Chapter 21

OCCUPATIONAL MEDICINE IN THE AIR FORCE

The purpose of this chapter is to provide the Flight Surgeon with concepts to aid him in the evaluation of occupational medicine problems occurring both on the ground and at altitude.

GENERAL PRINCIPLES OF AVIATION AND OCCUPATIONAL TOXICOLOGY

The Industrial Air Force

A major factor of the unprecedented upsurge of industry in this country, particularly in the chemical, electronic, and mechanical fields, has been the need to support our domestic needs as well as our national defense requirements. With industrial development and diversification come the inevitable problems of controlling environmental hazards to health. The Air Force is one of the largest "customers" for the newest chemical and electronic agents, and thus assumes the responsibility for protecting its personnel and the public from potential health hazards arising from Air Force operations.

Hazard Control by Team Effort

The control of industrial toxic or physical hazards depends upon the combined efforts of a team of specialists trained to predict hazards to health on a sound, scientific basis. They act to establish limits of exposure (threshold limit values (TLVs)) and control the exposure of employees and neighboring populations within such limits by the most effective means. Such action usually involves the installation of engineering control measures with periodic evaluation of atmospheric and biological concentrations of harmful substances and their metabolic products. This team frequently consists of the flight surgeon, the bioenvironmental engineer, and the ground safety specialist.

Need for Medical Judgment in Hazard Control

Because of the diversification of industrial operations at even the smallest Air Force facilities, it is essential that good judgment be applied in deciding the nature of actual or potential hazards and the degree of medical or engineering control necessary. Our aim is to aid in the accomplishment of the mission in the most efficient way with the least cost in manpower, materiel, and money. Desirable byproducts of such a program are better working conditions, health, morale, and productivity of the work force that are advantageous to both the Air Force and the employee.

The Flight Surgeon as an Occupational Medicine Practitioner

The Flight Surgeon is often the person best qualified to study problems of occupational medicine at Air Force bases. If he will study the everyday toxic problems that exist in the industrial areas or on the line, he will be in a far better position to evaluate the problems of toxic materials in flight.

Need for Caution in Diagnosing Industrial Disease

Before getting into some of the specific problems of toxicity that exist in Air Force operations at present, it is necessary to interject a word of caution concerning the diagnosis of occupational disease. The physician who has had minimal experience in the diagnosis of conditions produced by toxic materials often will make unfounded and erroneous guesses as to the cause of a disease condition when a history of working with toxic materials is presented. It is imperative to remember that there is much to lose and little to gain by "snap" diagnoses in such cases. There are many diagnostic aids in toxicology, the same as there are in other forms of clinical medicine, and such aids should be used along with consultation, when required.

A physician might hesitate to diagnose syringomyelia without the consultation of a neurologist. In contrast, he may be willing to stake his professional reputation on a case of lead poisoning although he had never seen such a case previously. Once an erroneous diagnosis has been entered on the medical record or related to the patient, the seed has been planted for an unfair compensation case and, quite often, a compensation neurosis. Therefore, caution should be exercised in diagnosing occupational disease.

Criteria for Diagnosis of Industrial Disease

Generally, the following criteria must be met for a diagnosis of occupational disease to be made:

a. The substance to which the person is exposed must be capable of producing the disease.

b. The time-dose relationship and the time between the exposure and the appearance of the illness must be adequate.

c. Other causes of the condition must be ruled out, if possible, in differential diagnosis.

The Air Force has provided for consultation in occupational health just as it provides for special support in other medical specialties.

Availability of Consultation

There are three Air Force Regional Environmental Health Laboratories that provide specialized laboratory support to the USAF Occupational Health Program, worldwide. These laboratories are operated by AFLC at McClellan AFB, California, and Kelly AFB, Texas, and by USAFE at Wiesbaden AB, Germany.

This consultation service is provided under AFM 161-2 and AFR 161-17. Further services are available in the area of radiological health through the USAF Radiological Health Laboratory, at Wright-Patterson AFB, Ohio.

HQ AFLC acts as the advisor to the Office of the Surgeon General, USAF, in evaluating potential hazards to health from new physical, chemical, or biological industrial agents, except when used as warfare agents.

The Concept of Threshold Limit Values

The majority of industrial agents capable of producing hazards to health fall into two general categories: chemical and physical. Considerable effort has been expended by both private and governmental research agencies to delineate the concentrations of chemicals that produce a potential health hazard to exposed workers. These levels (threshold limit values) are primarily based on time-weighted average concentrations to which the typical employee may be exposed on an 8-hour day, 5-day week schedule for his productive life without producing a health hazard. AFP 161-2-1 gives current threshold limit values for toxic chemicals.

Toxicity between agents cannot be compared on a quantitative basis solely with reference to their threshold limit values. A brief consideration of the basis for establishing the TLV in a few examples will demonstrate how prone to error such a comparison would be. In the case of solvents, if there is known to be chronic toxicity, the TLV is quite low—*e.g.*, 25 ppm for benzene and 10 ppm for carbon tetrachloride. If, on the other hand, chronic toxicity has not been found in animal or man, the TLV is based upon acute effect, such as narcosis—*e.g.*, 100 ppm for trichloroethylene and 200 ppm for chlorobromomethane. In both cases, adequate precautions must be taken to prevent overexposure, and there is little or no difference in the control ventilation needed. The reliance on the "safety" of a solvent simply on the basis of the comparison of its TLV with that of another is, thus, likely to cause error.

To apply TLVs intelligently, one must determine the following types of information about the agent:

a. Vapor pressure and density.

b. Solubility.

c. Particle size.

d. Means of absorption.

e. Acute effects.

f. Chronic effects.

g. Metabolic and excretory mechanism.

For example, silicosis may result from excessive, repetitious exposure to free silica of particle size less than 10 microns. Particles larger than this do not reach the pulmonary alveoli since they are trapped in the upper respiratory tract and removed by ciliary action. In fact, most particles five to ten microns in size are also removed from the air in the upper airway. Silica particles three to five microns in size are deposited in the mid-respiratory tract while many of the smaller particles are deposited directly in the alveoli. Submicron particles remain suspended and are usually exhaled. Silicosis attributed to living along the beach or in the desert where the sand is composed of pure-free silica would be most unusual because particle size is too large.

