous toxic waste disposal arises, special precautions and arrangements have to be made with the airport authority.

VI. INTERIOR CLEANING OF THE AIRCRAFT

Aircraft interior cleaners can be exposed to various biological risks. These may arise from the cleaning of sink drain pipes and toilets, airsickness bags, and from the remains of food and water. Regular use of an efficient bactericide in the daily cleaning routine is highly recommended.

The aircraft should be disinfected if a passenger was identified as having an infectious disease with the disinfecting material determined according to the infecting agent. The most commonly used disinfectants are sodium hypochloride diluted to a strength of 100 mg/liter and a 5% solution of formalin (Bailey, 1977). Personnel who carry out the disinfection process should wear masks and gloves to prevent exposure to the chemicals. Special disinfecting chemicals are also used such as carboxide (10% ethylene oxide and 90% carbon dioxide), a mixture of ethylene oxide and Freon II, and vaporous betapropiolactone. These special agents should be introduced only by a trained, protected worker since the materials carry special occupational risks.

VII. ANIMAL TRANSPORT

Many different animals which can cause zoonoses are transported by air, necessitating protection of airline and ground personnel. For example, domestic animals can transmit diseases such as rabies. In order to prevent hazards from animals, only healthy immunized or treated animals should be accepted for flight and they must be carried in suitable containers with handles that will allow proper control. Workers should avoid contact with animal wastes and food remains. The following have been recommended to protect ground personnel: (a) wearing washable impervious elbow-length gauntlets, (b) washing of gloves and hands with a germicidal soap after animals or cages have been handled, (c) avoiding contact with animals as far as possible, (d) reporting immediately to a physician for treatment if bitten or scratched by an animal, (e) cleaning any clothing soiled by animal blood or excreta, and (f) immunization against tetanus (Bailey, 1977; Graham-Jones and Bailey, 1978).

VIII. VECTOR CONTROL

It is of utmost importance to control mosquitos, flies, fleas, and other insects as well as rodents. Because many diseases can be transmitted by vectors, WHO recommends specific control measures applicable to airports as well as aircraft. Guidelines for disinsectification of aircraft can be found in Annex VI of the International Health Regulations and in Bailey's Guide for Hygiene and Sanitation in Aviation (Bailey, 1977).

The killing of insects on board aircraft can be done in one of the following ways using a standard reference aerosol: (a) spraying before departure, (b) spraying on arrival, and (c) spraying at the last airport before arrival at destination. Another method is a dichlorvos vapor disinsectification system which compresses warmed air through a cartridge containing an absorbent filter charged with a small amount of dichlorvos in 30 min at a dosage rate of 0.15–0.25 mg/liter of air (Bailey, 1978).

The killing of rodents on board aircraft can be done by fumigation, usually by hydrocyanic acid (Bailey, 1978). It is a highly toxic material and should be applied only by professionals. The aircraft has to be properly ventilated after fumigation and the environment has to be free from the fumigant before ground personnel can enter it. A list of vector-transmitted diseases is presented in Table I.

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CHAPTER

9

Ergonomic Risk Factors for Ground Personnel

JOSEPH RIBAK

I. INTRODUCTION

Ergonomics is the study of the behavior and activities of people working with mechanical and electronic machines and tools (Thompson, 1990). It is a multidisciplinary science involving many professionals, such as psychologists, physicians, physiologists, engineers, and safety experts, all working to fit the task to the person and the person to the task. In ergonomics we use data and methods from anthropometry, biomechanics, information processing, cognitive psychology, medicine, physiology, industrial engineering, safety, and human resources. Ergonomics has many alternate names and is often referred to as human factors engineering, human engineering, or biomechanics.

II. THE PURPOSE OF ERGONOMICS

The purpose of ergonomics is to increase efficiency and productivity, to increase safety, and to increase worker comfort and health. Increasing efficiency and productivity will result by optimizing output, minimalizing the qualification requirements for the worker, reducing the number of workers required for a specific job, and increasing the reliability of the man–machine system. Increasing safety will result by proper training and proper use of instruments and systems, the development of special aids for complicated tasks, and the development of monitoring and alarm devices to detect system failure or malfunctioning. Finally, increasing worker comfort and health can be achieved by ensuring (a) proper working conditions (good occupational hygiene, clean working environment, and proper physiological work load) and (b) job enrichment and enlargement (increasing motivation of workers, proper decision span, and proper work structuring). Taking all of these factors into consideration will optimize proper fitness between person and machine.

III. FITTING THE TASK TO THE PERSON AND THE PERSON TO THE TASK

In fitting a task and a person, analysis of each is critical. The most important factors to consider when defining a task or job are job content and requirements. Subsequently, individuals must be identified who possess those skills necessary to perform the job. As part of this selection process, the ability to work as a team player should receive special consideration.

In early times man's physical prowess was the main source of energy for the system and the work. Subsequently, as technology advanced, man began to function as a control in the person–machine system. Operating the machines through various displays and controls, the work load became more and more sensorimotor and less physical. We have now reached a point where the worker functions in many systems as a monitor for a computer-controlled machine which does the work. With this new function, which requires data receiving and processing, the work load has become more psychological and the motor element even further diminished. The human factor in the person–machine system has a lot of interindividual and intraindividual variability which influences the workers' performance on the job. Some of the reasons for this variability are (a) age, sex, and health status, (b) fitness factors including training and the ability to adapt to the job, (c) motivation, (d) sociological factors, and (e) the nature of the job.

IV. JOB ANALYSIS

Job analysis takes into account psychophysiological variables, job requirements, and environmental factors. It is of great value not only for placement of workers, but also for understanding the reasons for a specific work injury or disease. Periodic job analysis is needed to keep abreast of changes made in the workplace. It includes the following elements:

(A) Name of the workstation;
(B) job description;
(C) technological process involved in performing the job;
(D) environmental conditions of the workstation;
(E) physical effort required by the operator:
  (a) qualitative assessment: working postures (sitting, standing, stooping, crawling, bending, kneeling) and body movements (upper extremities, lower extremities);
  (b) quantitative assessment: energy consumption, maximal effort;
(F) neuropsychological requirements:
  (a) work rhythm imposed on the worker;
  (b) the required coordination of multiple activities;
  (c) the vigilance demanded;
  (d) degree of thinking and estimation;
  (e) emotional tension due to the job;
(G) involvement of the human senses:
  (a) hearing;
  (b) tactile sense;
  (c) vision (distant and near, field of vision, color vision, depth perception, glare, contrast);
(H) environmental condition of operation;
(I) opinion of the foreman on the job regarding exposures at the workstation under investigation;
(J) summary and conclusions.

An abbreviated job analysis including most occupational titles with descriptions of physical and mental requirements can be found in the Dictionary of Occupational Titles (U.S. Department of Labor, 1977).

Following is an example of a job analysis of aircraft luggage handlers compiled by Ruckert *et al.* (1991).

(A) Name of workstation: aircraft luggage handling.
(B) Job description: manual and machine-assisted load handling tasks carried out by aircraft luggage handlers loading and unloading freight and luggage out of/into aircraft. For example, a freight compartment of a Boeing 747 is between 64 and 175 cm, whereas in the Boeing 737-200 it ranges between 55 and 118 cm. Only two handlers can work in such a small compartment. The low ceiling causes an increase in maximum static action force. The maximum static action force in lower aircraft holds is twice as high as the static action force in the baggage claiming area.
(C) Technology: manual work and use of conveyor belts, driving luggage carts and forklift trucks, loading vans, vehicles.

(D) Environmental conditions: working in open air, exposure to extreme temperatures (cold and hot), aircraft engine noise, vibration, exhaust fumes of aviation fuel, shift work.

(E) Physical effort: (a) work postures—working in height-restricted workplaces (aircraft holds) and requiring frequent bending, standing, walking, and stooping that can, in turn, cause musculoskeletal and postural strain; (b) body movements—lifting and carrying freight and luggage of different sizes, forms, and weights (suitcases, travel bags, boxes, parcels) from 20 to 30 kg.

The quantitative assessment revealed that the heart rate of aircraft luggage handlers reached a maximum of 176 beats per minute (Ruckert, 1991; Rutenfranz *et al.*, 1980), while the average work heart rate was 129 beat/min. Heart rates were particularly high in workers in aircraft holds with a height less than 120 cm which required kneeling or crouching working postures. There was a positive correlation between average work heart rate and weight of the load. As working height in the aircraft increased and the weight of luggage decreased, worker performance improved. The estimated energy cost was between 7 and 10 mets (metabolic equivalents) (see Chapter 11) (Ruckert, 1991; Rutenfranz *et al.*, 1980; Karvonen *et al.*, 1980).

(F) Neuropsychological requirements: work rhythm is fast—the aircraft has to be unloaded and loaded in a short period of time in order to be on schedule. A high degree of crew coordination is required in order to operate different tools at the same time. Vigilance is very important since the chance of accidents from moving objects is considerable.

(G) Good hearing is important for communication and crew coordination. Good general vision is also required including normal color vision because cargo markings are color coded.

From this job analysis we can now assess what is required of aircraft luggage handlers. Consequently, a preemployment examination will take into consideration the requirements for such a job so that proper fitting of the worker to the task can be accomplished. Such a job analysis can also explain the increase in low back pain, neck, knee, and arm problems found in aircraft baggage handlers (Urdeutsch *et al.*, 1980).

V. THE ROLE OF THE OCCUPATIONAL PHYSICIAN

The occupational physician should use job analysis and continuously analyze data from workers. In this way specific job-related injuries or medical conditions can be quickly detected facilitating ergonomic solutions. Job analysis can be done for all jobs which carry a potential for ergonomic risk and may be done by consulting an ergonomist.

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CHAPTER

10

Special Aviation Environments

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I. MILITARY

A. Introduction

The military aviation environment, although basically similar to the civilian aviation environment, has special features which justify a separate description for a better understanding. Operations occur in times of peace as well as in times of crisis or war. Unlike their civilian counterparts, ground personnel are required to be ready for an instantaneous shift from peacetime to combat operations. Quick turnaround of many types of aircraft flying many different operational missions is essential. The missions are extremely diverse including air superiority, interdiction, bombing, transport of forces, rescue, support, medical evacuation, reconnaissance, and air-to-air refueling. Each mission requires very different ground support of the aircraft, often performed under difficult conditions.

Such intense activity places great strain on ground personnel. Working hours are long and desynchronized circadian rhythms can occur due to around-the-clock flying as well as rapid deployment to an airfield in another country situated in a different time zone. Operating from temporary airfields may create logistical problems as well as exposure to extreme weather conditions including high temperatures, snow, and winds, often without proper worker acclimatization. Psychological pressure may be high especially when under direct threat from enemy fire or attack. Conducting operations under chemical warfare threat requiring the use of special protective gear, especially in hot environments, poses significant physiological stress.

Finally, there may be exposure to occupational risk factors which are less common in civil aviation such as microwave, laser designators, depleted uranium ammunition, hydrazine in emergency power units, ejection seats, and arming.

B. Radiation

1. Lasers Lasers, widely used in military operations for target designation, illumination, or range finding, are carried on special pods under the wings. They are in the infrared, visible light and ultraviolet spectra and are classified I through IV, according to the potential optical radiation which can cause harm, usually to the visual system.

