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Biomedical Equipment Journeyman

Volume 2. Safety, Tools, and General Test Equipment

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THIS SECOND VOLUME of CDC 4A251A, *Biomedical Equipment Journeyman*, provides foundational instruction you need to safely and effectively perform your job.

Unit 1 covers many areas related to safety as a biomedical equipment technician. These topics include occupational safety and health, 4A2X1 specific hazards, and medical equipment quality assurance.

Unit 2 provides information to equip you with the knowledge of tools and techniques and how to properly use hand and power tools as well as the safety principles and precautions; it also covers some techniques for plumbing repairs and electronic soldering.

Unit 3 gives you a good working knowledge of general test equipment, including how to use electronic measurement instruments and other general test equipment, such as multimeters, oscilloscopes, manometers, and electrical safety analyzers.

A glossary is included for your use.

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Company	Literature	CDC Figure Number
Sparkfun, Inc.	How to Solder: Through Hole Soldering, 2017	2–40 through 2–42, 2–50
	How to Use an Oscilloscope, 2017	3–21
Fluke Corporation	80 Series V Multimeter User Manual, 2008	3–2 through 3–9
Fluke Biomedical	ESA620 Electrical Safety Analyzer User Manual, 2015	3–29
Tektronix, Inc.	XYZs of Oscilloscopes, 2016	3–10 through 3–20, 3–22 through 3–24, 3–26, 3–28

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NOTE:

In this volume, the subject matter is divided into self-contained units. A unit menu begins each unit, identifying the lesson headings and numbers. After reading the unit menu page and unit introduction, study the section, answer the self-test questions, and compare your answers with those given at the end of the unit. Then complete the unit review exercises.

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THERE IS NO DOUBT that accidents cause waste! Often, it involves the loss of highly trained technicians, essential materials, and/or sophisticated equipment. We have had biomedical equipment technicians (BMET) lose fingers, receive severe thermal burns, and experience electrical shocks by high-voltage systems. Safety is everyone's responsibility and not solely a management function. As you perform your duties, it is important to remember to do it the safest way possible. This might not sound like an exciting approach to life, but it could give you time to enjoy a longer and happier one. The first section of this unit covers occupational safety and health principles and how they relate to BMETs.

1–1. Occupational Safety and Health

Employee safety is a major concern in the Department of Defense (DOD) workforce. You will work on a variety of equipment and, while this is one of the benefits of being a BMET, it in turn, exposes you to several hazards. This section will look at some important factors of general safety principles, equipment hazards, and the Air Force Occupational Safety and Health (AFOSH) program, which is very large and covers many areas and topics. Also, mishap and hazard reporting and general Military Treatment Facility (MTF) safety are also addressed. Fortunately, you do not have to be an expert in the overall AFOSH program, but you do need to know how it applies to you as a BMET.

201. Safety principles and responsibilities

Some days working in an MTF can become quite hectic for BMETs. When work is overwhelming and you are focusing on getting the job done, it can be easy to forget about safety. However, we must never forget that safety is the most important aspect of any task, because if we are injured or incapacitated, we will not be able to do the job at all. In this lesson, we will discuss general safety principles, key base agencies' responsibilities, and some important publications that apply to you.

AFOSH program

The Occupational Safety and Health Administration's (OSHA) safety guidance, published in the Department of Labor 29-series Code of Federal Regulations (CFR), provides that workers have a safe and healthy workplace in both the federal and private sectors. OSHA dictates what must be accomplished in the workplace but not necessarily how or by whom. OSHA's *only* concern is worker safety and health. Section 19 of OSHA directs federal agencies to have and use comprehensive occupational safety and health programs consistent with those areas in OSHA that apply to the civilian workforce. The Air Force created its own occupational safety, fire prevention, and health program, which is AFOSH, to comply with this requirement.

The AFOSH program's primary objective is to prevent the loss of life *and* property based on trends or past history, including facility safety and loss reduction. AFI 91–203, *Air Force Consolidated Occupational Safety Instruction*, defines the Air Force's *minimum* safety, fire protection, and occupational health standards. It is important to note that your major command (MAJCOM) may have more stringent requirements than AFI 91–203 that you must follow. Ensure you are familiar with your local policies in addition to related Air Force policies.

Base organizations

All personnel that serve in the USAF help it to achieve its safety mission. You need to be aware of some base organizations that play key roles in providing program oversight for the Air Force Safety mission. The major three organizations are installation ground safety, Bioenvironmental Engineering (BE), and public health (PH).

Installation ground safety

This organization manages all on- and off-duty safety programs and oversees the mishap prevention program. It works in coordination with your unit commander and unit safety representative, which could be you, to satisfy the safety needs. An installation's ground safety office programs emphasize the prevention of personal injury and property damage. Some of the concerns include:

- personnel injuries, including on-duty and off-duty mishaps;
- physical structure problems, such as buildings, sidewalks, or streets;
- mishap investigations and reporting, including those involving machinery; and
- vehicle accidents.

BE

The BE office tests the workplace environment and monitors personnel for exposure to a variety of environmental conditions. While evaluating your work section, you or another technician may wear an air sampler, noise dosimeter, or x-ray thermoluminescent dosimeter (TLD) badge to analyze and monitor your work environment. The BE office conducts Industrial Hygiene Routine Surveillance at a frequency determined by the risk category assigned to your shop. BEs also assess the following:

- Chemicals (type, amount, and frequency of use).
- Radiation (ionizing and non-ionizing).
- Personal protective equipment (PPE).
- Hazardous noise.
- Ventilation.
- Heat stress.
- Ergonomics.
- Radio frequency (RF).
- Laser radiation.
- Ultraviolet radiation.

PH

PH investigates all Air Force-related occupational and environmental illnesses, to include food-borne and vector-borne illnesses. It ensures personnel receive appropriate pre-employment, periodic, and termination occupational examinations and conducts occupational audiometric evaluations. PH also conducts shop visits at the discretion of the Occupational & Environmental Health Working Group (OEHWG) and provides administrative oversight to the Aeromedical Services Information Management System (ASIMS) program. This consists of gathering data, producing rosters, and providing reports for Primary Care management teams regarding Individual Medical Readiness

(IMR) requirements. PH also plans and conducts deployment medicine programs and oversees medical clearances for all deploying personnel (pre- and post-), which includes:

- Acquired Immune Deficiency Syndrome (AIDS) testing,
- Tuberculosis (TB) testing, and
- pregnancy testing.

You need to report all suspected problems in any area of safety or health to the most appropriate agency. You will find that some of the base agency responsibilities in maintaining safety and health overlap between installation ground safety, BE, and PH. If you are trying to set up a new requirement or maintain an existing program, these organizations are your best sources of information and guidance.

Safety publications

There are many sources of guidance on safety. It is important for you to know where to obtain this information. As a BMET, you will use a variety of sources, to include Air Force instructions (AFI), commercial publications, federal agencies' guidance, and equipment manufacturers' literature. It is important to remember that although you will use different sources, you must always be sure to comply with the AFIs.

AFIs

AFIs provide guidance that meet or exceed regulatory requirements. The AFIs often take it a step further and cover areas not addressed by civilian or federal agencies, such as unique military equipment, systems, and operations. The best way to acquire AFIs is through the Air Force e-Publishing website. The requirements in AFIs are mandatory and apply to all USAF organizations, including Air Force Reserve Command (AFRC) units and Air National Guard (ANG) military and civilian personnel.

AFI 91–203

The Air Force used to publish 22 separate AFOSH standards, which made locating information quite difficult. Then, in 2012, one publication consolidated the separate standards into what is now AFI 91–203. The purpose of this AFI is to provide guidance in creating a safe and healthy workplace for personnel, ensuring OSHA compliance, and providing a uniform safety program for the Air Force. You will spend most of your time in this AFI for work-related safety issues. Some important topics covered in AFI 91–203 are:

- Physical hazards.
- Human factors.
- Manual materiel-handling and lifting techniques.
- Housekeeping.
- Fire protection and prevention.
- Electrical safety.
- Emergency shower and eyewash units.
- Safety color coding, labeling, and marking for piping systems.
- Confined spaces.
- Mishap prevention signs and tags.
- Computer and automatic data processing equipment.
- Jewelry safety.
- Office safety.
- Tools and machinery safety.

- PPE.
- Hazardous energy control (lockout and tagout [LOTO]).
- Flammables and combustibles.
- Welding.
- Batteries (maintenance, handling, and storage).
- Compressed gases.
- Liquid nitrogen.
- Radiology.

AFI 91–202, The US Air Force Mishap Prevention Program

This instruction establishes the Air Force policy governing the mishap prevention program. The purpose of the Air Force Mishap Prevention Program is to minimize the loss of Air Force resources and to protect Air Force personnel from death, injuries, or occupational illnesses by managing risks on- and off-duty. It also provides guidance on risk management (RM), hazard identification and abatement, and work center–level responsibilities.

AFI 91–204, Safety Investigations and Reports

In the unfortunate event that an accident does happen, this instruction provides guidance that is common to investigating and reporting Air Force mishaps. It identifies the forms used to report mishaps and explains how to coordinate the reports.

Commercial publications

Several commercial publications are invaluable to the BMET career field. Two of the main ones we discuss are the National Fire Protection Association (NFPA®) and the Compressed Gas Association (CGA®)

NFPA®

The NFPA® publishes over 300 codes and standards on fire and electrical-related hazards. The most applicable standards for BMETs are as follows:

- NFPA® 30, *Flammable and Combustible Liquids Code*.
- NFPA® 70, *National Electrical Code®*.
- NFPA® 70B, *Recommended Practice for Electrical Equipment Maintenance*.
- NFPA® 70E, *Standard for Electrical Safety in the Workplace®*.
- NFPA® 77, *Recommended Practice on Static Electricity*.
- NFPA® 99, *Health Care Facilities Code.*
- NFPA® 101, *Life Safety Code®*.

NFPA® 99 and NFPA® 101 directly relate to patient and personnel safety in the medical facility. These serve as primary standards for BMETs in the MTF.

CGA®

The CGA® publishes guidance for the safe use, transport, and storage of compressed gases. Medical equipment repair shops should consider having the following CGA® pamphlets on hand:

- C–9, *Standard Color Marking of Compressed Gas Containers for Medical Use*.
- G–4.1, *Cleaning Equipment for Oxygen Service*.
- M–1, *Standard for Medical Gas Supply Systems at Health Care Facilities*.
- P–2, *Characteristics and Safe Handling of Medical Gases*.

In addition to the NFPA® and CGA®, the following commercial sources have safety information on various areas related to healthcare and medical equipment:

- Association for the Advancement of Medical Instrumentation (AAMI).
- American National Standards Institute (ANSI).
- American Society for Testing and Materials (ASTM).
- Clinical and Laboratory Standards Institute (CLSI).
- Institute of Electrical and Electronics Engineers (IEEE).
- International Electrotechnical Commission (IEC).
- National Council on Radiation Protection (NCRP).
- National Electrical Manufacturers Association (NEMA).
- Underwriter's Laboratories (UL).

Safety requirements are often established or influenced from federal agency guidance. The two main ones that affect medical equipment are the Food and Drug Administration (FDA) and the CFR.

Equipment manufacturer's literature

The safety guidance discussed so far is general and covers subjects associated with the MTF environment or medical equipment, and although very helpful, no general guidance can provide more detailed information about the hazards of a specific equipment item than the manufacturer of that equipment. Most manufacturers are careful to identify any potential hazards associated with installing and using their equipment.

Carefully read and follow the safety advice of any equipment manufacturer. Additionally, equipment users should receive manufacturer safety advisories during in-service training sessions. Appropriately mark all equipment with safety precautions, and ensure personnel use required safety gear when operating equipment. Most accidents happen because of errors made by people. They range from improperly operating equipment to not wearing proper protective equipment. Maintaining all your facility's equipment in a safe condition and educating the staff on proper usage are significant steps to prevent accidents from occurring in your MTF.

The safety publications covered in this unit provide excellent guidance for workplace safety. A comprehensive list of guidance publications used by the medical maintenance career field is in the 4A2X1 Career Field Education and Training Plan and in AFI 41–201, *Managing Clinical Engineering Programs.*

The publications listed are essential for operating an effective medical equipment maintenance program. Maintain a current file of safety publications in your shop, and have newly assigned personnel overview the contents of each as part of their training.

General safety precautions

The Air Force attempts to reduce accidents by providing a safe workplace and educating workers on accident prevention. Unsafe acts or conditions cause most accidents due to people being unaware or ignoring them. The common denominator is people, which is why you must take an active role in safety. To do so, you must possess safety knowledge and the correct attitude about safety. Developing a good safety attitude is two-fold: first, realizing that you are not invincible and knowing that accidents can happen to you; second is taking responsibility to correct unsafe conditions when you discover them. By having the knowledge and right attitude, you can help prevent most accidents on the job.

Injuries to military personnel cost the government money and duty time. Even worse, serious accidents can cost Air Force members the use of limbs, loss of eyesight, and even loss of life. Many accidents happen on the job and most are preventable. To reduce the chance of injuries on the job, the

Air Force requires supervisors to educate personnel on the hazards of their job. All jobs have specific hazards associated with them and biomedical equipment maintenance is no exception.

You will encounter many potentially hazardous situations during your career. Adhere to proper precautions when maintaining x-ray systems, lasers, and nuclear medicine systems to prevent the potential for severe injuries. Even simple electronic equipment have the potential to deliver an electrical shock or cause injury from moving parts, such as a cooling fan blade. Never take safety for granted, no matter how simple the task. Keep these basic safety principles in mind and have a good attitude about safety as you perform your duties, and you will help reduce the chances of accidents occurring.

202. Mishap and hazard reporting

Despite all the efforts to make your workplace a safe and healthy environment, mishaps will still happen. In this lesson, we will cover how to report accidents and hazards.

Mishap reporting

The purpose for reporting mishaps is solely to prevent future mishaps. Fortunately, most mishaps are only minor incidents, causing only slight injuries or minor damages with easy repairs. The decision to report a mishap is sometimes unclear. We will differentiate between reportable and nonreportable mishaps and outline the process for handling and reporting mishaps.

Reportable versus nonreportable mishaps

The installation ground safety office uses the standards established in AFI 91–204, *Safety Investigations and Reports,* to determine if a mishap is reportable. The Air Force defines a mishap as an unplanned occurrence that results in damage to property or injury to personnel. There are two factors used to classify mishaps: (1) total dollar value and (2) extent of injuries involved.

A reportable mishap is any mishap involving active duty personnel (including Title 10 and Active Guard and Reserve [AGR]), whether on- or off-duty, that results in damage to government property or personal injury that requires medical attention. DOD civilians and inactive military members (Title 32) must only report a mishap if it occurs on-duty and caused by Air Force operations. There is no requirement to report any other type of mishap. Contact your installation ground safety office if there is ever any doubt on reporting requirements.

Handling and reporting procedures

Whenever you witness, or are involved in a mishap, your primary concerns are to immediately remove accident victims, and potential victims, from all hazardous situations and to render emergency first aid. Your next consideration is to help contain the situation that caused the mishap, if you can do so without unnecessarily exposing yourself or other personnel to danger. Otherwise, clear the area and call emergency personnel to the scene as quickly as possible.

Notify the supervisor of any injured personnel immediately after a mishap. Convey the name and rank of the injured party, time and location of the mishap, and the most detailed description you can provide of the injury or mishap to the injured person’s supervisor. After mishap notification, the supervisor must complete the AF Form 978, Supervisor Mishap Report.

The supervisor must coordinate the AF Form 978 with his or her respective unit safety representative and unit commander for review and signature before forwarding it to the installation ground safety office. Follow the established local reporting procedures to insure your chain of command stays informed of the situation. Make sure you turn in the AF Form 978 to the installation ground safety office within the required five workdays of the mishap. This is why it is important to notify the supervisor as soon as possible.

The supervisor is responsible for completing the AF Form 978 as accurately as possible, ensuring appropriate personnel sign, and for turning it in to the installation ground safety office by the deadline.

Hazard reporting

The best way to prevent accidents is to correct dangerous situations before a mishap occurs. BMETs typically work in most areas of the MTF. While working in these areas, take time to notice situations that may be potential safety hazards. These situations can range from a power cord creating a tripping hazard to a problem with the facility infrastructure. You should immediately correct the situation if it is possible to do so. For example, relocating an electrical cord to remove a tripping hazard solves the problem and no report is necessary.

However, if a safety problem is recurring or immediately correcting the problem is not possible, report it. Report all situations or conditions that may have a potential for personal injury or property damage to your supervisor and to the individual responsible for the area where the hazard is located. You will need to document the hazard on AF Form 457, USAF Hazard Report, and turn it in to the installation ground safety office. You can submit the AF Form 457 anonymously, and there is no requirement for any coordination or signatures prior to submitting the form. If there is a hazard, which presents a critical or imminent danger and an immediate fix is not possible, you should report it directly to the installation ground safety office by telephone or in person. You can obtain assistance from your unit safety representative in filling out form.

Your action may prevent major injuries or costly property damage. The safety of those around you depends on your safety attitude. Act to correct hazards. Accurate, detailed information is the key when reporting mishaps and hazards. The installation ground safety office uses this information to record damage to government equipment or facilities, personnel injuries, fatalities, medical costs, and lost duty. They also conduct investigations based on this data. More importantly, corrected hazards and mishap prevention measures stem from investigation results.

203. General medical treatment facility safety

There are safety concerns that only apply to working in the MTF. Working in a medical facility will occupationally expose you to a variety of infectious diseases, dangerous chemicals, and fire hazards. In this lesson, we will cover safety practices for biological, fire, and chemical hazards.

Biological hazards

Standard precautions and infection control procedures apply to all workers in the MTF, and they are routine for those healthcare providers whose duties bring them in contact with patients, but for the most part, you do *not* fall into this category. However, you do repair the equipment that patients and staff touch and there is a possibility that you may enter the rooms of infectious patients. For these reasons, it is important for you to be knowledgeable on the subject.

The MTF environment has many potential disease and infection hazards caused by different microorganisms, such as viruses or bacteria. These microorganisms are transmitted via several routes. The main three routes of microorganism transmission are contact (direct and indirect), droplet, and airborne transmission. See the following table for a description of each:

Transmission Route	Description
Contact	**Direct**: Involves direct body surface to body surface contact and physical transfer of microorganisms between a susceptible host and an infected person. Most frequently occurs while healthcare workers provide patient care but can also happen between two patients.
	Indirect: Involves contact of a susceptible host with a contaminated, intermediate object, such as contaminated needles, instruments, or equipment.
Droplet	Occurs when droplets containing microorganisms generated from an infected person are propelled a short distance through the air and deposited in an opening (e.g., eye, nose, mouth, or broken skin) of a susceptible host. An infected person can generate droplets by coughing, sneezing, or talking.

Transmission Route	Description
Airborne	Occurs by disseminating evaporated droplets or dust particles containing microorganisms that remain suspended in the air for long periods. Air currents can widely disperse microorganisms transmitted in this manner, so special air handling and ventilation are required. Airborne microorganisms include Mycobacterium tuberculosis and rubeola and varicella viruses.

The most frequent route of hospital-acquired infections is contact transmissions and as a BMET, you are most susceptible to indirect contact transmission. Disease transmission through blood or body fluids can occur in a patient's room or at the maintenance shop. Therefore, ensure the equipment is cleaned before you service it.

Handwashing is the single most critical measure to reduce the risks of transmitting microorganisms. It is important to wash your hands promptly and thoroughly after contact with patients and equipment or any other surfaces that may contain blood or body fluids. In addition to handwashing, use protective equipment, such as gloves, masks, eye protection, face shields, and gowns, as appropriate, to prevent spreading microorganisms.

You should handle all blood and body fluids as if they were contaminated. This also pertains to dried fluids since viruses can live for up to seven days in dried fluids. Due to the viruses and bacteria being microscopic, they could be present and you will never see them; therefore, use the following precautions to minimize the chances of picking up a "bug" when working on equipment.

- Treat all equipment (especially equipment used for or near invasive procedures) as if contaminated.
- Wear gloves.
- Wear a face shield if there is chance of a fluid splash.
- Do not eat or drink at your workbench.
- Do not touch your mouth, rub your eyes, or scratch your nose.
- Wash hands thoroughly after working with equipment.
- Disinfect your tools using approved solvent (e.g., wipes or alcohol).

If equipment received for maintenance has external signs of blood and body fluid contamination, contact the noncommissioned officer in charge (NCOIC) or officer in charge (OIC) of the section and request he or she sends someone down to clean the equipment. Do not return contaminated equipment to the originating section; this would unnecessarily increase exposure risk to others. If a department continually sends contaminated or dirty equipment to the maintenance shop, work with your NCOIC to report it to the MTF Risk Manager through your chain of command. This identifies the problem to the appropriate management level to help prevent the action.

You will have to open or remove external cases on some equipment to perform maintenance procedures. It is your responsibility as a BMET to clean internal equipment contamination, since the equipment operator does not have access. Clean the internal contamination with an approved solution before handling equipment. *Always* check the equipment manufacturer's literature for proper cleaning solutions and procedures because some chemicals may be too harsh for the material and damage equipment. Even after cleaning equipment, ensure you use proper handwashing techniques before and after handling.

Staff place patients who are transmitters of infectious diseases in isolation rooms to protect others. They isolate patients with airborne diseases in negative pressure rooms. In certain cases, the MTF staff may isolate patients who have a low tolerance to infections in positive pressure rooms. Your MTF should have these rooms marked and identified, but the best way to protect yourself and a patient is to check with the nursing staff before entering any patient's room, and do *not* go into any patient's room if you know you are ill. The nursing staff should provide you with the protective

clothing necessary for entering the room and let you know what precautions to take for a patient. No matter what the identified precautions are, at a minimum, *always* wash your hands before entering and after leaving a patient's room.

Fire hazards

A fire is devastating enough in an environment of healthy people, but a fire in a facility designed to house sick individuals could be disastrous. At any time, depending on the level of care provided in your MTF, you may have patients in surgery or on life-support that cannot afford to have their healthcare interrupted. That is why, during a fire, the entire MTF may or may not evacuate all at once. If it does not, it will evacuate by compartments. View each compartment as a separate facility, since it has all the necessary safety structures and precautions in place required by NFPA 99, *Health Care Facilities Code*, and NFPA 101, *Life Safety Code*. These regulations and state law, in certain cases (State code accepted in lieu of Life Safety Code), drive healthcare fire safety requirements. It is important for you to know your MTF's fire evacuation plan.

Hospital staff members must strive to be aware of hazardous conditions and practices around the facility since most fires happen due to human error. You play a crucial role in that effort. We will briefly look at some of the common fire hazards you need to be aware of and some precautions to take for making your MTF safer.

Common fire hazards

A critical area of concern is the patient's room. Many times, healthcare providers support patients with oxygen and this provides an atmosphere that supports combustion. Heat-producing appliances, such as hot plates, toasters, or coffee pots are not allowed in patient rooms. Smoking used to be a concern, but now AFI 40–102, *Tobacco Free Living*, requires all Air Force MTFs to be tobacco-free campuses. It is important for all staff to enforce this policy to maintain the safety and integrity of the program.

As a BMET, you play a big role in fire safety since there are many sections of the facility where you may see a condition or situation that needs attention when performing your duties. For example, you may see a storage area in your MTF that has improperly stored equipment, dirty linen, trash, and so forth, which could be a fire hazard. Always be vigilant for any equipment defects (even with patient-owned equipment), which could present a fire hazard. Such conditions as loose connections, frayed wires, or exposed circuitry could start a fire in an oxygen-enriched environment.

Some of the critical fire hazards you may see are blocked fire escapes, fire extinguishers, fire sprinklers, or detection devices (e.g., smoke alarm, heat detector, etc.). These can cause or contribute to catastrophic events if not corrected. It is important to ensure fire equipment always remains accessible. Some other common hazards to be aware of are overloaded surge protectors and extension cords, improper chemical handling, and facility damage (e.g., holes in walls, missing ceiling tiles, etc.).

If there is a situation you feel is potentially hazardous, immediately report it to the person in charge of that section, the unit safety representative/hospital safety officer, or your supervisor.

Precautions

The following is a list of some fire precaution guidelines that will help you avoid fire hazards and potential dangers around your facility:

- Enforce a tobacco-free MTF campus per AFI 40–102.
- Keep exits, fire doors, alarm pull stations, and fire extinguishers free of obstructions.
- Keep corridors free of equipment and clutter.
- Examine electrical cords for wear and remove from service if necessary.
- Be on the lookout for "daisy-chained" power strips and unauthorized extension cords.
- Ensure staff members use medical equipment in accordance with manufacturer's guidance.

- Store only flammable items in authorized storage cabinets.
- Store compressed gas cylinders properly in identified storage areas only.
- Ensure there is nothing stored within 18 inches of overhead sprinklers.
- Practice good housekeeping techniques.

Remember, human error causes most fires and can be prevented, so it is up to you and the rest of the staff to identify and correct those human errors.

Chemical hazards

Hazardous chemicals are virtually in every Air Force operation. You will encounter chemicals, such as lubricants, adhesives, paints, solvents, and cleaning agents. All work areas that use or handle hazardous chemicals must have a hazardous communication (HAZCOM) program. AFI 90–821, *Hazard Communication (HAZCOM) Program*, governs the program and BE oversees it. The program's purpose is to minimize the incidence of chemically-induced related illnesses. Before using any chemical, your knowledge of it must include the following:

- Intended purpose or use of the chemical.
- Proper application or use the chemical.
- Associated dangers and precautions with its use.
- Action to take if inhaled, ingested, or made contact with your skin.
- Proper clean-up procedures in the event of a spill.
- Type of personnel protection required to wear (i.e., gloves, goggles, etc.).
- Safe product storage and disposition.

For safety information on a specific chemical, the best source is the safety data sheet (SDS). The SDS addresses all the concerns listed above. Also, the SDS includes information such as chemical properties; physical, health, and environmental hazards; protective measures; and safety precautions for handling, storing, and transporting. OSHA requires chemical manufacturers to supply standard detailed information on the SDS for each chemical product they produce. Your work area must keep a copy of the SDS for each chemical it handles.

It is important that the BE office is aware of every chemical used in your shop; only then can the office provide the proper guidance. The BE office conducts periodic workplace surveys to determine if chemicals your work center uses match what is in HAZCOM program. To stay safe (and avoid a write-up), report any new chemicals acquired in your work center since the last survey to BE for evaluation. The BE office is your first stop for information on chemicals; contact them immediately in the event of a chemical spill. Some specific hazards of general chemicals used in medical equipment repair are contained in the table below:

Chemical Hazard	Description
General-purpose cleaners	Most general-purpose cleaners do not pose a substantial hazard to the user. However, use care and avoid spraying or splashing these cleaners in your eyes. Watch for any possible allergic reactions evidenced by changes in the skin. Never mix different types of cleaning agents unless you are sure they are compatible. For example, mixtures of agents, such as bleach and ammonia, are extremely hazardous, even though each agent alone poses no great risk.
Brush and aerosol paints	Many paints are flammable; use with great care. Use appropriate precautions to keep sources of heat or flame away from flammable paints. In addition, spray paint cans are under pressure so handle them carefully to prevent dropping or puncturing the container. Paint fumes are also an important consideration. Paint in a ventilated area and use a respirator.
Solvents	Many solvents are extremely flammable. Keep them away from any source of heat or flame. Use gloves, eye protection, or an apron as required.

Chemical Hazard	Description
Paint removers	These products demand great respect. They can cause extensive damage to human skin; use them with great care. Wear personal protective gear, such as gloves, aprons, and eye goggles.
Alcohol	This is extremely flammable. Keep away from any source of heat or flame. Use gloves, eye protection, or an apron as required.
Lubricants	These are possibly flammable. Avoid skin and eye contact.

After using any chemical, it is important to dispose of it by an approved hazardous waste disposal method. You cannot simply pour most chemicals down the drain (public sewer) or place in the trash. In addition, when chemicals fall into a hazardous waste category, any items used for the application of the chemical are also hazardous waste (e.g., rags, cotton-tipped applicators, etc.). Chemicals require a great deal of thought and care. Contact the BE office if you have any questions pertaining to safely handling a chemical. Contact your hazardous waste accumulation point manager to arrange for disposal of all hazardous waste in the unit. Facility management may act in this capacity or can direct you to your unit's hazardous waste accumulation point manager.

Two properties of chemicals that warrant special storage considerations are flammability and acidity. You must store flammable chemicals in an OSHA-approved flammable storage cabinet. Small amounts of flammable items constantly used may be exempt. An example is a small bottle of alcohol routinely used for cleaning. The small bottle may remain on a workbench, but you must store the unused bottles, or large supply bottle used to replenish the small bottles, in a flammable-materials cabinet.

The design of flammable-materials cabinets permits safe storage of flammable items. They have door mechanisms that close automatically. Never bypass this feature of a flammable-materials cabinet (sticking objects in front of a flammable-materials cabinet door or in the closing mechanism).

Store acids in approved cabinets designed for acid storage. This may not be necessary for very small amounts of acid. Consult the BE office for information about safe acid-storage methods in lieu of an approved cabinet. *Never* store flammables and acids in the same cabinet. Unit safety personnel, base fire department personnel, and the installation ground safety office all must inspect and approve flammable and acid storage areas.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

201. Safety principles and responsibilities

1. What is the only concern of the OSHA?

2. Explain the difference in AFOSH and OSHA safety concerns.

3. What are some concerns of an installation ground safety office?

4. Which organization conducts tests of the workplace environment?

5. Which tests does PH perform to support medical clearances for pre- and post-deployment personnel?

6. If you needed an AFI, where would you look to obtain it?

7. Identify at least five topics covered in AFI 91–203.

8. Which AFI identifies the forms required to report mishaps?

9. Which NFPA standards directly relate to medical facilities and are the BMET's primary standard?

10. What is the *best* source of safety information for a specific equipment item?

11. How do you develop a good safety attitude and take an active role in safety?

202. Mishap and hazard reporting

1. Which AFI establishes standards to determine if a mishap is reportable?

2. When must DOD civilians and inactive military members report mishaps?

3. With whom must the supervisor coordinate the AF Form 978 for review and signature before submitting it to the installation ground safety office?

4. How many days following a mishap does a supervisor have to submit the mishap report to installation ground safety?

5. Which form is used to document and report a hazard?

6. Explain the action(s) you should take to report a critical or imminent danger, if an immediate fix is not present.

203. General medical treatment facility safety

1. Which type of microorganism transmission route can an infected coughing person (host) generate?

2. BMETs are *most* susceptible to this type of transmission route.

3. Who is responsible for cleaning internal equipment contamination?

4. Why should you check the equipment manufacturer's literature prior to cleaning equipment?

5. What should you do prior to entering a patient's room to protect yourself and the patient?

6. What are some critical fire hazards you may see?

7. List at least five fire prevention guidelines that will help you avoid fire hazards in your facility.

8. What is the purpose of the HAZCOM program?

9. What type of information does the SDS provide?

10. Whom must you notify of new chemicals in your work center for evaluation?

11. What are two properties of chemicals that require special storage considerations?

1–2. 4A2X1 Specific Hazards

This section covers specific dangers that you may face as a BMET. Supervisors of medical equipment activities have the responsibility to evaluate specific exposures of their employees, determine their organization's level of risk, and develop a plan to minimize those risks. You should be aware of specific hazards associated with your facility and as you execute your duties.

204. Equipment-related hazards

This lesson examines hazards BMETs may encounter while maintaining medical equipment. There is a wide range of equipment hazards included from noise to electrical safety. While this lesson is not all-inclusive, it provides a good base. We will start with compressed gases and gas cylinders.

Compressed gases and gas cylinders

Compressed gases come from sources such as compressed air, compressed gas cylinders, and central gas systems. They are safe when you properly use them but can spell disaster if mishandled. There are many safety precautions you must take when dealing with compressed gases and gas cylinders. These precautions apply to handling, color-coding, and pin index systems, as set by the Department of Transportation (DOT), the CGA, and the NFPA. You can enjoy a safe working environment for yourself and others by having good working knowledge of compressed gas and cylinder safety.

General safety for compressed gases and cylinders

There are a few basic safety rules that apply to the safe use and handling of compressed gases. The following guidelines are for using and handling compressed gases and compressed gas cylinders:

- Inspect cylinders for damage (e.g., dents, gouges, cracks, etc.) before use. Remove leaking or damaged containers from use and report them to the supplier.
- Never point compressed gas outlets toward any part of your body. The pressure of the system can cause the gas to penetrate your skin, causing severe injury.
- Keep cylinders away from sources of high heat.
- Always keep cylinder valves closed *except* when cylinder is in use.
- Secure all cylinders, whether in use or in storage, full or empty, by using a chain or fastening device to a solid fixture (e.g., wall, stanchion, etc.) to prevent cylinder from falling.
- Put protective caps in place when you store or transport the cylinder.
- Only transport cylinders on approved carts and chain or strap them to the cart during transportation. Remember, gases stored in cylinders are under extremely high pressure and if an improperly transported cylinder were to fall, it could quickly become an unguided missile.
- Only use gases for their intended purpose. For instance, do *not* use oxygen in place of compressed air to blow dust out of an equipment cabinet.
- Only use cylinders with appropriate equipment. Do *not* force connections or use unauthorized adapters. *Never* use a cylinder without a regulator. Some examples are changing an oxygen regulator connector to permit its use on a nitrogen cylinder or changing an oxygen flow meter connector to connect it to a central compressed air wall outlet.
- Verify contents of cylinders or central systems, prior to use, to ensure proper dispensing of gas.
- Never mix gases in cylinders.

As an oxidizer, oxygen itself is not flammable, but it supports combustion of materials. Oxygen requires the following additional precautions:

- *Never* permit oil, grease, or other readily combustible substances from coming in contact with cylinders, valves, regulators, gauges, hoses, and fittings. This includes handling these items with oily hands or gloves.

- Use wrenches made of steel or other suitable material of adequate strength to connect apparatus. Use of nonsparking wrenches and tools are not necessary.
- Keep sources of heat, sparks, or flame away from cylinders and associated apparatus. Do not store within 20 feet of combustible material.

Built-in safety features

In addition to safely handling gases and cylinders, you must be sure to properly connect and deliver the correct gas. There are three safety features built into the design of the system to help prevent incorrect gas connections: color-coding, Pin Index Safety System (PISS), and Diameter Index Safety System (DISS).

