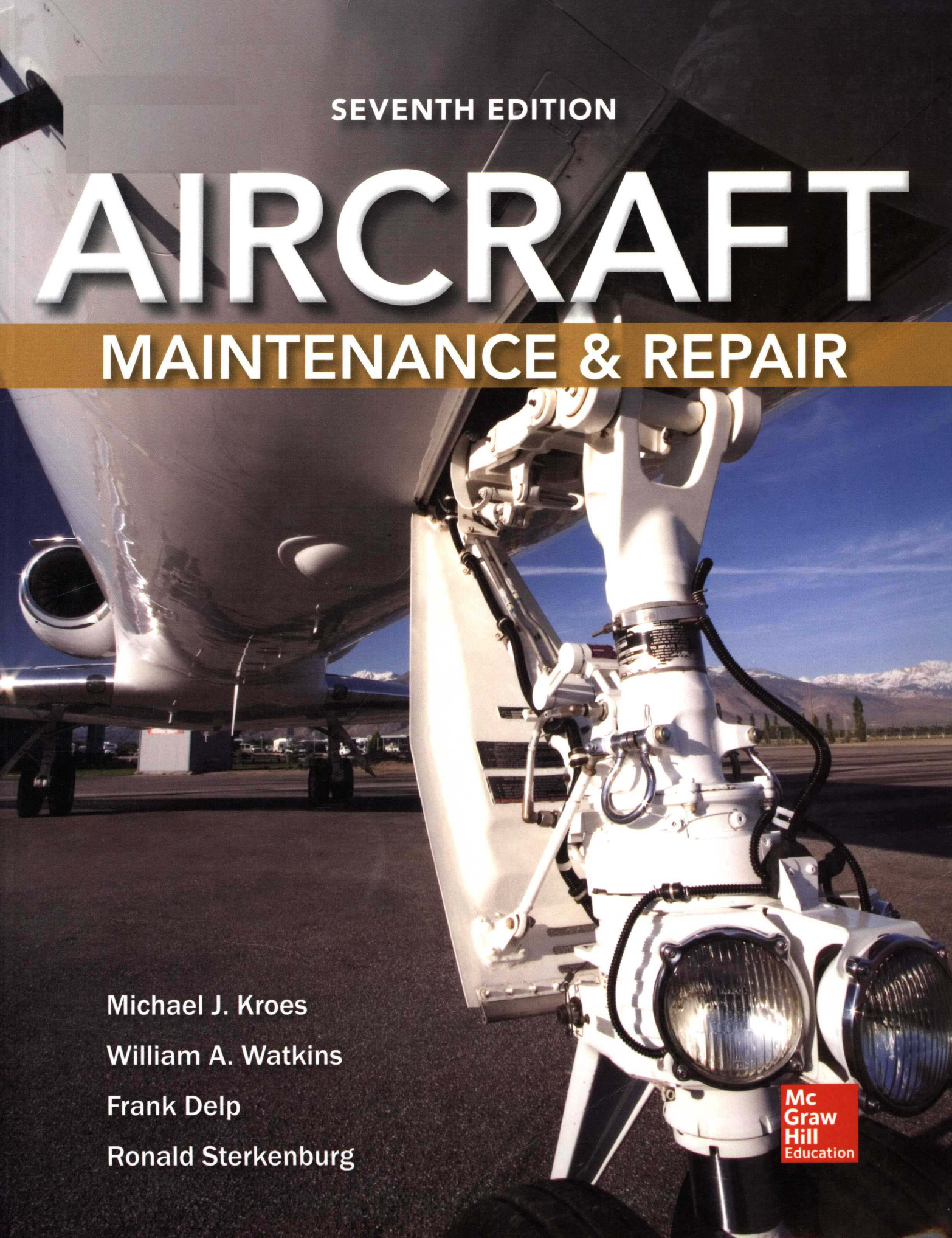
SEVENTH EDITION

AIRCRAFT

MAINTENANCE & REPAIR



Michael J. Kroes
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Mc Graw Hill Education