Those in Class I cannot under any conditions emit hazardous levels of optical radiation, even if viewed through collecting optics. Class II are low power, continuous wave lasers which emit visible radiation and have a total radiant power in excess of 0.4 mW but less than 1 mW. Direct, continuous staring into the beam should be avoided. Momentary exposure (less than 0.25 sec) is not hazardous. Class III lasers are medium powered with radiant power between 1 and 5 mW. Care is required to avoid direct beam viewing and to control specular reflection. Class IV lasers are high powered. Direct beam viewing is hazardous as is specular and diffuse reflection of the laser beam. For detailed health hazards from lasers, the reader is referred to Chapter 7.

2. Ionizing Radiation This type of radiation can be encountered in military aviation as in civil aviation, where x ray is used for the identification of metal fatigue or cracks. Furthermore, on military aircraft there are special light identification and marking devices which emit beta radiation. Radioactive material can also be found in the cathode tubes of range finders and in depleted uranium (Du) which is used for special ammunition or for balancing aircraft weight.

Depleted uranium can be hazardous to health because of its chemical toxicity and the ionizing radiation which is emitted in the process of radioactive decay (alpha, beta, and gamma radiation). Du alloys are made up of various metals such as titanium, or molybdenum, or a combination of titanium, molybdenum, zirconium, and niobium.

The Du enters the body mainly by the inhalation of the metal dust. It is not absorbed through intact skin, but uncommonly may penetrate through open wounds. Once absorbed, Du combines with the protein of cell walls. The heavy metals may cause chemical pneumonitis and once absorbed are preferentially distributed to the kidneys and liver, potentially resulting in chronic nephritis and hepatic degeneration. Du is eliminated from the body slowly with a half-life of 2 weeks. Du is an ionizing radiation hazard when sufficient quantities are absorbed into the body or when large quantities with a large surface area are present in close proximity to the body for an extended period of time. The main radiation hazard is tissue damage produced by alpha particles emitted during the radioactive decay process. Exposure should be minimized to as low as reasonably possible.

The main safety precautions include enclosure of the munitions, good ventilation in storage rooms, air monitoring, respiratory protection, and pre-employment examinations followed by periodic checkups and bioassays to determine the amount of radiation exposure. Du should be measured in urine at the beginning and at the end of a working week. Safe levels are 0–50 μg of Du per liter of urine. Anyone with an open wound or broken skin should avoid working with Du in order to prevent cutaneous contamination.

C. Biomechanical Hazards

1. Ejection Seats Ejection seats are one of the life-saving devices on board many of the military aircraft in use today. They are intended for use when aircraft control is lost, during a serious in-flight or ground emergency, and when damage from combat occurs. The seat is a complex electromechanical device which requires meticulous maintenance during which it must be disarmed and rearmed when the work is completed. Unfortunately, accidental firing of the seat sometimes occurs causing serious injury to workers. Ground personnel should be alert to such possibilities and exercise extreme caution.

2. Lifting and Carrying Military operations require special cargo delivery and preparation for air drop or transport. Ammunition (such as bombs, missiles, and rockets), external fuel tanks, and electronic counter-measure pods are often carried and loaded onto aircraft. Ground personnel involved in these tasks should practice correct lifting and carrying procedures to avoid musculoskeletal strain and injury. Special lifting and transportation devices, when available, should be used to prevent biomechanical strain (see Chapter 12).

3. Extreme Weather and Altitude Exposure Military operations may take place in extreme weather conditions such as desert and Arctic climates which require proper acclimatization of ground personnel. The same is true of operations at airfields situated at high altitudes. Because acclimatization time varies, taking as long as 1 to 3 weeks, enough manpower should be available, if at all possible, to allow proper work and rest cycles especially during the acclimatization process.

4. Chemical Protective Equipment Chemical warfare is a significant threat in the combat arena. When the threat is substantial, ground personnel will be required to do all maintenance operations and weapons loading of aircraft in full chemical protective gear. At present, available antichemical gear is heavy and has poor ventilation causing heat gain after relatively short periods of work especially when outside temperatures are high. Flight surgeons must give special attention to the work–rest cycle, shortening it when necessary and ensuring that ground personnel have adequate fluid replacement to prevent heat stroke. In addition, the wearing of protective gear, masks, and gloves significantly restricts the field of vision causing safety problems, particularly in operating hand tools and in weapons loading.

D. Chemical Exposures

1. Hydrazine Servicing modern combat aircraft involves replacing, emptying, and filling the hydrazine units carried on board aircraft. Hydrazine is used as fuel for emergency power units (EPU) which supply power to the plane when the engine fails. This gives the pilot the opportunity to try and restart the engine or power system while flying or to land the plane using the EPU instead of the main engine. Unfortunately, EPUs are sometimes inadvertently activated causing spills while the aircraft is on the flight line, or even worse, in underground aircraft shelters. Workers need protection from vapors and splashes. If levels reach 5–10 ppm, a filter may not be adequate for respiratory protection. Therefore, self-contained breathing apparatus is recommended. Safety gloves and coveralls are recommended since hydrazine can penetrate the skin. Because heat stress may be a significant problem during cleaning of a contaminated area, cooling vests could be worn under the safety coverall. (See Chapter 7 for further details about health hazards.)

2. Liquid Oxygen (LOX) LOX is a source for oxygen in-flight breathing systems. It is a cryogenic liquid which can cause severe burns if it contacts the skin. Special caution must be taken because it can burn or explode when in contact with fire or flammable substances such as methane, ethylene, or certain oils.

3. Fuels Military aircraft are sometimes fueled in underground shelters. During the process, jet fuel vapors are emitted (a mixture of aliphatic and aromatic hydrocarbons) which may cause fire if in contact with intense heat or sparks. In order to avoid excessive exposure during fueling, a proper ventilation system is required.

4. Emissions from Aircraft Engines Aircraft engines emit carbon monoxide (CO), nitrogen oxide, hydrocarbons, and particles. Without proper ventilation systems, engine run-up in hangars or shelters may cause ground personnel to complain of eye burning, lacrimation, cough, and shortness of breath.

5. Chemicals in Personal Equipment Life support or personal equipment shops are an integral part of military aviation operations. Personnel are responsible for inspecting, cleaning, and repairing equipment worn by aviators. Oxygen masks are usually cleaned with water, but technicians have been known to utilize unauthorized alcohols and solvents. The talc used on floatation gear (life vests) may cause respiratory complaints. In addition, these shops may produce form-fitting helmets for aircrew using polyurethane foam and toluene diisocyanate, the latter a known cause for occupational asthma.

6. Photographic Chemicals Aerial photography, one of the missions of military flying, is done by reconnaissance aircraft equipped with special flight cameras. When the aircraft lands, films are delivered to flight photography for immediate processing. Workers in the laboratory are exposed to a mixture of developers and fixers such as acetic acid, hydroquinones, xylene, and caustic soda. Skin contact and the inhalation of fumes are of particular concern. Special attention, therefore, should be given to the respiratory system and skin on preemployment and periodic examinations.

7. Chemicals in the Canopy and Radome Repair Shop This shop repairs canopies and radomes of helicopters and fixed-wing aircraft. The main exposures are ammonia containing substances for polishing canopies and asbestos containing compounds for radome repairs. Once the asbestos-containing compound is hardened, it has to be machined. Because the process causes asbestos particles to be emitted, local exhaust ventilation and respiratory protection are required.

8. Military Aviation Fire Fighting Departments Fire fighters on bases are on constant alert not only to extinguish fires on base or in aircraft, but also to assist the evacuation of disabled aircrew after a crash or emergency landing. This often requires fire fighters to spend long periods on the flight line wearing protective garments which can cause heat stress. Furthermore, military aviation fire fighters may be exposed to smoke and fumes containing carbon monoxide, nitrogen oxides, nitrogen compounds, hydrocarbons, and plastic pyrolysis products as well as CO_2, or halon (chlorodifluoromethane)-containing fire extinguishers.

9. Battery Shops Battery shops on military air bases contain many types of batteries with risks of exposure to metals, acids, and bases. The most common-metals are nickel and cadmium although lithium batteries are now being used more frequently. They have many portable power source applications suitable for military operations and are probably used to a greater extent than in the civilian arena.

Since lithium batteries have the advantage of producing high voltages, they have high storage capacity, constant discharge, long shelf life, and good tolerance for extreme temperatures. Because of these features, they are used for communications, remote sensing devices, memory storage units, and backup for power systems (Ducatman *et al.*, 1988). Besides pure lithium, lithium batteries contain other potentially toxic substances such as nickel, lithium aluminum chloride, and sulfur dioxide.

Since lithium is a highly reactive metal, it may explode if not handled properly, causing burns and physical damage from fragments. To prevent such a hazard, the battery vents and discharges vapors, particularly acid vapors, which can reach toxic levels especially in enclosed workspaces. Therefore, workers are at risk for chemical or thermal burns, laryngeal edema, pulmonary edema, and sometimes bronchiolitis obliterans, which has a grave prognosis.

10. Ammunitions Maintenance Chemicals Ammunitions maintenance squadrons are responsible for an array of munitions including bombs, missiles, and cannon ammunition. Besides the danger of explosions, workers can be exposed to various solvents, degreasing agents, paints, and laser radiation. Loud noise is also a common finding in these shops. Because there are so many types of munitions and chemicals used to maintain them, the reader must inquire into the specifics on the military base.

II. AERIAL PESTICIDE APPLICATION

A. Introduction

Agricultural aviation presents a number of unique occupational health hazards, particularly in those operations concerned with the application of pesticides: crop spraying or crop dusting. There is a growing tendency to encourage aerial rather than ground application of the more hazardous chemicals. Besides the obvious advantages of widespread and rapid coverage of fields and plantations, it can be shown that aerial spraying can decrease the number of acute and chronic poisonings from pesticides by limiting the hazards to a relatively small number of operators and adjunct personnel. Because pesticides are dangerous substances, the health and safety of individuals engaged in these aerial operations must be properly monitored and controlled. The occupational health of pilots as well as ground personnel in crop spraying operations continues to be of concern, particularly in the developing countries.

Personnel engaged in the aerial application of pesticides include pilots, pesticide loaders, aircraft washers, and other ground support personnel. A number of unique characteristics of their operational environment may contribute to the potential for acute or chronic exposure to these highly toxic chemicals. First, most aerial application operations are located at small, poorly developed seasonal airstrips, often lacking proper facilities such as restrooms, showers, and "clean" areas for occupational and personal hygiene. In addition, because this is a seasonal operation and pesticide applications are confined to specific times of the day, personnel are under great pressure to do their work as quickly as possible. As a result, inadequate time is often given to standard safety procedures, such as washing the airplane to remove contamination before minor maintenance. In addition, there is a large turnover in support personnel during seasonal operations, which ultimately results in less than satisfactory safety training.

There are a relatively large number of pesticides in use with different and often confusing chemical and trade names. Material Safety Data Sheets may be available but still require dedicated safety personnel to interpret them and to develop appropriate operational procedures. Safety procedures must be implemented and the health of all individuals engaged in this potentially hazardous occupation must be carefully monitored. This, in turn, imposes additional manpower requirements with which small, widely spread operations cannot always cope.