Color-coding

It is important to know how to identify the type of gas in a cylinder or pipe. A color-coding system allows easy identification of medical gases by the external color of the cylinder or pipe instead of relying solely on having to read a label or marking. This is a universal system within the United States so it is applicable at all MTFs (slight chance that older MTFs overseas may be different). The following is the standard color system you will see for medical gas cylinders and piping:

Gas	Symbol	Cylinder Color	Piping Color
Oxygen	O_2	Green w/white shoulder	Green
Nitrous Oxide	N_2O	Blue	Blue
Carbon Dioxide	CO_2	Gray	Gray
Nitrogen	N_2	Black	Black
Helium	He	Brown	Brown
Medical Air	-	Yellow	Yellow

PISS

The PISS prevents accidental interchange of medical gas cylinders. The system uses matching pins and holes. Figure 1–1 illustrates the two pins on the yoke assembly and how they match up to holes on the cylinder valve body. For each gas, there is only one combination of holes and pins. The pins and holes of that cylinder and the yoke assembly only match with the proper cylinder. This prevents cylinder gas from discharging in the wrong piping system.

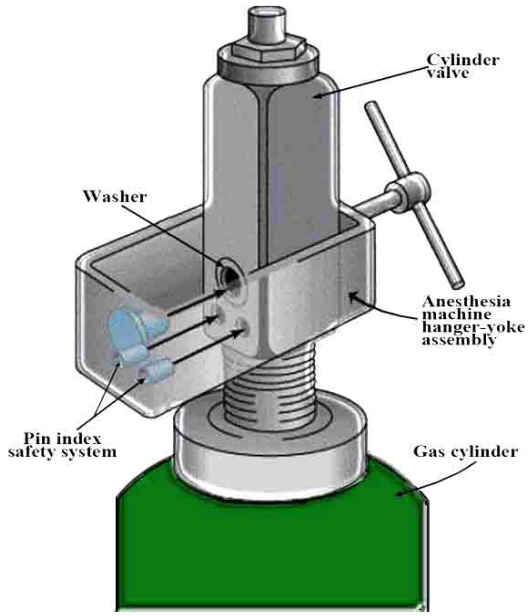

Figure 1–1. Pin Index Safety System (PISS).

The holes have a standard numerical designation (fig. 1–2), and the master-index shows all possible hole positions by number. The numbers range from one to six. Each cylinder head for a specific medical gas has a hole or pin position assigned. For example, find the oxygen cylinder in the figure. Its hole positions are at two and five. That means that a regulator designed for oxygen has pins at the two and five position. The regulator will easily attach to the head of the cylinder. Although the PISS system does not replace other means of identification already in use, it does add additional protection against accidents.

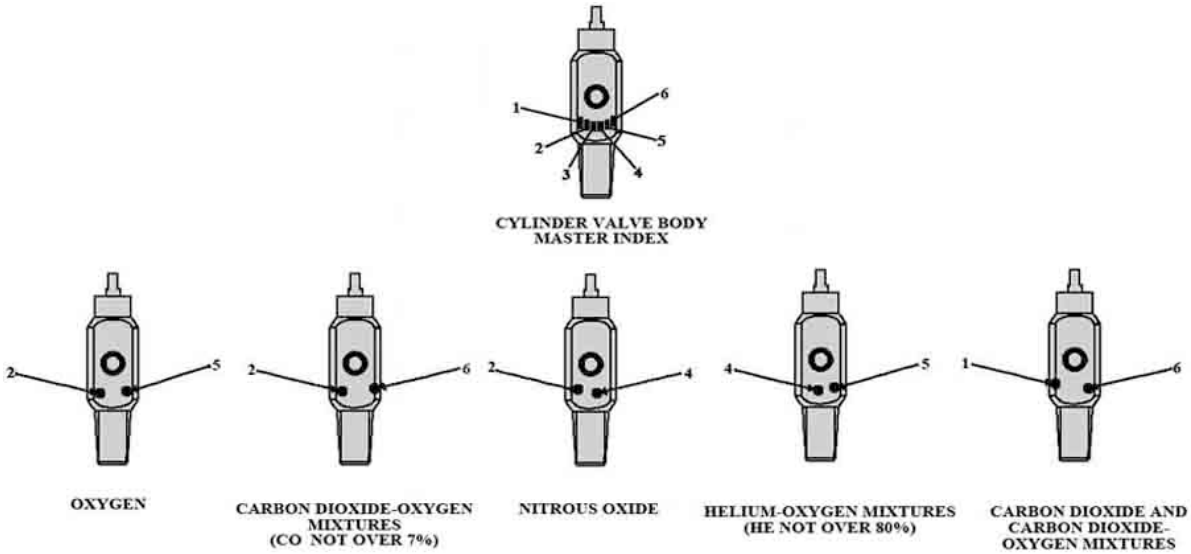

Figure 1–2. Hole positions for gas cylinder head and PISS regulator.

DISS

They developed the DISS to standardize low-pressure (under 200 pounds per square inch gauge), removable, and noninterchangeable medical gas connections. It is commonly found on regulators, anesthesia units, ventilators, resuscitation equipment, and other equipment using medical gas. Each specific medical gas connection has unique threads and size to fit equipment to outlets. The best place to see the difference side-by-side is on an anesthesia unit, which typically has oxygen, air, and nitrous oxide (fig. 1–3).

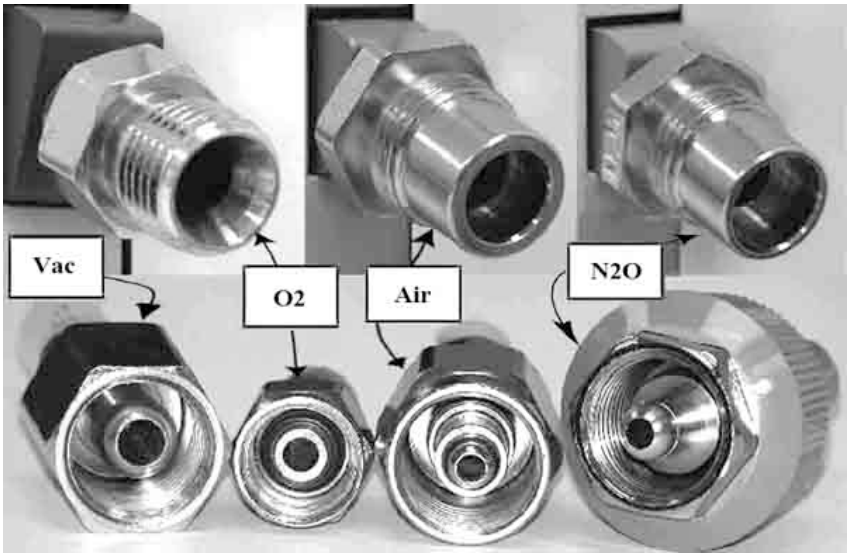

Figure 1–3. Diameter Index Safety System (DISS).

CGA publication V–5, *Diameter Index Safety System (Noninterchangeable Low Pressure Connections for Medical Gas Applications)*, covers the specifics of the different sizes in detail. You should *never* attempt to construct adapters to go from one to the other. This could allow you to use the wrong gas in a procedure and ultimately result in a patient's death.

Not following compressed gas precautions can lead to extensive physical damage to facilities and bodily harm to individuals, including death. If you have any further questions on what to do, or not to do, with compressed gases or cylinders, refer to the appropriate Air Force standards or materials published by the DOT, CGA, or NFPA.

Flammable gases

MTFs have virtually eliminated flammable gases. The days of cyclopropane and ethylene used as anesthetic agents have passed. However, for BMETs, there will be times when you will need to solder copper connections for plumbing applications, primarily for steam sterilizers. You will need a torch to solder copper pipe, and it will require propane or some other flammable gas for fuel. Propane bottles are very safe when handled correctly. Keep them away from high-heat sources and never point the flame from the torch back towards the propane bottle. Take care not to hit the tank or torch assembly against anything that may damage it.

Occupationally hazardous gases

Many of the gases you may encounter, such as argon, nitrogen, helium, and carbon dioxide, can cause asphyxiation when leaked into a closed environment by lowering the amount of available oxygen. A major concern for BMETs is waste anesthetic gases (WAG). WAGs are small amounts of volatile anesthetic gases that leak from the anesthetic breathing circuit into the surrounding area during anesthesia delivery. WAGs include nitrous oxide and halogenated anesthetics, such as halothane, enflurane, isoflurane, desflurane, and sevoflurane.

Some of the health effects include headache, fatigue, drowsiness, and liver and kidney disease. Your MTF should have scavenge utility systems to remove WAGs from operating rooms. The purpose of the anesthetic gas scavenging system is to trap waste gases at the site of overflow from the breathing circuit and then dispose of them to the outside atmosphere. A scavenge system that uses a vacuum source is as an active system and when there is no vacuum source, it is a passive system. You can still have exposure to WAGs even if your facility has a state of the art scavenge system by:

- gas leaking from tubing or connections that are not properly maintained or tightened;
- anesthetic gases escaping during hookup and disconnection of the system; and
- gas escaping from poorly fitted masks.

The heating, ventilation, and air conditioning (HVAC) system also contributes to the dilution and removal of waste gases.

If you notice any odd sounds or smells (although you cannot detect anesthetic gases by odor until concentrations are very high), or you notice that you are beginning to feel faint, weak, or dizzy, *do not* ignore it—get out of the area and seek help immediately. If you are going to be working in an environment where a hazardous gas concentration is possible, make sure you take a partner with you. Always make sure that you inspect the anesthetic delivery system (anesthesia machine, scavenge system, mask, and all connecting tubing) for irregularities or deterioration before each use.

Noise hazards

Exposure to loud noise can damage the nerve endings in your ears and cause permanent partial hearing loss. BE monitors occupational exposure to hazardous levels of noise and performs noise level surveys. They are responsible for assessing potential noise hazards and recommending appropriate control or protective measures if needed. You must contact BE if your work center purchases any new equipment that potentially generates hazardous noise. They must evaluate the new equipment within 30 days of your shop receiving it. BE may be able to control the noise with sound

walls or curtains or by enclosing the noise source. However, if you cannot remove the source of noise, BE may recommend using PPE whenever you are around the noise hazard. PPE used for noise protection are earplugs, earmuffs, or both. It is the work center supervisor's responsibility to make all required PPE identified by BE available to all workers in that shop. It is also a good idea for you to keep a set of earplugs in your tool kit.

Thermal hazards

BMETs are responsible to maintain some equipment items containing extremely hot surfaces that can cause thermal burns. You can prevent some thermal injuries by applying insulation or other protective measures, such as guarding. Some of the items to be aware of are motors, steam piping, and certain dental lab equipment. Sterilizer steam piping deserves the most attention since they often contain no insulation, and access for maintenance can be limited. Make sure you identify and mark all equipment that generates or contains hot surfaces. Newer equipment will come with caution signs already affixed if the hazard exists for the unit.

The preferred method for working on sterilizers and other equipment with thermal hazards is as follows:

1. De-energize equipment.
2. Remove or isolate heat sources from equipment.
3. Allow all components to cool before proceeding with maintenance.

This will not be practical for all situations. If it is not possible to follow the preferred method, be sure to wear the appropriate PPE and exercise extreme caution when working around hot surfaces.

Mechanical hazards

A large amount of medical equipment depends on mechanical systems, and anytime you have a moving part, you have a potential mechanical hazard. It is not possible to discuss every situation or equipment item that could present a mechanical hazard. Before you perform maintenance on any equipment item, take a moment to look it over for areas of potential danger. Look especially for items described in the following table:

Mechanical Hazard	Description
Moving parts	Parts can create hazard points when they move, such as pinch, wrap, shear, and crush points. Examples of this type of hazard are moving fan blades, gears, rollers, belt drives, and pulleys. Almost every equipment item has some type of moving part that could cause injury during operation and maintenance.
Lifting mechanisms	Use caution when working on any equipment with a lifting mechanism, such as a hospital bed or dental chair. The weight of the bed or chair is sufficient to cause severe injury if it closes or lowers onto a hand or foot. Likewise, the power of the lifting mechanism could crush a finger or hand. Always consult the manufacturer's literature for safe, correct procedures before working on these systems.
Counterbalance systems	Most x-ray tube assemblies use counterbalance, sometimes called counterweight, systems. It consists of a large weight connected to the tube assembly using a cable and pulley. The counterweight is equal in weight to the x-ray tube assembly; this allows tube assembly movement with minimal operator effort. Scheduled maintenance of these systems ensures that they work properly and safely. You may have to disconnect the counterbalance system to make repairs. Just like lifting mechanisms, it is imperative that you follow manufacturer's literature when connecting, disconnecting, or repairing these systems to prevent personal injury or equipment damage.

These are just a few mechanical-type hazards you may face. Each mechanical device poses some sort of potential hazard, whether from a sharp metal edge or a moving part that could pinch or crush a finger. Take time to identify potential hazards on each equipment item. Use appropriate guidance when performing maintenance, and exercise care while working to reduce your chances of injury.

Consider the following items before working on equipment to reduce your chances of injury from a mechanical hazard:

- Make a visual inspection of an item to consider the potential for mechanical hazards before you start maintenance.
- Use manufacturer's literature to find safe procedures for performing maintenance and to identify potential hazards.
- Use recommended equipment safety items, such as manufacturer-designed chocks or lock pins, to hold equipment parts safely during repair.
- Have a second technician assist you when performing maintenance on heavy items, such as lifting mechanisms and counterbalance systems. The second technician can help with heavy lifting and serve as a safety observer.
- Use appropriate PPE, if required. Work gloves, face shields, or goggles can prevent personal injury.
- Do *not* wear loose clothing or jewelry when working on machinery or mechanical devices. Mechanical devices can grab these items and cause injury.

Electrical hazards

Majority of BMET tasks involve electrical equipment, and getting yourself tied into an energized circuit will not be the highlight of your day. Electrical shocks can range from a minor "ouch" to a lethal jolt. You need to know how to prevent yourself from getting shocked or electrocuted.

Electricity naturally tries to seek ground through anything that will conduct; this includes the human body. For this reason, AFI 91–203 states that you will de-energize electrical circuits and equipment prior to performing maintenance *except* when authorized by applicable technical data or manufacturer's instructions as necessary to support a critical mission. When it is necessary to work on energized circuits, always make sure that your body does not provide a path to ground. The most dangerous path for electricity to take is through your chest cavity. Your heart is very sensitive to electricity and even a small amount of current can cause irreparable damage. The main thing to remember is that if your body provides a path to ground, you can expect something negative to happen (pun intended)!

Many people mistakenly assume electrocution takes a large amount of voltage or current, but that could not be farther from the truth. Receiving an electric shock from a 60 hertz (Hz) alternating current (AC) source with current in the range of 100 milliamperes (mA) to 300 mA could cause fatal heart disruptions. This small amount of current can cause your heart muscles to lose their rhythm and result in fibrillation. See below the effect different levels of amperages can have on your body.

Specific Amperages' Effect on Human Body	
Current	**Body's Response**
.007–5 mA	Start to feel the energy; tingling sensation.
5–15 mA	Experience pain; muscle contractions.
15–50 mA	Grip paralysis threshold (brain says let go, hand will not listen).
50–100 mA	Respiratory system shuts down.
100–300 mA	Heart fibrillation.
300–700 mA	Heart clamps tight, full contraction with no rest.
700–2,000 mA	Tissue and internal organs burn.

Electric burn

Another serious side effect of shock is electric burns. The severity of electrical burns factors include:

- length of contact with current;
- strength of current;

- type of current (alternating or direct); and
- direction or path of current through body.

AC tends to be more dangerous than direct current (DC), but you should respect all electricity the same and never treat it carelessly.

Electric shock prevention

Make sure you keep a keen eye for faulty electrical equipment or wiring and damaged receptacles or connectors. Ensure that wires and cords do not rub on sharp edges and are not positioned to allow roll over by equipment, chairs, and so forth. Take the time to correct potential problems you find and if you cannot correct it, report it to the person who is responsible for the area the hazard is located.

Always try to perform maintenance on electronic equipment with the power off; this is the best way to prevent an electrical shock. If you must troubleshoot with the power on, get your test equipment leads in place and know the points you are going to check before powering up the equipment. (**NOTE:** Always be aware of where your hands and arms are when you are working with energized circuits.) Finally, be sure to follow proper LOTO procedures when it is applicable. We will discuss this procedure at the end of this section.

Battery hazards

Many portable medical devices throughout the MTF use batteries. You will work with different types of batteries throughout your career. We will briefly cover some common types you may encounter, their associated hazards, and standard precautions you should take when handling batteries.

The following chart contains some of the most common types of batteries you will see and the hazards associated with them.

Battery Type	Associated Hazards
Lead-acid	Usually very heavy; contains sulfuric acid; emits explosive hydrogen gas while charging; has high-current capacity.
Nickel-cadmium (NiCad)	Contains very corrosive electrolyte; cadmium is a heavy toxic metal and hazardous to the environment; if improperly charged or discharged, it can emit explosive hydrogen gas.
Nickel-metal hydride (Ni-MH)	Contains very corrosive electrolyte but only mild toxins, so considered nontoxic.
Lithium ion (Li-Ion)	Contains a pressurized, flammable electrolyte; if overheated or overcharged, it may experience combustion.
Alkaline	Prone to leaking potassium hydroxide, which can cause respiratory, eye, and skin irritation.

There are general guidelines that will help you handle all batteries in a safe manner. The following list is a good starting point:

- Never heat or dispose of a battery in a fire.
- Never short battery terminals together.
- Charge a battery only with the specific charger designed for it.
- Never disassemble a battery or tamper with its design.
- Never reverse the polarity of battery connections.
- Never put water on a battery.
- Do not use a battery if it is leaking or appear abnormal in any way.
- Handle a battery with care—do not drop or hit it.
- Never mix old and new batteries together.
- Never mix batteries from different manufacturers.

- Do not carry batteries in your pocket. Metal objects in your pocket could short the terminals together and burn you.
- Take off rings or jewelry before handling batteries.
- Use insulated tools when working with charged cells.
- Do not place charged cells on metal surfaces.
- Store batteries in a cool, dark place (but not a refrigerator).
- Remove batteries when storing equipment for long periods (over one month).
- Do not smoke or allow any heat source near charging batteries.
- Do not allow the electrolyte to contact skin. If exposed to skin, follow the guidance on the applicable SDS and seek medical help.
- Do not dispose of hazardous batteries in the trash. Check with your hazardous waste accumulation point manager for proper disposal procedures.

It is important to follow these guidelines to keep an accident from happening. Batteries are generally safe devices, but handled or used improperly, they can cause severe problems. Always handle batteries with great care and keep these safety principles in mind.

205. Controlling hazardous energy

To protect yourself from some of the hazards previously discussed, BMETs must be sure to isolate hazardous energy and prevent the unexpected start-up of machines and equipment before the start of inspections, maintenance, or servicing operations. This section will introduce you to some important requirements of the LOTO program. AFI 91–203, Chapter 21, Hazardous Energy Control (Lockout and Tagout), provides detailed guidance for the LOTO program.

Hazardous energy sources

If you do not properly control hazardous energy prior to performing maintenance, it can cause serious injury or death. Some hazardous energy sources include the following:

- Electrical.
- Steam (thermal and pressure).
- Pressure/vacuum (hydraulic, pneumatic).
- Chemical.
- Ionizing and nonionizing radiation sources.
- Thermal, kinetic, or mechanical (rotational, gravity) energy.
- Energy stored in capacitors or springs.
- Suspended, blocked, or chocked machinery or system components.

LOTO devices

LOTO devices are locks affixed to hold energy-isolating devices in an “off” or “safe” position, which prohibits the machine or equipment from operating normally, allowing for maintenance or repairs. There are different types of LOTO devices: electric circuit breaker lockouts, power cord lockouts, valve lockouts, and cable lockouts. Equipment-specific procedures include the type of energy-isolating device to use, so be sure you use the correct type.

Each time you attach a lock you must also use a tag to serve as a warning and to provide information. Write the date, time, reason, and name of the worker applying the LOTO device on the tag. To prevent accidental detachment, securely attach tags with a self-locking and nonreleasable attachment (i.e., a nylon or plastic cable tie-off strap) with a minimum unlocking strength of 50 pounds.

The first authorized worker must attach the initial LOTO device(s) to each energy-isolating device. Additional authorized workers who perform service, maintenance, or modification on the equipment or machine shall apply their own locks during their maintenance activities.

Performing LOTO procedures

Only authorized individuals may perform LOTO. The person performing the operation must notify personnel directly affected by the system shutdown/LOTO. You must give notification before you apply controls and once you remove them. When performing maintenance, if you can unplug the power cord and keep it under your continuous control and there is no potential for stored energy, you do *not* have to LOTO.

Each applicable equipment item must have its own specific LOTO procedures. However, the specific procedures must incorporate the following general LOTO guidelines:

1. Before turning off machinery or equipment, the person performing the operation must know the type and magnitude of the energy source, the hazards to control, and the method or means to control the energy source.
2. The normal shutdown procedures must be used to turn off or shutdown the system. Unplug and tag machines using a simple wall plug as the power source with an AF Form 982, Danger Tag: Do Not Start.
3. All lockout devices needed to control the energy to the system must be applied, and equipment energy sources must be isolated. Attach the devices so that they will hold the energy-isolating devices in a safe or off position. Install both tags and locks. Tags must include the date, time, reason, and name of the worker installing the device.
4. After LOTO, all potentially hazardous stored energy should be relieved, disconnected, or restrained. Equipment should be in a zero-energy state; this may require installing chocks or blocks.
5. The supervisor or worker must confirm that the unit is de-energized or isolated by trying to restart the equipment under normal controls prior to starting work on the system.
6. Before returning the system to service, the person performing the procedure must remove all personnel, tools, servicing equipment, LOTO devices, and reinstall guards. Restore the energy-isolating device to the ‘ON’ position. Notify personnel of LOTO devices’ removal and that equipment is back in service.

In rare cases, you may not be able to lockout a device. In this situation, you would apply a tag-out only procedure. Use extra caution when utilizing the tag-out only procedure. Tags are only warning devices and do not provide the physical restraint and security of a lock, which may instill a false sense of safety by the worker. Apply tag-out only procedures if it is needed and your shop supervisor approves.

LOTO program management

The shop supervisor has overall responsibility for the LOTO program, but any capable worker may be tasked to manage and oversee it. The priority is to determine if any equipment your shop is responsible for maintaining requires LOTO. You should contact the BE office to assist with your LOTO requirements.

You must develop specific procedures for all equipment requiring LOTO that incorporates the general guidelines discussed earlier. The specific procedures should identify all sources of energy and the LOTO devices needed to isolate them. All necessary LOTO devices must be readily available to all trained personnel and accurately inventoried. You must number and mark the LOTO devices.

Establish and use a LOTO log each time an authorized worker applies and/or removes LOTO devices. The log should include the following information:

- LOTO device number.

- Date applied/removed.
- Equipment control number or serial number.
- LOTO reason.
- Name and contact information of worker.

The shop supervisor must identify all workers authorized to execute the LOTO procedures in writing. Properly training and identifying authorized workers are important parts of managing the LOTO program.

Training ensures that workers understand the purpose and function of the LOTO program. In addition to ensuring authorized workers understand the purpose and function of LOTO program, and have the skills to safely use the LOTO procedures, the shop supervisor will verify training of authorized workers, which includes:

- recognition of hazardous energy;
- type and magnitude of energy found in the workplace;
- means and methods of isolating and/or controlling energy; and
- means of verifying effective energy control and the purpose of using procedures.

Personnel who work in sections affected by LOTO procedures must receive general awareness training, and your shop maybe tasked to provide this training.

Conduct LOTO training annually and whenever the program changes, such as acquiring new equipment, developing new procedures, or finding an authorized worker deficient in his or her knowledge or ability to implement the LOTO procedures correctly. Certify and document all training on AF Form 55, Employee Safety and Health Record, or an equivalent document.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

204. Equipment-related hazards

1. Briefly describe five guidelines for using compressed gases and compressed gas cylinders.

2. Why is it not acceptable to work on *oxygen* regulators with oily hands?

3. What color is used to indicate oxygen piping?

4. How does the DISS prevent wrong gas connections?

5. Which type of flammable gas are you likely to use?

6. How can certain gases, such as argon and nitrogen, pose an occupational hazard?

7. What are some examples of WAGs?

8. What is the purpose of an anesthetic gas scavenging system?

9. Within how many days of your shop receiving new equipment with potential noise hazards must BE evaluate it?

10. Who is responsible to ensure all required PPE is available to personnel of a work center?

11. What three steps should you take before working on a sterilizer?

12. List three typical mechanical hazards found on medical devices.

13. Where should you look to find safe maintenance procedures for mechanical hazards?

14. Describe the *most* dangerous path for electricity to pass through your body.

15. At what amperage range do you begin to feel pain?

16. What determines an electrical burn severity?

17. What is the *best* way to prevent an electric shock while performing maintenance?

18. Why should you not carry batteries in your pockets?

19. What precaution should you take concerning batteries if storing medical equipment for more than a month?

205. Controlling hazardous energy

1. If an authorized worker already has a LOTO device attached to equipment, what must additional authorized workers do prior to performing maintenance on that equipment?

2. Whom must you notify before and after you apply LOTO controls?

3. How must you confirm that a unit is de-energized and isolated prior to starting work on a system?

4. Name the information that should be included in the LOTO log.

5. How is LOTO training documented?

1–3. Medical Equipment Quality Assurance

You may wonder: what happens if an equipment-related incident occurs? The answer is that it is important for you to know some basic information about what to do if something happens in your facility that relates to medical equipment. We will cover how to comply with the Food and Drug Administration Modernization Act (FDAMA) and the Medical Device Reporting (MDR) program; the how, when, and why of modifying a piece of medical equipment; and how to investigate an equipment-related incident.

206. Equipment compliance and tracking

In a perfect world, we would never encounter an equipment problem or defect; however, you have probably figured out by now that the world of medical equipment is not perfect. You need to be familiar with how to handle an equipment complaint or incident. Next, we will look at the FDAMA and MDR procedures.

FDAMA

The FDAMA, formerly the Safe Medical Device Act of 1990 (SMDA), is a directive from the FDA, enacted by law in 1997, and has numerous requirements for Air Force MTFs. The primary responsibility for compliance with the FDAMA lies with your MTF's quality assurance (QA) and/or RM office; but because it involves medical devices, your shop will play an important role in helping the MTF comply with requirements. The FDAMA establishes tracking and reporting requirements for medical devices.

Medical device tracking

The FDAMA established tracking requirements to facilitate notification and recalls if a medical device presents serious risk to health. The FDA requires that manufacturers track chosen devices from two categories. First, the MTF must track devices implanted in the human body for more than one year (whose failure would reasonably have serious, adverse health consequences). You will most likely *not* be actively involved in the process of tracking this category. These include:

- implantable pacemakers/defibrillators,
- implantable infusion pumps,

- replacement heart valves (mechanical), and
- silicone gel-filled breast implants.

The other medical devices that requires tracking is life-sustaining or life-supporting devices used *outside* of the MTF. BMETs are responsible to provide data for devices in this category. Some of these devices are:

- breathing frequency monitors (Apnea monitors),
- continuous ventilators (continuous positive airway pressure [CPAP] machines),
- ventricular bypass (assist) devices, and
- DC defibrillators and paddles (Automated External Defibrillators [AED] fall under this category).

The manufacturer of a tracked device has primary responsibility for tracking the device from manufacturing and distribution to the end user through issue, implant, explant, and retirement. However, the user facility must ensure manufacturers receive information in a timely manner. The following local procedures ensure your MTF's compliance with FDAMA tracking requirements.

Upon receipt of each equipment item (nonimplantable) intended for use *outside* of the facility, BMETs will complete and return the manufacturer's tracking form. You must also use the Defense Medical Logistics Standard Support (DMLSS) Historical Maintenance Record (HMR) to track equipment and maintenance history. If equipment outside of the facility is subject to tracking and is assigned to a specific patient, the Medical Logistics Medical Equipment Management Office (MEMO) will record and maintain additional information, to include the following:

- Name, address, telephone number, and Social Security number of the patient receiving the equipment.
- Date the device was provided to the patient.
- Telephone number of prescribing physician.
- Name, mailing address, and telephone number of physician assigned to follow-up with the patient if different from the prescribing physician.
- Date the equipment returned.

Patients may refuse to have any of their personal identifying information used for tracking purposes. Document such refusals by the product, model, and serial number, and provide that information to the manufacturer.

All tracked items in war reserve materiel (WRM) fall under the same FDAMA requirements as those found in the MTFs. Report to the manufacturer when records transfer to other accounts when assets deploy. The location of the deployed asset need not be provided to the manufacturer due to national security issues. BMETs must ensure a program is in place to identify all items that require tracking, both in operating and WRM accounts. If you receive a trackable item back from deployment, or from excess, you must notify the manufacturer of the new asset location.

You must also notify the manufacturer when a tracked item is condemned or transferred to a new location. BMETs must ensure to accomplish this prior to turning in any trackable item to Defense Reutilization and Marketing Office (DRMO) or to the Excess listing.

MDR

Not only does design and manufacture affect the satisfactory performance and safe operation of medical equipment, but the conditions of its use and its dependence on utilities, such as electric power, compressed gases, and steam, do also. Considering these factors, the criticality of equipment-related problems and the dangers they present to patients and staff may not always be clear. To ensure that appropriate levels of medical personnel evaluate all potentially significant hazards and

appropriately comply with the requirements of the FDAMA, use the guidelines presented in the following paragraphs to help determine which problems you need to report and how to report them.

Medical staff, patient safety, RM, and medical logistics personnel will evaluate the credibility, validity, and potential harm of an item before submitting a materiel complaint. The MTF's risk manager will make the final determination if a materiel-related incident warrants processing a complaint. Depending on the type of medical device defect, BMETs will report it to the Defense Logistics Agency (DLA), the FDA, and/or the manufacturer.

DLA has two categories for defects: Category 1 and 2 complaints. Category 1 complaints are materiel, which is determined by use or testing to be harmful or defective to the extent that its use may cause death, injury, or serious illness. Category 2 complaints are materiel suspected of being harmful, defective, deteriorated, or unsatisfactory because of a malfunction or design, which are attributable to faulty materiel, workmanship and/or quality inspection, performance, or otherwise unsuitable for use.

DLA requires Standard Form (SF) 368, Product Quality Deficiency Report, to be used for reporting materiel defects. When you submit the SF 368, the following agencies receive it: DLA, the Defense Supply Center, Philadelphia (DSCP), and medical commands of the United States Air Force, Army, and Navy. You can locate the SF 368 on the DLA Troop Support Medical website at https://www.medical.dla.mil/Portal/Customer/ProductQualityDeficiency.aspx or on the AF e-publishing website at http://www.e-publishing.af.mil/otherpublishingsites.asp. The FDA requires mandatory reporting of medical device-related deaths and serious injuries; all other defects and malfunctions are optional.

Use Form FDA 3500A, MedWatch Mandatory, for FDA mandatory reporting. It can be located on the FDA's website along with submission instructions at: https://www.fda.gov/MedicalDevices/DeviceRegulationandGuidance/PostmarketRequirements/ReportingAdverseEvents/ucm2005737.htm. Accomplish optional voluntary reporting on all other defects and malfunctions on Form FDA 3500, MedWatch Voluntary. The FDA also requires an annual summary, which is an accumulated summary for all Air Force MTFs based on submissions, but you will not be directly responsible for the annual summary. See the table below for a summary of medical device-reporting requirements:

What to Report	Form #	To Whom	When
Death (DLA Category 1)	Form FDA 3500A	FDA & Manufacturer	Within 10 work days
	SF 368	DLA	Within 48 hours
Serious injury (DLA Category 1)	Form FDA 3500A	Manufacturer (FDA, if unknown)	Within 10 work days
	SF 368	DLA	Within 48 hours
Device malfunctions (no death or serious injuries) (DLA Category 2)	Form FDA 3500 (optional)	FDA	N/A
	SF 368	DLA	N/A
Annual reports of death and serious injury	Form FDA 3419, Medical Device Reporting Annual User Facility Report	FDA	January 1

Ensure you adhere to all Health Insurance Portability and Accountability (HIPAA) privacy rules and national standards when reporting to the DLA, FDA, and manufacturers to safeguard patients' protected health information.

Do *not* report the following types of equipment-related problems as a materiel complaint:

- Unfavorable interaction or connection between equipment and MTF utilities, such as electrical power, compressed air, medical gases and steam, which result in performance or safety problems.
- Operator practices that substantially reduce equipment life expectancy, safety, or performance.
- Any problems related to obtaining timely and effective responses from manufacturer's service representatives.

As you can see, you will be reporting medical device-related problems to different agencies, depending upon the level of damage either caused or potentially caused. Initiate an incident investigation if a medical device has caused, or believed to have caused, any injuries.

207. Incident investigations

An incident is an event where equipment or a procedure has caused, or may have caused, injury to a patient, staff member, or visitor. When an incident involving a medical device occurs, the clinical engineering officer or senior BMET conducts a formal investigation in conjunction with the medical facility patient safety officer, risk manager, or others as appropriate.

Your role

It is important that you know the procedures to follow when your shop receives a call about an equipment-related incident because if the senior BMET is not available, you may be responsible for taking charge of the process. Additionally, at least two BMETs must perform the investigation, so you may assist in an investigation. Medical equipment items involved in, or suspected of being involved in, an incident require proper evidence preservation. The initial response to the incident scene is important. Any delays in your arrival can result in changes to equipment settings or the loss of disposable accessories that may be crucial to the investigation. Accuracy is also important. Arrive on the scene with a pencil, paper, and digital camera to annotate pertinent information. *Do not rely on your memory*!

Investigation procedures

The investigation *must* include, but is not limited, to the following:

- A minimum of two BMETs must perform the investigation. In a small facility where two BMETs are not available, one BMET may perform the investigation with assistance from another disinterested MTF staff member.
- The equipment operator should ensure that no one changes device settings and all accessories and consumables are attached or intact.
- The equipment should be impounded, and the position of all knobs and dials should be noted; look for any missing components or parts and note the overall condition of the equipment. Photograph the equipment, if possible.
- It is important to work with the department that experienced the incident; medical maintenance will report the incident and document the findings using AF Form 765, Medical Treatment Facility Incident Statement, or other equivalent tool to report the incident to the MTF risk manager.
- The equipment is *not* cleaned until *after* the investigation unless infection control procedures require cleaning. Label contaminated equipment with an AF Form 980, Caution Tag.
- The equipment data file (EDF) and all other documentation relating to that piece of equipment must be secured. Review the maintenance history and test procedures.
- All personnel who were involved must be interviewed.