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About the Authors

Michael J. Kroes has been an aviation practitioner and educator for over 35 years. He has held various FAA certifications, including Airframe and Powerplant Mechanic, Inspection Authorization, Designated Mechanic Examiner, and Designated Engineering Representative, and he holds a commercial pilot license. Mr. Kroes has worked for some of the leading aviation companies, including Raytheon and Allied Signal, and has also spent 25 years as a professor and department head at Purdue University. Recognized as a leading expert on FAA technician certification, he authored a comprehensive study funded by the FAA. This study was used to develop new FAA technician certification content and guidelines. Mr. Kroes resides in Pinehurst, North Carolina.

Ronald Sterkenburg is a professor in the Aviation Technology Department at Purdue University. He is a certificated Airframe and Powerplant (A&P) Mechanic, holds an Inspection Authorization (IA), and is a Designated Mechanic Examiner (DME). Although his main research interests are in advanced composite materials for aerospace vehicles, he has published many articles, book chapters, and books on all types of aviation maintenance topics. Dr. Sterkenburg resides in West Lafayette, Indiana.

Preface to the Seventh Edition

In preparing this edition, the authors reviewed FAR Parts 65 and 147, FAA-H-8083-30 & 31, AC 43.13-1B & 2B, and manufacturers' and operators' manuals and data to ensure that all required areas of study were included.

This revised edition updates material from the previous edition relating to aircraft structures and systems on current operational aircraft. Figures, charts, and photos have been updated to reflect new technology. The advanced composite materials chapter has been completely rewritten to reflect state-of-the-art maintenance and repair information and techniques for advanced composite structures used in modern aircraft. Advanced automated systems such as ECAM and EICAS are discussed in most chapters to reflect their operation relative to particular aircraft systems. The structures chapter has been expanded with multiple examples for the calculation of bend allowance and the setup of shop equipment. The hydraulics chapter has been expanded to include the 5000-psi hydraulic systems used in some new aircraft models. A discussion of a centralized fault display system (CFDS) has been added to the troubleshooting chapter.

Michael J. Kroes
Ronald Sterkenburg

Preface to the Sixth Edition

Aircraft Maintenance and Repair is designed to provide aviation students with the theoretical and practical knowledge required to qualify for certification as FAA airframe technicians in accordance with Federal Aviation Regulations (FARs). This text covers the subjects categorized in the FARs under Airframe Structures and Airframe Systems and Components and may be used as a study text in connection with classroom discussions, demonstrations, and practical application in the shop and on aircraft.

Aircraft Maintenance and Repair is one of five textbooks in the McGraw-Hill Aviation Technology Series. The other books in the series are *Aircraft Powerplants, Aircraft Basic Science, Aircraft Electricity and Electronics*, and *Aircraft Gas Turbine Engine Technology*. Used together, these texts provide information dealing with all prominent phases of aircraft maintenance technology.

In preparing this edition, the authors reviewed FAR Parts 65 and 147, Advisory Circular (AC) 65-2D, AC 65-15A, and AC 43.13-1A & 2A to ensure that all required areas of study were included. Related FARs and the recommendations and suggestions of aviation maintenance instructors, aircraft manufacturers, aviation operators, and maintenance facilities were given full consideration in the revision of this text.

This revised edition retains material from the previous edition relating to structures and systems that are employed on current operational aircraft. In addition, information dealing with expanding and emerging maintenance-related technologies has been incorporated to provide a comprehensive source of information for the aviation student, technician, and instructor. Two new chapters have been added. They include information about the identification of hazardous materials, their storage, use, and disposal. Troubleshooting has been identified as its own process and is discussed generically.

Key revisions to and the expansion of the previous edition include designing repairs so that the repairs are repairable and techniques in designing repairs based upon the mechanical properties of the materials. Also, bend allowance calculations and terminology have been revised to follow the more traditional industry conventions.