In the case of lead sulfide, the miners of "galena" are not known to develop typical inorganic lead poisoning or plumbism because the lead sulfide is so extremely insoluble in the gastrointestinal tract that it passes through without being absorbed. On the other hand, free lead, lead oxide, or other soluble lead compounds are quite readily absorbed via the gastrointestinal tract and capable of producing recognizable clinical disease.

Use of Special Laboratory Tests

Considerable care is required in the selection of laboratory tests to aid in implementing an occupational health program. *For example,* there are still some persons who continue to use stipple cell counts or coproporphyrin determinations alone as a means of detecting overexposure to lead. It is true that such tests of altered physiology may be of some value if evaluated in the light of other findings (atmospheric concentration of lead, urine and blood lead, etc.), but when used alone, they may be worse than nothing in that negative results may give a false sense of security. In the case of inorganic lead, the most important periodic tests are the atmospheric concentration of lead and the urinary lead level. In cases where the urinary lead is elevated, a blood lead determination should be obtained. The urinary lead level is most sensitive to fluctuations in ambient air lead concentrations while blood lead level is far more reliable to indicate accumulation of toxic amounts of lead.

Great care must be taken to prevent contamination of the specimens, and "positive" laboratory results should be repeated. Air Force clinical laboratories are usually unable to perform the necessary analysis involving microtechniques and special equipment; thus, all such specimens should be forwarded to an environmental health laboratory for analysis. The altered physiology of the employee should never be used as the primary indicator of hazardous levels of toxic materials in the working environment. Proper environmental monitoring through sampling procedures is, of course, the method of choice.

Estimation of Toxicity From Chemical Formula

The estimation of toxicity on the basis of chemical formula alone is unreliable. Experience has demonstrated that some compounds that should be exceedingly toxic, on the basis of formula, are not; whereas, others which, on the same basis, would be expected to be ralatively harmless, have caused serious symptoms.

Interpretation of Literature

Probably no other field of medicine possesses such a wide variation in quality of medical literature. Some of the finest scientific work has been done in the field of occupational medicine and, yet at the same time, one can find examples of the poorest. The Flight Surgeon should bear this in mind as he reviews the literature, and not hesitate to request assistance in the event his decision may be expected to have far-reaching consequences.

AIR FORCE OPERATIONS

Ground Operations and Exposure

Eighty percent of the Air Force's total effort is spent in ground support of airborne activities. Air Force operations in which toxic agents have been found are listed in table 21-1. A similar table should be prepared by the Flight Surgeon who has industrial medical responsibilities. The Flight Surgeon and the Bioenvironmental Engineer are responsible for controlling health hazards found in Air Force operations and should survey the working environment, studying any potentially hazardous situations they encounter by actual measurement of the quantity of potentially hazardous material present in the atmosphere.

Technical Orders

Technical orders usually outline safety and health aspects of procedures prescribed. Valuable aids in the study of such operations are military specifications which often outline the constituents of solvents, rust inhibitors, oils, greases, gasoline and other fuels, paints, paint thinners, dope, carbon remover compounds, and hand cleansers.

Survey Equipment

Survey equipment used in studying environmental contamination is listed in Table of Allowance (TA) 906, Set, Environmental Health. The equipment it contains will allow study of the work atmosphere for common gases and vapors, ionizing radiation, and air movement. In addition, there are sound and light meters and temperature and humidity instruments available. Bases where this equipment is not available may request assistance from a regional environmental health laboratory through their major command headquarters.

Survey Evaluation

It is to be emphasized that survey equipment be used only by trained personnel if valid and reliable results are to be obtained. Sensitive instruments in the hands of inexperienced personnel with inadequate professional training may produce erroneous results or misinterpretations, as well as damaged instruments through improper use. As a consequence, proposed corrective engineering control measures may be inadequate or excessive. All survey results, whether atmospheric or biological, require thorough interpretation if effective control measures are to be applied.

TOXIC GASES, FUELS AND VAPORS

The Flight Surgeon should be especially aware of the toxic gases and vapors that may be found in crew and passenger compartments of aircraft. Although care has been taken in aircraft manufacture and design, unusual circumstances may allow gases and vapors to permeate occupied areas. When this occurs, dangerous physiological effects may result from a combination of toxicity, concentration, and prolonged exposure.

Exposure to toxic chemicals in flight is usually brief, and when toxic effects are discovered, they are usually acute. Therefore, it is essential that flying personnel have a sound understanding of the toxic chemicals that may be encountered in aircraft. It is important that they develop an awareness of the possible presence of the toxic vapors and that they be able to institute appropriate emergency measures when necessary.

Contamination of the atmosphere of an aircraft may result from the following: exhaust gases, hydraulic fluid mist, fuel vapors, coolant fluid vapors, oil vapors, anti-icing fluid vapors, fire extinguishing fluids, cargo, and the thermal decomposition products of electrical insulation.

Exhaust Gases in Piston Engines

The composition of exhaust gases varies widely, depending largely upon the type of engine and the fuel-air ratio at which the engine is operated. Carbon monoxide, methane, and hydrogen result from incomplete combustion of the fuel. As the fuel-air ratio decreases and the completeness of combustion increases, the percentage of carbon dioxide in the exhaust gas rises, with a corresponding decline in the percentage of carbon monoxide. Conversely, as the mixture