- Any consumable supply items must be identified by lot number, date of manufacture, or any other means to identify the exact items. This identification may require getting the original packaging out of the trash.
- Document the inspection results on a DMLSS QA work order.

The investigating team should utilize the Incident Investigation Checklist provided on the AF Medical Logistics website. The checklist covers the three interfaces you must investigate: BMET-device, operator-device, and the consumable supply-device as discussed in the table below:

Interface Area	Questions to Answer
BMET-device	Were maintenance actions for the device current? Was the service manual followed for maintenance procedures? Was the technician qualified to perform maintenance? Were all recalls and hazard alerts addressed and required actions taken? Were all original equipment manufacturer (OEM)-approved software patches/updates installed on device?
Operator-device	Was the device used appropriately? (**NOTE:** Review operating manual.) Were control settings appropriate for intended diagnosis/treatment? When was operator training accomplished and documented? Were any facility utility (electrical, medical gas, water, suction, or HVAC) problems identified prior, during, or after the procedure? Was an operational check performed before use?
Consumable supply-device	Were the items designated for use with the device? Were the items properly connected to the device? Were items reusable or intended for one-time use?

During the investigation, maintain close coordination with your Medical Logistics Flight Commander (MLFC), risk manager, and MTF administrator. Advanced preparation is the key for a successful program. Knowing what to do prior to an incident makes the process much easier if you must ever investigate at your facility. Your regional Medical Equipment Repair Center (MERC) and the Clinical Engineering Branch at Air Force Medical Operations Agency (AFMOA) are available for any assistance needed during an investigation. Contact these organizations if you experience a problem, require technical assistance, or are just seeking some guidance.

Medical maintenance shops must develop local procedures that clearly delineate the responsibilities for investigations to ensure that the procedures are well known. The BMETs should also develop a program to keep equipment custodians and operators aware of their responsibilities in device-related incident investigations. Finally, you must be sure to include responsibilities for conducting equipment incident investigations in the medical treatment facility's QA/RM plan.

208. Managing hazard alerts

We have discussed what, when, why, and how to report a medical device-related problem you may experience in your facility. So how do other MTFs and hospitals find out about these problems before they become an issue at their facility? BMETs are responsible for managing hazards and alerts from different sources for their respective MTF.

A recall is a method of removing or correcting products that are in violation of laws administered by the FDA. The manufacturer usually voluntarily performs medical device recalls, but in rare cases, the FDA may issue a device recall.

Recall classifications

Most sources in the United States, including the Air Force, use the classification system developed by the FDA to indicate the relative degree of health hazard presented by the recalled product. The following table describes the three classes of recalls.

Recall Class	Description
I	A situation in which there is a reasonable probability that the use of, or exposure to, a violative product will cause serious, adverse health consequences or death.
II	A situation in which the use of, or exposure to, a violative product may cause temporary or medically reversible adverse health consequences or where the probability of serious adverse health consequences is remote.
III	A situation in which the use of, or exposure to, a violative product is not likely to cause adverse health consequences.

You must suspend items subject to Class I recall until a repair or modification is completed to correct the described problem. Class II and III recalls are *not* generally serious enough to require suspension of the item until corrected. Unless the recall specifies otherwise, you do not suspend devices from Class II or III.

Sources

To facilitate the management of alerts and recalls, medical maintenance will use the following sources: Alerts Tracker™ from ECRI Institute, Medical Materiel Quality Control (MMQC), or direct sources, such as the FDA, manufacturers, prime vendors, AFMOA-generated QA messages (AF-unique materiel). You need to be familiar with these organizations and their functions relating to medical device hazards. Medical maintenance personnel must monitor alerts and recall notices and take recommended actions for affected medical devices. Some recalls may come simultaneously from more than one source.

ECRI Institute Alerts Tracker™

ECRI Institute is a nonprofit organization that operates Alerts Tracker™, which is a web-based automated alerts management system. This tracker includes FDA recalls, manufacturers' recalls, and other verified product safety data. It is the primary method for BMETs to manage all alerts and recalls. All Air Force medical maintenance shops have a subscription to the ECRI Institute website, which is centrally-procured through the AFMOA Clinical Engineering Branch. To obtain access to the services, or for any account issues, send an e-mail to bmet@us.af.mil. ANG and Air Force Reserve members are authorized access under the active duty base that provides their direct medical logistics support. You only have authorization to use these services for official duty.

Once you have established your account, you must subscribe to the type of alerts you want to receive. Alerts Tracker™ will periodically populate notifications in your box based on the categories you have subscribed to (fig. 1–4).

You must process each alert that populates in your facility's box in Alert Tracker™. If the alert is not applicable, you simply select N/A. If it applies to your facility, you must provide information, including the corrective action taken, before you can close it out. You will learn your shop's specific policies on alerts during on the job training.

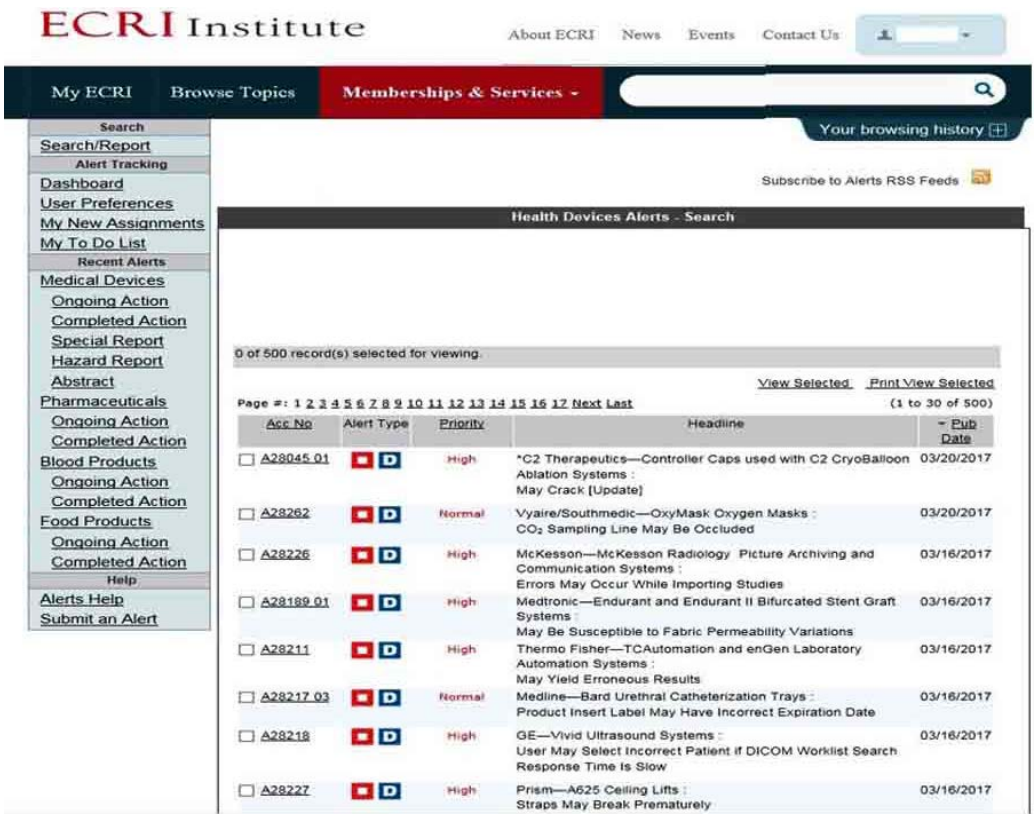

Figure 1–4. Alerts Tracker™ screen shot.

MMQC

MMQC messages are a DOD product issued by the US Army Medical Materiel Agency (USAMMA). MMQC sends emails that contain pertinent materiel alerts and notices to include background information and actions to take. Each BMET should subscribe to receive MMQC messages. You can subscribe via two ways: through the medical logistics website: https://medlog.us.af.mil/apps/medlog/#home, or by using the USAMMA website: http://www.usamma.amedd.army.mil/assets/apps/listserv/messages.cfm.

Equipment manufacturers and AFMOA

The medical device manufacturer plays a key role in hazards and alerts. Once the manufacturer is aware of a deficiency with one of its devices, it must analyze the deficiency and determine the corrective action. This usually results in a hazard recall or notice. The manufacturer conveys the corrective actions by direct notification to every owner and/or the FDA. If notified directly by a manufacturer of any type of recall action, not previously published through MMQC or Alerts Tracker™, you must notify the Clinical Engineering Branch at AFMOA/SGLAE by email (bmet@us.af.mil) and submit online to notify the ECRI Institute, within two duty days, of the recall event.

Alerts documentation and reporting

As previously covered, you will have to document the actions you take to rectify alerts in ECRI Institute's Alert Tracker™. However, that is not the only documentation required for alert notifications. AFI 41–201, *Managing Clinical Engineering Programs*, requires that all medical maintenance activities document recalls that affect items in their inventory as a quality assurance or modification work order within DMLSS. BMETs will document all recall procedures completed to satisfy the alert. Update DMLSS equipment notes with the Alerts Tracker™ accession number and any other relevant information.

Medical maintenance will inform the medical logistics QA log monitor monthly of completed actions and work orders for recalls. The medical maintenance shop must notify the Environment of Care (EOC) Committee or function of all equipment defects and recall actions taken for equipment in the MTF inventory. They must explain to the EOC Committee or function what your shop did to ensure the equipment is safe for use by staff on their patients.

209. Equipment modifications

A modification is a change in the design of an item of materiel to meet revised specifications, correct defects, or improve performance. A modification may be in the form of a modification instruction sheet, a parts kit given or sold to all users of the affected device, or it may require returning the device to the manufacturer for the modification. Equipment modifications happen very infrequently, but you need to know how to handle and formulate modifications for when the time comes.

Authorization and application

The Surgeon General, HQ USAF, may authorize medical device modifications to accomplish one or more of the following:

- Correct design deficiencies.
- Reduce excessive maintenance.
- Increase equipment effectiveness.
- Increase the useful life of the equipment.
- Provide greater safety for patients and equipment operators.

When performing or requesting modifications, make sure the action will not modify or alter a medical device to the extent that you change the item's essential characteristics or that you compromise compliance with the manufacturer's specifications and/or federal standards, unless specifically authorized or directed by the Surgeon General, HQ USAF. Do all directed modifications within prescribed time limits and in strict accordance with the modification instructions. AFMOA sends hazard alert messages through the Air Force message system if it issues emergency modifications.

The MTF commander may approve minor equipment modifications when required to meet local operating requirements, when such modifications do not result in a change to essential characteristics, manufacturer's specifications, or federal standard compliance of the item. Even if a modification is minor, do not perform modification if it introduces any potential safety hazards.

Requests for modifications

If an item is satisfactorily serving its designed purpose and you determine, by use or test, an improvement to its design, performance, maintenance upkeep, or safety features, you may recommend a modification. Before submitting, have your local medical staff evaluate proposed modifications; this ensures that the proposed modification is compatible with operating requirements and equipment construction.

Once the MTF commander determines the need and appropriateness of the modification, send an email requesting Air Force Surgeon General's approval of the modification to AFMOA at AFMOA.SGAL.taskmanagement@us.af.mil. Ensure you include any photos, drawings, diagrams, or other applicable supporting documents in the email.

When considering a modification, ensure that its purpose is to improve a satisfactory medical device and not to correct equipment deficiencies or unsatisfactory performance. If you are recommending an item for modification because it fails to perform according to its designed purpose, first submit a medical materiel complaint as previously discussed.

Documentation

You must document all modification actions in DMLSS, or on AF Form 509, Medical Equipment Maintenance Record, for all nonautomated accounts. Retain modification work orders in the EDF

throughout the life of the item. After performing modifications authorized by the Surgeon General, HQ USAF, use the letters “MP,” followed by the instruction title, or number, when you annotate the equipment record. Enter this information in the appropriate NOTES section of the equipment record in DMLSS. You also need to document DMLSS for minor modifications directed by the MTF Commander; in this case, however, the annotation is “MP,” followed by the work order number. You must update schematics and circuit descriptions for the affected equipment to reflect any modifications.

Process manufacturer-directed software updates not required as part of scheduled maintenance in DMLSS as an unscheduled modification work order. Update the equipment and work order notes to reflect the current version and date of update.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

206. Equipment compliance and tracking

1. What is the purpose of FDAMA tracking requirements?

2. Which types of life-sustaining or life-supporting equipment requires tracking under the FDAMA?

3. What must you do when your MTF receives a medical device used outside of the MTF?

4. Whom must you contact prior to turning in any trackable items to DRMO?

5. Describe the two complaint categories that DLA uses for defects.

6. Which two forms would you use to report a death caused by a medical device?

7. What type of equipment related problems do you *not* report as materiel complaints?

207. Incident investigations

1. Why is it important to know how to handle an incident investigation?

2. What should you take with you when responding to an incident investigation, and why is it important?

3. Which form do you use to report an incident?

4. What must you document if consumable supply items are involved in an incident?

5. Where can you find the Incident Investigation Checklist?

208. Managing hazard alerts

1. Which FDA recall class is the most severe, and why?

2. Which recall classes do *not* require suspension?

3. What are the *main* sources of equipment recall information?

4. What is the *primary* method for AF BMETs to manage alerts and recalls?

5. Who issues MMQC messages?

209. Equipment modifications

1. Who may approve minor equipment modifications to meet local operating requirements?

2. What must you include with email to the Air Force Surgeon General seeking approval for modification?

3. Where do you document modification actions?

Answers to Self-Test Questions

201

1. Safety and health of the worker.
2. AFOSH is concerned with facility safety and loss reduction (property) in addition to safety and health of the worker, while OSHA's only concern is the worker.
3. (1) Injuries to personnel, including on-duty and off-duty mishaps;
   (2) Problems with physical structures, such as buildings, sidewalks, or streets;
   (3) Investigating and reporting mishaps, including those involving machinery; and
   (4) Vehicle accidents.

4. BE.
5. (1) AIDS); (2) TB, and (3) pregnancy testing.
6. Through the Air Force e-Publishing website.
7. Any five of the following: (1) physical hazards, (2) human factors, (3) manual materiel handling and lifting techniques, (4) housekeeping, (5) fire protection and prevention, (6) electrical safety, (7) emergency shower and eyewash units, (8) safety color coding, labeling and marking for piping systems, (9) confined spaces, (10) mishap prevention signs and tags, (11) computer and automatic data processing equipment, (12) jewelry safety, (13) office safety, (14) tools and machinery safety, (15) PPE, (16) hazardous energy control (LOTO), (17) flammables and combustibles, (18) welding, (19) batteries (maintenance, handling, and storage), (20) compressed gases , (21) liquid nitrogen, (22) and radiology.
8. AFI 91–204.
9. NFPA 99 and NFPA 101.
10. The manufacturer's manuals.
11. By knowing that accidents can happen to you and by taking responsibility to correct unsafe conditions when discovered.

202

1. AFI 91–204.
2. Only if it occurs on-duty and is caused by Air Force operations.
3. His or her respective unit safety representative and unit commander.
4. Five workdays.
5. AF Form 457.
6. Report it directly to the installation ground safety office by telephone or in person and seek assistance from the unit safety representative to complete the form.

203

1. Droplet.
2. Indirect contact.
3. BMET.
4. To ensure you use the right chemical because some chemicals may be too harsh for material and damage equipment.
5. Check with the nursing staff before entering any patient's room.
6. Blocked fire escapes, fire extinguishers, fire sprinklers, or detection devices.
7. Any five of the following: (1) enforce a tobacco free-MTF campus; (2) keep exits, fire doors, alarm pull stations, and fire extinguishers free of obstructions; (3) keep corridors free of equipment and clutter; (4) examine electrical cords for wear and remove from service if necessary; (5) be on the lookout for "daisy-chained" power strips and unauthorized extension cords; (6) ensure all staff use medical equipment in accordance with manufacturer's guidance; (7) store flammable items in authorized storage cabinets; (8) store compressed gas cylinders properly in identified storage areas only; (9) ensure there is nothing stored within 18 inches of overhead sprinklers; and (10) practice good housekeeping techniques.
8. To minimize the incidence of chemically-induced related illnesses.
9. Chemical properties; physical, health, and environmental hazards; protective measures; and safety precautions for handling, storing, and transporting.
10. BE.
11. Flammability and acidity.

204

1. Any five of the following: (1) inspect cylinders for damage before use; (2) never point compressed gas outlet toward yourself; (3) keep cylinders away from sources of high heat; (4) keep cylinder valve closed except when in use; (5) secure all cylinders with chain/fastening device; (6) put protective caps in place when you store or transport the cylinder ; (7) only transport cylinders on approved carts and chain or strap them to the cart during transportation; (8) only use gases for their intended purpose; (9) only use cylinders

with appropriate equipment; (10) verify contents of cylinders or central systems prior to use; and (11) never mix gases in cylinders.

2. Because oil is a readily combustible substance.
3. Green.
4. Each gas has a unique thread and size to fit equipment outlets.
5. Propane or other gas to fuel torch.
6. When the amount of available oxygen is lowered if leaked into a closed environment, causing asphyxiation.
7. Nitrous oxide and halogenated anesthetics, such as halothane, enflurane, isoflurane, desflurane, and sevoflurane.
8. To trap waste gases at the site of overflow from the breathing circuit and then dispose of them to the outside atmosphere.
9. 30 days.
10. Work center supervisor.
11. (1) De-energize equipment, (2) remove or isolate heat sources, and (3) allow all components to cool.
12. Moving parts, lifting mechanisms, and counterbalance systems.
13. Manufacturer's literature.
14. Through the chest cavity because the heart is sensitive to electricity.
15. 5–15 mA.
16. (1) Length of contact with current; (2) strength of current; (3) type of current; (4) and direction or path of current through body.
17. Always try to perform maintenance on electronic equipment with the power off.
18. Metal objects can short terminals and burn you.
19. Remove the batteries.

205

1. Apply their own locks during their maintenance activities.
2. Personnel directly affected by the LOTO.
3. By trying to start the equipment under normal conditions.
4. LOTO device number; date applied/removed; equipment control number or serial number; LOTO reason; and worker name and contact information.
5. On AF Form 55 or something equivalent.

206

1. To facilitate notification and recalls if a medical device presents serious risk to health.
2. Breathing frequency monitors (Apnea monitors), continuous ventilators (CPAP machines), ventricular bypass (assist) devices, and DC defibrillators and paddles (AEDs).
3. You must fill out the manufacturer's tracking form and return it to the manufacturer, and use the DMLSS HMR to track the equipment and its maintenance history.
4. The equipment manufacturer.
5. Category 1 complaints are materiel determined by use or testing to be harmful or defective to the extent that its use may cause death, injury, or serious illness. Category 2 complaints are materiel suspected of being harmful, defective, deteriorated, or unsatisfactory because of malfunction or design, which are attributable to faulty materiel, workmanship and/or quality inspection, performance, or otherwise unsuitable for use.
6. Form FDA 3500A and SF 368.
7. (1) Unfavorable interaction or connection between equipment and MTF utilities, such as electrical power, compressed air, medical gases and steam, which result in performance or safety problems; (2) operator practices that substantially reduce equipment life expectancy, safety, or performance; (3) problems related to obtaining timely and effective response from manufacturer's service representatives.

207

1. Any BMET may be required to investigate if the senior BMET is not available, and two BMETs are required for an investigation and you may be the additional one.
2. Pencil, paper, and digital camera; to annotate any pertinent information so there is no reliance on memory.
3. AF Form 765 or an equivalent tool.
4. Lot number, manufacture date, or any other means to identify the exact item.
5. On the AF Medical Logistics website.

208

1. Class I, because it may cause serious harm or death.
2. Class II and III.
3. ECRI Institute Alerts Tracker™, MMQC, AFMOA, and sources such as the FDA, manufacturer, and prime vendor.
4. ECRI Institute Alerts Tracker™.
5. The USAMMA.

209

1. MTF commander.
2. Any photos, drawings, diagrams or other supporting documents.
3. DMLSS or AF Form 509.

Complete the unit review exercises before going to the next unit.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter. When you have completed all unit review exercises, transfer your answers to the Field-Scoring Answer Sheet.

Do not return your answer sheet to the AFCDA.

1. (201) Which organization oversees mishap investigations and reporting involving personnel and property?
   a. Bioenvironmental Engineering (BE).
   b. Installation ground safety.
   c. Environmental health.
   d. Public health (PH).

2. (201) *One* responsibility of the Bioenvironmental Engineering (BE) office is
   a. managing the Aeromedical Services Information Management System (ASIMS).
   b. investigating Air Force-related occupational illness.
   c. testing the workplace environment.
   d. overseeing accident investigations.

3. (201) Which agency is responsible for investigating food-borne illnesses?
   a. Bioenvironmental Engineering (BE).
   b. Installation ground safety.
   c. Environmental health.
   d. Public health (PH).

4. (201) This Air Force instruction (AFI) is used to provide a *uniform* safety program for the Air Force.
   a. AFI 41–201, *Managing Clinical Engineering Programs*.
   b. AFI 91–202, *The US Air Force Mishap Prevention Program*.
   c. AFI 91–203, *Air Force Consolidated Occupational Safety Instruction*.
   d. AFI 91–204, *Safety Investigations and Reports*.

5. (202) After an accident, you *immediately* notify an injured victim's
   a. commander.
   b. next of kin.
   c. first sergeant.
   d. immediate supervisor.

6. (202) Which form is used to report mishaps *after* mishap notification?
   a. AF Form 55, Employee Safety and Health Record.
   b. AF Form 457, USAF Hazard Report.
   c. AF Form 978, Supervisor Mishap Report.
   d. AF Form 1800, Operator's Inspection Guide and Trouble Report.

7. (202) To whom, or which agency, *must* you turn in AF Form 457, USAF Hazard Report, for documented hazards that recur or for those that *cannot* be immediately corrected?
   a. Public health (PH).
   b. Immediate supervisor.
   c. Installation ground safety.
   d. Installation ground safety and Bioenvironmental Engineering (BE).

8. (203) Which type of microorganism transmission route involves contact with a *contaminated intermediate* object?
   a. Droplet.
   b. Airborne.
   c. Direct contact.
   d. Indirect contact.

9. (203) Special air handling and ventilation are required for this type of microorganism transmission route.
   a. Droplet.
   b. Airborne.
   c. Direct contact.
   d. Indirect contact.

10. (203) Which handling precaution should you use for blood and bodily fluids found on or in equipment?
   a. There is no special precaution required.
   b. Treat all fluids as if they were contaminated.
   c. Have the laboratory check fluids for contamination.
   d. Take precautions only for fluids you know are contaminated.

11. (203) Which heat-producing item should *not* be used in a patient's room due to possible combustion in the atmosphere?
   a. Coffee pot.
   b. Television.
   c. Laptop.
   d. Radio.

12. (203) Tobacco use on Air Force medical treatment facility (MTF) campuses is
   a. at the discretion of the medical group/wing commander.
   b. at the discretion of the installation commander.
   c. only allowed in authorized locations.
   d. not allowed by Air Force instruction (AFI).

13. (203) As a biomedical equipment technician (BMET), you play a big part in fire safety because
   a. medical equipment repair is the office of primary responsibility for fire safety.
   b. medical equipment is the primary cause of most fires in a hospital.
   c. a BMET has more working knowledge of fire safety than anyone in the facility.
   d. a BMET is in many sections of the facility during the performance of duties.

14. (203) Use this as the *best* source for finding safety information about a specific chemical.
   a. Bioenvironmental Engineering (BE).
   b. Safety data sheet (SDS).
   c. Immediate supervisor.
   d. Product label.

15. (203) Which precaution(s) should be taken with a cotton-tipped swab if you use it to apply a hazardous chemical?
   a. It is not considered hazardous and requires no special precautions.
   b. It is considered hazardous and disposed of as hazardous waste.
   c. Do not use it to apply hazardous chemicals.
   d. It must be burned.

16. (203) Flammable chemicals *must* be stored in
    a. an Occupational Safety and Health Administration (OSHA)-approved flammable cabinet.
    b. any metal cabinet with a door closer installed.
    c. a room with a sink and ventilation.
    d. any operable metal cabinet.

17. (204) This statement about compressed gases *is correct*.
    a. Mix gases in cylinders only if you are properly trained.
    b. Keep cylinder valves should be kept closed except when the container is in use.
    c. Oxygen can be used in place of compressed air to blow dust out of an equipment cabinet.
    d. Cylinder caps must be in place when a cylinder is transported but not when the cylinder is stored.

18. (204) The three safety features built into the compressed gas system to prevent incorrect gas connections are the Pin Index Safety System (PISS), Diameter Index Safety System (DISS), and
    a. Cylinder exchange system.
    b. Fail-safe valve system.
    c. Quick disconnects.
    d. Color-coding.

19. (204) Which type of gas cylinder is color-coded gray?
    a. Carbon dioxide.
    b. Nitrous oxide.
    c. Oxygen.
    d. Helium.

20. (204) A system that uses a vacuum source to remove waste anesthetic gases (WAG) is a(n)
    a. central gas supply system.
    b. passive scavenge system.
    c. humidity control system.
    d. active scavenge system.

21. (204) This helps remove waste anesthetic gases (WAG).
    a. Heating, ventilating, and air conditioning (HVAC).
    b. Central gas supply.
    c. Humidity control.
    d. Oscillating fan.

22. (204) Which agency should you contact to perform a workplace survey for noise exposure?
    a. Public health (PH).
    b. Environmental Health.
    c. Installation ground safety.
    d. Bioenvironmental Engineering (BE).

23. (204) This type of sterilizer steam piping *thermal hazard* requires the *most* attention.
    a. Has no steam isolation.
    b. Contains no insulation.
    c. Does not cool.
    d. Heats quickly.

24. (204) What can you do to *minimize* the risk of electrical shock when troubleshooting equipment with power applied?
    a. Remain seated while troubleshooting.
    b. Remember to troubleshoot with power applied.
    c. Always have test leads in place before applying power.
    d. Always keep one hand on a metal object while troubleshooting.

25. (204) Which type of battery may combust if it is overcharged or overheated?
    a. Lead-acid.
    b. Lithium ion (Li-Ion).
    c. Nickel-cadmium (NiCad).
    d. Nickel-metal hydride (Ni-MH).

26. (204) Observe this guideline when working with a *charged* battery cell?
    a. Carry the cell in your pocket to prevent shorting the terminals together.
    b. Discharge the cell slightly before placing it into a piece of equipment.
    c. Place the cell on a metal surface.
    d. Use insulated tools.

27. (205) Secure lockout/tagout (LOTO) tags with a self-locking attachment consisting of a *minimum* unlocking strength of
    a. 5 pounds.
    b. 20 pounds.
    c. 50 pounds.
    d. 100 pounds.

28. (205) In which situation is a lockout/tagout (LOTO) *not* required?
    a. During times outside of normal operating hours.
    b. During an estimated maintenance time of less than 15 minutes.
    c. When an unplugged power cord remains under your control and there is no potential for stored energy.
    d. When maintenance time is less than 15 minutes and an additional employee safeguards the device.

29. (205) If a device *cannot* be physically locked, when can you use a tag-out *only* procedure?
    a. With maintenance time of less than 15 minutes and an additional employee assists.
    b. With the shop supervisor’s approval when it is justified as needed.
    c. When maintenance time is less than 15 minutes.
    d. When it is outside of normal operating hours.

30. (206) The *primary* responsibility for compliance with the Food and Drug Administration Modernization Act (FDAMA) lies with the
    a. Biomedical equipment technician (BMET) shop.
    b. Medical treatment facility (MTF) commander.
    c. MTF quality assurance/risk management office.
    d. Clinical engineering branch.

31. (206) Which action does *not* require reporting to the manufacturer for tracking purposes?
    a. Tracking asset movement to another account in the same medical treatment facility (MTF).
    b. Tracking asset being turned in to Defense Reutilization and Marketing Office (DRMO).
    c. Deploying tracked war reserve materiel (WRM) asset to another account.
    d. Gaining tracked asset from the Excess listing.

32. (206) Who makes the *final* determination on whether a materiel-related incident complaint will be processed?
    a. Senior biomedical equipment technician (BMET).
    b. Clinical engineer.
    c. Medical treatment facility (MTF) commander.
    d. MTF risk manager.

33. (206) You *must* report Category 1, death and serious injury, complaints to the Defense Logistics Agency (DLA) within
    a. 24 hours.
    b. 48 hours.
    c. 10 work days.
    d. 30 work days.

34. (207) Use this form to document the summary of a hospital incident investigation to the medical treatment facility (MTF) risk manager?
    a. AF Form 765.
    b. AF Form 988.
    c. AF Form 1098.
    d. AF Form 2005.

35. (207) Which procedure would *not* be appropriate when performing an incident investigation involving a medical equipment item?
    a. Make sure the equipment operator does not change and device settings and keep accessories attached.
    b. Review maintenance history and test procedures of the equipment.
    c. Impound all similar pieces of equipment throughout the facility.
    d. Interview all personnel who were involved.

36. (208) Which type of device recall is used for use of, or exposure to, a product that is capable of causing serious injury or death?
    a. Class I.
    b. Class I & II.
    c. Class III.
    d. Class II & III.

37. (208) Which type of device recall is for product exposure that is *not* likely to cause *adverse* health consequences?
    a. Class I.
    b. Class II.
    c. Class III.
    d. Class IV.

38. (208) This is the *primary* method for biomedical equipment technicians (BMET) to manage alerts and recalls.
    a. ECRI Institute Alerts Tracker™.
    b. Air Force Medical Operations Agency (AFMOA) website.
    c. Food and Drug Administration (FDA) website.
    d. Defense Medical Logistics Standard Support (DMLSS).

39. (209) Modifications of medical devices are approved by the
    a. Surgeon General, HQ USAF.
    b. Defense Medical Materiel Board.
    c. Defense Supply Center, Philadelphia (DSCP).
    d. Air Force Medical Operations Agency (AFMOA).

40. (209) *Minor* modifications on equipment may be authorized by the
    a. Air Force Medical Logistics Office (AFMLO).
    b. Medical treatment facility (MTF) commander.
    c. Medical logistics flight commander (MLFC).
    d. Biomedical equipment technician (BMET).

41. (209) You *must* take this action *before* submitting a proposed equipment modification.
    a. Get approval from medical treatment facility's (MTF) safety officer.
    b. Have local medical staff evaluate proposal.
    c. Develop proposed electrical schematics.
    d. Perform a cost analysis of modification.

Please read the unit menu for unit 2 and continue ➔

Student Notes

Unit 2. Tools and Techniques

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MAINTAINING MEDICAL EQUIPMENT requires spending a good deal of time on tasks, such as removing cover panels, replacing parts, or leveling equipment. To successfully complete these tasks, you most often must use general hand and power tools, such as hammers, chisels, files, drill presses, or bench grinders. Tools can be efficient, time-saving, and even convenient; but they can also be dangerous. Improperly using tools can damage equipment, destroy tools, and worst of all, cause personal injury. This unit focuses on the proper use of tools and their safety principles and precautions.

2–1. Hand Tools

You gained some experience with tools in the BMET basic course. However, you may not be familiar with all the hand tools you will use. This section provides information on the use, care, and safety of common hand tools. We cannot possibly discuss all common hand tools available, and there are many variations and special designs for specific jobs. Remember that the proper use and care of tools makes your job much easier and safer. Proficiency in tool use comes with experience and practice using the proper care and techniques.

210. Hand-tool safety principles

As stated in Unit 1, safety should be your first concern with any task—using tools is no exception. In this lesson, we will cover some important precautions and general safety you need to consider when using hand tools. Pay careful attention to this material and apply it as you perform your duties.

Developing good behavior habits for using tools will prevent injuries to yourself and others. Below are some general behavior guidelines to follow:

- Always inspect tools for safe conditions prior to starting work.
- Never carry tools in your pockets or leave them lying around.
- Ensure you clean up the work area when you complete the job.
- Learn the safe way to perform the task before you start.
- Ensure you wear proper clothing and PPE for the job.
- Make sure you always conduct yourself professionally and never engage in horseplay.

BMETs should train on properly using all tools and be able to recognize the hazards associated with different types of tools. To help avoid hazards, it is important to know general hand tool safety principles.

The greatest hazards posed by hand tools result from misuse and improper maintenance. Use each tool only for its intended purpose. For example, some technicians fail to select the proper wrench or screwdriver for the job. When a screwdriver is too small for the job, the blade does not fill the width

of the slotted screw, bolt, and so on. This exerts pressure on only a small surface and there is inadequate leverage, which can damage the tool, screw, bolt, and/or equipment and cause personal injury if the tool slips out of the screw slot. Use care when selecting tools. Be sure to not only choose the right tool but to select the right size, shape, and length to do the job.

It is important that you keep your tools clean and in good condition. Who likes to reach into a toolbox and grab a greasy screwdriver or wrench? Aside from the fact that your hands will get dirty, if you use the tool when it is not clean, your hand could slip and cause injury or damage to equipment. Minor surface damage, such as nicks and burrs, are no cause to remove tools from service. However, if the damage has progressed to a point that it affects functionality, you must remove the tool from service.

Always place an equipment item or assembly on a proper work surface or in a vise if possible. This allows the item to be secure while attempting repair, adjustment, or disassembly. It is dangerous to hold work in your hand, because if the tool slips you can cut or injure your hand. Ensure there is an electrical ground on all metal workbenches to prevent electrical shocks and a rubber mat for the floor in front of the bench to minimize both breakage and electrical shock.

When using an abrasive device on electronic equipment, such as a small file or emery cloth, be sure to clean up the residue created before installing the device and restoring power. The residue from the metal deposits could be a perfect path for current flow and just might end up destroying what you worked so hard to repair. Below are some other general precautions regarding the use and care of tools you should practice:

- Keep your workbench, work area, and tool kit orderly. Know where each tool is so that you can find it immediately when you need it.
- Protect any cutting edges at all times. Wrap sharp tools with cloth if stored with other tools or keep them in a suitable rack.
- Keep all tool handles and working surfaces free of oil; this eliminates the possibility of your hand or the tool slipping while you are working.