The agricultural aviation sector, therefore, poses a large number of specific acute and chronic health hazards which are not encountered in other aviation and airport operations. Proper control and monitoring of both the hazards and the health of the individuals engaged in this occupation is a challenge to the occupational health profession.

B. Types of Pesticides

Pesticides primarily employed in aerial applications can be classified into a number of categories although most of them are organophosphates (cholinesterase inhibitors), carbamates (cholinesterase inhibitors), and organochlorines. Other categories which are less prevalent include thiocarbamates, pentachlorophenol, chlorphenoxy compounds, dipyridyl compounds, urea, uracil and triazine-based compounds, and other liquid fumigants—paradichlorobenzene, naphthalene, sulfuryl fluoride.

The World Health Organization (WHO) Recommended Classification of Pesticides by Hazard classifies these materials according to their acute risk to human health as follows: Class IA, extremely hazardous; Class IB, highly hazardous; Class II, moderately hazardous; and Class III, slightly hazardous (WHO, 1975). Organophosphates and carbamates used in crop spraying are usually included in Class IA and IB, respectively, because they are perhaps the most toxic materials involved in occupational exposures. Their acute effects are rapid and immediately life threatening but with slower absorption through the skin, symptoms may be delayed (see Chapter 7). Organochlorines, while moderately toxic (Class II), have been implicated in various experimental studies as animal and human carcinogens (Kaloyanova-Simeonova, 1983).

An Australian study of aerial spraying (Simpson, 1973) showed reduced cholinesterase blood levels involved with the aerial application of methylparathion (organophosphates, class IA), monocrotophos (organophosphates, class IB), and methyl demeton (organophosphates, class IB). Therefore, workers engaged in such operations must be monitored accordingly for blood cholinesterase.

C. Possible Routes of Exposure

Routes of entry into the body are by inhalation, skin absorption, or ingestion. Possible exposures to pesticides can result during mixing formulations, loading and unloading spray tanks, airplane washing, and routine maintenance or repair. Personnel involved in mixing formulations and loading and unloading spray tanks are usually the least-exposed individuals because they understand the dangers through training and more willingly wear protective clothing. All of the other operations have been shown to result in significant exposures (McConnel *et al.*, 1990).

Tight schedules leave little time for washing contaminated airplanes, especially before minor maintenance. Clumsy protective gloves are necessary for most maintenance, such as changing pesticide filters, adjusting spray nozzles, and inspecting the landing gear. However, exposure to the hands is common since most mechanics do not routinely use these gloves when performing "delicate" operations. Respiratory masks are burdensome under most conditions, especially in hot, humid, and dusty climates. Even when conscientious employees wear them, they often do not fit properly. Puddling of pesticides resulting from aircraft washing and improper drainage may also result in exposure. The situation is further aggravated by poor personal hygiene due to the unavailability of washing and showering facilities, infrequent changes of work clothing, and lack of safe eating and rest facilities.

D. The Occupational Health Program

The establishment of a proper and effective occupational health program in agricultural aviation operations includes a number of steps. Of prime importance is a hazard analysis in order to become familiar with operations and hazards in the receipt and storage of the pesticides, their preparation and use, their disposal, and the decontamination and maintenance of the aircraft. This material will also serve as the basis for the "right to know" information and safety/accident training for all employees.

Preemployment medical examinations should be given to all personnel in contact with these substances (ILO, 1979). Employees with a history of asthmatic attacks or convulsive disorders should be excluded as well as those with advanced kidney or liver disease. Because solvent vehicles and the pesticides themselves can exacerbate chronic skin conditions, all lesions should be healed before going to work.

Periodic, even daily, physical scrutiny and examination may be mandated for some workers regularly exposed. Biochemical monitoring of blood cholinesterase levels is mandatory because it is an excellent indicator of subacute exposure to organophosphates and also serves as an indicator of proper use of protective equipment and adequate personal hygiene.

Education is vital to the Occupational Health Program. All workers should receive thorough education programs on the warning symptoms of pesticide poisoning (headache, light-headedness, blurred vision, lack of appetite, nausea, stomach ache) and should be instructed to report such symptoms to their supervisor or physician immediately. They should also understand that symptoms may be delayed until after their shift. Instruction in the proper use of personal protective equipment (masks, gloves) as well as the need to promptly remove and/or neutralize any spill or puddle resulting from decontamination (washing) of the aircraft must be emphasized.

A proper personal hygiene program for employees will include facilities for showering and handwashing, especially before meals. As an added safety measure, eating facilities should be located at a distance from the worksite (ILO, 1979).

Because most pesticides are similar to chemical warfare agents, protective equipment, including masks and clothing, must be employed. These masks must be maintained on a regular basis by changing filters and cleaning the inner mask surfaces with water/alcohol to remove possible contamination. Outer protective wear (suits, aprons, boots, goggles, hats, gloves) is also essential and should be cleaned, maintained, and inspected for cracks or holes. Finally, safeguards are needed to prevent heat stress and fatigue during prolonged use of protective equipment under extreme climatic conditions, i.e., ample fluid intake and adequate rest periods.

Planning for the medical management of poisonings is essential. Medical facilities in the area should be kept informed of the pesticides employed and, if necessary, provided with the information and antidotes for appropriate treatment. Workers who complain of, or show typical symptoms of poisoning, or who were involved in accidents involving exposure to pesticides should be taken promptly to the medical facility where they should remain under observation for a number of hours and treated accordingly. If the worksite is not conveniently located near a medical clinic or hospital, a first-aid program including instruction for supervisors in the use of antidotes and emergency supportive measures should be established.

Medical surveillance for evidence of chronic exposure is an essential part of the health program. Although the acute effects of these highly toxic pesticides are well known, there have been a number of efforts to establish the chronic effects of low-dose, subacute occupational exposures. These include abnormal behavioral effects caused by organophosphates such as decreases in alertness and memory, irritability, lethargy, and lack of energy. Thiocarbamates and organochlorine compounds have been implicated as carcinogens and one Polish study has shown that repeated long-term occupational exposures to DDT and lindane, both organochlorines, resulted in the increased prevalence of upper respiratory tract disorders: tonsillitis, pharyngitis, and bronchitis (Hermanowicz *et al.*, 1982).

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CHAPTER

11

Common Occupational Health Problems in Airline Workers

PAUL FROOM *and* BETTY CLINE

I. INTRODUCTION

Workers are seen by the occupational physician for three primary reasons: preemployment physical examinations, periodic statutory checkups, and for various medical problems which may influence their ability to work. Principal tasks of the occupational physician are to decide whether or not acute or chronic conditions are the result of work (i.e., an occupational disease), if work will aggravate a preexisting condition, and if the medical problem will influence the quality of the work or safety of the worker and his/her environment. These decisions will determine if a worker can be safely returned to the job and if an applicant is 100% fit.

II. PREEMPLOYMENT PHYSICAL EXAMINATIONS

Preemployment physical examinations are increasing in popularity. Although cost benefit has not been demonstrated, they are usually required for potential airline workers. The most informative part of the preemployment physical is the medical and occupational histories, whereas laboratory abnormalities often give additional information which may be difficult to interpret (see Chapter 2). It is commonly recommended not to accept workers with conditions that may be aggravated by exposures in the workplace. For example, a potential worker with a preexisting hearing loss should not be employed in an area with excess exposure to noise. There are not, however, any hard and fast rules. For example, it is unclear whether or not a potential worker with microscopic hematuria or minimal proteinuria should be allowed to work with nephrotoxic substances like cadmium.

The degree of risk is usually poorly defined in the medical literature and, therefore, decisions are often arbitrary. If there is enough qualified manpower available, management would prefer workers without such risks. On the other hand, if a candidate is particularly qualified, minimal risks may be acceptable if careful follow-up is implemented and informed consent obtained. In general, the ability to predict applicants with significantly increased risks of disability has not been demonstrated.

Table I summarizes tests often recommended on preemployment examinations (also see Chapter 7). Such baseline values are obtained in order to compare with subsequent determinations should they become necessary.

In addition to the tests shown in Table I, there are other screening tests which should be required in certain circumstances. For example, an applicant who will be exposed to mercury should give a handwriting sample to serve as a baseline in the evaluation of the development of tremor. Tremor is not necessarily the first, but is the most common symptom of mercury poisoning. And for those who may be exposed to organophosphates, a preemployment blood acetylcholinesterase level is needed to evaluate subsequent levels which are expressed as the percentage of baseline.

III. PERIODIC STATUTORY EXAMINATIONS

Periodic checkups are often required by law when exposures in the workplace may lead to symptomatic or asymptomatic disease. They should include a history and physical examination with emphasis on areas of potential injury (e.g., skin examination in those exposed to nickel) and biological monitoring as required (for the timing of sampling and appropriate tests for different exposures, see Chapter 4). As a rule, recommended testing on periodic checkups (most commonly either annually or biannually) is similar to that of preemployment

TABLE I
Commonly Recommended Tests for Workers Preemployment Examinations

Exposure	PFTS/CXR	UA+RFTs	LFTs	EKG	CBC	Other
Asbestos	+					1
Beryllium	+		+	+	+	2
Nickel	+	+	+			2,3
Cadmium	+	+	+		+	
Mercury	+	+			+	4,5
Chromium	+	+	+		+	1–3
Lead		+			+	4,5
Titanium						4,5
Tricresol phosphate						2,4,5
Toluene		+	+	+		5
Diisocyanate	+					2
Trichloroethylene	+	+	+	+		2
Freon		+	+	+		4
Methylethylketone						
Methylene chloride		+	+	+		4
Xylene		+	+	+		

Note: PFTs, pulmonary function tests; CXR, chest x ray; UA, urinalysis; RFTs, renal function tests; LFTs, liver function tests, CBC, complete blood count, 1, smoking history; 2, history of atopy; 3, x-ray of nasal passages; 4, central nervous system symptoms; 5, peripheral neuropathy.

examinations with important exceptions. In the absence of symptoms, for example, chest x rays are not usually repeated except in the case of dust exposures (talc, silica, and asbestos) where every few years a chest x-ray is recommended.

Periodic checkups require a knowledge of the workplace. Therefore, regular visits to the workplace are essential to gain a better understanding of potential exposures, to increase rapport with the workers, and to make recommendations if remediation is required.

IV. FITNESS-FOR-WORK ASSESSMENTS

Fitness-for-work assessments are necessary to determine if the worker has the physical ability to return to work, and if there is excessive risk to the worker or to fellow employees if he or she is returned to work before there is complete recovery. The 10 most common medical problems encountered by the occupational physical at Ben Gurion Airport during fitness-for-work assessments are presented in Table II (unreported data). Although the data are from one international airline, given the commonality of ground support operations, they can probably be extrapolated to other large airports. A brief discussion of these conditions follows.

TABLE II
The Most Common Diagnostic Categories Made by Airport Physicians at the Ben Gurion Airport

Condition	Frequency (%)[a]
Lower back pain	25.1
Ischemic heart disease	24.1
Status postoperation	15.7
Fractures	8.8
Phonal trauma	6.3
Knee pain	5.3
Cancer	4.1
Pregnancy	4.1
Hypertension	3.8
Shoulder–neck pain	3.1
Other	22.3

[a]The total is over 100% since more than one diagnosis can be made per visit.