Each topic covered in this series of texts is explained in a logical sequence so students may advance step by step and build a solid foundation for performing aviation maintenance activities. Students' understanding of the explanations and descriptions given in the text should be enhanced by the use of numerous photographs, line drawings, and charts. Review questions at the end of each chapter enable students to check their knowledge of the information presented.

In addition to being a classroom and shop instruction text, the book is valuable for home study and as an on-the-job reference for the technician. The materials in this text and in others in the series constitute a major source of technical knowledge for technical schools and colleges and universities.

Although this text is designed to provide information for the training of aviation personnel, the user must realize that product and aircraft manufacturers establish guidelines and procedures for the correct use and maintenance of their product or aircraft. Therefore, it is the responsibility of the user of the text to determine and follow the specific procedures recommended by the manufacturer when handling a specific product or when working on a specific aircraft or component.

Michael J. Kroes
William A. Watkins

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AUTHORS' NOTE

Although every effort has been made to ensure that the regulations and standard practices referred to in this text are current, recommended safety practices and associated regulations are always subject to change. Since the distribution of this book is not controlled, revisions to all existing copies is impossible. As a result, the technical information, such as material safety data sheets, is included only for educational purposes and should not be used in application. In addition, there are applications that are unique in one aspect or another. In these cases the recommended practices may differ from those used as general industry standard. Before attempting any activity, the aviation maintenance technician should review the most recent regulations, recommended practices prescribed by their employer, the associated equipment manufacturer's recommendations, and the information provided by the manufacturers of any supplies being used.

INTRODUCTION

There are many specialized careers available to today's aviation maintenance technician. As with any technical career, each career path has associated with it activities that can subject the technician and others to varying degrees of harm if performed without care. This chapter is intended to help the aviation maintenance technician identify potentially hazardous materials and ways in which the potential for harm can be minimized.

Today there are tens of thousands of products used in industry, with more being developed each day. Numerous governmental agencies (and, therefore, hundreds of governmental regulations) control the development, safety requirements, and health and environmental issues related to these products. Key among these agencies are the Consumer Product Safety Commission (CPSC), the Food and Drug Administration (FDA), the Department of Transportation (DOT), the Environmental Protection Agency (EPA), and the Occupational Safety and Health Administration (OSHA). Although all these agencies have some effects that may be felt in the aviation industry, the primary impact results from the last three organizations mentioned.

Some Federal Air Regulations (FARs) refer to the DOT standards in their text and use these standards as the criteria with which the aviation industry must comply. In addition, as users of potentially dangerous chemicals, the aviation industry must comply with both the regulations of the EPA as they relate to environmental concerns and OSHA as their usage relates to the safety and health of its employees.

Since the aviation industry is by its nature predominantly interstate commerce, most businesses in the aviation industry are subject to federal regulations. In addition, most state and some local governments have also passed safety and environmental related legislation that parallels or supplements federal legislation. As a result, the regulations associated with each are quite similar. Regardless of which jurisdiction applies to the operations of the aviation business, the operation must comply with some type of hazardous-materials regulation. In some instances, more than one jurisdiction may control the operations of the business.

Because of the vastness of this subject area and the general duplication of regulations between federal, state, and local governments, discussions in this chapter are limited to federal regulations and generic handling of hazardous materials. In addition to the information found in this chapter, in later chapters the aviation maintenance technician will find more safety data related to the specific types of equipment and/or processes as they are discussed throughout the text.

HAZARDOUS MATERIALS

The aviation maintenance technician frequently must work in potentially dangerous environments. In many cases, particularly when dealing with hazardous materials, the technician may not easily recognize those hazards. Some of these dangerous environments may be caused directly by the materials with which the aviation maintenance technician must work. In addition, exposures may be caused by other activities

occurring in the area that are not directly related to the technician's activities.