Following are some precautions to observe when exposed to outside weather conditions, such as in readiness or facilities, or when deployed:

- Keep all tools not in use out of the sun in hot climates; tools exposed to the sun for a long time can burn you.
- Keep tools from prolonged exposure to very hot, dry environments. Extreme heat in a dry climate evaporates the protective oil from the metal, causing rust and corrosion.
- Keep tools dry. Dampness, salt-laden air, sleet, and snow are climate conditions that increase rust and corrosion. Keep tools off the ground, cover them with adequate protective material, and coat them with a film of oil when not in use. This will minimize their deterioration.
- Avoid exposing tools to rapid and extreme changes in temperature when possible. Cold metals sweat when taken into a warm room. To prevent the formation of rust, dry tools carefully when moisture condenses on them.

211. Using hand tools

We will start this lesson with one of the most common tools you will use—the screwdriver—and then move on to hammers, chisels, and punches. Although you may have used these tools many times in your lifetime, the following material will present some information that may be new to you and help ensure these common hand tools are properly used.

Screwdrivers

Technicians abuse screwdrivers more than any other tool. Screwdrivers should *only* be used to drive or remove screws. Do not use them as chisels, punches, pry bars, or nail pullers. Screwdriver

classifications (fig. 2–1) are standard or common, cross point (Phillips, Reed & Prince), and offset. These types may have variations to fit a unique job or special screw design.

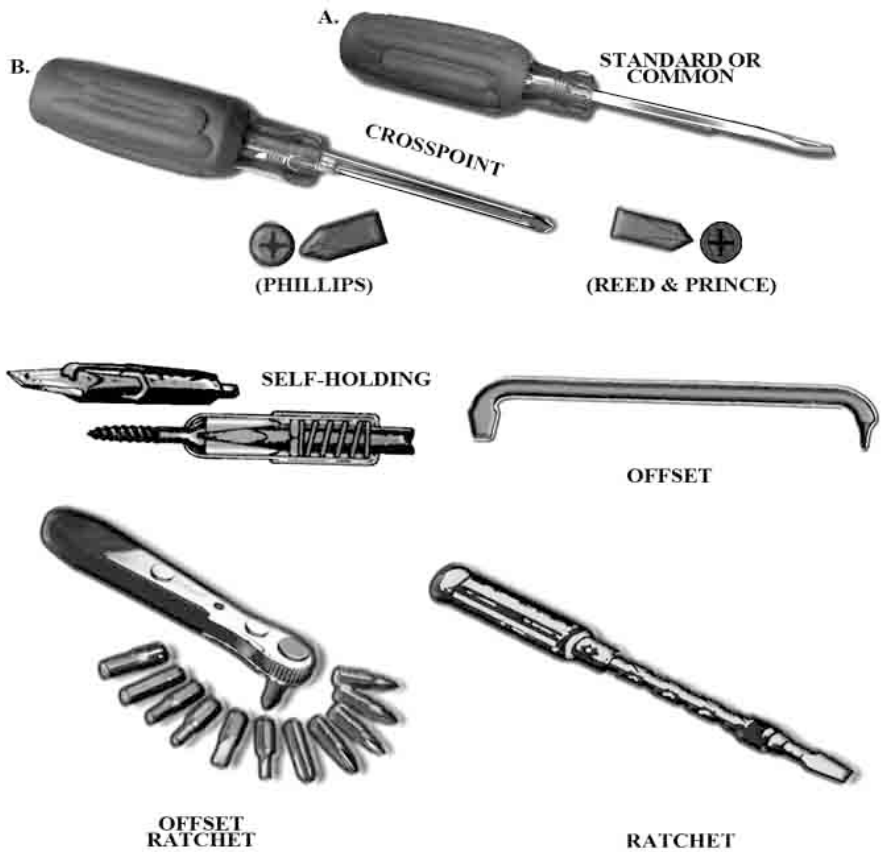


Figure 2–1. Types of screwdrivers.

There is a correct size screwdriver for every screw slot. A screwdriver that is either too large or too small for a screw will score the screw slot. When using a common screwdriver, the screwdriver blade width should be close to the slot width on the screw head, and the blade thickness should fit as snugly as possible in the screw head slot, without forcing the blade into the slot (fig. 2–2). Technicians often mistakenly interchange Reed & Prince and Phillips screwdrivers because they look similar, but a Reed & Prince tip comes to a point and the Phillips has a rounded tip. Phillips and Reed & Prince screwdrivers should fit snugly into the screw head. Whichever screwdriver you use, hold it firmly against the screw to prevent it from slipping.

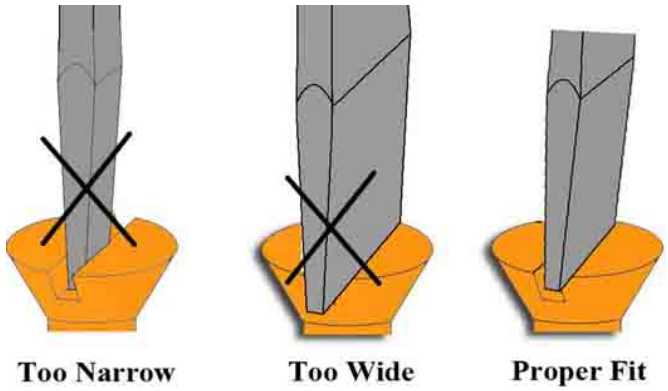


Figure 2–2. Using a screwdriver.

Hammers

Hammers (fig. 2–3) are classified as either common or soft (mallets). Each has a special purpose, so it is important to select the right hammer for the job. Misusing a hammer can cause damage to the hammer and/or equipment. If you choose the wrong hammer shape, you will not have the right striking surface to do the work properly. If the hammer is too large, the work may be damaged; and if it is too small, the hammer or mallet may be damaged. Also, if a mallet head is not soft enough, it can damage the surface of the items struck. Remember the following techniques when using hammers:

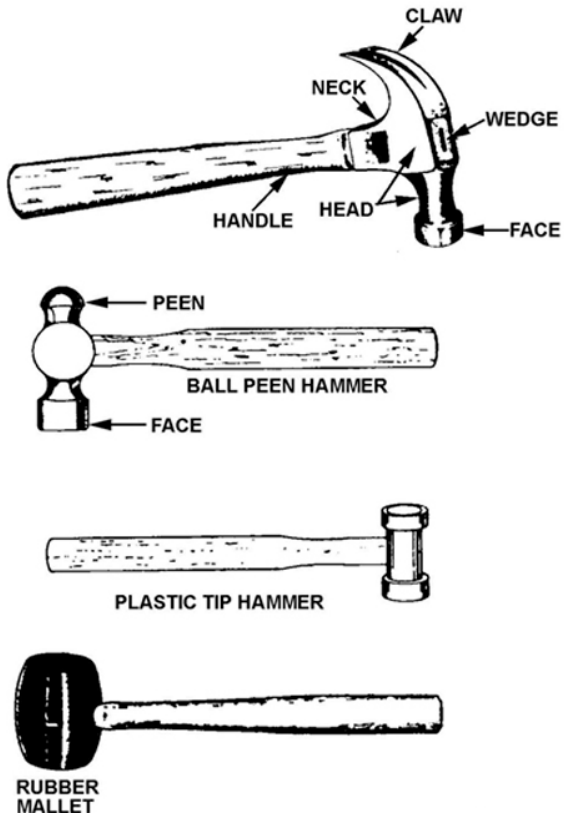


Figure 2–3. Types of hammers.

1. Hold the hammer near its end, with the hammer's face parallel to the work (fig. 2–4).
2. Grip the handle just tight enough to control the blow.
3. Move the hammer's head straight away from the work, using your elbow as a pivot point, and then bring it back into contact with the work with a quick, sharp motion.

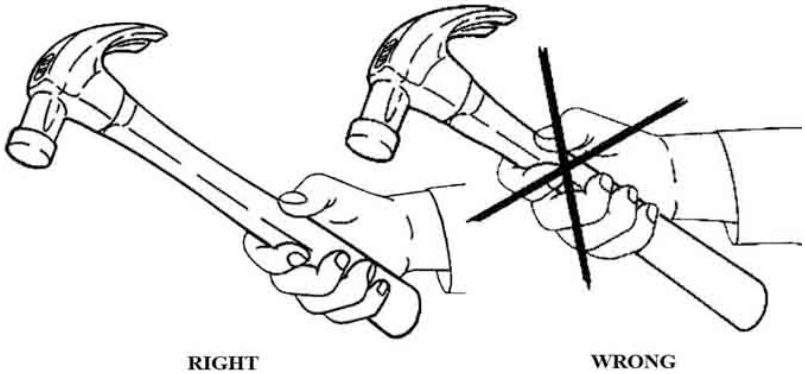


Figure 2–4. Properly gripping/using a hammer.

The weight and amount the head travels determines the strength of the blow. Small nails require light blows, almost entirely from a wrist motion. Heavy blows that are needed to drive a large nail or other similar work, come from the wrist, forearm, and shoulder. Keep the blows even with your eyes on the spot you are striking, not the head of the tool. Ensure to strike the work squarely and in the center to prevent the hammer from glancing off. Always observe the following safety precautions:

- Make sure the handle is clean.
- Keep the hammer's face or mallet clean and properly dressed.
- Clean and dry your hands.
- Never use a hammer or mallet with a loose head (this is the most common cause of hammer-related accidents).
- Use safety goggles, especially when using a hammer to strike a chisel.

Several types of common hammers and their uses are listed in the table below:

Type	Description
Claw hammer	Used for driving and pulling nails. Various face and claw shapes are available.
Ball-peen hammer	Used for forming heads on rivets and similar metal-preening operations. Use the flat-faced end for tapping punches, chisels, and other rough work.
Soft hammer (mallet)	Soft-faced and true mallets are the two types. The only difference between a soft-faced hammer and mallet is that the entire mallet head is rubber, brass, lead, or plastic; the face of a soft-faced hammer is only rubber, brass, lead, or plastic. Used to form soft metals or drive close-fitting parts together; specifically designed to deliver heavy blows to highly polished or soft surfaces without damaging the surface. Do not use them for rough work, such as driving punches, nails, or bolts.
Sledge hammer	Designed specifically for use when you require a large amount of force; typically used for heavy chiseling or to move a heavy object. Sometimes you may need to place a buffer, such as a wooden block, against the object you are moving. Then, you strike the wooden block with the sledge hammer; this prevents damage to the object. Be very careful when using a sledgehammer and only use when it is appropriate.

Chisels

A chisel is made from a hard, tough metal, usually tool steel. Its cutting edge is ground and usually shaped like one of the four types shown in figure 2–5. Chisels are classified according to their point type.

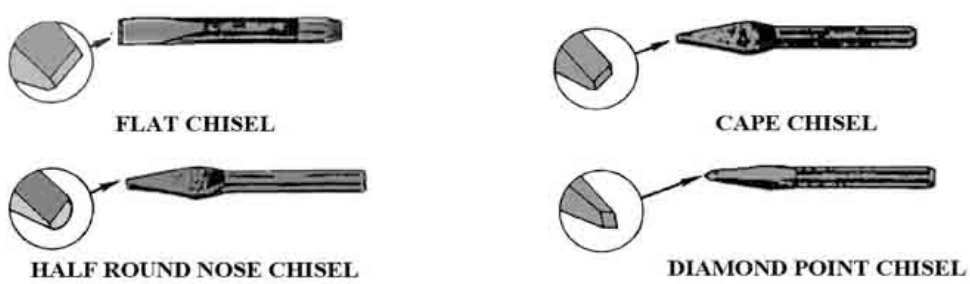


Figure 2–5. Types of chisels.

Types of chisels

The chisel you select should be appropriate for the work required. Let us look at the chisels used for metalworking and their descriptions.

Type	Description
Flat chisel	Most common type; has a cutting edge, ground at an angle of 60–70 degrees (°). Used for cutting sheet metal, chipping, cutting heads off rivets or screws, and all general cutting procedures.
Cape chisel	Some uses include cutting grooves, slots, and keyways, as well as chipping flat surfaces too narrow for a flat chisel.
Half-round nose chisel	The purpose is to cut round (concave) grooves.
Diamond point	Used for cutting V-shaped grooves.

Using chisels

Now that you have selected the right chisel for the job, the next step is to learn how to handle it properly. Follow these procedures:

1. Wear safety goggles when using any type of chisel since fragments of the item will break off and pieces of the chisel itself can break and become airborne.
2. Hold the chisel with the cutting edge precisely at the point where you want to make the cut. Choose an angle that will cause it to follow the desired finished surface. The larger this angle is, up to 90°, the deeper the cut will be.
3. Strike the back end of the chisel with a ball-peen hammer. You should strike by using sharp, quick blows, while being careful that the hammer does not slip off the end of the chisel and injure your hand. It is best for you to watch the chisel edge and not the head.
4. Set the chisel, after each hammer blow, to the correct position for the next cut. Remember that the depth of the cut depends on the angle that you hold the chisel in as it relates to the work.

Care of chisels

Chisels, like all cutting tools, must be sharp to give satisfactory service. To maintain chisel serviceability, ensure you use the following guidelines:

- Protect the cutting edges by installing protective covers.
- Avoid chipping and breaking by storing in racks.
- Lubricate with a light coat of oil before storing.
- Regrind broken or chipped edges before using.

Hammer blows eventually cause a chisel head to spread out until it resembles a mushroom. When this happens, dress the chisel by grounding the head back to its original shape. It is dangerous to use a chisel with a mushroomed head because pieces may fly off and cause injury. Figure 2–6 shows the dressed chisel.

Figure 2–6. Dressed chisel.

Punches

There are two basic categories of punches—solid and hollow. Solid is the most common type you will use. See figure 2–7 for the different types of solid punches.

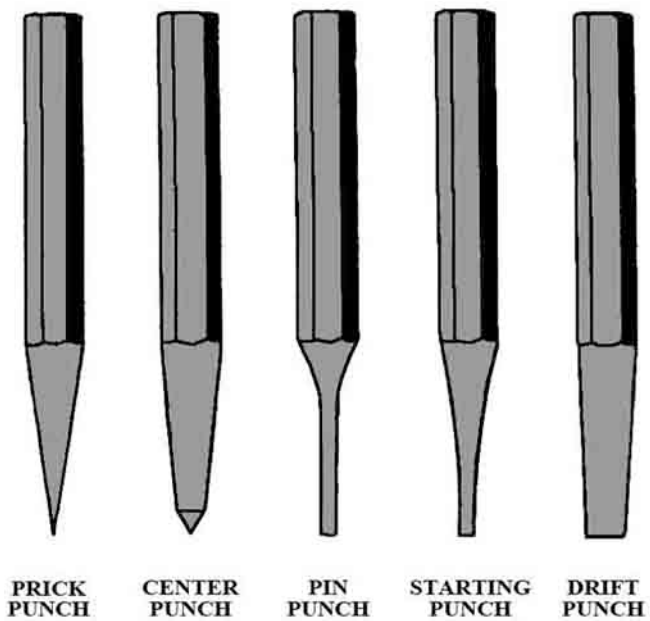


Figure 2–7. Types of solid punches.

Types of punches

The type of punch you use will depend on the job you are trying to accomplish. All punches vary in size, so you may have quite a selection of the same basic design available to you.

Type	Description
Prick punch	Used to mark soft metal; has a long, conical-shaped point.
Center punch	Modified prick punch; used in metal work for starting drill holes.
Pin punch	Used to remove straight or taper pins and is a straight shaft with a flat tip that may be tapered.
Starting punch	Modified pin punch; sturdy with a tapered shaft used to start the removal of, or loosen, straight pins or taper pins.
Drift punch	Used to remove shafts, pins, rivets; and to align small parts, it has a narrow, tapered, flat point.

Use and care of punches

Make sure you use a punch solely for its designed purpose and always wear eye protection. Clean punches with a clean rag after each use and apply a light coat of oil before storing them. Occasionally, you will have to refinish the tip and the head. Dress the punch to the correct shape if the head of a punch becomes mushroomed.

Pliers

Use pliers (fig. 2–8) for holding small objects, bending or cutting thin, soft wire, or thin, soft metal strips. They vary in size and shape, depending on their purpose. Take the following precautions when using any type of pliers:

- Keep the joint of the pliers well lubricated. You can operate pliers with one hand if the pivot point works freely.

- Never use pliers for tongs. Excessive heat draws the temper and softens the steel.
- Never use pliers to tighten or loosen a nut. Using pliers on a nut damages both the nut and the pliers.

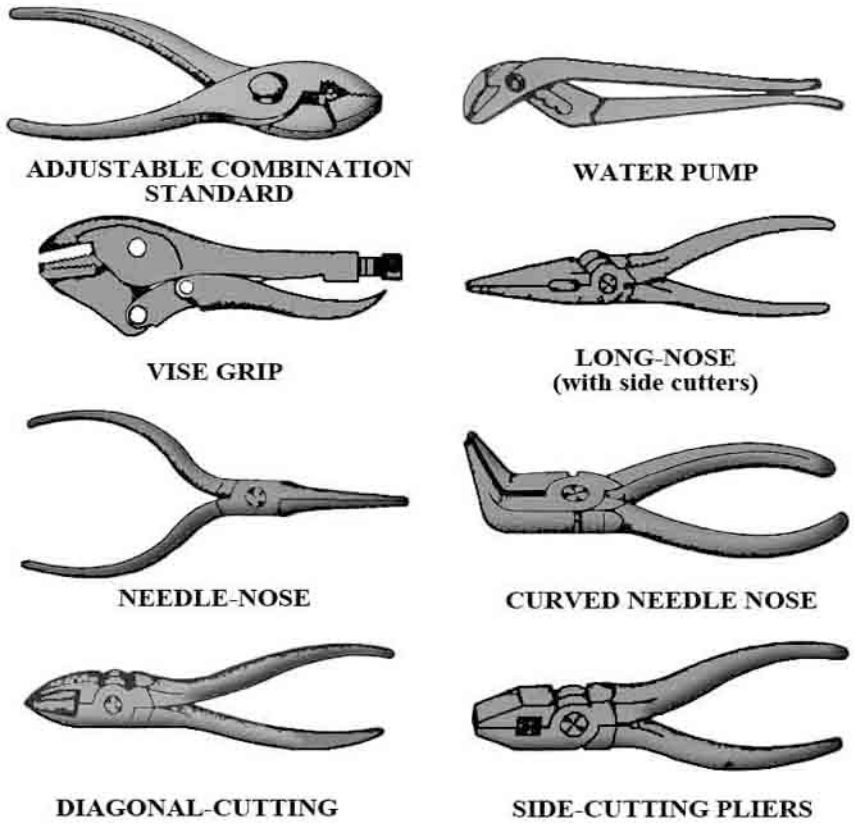


Figure 2–8. Types of pliers.

Types of pliers

There are many types of pliers available. We will only discuss the most commonly used types.

Adjustable combination standard pliers

Also referred to as slip-joint pliers, these pliers are used for cutting and twisting wire, pulling or spreading cotter pins, and using general utility operations. They are useful for holding round, stock, or light metal.

Adjustable water pump pliers

These are similar to standard combination pliers with the exception of the jaws being offset. This allows you to apply more leverage to these jaws of in comparison to combination pliers of equal length. Unlike combination pliers, water pump pliers have several adjustment positions instead of just two. This feature makes them a handy tool for gripping oddly-shaped objects and hard-to-reach fittings when no other tool is available. You may also hear these referred to as Channel Locks®.

Locking pliers

Locking pliers, commonly called Vise Grips®, have a locking device on the movable jaw and the jaws are adjustable to openings of various sizes, which automatically lock in position when you close the handles. Use this tool primarily to hold parts secure while you work on them. They also provide a large amount of gripping force for loosening stubborn, or rounded, bolts or nuts.

Long-nose pliers

The long-nose, or needle-nose, plier design makes them desirable for reaching into most inaccessible places. They come in various sizes and shapes for special purposes and convenience. Figure 2–8 shows three styles—long-nose with side cutters, needle-nose, and curved needle-nose. They are suitable for bending or forming fine spring wire and thin, narrow sheet metal strips. You can easily strain the long jaws, so do not use them for heavy work or for any twisting action that might bend the jaws out of alignment. Use these only for small, light work.

Diagonal-cutting pliers

The diagonal cutter is a soft wire-cutting tool only; it has no gripping jaws. Although the cutting edges extend the full length of the jaw, place the material you are cutting as close as possible to the pivot point.

Side-cutting pliers

Side-cutting (fig. 2–8), or lineman's (electricians), pliers are heavy-duty pliers that combine the gripping jaw of the combination pliers and the cutting surface of the diagonal cutters. The jaws of the side-cutting pliers are broader than combination pliers are. The jaws are excellent for pulling and bending heavy-gauge electrical conductors, and the cutting edges are great for cutting heavy-gauged soft wire.

Caring for pliers

Clean the serrated jaws with a small, wire brush and wipe the pliers with a clean rag to remove grease and oil. Lubricate the pivot point with one or two drops of lubricating oil.

Wrenches

A wrench is a tool used to tighten or loosen nuts, bolts, studs, and pipes. Figure 2–9 illustrates some common types you will use. We will first look at the precautions required for all wrenches, then discuss the different types of wrenches.

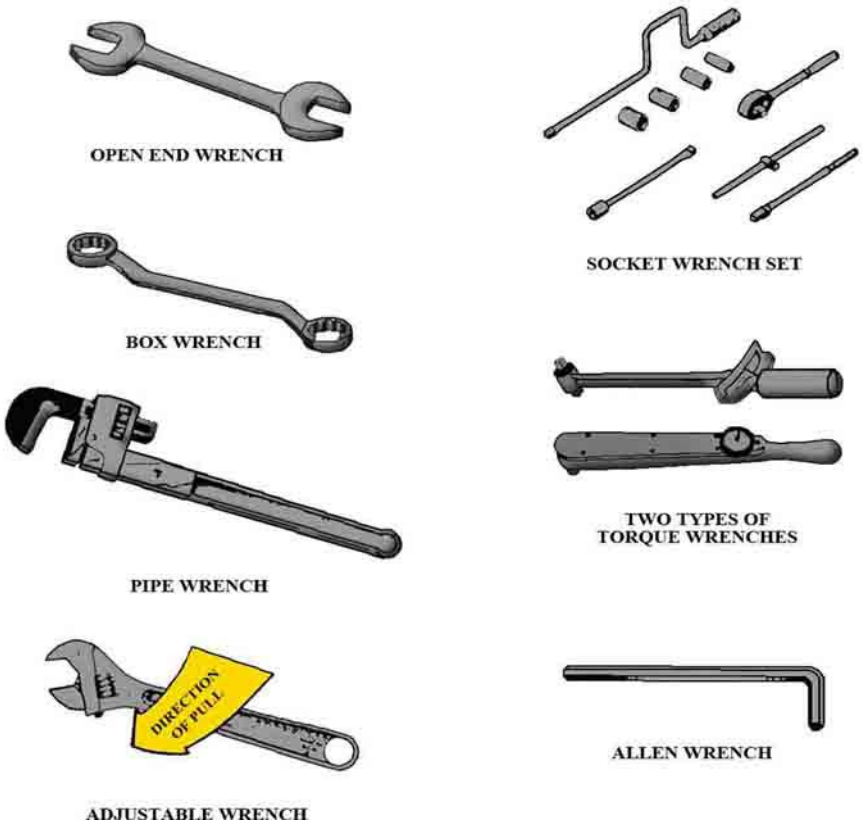


Figure 2–9. Commonly used wrenches.

Precautions

Each type of wrench has a specific purpose and you must use each one properly or you risk injuring yourself or damaging the equipment you are working on. A wrench too large can damage work; and if it is too small, the wrench itself can be damaged. Always make sure that the wrench opening fits the nut exactly. Do not try to use standard-sized wrenches on metric or vice versa. When you use a wrench that is too large, it rounds off the nut corners and springs open the wrench jaws.

At times, you must apply a large amount of force to a wrench to do work. Only use extension handles if they are designed specifically for the wrench you are using. Get a wrench with a longer handle if you cannot apply enough force with the wrench you are trying to use. This increases the mechanical advantage without overloading the jaws. Always arrange the wrench and the work so that you pull on the wrench; it is dangerous to push on the wrench. You can injure your hand if the nut or bolt should break loose unexpectedly or if the wrench slips. The type of work you are doing determines the type of wrench you will use.

Types of wrenches

Described below are some common wrenches you will use on the job and their uses. Follow using figure 2–9 as each wrench is discussed.

Open-end wrench

An open-end wrench is the most widely used type due to the ease of getting it on and off the bolt or nut. They come in multiple sizes and openings; the openings of most wrenches offset by 15°, making them easier to work in close quarters. For further ease, turn the wrench over (often called flopping) after each stroke. Using this technique, you can turn a nut even with a 30° limited wrench swing.

Box wrench

A box wrench is better than an open-end or an adjustable wrench. You should use it whenever possible because it provides the best protection to the user and the equipment. Some of the benefits are that you can apply more torque, it is less likely to slip off nuts or bolts, and its area of contact is greater. The disadvantage is that there must be enough clearance above and around the bolt head to place the box wrench over it.

Pipe wrench

Use pipe wrenches for pipes or round materials. The pipe-wrench jaws have teeth that bite into round material and only grabs in one direction. Moving the wrench in the opposite direction allows it to be repositioned for more pulling, like a ratcheting action. The strap pipe wrench is a pipe wrench variation that does not have jaws; a leather or canvas strap is used to turn the pipe. This ensures that you will not scratch or damage the pipe surface.

Adjustable wrenches

Close the jaws as tightly as possible on the work when using adjustable wrenches, which are often referred to as Crescent® wrenches. Place the work into wrench jaws against the back wall of the opening. Check the adjustment of the wrench carefully each time you use it to ensure a close fit. Always position the adjustable wrench on the work so you apply pulling force towards the stationary jaw, as in figure 2–9. The pressure on the movable jaw spreads it out if you apply excessive force. *Only* use adjustable wrenches when the correct, specific size wrench or socket is not available.

Socket wrenches

The socket wrench is an adaptation of the box-end wrench. Sometimes, access to a bolt head or a nut is so difficult that you have no choice but to use a socket. Sockets come in sets with measured-size openings. Some precautions with socket wrenches are:

- avoid overstressing;
- *never* use an extension on the ratchet handle to increase torque;
- use a socket that snugly fits the bolt or nut; and

- use correct drive size; drive size refers to the size of the square boss in the socket into which the external drive end of the extension or handle fits.

Torque wrench

A torque wrench is a special handle for a socket used when the torque of a nut or bolt is critical. The two types of torque wrenches are indicated by the breakaway, shown in figure 2–9. There are two types of torque wrenches: the *indicating* type shows the amount of applied torque, either on a dial or with a pointer, while the *breakaway* type automatically releases force when it reaches the predetermined torque value. Torque wrench measurement settings are in inch-pounds or foot-pounds.

Hex wrench

Your toolbox should contain several sizes of hex wrenches, popularly known as Allen® wrenches, in both metric and standard. You will use them to tighten or loosen recessed hex head screws. The L-shape of the wrench is the same size on both ends; this enables you to use it for short or long reach or to obtain a leverage advantage. Do not use hex wrenches for high-torque applications. These small wrenches will snap and the large ones will twist out of shape if you apply excessive torque.

If a setscrew is difficult to remove, use penetrating fluid to help loosen it. Remember, hex wrenches come in standard and metric sizes, so be sure to select the correct size for the job. The difference in their sizes is very small and it is easy to pick the wrong size and strip a screw.

212. Specialized hand tools

There are hand tools that you must be familiar with that are only used sparingly. Because you do not frequently use these tools, you are more likely to misuse them than the tools previously discussed. This lesson will prepare you for using these tools when the time comes. We will start with files and saws.

Files

A file is a hardened, high-carbon, steel tool used for cutting, removing, smoothing, or polishing metal. The cutting teeth consist of diagonal rows of chisel cuts along the file face.

Files are available in various shapes and sizes and range in length from 3–24 inches. The file you use will depend on the job you are doing. Figure 2–10 displays common file shapes.

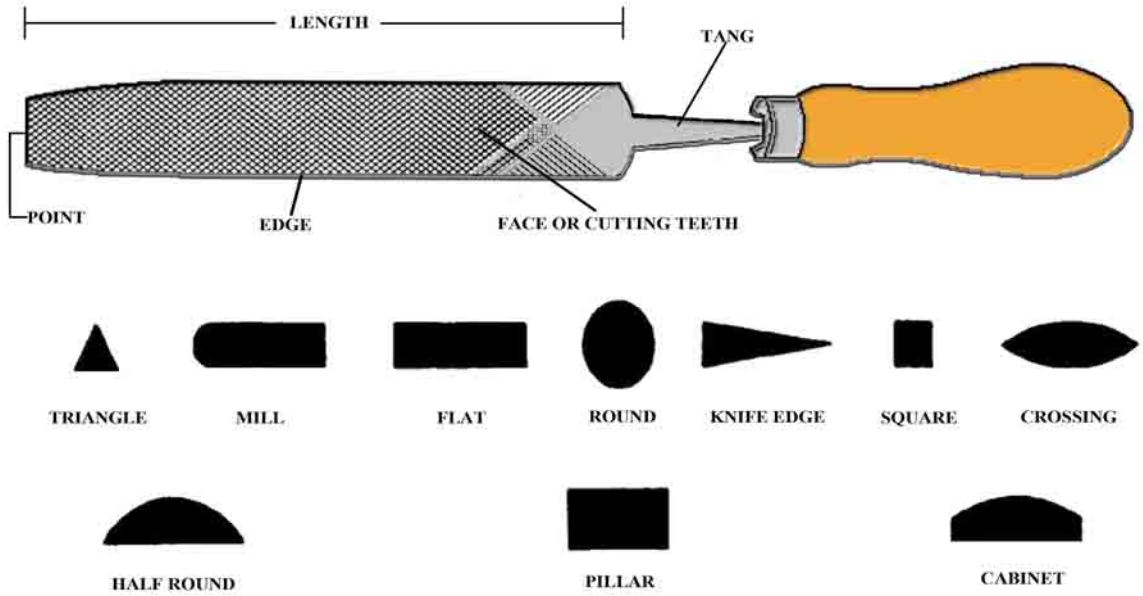


Figure 2–10. File shapes.

Files categories are listed by name and/or grade and cut. The grade refers to the distance between the parallel cuts, which are listed in the order of coarseness. Figure 2–11 shows the seven most common grades.

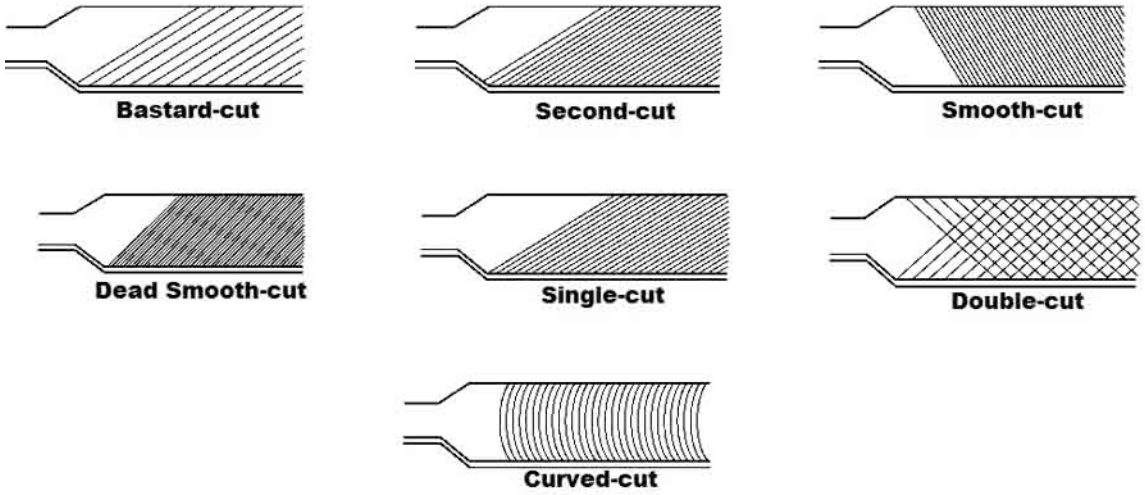


Figure 2–11. File cuts and grades.

Use the following information to select the correct file for your work:

- For heavy, rough cutting, use a large, coarse, double-cut file.
- For finishing cuts, use a second-cut or smooth, single-cut file.
- When filing cast iron, start with a bastard-cut and finish with a second-cut file.
- When filing soft metal, start with a second-cut and finish with a smooth-cut file.
- When filing hard steel, start with a smooth-cut file and finish with a dead smooth-cut file.
- When filing aluminum, lead, or any very soft metal, use a curved-cut file.
- For small-sized work, use a short file; for medium-size work, use an 8- or 10-inch file.
- When using a file, only use one as large as you can conveniently control.

Using files

To correctly file, apply pressure on the forward stroke only. Unless you lift the file from the work on your return stroke, it will become dull much sooner. Do not exceed 30–40 strokes per minute because too much speed will ruin the file and the work. You get the best results by using a rocking motion when filing round surfaces. Always use a file handle to prevent cuts or punctures from the tang.

Caring for files

For files to work as intended, you must maintain them in good condition. When you file soft metals or narrow surfaces, small particles of the work are likely to clog the file teeth and scratch the material you are filing; this is known as pinning. Pinning is usually the result of putting too much pressure on the file, especially new files. Break a new file in on soft metal first to avoid pinning. Clean a file with a file card, brush, pick, or pin if a file is pinning or not cutting properly. Use the pick to clean out clogs in individual cuts of the file that are too tight to clean with a file card. To clean a file, lay it flat on the bench and draw the file card or brush back and forth across it, parallel with the cuts, and finish by brushing the file lengthwise.

Rough or improper handling easily dulls a file. Do not throw files into a drawer or toolbox where they can rub against each other or against other tools. Store the files in separate holders, such as clips, straps, or holes cut in a wooden block. Wrap files in heavy paper to preserve their cutting edges if you

carry them in a toolbox. Do *not* oil files; this will cause them to slide across the work preventing fast-cutting.

Saws

The three types of saws commonly found in maintenance sections are the crosscut saw, ripsaw, and hacksaw. You use the crosscut and ripsaws for cutting wood and the hacksaw for cutting metal. Each type of saw and its description are in the table below:

Type	Description
Crosscut saw	Used to cut across wood grain, available in various lengths. The teeth are shaped and filed to cut like knives. The number of teeth per inch varies, either 8, 10, or 12. For best results, hold the blade with the teeth at a 45° angle from the work.
Ripsaw	Used to cut parallel to the grain. The teeth are shaped and filed to cut like chisels. Ripsaws usually have 5 ½ to 6 ½ teeth per inch to provide easier cut start. Hold the blade with the teeth at an angle of 45° on thin boards and 60° on boards of average thickness for best results.
Hacksaw	Used to cut metal. A hacksaw has either a solid frame that holds a standard-length blade or an adjustable frame that can hold blades of different lengths. Figure 2–12 illustrates variations in hacksaw frames. You can set the blades parallel either to, or at, *right angles* to the plane of the frame. Use screws mounted on the frame to pull the blades tight.