A. Lower Back Pain

Lower back pain (LBP) is common in both the general population and in the work force with over 50% of adults reporting an attack some time in the past (Kelsey and Golden, 1988; Anderson, 1981; Frymoyer *et al.*, 1980). It is the most common cause of restricted activity for those under 45 years old and is third after heart disease and arthritis in those 45–64 years of age (Kelsey *et al.*, 1979). During the last 7 years in the Ben Gurion Airport complex, of 40 cases of disability resulting in the changing of jobs or cessation of employment, the most common cause was LBP (32.5%).

Previous studies of LBP in the workplace are limited in number and quality. Although an increased incidence has been reported in farmers (Leight and Sheetz, 1989) and other workers with more physical tasks (Burchfiel *et al.*, 1992), the role of mechanical factors in its etiology remains uncertain (Troup, 1984).

The evaluation of workers with LBP is difficult since even the demonstration of an anatomic cause may be misleading. Recently, it has been shown that 20% of asymptomatic patients 20 to 59 years of age and 57% of those over age 60 have a herniated nucleus pulposus (HNP) demonstrated by magnetic resonance imaging (MRI) of the lumbar spine (Boden *et al.*, 1990). Thus, a disc shown by either MRI or CT scan does not necessarily prove causality with LBP. And it is difficult, if not impossible, except in cases of acute trauma, to determine whether or not the LBP is due to mechanical factors involved in the workplace. The ability of the patient to return to work is often subjective and depends on self-reported symptomatology.

There is a vast literature on the treatment of LBP but only a limited number of prospective case–control cohort studies with adequate numbers of patients and followed by a nonbiased observer (Nachemson, 1992). Treatment of LBP must take into consideration the duration and whether or not the pain is associated with demonstrated disc diseases (those with LBP associated with conditions such as spondylolisthesis need special consideration and will not be discussed).

Treatment for unspecified LBP and HNP can be prescribed by dividing patients into four groups according to the duration of the pain: pain less than 7 days, 7 days to 6 weeks, 6 weeks to 3 months, and over 3 months. In unspecified LBP, there is conclusive evidence that bedrest of less than 2 days is effective in pain of less than 6 weeks duration (Table III). On the other hand, there is no evidence that bedrest of over 7 days is effective in treating LBP of any duration. Nonsteroidal anti-inflammatory agents are effective in pain which has persisted for less than 3 months. Furthermore, back school and manipulation may be effective in pain lasting from 7 days to 6 weeks. Finally, there is no evidence that either traction or surgery is effective in such cases regardless of the duration of the pain.

For LBP consistent with disc disease (with radiation below the knee and moderate neurological signs), bedrest for 1 week but not more is effective for pain that has persisted for less than 3 months. Medications have not been shown to be effective regardless of the chronicity of the pain. On the other hand,

TABLE III
Treatment of Unspecified Lower Back Pain and That Associated with Disc Disease

	Duration of pain before treatment			
Treatment	<7 ds	7 ds–6 wks	6 wks–3 ms	>3 ms
Unspecified LBP				
2 ds bedrest	+	+	–	–
7 ds bedrest	–	–	–	–
NSAI drugs	–	–	–	–
Back school	–	+	–	–
Traction/surgery	–	–	–	–
Disc disease				
7 ds bedrest	+	+	+	–
>7 ds bedrest	–	–	–	–
NSAI drugs	–	–	–	–
Surgery	–	–	–	+

Note: ds, days; wks, weeks; ms, months.

surgical removal of the hernia or offending structure has been found to be efficacious for pain lasting over 3 months.

Despite this summary of the literature, each case must be individualized. Treatment is by trial and error, and as is often the case for conditions where treatment is largely ineffective, there is extensive use of alternative medicine.

Sometimes encouragement to return to work despite continued LBP is in the best interest of the worker. In general, if the pain is not aggravated by work, then work can be continued. Back pain, however, may continue despite negative findings on physical examination and imaging procedures, and in such cases it is difficult to determine the degree of the patient's disability.

B. Cardiovascular Disease

Ischemic heart disease is very common in the general population in those over age 40. Nearly 25% of medical problems faced by the occupational physician in Israel fall in this category (Kupat Holim Occupational Medicine Clinics, Israel, unpublished observation). In evaluating the cardiac patient, the major role of the occupational physician is to determine work loads which allow safe performance.

Work load or the energy requirements of work are usually described in metabolic equivalents (METS). One MET is the resting oxygen consumption which is approximately 3.5 ml O_2/kg body wt per minute. Exercise testing can give an estimation of the patient's ability to do physical work. Table IV shows the METS during exercise testing using the Bruce protocol and bicycle ergometry, as well as the number of METS required to work at various tasks in the air-

TABLE IV
METS Needed for Various Occupations and Ability Based on Exercise Testing

	Ergometry		
METS	Bicycle watts[a]	Treadmill[b] (minutes)	Work
2 or 3	<50	<3	Ground steward/ess, machine operation, car driving, car mechanic
3 or 4	50	3	Cook, welder
4 or 5	50	3	Painter, carpentry, store keeper, airplane mechanic, airplane electrician
6 or 7	100	6	Gardening, digging, airplane cleaning
8 or 10	150	9	Porter, ground equipment operator
Over 100	200	12	Fire fighting

[a]Assuming a weight of 70 kg.
[b]Bruce protocol.

port. The exercise tests are graded with each stage defined as a 3-min period. Two minutes of a 3-min stage must be completed to obtain full-stage METS values. Healthy active individuals can usually attain 12–15 METS and endurance athletes 16–20 METS.

If silent ischemia is ruled out, then symptoms can be an indication of the amount of work that can be done. As a rough estimate, the speed of walking in kilometers per hour is approximately equal to the number of METS. In other words, a slow walk is equivalent to 2 METS, whereas a normal pace is 4 METS, and a fast pace is equivalent to 6 METs. Jogging is approximately 7 or 8 METS. It is usually recommended that the METS allowed during work over an 8-hr period be limited to 50% of the maximum level achievable before the onset of chest pain. This is based on data from healthy men in which the maximal METS is usually twice that of the METs that are sustainable over 8 hr. There are no studies, however, which substantiate these recommendations.

The patient with ischemic heart disease who is returned to work may be asymptomatic despite ischemic episodes. Ambulatory electrocardiographic monitoring (AEM) may demonstrate silent ischemia during times of mental or physical stress. The exercise test also may have not predicted such episodes because the ergometry is a graded test, whereas in real life physical stress is episodic. Therefore, ideally the observation of ischemic events in patients with coronary artery disease should be done during daily work and activities rather than by extrapolation from an exercise test done in the hospital. Whether or not AEM can predict those who can safely return to work is uncertain. Still, it may be prudent to use AEM, and only allow those without ischemia at work to continue.

A normal exercise test 2 or 3 weeks after an uncomplicated myocardial infarction is safe and identifies a group with a very low 1-year mortality (2%). Such patients can usually return to work within 1 month after discharge, while others need to be considered individually. In any case, all patients should be stable, on maximal medical treatment, and doing work which will not result in ischemia.

C. Status Postoperations, Fractures, and Chronic Pain Conditions

There are three factors which need to be considered in evaluating workers who have chronic pain conditions or are recovering from an operation or fracture: the degree of discomfort, the time needed for adequate healing in order to prevent aggravation of the condition, and the degree of expected rehabilitation. This is a gray area with little help available in the medical literature. As a rule, after the time needed for healing, a return to work is in order which, in itself, may aid in the rehabilitation process. Because repetitive trauma-related disorders can be aggravated by continued employment, the disposition of such cases must be determined on an individual basis.

D. Hypertension

An elevated blood pressure is the most common cardiovascular condition found in the general population. Ten to 15% of men in their twenties have a borderline elevated blood pressure (Froom *et al.*, 1983). In young men the significance of such a finding is limited, since only 1–3% will develop hypertension requiring treatment over the next 20 years. Therefore, in young asymptomatic men, one must be careful of labeling healthy patients as having "hypertension," since such labeling has been shown to adversely affect patient behavior and may increase absenteeism.

Although hypertension is an important risk factor for future disease, it usually does not influence worker fitness. Thus, it accounted for only 3.8% of diagnoses in workers seen by the occupational physician at Ben Gurion Airport. Furthermore, hypertension was accompanied by ischemic heart disease in most cases rather than being an isolated finding. In any event, blood pressure control must be attained by nonpharmacological as well as pharmacological means.

E. Pregnancy

Special consideration must be given to pregnant workers. For example, they should not be exposed to mercury, arsenic, or benzene and radiation exposure should be limited to less than 1 REM over the gestational period. Lead exposure should also be limited; usually TLVs less than 50 $\mu g/M^3$ are acceptable. Physical activity required by the job may be excessive requiring some restrictions. Finally, the pregnant female should be encouraged to stop smoking and to avoid excessive alcohol intake.

F. Phonal Trauma

1. Damage The most common occupational disease both in and out of the aviation industry is noise-induced hearing loss (NIHL). (Recognition of NIHL is dependent on the frequency of periodic audiometric examinations.) The airport environment has significant noise pollution. In one study, for example, over 50% of airport maintenance workers and firemen who were exposed constantly to aircraft noise were found to have high-frequency tone hearing loss (Chen *et al.*, 1992). In addition, airport policemen and airline ground staff had a 32–42% prevalence. Besides aircraft noise, as in other industries, there are sources of noise in the repair and maintenance of the aircraft.

The worker may present with tinnitus and a temporary threshold shift (TTS) which often precedes a permanent threshold shift (PTS) and occasionally permanent tinnitus. The TTS is due to the acute effects of noise but is reversible, persisting for a few minutes up to a day. Therefore, it is important to wait 24 hr after exposure to test for permanent damage. On the other hand, in order to pick up disease before permanent damage occurs, periodic audiometry should be done in the workplace. In any event, the time from last exposure to noise needs to be taken into account when attempting to compare the results of repeated audiometric testing.

With NIHL, there is a progressive loss of hearing, especially in the range of 3 to 4 kHz, with subsequent loss of the lower frequencies to a lesser degree. Although 2–4 kHz is most important for speech comprehension, 3 to 4 kHz is more important for speech discrimination in noisy environments. Thus, the worker may complain at first that hearing is normal except in areas with a lot of background noise in which case words can be heard but not necessarily understood.

The maximal permissible exposure to noise is usually either 85 or 90 dB (depending on the country) for an 8-hr period. It is easy to remember the table for permissible exposures (Table V) since for every 5 dB increase in noise level, the period of allowable exposure is halved. Note that the maximal level of exposure is 115 dB. Unfortunately, even a TLV of 85 dB is a compromise between the ideal and the practical. It has been estimated that 8% of the workers will have a significant NIHL (Dubno *et al.*, 1984) if exposed to 90 dB over a 20-year period. Therefore, workers should be given an audiogram annually even if they have remained within the maximal permissible exposure levels.