TABLE 21-1. CONTROL OF PRINCIPAL TOXIC AGENTS FOUND IN AIR FORCE OPERATIONS

Process Where Found	*Toxic Agent*	*Health Hazards*	*Control Measures*
Aero-Repair	Solvent dry cleaning Fed Spec PS-661a Small quantities other toxic agents such as toluene, acetone, amyl acetate, lead, ethyl alcohol, butyl alcohol, ethyl acetate, butyl acetate, petroleum naphtha, turpentine, carbon monoxide, caustic cleaners, greases.	Dermatitis Pulmonary inflammation	General exhaust or good natural ventilation Local exhaust ventilation for cleaning inside of planes Protective hand creams Strict personal hygiene Good housekeeping Covered solvent containers Protective clothing
Assembled Engine Cleaning	Solvent dry cleaning Fed Spec PS-661a Rust inhibitor	Dermatitis Pulmonary irritation	Local exhaust ventilation Protective hand creams Protective clothing such as gloves, aprons, and boots
Battery	Lead Sulfuric acid Sulfur dioxide	Dermatitis Pulmonary irritation	General or local exhaust ventilation Personal protective clothing Isolation of process
Blacksmith	Carbon monoxide Sulfur gases Radiant heat Dust	Dermatitis Anoxemia Heat exhaustion	General and local exhaust ventilation Personal protective clothing Good housekeeping
Carburetor and Ignition	Solvent dry cleaning Fed Spec PS-661a Trichloroethylene	Dermatitis Pulmonary irritation Renal damage Central nervous system damage	Local exhaust ventilation Covered solvent containers Protective hand creams
Electrical Shop	Degreasers, solvents, oxides, selenium beryllium sulfate, carbon tetrachloride	Dermatitis, Lung and Liver damage, malignant ulcers.	Adequate ventilation both general and local, which may include booths, respirators, proper handling and disposal of fluorescent lighting tubes.
Electroplating	Sodium cyanide Cadmium oxide Oxides of nitrogen Hydrofluoric acid Other chemicals which may be used are lead carbonate, copper sulfate, nickel sulfate, nickel chloride, phosphoric acid, acetic acid, caustic soda, chromic acid	Dermatitis (acid and caustic burns) Effects of hydrogen cyanide Edema of lungs Plumbism Conjunctivitis Chrome ulcers	Local exhaust ventilation (horizontal slot type preferable) General exhaust ventilation Isolation of process Protective cream Separate rooms and ventilation systems for acid solutions and cyanide solutions Personal protective clothing

TABLE 21-1. Continued

Process Where Found	*Toxic Agent*	*Health Hazards*	*Control Measures*
Engine Block Test	Carbon monoxide Solvent dry cleaning Fed Spec PS-661a Noise Oils, greases Gasoline, jet fuel	Dermatitis Anoxemia Temporary partial hearing losses Pulmonary irritation	Positive pressure ventilation of control room Local exhaust of oil return system Protective hand creams Protective ear plugs Proper design and location of block test buildings
Engine Cleaning	Solvent dry cleaning Fed Spec PS-661a Caustic cleaners removing (creosols and ortho-benzene)	Dermatitis Pulmonary irritation Possible CNS, kidney and liver damage	Local exhaust ventilation Good natural ventilation Strict personal hygiene Protective creams Protective clothing
Engine Disassembly	Solvent dry cleaning Fed Spec PS-661a Oils, greases Other volatile solvents	Dermatitis	Good general or local exhaust ventilation Strict personal hygiene, protective clothing, protective creams
Fire Protection and Crash Rescue	Fire extinguishants C. B., CO² Carbon Tetrachloride, heat, thermal decomposition, products of the extinguishants.	Acute narcosis, asphyxiation, liver and kidney damage, heat exhaustion, lung irritations.	Proper training, ventilation of filling booths, use of respirators and masks. Strict control and supervision in the use of carbon tetrachloride as extinguishant.
Foundry	Silica Carbon monoxide Metal fumes Excessive heat	Silicosis Anoxemia Heat exhaustion Metal fume fever	General and local exhaust ventilation Approved type dust respirators Good housekeeping Use of nonsilica parting compound
Fuel System Repair Shops	Solvents, gasoline, jet fuel, methylethylketone, ethylene dichloride, petrol naphtha.	Dermatitis, narcotic effects, eye irritation, liver and kidney damage, acute anesthetic effects.	Thorough indoctrination in precautionary measures. Use of protective equipment (hand creams, respirators, local exhaust ventilation).
Heat Treating	Sodium cyanide Carbon monoxide	Dermatitis Effects of hydrogen cyanide Anoxemia	General and local exhaust ventilation (individual exhaust pipe for cyanide) Strict personal hygiene
Hydraulic	Solvent dry cleaning Fed Spec PS-661a Hydraulic fluids	Dermatitis	Good general or local exhaust ventilation Protective hand creams Protective clothing

TABLE 21-1. Continued

Process Where Found	*Toxic Agent*	*Health Hazards*	*Control Measures*
Hydraulic and Pneudraulic Shops	Solvents, alcohol hydraulic fluid.	Dermatitis, aplastic anemia, atrophy of optic nerve, liver and kidney damage.	Careful indoctrination of personnel; hand creams, respirators, adequate ventilation.
Insect and Rodent Control Section	Various economic poisons (Insecticides and rodenticides). Solvents, kerosene.	Skin irritants, dermatitis, systemic poisoning (Liver necrosis, Nephritis, convulsions, tremors from spinal cord and brain damage.)	Skin protected, by protective clothing. Safety goggles (chemical), respirators.
Instrument Repair	Solvent dry cleaning Fed Spec PS-661a Naphtha Small quantities of miscellaneous organic solvents	Dermatitis	Local exhaust ventilation for solvent spray booth Good general ventilation Covered solvent containers Protective hand creams Protective clothing
Insulation	Toluene Diisocyanate (TDI) Tetrafluoroethylene (Teflon) Thermal products	Dermatitis, Pulmonary irritation Fume fever	Precautionary measures Personal hygiene Good housekeeping Exhaust ventilation Personal protective clothing
Jet Engine Test Stand & Jet Engine Runup.	Excessive noise exposure.	Loss of hearing, damage to the cochlea, damage to the middle ear, rupture of the tympanic membrane. Fatigue, loss of muscular coordination. G. I. symptoms.	Earplugs, muffs or helmets—Both helmets and plugs are recommended where the exposure is high and over a long period of time. Noise suppressor devices (when feasible)
Luminous Dial Painting & Repair	Alpha and beta particles Gamma rays Radon gas Organic solvents	Radiation poisoning Dermatitis	Thorough indoctrination in precautionary measures Rigid enforcement of proper techniques Strict personal hygiene
Machine Shops	Cutting oils and greases Misc. dusts	Dermatitis	Strict personal hygiene Protective creams Local exhaust ventilation of dusty processes