Hazardous materials are typically grouped into three categories: *chemical agents,* and *physical* and *biological hazards.*

Chemical Agents

Within the **chemical agents** category, four classes exist. Comprehensive Loss Management, Inc., a professional developer of and consultant for safety and health awareness systems headquartered in Minneapolis, Minnesota, has trade-marked the acronym **FACTOR**™ to help remember the classes of chemical agents. Much of the information in this chapter comes from and is included in their programs. Because each class of chemical agent requires different usage, handling, and storage techniques, it is important that the aviation maintenance technician be able to recall and identify each of these classes. FACTOR™ stands for

Flammable
And
Corrosive
Toxic
Or
Reactive

The two outside letters of the acronym FACTOR, F and R (flammable and reactive), become hazardous primarily after some outside event, condition, or substance interacts with them. For example, the necessary components for a fire to occur are fuel, oxygen, and heat. In that relationship, **flammables** are the fuel, and heat and oxygen are the outside agents. **Reactives**, when combined with certain other materials, are capable of generating heat and/or gases, causing an explosion.

The inside letters of the acronym, C and T (corrosives and toxins), on the other hand, act directly on the human body when exposure occurs. Exposing the skin, eyes, and other mucous membranes (such as the nose) to these elements can cause varying degrees of harm. **Toxic agents** cause poisoning. Aviation maintenance technicians should be particularly concerned when using toxic agents, because the ultimate effects of toxic poisoning are frequently delayed. It may take weeks, months, or even years for the poisoning to become apparent; because the toxic poisons are capable of using the bloodstream to move through the body, the cause-and-effect relationship may not be easily recognized.

As a general rule, when working with flammable and reactive agents, to avoid hazardous situations the aviation maintenance technician first needs to be concerned with exposing the agents to outside materials and conditions. Personal exposure to corrosive and toxic agents is the primary concern when dealing with toxins and corrosives. Therefore, the personal safety equipment used with corrosive and toxic agents should be designed to limit contact and/or exposure. Personal safety equipment designed for use with flammable and reactive materials is designed to limit heat exposure or impact, such as flying objects in the case of an explosion. In all cases, the recommended safety equipment recommended by the agent manufacturer, the employer, or the instructor should always be used.

Table 1-1 is a partial listing of frequently used chemical agents found in the aerospace industry. The aviation maintenance technician should be aware of the labels on the materials found in the work area and read them carefully.

TABLE 1-1 Frequently Used Chemical Agents

Listing of Commonly Found Hazardous Materials in an Aviation Environment*		
Aircraft Systems	*Aircraft Servicing*	*Component Shops*
System Liquids	Lubricants	Inspection
Gasolines	Dry lubricants	Liquid penetrants
Jet fuels	Spray lubricants	Dye penetrants
Hydraulic fluids	Greases	Welding
Brake fluids	Solvents and Cleaners	Argon gas
Anti-ice additives	Methyl ethyl ketone	Hydrogen gas
Gases	Toluene	Oxygen gas
Freons	Engine cleaners	Acetylene gas
Nitrogen	Carburetor cleaners	Fluxes and pastes
Oxygen	Paints and Primers	Other
Halons	Paint strippers	Compressed air
Others	Primers	Glass beads
Alcohols	Doping products	Bluing and thinner
Methanol	Lacquers	Quenching fluids
Battery acids	Enamels	Muriatic acid
Glycol	Epoxies	Locking compounds
Baking soda	Adhesives	Anti-seizing compounds
Degreasers	Fiberglass resins	Mineral spirits
Disinfectants	Gasket adhesives	Cutting fluids
Squibs	Rubber adhesives	Soldering fluxes

*This listing is a partial generic listing of potentially hazardous materials. The aviation maintenance technician should always refer to label instructions and warnings as well as MSDS data.