2. Personal Hearing Protection There are three types of hearing protectors each with individual attenuation capabilities called the noise reduction rating (NRR). Ear plugs are made of high-density foam or rubber compounds or silicon and generally have NRRs of 25–30 dB if used properly. Ear muffs theoretically give about the same degree of protection as do ear plugs, but because they are easier to fit, they may have a better protective effect. On the other hand, they are uncomfortable, especially when the workplace is hot, and

TABLE V
Maximal Permissible Exposures for Noise in the Workplace

Intensity (dBs)	Time of maximal exposure (hours)
85	8
90	4
95	2
100	1
105	½
110	¼
115	⅛

they may be incompatible with other equipment. Canal caps consist of a pair of ear plugs on the end of a headband. Their effectiveness is less than that of ear muffs, yet they are more comfortable and can be removed easily.

The maximal noise reduction can be obtained by combining ear plugs and ear muffs. Using such a combination, up to 50 dB noise reduction is obtainable. Therefore, the worker can be adequately protected from nearly all sources of noise in the airport environment. Ear protection should be worn in any environment in which noise levels reach 85 dB.

Unfortunately, many workers do not comply with ear protection recommendations. Therefore, visits to the work areas are essential. A walk-through survey is important in order to recommend remedial action (such as moving a workstation to an area where less people will be exposed to noise) and to ensure compliance with the use of personal hearing protection.

3. Recommendations for Screening and Fitness Examinations Workers should be screened before beginning work. This is important in order to establish a baseline for comparison with subsequent audiograms and to recommend against employment in a noisy work environment of a new worker with significant NIHL.

Those who work in an area with over 80 dB continuous noise intensity should be examined annually. If either PTS or a TTS is found, preventive measures should be taken which in some cases may require removing the worker from the noisy area.

G. Contact Dermatitis

Contact dermatitis is a major occupational disease (Hogan *et al.*, 1990). The criteria of occupational contact dermatitis are as follows: (a) onset after beginning work, (b) agent identified, (c) exposure to the agent is primarily at work, (d) distribution of lesions corresponds with exposed areas, (e) exclusion of other causes, (f) other worker's similarly affected, and (g) positive patch test if allergic etiology. It must be emphasized that a positive patch test does not prove that the dermatitis is caused by that agent. Furthermore, stopping the exposure does not necessarily lead to resolution of the dermatitis.

There are two major types of contact dermatitis: allergic and irritant. They may be differentiated by history and physical examination (Table VI). The gold standard for diagnosing allergic contact dermatitis is the patch test [with a nonirritating concentration of an allergen (0.01–1%)] defined by redness, infiltrates, or vesiculation. However, the history, physical examination, or even the patch test are not 100% reliable. For example, in allergic contact dermatitis due to exposure to nickel, the patch test may be negative in up to 40% of those with Ni allergy. Also, sun exposure may result in negative tests due to the suppression of macrophages, an important cell in the reaction. Retesting after 3

TABLE VI
Allergic and Irritant Contact Dermatitis

Findings	Allergic	Irritant
Dependent on concentration	−	+
Symptoms	Itching	Pain
Involvement	>Area of contact	Area of contact only
Patch test	+	−
Other workers	−	+

weeks without sun exposure may result in a positive test. In the aviation industry allergic dermatitis may be due most commonly to nickel or chromates. However, allergic dermatitis, especially from nickel, may not necessarily be due to work exposure, but rather from jewelry. Nickel is but one substance of many in aviation flight line shops which can cause contact dermatitis.

Cessation of exposure often results in prompt recovery from irritant contact dermatitis. On the other hand, those with allergic contact dermatitis often continue to suffer despite having stopped working with the antigen which is important in worker's compensation cases. Prognosis may be better in allergic dermatitis if exposure is limited. Therefore, early detection is important and the best treatment is the avoidance of future exposure.

Although routine preventive measures and treatment for contact dermatitis include barrier creams, gloves, and topical steroids, each has its deficiencies. For example the thickness of the barrier creams must be adequate if they are to be protective. Also, some may be irritative in themselves. Some allergens, such as nickel and epoxy resins, can penetrate rubber gloves. And even though topical steroids are often effective, some patients develop allergies to such preparations.

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CHAPTER

12

Ground Accidents

JOSEPH RIBAK *and* BETTY CLINE

I. INTRODUCTION

The aviation world is a complex environment. Numerous exposures occur simultaneously, the worker is usually under time constraints, disorder is created by the constant transit of passengers, crew, cargo, and mechanics, and rain, snow, or extreme temperatures may be present. Such a complicated environment carries a significant risk for ground accidents.

Accident investigation is important in order to collect information which can be used to prevent other similar accidents. Recommendations may include technological changes in the work environment or work processes or changes in work procedures.

Although accidents can occur due to system failure (mechanical, electrical, electronic), human failure, or both, most are due to human error. The ergonomic approach to accident investigation is oriented toward the detection of failure in the interaction between man and the technological environment. This approach requires a thorough examination of all possible man–machine interactions and knowledge about environmental and job characteristics, job requirements, and the ability of the operator. The main components of this process are accident investigation and analysis.

II. ACCIDENT INVESTIGATION

The purpose of accident investigation is to gather all relevant information and to utilize it to prevent another one. The process should be started without delay when essential evidence and information are still clear in the memory of those involved in the accident (as well as in the memory of witnesses). In order to facilitate a rapid response, we advise that a special preprepared accident investigation kit (including the proper forms, checklists, camera, and other necessities for investigation) be ready for immediate use in the event of an accident.

III. ACCIDENT ANALYSIS

The purpose of accident analysis is to compare job requirements with the ability of the operator in order to detect discrepancies which may have caused the accident. The analysis attempts retrospectively to identify the basic malfunction which led to the accident (Monteau, 1983). It is of the utmost importance to investigate and analyze not only accidents, but also near accidents (or incidents) because the lessons learned from an incident can be just as instructive as those learned from a full-blown accident. Every analysis starts with the collection of information available on the involved worker(s), time and place of the accident, the tools and work methods used, and the operational environment.

A causal tree should be constructed that shows all the antecedents that led to the accident including the chronological order in which they occurred. After the cause(s) of the accident is ascertained, appropriate corrective and preventive measures can be taken. Workers should be informed of the accidents and incidents that have occurred, their causes, and measures taken to prevent them.

IV. COMMON CAUSES OF GROUND ACCIDENTS

A synopsis follows of work-related ground accidents that occurred over a 5-year period (1988–1992) in one major airline in Israel which employs close to 2000 ground workers in all job titles. Only accidents that required 3 or more days of absence from work were recorded.

Accidents are classified according to one of the five major accident categories, namely: (a) slips, trips, and falls; (b) handling material, lifting, and carrying; (c) physical and chemical exposures including, among others, electrical or thermal burns, exposure to chemicals (lead, cadmium, organic solvents, etc.), and foreign bodies in the eyes; (d) machinery accidents; and (e) work transport accidents which also include road accidents on the way to or from work.

The airline has a Safety Committee with representatives from management and the work force. Included are the chief physician and the safety warden. The committee functions by promulgating safety regulations and by issuing educational material regarding accidents that have occurred.

During the 5-year period studied, 510 work-related ground accidents were reported which required absence from work of 3 or more days. The annual accident rate declined over the period from 7.1% in 1988 to 4.0% in 1992 (Table I). In contrast, the days lost per accident over the period tended to rise from 11 to almost 16, resulting in mean days lost for the 5-year period of 13 per accident. This suggests that the prevention efforts had a larger effect on the less serious accidents.

Table II displays the major types of accidents that occurred, the most frequent being slips, trips, and falls (41%). Handling materials (lifting and carrying accidents) was the second leading cause for accidents and machinery accidents third. It is of interest to note that transportation accidents either on the airport premises or on the way to or from work accounted for 12% of all accidents and were more common than accidents due to physical or chemical exposures.

Even though lifting and carrying were the second leading cause of accidents, they ranked first regarding lost days from work accounting for a mean of 23 lost days of work per accident in comparison to 14 in the slips, trips, and falls category.

The major cause of accidents in aviation ground personnel was slips, trips, and falls accounting for 40% of the total ground accidents reported by the airline. They are most common in maintenance work on and about the aircraft since

TABLE I
Work-Related Accidents and Workdays Lost in Ground Personnel in an Israeli Airline—1988–1992

Year	No. of accidents	Workdays lost	Mean days lost per accident	Rate per 2000 workers (%)
1988	142	1602	11.28	7.1
1989	95	1156	12.16	4.8
1990	98	1618	14.98	5.4
1991	94	1033	10.98	4.7
1992	81	1267	15.64	4.0
Total	510	6676	13.09	5.0

TABLE II
Major Types of Work-Related Accidents in Ground Personnel in an Israeli Airline—1988–1992

	N	%
Slips, trips, and falls	208	41.0
Lifting and carrying	104	21.0
Machinery accidents	97	18.5
Work transport accidents	63	12.0
Physical and chemical exposures	38	7.5
Total	510	100

work is often done on flight lines covered with ice or snow, or on platforms working on high parts of the aircraft fuselage (wings, body, tail). [Falls are the second largest cause of accidental death in the United States (Marletta, 1991).]

Slips occur when a surface is slippery or when there is an unexpected change in friction between surfaces, especially when the change in friction is toward a lesser friction surface such as when moving from a carpeted floor inside the aircraft to the staircase or ramp outside. Slips can also occur when there is water, ice, or oils on the surface. Ground personnel need to be aware of areas where there is a possibility of changing friction surfaces in order to prevent slipping incidents and accidents.

Trips usually occur when unexpected objects are left in the way. Care should be taken by aviation ground personnel not to leave loose wires or objects lying around on the floor or ground outside the aircraft. Also, ramps, walkways, and platforms should be kept level, avoiding elevations, depressions, or protrusions of more than a quarter inch. Guard rails, hand rails, and properly designed surfaces, stairs, and ramps will help prevent falls. The proper use of ladders, either fixed or portable, is another safety factor.

Careless and improper lifting and carrying accounted for 21% of ground accidents which is in accordance with the published literature (Thacker, 1983). Heavy lifting is one of the major causes of occupational low back pain (Walsh *et al.*, 1989) mainly because it is not performed properly. Workers stoop instead of squat, which causes a significant increase in the intervertebral disk pressure and a static strain on the trunk muscles (Schürmann and Luginbühl, 1983).

Lifting and carrying ability depends on the weight and size of the load, the frequency of lifting, and the height of the lift (Mital, 1984). An action limit (AL) for lifting has been determined which takes into consideration these factors. The National Institute for Occupational Safety and Health set the action limit to 39 kg if lifting is accomplished in an optimal manner (Weinstein and Scheer, 1992).

The maximal permissible limit (MPL) is three times the AL. The relative risk of injury when the MPL is exceeded is 75% for males and 99% for females. Asymmetric lifting (one-handed lifting on the side) may reduce the AL and MPL by 40% (Weinstein and Scheer, 1992). To prevent lifting and carrying accidents, it is suggested that material handlers have their personal strength limit tested and that they be restricted to lifting objects to 50% of this figure. The worker should keep the load as close to the body as possible and avoid rotating the trunk. Lifting should be done with bent knees in the squatting position with particular caution taken on slippery surfaces (Thompson, 1990).

The education of workers concerning safety at work and the effective enforcement of safety rules and regulations will minimize ground accidents in the aviation environment and ensure better productivity and well being of ground personnel.