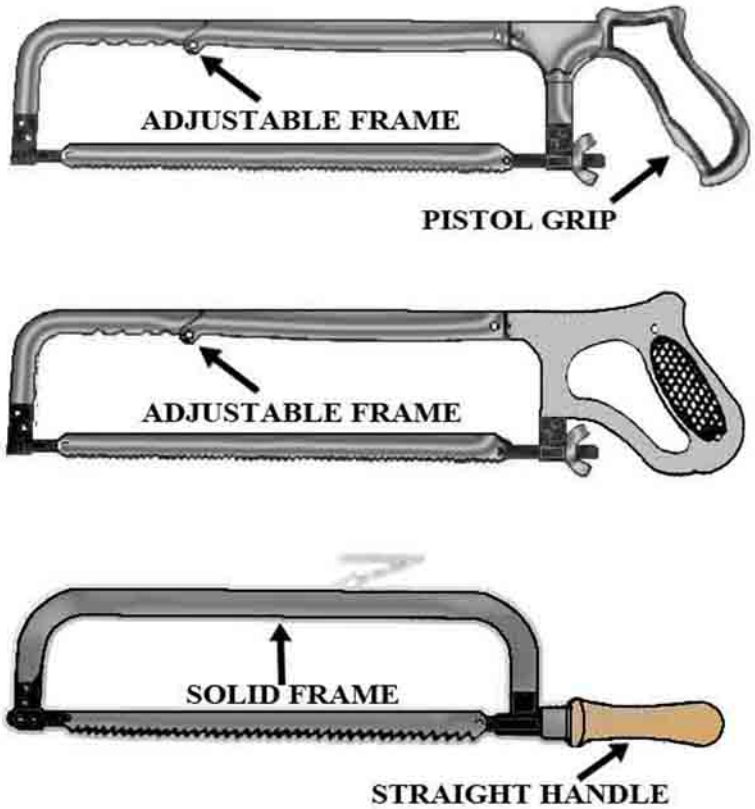


Figure 2–12. Hacksaw frames.

Different hacksaw frames use the same type of blades—either all-hard or flexible. Both types consist of a hardened and tempered, high-grade tool steel. On the flexible blade, only teeth are hardened; therefore, the blade does not break as easily under bending stress. Use an all-hard blade for sawing brass, tool steel, cast iron, and other stock with a heavy cross section. Use a flexible blade for sawing

hollow shapes and metals with a light cross section, such as channel iron, tubing, tin, copper, and aluminum.

Blades have pitches (teeth per inch) of 14, 18, 24, and 32. The information in the following table will help you in making the best pitch selection for your work:

Pitch	Uses
14 or 18	For machine steel, cold-rolled steel, or structural steel. Coarse pitch makes the saw free and fast cutting.
24	For tubing (tin, brass, copper, channel iron) and sheet metal thicker than 18 gauge. A coarser pitch tends to strip the teeth and makes pushing the saw difficult.
32	For thin-walled tubing, electrical conduit, and sheet metal thinner than 18 gauge.

Select a pitch that permits two or more teeth to contact the material at one time. Some possible troubles and their corrective actions are in the table below:

Trouble	Corrective Action
Difficulty starting the blade	File a small notch to guide the blade.
Loss of blade temper	Use a new blade and reduce cutting speed to 40–50 strokes per minute.
Binding	Apply a small amount of oil to both blade sides.
Stripped teeth or broken blade	Use a finer pitch blade, apply less pressure on the cutting stroke, or tighten the vise to eliminate work slippage.

Ensure you install the blade with the teeth pointed away from you. Mount the work to be cut in a vise if possible. Apply pressure only on the forward stroke and not on the return stroke because hacksaw blades only cut in one direction.

Taps and dies

Use taps and dies, shown in figure 2–13, to cut and repair threads in holes and outside threads on rods or bolts.

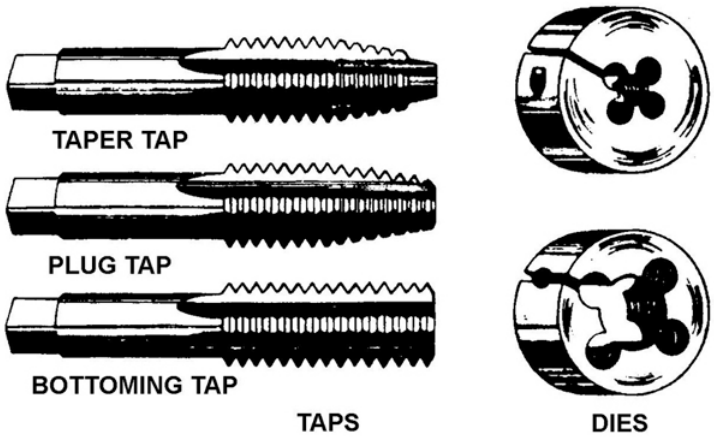


Figure 2–13. Taps and dies.

Taps

Use taps for cutting threads inside of holes in metal, fiber, or other material. Figure 2–13 shows three types of taps and their descriptions for use below:

1. Taper taps are used to start and finish threads if the threading runs entirely through the work.

2. Plug taps are used when one end of the hole is closed.
3. Bottoming taps are necessary to cut full thread to the bottom of a closed hole.

Preparation is an important part of tapping. First, you must determine which screw size to use. Use a screw pitch gauge (discussed later in this section) to perform this step. However, you can use the taps themselves to measure screw pitch if a screw pitch gauge is not available. To do this, use the tap as a screw pitch gauge and perform the operation described later in the screw pitch gauge lesson. Once you determine the screw size, use a tapping table to choose the proper drill size.

Now that you have the proper drill size for the tap you selected, you are ready to begin tapping using a tap and one of two tap wrenches (fig. 2–14). Figure 2–15 shows the proper, step-by-step tapping procedure.

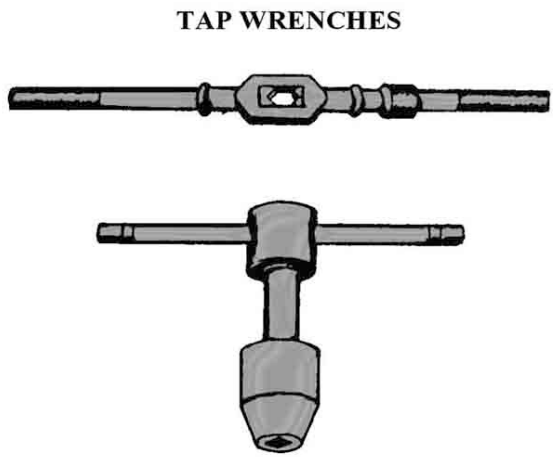


Figure 2–14. Tap wrenches.

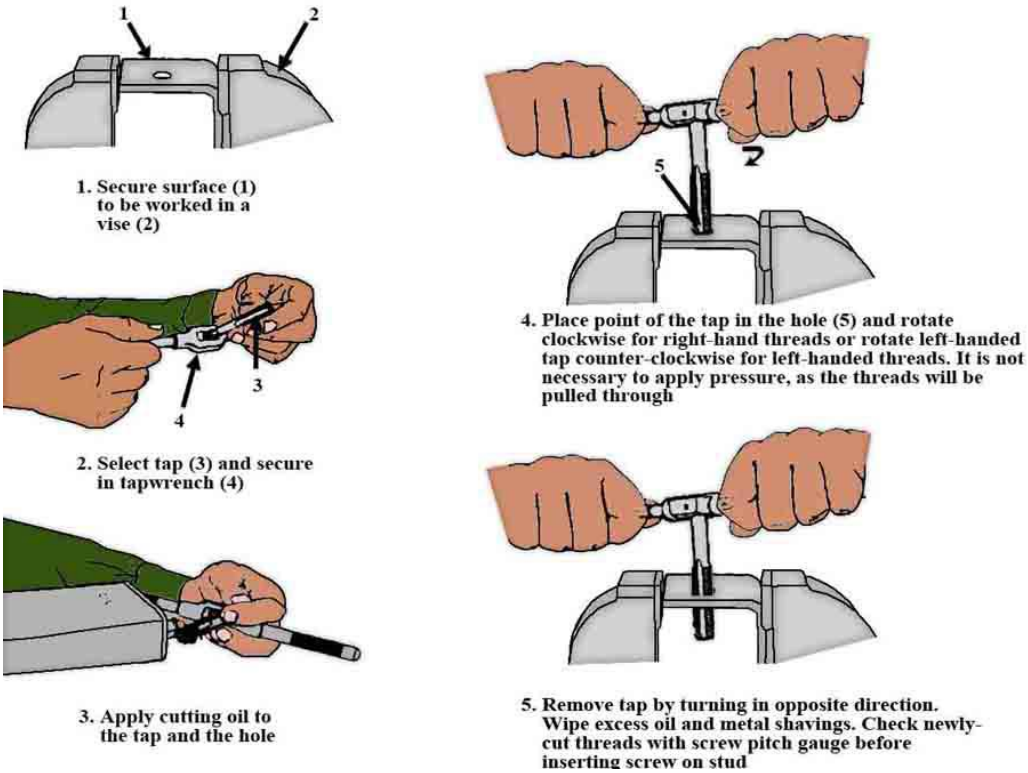


Figure 2–15. Tapping procedure.

Dies

Use dies to restore rounded or rusty threads on screws and bolts. You must use die in a die stock (fig. 2–16) to rethread the work. They are available in a variety of sizes and usually assembled in sets with a case.

Figure 2–16. Die stock.

Figure 2–17 illustrates the proper die procedure to follow to rethread a bolt.

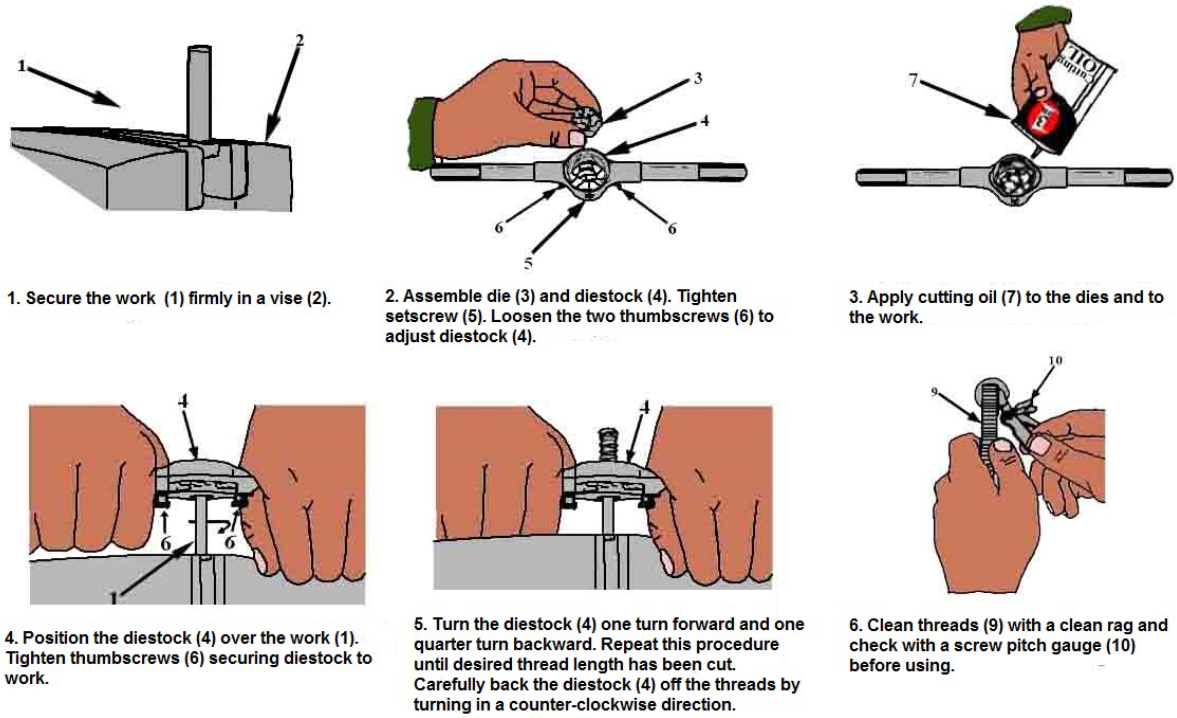


Figure 2–17. Die procedure.

Screw extractor

Screw extractors remove broken screws, bolts, or studs. The screw extractor (fig. 2–18) has tapered sharp ridges (like left-hand threads) that grip the sides of the drilled hole in the broken part so you can back it out of the hole.

Figure 2–18. Screw extractor.

Figure 2–19 illustrates the proper screw extraction process. You may need to start larger bolts and studs out with a chisel or pin punch.

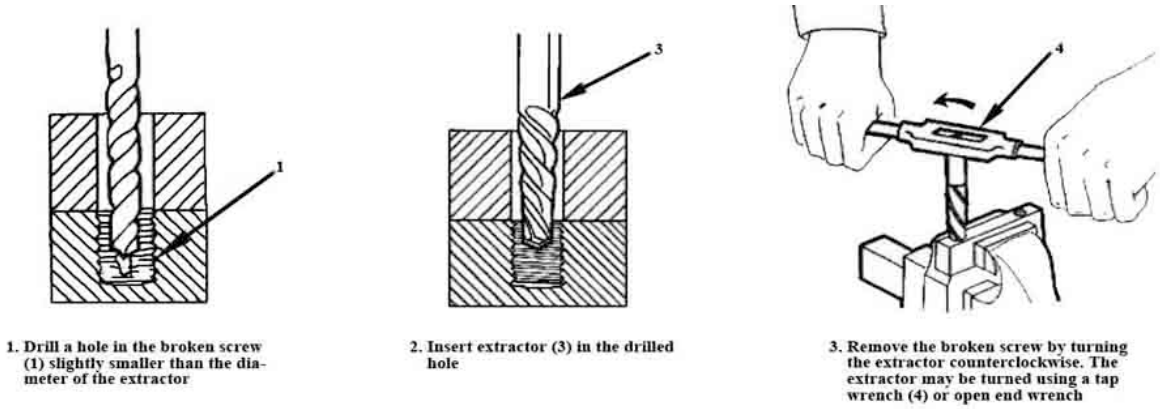


Figure 2–19. Screw extraction procedure.

Measurement gauges

Gauges have certain set dimensions and you use them to check clearances and sizes of parts and material. You can take measurements with micrometers and rulers, but it is much easier, and more accurate, to use a gauge. You will use gauges for checking the size of twist drills, wire, screw pitch, and thickness.

Drill gauge

The drill gauge (fig. 2–20) consists of a rectangular metal plate with various sized drill holes marked to indicate the size. There are separate gauges for letter, number, or fractional size drills. Use a gauge for checking the size of a twist drill or for separating an assortment of unknown sizes. The gauge is especially useful in checking small drill sizes that are hard to read or worn off. The drill gauge also provides an index of drills for various tap sizes.

For example, assume that you must tap a piece of metal to receive a 10–32 bolt. From the gauge, you can see that for a tap size of 10–32, you must drill the hole with a number 21 drill (fig. 2–20). This will allow sufficient material inside the hole for threads. If the bolt needs to go all the way through the material without threads through it, use a number 11 body drill (fig. 2–20). This allows clearance in the material for the bolt to pass through unrestricted.

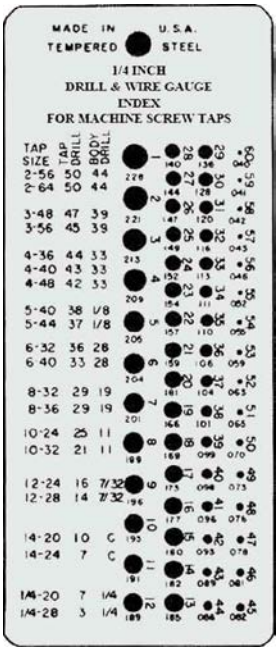


Figure 2–20. Drill gauge.

Wire gauge

The wire gauge (fig. 2–21) is a circular metal plate with precision slots that correspond to various gauges of wire. Use the squared slots to determine the thickness, or gauge, of sheet metal. The gauge checks from 0-gauge to 36-gauge wire and metal. Each slot has a corresponding gauge number stamped to compare an unknown wire gauge against a known gauge.

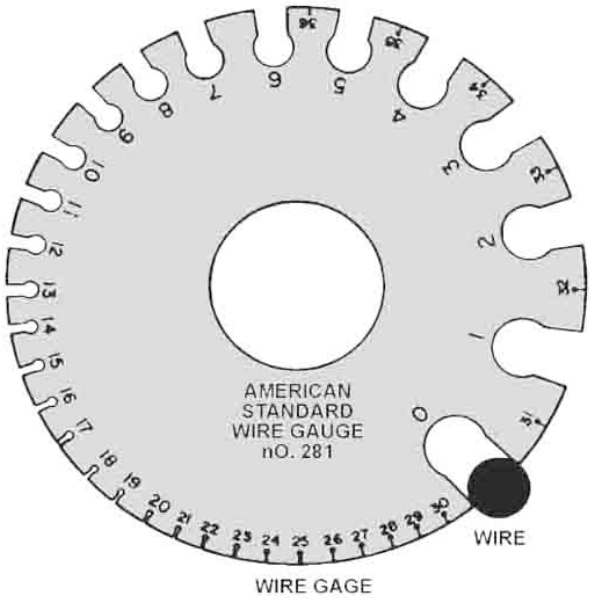


Figure 2–21. Wire gauge.

Screw pitch gauge

The screw pitch gauge (fig. 2–22) checks the pitch of an unknown thread. It has a holder that contains several blades with teeth that correspond to the various screw threads. Each blade has a number indicating the number of threads per inch, or the adapted thread pitch. You determine the right blade by trial or error.

Select any one of the screw pitch gauges and hold its teeth against the screw. Look at the fit of the blade teeth and screw threads toward a source of light. Continue to select different pitch gauges until you get an exact match to the screw thread. It is difficult to distinguish the difference of pitch in finer threads. You can also use the screw pitch gauge to determine the inside thread size of nuts and holes.

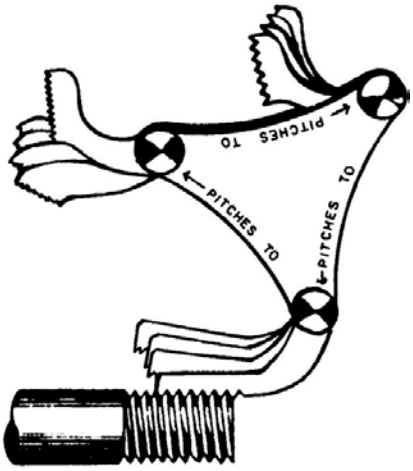


Figure 2–22. Screw pitch gauge.

Thickness gauge

Use a thickness gauge (fig. 2–23), also known as a feeler gauge, to measure the space between two objects. It has a holder with hardened steel blades ground to a definite thickness. The blades attach to the holder on one end, and each blade of the gauge has a marking with its thickness, usually from 0.001–0.030 of an inch. To measure a space that is more than 0.030 of an inch, use two or more blades together. The knurled nut on the end of the holder varies the tension at the pivot point. This can become critical when using the thinner blades since they bend and kink easily. The thinner blades are between the larger blades in the holder to offer some protection.

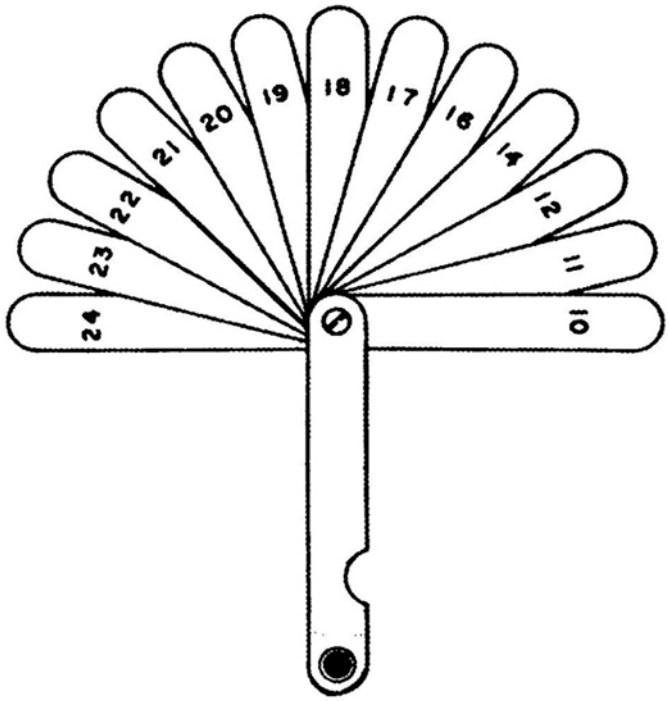


Figure 2–23. Thickness gauge.

When checking the clearance between two surfaces, clean both surfaces, and the gauge blades, since minute particles can cause a measurement error. The blade should slide in and out of the gap with a snug, slightly dragging fit. Hold the blade as flat as possible and check at least two or three times to ensure accuracy. One way to check accuracy is to try to insert the next larger blade. If it does not fit, the clearance check is good.

Keep gauges clean and free of dirt and grease. A light coat of oil will prevent rust and keep the numbers readable. Be sure to wipe gauges clean after use to remove body oils and water, which may corrode them.

Inspection mirrors

The inspection mirror aids in making detailed inspections where you cannot see. By angling the mirror, with the aid of a flashlight, it is possible to inspect most areas. Inspection mirrors are handy for viewing information on equipment identification plates when you cannot move the device. Be careful when using these metal tools around electrically-energized equipment. Contact with the metal parts could cause you injury and damage the equipment. If it is necessary to use mirrors around energized equipment, insulate your mirror with electrical tape or obtain a disposable, plastic-handled mirror.

Mechanical fingers and magnetic pickups

Murphy's Law dictates that whenever you drop a screw or nut, it will inevitably end up in some place that you cannot reach it with your fingers. This is where mechanical fingers and magnetic pickups are handy. Mechanical fingers are also useful when starting nuts or bolts in difficult areas.

Mechanical fingers (fig. 2–24) have a tube containing flat springs that extend from the tube end to form claw-like fingers. The end of the tube has a plate attached and a similar plate, pressed by the thumb, attaches to the end of the rod. A coil spring placed around the rod between the two plates holds them apart and retracts the fingers into the tube. With the bottom plate grasped between the fingers, and enough thumb pressure applied to the top plate to compress the spring, the tool fingers extend from the tube in a grasping position. When you release thumb pressure, the tool fingers retract into the tube as far as the object they hold will allow.

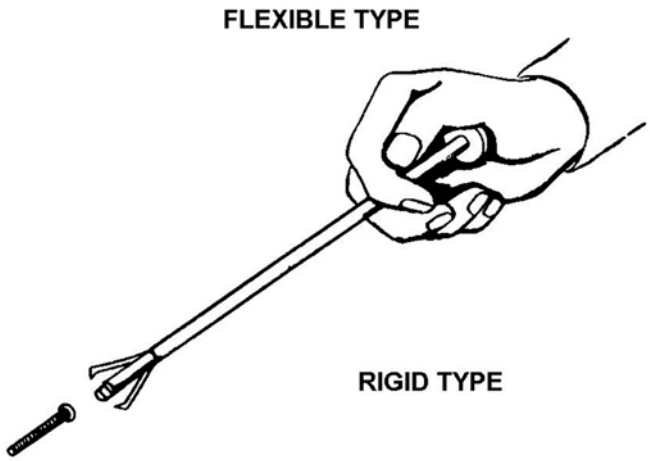


Figure 2–24. Mechanical fingers.

This pressure applied on the object securely holds it. Some mechanical fingers have a flexible end on the tube to permit their use in close quarters or around obstructions.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

210. Hand-tool safety principles

1. List three general behavior guidelines associated with the use and care of tools.

2. What is the *greatest* hazard posed by hand tools?

3. When must you remove a tool from service due to damage?

4. Why is it important to clean up residue when using an abrasive device, such as a file?

5. List at least three special precautions to observe when using tools in outside weather conditions.

211. Using hand tools

1. What is the *only* purpose of a screwdriver?

2. What is the proper method for using a hammer to perform the work effectively?

3. Which type of hammer do you use for forming heads on rivets?

4. List the types of chisels and their uses.

5. What must you do if a chisel head mushrooms out?

6. Which punch would you use to remove shafts and rivets?

7. Describe the maintenance that is required for punches.

8. What is the purpose of pliers?

9. Which type of pliers allows more leverage to be applied to the jaws? Why?

10. How are diagonal-cutting pliers used?

11. What could happen if you use a wrench too small for a task?

12. How should you position an adjustable wrench on the work?

13. What is a socket wrench drive size?

14. What are the two types of torque wrenches?

212. Specialized hand tools

1. Which file should you select for rough cutting?

2. How is pressure applied when you are filing correctly?

3. How are round surfaces filed to get the best results?

4. What is pinning? How can you avoid it?

5. List saws commonly found in a maintenance shop, and describe the uses for each.

6. Which saw blade pitch should you use on copper tubing?

7. What can you do if you experience binding while using a hacksaw?

8. Why would you use taps?

9. What is the *first* step you must take in the tapping process?

10. What is the purpose of dies?

11. What would you use to remove a broken bolt?

12. When do you use a drill gauge?

13. Which type of gauge would you use to check the pitch of an unknown thread?

14. Why should you clean the surfaces and thickness gauge blade prior to measuring?

15. When would you use an inspection mirror?

16. Explain the primary precaution you must observe when using inspection mirrors.

17. What two purposes do mechanical fingers serve?

2–2. Power Tools

In comparison with hand tools, power tools offer an even greater risk for serious injuries. You will study safe procedures for operating common power tools in this section.

213. Observing power-tool safety precautions

When using a power tool, there are three major safety concerns listed below that you must address:

1. Power-tool safety.
2. Personal safety.
3. Operational safety.

Learn and apply this safety guidance whenever you operate a power tool. Every power tool has the potential to injure or kill if used in an unsafe condition or operated in an unsafe manner.

Power-tool safety

Safety begins with a preoperative inspection of the tool you are going to use. A few things to look for prior to operation are as follows:

- Ensure all guards are in place. Omitting a guard or using an unsatisfactory one is an invitation to serious injury.
- Check the features and quality of the tool. Ensure the tool is of good quality and not a cheap item that could present hazards. Parts should not wobble or give under pressure.
- Ensure it is not likely for power switches to trip easily and all parts are intact. Portable power tools may have plastic housings that can crack and break off to expose electrical parts that can shock you.
- Always seek someone who has a good working knowledge of the machine if you have questions about the operation of a tool.

Personal safety considerations

Following are personal preparations you must take before operating power tools:

- Use PPE—always use some form of proper eye protection. Use other items, such as a face shield, respirator, or safety shoes, as needed.
- Dress for the occasion—avoid loose-fitting clothing, long sleeves, jewelry, gloves with gauntlets, or neckties.
- Keep your mind on what you are doing—do not let your attention wander or the tool you are operating may do the same. Never indulge in horseplay. Even under safe conditions, playing around can be dangerous.

Operational safety procedures

When operating tools, it is important that you do not work too fast; however, work defensively.

Follow these pointers to prevent accidents and to protect your equipment:

- Clamp work to a workbench or in a vise if possible.
- Keep your hands, hair, and clothing away from blades, bits, discs, belts, or other moving parts while in use.
- Ensure power switches are off before plugging in a tool.
- Make certain the tool always has proper grounding equipped.
- Clean or tighten any part of a power tool when changing parts; turn the switch off and then unplug the cord.
- Ensure that a portable tool has stopped running before laying it down.
- Be sure you remove the key before operation if you use a key to tighten parts of a power tool.
- Never yank power cords from the wall socket; this can ruin the plug and the socket. Never carry a tool by its cord.
- Exercise extreme care when working in wet areas. Make sure the power cord is not in water. Avoid standing in wet areas if possible. Place a rubber mat on a skid, raised above the wet floor, and stand on the mat.
- Keep your work area clean. Clean oil and debris immediately to prevent slips.

214. Using power tools

There are varieties of power tools you may see during your BMET career. We cannot cover them all, so in this lesson we will cover the most common power tools that you will probably have in your shop. These consist of electric drills and bench grinders.

Drilling precautions

Occasionally, you will perform drilling operations in the hospital or clinic. If precision is a key factor, consult a machinist at the base machine shop; however, most work will not require such tight tolerances. Therefore, you should learn proper drilling procedures.

You drill by hand with a manual or electric drill. Other drilling operations require a drill press. In either case, the precautions and setup procedures are the same. Use a prick punch for layout and a center punch to center a hole before you drill. This mark gives the drill a starting point and prevents it from drifting, or “walking,” all over the work. You may have to use a pilot drill (smaller than the desired size) with large holes to prevent damage to the larger drill bit.

When you are drilling a hole of any size with any drill, the pressure you apply should not be so great that it stops the drill from turning. You must also take special care with smaller drill bits as they can break with minimal pressure. However, you must apply enough pressure to prevent the drill from riding (turning, but not cutting) on the work. Riding dulls the cutting edge of the drill, and metal chips can chip the drill’s cutting edge.

Portable electric drill

Electric motors power portable electric drills for AC or DC operation. Bearings are factory lubricated for lifetime service. If the drill has a metal case, it needs to have a three-conductor cable and a three-prong plug. Always plug a metal-cased drill into a grounded outlet to protect the user. Most modern drills are double-insulated. This means that there are no conductive surfaces on the tool. These drills may have a two-prong plug without a ground connector.

Commonly used electric drills have the capacity for drilling holes from 1/16 inch up to 3/4 inch in diameter. Figure 2–25 shows a common, pistol-grip–style electric drill used in most medical maintenance shops. Ordinarily, a key-type gear chuck that automatically centers the drill shank secures straight-shank twist drill bits. Many electric drills have attachments for driving screws, rotating small wheels, drilling at right angles, and other special work. When drilling metal with an electric drill, first be sure that the diameter of the desired drill hole is within the drill capacity.

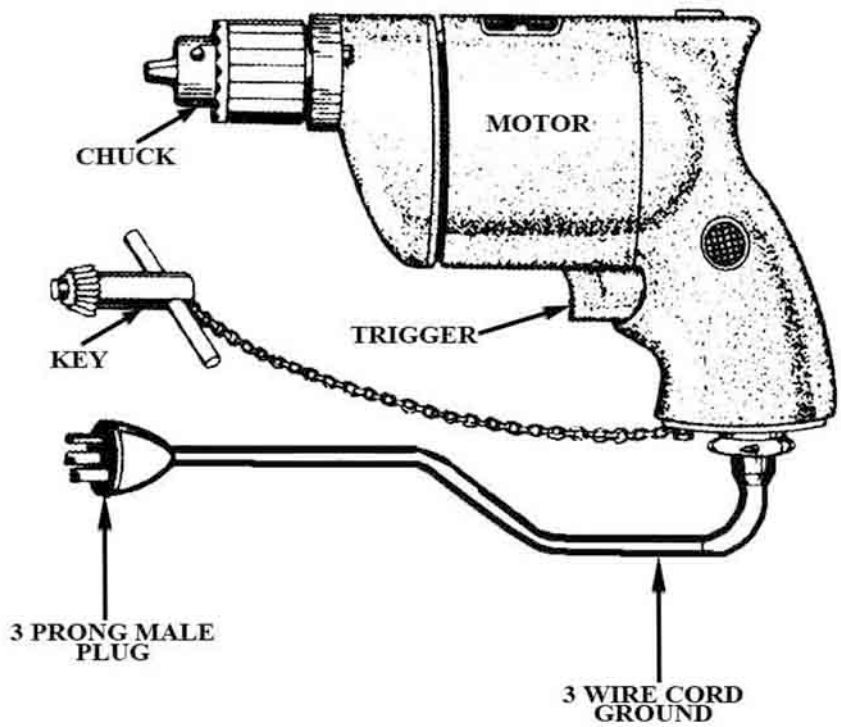


Figure 2–25. Portable electric drill.

The capacity of the drill chuck determines the size of an electric drill. For instance, a 1/2 inch drill has a chuck that will take a twist drill 1/2 inch in diameter and no larger. Do not use a larger than recommended twist drill. Overloading an electric drill or using excessive pressure can either stall or overheat the drill motor. Continued stalling and overheating will damage the drill motor to a point where it will become unserviceable. When drilling holes:

- be sure to hold the electric drill at a right angle to the surface you are drilling;
- exert a light pressure on the drill for continued drilling. Relieve pressure on the drill when the twist drill begins to break through, exerting only enough pressure to complete drilling the hole; and
- pull straight back until the twist drill is out of the hole before shutting off the motor.

Remember, drill bits do not pull themselves into the work; they must have some pressure applied. Varying the drill speed may also help its cutting ability. Very high speeds are not appropriate for cutting hard metals.

The drill is oiled according to manufacturer's specifications. Also, keep the ventilation holes on a drill free of dirt, dust, or lint to prevent the motor from overheating and keep the chuck clean and oiled to prevent rust or corrosion. Always use the correct chuck key for the drill you are using. Replace the key when worn to prevent damaging the chuck teeth, and never use anything other than the chuck key to tighten the chuck.

The chuck is what holds the twist drill bits. Many types of chucks are available for various purposes. The most popular chuck is known as the Jacob's chuck, which is shown in figure 2–26. This is a gear-type chuck where you clamp the bit into place with a gear-type key. Many drills are now using a keyless chuck. This convenient feature eliminates the need for a chuck key.