TABLE 21-1. Continued

Process Where Found	*Toxic Agent*	*Health Hazards*	*Control Measures*
Metal Cleaning Shop	Solutions and vapors of acids Hydroxides Trichloroethylene Methylene chloride Potassium permanganate Fed Spec PC-111a	Dermatitis Mucous membrane irritation Narcosis CNS, liver and kidney damage	Local exhaust ventilation (horizontal slot type preferable) General exhaust ventilation Personal protective clothing Eye wash and safety shower
Metal Inspection (defects)	Penetrant dyes (Zyglo process) Industrial X-ray	Dermatitis Acute & chronic radiation effects	Strict personal hygiene Protective creams Personal protective clothing and equipment (See "X-ray and Ionizing Radiation.")
Minor Repairs	Solvent dry cleaning Fed Spec PS-661a Trichloroethylene Small quantities of miscellaneous organic solvents Caustic cleaning materials Oils and greases	Dermatitis Mucous membrane irritation CNS, liver and kidney damage	Local and general exhaust ventilation Protective hand creams Personal hygiene Personal protective clothing and equipment
Missile Operations (See AFM 127-201 and AFM 160-39.)			
Paint & Dope (brush and spray painting)	Paint thinner & dope containing misc. organic compounds, such as benzol, toluene, acetone amyl acetate Ethyl or butyl alcohol Butyl acetate VM and P naphtha Turpentine Lead	Dermatitis Possible plumbism Blood changes and nervous symptoms	Exhaust ventilated paint spray booth Supply air respirator Chemical cartridge respirator Protective hand cream Isolation of process Closed solvent containers and separate storage of bulk paint and solvents
Parachute, Leather, Rubber and Textile Shop	Solvents, caustic cleaners, naphtha, methylethylketone, ethylene dichloride.	Dermatitis, narcotic effects, acute anesthetic effects, eye irritations	Same as "Fuel System Repair."
Plexiglas	Small quantities ethylene dichloride	Dermatitis Anesthetic effect	General exhaust or good natural ventilation Covered solvent containers

TABLE 21-1. Continued

Process Where Found	*Toxic Agent*	*Health Hazards*	*Control Measures*
Plumbing Shop	Aircraft & vehicle fuels and sludges, including tetraethyl lead	Dermatitis CNS damage	Supplied air respirators and local exhaust ventilation for tank cleaning General exhaust ventilation Personal protective clothing
P. O. L. Hydrant Refueling	Gasoline, J. P. fuels, Methanol.	Dermatitis, Plumbism, eye irritations, optic atrophy, acute anesthetic effects.	Orientation of personnel in prescribed precautions, use of protective equipment such as chemical safety goggles, full face shield. Respirators may be required in high concentration. Protective clothing, deluge type shower—bubble type, eye washings, blankets.
Precision Measuring Equipment Laboratory (PMEL)	Ionizing radiation Mercury spills	Neurological disturbances (See "X-ray and Ionizing Radiation.")	General exhaust ventilation Flowers of sulfur (sublimed sulfur) for Mercury spills (See "X-ray and Ionizing Radiation.")
Pre-Dock Aircraft Washings	Moisture, cold, kerosene and detergents.	Chilling, dermatitis, nose, throat and eye irritations.	Using ample protective clothing. Protective skin creams, respirators.
Propeller	Solvent dry cleaning Fed Spec PS-661a Small amounts of oils, greases and trichloroethylene Paint remover	Dermatitis Possible narcotic effect and renal damage	Good general and local exhaust ventilation Protective hand creams Protective clothing
Radiator and Tank Oil Coolers	Lead Compound carbon remover Caustic cleaning solution Solder and solder fluxes Greases and oils Solvent dry cleaning	Dermatitis Plumbism CNS, liver and kidney damage	Local exhaust ventilation General ventilation Protective hand cream Protective clothing and equipment.
Refilling Fire Extinguishers	Carbon tetrachloride Carbon dioxide Chlorobromomethane	Dermatitis Narcotic effect CNS, kidney and liver damage	Local exhaust ventilated booth Good general ventilation Personal protective clothing and equipment
Rubber Tank Repair	Toluene Ethylene dichloride Small quantities of other materials, such as ethyl acetate, ethyl alcohol, methylethylketone, benzol, petroleum naphtha	Dermatitis Narcotic effect Nervous symptoms	General and local exhaust ventilation Protective hand creams Personal protective clothing and equipment.

TABLE 21-1. Continued

Process Where Found	*Toxic Agent*	*Health Hazards*	*Control Measures*
Sandblasting (abrasive cleaning)	Dust produced by pure silica sand organic abrasives, and steel shot	Dermatitis Pneumoconiosis (the higher the free silica content of the dust, the greater its hazard)	Proper maintenance of sandblast cabinets and equipment US Bureau of Mines approved respiratory protective devices (supplied air helmets) Use of nonsilicious abrasives when possible
Sewage Disposal Plant	Methane, chlorine, H_2S and Infections of skin and G. I. tract.	Asphyxiations, Lung irritations, dermatitis, conjunctivitis and anemia.	Training—Use of respirators or gas masks and immunization.
Sheet Metal Shops	Deficiency of illumination, noise. Source — mechanical injury.	Dermatitis, Injury Eye strain Hearing loss	Properly designed work room, protective clothing, frequent washings, ear defenders.
Spark Plug Cleaning	Pure silica sand Solvent dry cleaning Fed Spec PS-661a Trichloroethylene	Dermatitis Silicosis Narcotic effect CNS and renal damage	Local exhaust and general ventilation Protective hand creams Personal protective clothing and equipment
Teletype and Other Communication Maintenance	Methyl chloroform (1-1-1 trichloroethane)	Dermatitis CNS depressant	Good general or local exhaust ventilation
Vapor Degreasing	Trichloroethylene Perchloroethylene	Narcotic effect CNS, liver and kidney damage	Proper operation of vapor degreasers Locate degreasers away from drafts Keep degreasers covered when not in use Local exhaust ventilation when other corrective measures fail Supply air respirators and personal protective clothing when cleaning degreasers
Water Plant	Chlorine gas, lime, soda ash, fluorides.	Lung, nose, eye irritations, dental flurosis, caustic effects on skin.	Use of respirators, gas masks and good personal hygiene.
Welding	Radiant energy Metal oxides including lead, iron, cadmium Gaseous decomposition products of red coatings Other toxic substances in small quantities, such as oxides of nitrogen, fluorides, and carbon monoxide	Dermatitis Flash burns of eyes Metal fume fever Heat exhaustion Edema of lungs Anoxemia	Protective helmet, shield, gloves, and apron (electric weld) Isolation of process General ventilation Local exhaust ventilation (always when producing cadmium or lead fumes) Portable or permanent black shield to protect adjacent workers