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CHAPTER

13

Components and Management of an Occupational Health Program

RALPH SHAIN

I. INTRODUCTION

The culmination of the material included in the previous chapters and its successful application toward the prevention and treatment of occupational disease and injury requires a comprehensive and well-managed occupational health program. Such a program with clearly stated policies, objectives, and goals, and well-defined resources, organization, coordination, and control will optimize the resources invested in its various components which will contribute to the health and safety of employees.

II. MODELS OF OCCUPATIONAL MEDICINE SUPPORT

A review of six major U.S. international air carriers (DeHart, 1990) has indicated that occupational medical services can be provided in any one of several ways. Medical departments can be centrally located in the airline head office in the city or in several locations along the routes or both. Likewise, the medical staff might be employees of the airline, contract personnel, or part-time consultants. Each of the six airlines has its own model for providing these services tailored to its own needs and budget. Such systems are a function of corporate size, distribution of facilities, and corporate responsiveness (Knight and Zenz, 1988). These range from well-defined and legislated systems in Japan, Germany, and Sweden, through large private in-house programs in the high-tech aeronautical industries to health maintenance organizations, preferred provider organizations, emergency clinics, and local occupational health clinics. The diversity of such systems is further complicated by the constant evolution of corporate structure and organization as well as frequent changes in both national and local legislation.

Because there are so many possible models for an occupational health program, this chapter will describe various components and a framework for management only in general terms. Management, coordination, and communication are crucial. Management can be defined as the process of motivating and coordinating an appropriate group of people to perform the actions necessary to achieve a derived set of objectives. Good coordination is vital so that the necessary acts supplement and complement one another so as to yield a synergistic effect. This is true of the seemingly large number of professionals and programs in the field of corporate safety, health, total quality management, reliability, maintainability, and last but not least—profitability. The four major functions of management are planning, organizing, coordinating, and operating and controlling.

An essential activity fundamental to all of the above activities is communication. It is important for the manager of an occupational health program to view communication as a two-way process which includes a message and a response to that message. Simply sending out a message, such as a daily bulletin, a regulation, or a directive, is no guarantee that communication has occurred. Unless response to these messages is observed or measured in some way, the communication effectiveness is unknown and might vary from very good to very bad. Thus, when managers communicate they must always provide for a measure or observation of the response to their messages.

III. PLANNING

A. The Planning Process

The planning process is essential to the establishment and implementation of the occupational health program. As a manager you may be involved in this activity even before a formal organization exists. Planning consists generally of examining alternatives along with their respective risks and choosing the best ones. This assessment and selection covers objectives, policy strategy, organization, resources, procedures, staffing, incentives, and control procedures. In other words, it encompasses and is involved in all of the management functions.

The first and most important alternatives to consider in top level planning are the objectives of the organization. Without these you do not know where you are headed or what you are supposed to accomplish. The objectives should be clear, concise, specific, and, if possible, expressed in quantifiable or measurable terms so that subordinates can easily understand them and progress toward them can be readily measured. Overarching these objectives is corporate commitment as expressed in a written policy statement describing the purpose and objectives of such a corporate occupational health program. The purpose of such a program should be the promotion of well being among workers and the primary prevention of occupational disease and injury. Not only must we address commitment to the elimination and effective control of health hazards, but also to continued medical surveillance of workers who might be exposed to them.

Therefore, a good corporate occupational health and hygiene policy statement should include (Bond, 1988): (a) a commitment that all places of employment will be maintained in a clean and healthful manner; (b) compliance with federal, state, and local legislation in both design and operation; (c) responsibility for "Right to Know," i.e., to provide current and comprehensive information to both employees and customers of potential adverse health effects; (d) collective responsibility and concern of all employees toward the health and safety of fellow employees and human beings; and (e) establishment of a viable corporate occupational health and hygiene program to complement and implement the above commitments.

With a publicized corporate commitment in hand, the planner can now readily derive objectives and communicate them to the organization. When detailing these objectives, it is important that the premises, assumptions, or ground rules upon which the objectives are based are linked to these same objectives. This will aid reevaluation of the objectives and concepts should the premises or environment later change. Finally, objectives should be prioritized so that they may receive appropriate resource allocations and guide the preparation of derivative plans. Examples of prioritized objectives which also provide for a measure of program performance include (Hatch *et al.*, 1978): (a) creation and maintenance of a worker placement program that evaluates employees physically, mentally, and emotionally to maximize their effectiveness in their jobs without endangering their own health and/or safety; (b) creation of a medical care and rehabilitation program for occupationally ill and injured; (c) provision of information and education to employees and their families in specific occupational hazards and basic preventative health maintenance and practices; and (d) inspection and identification of potential health problems through various surveys, assessments, and measurements.

Additional planning is needed to establish the overall procedures and resources for accomplishing these objectives. That is, "how shall we do it?" In general, planning activities can be grouped into major categories: strategic plans and operating plans. The strategic plans will address assumptions, general method, and needs and will generate objectives, priorities, strategy, resource needs, and program milestones. Operating plans generally address activities, coordination tasks, personnel, key events, progress measurement, money, and facilities, and will generate functions, organization, schedules, procedures, control methods, resource allocations, and budgets.

Plans are made at every level. Top management will construct both strategic and operational plans and detail them to a certain extent. These will be passed down for additional planning and detail. The process continues all the way to the individual level where each person will make his or her personal plans for accomplishing the tasks and each level will set its own goals. However, these goals must be consistent with the corporate objectives. It is crucial to periodically reevaluate plans (at least annually) to reaffirm both their contributions toward objectives and policies as well as their cost effectiveness in allocation of resources and achievement of benefits.

B. Familiarization with Your Company and Workplace

The preparation of detailed plans and program elements necessitates an intimate, first-hand knowledge of both your company and the workplace. This knowledge may be gained from written materials (such as reports), statistical data and records, and private consultants. However, there is no substitute for actual "walk-throughs" and meetings with company personnel. Such a familiarization will ensure that your objectives and plans are in tune with corporate policy and "culture" and that you will have a full understanding of actual conditions in the workplace.

There are a number of methods for identifying, evaluating, and assessing occupational health hazards but each method requires a detailed walk-through survey utilizing your own sensory organs—eyes, nose, ears (see Chapter 6). Talk to employees and line managers who are most familiar with the processes, machines, conditions, and practices and have them explain operations to you. Listen to their complaints—some of them are valid and will help you identify potential health problems. Get to know their environment—this will aid your understanding of their complaints should they later come to your clinic. Try to establish good communications with them and get them interested and involved in health and safety programs—establish rapport. Look for clues like poor housekeeping, failure to remedy unsanitary or unhealthful conditions, distractions to workers—they are usually indicative of immediate occupational health hazards and are better predictors of potential dangers than most technical material and reports.

Additional information sources may aid in your understanding and enable you to prioritize these hazards. These sources include workers' compensation insurance companies, trade unions and associations, national and local health and labor departments, machine or product manufacturers (material safety data sheets), occupational hygiene societies, and local colleges and universities with occupational or public health departments, facilities, and libraries.

The information gained from both your personal surveys and information sources can be summarized in a number of simple and efficient methods which will readily provide the information necessary for your strategic and operational plans. One commonly used method is the incorporation of what you have learned into an Activity/Personnel/Hazard Matrix. This matrix incorporates data regarding the plant/building/work area with job descriptions and then notes potential health hazards both general and specific. An example of such a matrix is provided in Fig. 1.

Company .... Survey date ....

Location/Building /Work Area ....

Department/Job Description (Code)	General Hazards						Specific Hazards											
	MECHANICAL	CHEMICAL	PHYSICAL	BIOLOGICAL	CLINICAL	PSYCHOLOGICAL	THIONYL CHLORIDE	LEAD	BENZENE	MERCURY	TALC	SILICA	BERYLLIUM	CADMIUM	NICKEL	CHROMIUM	NOISE	RADIATION
AIRCRAFT																		
Structure	X		X		X	X											X	
Welders	X		X		X	X											X	
Machinists	X		X		X	X							X				X	
Coatings	X	X	X			X						X		X	X	X	X	
Painters		X	X		X	X			X								X	
Production and Remodel.																		
Electronic tech.	X	X			X					X	X							
Hydraulic tech.	X	X																
Engine mechanic	X				X	X											X	

FIG. 1.

Other more detailed methods can be used to incorporate this information with future medical and industrial hygiene records. The Job Exposure Profile (Holzner *et al.*, 1993) or Workplace Exposure Assessment (Tait, 1992) techniques are but a few of the more recent tools for this purpose.

The familiarization process has enabled you to obtain and summarize the relevant information necessary for planning and establishing priorities. In addition, these summaries are an integral part of your health program and will enable you and your employees to relate the potential hazards and job stressors to the individuals and to the components of your occupational health program.

C. Components of an Occupational Health Program

The essential components of an aviation occupational health program are: (a) preplacement examinations, (b) health hazard reduction, (c) management of job-related illness and injury, (d) return to work evaluations, (e) health maintenance, (f) hazard communication, and (g) workers' compensation (DeHart, 1990).

These components have been developed from the objectives, policies, and corporate commitments and address the potential occupational hazards as well as employee and societal needs and in some cases relevant legislation.

1. Preplacement Examinations Preplacement examinations are one of the most important components of the health program (see Chapters 2 and 11). Just as past employment, education, and references are considered when hiring new employees, so should the past and present health. The purpose of the preplacement examination is to determine the health condition of prospective employees so that their assignments and job requirements are matched to their physical and mental capacity and to identify preexisting illness. This can minimize future costs arising from reduced work contribution due to impaired health, injury due to accidents (even death), sick leave, and litigation.

While there is no complete agreement among occupational physicians concerning the scope of the examination for applicants (Bond, 1988), it is recognized that no universal examination is applicable to all jobs in the company because every job differs in its requirements and hazards. Moreover, we do not know which screening tests are really cost effective. The methods employed (alone or in combinations) range from the basic and minimal questionnaire (processed by a selection officer) through health and hygiene appraisals by occupational nurses, to complete assessments by occupational health physicians.

Occupational medicine physicians must determine the extent and scope of the preplacement (as well as periodic) physical examination relying very much on the nature of the job, particularly physical demands, and potential exposure to physical and chemical hazards. This would basically entail a tailored physical examination with selected laboratory and diagnostic tests (questionnaires completed by the workers may also be useful). Although recommendations abound in the literature (Smith *et al.*, 1992; Frank, 1983), the selection of appropriate screening tests must be dictated in part by law or regulation, as well as by sound medical judgment and cost effectiveness.

2. Health Hazard Reduction Health hazard reduction is an important and challenging component of the occupational health program addressing stressors in the workplace such as noise, physical and chemical hazards, as well as psychosocial stress. Orienting the occupational health plan toward prevention by reducing hazards rather than just providing medical disposition will, in the long run, prove cost effective.

There are many reasons for establishing a hazard reduction plan, including regulations, union demands, compensation costs, insurance considerations, and corporate altruism. Prevention is facilitated by periodic workplace surveillance and biomedical monitoring: surveys, monitoring of workplace hazards (noise, ventilation, fumes, dusts, radiation), and biomonitoring (audiometry, physical examinations, and specific blood and urine chemical analyses).