Flammables (and Combustibles)

Flammables are materials that may easily ignite in the presence of a catalyst such as heat, sparks, or flame. They may be in any of the three physical forms: solid, liquid, or gas. Combustible liquids are very similar to flammable liquids, but they are not as easy to ignite.

Frequently found **flammable** or **combustible** materials in the aviation industry include *fuels, paint-related products, alcohols, acetone, toluene,* and some *metal filings.*

Generally Recommended Personal Safety Equipment

- Fire-retardant clothing
- Fire extinguisher

Handling and Storage

- Limit access to open flames, sparks, hot surfaces, etc. ***Note:*** Static electricity may produce sparks. To avoid sparks, containers should be grounded.
- Limit quantities to the minimum needed to accomplish the desired task.
- Store the materials in approved containers only and in designated areas only.
- Store flammable toxins and corrosive toxic materials separately. The corrosive gases could attack the flammable containers, eventually leading to a leak of flammable materials.

Typical Emergency Procedures

- Turn off electrical equipment or any other potential source of sparks.
- Attempt to close shutoff valve(s).
- Remove container(s) from the area.
- For large spills, leave the area immediately and notify your supervisor.
- In case of direct contact with skin or eyes, rinse immediately with water.
- If toxic substances are inhaled, go to a fresh-air area.
- If contact is made through clothing, remove wet clothing and store it in a proper container.
- Do not attempt to remove the substance with compressed air.

Corrosives

Corrosive materials are materials that can react with metallic surfaces and/or cause burning of the skin.

Frequently found corrosives in the aviation industry include *acids* and *bases*, such as battery acids and metal-cleaning solutions. Strong acids are most normally found in a liquid form, whereas bases tend to come in powdered form.

Generally Recommended Personal Safety Equipment

- Gloves, aprons, respirator, face shield or goggles, and, sometimes, protective footwear.

Handling and Storage

- Containers must be corrosive resistant.
- Eye (goggles and/or face shields) and skin protection (such as gloves) should always be worn.
- Never add water to acid.
- Acids and bases should be stored separately.
- Eye washes and showers should be easily accessible to the work area.
- Flammable toxins and corrosive toxic materials should be stored separately. The corrosive gases could attack the flammable containers, eventually leading to a leak of flammable materials.

Typical Emergency Procedures

- Remove any corrosives that have come in contact with your skin or eyes by rinsing with fresh water (approximately 15 minutes).
- Remove any contaminated clothing.
- Go to fresh air area.
- Ventilate area.
- Check safety equipment before attempting to stop the flow of spillage by creating a dam.
- If swallowed, DO NOT INDUCE VOMITING. Drink large amounts of water. Seek medical attention immediately.

Toxins

Toxins are generally defined as any substance that can cause an illness or injury. The effects of toxins, unlike flammables and corrosives, may appear all at once (called acute effects) or may build up over time with additional exposure (chronic effects). Some toxins may dissipate over time when further exposure is eliminated, while others remain in a human's system, even after death.

Frequently found toxins in the aviation industry may be grouped into eight categories.

1. *Solvents and thinners for bluing (such as Dykem), paints, ketones, and adhesives.*
2. *Solids such as metal dust or asbestos.* Compressed air should never be used to clean metal dust from equipment or clothing. The use of compressed air may result in minute particles of material being embedded in the pores of the skin.
3. *Machine lubricants, cutting fluids, and oils.*
4. *Gases such as carbon dioxide or nitrogen.* These gases may not only possess a toxic nature but also displace the oxygen normally found in the air.
5. *Polymers, epoxies, and plastics.* Although not normally toxic in their final form, these materials possess toxic properties during the fabrication process.
6. *Sensitizers, such as epoxy systems.* Such materials react with and may destroy portions of the body's immune system. The effects of sensitizers may be cumulative, so minimal levels of exposure are recommended.
7. *Carcinogens.* Carcinogens may cause changes in the genetic makeup of a human cell, resulting in cancer.