TABLE 21-1. Continued

Process Where Found	*Toxic Agent*	*Health Hazards*	*Control Measures*
Woodworking Shops	Wood, dust, glue, mechanical injury	Poor illumination and safety devices. Toxemia from Phenolic resins and paint solvents. Allergic skin reactions.	Good ventilation and adequate lighting. Little or no contact with the skin. By using gloves, aprons and respirators, and adequate hand washing facilities.
X-ray and Ionizing Radiation	Ionizing Radiation	Acute and chronic radiation sickness. Beta burns, adverse effect on the bones, lungs and blood, gonads, skin and mucus membranes. *a.* Skin-Brittleness and ridging of the nails. *b.* Hands—Increased susceptibility to chafing. *c.* Blunting or leveling of the finger ridges. *d.* Dryness and epilation. *e.* Changes in nail fold capillaries in the way of disordered pattern. *f.* Eyes—Cataracts from neutrons.	Control of time of exposure; provision of shielding, respirators, etc. Use of distance to maintain total radiation dose below the permissible levels.

becomes richer, the carbon monoxide of the exhaust gas increases.

Exhaust Gases in Jet Engines

The exhaust gases from jet engines contain over 95% air, the balance being essentially carbon dioxide. The probability of toxic levels of carbon monoxide being present is remote. However, since jet fuel is permitted to contain considerably more sulfur than is gasoline, irritating concentrations of sulfur dioxide and aldehydes may appear in the exhaust gas.

All new aircraft models must meet rather rigid specifications for freedom from contamination by carbon monoxide before they are accepted by the Air Force. However, since exhaust gases may get into the crew and passenger compartments by several ways, aircraft which were originally free from contamination or contained only slight amounts of carbon monoxide at the initial test, may deteriorate from wear and tear or change as a result of structural modifications introduced while in service. Periodic tests are required to reveal such contamination and serve as a check on the adequacy of the maintenance service.

Carbon Monoxide (CO)

Carbon monoxide should be suspected when fumes suggestive of heater or exhaust sources are noted. Since the gas is odorless, it is necessary to use one of the various carbon monoxide detectors when its presence is suspected. It can be detected readily in air by commercial carbon monoxide indicators or by a colorimetric method which has been developed by the National Bureau of Standards (Detector, carbon monoxide, Type B-1, FSN 6685-490-2010). The threshold limit value of carbon monoxide in Air Force cockpits is 50 parts per million.

Tests of cabin air give an indication of the conditions only at the particular moment when the air is tested. These conditions vary according to the length of time the engine has been running, the fuel-air ratio, the ventilation, and the position in the cabin from which the sample is taken. From a practical standpoint, the carbon monoxide content of the pilot's blood is a more important consideration as this represents the cumulative effect of the gas to which he has been exposed. Blood gas analyses are difficult, and if they are to be considered reliable, they must be performed by experienced technicians. The average hospital clinical chemistry laboratory is rarely capable of providing uniformly reliable results with blood gas techniques.

The Environmental Health Laboratories are equipped and have trained personnel to make blood carboxyhemoglobin determinations on sampled blood. In handling blood samples, precautions must be taken to prevent loss of carbon monoxide. Tubes must be completely filled, covered, and protected from light. In evaluating blood concentrations, it is important to consider the "normal" values, especially in smokers in whom the control values of carbon monoxide may be as high as 8% saturation.

Failures in the exhaust system have been responsible for several cases of seepage of carbon monoxide into the cockpit. In some instances, this failure has consisted of cracks in the exhaust stacks from excessive vibration. In others, the gas has gained access to the cockpit through worn packings around the collector rings. In aircraft equipped with exhaust heaters, contamination has occurred from wear of the intensifier tube assembly and from defects caused by enemy fire. Because of the latter possibility, pilots are advised not to use their exhaust heaters in combat.

Carbon monoxide is absorbed exclusively through the lungs. The rate of uptake depends upon the rate and depth of respiration, the concentration of carbon monoxide in the air, the duration of exposure, the blood volume and hemoglobin concentration, and the degree of saturation of the blood with carbon monoxide.

At rest or during light activity, about 50% of the inspired carbon monoxide is taken up by the blood initially. Of the gas which actually enters the alveoli, a much larger proportion, about 90%, is retained by the blood. Carbon monoxide has a greater affinity to hemoglobin than does oxygen and the rate of dissociation of carboxyhemoglobin is much slower.

The affinity of human hemoglobin for carbon monoxide is 210 to 300 times its affinity for oxygen. The formation of carboxyhemoglobin is favored by a reduction in the concentration of oxygen in the air and by an increase in the temperature or humidity. When any of these changes occur or the amount of physical activity is increased, the toxic effects of carbon monoxide occur more quickly.

Strictly speaking, carbon monoxide is not a poison. It acts rather as a tissue asphyxiant, accomplishing this function by a twofold action. First, by combining with the hemoglobin to the partial exclusion of oxygen, it interferes with the uptake of oxygen by the blood. Secondly, it causes a shift to the left of the oxygen dissociation curve of the remaining hemoglobin and, also, makes the curve less S-shaped and more hyperbolic (Haldane effect). Thus, hemoglobin which is partially saturated with carbon monoxide clings to its oxygen with increased tenacity with the result that less oxygen is liberated to the tissues. Both phenomena combine to produce hypoxia.