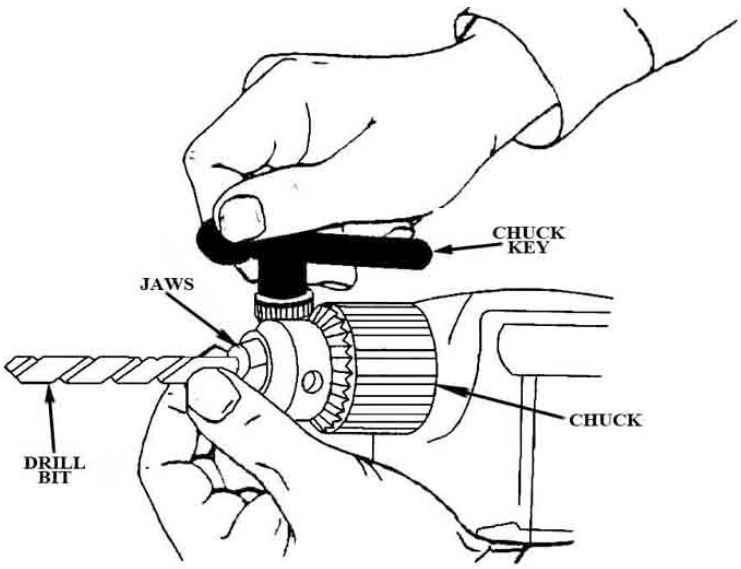


Figure 2–26. Drill chuck and key.

Twist drill bits

The drill bit most generally used for boring small holes in metal is the straight shank twist drill (fig. 2–27). Ordinarily these bits are high-carbon steel and are suitable for almost all classes of work. The properties of carbon steel are such that if you heat it excessively and allow it to cool, it can lose its hardness. On the other hand, high-speed drill bits can become red hot without the temper being "drawn" or lost. High-speed drill bits are special alloy containing tungsten, chromium, and cobalt. You should use high-speed drill bits when drilling several holes in Bakelite or other plastics, especially when used with an electric drill. This is because plastics are very poor conductors of heat and the drill bit absorbs the heat produced instead of it conducting through the work.

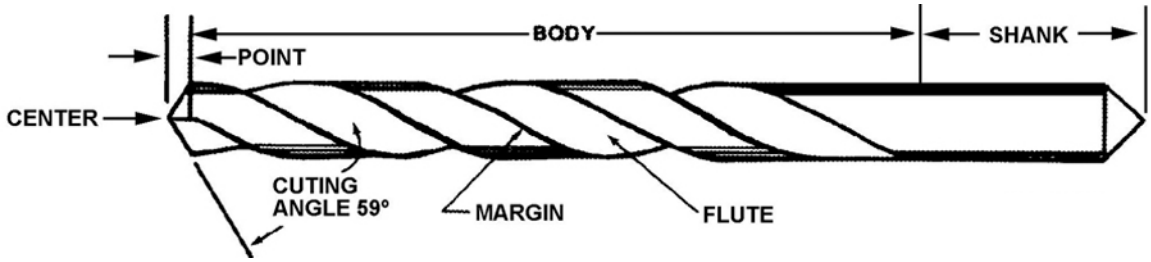


Figure 2–27. Twist drill bit.

To perform tasks that are not routine, you may have to use special drill bits. Use a masonry bit for drilling holes in stone, cement, brick, and tile. Auger bits for drilling large-sized holes in wood. To drill holes in extremely hard metals and special alloys, you will need cobalt or titanium-nitride bits. Drill bits up to 12 inches long are available for special jobs, such as drilling through wallboards or wooden floors.

The twist drill bit has three principal parts—point, body, and shank (fig. 2–27). The point is of the greatest interest because it does the cutting. You must ground or sharpen the point when it becomes dull. Also, the point is the entire cone-shaped region at the cutting end of the bit. The sharp edge at the extreme tip is the center and it does the first cutting.

After the center penetrates the surface, the "lips" of the drill point do the cutting. The back edge, or noncutting part, of the point is the *heel*. The body of a drill bit has a spiral groove, or "flute," cut in each side to raise the cuttings of the hole; the raised leading edge of the body is the "margin," which

also cuts and maintains the hole shape. Finally, the shank is the same diameter as the margin of the body and is the part of the drill the chuck holds.

You can sharpen drill bits if necessary, but normally they are so inexpensive it is not worth the effort. Never store drill bits loose in a toolbox. This will cause the cutting edges to become unnecessarily dull. Keep them in a rack, divided box, or drill index when not in use.

Drill press

Use drill presses for light- and medium-type work. You may have a floor- or bench-mounted type press in your shop; both are quite common. Figure 2–28 shows a typical bench-mounted drill press.

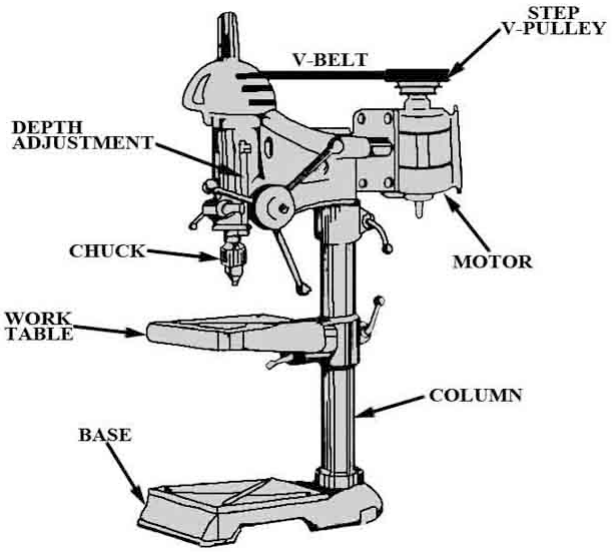


Figure 2–28. Bench-mounted drill press.

The main parts of the unit are a steel post fastened to a cast iron base, a table for holding the work, and a motor-driven head mounted at the top of the post. Cone-shaped, or stepped, pulleys make it possible to change drilling speeds from slow to as high as 5,000 revolutions per minute (rpm). Some modern drill presses use a variable speed motor to change speeds instead of a pulley system.

There are several important steps to take before plugging in and turning on the drill press. Prior to drill press operation, perform the following procedures:

1. Check the areas to make sure that you have adequate room to work and that the floor is clean and free of grease and oil.
2. Ensure the drill speed is correct for the material you are drilling. Normally, the harder the material or larger the drill bit, the slower the drill speed.
3. Set the drill table at the proper height for you. While this height is usually even with the bottom of your breastbone, the height of the item worked on may require the drill table to be set lower.
4. Select a sharp bit, of the correct size, and center it in the drill chuck, ensuring that all chuck jaws contact the bit shank.
5. Be sure that no cutting edge of the twist drill is in the chuck jaws.
6. Operate the spindle with your hand to ensure the spindle is free to turn. Move the operating level to make sure you can raise and lower the drill bit to line it up with the hole in the center of the table to avoid drilling into the table. Readjust the table, if necessary.
7. Wear goggles or a shield, remove jewelry, and be sure clothing will not get in the drill press' moving parts.

Once the above procedures have been accomplished, you can now begin drilling by following the procedures below:

1. Lower the drill bit, with your work in place, to where the point will just clear the bottom of the work and set the stop nuts at that position.
2. Place a wood block under the work, when possible, if the material is small or thin. This is used to prevent “dimpling” around the drill hole.
3. Align the drill bit and secure the work, either with a “C” clamp for large material, a drill vise or pliers for smaller work, after marking a pilot point with a center punch.
4. Apply power and lower the drill to the work, making sure the drill tip contacts the point marked for drilling.
5. Exert a light pressure on the operating lever, and once the bit begins to cut metal, raise the bit to recheck the alignment.
6. Continue drilling with a light, steady pressure on the operating lever if the alignment is good. When you feel the bit going through the bottom, relieve the pressure slightly on the operating lever.
7. Raise the bit, turn off the drill press, and remove the work when the bit is completely through the material.
8. Do not try to remove shavings with your hands. They may be extremely hot and sharp. Use cutting oil at the drill site when drilling harder material to keep the bit tip cool.

Clean the drill press after use. Metal shavings can lodge between the movable table and the polished steel post, which scratches the post. Use a light coat of oil to inhibit rust and lubricate the post. Lubricate the drive motor as required by manufacturers’ specifications.

Bench grinder

The bench grinder (fig. 2–29) is a tool used for reshaping and sharpening chisels, drills, hatchets, and other similar small hand tools; it is usually fitted with both medium- and fine-grain abrasive wheels. You can remove these abrasive wheels and substitute them with wire-brushing wheels, buffing wheels, or polishing wheels. Each wheel has an eye shield over the working area and a work rest in front of the working surface. The rest serves to steady the work held against it and should stay about 1/8 inch from the wheel.

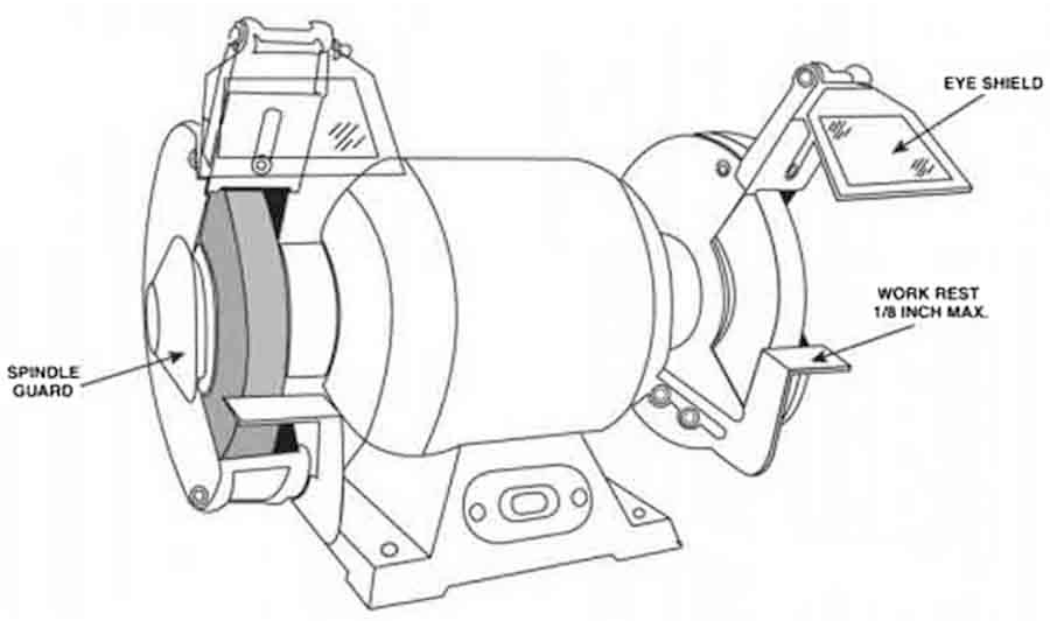


Figure 2–29. Bench grinder.

Precautions

Before applying power to the grinder, there are some preventive measures you need to take and they are as follows:

1. Conduct a visual inspection of the grinding wheels to ensure they are securely mounted on the shaft, are centered, and free of cracks and breaks. A cracked or broken wheel may injure the operator due to the grinder turning at a high speed and torque.
2. Ensure that the grinder is secured and mounted. Loose or missing bolts can cause damage to the work or the operator by allowing the grinder to shift or turn.
3. Inspect the area to make sure sufficient room is available to move material; ensure the floor is free of oil, grease, or other loose material that could cause poor footing.
4. Adjust the work rest to the proper angle for the work you are completing. Make sure the work is not caught between the work rest and grinding wheel.
5. Select the proper grinding wheel for the task you are performing. This normally consists of using the coarse wheel to grind the work, roughly to size, while you use the fine wheel to finish the work.

Operation

Always keep your eye shield in place and always wear goggles or a face shield when operating the bench grinder. The eye shield does not give you total protection from tiny pieces of red-hot metal or stone. Protect your hands since the metal can become very hot.

Follow the below procedures when operating the grinder:

1. Hold the work securely and do not force it against the wheel.
2. Hold all the work firmly and small items with pliers because the heat generated can reach extremely high temperatures.
3. Ensure that you, as often as possible, cool off tool edges you are grinding to prevent the temper from drawing.
4. Be sure the grinding wheels stop completely before touching them. Although the grinder is off, after operation, it takes time for it to wind down due to the inertia stored in the grinding wheels and motor armature. Remember, the abrasive wheel that grinds metal can also easily grind human fingers.

Maintenance

The bench grinder has a simple construction. However, its parts and accessories do require care to prevent damage to the machine and its operator. Let us look at the items that require your care and what that care involves.

Grinder

Lubricate the electric motor that drives the abrasive wheels according to the manufacturer’s specification. Periodically, remove the wheel guards and clean out the dust, dirt, abrasive compounds, and work filings. Make sure to disconnect the power source before removing the wheel guards. Check the eye shields to ensure they are tight in their mounts and are not at risk of falling out.

Abrasive wheels

Inspect the abrasive wheels to be sure that the maximum rpm of the grinder do not exceed the wheel’s maximum rpm. This could cause the wheel to disintegrate, which can in turn cause injuries. Check the abrasive surface of the wheel to see if it is glazed or loaded (filled spaces between the abrasive particles by soft materials). If so, recondition the wheel surface with a wheel dresser. Replace any abrasive wheels that are badly worn, excessively rounded, or cracked in any way.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

213. Observing power-tool safety precautions

1. What do you look for during your preoperational inspection?

2. Which personal safety considerations should you observe?

3. Name six operational safety procedures.

214. Using power tools

1. How should you set up your drill to make a hole?

2. What type of protection do *most* modern drills have that protect the user?

3. What determines the size of an electric drill?

4. Which type of bit would you use to drill holes in cement?

5. When do you use cobalt or titanium-nitride bits?

6. Which part of the drill bit cuts?

7. How should you secure work on the drill press?

8. Why should you *not* use hands to remove metal shavings?

9. On a bench grinder, when would you use a coarse wheel and when would you use a fine wheel?

10. How is a bench grinder required to be maintained?

11. What type of dresser is used to recondition an abrasive wheel?

2–3. Plumbing and Soldering

It is important that every BMET becomes proficient in plumbing and soldering techniques. These are critical skills that you may not use every day, but when you do need them, it is very important that you do them well. You started learning some of these skills in 3-skill level training and you are continuing to expand on them in your upgrade training. The material in this section is to refresh your memory on a few items, while teaching some new ones that will help you perform these tasks more efficiently when the need arises.

215. Understanding plumbing components and techniques

Installing equipment, such as ultrasonic cleaners, washer/disinfector units, dental units, and large sterilizers, requires some type of plumbing connection to complete the installation. Also, plumbing repairs are required to keep them operational. At times, civil engineering (CE) plumbers, or your facility maintenance team contractors, will accomplish these tasks under your guidance. However, sometimes their responsibilities will extend only to supplying utilities “to the wall.” This means that CE or the facility maintenance contractor will ensure you have the required electrical, water, air, steam, and waste lines available at the installation site but only if you correctly processed all the pre-installation coordination.

In the end, the BMET is responsible for the connections directly to equipment items. BMETs are also responsible for any plumbing repairs made on the equipment; therefore, you need a basic, working knowledge of plumbing to accomplish these tasks effectively and efficiently.

Types of pipe and tubing

The four basic materials you will encounter when performing plumbing tasks are galvanized (steel) pipe, soft copper tubing, hard copper tubing, and polyvinylchloride (PVC). PVC does not require in-depth training since it only consists of simple cutting, cleaning, and applying adhesive, so it will not be covered. However, you must cut, ream, thread, and bend galvanized pipe. Copper consists of you cutting, reaming, flaring, swaging, bending, and sweating (soldering). Both galvanized pipe and copper tubing utilize various fittings and adapters that ensure adaptability to almost any job situation. Here, we will address galvanized pipe and copper separately.

Galvanized pipe

Galvanized piping is an older standard that was previously used in many plumbing applications. You will still encounter these pipes in use today, so our main concern lies primarily with cutting and threading galvanized pipe to enable repairs.

Cutting techniques

You should cut galvanized pipe with a pipe cutter (fig. 2–30), but you may also use a hacksaw. When using a hacksaw, use some type of oil to keep the work and the hacksaw blade cool and to move the filings clear of the cut. You can use a miter box with the hacksaw to keep the cut straight. Use the pipe cutter without oil and, when properly positioned, you should make a straight cut. Figure 2–31 shows the proper procedures to cut piping.

Figure 2–30. Pipe cutter.

Threading techniques

Figure 2–32 shows how to properly thread pipe, from measuring the pipe to wiping excess oil and shavings off newly created threads.

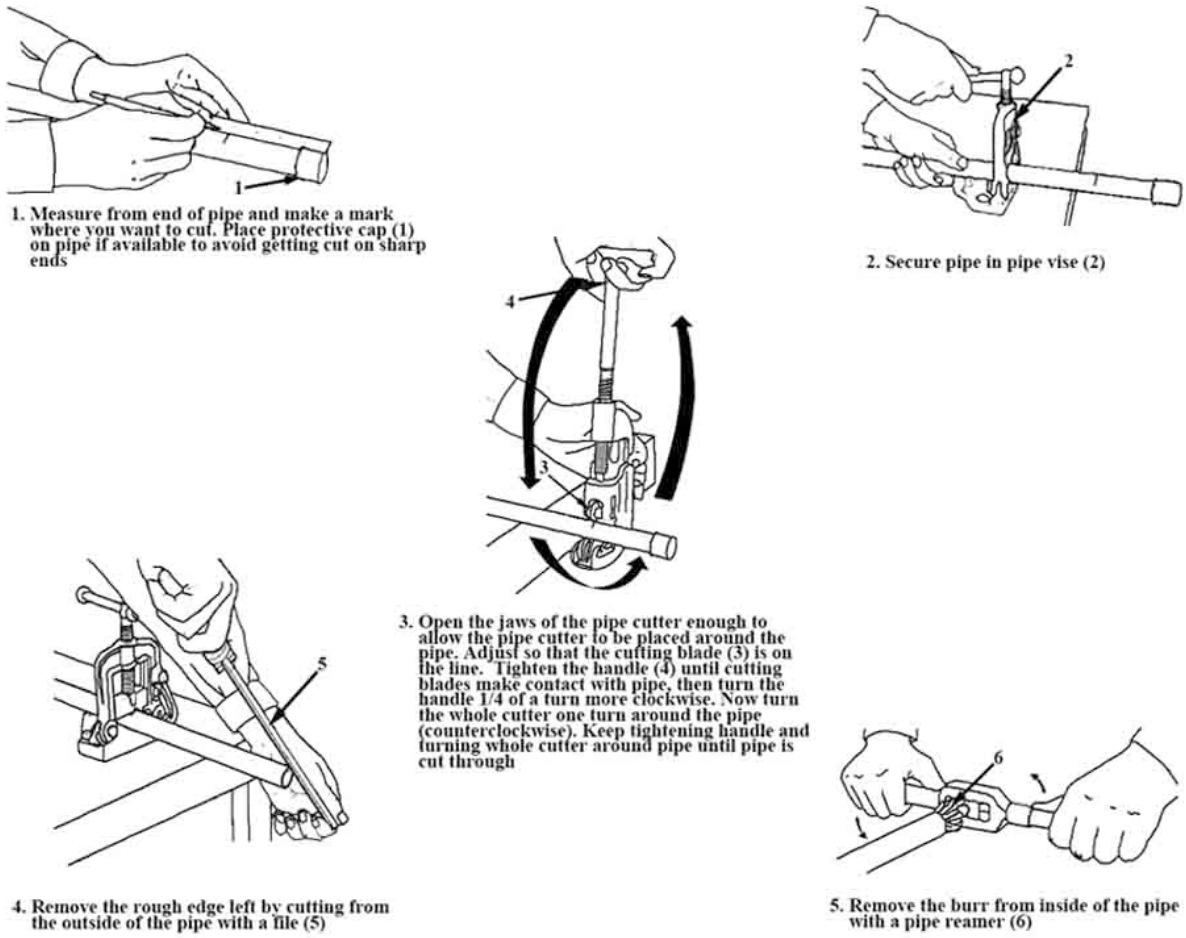


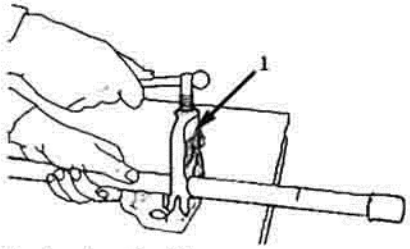
Figure 2–31. Pipe cutting procedure.

Soft copper tubing

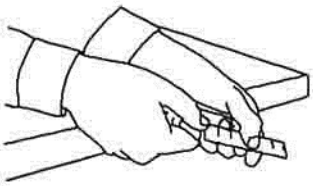
The versatility of copper allows its use in water, waste, air, gas, steam, vacuum, and hydraulic applications. It is easy to adapt soft copper tubing to many situations through flaring, swaging, bending, compression fittings, and so forth.

Tube cutting

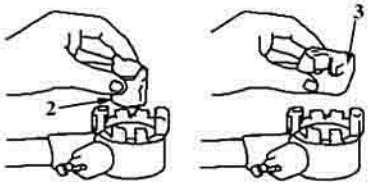
The desired tool for cutting copper tubing is the tubing cutter (fig. 2–33). It operates like a pipe cutter. Copper tubing is softer than iron or steel and rigid copper pipe; therefore, never use a pipe cutter on these materials. Use caution when tightening the cutting wheel against the tubing since the tubing may flatten under pressure. Insert the tubing between the rollers and cutting wheel, and then apply sufficient pressure to the handle to force the cutting wheel into the tubing on the measured mark. Slowly rotate the cutter around the tubing. After each turn of the cutter, apply additional pressure (about one-fourth turn of the handle) to the cutter wheel until you cut the tubing.



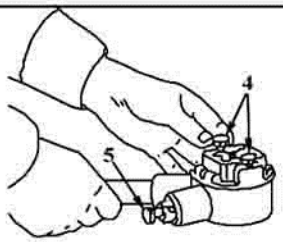
1. Secure pipe in pipe vise (1)



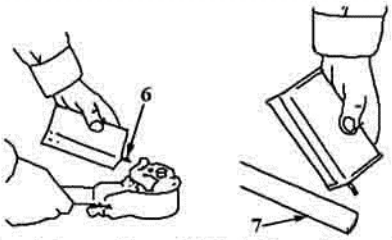
2. Measure outside pipe diameter to determine the proper die



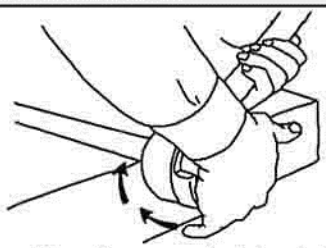
3. Assemble die on ratchet die stocks: insert collar (2), insert cutting die (3) over top of collar (2)



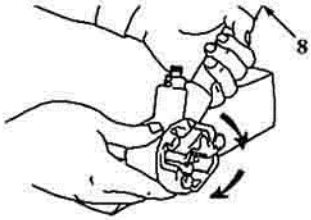
4. Secure in place with locking screws (4). Set ratchet to turn counterclockwise by pulling out ratchet control knob (5) and turning it 180 degrees. The ratchet allows cutting threads on pipes where it is not possible to turn the handle 360 degrees. You can set to counterclockwise or clockwise by pulling out and turning the ratchet control knob (5) from one detent to the other



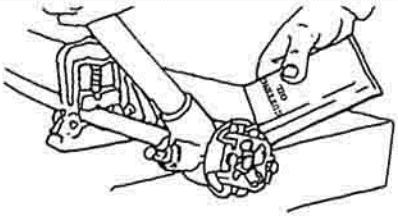
5. Applying cutting oil (6) to die and to end of pipe (7) prevent overheating of dies and damaging of threaded surface



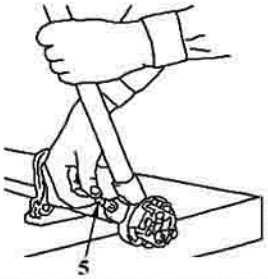
6. Slide cutting die over end of pipe to be threaded and apply light pressure with the heel of your hand



7. Start die with short strokes of the ratchet handle (8). Be sure the die is going on the pipe squarely



8. After a full turn of the die, apply another coat of cutting oil. Keep repeating this step until desired thread length is obtained



9. Reverse ratchet by pulling ratchet control knob (5) from detent and turning it 180 degrees. Then back off the cutting die

10. Wipe excess oil and shavings from threaded end of pipe

Figure 2–32. Pipe threading procedure.

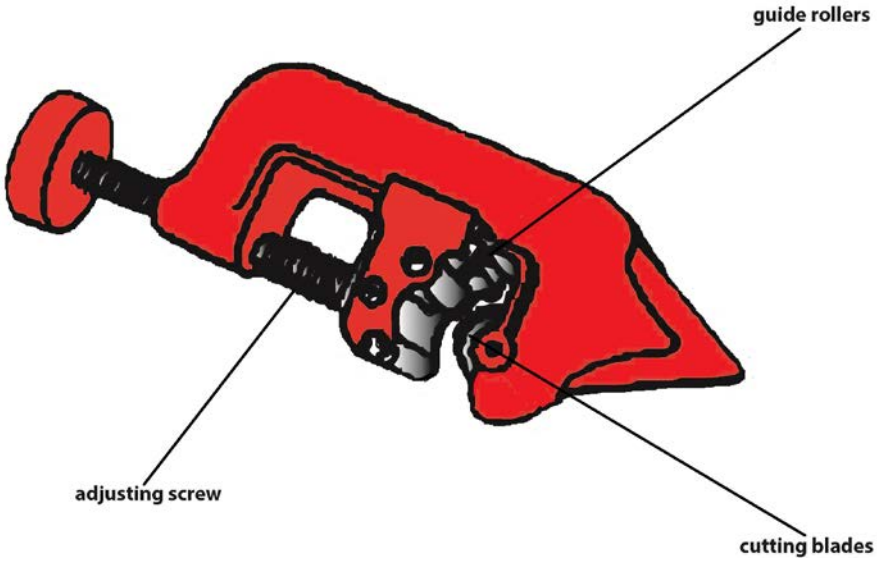


Figure 2–33. Tubing cutter.

Excessively tightening the cutting wheel will leave burrs inside the tube, causing it to collapse or become out-of-round. A sharp tube cutter will leave little burring inside the tubing. Most tubing cutters have a reamer attached, which you use to smooth the inside of the cut. Hold the tubing in a position that will ensure no chips or filings will fall into the tube.

You may also use a hacksaw, with a blade of 32 teeth per inch, to cut tubing. A coarser blade tends to tear the tubing, causing excessive pressure, which will flatten the tube. Take extra care to ensure that the cut is square. After you cut the tube, ream or file it to free the ends from burrs.

Flaring

The first, and most important, step in flaring is to be sure to install the flare nut on the tube before flaring, since it is not possible to install it after flaring. The next step is to make sure the tube ends, both inside and outside, are smooth and completely free of burrs. It is almost impossible to produce a leak-proof connection if this is not performed.

A flaring kit consists of a flare block (bar) and a yoke (clamp), with a screw-driven flaring cone attached (fig. 2–34). Always ensure these tools are in good condition and clean.

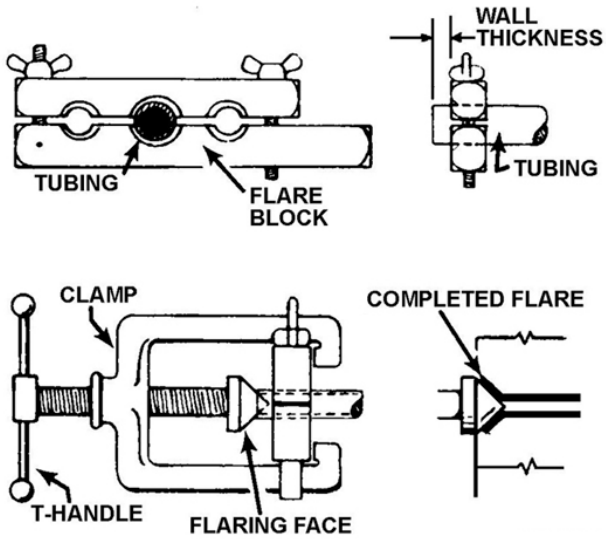


Figure 2–34. Flaring tools.

To produce a correctly-sized flare, follow these procedures:

1. Slide the flare nut onto the tubing that you are flaring.
2. Insert the tube into the correct-sized hole in the flare block, with the end you are flaring on the beveled side, extending approximately a wall thickness of the tube above the surface of the block.
3. Tighten the wing nuts firmly to secure the tubing in the flare block.
4. Position the yoke over the tube end with the flare cone centered in the opening, and put a drop or two of oil on the cone where it contacts the tubing.
5. Tighten the spinner approximately three-fourths of a turn and back it off one-fourth of a turn. Repeat this procedure until you get a flare to the correct size and have a contour.
6. Remove any burrs, both inside and outside, with a smooth- or medium-cut file. This ensures that there will be no burrs to prevent the flare from being properly seated both inside the flare nut and around the flare fitting.

Shape the flare to about seven-eighths of its full contour, so that when tightened into its fitting, the flare will assume the shape of its fitting. Never tighten the spinner too much, under any circumstances, or the tube can crack, thin, or weaken.

A completed flare should almost fill the flare seat inside the flare nut. The flare should not be large enough to contact the threads inside the flare nut since copper particles taken from the flare may prevent a leak-proof connection.

Swaging

Swaging is the process where you stretch or expand the end of one section of tubing for the end of another section of tubing, the same size, to fit inside of it. After swaging, you seal the joint by soldering or brazing it. A good swage connection will reduce the possibility of leakage. By swaging, you eliminate the use of a fitting, and it is useful in close places where there is not room for fittings. The swaging kit consists of a swaging punch and a swaging block (fig. 2–35).

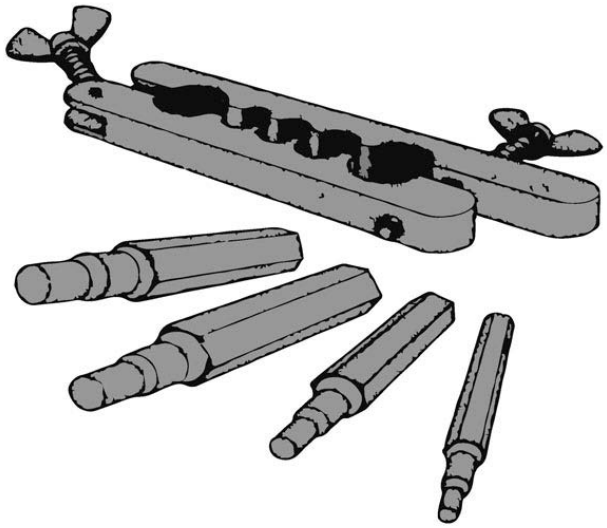


Figure 2–35. Swaging tools.

The swaging punch has a small portion called a pilot that fits easily into the inside of the tubing. It also has a tapered lead that connects the pilot with an enlarged portion, which is slightly larger than the outside diameter of the tube. You can use the flaring block for swaging by using the side of the block away from the bevel. Clamp the tube in the block with the tube extended above the block, a

distance equal to the distance from the swaging punch bottom to the bevel top, as illustrated in figure 2–36.

Hold the block firmly in a vise and, using a hammer, drive the swaging punch into the tube. Lightly coat the punch with oil and turn it slightly after each hammer blow.

The completed swage (fig. 2–37) will have an outside diameter slightly larger than the original outside diameter of the tube and should always have a depth of at least equal to the original outside diameter. Do not make a swage within 1 inch of the point of a flare or a bend. The swaged portion of the tubing will have a double thickness, making it very difficult to bend.

In flaring, it may be impossible to slip the flare nut back far enough on the tube to clamp the tube into the flaring block. If done properly, swaging will make a connection as strong as the tubing.

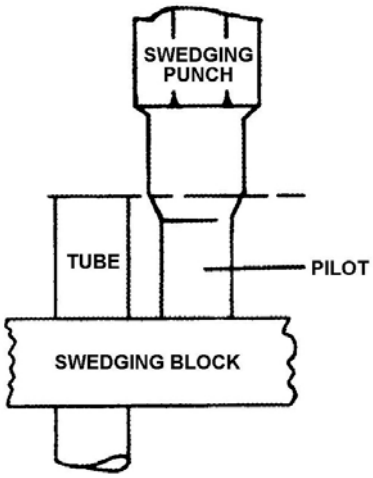


Figure 2–36. Checking swage depth.

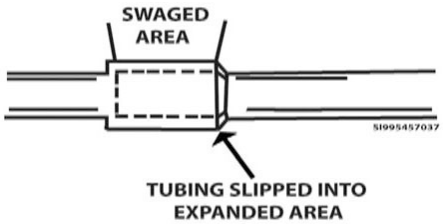


Figure 2–37. Completed swage connection.

Compression fittings

The use of compression fittings on soft copper tubing is the least complicated to accomplish and the preparation is relatively simple. Cut and ream the tubing, slide the compression nut on the tube, install the compression ring, and tighten the nut onto the fitting while maintaining pressure on the tube into the connection. Normally, you use a fitting when changing direction with hard copper. However, you can use the process of annealing (softening) if the bend is not too severe.

The minimum radius that you can bend copper is five times the diameter of the tube. The bend should be between 5 and 10 times the diameter of the tube, if possible. Use a torch to heat the pipe to a dull-red glow, and then bend it to the desired angle. Applying a cold, wet rag to the area will aid the annealing process and cool the metal quickly.

Hard copper tubing

In some ways, the treatment of hard copper and galvanized pipe is the same, and in other ways, hard copper is more like soft copper. You can cut it with a hacksaw or pipe cutter. (**NOTE:** Never cut hard copper with a tubing cutter since it will damage the wheel and the tool rendered useless.) When you place hard copper in a vise, place brass or lead sleeves over the vise jaws to protect the pipe from scratches or marks by the vise jaws. The thin-walled hard copper thickness prevents it from threading and the rigid construction prevents flaring and swaging. Therefore, sweating (soldering) hard copper to fittings and adapters is the only practical method of making good air- and water-tight connections.

Sweating procedures

It takes considerable time and practice to become proficient in sweating (soldering) pipe. Sweating is the process of applying a solder to seal a new or faulty joint in a pipe. The surfaces being jointed must be very clean and remain clean throughout the sweating process.

Once cleaned, apply a thin, uniform coating of noncorrosive soldering flux to the tube with a brush or paddle. Do not apply flux with your fingers or any oily object. If you apply too much flux, the excess can form bubbles when heated and prevent the solder from flowing into the joint, or some excess may fall inside the pipe and potentially clog strainers, filters, or valves. After a mechanical cleaning, a noncorrosive flux contains an antioxidizing agent that can keep the metal clean. (**NOTE:** Applying alcohol prior to fluxing will clean most oils from the surface.)