There are three basic means of controlling or correcting hazards (Hatch *et al.*, 1978): engineering controls, administrative controls, personal protective equipment (Chapter 3). The controlling and correcting process makes use of all three. Although the most preferred control is through engineering, financial constraints may not allow this. However, it is advantageous and cost effective to introduce such controls when new processes, material, or equipment are being planned. The impact of the occupational health professions at this stage will ensure hazard reduction or elimination and impose little if any additional financial burden and might even reduce future health program costs. The least preferred control is the use of personal protective equipment. Although a continuing developmental effort has greatly improved protective equipment, employees often do not always use them. Compliance, however, can be improved by frequent visits to shops, education programs, and rapport with workers, especially supervisors.

3. Management of Job-Related Illness and Injury The management of job-related illness and injury includes both the medical aspects of the case in addition to workers' compensation issues which will be fully addressed at the end of this section. It is advisable to keep good records on job-related illness. Records, statistics, and epidemiological surveys which are specific to the workplace can be extremely instructive and can serve as a guide for identifying trouble spots and evaluating remediation. Good concise medical records are particularly imperative in cases in which subsequent compensation or other legal actions are at issue.

4. Return-to-Work Evaluations Return-to-work evaluations are performed on employees after accidents or major illnesses or when returning to work from prolonged vacation or layoffs. These evaluations are directed toward ensuring that the employee is sufficiently fit to return to work, will not incur a repeat injury, nor present a hazard to the health or safety of fellow employees. In selected cases return of the employee to lighter or less hazardous work or even shortened hours may be part of the rehabilitation process. Such evaluations may also be included in cases in which return to work is longer than reasonably expected especially if malingering is suspected (Bond, 1988). They may lead to discoveries of improper diagnosis or treatment and even in some cases permit detection of those employees abusing sickness disability payment plans by not returning to work when adequate recovery has been achieved.

5. Health Maintenance Health maintenance and health promotion programs should not only provide periodic health surveillance, but also include employee intervention and assistance programs for substance abuse, diet and nutrition, physical fitness, and smoking cessation.

Regular examinations are required, and in some cases legally mandated, for workers exposed to health-hazardous processes or materials and to excessive physical agents (noise). Other employees included in this category are those engaged in jobs responsible for the safety of others. These examinations should ensure that the employees have sufficient skills and abilities to safely continue their jobs and that potential harm to the worker from the work environment is minimal. Health maintenance programs also enable early detection of the hypersusceptible individual and the worker who may engage in unsafe practices that defeat control measures. Upon termination of employment, some companies perform a final physical examination to be kept on permanent file. This is particularly important where operations involve exposure to health hazards (lead, benzene, silica, asbestos, excessive noise) which can have long-term implications.

In addition to health concerns directly related to the job, health promotion programs can also be beneficial to the company. For example, nutrition, weight reduction, and fitness programs demonstrate the commitment of management toward the general well being and morale of their employees. These programs can also serve as a vehicle for introducing occupational health concepts. The successful integration of a robust program will allow the worker to properly assess the relative risks of life-style, environmental, and occupational hazards. Additional direct benefits may accrue through a healthier and more physically fit work force with fewer job-related illnesses and accidents, less absenteeism, and reduced health care costs.

Many companies have established employee assistance programs for individuals who have found their lives altered due to substance abuse (Hatch *et al.*, 1978; DeHart and Gullett, 1985). Although many forms of abuse are found in the workplace (prescription drugs, illicit drugs), the greatest abuse is alcohol. Alcoholism is quite prevalent in many countries and cultures and may result in increased losses of working days and much higher (two or three times) on-job and off-job accident rates. Workplace policy on alcoholism and drug abuse must be clearly stated and understood by both employees and management. This policy can have a significant effect on whether employees seek help on their own or await managerial intervention—which is often too late. A typical policy statement includes the following information: (a) recognition of substance abuse as a health problem affecting the employees' job performance, conduct, attendance, and safety; (b) recognition of the need for early identification and treatment to maximize the recovery rate; (c) application of company's health benefit programs (sick leave, group insurance) toward employees participating in a suitable treatment program; (d) confidentiality as the basis for both diagnosis and treatment; and (e) recognition that the company will not dictate employees' social habits. Your company's concern is only with problem drinking as an illness and is not meant as an intrusion into the employees' private lives.

Once treatment has been initiated and recovery is evident, it is useful to refer the employee to a support organization such as Alcoholics Anonymous and thus complement the broad-based support system which includes the occupational health program, company policy, co-workers and unions, and the home.

Smoking cessation programs are especially important and, if effective, of proven value. The mounting and well-publicized evidence of the detrimental effects of both active and even passive smoking has created the proper environment for such programs. Besides direct benefits of job health and fitness, smoking cessation can also remove one of the confounding factors for clinical diagnosis and biomedical monitoring of many chemical and cytogenetic hazards and thus facilitate medical surveillance programs.

6. Hazard Communication Programs The "right to know" or hazard communication program is mandated by laws and regulations in a majority of countries. It requires that employees be made aware of any potential chemical (and in some cases physical) health hazards to which they may be exposed while at work. In addition, there should be an educational effort toward increasing employee recognition of adverse health effects.

The occupational health department may be required to publicize specific health or safety information on a continuous or ad hoc basis as part of an educational or job-training program. Initially, this might include orientation programs for new employees and advanced training courses which may be combined with periodic health assessments and scheduled health screening tests. Much of this information can be reinforced by talking with workers and supervisors during walk-through surveys and visits.

7. *Workers' Compensation* The management of a workers' compensation system has become a part of occupational health programs. The company occupational health activity must have the proper professional resources and expertise available to assure fair and prompt case resolution. This component of the program will, therefore, directly assist the personnel or human resources department. DeHart (1985) has noted that for corporations operating in multiple states and in foreign countries, the workers' compensation system is both cumbersome and complex due to the diversities and inequities of various local (state) and national laws.

There are specific problems regarding coverage of work-related diseases with long latency periods (there may be a limited time after cessation of work for filing disability claims), as well as multiple causations and "ordinary diseases of life" with a work-related element. A standardized company policy which relates to this problem and which has been negotiated with labor representatives will be instrumental in fair and prompt responses to these claims.

The various components of an occupational health program which were discussed above are typical of a progressive and large industrial health program. They should be regarded as essential and general approaches which are not mutually exclusive but rather complementary. Proper integration of these components in the planning process will result in an optimal and effective approach to company policy.

D. Resources

An important and essential part of the planning process is the preparation of budgets. It is imperative that this planning activity be initiated at an early stage so that management will be aware of resources which may be required for your program. The budget should be compatible with that of the company yet reasonably adequate to meet your needs. In calculating requirements, consider the number of employees and locations, types of potential hazards, and mandatory legislation. Basic assistance in budget development, including sample budget worksheets, can be found in a NIOSH publication (Hatch *et al.*, 1978). You will, in general, have to identify all costs and relate them to the relevant services and activities.

Future operations should be taken into account while preparing your budget. These may include, for example, the addition of new, potentially hazardous manufacturing or operating processes that would require health surveillance and biomedical monitoring, the need for new equipment, or an additional satellite service. Differences in methods of cost accounting among workplaces also influence your program costs. One example might be company policy which back charges overhead costs to the health program.

It is imperative that the budget directly contributes to the objectives of your program and that costs reflect increased efficiency over the years as your program becomes more beneficial to the company. Since your occupational health program will not be a revenue-producing operation, it may be tempting for higher management to cut your budget. Consequently, it is often necessary to continually justify programs on the basis of their benefits such as increased productivity, reduced absenteeism and illness, reduced health care costs, reduced injury, severity and frequency rates, and improved employee morale. At the same time it must be remembered that funds which are earmarked for a program should be treated as a scarce resource. There should be a continual process of prioritization among the various program components on a cost-effectiveness basis so that these scarce resources may be allocated to provide the most benefit for the expenditure.

IV. ORGANIZING AND STAFFING

The management function of organizing has the fundamental purpose of establishing a structure of functional activities and their relationships which will serve as a coordinating framework in which the program will operate. This is accomplished by first listing all of the activities which must be performed in order to accomplish the program objectives. These activities are then grouped according to skill requirements or according to geographic location where they are performed, or when they need to be performed. The next major step in organizing is to integrate these grouped activities into a network which clearly delineates their relationships to each other. The individual in charge of each grouped activity is identified and must be given sufficient authority to coordinate and manage activities within the group. Furthermore, there must be hierarchical and lateral relationships between groups with delegation of authority to individuals who can effectively coordinate their activities. These relationships should be graphed in the form of an organizational chart. In addition to the chart, written statements of group functions and individual jobs, responsibilities, and authority will complete the organizational picture. Built in to these statements of jobs and functions are the procedures for coordination of activities within and between groups.

The integration and coordination of various disciplines, including biomechanics, psychology, ergonomics, nutrition, industrial hygiene, insurance evaluation, law, health promotion, statistics, safety, data processing, and cost analysis, into an occupational health program requires skilled management. An analysis of the program activities, their frequency, and the time required per week or per month, when matched with the job skills required to perform the activity, will determine the number and type of staff needed. In some cases it may be found to be more cost effective to hire consultants and part-time ancillary help rather than to operate totally with in-house staff. In any event, depending upon the size of the company, the professional staff will consist of physicians, occupational nurses, and technicians. These will be supported by in-house or consulting industrial hygiene services and clinical laboratory services. There are many formulae for calculating staffing levels (Knight and Zenz, 1988; Hatch *et al.*, 1978).

One example of a corporate high-tech primarily aerospace firm is the Garrett Corporation in Los Angeles, California (Waggener, 1985). In 1985 this corporation employed 24,000 workers worldwide, with 24 divisions and subsidiaries at 25 U.S. locations and in 27 other countries. The corporate program was staffed by a medical director, three full-time physicians, 19 full-time engineers, 3 industrial hygienists, and 2 radiologic technicians as well as secretarial and clerical staff. At other locations, fee-for-service consultants were utilized.

The next step is staffing the program. This is the management function of recruiting, selecting, placing, training, and appraising qualified people to fulfill the duties which have been defined through the previous processes of planning and organizing. The challenge is to pick the right person for the right job. Skilled recruitment personnel must have a good understanding of the jobs and requisite technical skills as well as good insight into the human factors or personality attributes most appropriate for the position. Therefore, each job description should include a list of necessary personality traits and technical skills which will enable the recruiter to judge whether a potential candidate can effectively perform the designated job.

Once individuals have been hired or assigned to a job, there is a continuing need to train and develop their skills in technical areas to improve technical abilities, communication techniques, management, and interpersonal relationships. This should be viewed as a continual process and adequate resources should be budgeted and allocated. The professional employees on your program should be aware that you value their continued professional and managerial development as this usually results in reduced employee turnover and thus a more efficient program.

A periodic function of staffing is the appraisal of employee performance to enable management to make appropriate changes in job assignments and to validate training and development programs. Although most appraisal methods are based upon essentially subjective judgements, they can also be based upon the individual's achievement of quantifiable objectives. Thus, the appraisal should be focused on objectives and how well they were or were not met along with the various reasons why. This process may also provide useful feedback which will modify your planning and organization.