The structures which are most sensitive to anoxia, such as the central nervous system and the myocardium, are the first to be affected. In cases of acute poisoning, there are fewer symptoms since unconsciousness soon occurs. The greatest individual variation in symptoms is encountered in those cases in which the exposure has been less severe, yet more protracted and repeated.

Blood concentrations of carbon monoxide up to 10% saturation usually cause no symptoms under ordinary conditions (sea level, moderate physical activity, normal hemoglobin). With increasing blood saturation, symptoms appear usually in the sequence shown in table 21-2. The approximate times required for the appearance of symptoms with exposure to varying concentrations of carbon monoxide are shown in table 21-3.

The hazard of carbon monoxide increases sharply at altitudes above sea level. Mild degrees of hypoxia caused by increasing altitude and small amounts of carbon monoxide, each of which might be harmless alone, may, when combined, cause serious impairment of efficiency as a result of the additive hypoxic

TABLE 21-2. SYMPTOMS OF VARIOUS BLOOD CONCENTRATIONS OF CO AT SEA LEVEL

% Saturation	Symptoms
Less than 10	None
10	No appreciable effect except shortness of breath on vigorous muscular exertion.
20	Shortness of breath, even on moderate exertion; slight headache.
30	Decided headache; fatigability; irritability; impaired judgment.
40 to 50	Headache; confusion; collapse; fainting.
60 to 70	Unconsciousness; respiratory failure, and death if exposure is prolonged.
80 or more	Rapidly fatal.

(Reproduced from "Noxious Gases and the Principles of Respiration Influencing Their Action," ACS No. 35, by Y. Henderson and H. W. Haggard, by permission of Reinhold Book Corporation, a subsidiary of Chapman-Reinhold, Inc., New York, 1943.)

TABLE 21-3. EFFECTS OF VARIOUS CONCENTRATIONS OF CO IN AIR AT SEA LEVEL

PPM CO in Air	Effects
200	Possibly headache, mild frontal in 2 to 3 hours.
400	Headache, frontal, and nausea after 1 to 2 hours; occipital after 2 1/2 to 3 1/2 hours.
800	Headache, dizziness and nausea in 3/4 hours; collapse and possibly unconsciousness in 2 hours.
1,600	Headache, dizziness and nausea in 20 minutes; collapse, unconsciousness, possibly death in 2 hours.
3,200	Headache and dizziness in 5 to 10 minutes; unconsciousness and danger of death in 30 minutes.
6,400	Headache and dizziness in 1 to 2 minutes; unconsciousness and danger of death in 10 to 15 minutes.
128,000	Immediate effect; unconsciousness and danger of death in 1 to 3 minutes.

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effects. If a minimum blood O_2 saturation of 85% is required for the maintenance of flying efficiency, the ceiling at which flights may be made without oxygen is reduced to below 10,000 feet when small concentrations of carbon monoxide are present.

For example, a concentration of 0.01% (100 ppm) CO, relatively safe at ground level, reduces the oxygenation of the blood by 10.5% and at 10,000 feet, is superimposed on the reduced blood O_2 saturation occurring at this altitude, resulting in a dangerous state of hypoxia. This condition is even more serious in aircrew members who are heavy smokers with an elevated base line of 8% carbon monoxide saturation. Smoking may reduce a crew member's altitude tolerance as much as 5,000 feet.

Above 10,000 feet, when the demand oxygen is used, the dangers of carbon monoxide decrease with increasing altitude. This is due to the fact that, as a higher percentage of oxygen is obtained from the demand system with increasing altitude, less of the atmospheric air and, consequently, less carbon monoxide are obtained. Above 30,000 feet, where the demand system furnishes 100% oxygen, the inhalation of carbon monoxide is completely prevented.

Some of the carbon monoxide taken up by the blood is converted chemically to other substances in the body; the remainder is excreted as carbon monoxide in the expired air. Yet, for practical purposes, the rate of elimination depends upon the respiratory volume and the percentage of oxygen in the inspired air. Breathing pure air at sea level, after absorption of moderate amounts of carbon monoxide, clears the blood of about one-half of the gas in 1 hour. Elimination is practically complete within 8 hours. Increased amounts of oxygen accelerate the rate of excretion of carbon monoxide. When pure oxygen is breathed following exposure to the gas, the elimination time is reduced to an hour or less. Hyperbaric oxygen has been effectively used in the therapy of persons asphyxiated by carbon monoxide.

When flying personnel suspect the presence of carbon monoxide in the plane because of either the odor of exhaust gas or untoward symptoms, such as headache, nausea, dizziness or dimming of vision, they should turn off exhaust heaters if in use and don oxygen masks with the Auto-mix of the regulator turned to the "Off" or "100% Oxygen" position. By so doing, they will insure themselves of protection from carbon monoxide by excluding all cockpit air.

If breathing is weak or has ceased, definitive treatment of carbon monoxide asphyxia by medical officers should include artificial respiration, the administration of 100% oxygen, and the application of warmth to the patient placed at rest. Indicated supportive measures should be initiated as well.

Aviation Gasoline

Aviation fuel is a complex mixture of aliphatic and aromatic petroleum hydrocarbons and special additives, such as tetraethyl lead and xylidine, in varying proportions. Grades and types of aviation fuel used by the US Air Force are listed in table 21-4.

One gallon of gasoline completely evaporated will form approximately 30 cubic feet of vapor at sea level. These vapors are heavier than air. Since they are readily absorbed by the pulmonary epithelium, their toxicity is a matter of practical importance. Untoward reactions have occurred among flying personnel who have been exposed to volatilized gasoline.

The concentration of gasoline vapors that can be tolerated by man is far below that required to produce combustible or explosive mixtures with air. If the concentration of gasoline vapor in air is high, absorption by the lungs may be extremely rapid and symptoms may appear after only a few minutes of exposure. Even one-tenth of the concentration necessary to support combustion or to form an explosive mixture is harmful if inhaled for more than a short time, and causes dizziness, nausea, and headache. Large amounts act as an anesthetic and cause unconsciousness.