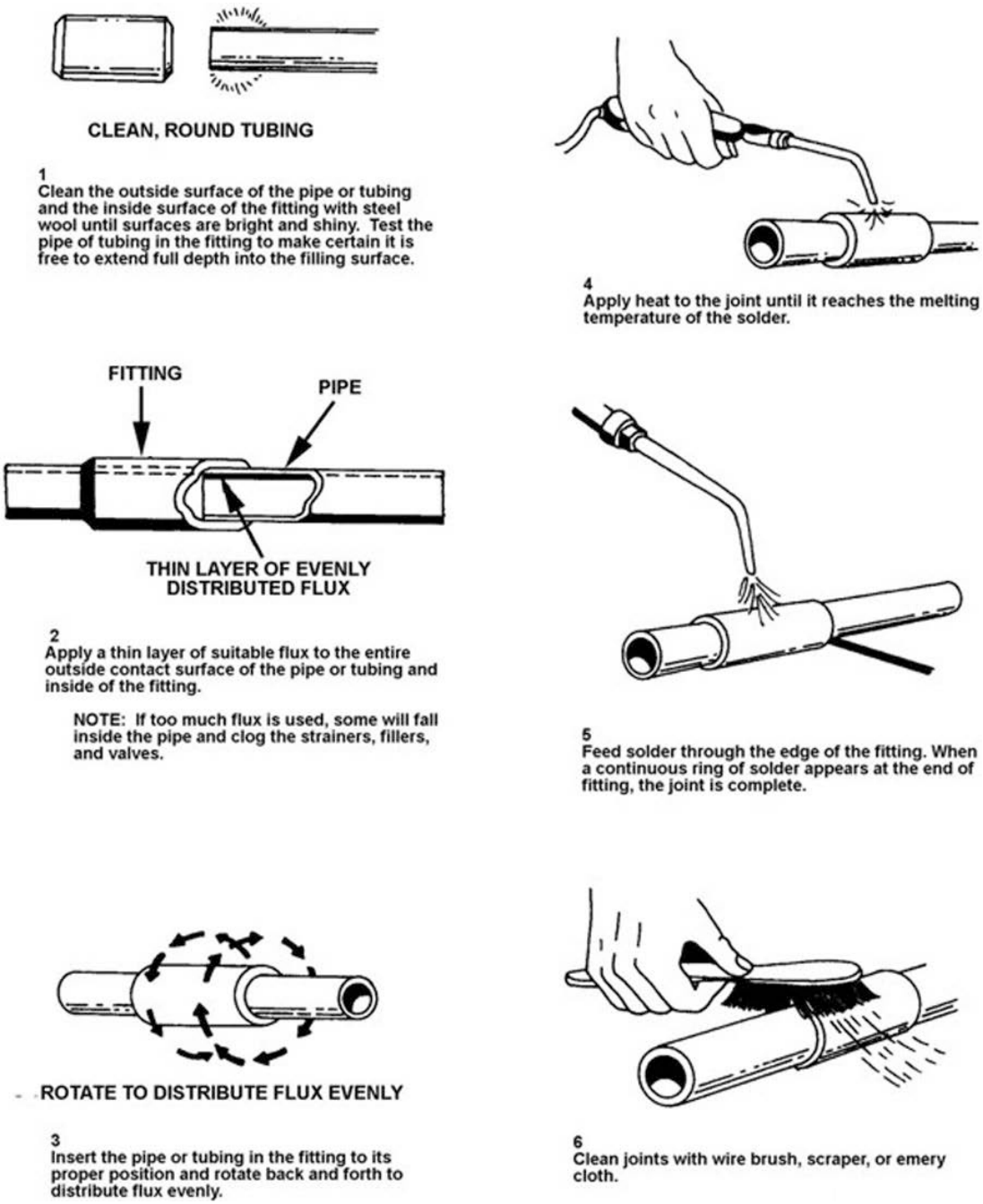


Figure 2–38. Sweating copper (1 of 2).

You must use a sufficient quantity of heat when sweating copper. The most commonly used heat source is a propane torch, which provides a sufficient temperature to produce a mechanically-sound, leak-proof joint. The process of the solder drawing into the heated fitting is a capillary action. Fifty–fifty (50 percent lead, 50 percent tin) solder used to be the standard for sweating copper pipes, but due to safety, lead-free solder, such as 95–5 (95 percent tin, 5 percent antimony) is desired. Figures 2–38 and 2–39 illustrate proper sweating techniques and give helpful tips to produce a leak-proof connection.

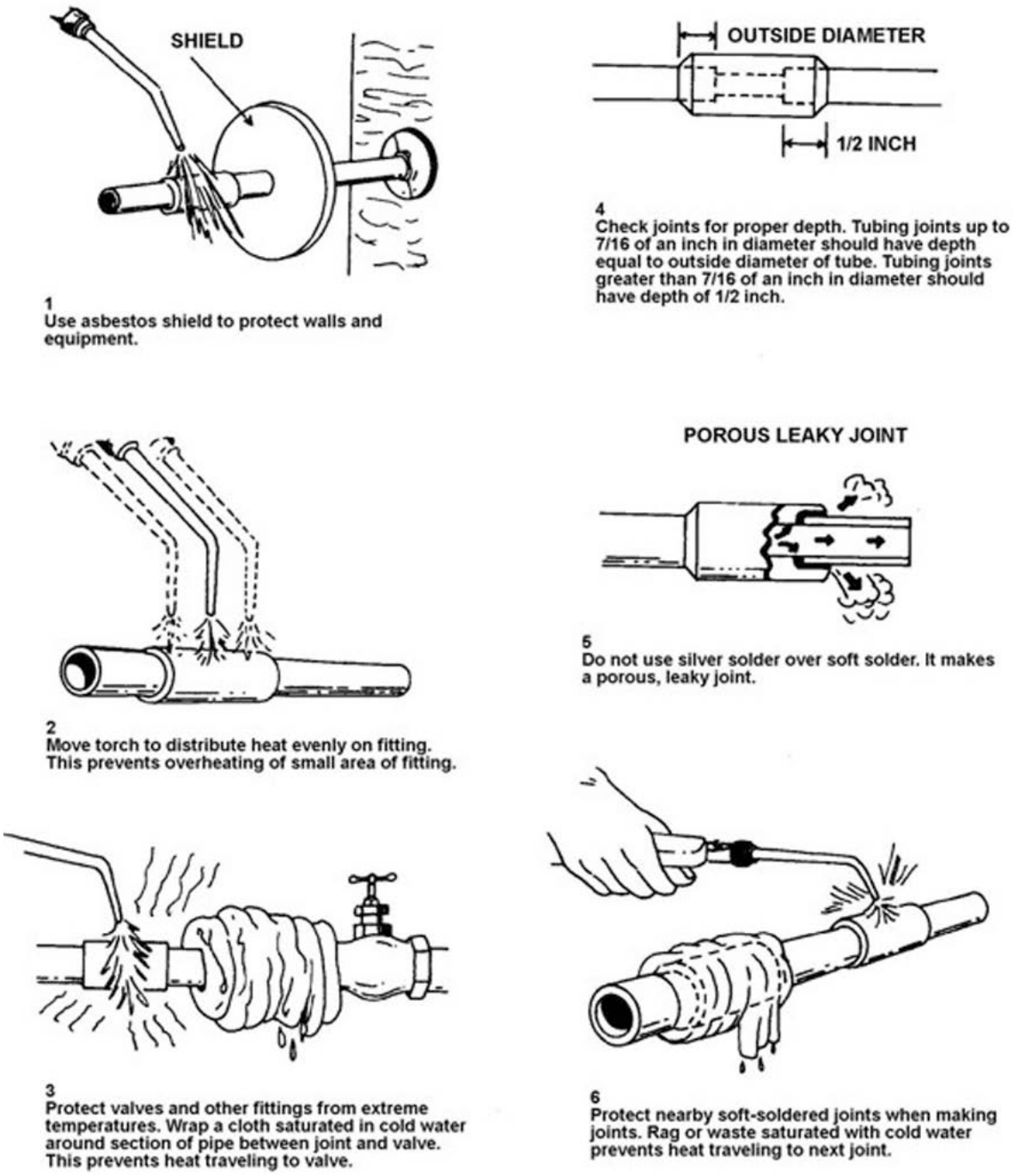


Figure 2–39. Sweating copper (2 of 2).

216. Electronic soldering techniques

Soldering is an important fundamental skill for electronic maintenance training. You can master the art of soldering electronic components and wiring through proper training and experience. Electronic medical equipment is only as dependable as the electronic components it uses. The electronic components are only as reliable as the soldered connections that join them into circuit configurations. You first need to be familiar with some soldering tools and supplies so that you can do the task. Our discussion begins with soldering irons and guns.

Soldering irons, guns, and their uses

Carefully selecting the correct size, shape, and wattage of soldering iron is a prerequisite for reliable soldering. The size and shape of the iron and tip should permit soldering with maximum ease and minimum danger of damaging the surrounding areas. Soldering irons (fig. 2–40) and guns come in a variety of sizes and wattage ratings. You determine a suitable soldering iron or soldering gun by type of soldering operation and personal preference.

Figure 2–40. Soldering iron.
("How to Solder: Through Hole Soldering" by SparkFun is licensed by CC BY SA 4.0).

Use a variable voltage supply (fig. 2–41) for controlling the soldering iron temperature when you solder printed circuits. In continuous use, such as production-line work, a soldering iron is usually more suitable. In repair and maintenance work, where soldering operations are of short duration and occur intermittently during testing, a soldering gun may be more helpful.

Figure 2–41. Variable voltage supply.
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The size and shape of the joint are used in determining the soldering iron or gun wattage rating required. Ratings of 25–100 watts are common for soldering ordinary electrical connections, while ratings of 100–450 watts are for soldering large terminals and metal chassis. For general soldering, a single 35-watt, wand-type soldering iron will suffice for miniature printed circuits and large terminals.

Soldering iron tips

Soldering iron and gun tips are available in many different shapes and sizes (fig. 2–42). The most common shapes of soldering iron tips used for maintaining conventionally-wired electronic equipment are the pyramid, screwdriver, and chisel. Soldering iron tips' base metal is generally copper or copper-based.

Figure 2–42. Soldering tips.
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Most soldering irons come with pre-tinned, copper tips in various shapes, diameters, and lengths to suit different types of barrels and applications. On most electric soldering irons, the tip is removable. Internal threads fasten the heating element of the iron, which accept the threaded shank of a tip, or the tip simply plugs into the heating elements and a setscrew secures it.

Using heat sinks

During a soldering operation, use heat sinks or thermal shunts, as necessary, to protect heat-sensitive components, such as semiconductors, integrated circuits, meter movements, and insulating materials from heat damage. Place heat sinks between the heat source and the component that you are protecting from heat. See figure 2–43 for an example of heat sinks.

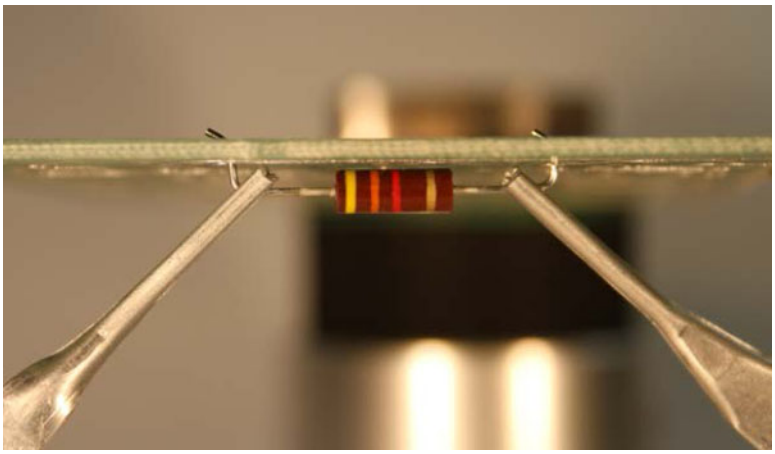

Figure 2–43. Heat sinks.

A heat sink needs to be of such material, size, shape, and design to permit rapid application and removal with minimum interference to the soldering procedure and provides rapid heat removal from the soldered area. Recommended thermal shunts are the clip-on type that is held in place by spring tension. An example is the alligator clip. Using this type of thermal shunt is the approved method. It will usually result in minimum damage to metal surfaces, wire insulation, and the soldered component. You must protect meter movements and other sensitive instruments in a boxed assembly by placing electrical current shunts across the positive and negative terminals until the instruments become integral parts of their respective circuits.

Bending tools

Wire-bending tools should have smooth bending surfaces so you can bend component leads without nicking, ringing, or damaging them. You may use standard needle-nose pliers for bending wires and leads. Tweezers and forceps will prove beneficial for those same tasks but on small parts.

Using soldering aids

Soldering aids usually have a slotted and pointed end; some have synthetic bristle brushes. These aids are useful in de-soldering any soldered connections. Use the slotted end of the solder aids to lift the ends of wires and part leads from the terminals; the pointed ends are used to remove solder from terminal holes and slots. You may use the synthetic bristle brush to remove molten solder (do not use wire brushes).

Do not use soldering aids to exert force on wires for security testing. You can only visually inspect to determine the quality of a properly bonded solder connection. The practice of bending or pulling wires to verify the connection's security can present a serious reliability hazard and is acceptable only when a visual inspection is not possible. Figure 2–44 illustrates various soldering aids you may use.

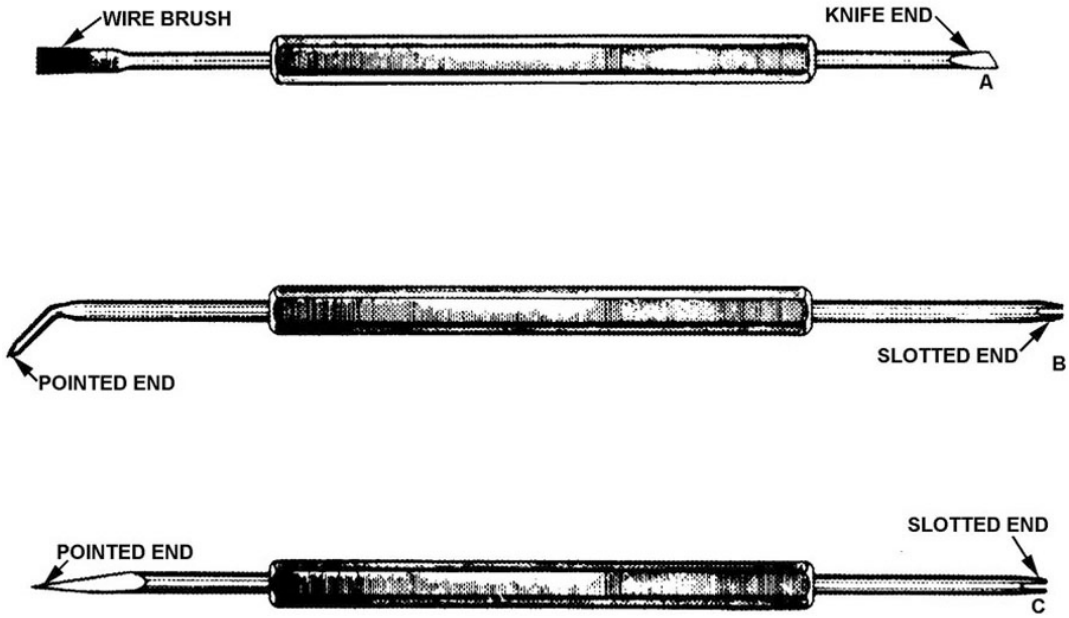

Figure 2–44. Typical soldering aids.

Solder composition

Solder is a conducting alloy made up of a mixture of metals, such as tin, lead, and silver. It forms a mechanical bond between electronic components. The makeup of the solder determines whether it is the "soft" or "hard" type. Soft solders consist of tin and lead in various ratios. A common soft solder is 60 percent tin and 40 percent lead that melts at 370° Fahrenheit (F). Hard solder contains silver and is known as silver solder.

With solder made of a 60/40 tin-to-lead ratio, it remains in the plastic condition from 370–361° F, which is a comparatively small temperature change. This change from the liquid to the solid state within a narrow temperature range is desirable in solder because any movement of the metal parts while the cooling solder is plastic will fracture and weaken the connection. The narrower the temperature range from liquid to solid, the less chance for fracture.

As mentioned in the pipe-soldering lesson, consider the use of lead-free solders. Initial development of lead-free solders did not include varieties for fine electronic work because it could not obtain lower melting temperatures needed in electronics without the lead content in the solder. Modern technology

advancements in this area have led to the production of lead-free solders suitable for some electronics work. Although they may not be suitable for every application, you need to consider these lead-free solders wherever possible.

Flux and its usage

Flux is an agent used in soldering to facilitate rapid heat transfer and to remove surface oxidation from both the solder and the solder connection surface. When activated by heat, flux removes the oxidation layer on top of the base metal, allowing the solder to react with the metal and form a metallic bond. It is important to use flux sparingly.

Apply the minimum amount of flux necessary to solder the work. Too little flux will not allow the solder to bond with the metal, and excess flux leads to defects in the solder joint. There are two classes of flux—corrosive and noncorrosive. Only use noncorrosive, nonconductive, rosin fluxes for all electronic soldering. Rosin is a noncorrosive flux and is available in paste, liquid, and powder forms.

Solvents' composition and use

Solvents are used for cleaning and removing flux and other contaminants from the soldered connection. Solvents must be nonconductive and noncorrosive. Use solvents to keep dissolved flux residue from "contact" surfaces, such as those in switches, potentiometers, and connectors. The following two solvents are acceptable:

- Ethyl alcohol—American Chemical Society (ACS) grade, 99.5 percent or 95 percent by volume.
- Isopropyl alcohol—best commercial grade, 99 percent pure.

Safety considerations

There are specific precautions to observe before and during the soldering and de-soldering operations. Observing these precautions can prevent serious injury to you and the equipment.

Precautions before soldering

To prepare electronic equipment and the work area, observe the following precautions:

- Remove your rings, watches, and other jewelry.
- Wear safety glasses during all soldering operations.
- Check the power source before working on any electronic equipment to ensure that the circuit is open. Remove fuses and/or trip the circuit breakers. Perform proper LOTO procedures, if appropriate.
- Protect nearby equipment against damage from falling tools, wire ends, and solder splash, etc., by covering it with some type of drop cloth.
- Clear the work area of all objects that might obstruct your hand and arm movement.
- Place the soldering iron holder where you will not have to reach over or around it.
- Connect the soldering iron to the proper electrical outlet and arrange the cord so it will not interfere with your work.
- Inspect all electrically-driven tools for defects before using. Ensure that the cords and plugs are in good condition and that metal housings have proper grounding.
- Place the open side of the wire cutters away from your body when you cut wires. Keep all wire scraps together at one side of your work area.
- Remove all spring tension from the wire before de-soldering it by clamping the wire during the operation. Otherwise, hot solder may project into the air when the connection separates.
- Work with a limited amount of cleaning solvent; when using it, stored in a small, airtight safety can. Do not spill the solvent or breathe its vapor smoke when the can is open nearby.

- Do not allow fluxes or cleaning solvents to remain on your skin unnecessarily. Wash them off with water since these products can cause skin irritations.

Precautions during soldering

As you proceed through the soldering or de-soldering process, observe the following precautions:

- Make certain that the soldering iron is free of wire strands or metal.
- Do not remove the tip from a hot electrical soldering iron to avoid damage to tip threads or setscrews.
- Hold the soldering iron well away from your face to avoid burning yourself with molten solder when you are tinning.
- Do not test the heat of a soldering iron by holding it near your face. Test it with solder while you hold it away from your body to avoid injury from sputtering particles of solder or flux.
- Do not attempt to remove molten solder from a soldering iron tip by flipping. Instead, use a rag, damp sponge, or canvas pad to wipe solder from the tip.
- Avoid contact with the barrel by looking at the soldering iron whenever you pick it up.
- Do not allow the cord to drag on the floor when you are carrying a hot electric soldering iron. It may catch on equipment and drag the iron through your hand.
- Always place a soldering iron in its holder or other safe place when not in use. Do not leave it connected when you leave the area.
- Make a sign stating “Hot Iron” and place it at the site where the iron is sitting to warn other personnel not to touch it.

Soldering procedures

Now that you are ready to begin soldering, we need to go over the basics of proper soldering. Each step is important and, if correctly done, will help produce a clean, reliable connection. Pay attention to these steps and use them when you perform your next soldering job.

Dressing the soldering iron tip

Taking care of and preparing the tip is important and will determine the type of work you do. Let’s look at dressing copper soldering iron tips.

The copper tip is dressed as often as necessary. It is important to maintain a clean, uniform tip surface that is free of pits and will easily tin. The type of job will determine which tip shape will provide the best heat transfer. For example, a wedge-shaped tip with a 45° angle, with a slightly blunt point, is most suitable for terminals and printed circuit board work. To dress, follow these procedures:

1. Remove the tip from the soldering iron by loosening the setscrew. Always use round-nose pliers to handle a soldering iron tip and always assume that it is hot.
2. Clean the entire length of the tip with a clean, wire brush.
3. Clean the barrel (hole in the iron where the tip fits).
4. File the tip to the required shape using a flat, fine, single-cut file. (**NOTE:** Never file a hot tip. It will oxidize quickly and cause tinning to be difficult.)
5. Insert the tip into the barrel until it is fully seated and then tighten the setscrew.
6. Plug in the iron. When the tip reaches the lowest temperature required to melt solder, apply rosin core solder to each face of the tip.
7. Keep a pool of solder on the soldering iron tip while it is not being used. The solder pool will reduce pitting, surface oxidation, and increase the time between tip rework.

Preparing conductors and leads

Clean metal is the key to reliable soldering. Remove all dirt, grease, oxides, scale, and lacquer from surfaces. No matter how shiny a lead may appear, clean it because the manufacturing process often

leaves invisible oxides on component leads. “Wetting” is the ability of liquid solder to adhere to a conductor. To ensure good wetting action, remove all impurities by first cleaning with an eraser or a solvent. Good wetting action results in a well-tinned stranded wire that is ready for soldering.

Insulation removal

Strip the insulation from the wire with a nonadjustable, factory-set wire stripper. Do not use knives, adjustable wire strippers, or diagonal-cutting pliers to strip the insulation. See figure 2-45 for proper wire insulation stripping.

Figure 2–45. Wire insulation removal.

Using improper tools will cut, nick, or scrape the wire and weaken it. Twist wire strands back into the main part of the conductor in their original direction of rotation if they separate or become disarranged when you strip the wire. Figure 2–46 shows a properly stripped wire and some with common defects.

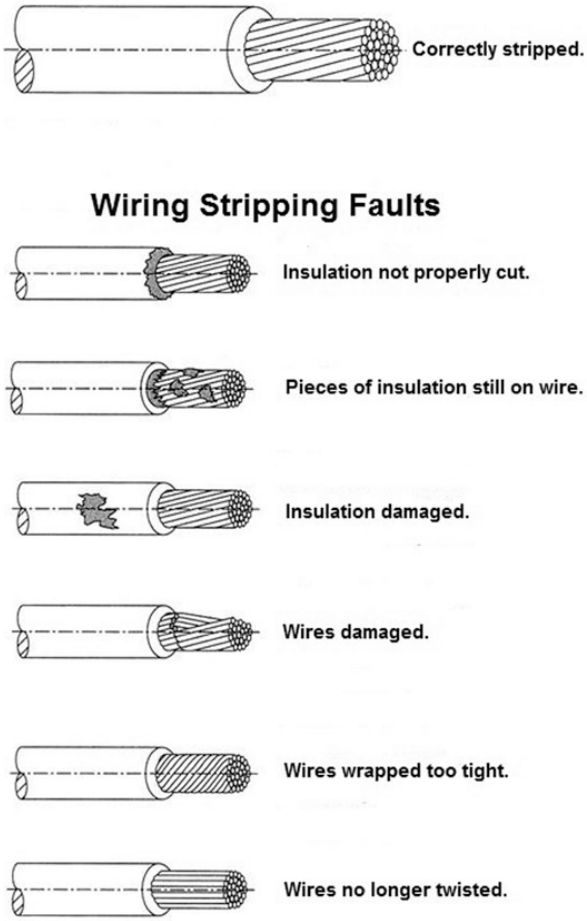

Figure 2–46. Proper wire stripping and defect examples.

Tinning stranded wire

Tinning wires is important to ensure a reliable solder joint. Tin all stranded conductors before you solder to terminals or components, and tin solid wire for better bonding. Use the procedures below to tin:

1. Clean the wire with isopropyl alcohol using an acid brush and blot dry the wire with a lint-free rag.
2. Apply a heat sink (fig. 2–43) to prevent the liquid solder from flowing under the insulation while you are tinning and soldering.
3. Coat the exposed strands of wire with a small amount of flux.
4. Place the soldering iron on a holder with one face of the tip up.
5. Apply a small amount of rosin core solder to the face of the iron.
6. Hold the wire with one hand and hold a piece of solder with the other. Lay the wire on the face of the iron.
7. Begin at the heat sink and apply the solder along the length of the wire.
8. Roll the wire across the face of the iron until the solder absorbs and wets the entire tinning area. Do not apply too much solder because the strands of wire must be visible to produce a properly tinned conductor, as shown in figure 2–47.
9. Remove the solder from the wire, and then lift the wire from the iron.
10. Dissolve the excess flux with alcohol and wipe the conductor clean with lint-free tissue when the tinned wire has cooled.
11. Wipe the excess solder from the tip. See figure 2–48 for an example of a properly tinned wire.

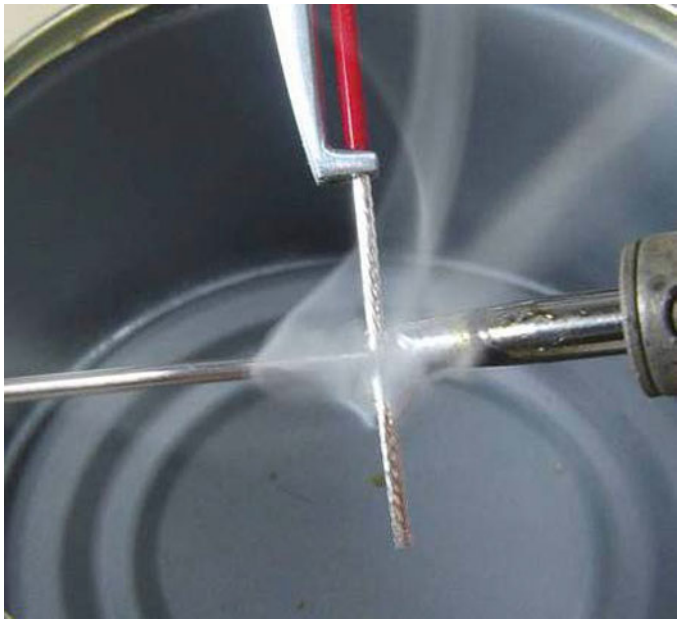

Figure 2–47. Tinning stranded wire.

Figure 2–48. Properly tinned wire.

Applying solder

During soldering and cooling, support the wire, or component, lead so that there is no movement. Apply the working surface of the heated soldering tip to the connection so that it transfers optimum heat to surfaces. When surfaces of the connection are hot enough to melt solder, apply the proper amount of solder directly to the connection. Maintain contact between the soldering tip and connection until all the flux boils out and the solder completely fuses in a smooth, continuous blend with the wire and the terminal surfaces. Do not melt solder on the soldering tip and then allow the solder to flow onto the connection. Also, do not overheat the connection even though you are using a heat sink.

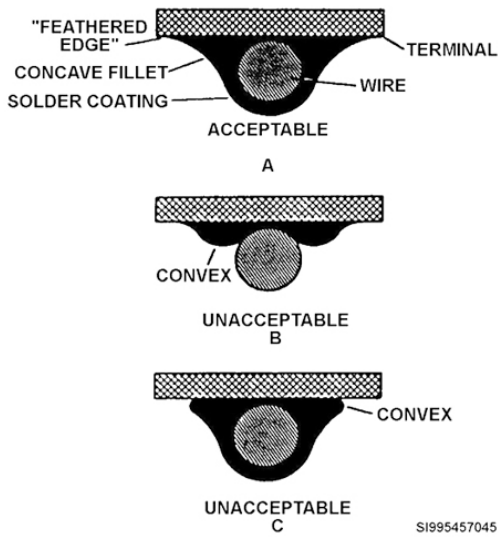

Figure 2–49. Acceptable and unacceptable solder connection cross-sections.

Figure 2–49A shows a properly completed solder connection. The wire contacts the terminal and its contour is visible under a thin solder coating. The solder, forming a concave fillet on each side of the wire, blends into the terminal surface in a smooth, continuous feathered edge. If you fail to properly clean or heat the wire, you will produce an unacceptable solder connection, as illustrated in figure 2–44. Also, as in figure 2–49B, the solder does not cover the wire; instead, it terminates in small convex fillets on each side of the wire. In figure 2–49C, the solder fillet does not spread into a smooth blend with the terminal surface on each side of the wire. Figure 2–50 provides tips and “dos” and “don’ts” for successful solder joints.

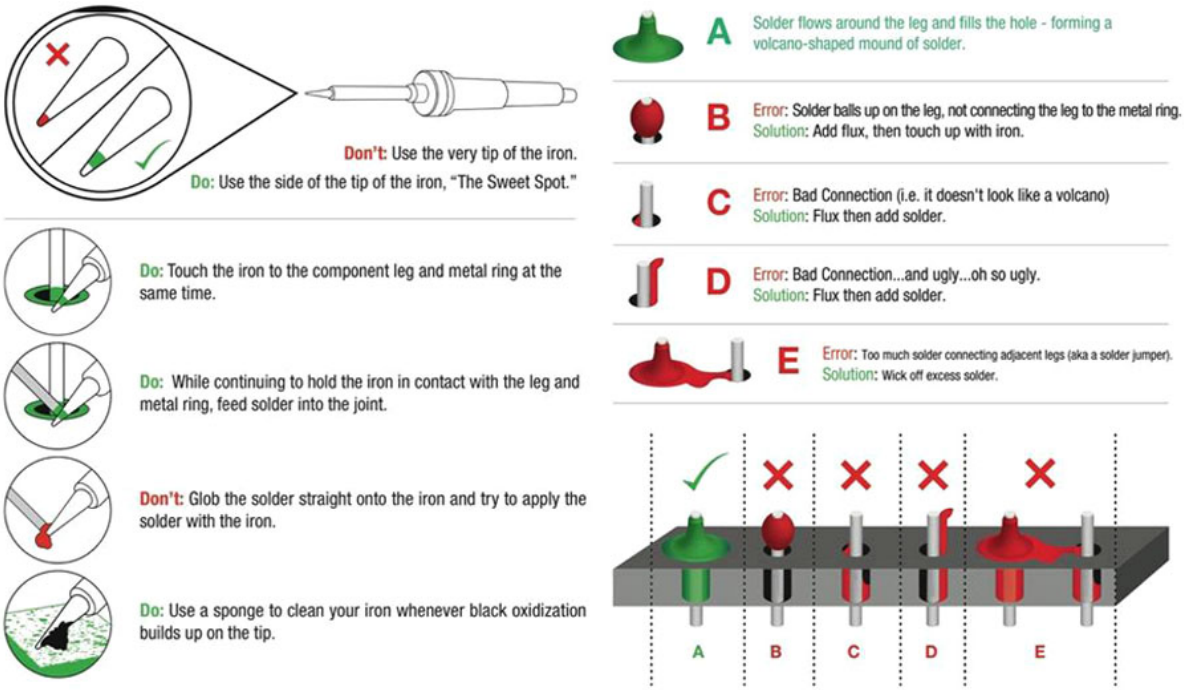

Figure 2–50. Soldering techniques and tips.
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Do not disturb the joint until it cools; otherwise, the solder may crack or “fracture.” Remove the heat sink only after the connection has cooled. Clean the finished connection thoroughly with a brush and alcohol, wipe it dry, and then polish it with a soft material. Be sure to remove all flux, dirt, lint, and residue.

The wire must form a good, metallic bond with the terminal. There must be a slight fillet between the conductor and the terminal base. The strands of the conductor must be the same as their normal lay. Cover the wire tip with solder to resist corrosion. No solder should appear on any surface of the terminal other than the two surfaces where the conductor touches. The solder joint must be clean, shiny, and smooth.

De-soldering

It is necessary to de-solder during some troubleshooting procedures, such as replacing faulty electronic parts and reaccomplishing unacceptable solder connections. The three methods of removing solder are: continuous vacuum extraction, wicking, and manual vacuum extraction.

First is the most effective method for solder removal—continuous vacuum extraction, which provides controlled combinations of heat and vacuum. This process involves using a vacuum control switch or foot pedal with a solder extractor consisting of a hollow-tipped heating element, transfer tube, and collecting chamber in the handle that collects the waste solder.

Second is wicking (fig. 2–51), which is the most used method to de-solder due to its simplicity and cost. Wicking is the act of transferring solder from the soldered connection to the surface of the de-soldering wick. To de-solder a connection by wicking, follow these procedures:

1. Connect a heat sink between the heat-sensitive part and the connection to be de-soldered.
2. Apply flux to the wicking material.
3. Place the end of the wick on the soldered connection and the soldering tip onto the wick. This heats both the wick and the soldered connection simultaneously. The wick absorbs molten solder from the connection.
4. Remove the soldering tip and wick simultaneously after removing sufficient solder from the solder connection.

Figure 2–51. Wicking.

The third, and final, method of removing solder from a connection is by manual vacuum extraction. You must use a manual vacuum solder extractor (fig. 2–52) to remove solder using this method.

Figure 2–52. Manual vacuum solder extractor.

The vacuum is applied through the tip. This technique involves melting the solder joint and placing the manual solder extractor tip on the molten solder (fig. 2–53), and then releasing the plunger to create a short period of vacuum that extracts the molten solder. The manual vacuum solder extraction procedure is as follows:

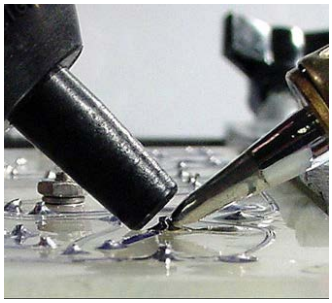

Figure 2–53. Manual vacuum extraction procedure.

1. Apply flux to the solder joint.
2. Lock the manual solder extractor plunger in the compressed position.
3. Apply the soldering iron tip to the solder joint simultaneously, and place the tip of the manual solder extractor directly beside the solder joint.
4. Observe the solder melting completely; then remove the solder iron, place the manual vacuum extractor tip over the joint at a 90° angle, and press the release trigger.