Although the use of carcinogens is rare in the aviation industry, aviation maintenance technicians associated with cargo aircraft should pay particular attention to the cargo manifest before cleaning spillage.

8. *Reproductive hazards, such as carcinogens.* These hazards are rare in the aviation industry. Such materials may either interfere with the reproductive process (as in the cases of DBCP) or affect the developing process of the fetus (such as dimethyl acetamide).

Generally Recommended Personal Safety Equipment

- Gloves, aprons, respirator, face shield or goggles, and, sometimes, protective footwear are recommended.
- Be sure to use the environmental control systems that may already be in place, such as ventilation fans and filters.

Handling and Storage

- Minimize the release of toxic agents into the environment by capping all containers and storing them in properly ventilated areas. When toxins are used in open containers, such as dip tanks and trays, their surface areas should be kept to a minimum in order to reduce the rate of evaporation into the surrounding environment.
- Flammable toxins and corrosive toxic materials should be stored separately. The corrosive gases could attack the flammable containers, eventually leading to a leak of flammable materials.

Typical Emergency Procedures

- If there is any doubt in your mind regarding the degree of toxicity of the substance spilled, **LEAVE THE AREA IMMEDIATELY AND NOTIFY YOUR SUPERVISOR**.
- Generally speaking, if the spillage is less than 1 gal, it may be cleaned up by wiping it up with absorbent materials.

Reactives

Reactive agents are those materials that react violently with other materials (not necessarily solids). The reactions that may take place range from violent explosions to the emission of heat and/or gases.

The following reactives are frequently found in the aviation industry:

1. Oxidizers, which add oxygen to situations where high levels of heat and burning are present
   a. Peroxides
   b. Perchloric acid and chromic acid
   c. Halogens, such as bromine and iodine

2. Water-reactive materials, such as lithium, react with water and form hydrogen gases, which are very explosive.

Examples of incompatible reactive materials include

- Cyanides (frequently used in plating) and acids
- Chloride bleach and ammonia (this combination forms highly toxic chlorine gas)

Generally Recommended Personal Safety Equipment

- Gloves, aprons, respirator, and face shield or goggles are suggested.
- Be sure to use the environmental-control systems.

Handling and Storage

- Store reactive materials in a location separate from other materials. Always review the MSDS (material safety data sheet) for incompatible materials.
- Many reactives are both toxic and corrosive.

Typical Emergency Procedures

- Shut down electrical equipment whenever possible.
- If there is any doubt in your mind regarding the degree of reactivity and toxicity of the substances involved, **LEAVE THE AREA IMMEDIATELY AND NOTIFY YOUR SUPERVISOR.**

Material Compatibility with Chemical Agents

Before leaving the topic of chemical agents, it is important to realize that although some materials meet the minimum standards for protective equipment in particular applications, other materials surpass these requirements. Table 1-2 lists various types of protective equipment materials and their relative effectiveness when used with common chemical agents. Although Table 1-2 provides generally accepted data, the aviation maintenance technician should always consult the MSDS, discussed later in this chapter, for specific protective equipment requirements.

Physical Hazards

Physical hazards are those to which the aviation maintenance technician is exposed that are usually caused by the use of some type of equipment not directly controllable by the technician. Typically, this type of hazard is generated by the operation of equipment that can be detected by the human senses. However, many physical hazards that fall into this classification are not detectable by the human senses. These hazards include X rays, microwaves, beta or gamma rays, invisible laser beams, and high-frequency (ultrasonic) sound waves.

Compressed liquids and gases, such as welding oxygen and acetylene, aviator's breathing oxygen, nitrogen, and hydraulic accumulators, present another physical hazard to the aviation maintenance technician. Although some of these substances by themselves present hazards as chemical agents, placing them under pressure may create another unique hazard.

OSHA requires that areas where this exposure exists be clearly marked and that individuals exposed to these hazards