The tolerance level value for exposure to vapors of ordinary gasoline is about 500 parts per million or 0.05%. However, because of its content of aromatic hydrocarbons, aviation gasoline is probably at least twice as toxic. Furthermore, because of the precise and frequently complicated activities which flying personnel are required to perform, even small amounts of gasoline vapors in the plane must be considered dangerous.

When vapors are detected, there is a psychological excitability which, when coupled with a toxicological excitability, can cause poor judgment on the part of the various responsible aircrew members and have probably been the cause of some accidents attributed to pilot error. The vapors from gasoline, not being unpleasant, do not cause enough concern to the aircrew. It should, therefore, be emphasized that, when gasoline

TABLE 21-4. GRADES AND TYPES OF AVIATION FUEL USED BY THE AIR FORCE

Specification	Grade	Tetraethyl Lead (cc/gal) Maximum	Aromatics
MIL-F-5572	80 Octane 91/96 Octane 100/130 Octane 115/145 Octane	0.5 4.6 4.6 4.6	3-15% 3-15% 3-15% 3-15%
MIL-J-5616	JP-1	0	0-20%
MIL-F-5624a	JP-3 JP-4	0 0	0-25% 0-25%
MIL-3-3056	Motor Vehicle Gasoline	3	Varies by Process of Manufacture
VU-M-561	11	3	(None required by specification)

vapors are noted, the aircrew should use 100% oxygen to avoid inhalation of these fumes.

The symptoms and pathologic changes induced by gasoline are caused by both its irritant and its lipolytic actions. Acute poisoning is marked by burning of the eyes, lacrimation, and severe cerebral symptoms, such as restlessness, excitement, disorientation, disorders of speech, visual difficulties, and convulsions leading to coma and death.

Tetraethyl Lead

Tetraethyl lead, which is used as an antiknock substance, is very toxic. Poisoning from this substance may occur by absorption through the intact skin as well as by inhalation of its vapors. Unlike inorganic lead, tetraethyl lead, an organic compound, primarily has a central nervous system effect in cases of poisoning. Insomnia, mental irritability, and instability are noted. Lead encephalopathy with acute mania develops. In less dramatic cases, sleep may be broken with restlessness and terrifying dreams. Other symptoms include nausea, vomiting, muscle weakness, tremor, myalgia, and visual difficulty.

The amount of tetraethyl lead in aviation gasoline, about 4.6 cc per gal, is so small that a lead hazard through normal handling is remote. There is usually no requirement to periodically determine the lead content in the urine of workmen who refuel airplanes. Poisonings encountered in the Air Force have been the result of entering gasoline storage tanks containing concentrated amounts of tetraethyl lead within the accumulated sludge. Also, maintenance, such as welding, buffing, and grinding on engines which have burned leaded gasolines, can result in significant exposure to lead compounds.

JP Fuels

JP fuels, as used by the Air Force, are classified in three grades: JP-1, which is essentially paraffins similar to kerosene and containing up to 20% naturally occurring aromatics; JP-3, which is a mixture of one-third fuel oil, one-third kerosene, and one-third gasoline and containing up to 25% naturally occurring aromatics; and JP-4, which has a narrower distillation range with up to 25% naturally occurring aromatics.

Unlike aviation gasoline, JP fuels do not contain tetraethyl lead.

The recommended threshold limit value for JP fuel vapors has been set at 500 parts per million. Toxic effects occur below explosive levels; therefore, a toxicological problem exists even in the absence of a fire hazard.

Inhalation of vapors can result in slight narcotic effects similar to those of other hydrocarbon vapors. The vapors can cause conjunctivitis. JP fuels may contain more toxic aromatics than aviation gasoline and, therefore, should be handled with the same precautions.

Hydraulic Fluid

Two types of hydraulic fluid are currently in use in the Air Force: (1) Fluid, hydraulic, petroleum base, Spec No. MIL-O-5606, and (2) Fluid, hydraulic, castor oil base, Spec No. 3586C.

Oil, hydraulic, aircraft, petroleum base, is the hydraulic fluid that is used in virtually all US Air Force aircraft at the present time. There is only a very small usage of the castor oil base hydraulic fluid, primarily in certain trainer aircraft.

Important differences exist between the two types of hydraulic fluid with respect to the toxicity of their constituents. Fluid covered by Spec No. MIL-O-5606, consists, essentially, of a mineral oil base plus a viscosity index polymer and 0.5% tricresyl phosphate. Both of these substances are of relatively low volatility and their vapors possess a low toxicity. On the other hand, Spec No. 3586C contains, in addition to a castor oil base, diacetone, butyl cellosolve, ethylene and propylene glycol, and octyl and isoamyl alcohols in varying proportions.

The volatile constituents, especially butyl cellosolve, the glycol derivatives, and the alcohols, are toxic when inhaled. The alcohols, for example, are about 12 times as potent a narcotic as ethyl alcohol and, in addition, cause considerable irritation of the eyes and respiratory tract as well as headache and vertigo. The toxic effects of butyl cellosolve vapors also include irritation of the eyes and respiratory tract, headache, vertigo, and impairment of judgment and vision. Experimental animals have been killed within a few hours by a single exposure to air containing 3 mg per liter (about 700 ppm) of butyl cellosolve.

The toxic effects from inhaling the vapors of this hydraulic fluid are accentuated by increasing temperature or altitude which serves to increase the concentration of the vapors.

Coolant Fluid Vapors

Coolant fluid for use in liquid-cooled engines consists of ethylene glycol diluted with varying amounts of water, up to 80% according to the specific aircraft type. A small quantity of an inhibitor, designated as NaMBT, is present in the ratio of about 1 to 2,000.

Ethylene glycol is toxic when ingested. Although fairly volatile, it does not exert any important toxic effects through inhalation of its vapors. Even after continued exposure to ethylene glycol vapors over a period of several months, no deleterious effects result except moderate irritation of the respiratory passages. No instances of intoxication from coolant fluid vapors in flight have been reported.