No program can be carried out without competent, well-organized, and properly managed staff. Clear organizational charts, activity function statements, job descriptions, authority delegations, and coordinating procedures coupled with qualified and well-trained staff will ensure that your program is on the right track to achieving its objectives.

V. COORDINATING AND OPERATING THE PROGRAM

The best planned, organized, and staffed occupational health program will never realize its full potential without an effective leadership. It must set the organizational activities into motion toward defined objectives within the established resources and, at the same time, motivate the occupational health team. A first and fundamental activity for an effective leader is to make organizational objectives very clear to all subordinates, so that everyone will clearly understand how his or her duties contribute to the accomplishment of those objectives. Detailed plans with explicit and tangible objectives which can be measured or observed should be developed for all levels throughout the organization. In addition, individuals should be encouraged to suggest changes in their duties if they feel it is to the advantage of the organization.

A second fundamental activity is to clarify all rules, policies, and procedures resulting from the planning process. This task involves explanation of these policies and procedures so that if any "bugs" are discovered, they can be eliminated. The leader then initiates action by issuing explicit instructions which, with procedures, should ensure that activities are coordinated.

Motivating individuals to perform is one of the most challenging tasks of management. It involves setting a good example, making work seem enjoyable and satisfying, setting high standards of professional integrity and performance, praising good work (in private and public), showing how to correct deficiencies (in private), handling human relations problems with fairness and respect for the individual's dignity, and promoting an atmosphere of open communications in all organizational directions.

Success of the occupational health program depends not only on commitment by management, but also on the support and participation of all corporate employees. Conditions should be such that there is open communication and dialogue between management and staff. Motivating the staff to participate and rewarding them for outstanding performance are key elements in a successful management–staff relationship. A favorable climate can be created by a safe, healthy, and comfortable workplace with adequate controls to protect employees from hazardous substances and operations. Management can further contribute toward this climate by convincing employees that productivity goes hand-in-hand with a safe and healthful workplace. Two-way, open communications, without fear of reprisal, will allow employees to freely express problems and recommendations and, at the same time, facilitate the publication by management of decisions and policies.

Job satisfaction is also essential because a dull, repetitive job can lower employees' sense of involvement and alertness to hazard prevention or avoidance. Since such repetitive jobs are the rule in many occupations, special efforts should be made to stimulate employee concern for their safety and health, both in and outside the workplace.

The employees' confidence in management's commitment to their health and safety can be determined by brief anonymous surveys of their opinions and attitudes. Confidence can be increased by employee surveys of safety and health hazards in their own departments; employee representation on company safety, health and hygiene committees; a suggestions award program for health improvements offering bonuses for individuals whose suggestions are implemented; competition between departments with appropriate recognition for those with the best safety record; and training programs in first aid, CPR, and other safety and health-related areas.

Developing and maintaining a sustained interest in occupational health is a difficult task. In general, there is a tendency to overlook practices or programs for which there is no strong personal commitment. It is, therefore, imperative to supplement corporate commitment and educational activities with incentives designed to maintain employee interest. These incentives should reflect the values and interests of the employees so that they will be meaningful to them. Components of an incentive program include: (a) recognizing safety and health as a personal responsibility, a part of each employees job; (b) stressing the costs of accidents and occupational illnesses to both management and employees (increased insurance and repair costs, increased work loads, and loss of employee time, all of which contribute toward both reduced profitability and subsequent employee benefits); (c) encouraging good health and safety practices through in-house and community publications together with awards and bonuses for no absenteeism, incidents, or accidents over a period of several months; and (d) considering health and safety activities in overall individual performance evaluations as an element in determining promotions or pay increases as well as disciplinary actions or terminations.

Effective day-to-day management of an occupational health program will require coordination with external groups and agencies. These may include municipal and national authorities, as well as other health professionals involved with the health of the company's employees. Leadership qualities and communication skills should be utilized to gain their cooperation, understanding, and support. This will, in the long run, result in a minimum of friction and expedite the management process. For example, there is an increasing tendency today to interface with environmental protection agencies in order to control and eliminate hazardous substances in the workplace. Corporate management should be made aware of such relationships, especially when significant investments are involved.

VI. CONTROLLING THE PROGRAM

Effective management depends on a responsive and efficient system for controlling the occupational health program to assure adequate performance, efficient use of resources, timely detection and correction of deviations, and feedback for future plans. Control requires the measurement of accomplishments, comparing them with preplanned standards, and taking corrective action if deviations are unacceptable. Control procedures should be planned for all organizational activities and should be formal for critical, high priority activities but can be informal for lesser ones. The appropriate degree of control depends on the impact of the specific activity on the program's objectives. Formal control is usually applied to resource expenditures, service quality and quantity, task accomplishment and timeliness, and compliance with procedures.

Effective controls focus on a relatively few strategic parameters or indicators of progress toward objectives of program activities. Controlling requires gathering data, analyzing and summarizing it, and presenting it in an easy-to-comprehend form. This can be a costly and time-consuming administrative task—prudence is advisable.

Records and reports are an important part of the occupational health program and serve as the basis for control. Adequate up-to-date records coupled with sufficient computer resources can expedite the management of the program as well as reveal type and amount of service rendered, costs of the program, state of employee health, and the standards of industrial hygiene in the various facilities. These records can also serve as the basis for occupational epidemiology in the company and, when compared with other information sources, can increase the knowledge of the relationship between work and health.

Melius (1988) recommended that there should be a separate file for each employee containing information on that employee's health (including history, examinations, laboratory tests, and procedures), counselling, workers' compensation reports, and copies of group insurance reports. This information should be supplemented by occupational and environmental (industrial hygiene) data including industrial hygiene reports, sound surveys, and information on environmental hazards such as amount, frequency, and duration of any exposures. Accurate records can be used to analyze illnesses and injuries so that problem areas can be identified and corrected.

One way to compile such data for control purposes would be a computer listing for each accident or illness which includes (Hatch *et al.*, 1979): name, job title, type of work being performed, extent of injury or illness (including sick leave), part(s) of body affected, and equipment or material, or both, being used. Such an analysis, for example, may show employees have had a large number of eye injuries in a year and suggest that eye protection measures should be prioritized as an objective of the occupational health program. These listings can also reveal accident or illness-prone employees as well as problem departments and supervisors. And finally, they also serve as a basis for calculating the costs involved in an accident or illness.

The supplemental industrial hygiene records are essential for evaluation and control of employee exposures and may protect the company in legal cases in which employees become ill from sources other than in the workplace. Correlation of these records with preplacement and periodic medical examinations can also help identify the origin of an illness. All records should be complete, up to date, and retained long enough so that the latent period between exposure and the onset of an illness or disease manifestation is covered. In some cases this may require that records be retained for length of employment plus 30 years. Recordkeeping and retention of information for such lengthy periods require substantial resources and quality control.

The gathering, analysis, and presentation of control data should be planned at an appropriate frequency and on a reasonable scale. For example, if there was a $50,000 monthly budget which, due to mostly fixed costs, could be varied by only $10,000 in any one month, it would be senseless and counterproductive to review expenditures to the nearest dollar on a daily basis. A weekly or biweekly review rounded off to the nearest $100 would be more reasonable.

Usually recordkeeping alone is not sufficient to provide the necessary data for analysis and control. Audits, inspections, and meetings which include verbal progress reports augment written records and summaries and also provide personal contact with employees and program staff. These audits and inspections should be both formal and informal, based on checklists employed during the planning phase of the program. These checklists should be designed so that progress in elimination or control of health hazards can be measured and new problems recognized and remedied. This "hands-on" approach to gathering information will ensure personal interface with the recipients of the occupational health program in their natural environment and will facilitate employee motivation as well as generate feedback guidance essential for proper program control.

Controlling the program necessitates measurement of program progress and effectiveness and comparing this performance with preplanned standards in order to demonstrate its value, especially to higher management and to those who control budgets. A well-structured program should lend itself to objective performance measurement as well as to more subjective evaluation as suggested by NIOSH (Hatch *et al.*, 1978). For an objective analysis, statistical data are the principal evaluation tool. For example, inspection (medical, hygienic), illness, and accident data can be analyzed and compared over time within the company or other similar industries. The cause and cost analysis of injury and illness incidents indicates the overall effectiveness of a program and identifies areas of weakness. First-aid services for minor injuries as well as minor complaints (headache, respiratory irritations, etc.) can provide early warning of potential health hazards and should be included in the analysis. In addition, a number of epidemiological calculations may be used to summarize program performance. These include:

Frequency or incidence rate (FR) [1]

$$FR = \frac{\text{No. of disabling illnesses or injuries} \times 200{,}000^{1}}{\text{No. of man-hours worked}}$$

Severity Rate (SR) [2]

$$SR = \frac{\text{No. of man-days lost} \times 200{,}000^{1}}{\text{No. of man-hours worked}}$$

Disabling Injury/Illness Index (DII) [3]

$$DII = \frac{SR \times FR}{40}$$

An effective program should continually strive to reduce these rates or maintain them at acceptable levels comparable with the best performance levels of other workplaces in the industry. The data used for these measures should be collected on a monthly, quarterly, and annual basis for comparison purposes.

An important objective criterion for measuring program effectiveness is cost reduction associated with illness, injury, absenteeism, and employee turnover. In calculating these savings there should be fewer and smaller insurance claims, fewer lost hours, and fewer training or start-up costs, or both, associated with hiring new employees. Nevertheless, reliance on these calculations of financial return as a sole effectiveness measure or selling point for a program can be misleading because much of the economic impact of a good program will be in costs never incurred (e.g., fatalities and costly legal suits from occupational illnesses or injuries) often attributable to sound prevention measures.

Subjective measures of program effectiveness should be perceived in the changing attitudes and behavior of employees regarding their health and safety, increased employee awareness of occupational hazards, enthusiastic participation in health promotion and health maintenance activities, and better personal protection and prevention practices.

Accurate assessment of program effectiveness should include evaluations not only of results, but also of activities which were generated or stimulated at

[1]The 200,000 is equivalent to 100 full-time workers at 40 hr per week for 50 weeks and automatically adjusts for differences in hours of exposure.

other corporate levels. These may include "ratings" of management involvement, environmental assessments, and public awareness generated.

The gathering, analysis, and presentation of this control data and their comparison to program effectiveness standards should highlight unacceptable deviations of performance. This should, in turn, generate timely and effective remedial action in order to reduce or eliminate the chances of similar deviations in the future. Once corrective action is implemented by the responsible individual, there should be provision for feedback on its effectiveness. Any corrective actions could have an impact on future planning and activities.

It is important to recognize that motivation of the individual to control his or her own performance toward organizational objectives is a far superior and less costly approach than complete comprehensive "external" control by superiors. A suitable combination of both individual and external control will assure effective program management.

In conclusion, this chapter has reviewed the components of an occupational health program and its management. No single chapter can include all of the information relevant to occupational health programs as well as management methods and procedures. Even if such a textbook was written, it would contain some outdated and irrelevant material due to rapid changes in these disciplines. Finally, there is no substitute for actual experience in establishing and managing successful occupational health programs for the mutual benefit of both employees and employers.

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