Oil Fumes

The oil hose connections in airplanes consist of various types of adjustable clamps in contrast to the pressure-type connections used in the hydraulic system. Hose clamps occasionally break or come loose. When oil escapes on hot engine parts, smoke is often formed and finds its way into the cockpit. Several cases have been reported in which hot fumes were breathed during flight, and the symptoms that developed were similar to those of carbon monoxide poisoning, including headache, nausea, and sometimes vomiting, in addition to irritation of the eyes and upper respiratory passages. The specific chemical compounds responsible for these symptoms are not clearly defined but probably include methyl and ethyl aldehyde, acrolein, and paraformaldehyde which are the principal breakdown products of lubricating oil.

OTHER OCCUPATIONAL HAZARDS

Fire Extinguishants

There are two chemicals commonly used in aircraft as fire extinguishants. Two are used in the fixed systems: carbon dioxide, Spec No. 14069, and chlorobromomethane (CB), Spec No. 14163. Hand extinguishers on aircraft contain carbon dioxide or chlorobromomethane. CB has replaced carbon tetrachloride in hand extinguishers used on aircraft.

Carbon Dioxide. The initial effect of inhalation of carbon dioxide is noticed in concentrations of about 2%; breathing becomes labored and the total volume is increased. Depth of respiration is markedly increased at 4%. At 4.5 to 5%, breathing becomes labored and distressing to some people. Other effects at or near maximum tolerance for voluntary subjects are failure of compensatory reactions at concentrations of 5 to 10%, and marked deterioration and inability to take steps for self-preservation at concentrations exceeding 10%.

Carbon dioxide absorption will result in excitement, headache, vertigo, dyspepsia, drowsiness, weakness, dizziness, and muscular weakness. High concentrations may result in coma or death.

Chlorobromomethane (CB). This is a narcotic agent of moderate intensity but of prolonged duration. Therefore, it is apparent that acute exposures to chlorobromomethane should be avoided. Exposure to high concentrations of the vapor causes such effects as staggering, uncoordination, stupor, confusion, headache, nausea, and dizziness. Chronic toxicity is very low and adverse effects may not be expected from repeated exposures below .01% (100 ppm).

In contrast to the intensity of the narcotic action, the acute exposure to chlorobromomethane is less liable to cause necrosis of the liver, as observed with carbon tetrachloride, although it may produce fatty degeneration of the liver. The chronic toxicity of chlorobromomethane is definitely lower than that of carbon tetrachloride. The decomposed vapor is much more toxic than the undecomposed vapor. When CB is heated to decomposition, it emits highly toxic fumes of chlorides and bromides that are irritating and damaging to the lungs. Accumulations of these fumes within small spaces, such as aircraft cockpits, can lead to serious consequences.

Missile Fuels and Oxidizers

Health hazards from propellant fuels and oxidizers and safe handling procedures are outlined in various publications. However, several basic principles do bear emphasis. First, adequate safety precautions, based on an understanding of the hazards of the materials to be handled, are of primary and utmost importance. Secondly, rapid and adequate self aid and first aid following exposure to missile fuels can eliminate or vastly reduce subsequent medical treatment. Finally, the principles of mass casualty treatment for chemical or physical burns are applicable to the therapy of exposed missile fuel handlers.

Radar

Radar generators which, in certain cases, may have associated health hazards from ionizing and/or microwave radiation, are covered in other publications.

Ionizing Radiation

One area of industrial technological development has been in the use of ionizing radiation either from an X-ray source or from radioactive isotopes. This poses the problem in occupational medicine of possible personnel exposure. Industrial X-ray units may be employed on a base to examine aircraft structures for evidence of metal fatigue. The Flight Surgeon must insure that personnel working with such equipment are included in an effective monitoring program and that the equipment is used safely. Current directives provide the necessary guidelines in establishing and maintaining an adequate program.

Laser/Maser

Lasers (optical masers) are employed both in the industrial/research setting of the Air Force and operationally. Each individual type of laser has hazards peculiar to it, but all possess in common the severe eye hazards. AFR 161-24 contains guidance on the problems, hazards, and responsibilities with regard to laser operations. As additional data are accumulated in hazards in laser operations, specific Air Force publications will be issued.

Hazardous Noise Exposure

On most Air Force bases, there is a variety of equipment that can be a source of hazardous noise exposure to both military and civilian employees. The Occupational Medicine Program must insure that a program similar to the one proposed in chapter 5 of this manual, and by AFR 160-3, is fully implemented and supported.

Eye Hazards

Employees working with drill presses, grinders, sanders, and other similar types of machinery are exposed to a potential hazard of eye injury from flying debris. Additionally, many other occupational groups are exposed to potential eye hazards. To protect its employees, the Air Force supports the Occupational Vision Program (AFR 160-112). The Flight Surgeon must work closely with ground safety personnel in supporting this program. The importance of prevention as being preferred to treatment is paramount in considering eye injuries.

General Principles of Therapy

Safety manuals on emergency treatment of occupational overexposure usually advise immediate removal from exposure, self aid or first aid, and calling a physician. Therapy of massive overexposure to toxic chemicals is unsatisfactory at best.

It is extremely important that the responsible physician get the most precise, quantitative information possible on the time, degree, and duration of exposure. Such information should be made a permanent part of the medical record.

Care should be taken not to discharge a patient on the basis of "no abnormal findings" if he has been exposed to a pulmonary irritant. Pulmonary edema may occur up to 48 hours after exposure. Physical exertion often precipitates such attacks. Latent periods are also described prior to onset of convulsions from tetraethyl lead and decaborane. It is always safest to place the person on strict bed rest (in the hospital) with close medical and nursing supervision for a 24 to 48-hour period or longer. Some deaths from tetraethyl lead have occurred from self-injury—*e.g.*, jumping out of the window; thus, constant observation is necessary in such cases.

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AFR 160–124, *Application for Radioisotope Licenses.*

AFR 160–132, *Control of Radiological Health Hazards.*

AFR 161–10, *Precautionary Measures for Handling Solvents.*

AFR 161–17, *Environmental Health, Forensic Toxicology, and Radiological Health Professional Support Functions.*

AFR 161–24, *Laser/Maser Hazards.*