NOTE: Repeat steps as necessary to remove remaining solder.

No matter what method you use, always exercise caution when de-soldering. This is necessary because the heat from the de-soldering action can damage the component you are working on, adjacent components, or the circuit board itself.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

215. Understanding plumbing components and techniques

1. What are the four types of pipe materials you will use?

2. What do you use to cut galvanized piping?

3. Why is it important to install a flare nut on the tube before flaring?

4. Why should you remove burrs after flaring?

5. Give two advantages of swaging.

6. What is the *minimum* radius allowed when bending copper?

7. How and which type of flux should you apply when sweating?

8. What is the desired type of solder for sweating copper, and why is it preferred?

216. Electronic soldering techniques

1. How do you control the solder iron temperature?

2. What determines whether a soldering iron or a soldering gun is more suitable for a job?

3. Which wattage, and type, of soldering iron should you use for general electronic repairs?

4. Why are heat sinks used?

5. Match each function in column A with its soldering material in column B. Each option can only be used once.

Column A	*Column B*
____ (1) Facilitates rapid heat transfer and removes surface oxidation.	a. Solder.
____ (2) Removes contaminants from the soldered connection.	b. Iron.
____ (3) Bonds electronic components together mechanically.	c. Flux.
	d. Solvent.

6. During soldering operations, which safety precaution should you take before working on any electronic equipment, to ensure that the circuit you are working on is de-energized?

7. How do you avoid damage to tip threads?

8. Which type of file do you use to file copper solder iron tips?

9. Why is it important to clean lead or wire, no matter how shiny it appears?

10. Which tool must you use to remove wire insulation?

11. What must you do to conductors prior to soldering them to terminals?

12. Which is the *most* used method of removing solder?

13. Briefly explain the principle of wicking.

Answers to Self-Test Questions

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1. Any three of the following: (1) always inspect tools for safe conditions prior to starting work; (2) never carry tools in your pockets or leave them lying around; (3) ensure to clean up your work area when the job is complete; (4) learn the safe way to perform the task before you start; (5) ensure you wear proper clothing and PPE; and (6) make sure you always conduct yourself professionally and never engage in horseplay.
2. Misuse and improper maintenance.
3. When it affects functionality.
4. Residue may create a path for current to flow and damage equipment.
5. Any three of the following: (1) keep tools out of the hot sun to prevent burns; (2) keep tools from prolonged exposure to hot, dry environments; (3) keep tools dry; (4) avoid exposing tools to rapid and extreme changes in temperature.

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1. To drive or remove screws only.
2. Hold handle near its end with it facing parallel to the work; only grip the hammer tight enough to control the blow; and move tool straight away from work using elbow as pivot point; bring back into contact with the work with a quick, sharp motion.
3. Ball-peen hammer.
4. (1) Flat chisel is for cutting sheet metal, chipping, cutting rivets or screw heads, and all general cutting procedures; (2) cape chisels are used for cutting grooves, slots, keyways, and for chipping flat surfaces too wide for a flat chisel; (3) half-round nose chisels are used to cut round (concave) grooves; and (4) diamond point is used to cut V-shaped grooves.
5. Ground the head back to its original shape.
6. Drift punch.
7. They should be cleaned with a rag after each use with a light coat of oil applied before storing them. You will occasionally have to refinish the tip and the head. Also, dress the punch to the correct shape if its head becomes mushroomed.
8. To hold small objects and to bend or cut thin, soft wire or thin, soft metal strips.
9. Water pump pliers because the jaws are offset.
10 For only cutting soft wire since there are no gripping jaws.
11. The wrench can be damaged.
12. So pulling force is applied towards the stationary jaw.
13. The size of the square boss in the socket into which the external drive end of the extension or handle fits.
14. Indicating and breakaway.

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1. A large, coarse, double-cut file.
2. On the forward stroke only.
3. By using a rocking motion.
4. It is when small particles of work clog the file teeth and scratch the material. Break in a new file on soft metal first to avoid pinning.
5. (1) Crosscut: cuts across the wood grain.

(2) Ripsaw: cuts parallel to the wood grain.

(3) Hacksaw: cuts metal.

6. 24.
7. Apply a small amount of oil to both sides of blade.
8. To cut threads inside of holes in metal, fiber, or other materials.
9. Determine screw size.
10. To restore rounded or rusty threads on screws and bolts.
11. Screw extractor.
12. To check the size of a twist drill, for separating an assortment of unknown sizes, or for indexing various tap sizes.
13. Screw pitch.
14. Minute particles can cause errors in measurement.
15. To inspect hard to see areas.
16. With metallic mirrors avoid contact around energized electrical equipment because it could harm you or the equipment.
17. For retrieving articles that cannot be reached by hand and for starting nuts or bolts in difficult areas.

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1. Ensure all guards are in place; inspect the quality features of the tool; ensure electrical features and parts are intact; if unsure of tool operation, ask for help from a person who is familiar with the tool.
2. Use PPE; always wear eye protection; avoid wearing loose-fitting clothing, sleeves, jewelry, etc.; pay attention to what you are doing, and never horseplay.
3. Any six of the following: (1) clamp work to a workbench or vise; (2) keep hands, hair, and so forth, from blades, discs, and moving parts; (3) ensure power switches are off before plugging in a tool; (4) ensure tool is properly grounded; clean or tighten power tool when changing parts, switch the tool off, then unplug it; (5) ensure a portal tool is not running before it is put away; (6) remove the key before operating a tool if key is used for tightening parts; (7) do not yank power cords from wall socket and never carry a tool by its cord; (8) when working in wet areas, be sure the power cord is not in water and avoid wet areas if possible; place a rubber mat on a skid above a wet floor and stand on mat; finally, (9) keep your area clean and clean oil and debris immediately.

214

1. Use a prick punch for layout and a center punch to center the hole.
2. They are double-insulated, meaning there are no conductive surfaces.
3. Its chuck capacity.
4. Masonry.
5. To drill holes in extremely hard metals and special alloys.
6. The point.
7. With a “C” clamp for large material or a drill vise or pliers for smaller work.
8 They may be extremely hot and sharp.
9. The coarse wheel is for grinding roughly to size; a fine wheel is to finish the work.
10. Lubricate the motor as required by manufacturer; remove the wheel guards periodically and clean out; disconnect the power source before removing wheel guards, and check eye shields to be sure they are tight and in place.
11. Wheel dresser.

215

1. Galvanized (or iron) pipe, soft copper tubing, hard copper tubing, and PVC.
2. Pipe cutter.
3. It is not possible to install after flaring.
4. To ensure the flare will seat properly inside the flare nut and around the flare fitting.

5. Any two of the following: reduces the possibilities of leaks; eliminates the use of a fitting; and is used in close places where there is no room for fittings.
6. Five times the diameter of the tube.
7. As a thin, uniform coating of noncorrosive flux to the tube with a brush or paddle.
8. 95–5, because it is lead-free.

216

1. By using variable voltage supply.
2. Whether it is production-line work or repair work that is intermittent and of short duration.
3. 35 watt, wand-type.
4. To protect heat-sensitive components by insulating materials from heat damage.
5. (1) c.
   (2) d.
   (3) a.
6. Remove fuses and/or trip circuit breakers, then perform proper LOTO procedures.
7. By not removing the tip from a hot soldering iron.
8. A flat, fine, single-cut file.
9. The manufacturing process often leaves invisible oxides.
10. Nonadjustable, factory-set wire stripper.
11. Tin all that are stranded.
12. Wicking.
13. It is the act of transferring solder from a soldered connection to the surface of de-soldering wick.

Complete the unit review exercises before going to the next unit.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter. When you have completed all unit review exercises, transfer your answers to the Field-Scoring Answer Sheet.

Do not return your answer sheet to the AFCDA.

42. (210) Which is *not* a good general hand tool behavioral guideline?
    a. Always inspect tools prior to work.
    b. Carry tools in your pocket for easy access.
    c. Wear proper clothing and personal protective equipment (PPE).
    d. Conduct yourself professionally and never engage in horseplay.

43. (210) What is the purpose of using a rubber mat on the floor in front of your workbench?
    a. Prevents slippage of personnel.
    b. Prevents breakage of equipment and tools.
    c. Insulates personnel from electrical shock.
    d. Minimizes electrical shock and breakage.

44. (211) Which two types of screwdrivers are *often mistakenly* interchanged?
    a. Phillips and Reed & Prince.
    b. Standard and cross point.
    c. Standard and common.
    d. Offset and ratchet.

45. (211) Use this type of tool for *tapping* punches and chisels.
    a. True mallet.
    b. Claw hammer.
    c. Ball-peen hammer.
    d. Soft faced hammer.

46. (211) Which type of chisel would you use for performing *all* general cutting procedures?
    a. Flat.
    b. Cape.
    c. Diamond.
    d. Half round nose.

47. (211) This is the *best* reason to *not* use a chisel with a mushroomed head.
    a. Work may be damaged by missed blows.
    b. Hammer blows could be misdirected.
    c. Injury may be cause by pieces flying off.
    d. Ability to cut may be impaired.

48. (211) How should you apply a *large* amount of force to a wrench once the wrench and work are properly arranged?
    a. Pull on the wrench.
    b. Push on the wrench.
    c. Use right or left movement.
    d. Apply sideways action only.

49. (211) Which action should you *not* take when using socket wrenches?
    a. Avoid overstressing.
    b. Use the correct drive size.
    c. Use a socket that snugly fits the bolt or nut.
    d. Use an extension on the ratchet handle to increase torque.

50. (212) Files used for cutting, removing, smoothing, or polishing metal are *categorized* by
    a. name and cut.
    b. shape and cut.
    c. name and shape.
    d. length and shape.

51. (212) This is the *correct* way to apply pressure when using a file.
    a. On the return stroke.
    b. On the forward stroke.
    c. With a circular motion.
    d. With a back and forth motion.

52. (212) An *all-hard* hacksaw blade is designed to cut materials that have a
    a. heavy cross-section.
    b. light cross-section.
    c. soft composition.
    d. hollow shape.

53. (212) Which type of tap do you use to cut *full* threads to the bottom of a *closed* hole?
    a. Bottoming.
    b. Closed.
    c. Taper.
    d. Plug.

54. (213) There are three *main* types of safety precautions taken with tools. Which type of safety concern is being observed when you wear safety shoes?
    a. Organizational.
    b. Operative.
    c. Directive.
    d. Personal.

55. (214) The size of an electric drill is *usually* determined by its
    a. drill chuck capacity.
    b. current rating.
    c. physical size.
    d. motor size.

56. (214) Why are high-speed twist drill bits *preferred* when drilling numerous holes in Bakelite or other plastics?
    a. Cuts quicker.
    b. Cuts cleaner.
    c. Absorbs heat.
    d. Disperses heat to work.

57. (214) On a bench grinder, how far from the grinding wheel should you steady the work held against the work rest?
    a. 1 inch.
    b. 1/2 inch.
    c. 1/4 inch.
    d. 1/8 inch.

58. (215) Which type of pipe requires *little* specialized training in order to work with it?
    a. Galvanized.
    b. Soft copper.
    c. Hard copper.
    d. Polyvinylchloride (PVC).

59. (215) This is the *desired* tool for cutting copper tubing.
    a. Tubing cutter.
    b. Side-cutting pliers.
    c. Hacksaw with flexible blade.
    d. Hacksaw with all-hard blade.

60. (215) What could happen if you apply *too much* flux when sweating copper?
    a. Bubbles form.
    b. Oxidation forms.
    c. Tighter seals form.
    d. Excess solder forms.

61. (216) The *most effective* method for removing solder is
    a. wicking.
    b. suctioning.
    c. using manual vacuum extraction.
    d. using continuous vacuum extraction.

62. (216) This is the *most used* method of solder removal due to its simplicity and cost.
    a. Continuous vacuum extraction.
    b. Manual vacuum extraction.
    c. Wicking.
    d. Sniffing.

Student Notes

Unit 3. General Test Equipment

3–1. Electronic Measurement Instruments 3–1
217. Using multimeters 3–1
218. Oscilloscopes 3–8
3–2. Other General Test Equipment 3–28
219. Manometers 3–28
220. Electrical safety analyzers 3–28

PERFORMING CALIBRATIONS AND diagnosing problems on complex medical equipment require using electronic component measurements and other parameters to verify or analyze the system. It is necessary for you to know how to operate the test equipment used to obtain these measurements. This unit will focus on the general test equipment that you will use on a multitude of equipment. Later volumes will discuss more specific test equipment along with their applicable devices. We will start with general electronic measurement instruments.

3–1. Electronic Measurement Instruments

You will use test equipment often to help pinpoint a location or cause of a malfunction when equipment is not functioning properly. In the day-to-day operations as a BMET, there are common measurement tools that you will need to be familiar with to troubleshoot equipment. The two most important electronic measurement instruments are the multimeter and oscilloscope.

217. Using multimeters

The multimeter is used more than any other test instrument in electronics maintenance. Hardly a day will go by when you will not use this device. It is simple to use and capable of using to perform many different tests. This lesson covers the multimeter's use to test or check for: voltage, current, resistance, continuity (ohms), capacitor checks, and diode testing. You will see different multimeter models throughout your career, but they all operate similarly. We will use the Fluke© 80 series V-multimeter as an example in this lesson.

Voltage

Below are the steps required to take voltage readings with a multimeter:

1. Take voltage readings using the multimeter's common lead connected to the circuit ground.
2. Measure various points of the circuit with a common reference point. Selecting this common reference point requires some thought. Usually, a metal chassis serves as a ground point for the entire unit and serves that same function for the multimeter common lead. This point is referred to as chassis ground. Your multimeter is only as accurate as its reference. The multimeter performs as a simple calculator when measuring voltage by taking the reading from the common lead and subtracting it from the measuring lead.

NOTE: Occasionally, the design of a unit consists of internal circuits that do not use the chassis as its common or ground point. These circuits use a unique common point that is isolated from the chassis ground point and is referred to as signal ground or circuit ground. The equipment schematic or maintenance manual will identify these circuit grounds with the ground symbol resembling an upside-down, enclosed triangle. Figure 3–1 shows the three most common grounding symbols you will see. Earth ground simply means in reference to the earth.

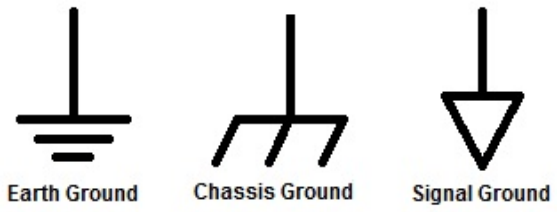

Figure 3–1. Grounding symbols.

3. Use caution so you do not violate these separate grounding systems during troubleshooting. This can occur if you connect the multimeter common lead to a chassis ground to take some measurements and, in the course of these measurements, you wander into an isolated circuit (one with a common point other than chassis ground) to take some readings. At this point, you have created some potential problems: (1) the readings taken are not accurate because of the improper reference point and (2) you may have damaged the equipment under test by connecting the isolated circuit to a chassis ground through the multimeter circuitry. A simple scan of the schematic before taking measurements in each circuit, or section, of a piece of equipment will identify isolated ground/common circuits and prevent possible problems.
4. Measure the voltage of a power source by *first* knowing if it is AC or DC—this is a must. Double-check the type of voltage you are measuring by setting the meter to the correct position and connecting the probes in parallel with the powered source. Figure 3–2 shows an example for both AC and DC measurements.

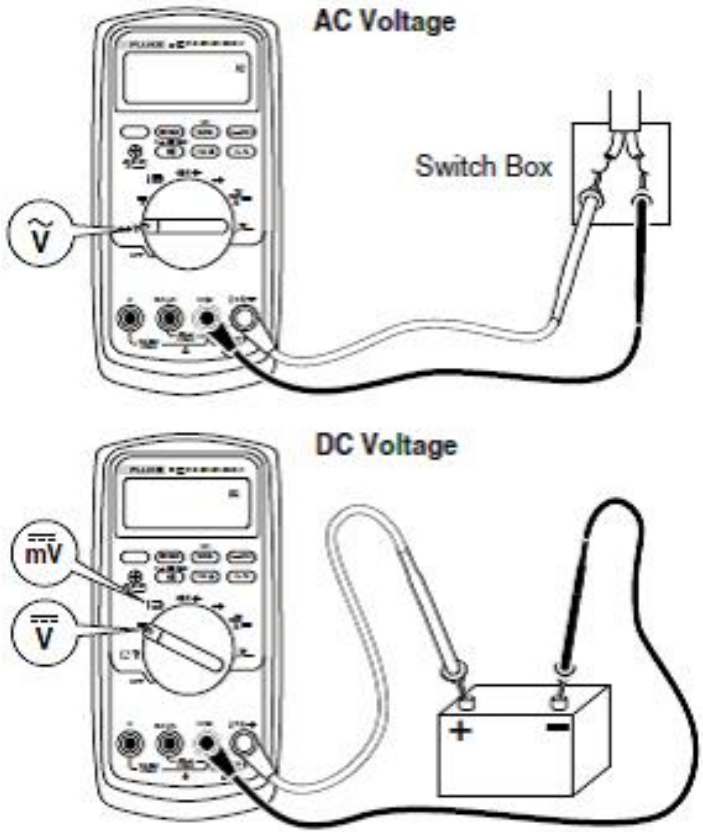

Figure 3–2. Measuring AC and DC voltage. (Printed with permission, Fluke Corporation).

5. Turn off power to the unit under test, connect the meter lead, reconnect power to the unit, and then take the reading. Although this is not always practical, it is the safest way to take a voltage reading. Use this procedure for each successive reading. (**NOTE:** It is common, and sometimes required, for technicians to leave the equipment energized and step through a circuit with the meter probe to take various voltage measurements. If the unit must be energized, it is important to use the "one-handed troubleshooting" technique.) One-handed troubleshooting simply means that you should only have one hand on or near a device under test while the power is on. You must keep the other hand away from any point conductively connected to the device. Some areas considered potentially hazardous are:
   a. any components or circuitry in the unit under test;
   b. the chassis of the unit under test; and
   c. any conductive test leads (including the multimeter leads) that are connected to the unit under test.

With only one hand near the equipment, you do not present an easy path for current flow to ground. If you place your other hand on the equipment, it is possible to introduce a path for current from one hand, through your arms and chest, and out through the other hand. If possible and practical, turn the power off whenever you move the voltmeter leads, and if it is not practical, be careful and aware of the safety factor provided by one-handed troubleshooting.

One final area of concern when working with a multimeter is the possibility of shorting components or circuit runs with the meter probe. In these days of small-circuit architecture and tightly designed equipment compartments, everything inside the equipment is so close together that it is easy to accidentally short two areas of a circuit together. To help prevent this from happening, be cognizant when moving and placing the meter probe in the circuit and use special probe tips, clips, and devices specially designed for use in tight spaces when appropriate. Something as simple as electrical tape or heat shrink tubing around the probe tip of a multimeter that allows only a small portion of the tip to protrude may provide some additional protection.

Current

You will not perform multimeter current measurements as frequently as voltage, but it remains just as important. There is an important concern about a multimeter in current mode (ammeter) that makes it susceptible to damage. When set to measure current, you must connect the meter in series with the test component or circuit. This causes the same current passing through the tested circuit to pass through the meter. The meter must have very low resistance to allow it to measure current flow of a circuit without affecting it. This very low-resistance characteristic of the meter makes it susceptible to damage.

Ammeter

Most multimeters are set for ammeter (measuring current) operation in two steps—(1) place the function switch in the appropriate setting/range, and (2) change the position of the leads to the ammeter connection. There is a tendency to forget that the multimeter leads are in the ammeter sockets because you do not use the ammeter function often. If you then try to measure voltage without realizing that the meter leads are in the ammeter sockets and configured to measure current, you are heading for trouble. Placing the leads in parallel with a circuit component to measure voltage in this configuration can damage the meter and possibly cause damage to circuit components. If you are lucky, this will only result in a blown fuse. The damage is due to the low resistance of the ammeter circuitry that allows large amounts of current to shunt around the component and through the meter.

To avoid this problem, immediately reconfigure the meter out of the ammeter mode after completing the current measurement. If not done immediately after taking the measurement, you may forget, and the next time the meter is used may be the last.

When checking amperage, there are safety precautions on the equipment you must take beforehand. To avoid possible damage to the meter or to the equipment under test, make sure you do the following:

- Check the meter's fuses before measuring current.
- Use the proper terminals, function, and range for all measurements.
- *Never* place the probes across (in parallel with) any circuit or component when the leads are plugged into the current terminals.

To measure current in an AC or DC circuit: (1) you must turn off the circuit being tested, (2) connect the probes in series with the circuit, (3) turn the power on, (4) take the reading, (5) power off, and (6) disconnect the probes.

Before measuring, you must reconfigure the multimeter. Take the following steps to do this:

1. Turn off power to the circuit. Discharge all high-voltage capacitors. Providing a conducting path with sufficient resistance (resistor, light circuit, voltmeter, etc.) across the leads will safely discharge the capacitors. *Never* use a screwdriver to discharge a capacitor; the current discharge may melt the screwdriver or damage the circuit if the capacitor is still connected to it.
2. Insert the black lead into the communication (COM) terminal. For currents *between* 6 mA and 400 mA, insert the red lead into the *mA/microampere (µA) terminal*. For currents *above* 400 mA, insert the red lead into the *A terminal*. Refer to the figure 3–3 below.
3. Use the mA/µA terminal only, to avoid blowing the meter's 400 mA fuse, if you are sure the current is less than 400 mA continuously.

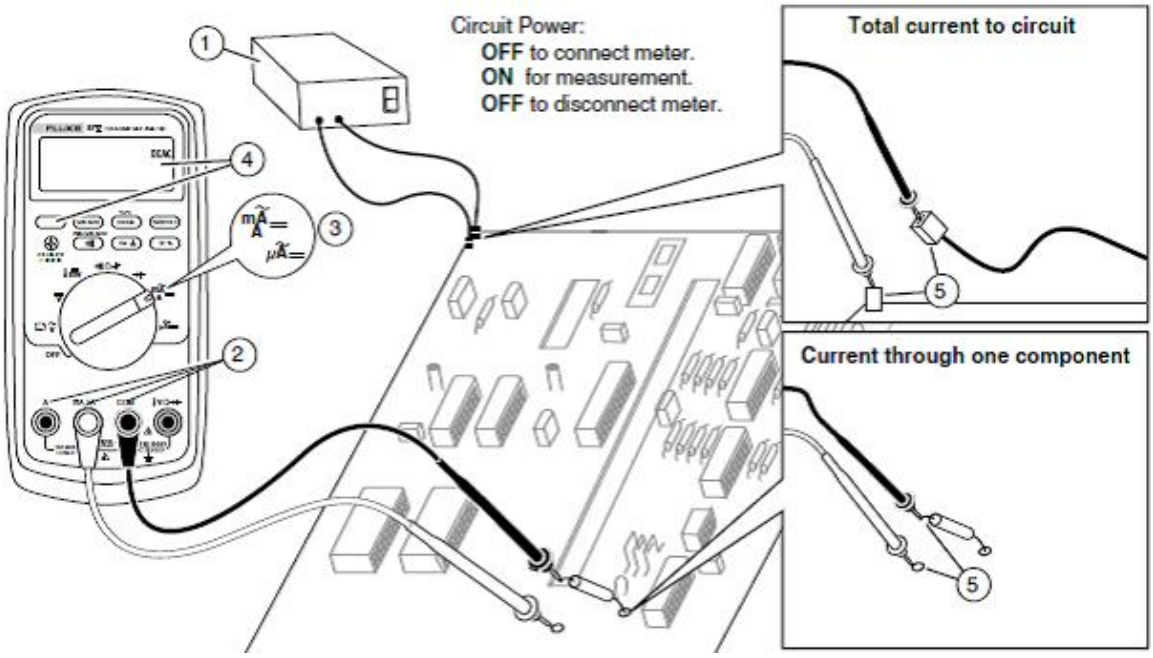

Figure 3–3. Measuring amperage. (Printed with permission, Fluke Corporation).

Using a clamp-on meter

A safer, noninvasive way to measure current is with clamp-on meters, which are unique multimeters. A clamp-on meter provides information on current flow without interrupting the circuit. This instrument can be very helpful when figuring generator loads and power requirements. There are many types of clamp-on meters. We will use the Fluke 325 clamp-on meter as an example (fig. 3–4).

Before checking amperes in a circuit with a clamp-on ammeter, make sure you follow these safety steps:

- Do *not* measure current with test leads connected to the input jacks.
- Do *not* use the product around explosive gas, vapor, or in damp or wet environments.
- Limit operation to the specified voltage and amperage ratings.
- Examine the product before each use. Look for cracks or missing pieces of the clamp housing. Also, look for loose or weakened components. Carefully examine the insulation around the jaws.
- *Never* work alone.

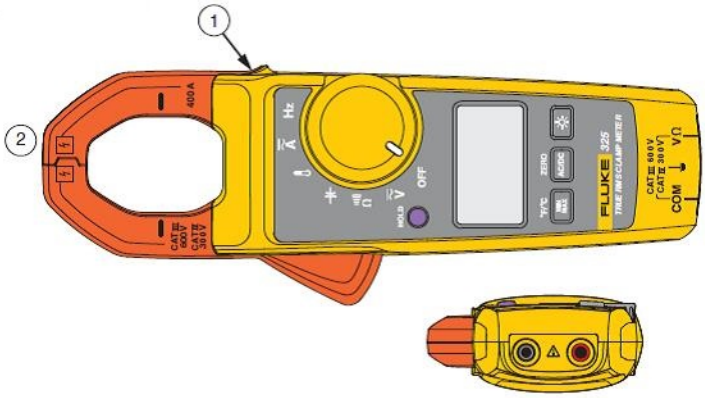

Figure 3–4. Fluke 325 Clamp-on meter. (Printed with permission, Fluke Corporation).

To take measurements, place the elector switch to the correct position, open the jaws (2) (fig. 3–4) using the pushbutton (1) (fig. 3–4) on the side. Then place the jaws around the conductor. Take note of the reading, and then remove the meter using the same steps in reverse. Ensure to measure one conductor at a time so that you get the most accurate readings (fig. 3–5).

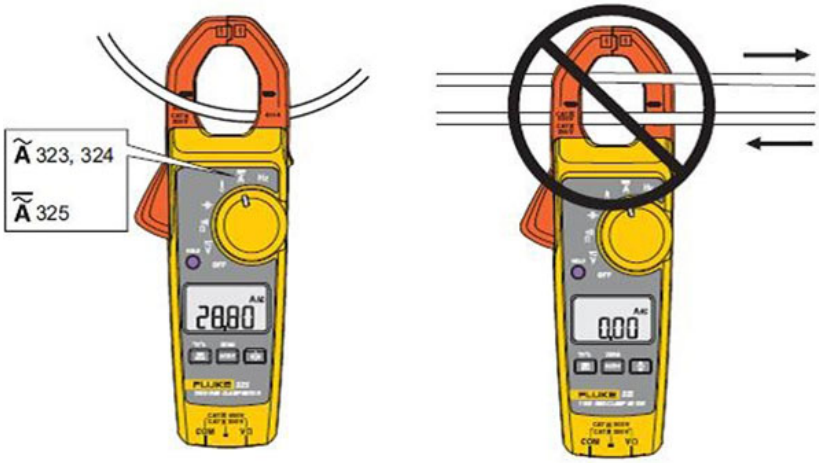

Figure 3–5. Using clamp-on ammeter. (Printed with permission, Fluke Corporation).

Resistance

There are two primary concerns to be aware of when making resistance measurements and they are as follows:

1. Power from the circuit in test must be removed and all high-voltage capacitors discharged to prevent damage to the meter.
2. There is the possibility of parallel current paths when taking resistance measurements.

It is essential that you only use the resistance meter on a de-energized circuit under test. When multimeters are set to measure resistance, they produce an internal current used for determining the resistance of the component in test. The voltage and current present in an activated electronic circuit are large enough to damage the meter circuitry.

The internal current that the meter produces flows through all possible paths between the probes; the resistance reading represents the total resistance of all paths. To accurately measure the resistance of a component, isolate it from other items that could affect current flow. In-circuit resistance measurements present some problems.

Resistances in parallel offer multiple paths for current flow. This is the reason the combination offers less resistance than any single resistor value in the circuit. If you ignore this fact, it will produce incorrect resistance readings and incorrect assumptions about the circuit operation. You should also consider this when attempting to measure any resistors in a circuit with other components. Any additional paths for current flow will affect the resistance reading.

It may be impossible to measure the true value of resistance of a single resistor or component until it is isolated from the circuit by clipping or de-soldering one of its leads. This effectively removes the component from the rest of the circuit, allowing measurement as a discrete component. The same rule applies to continuity measurements when checking wiring. Isolating one end of the wire in test will eliminate the chance of other circuit components causing false readings. Figure 3–6 shows the proper setup to measure resistance.

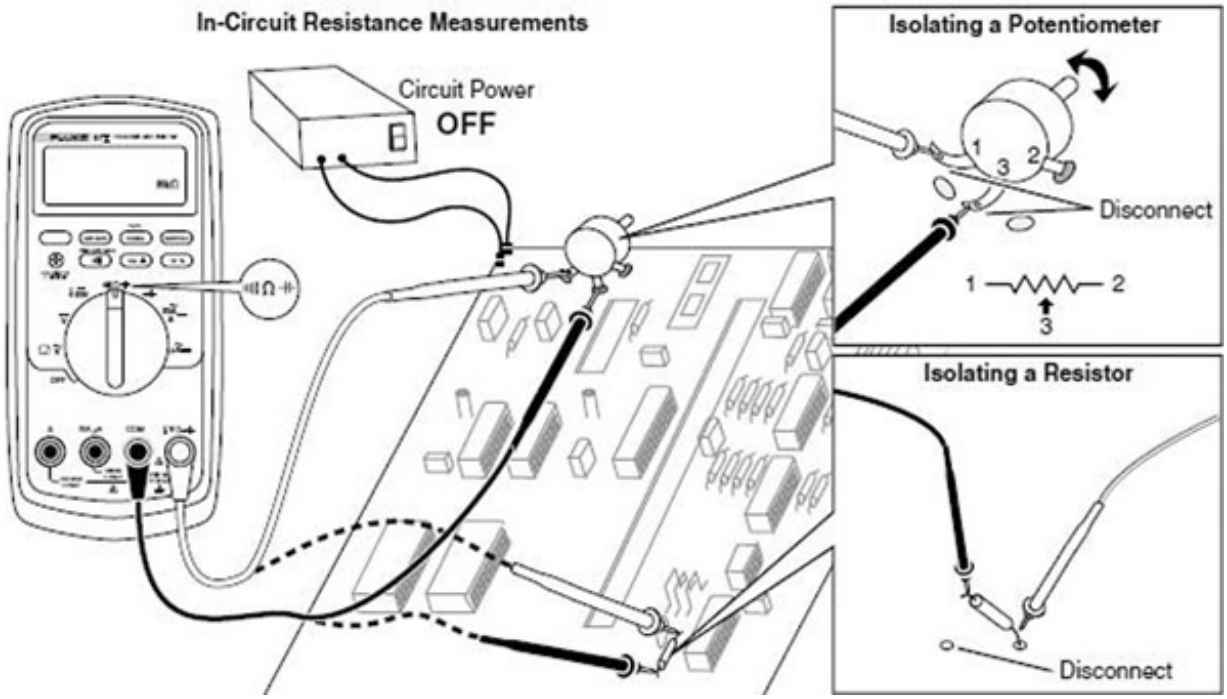

Figure 3–6. Measuring resistance. (Printed with permission, Fluke Corporation).

Continuity

When testing for continuity, ensure the component is isolated and the power to the circuit is off. To test for continuity in a circuit, position the meter's function switch as shown in the figure 3–7. If continuity is present, you will hear a beep; if not, the meter will be silent.

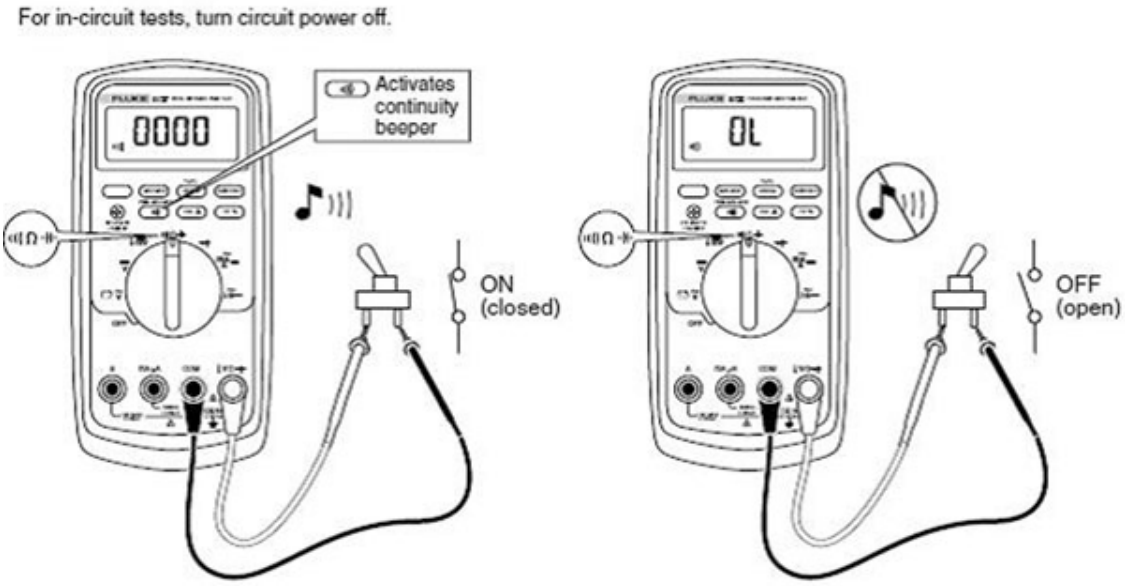

Figure 3–7. Measuring continuity. (Printed with permission, Fluke Corporation).

Capacity

To measure capacitance, set up the meter as shown in figure 3–8. To improve the accuracy of measurements less than 1000 nano farad (nF), use the relative (REL) mode to subtract the residual capacitance of the meter and leads. See figure 3–8 below for configuration. If too much charge is present on the capacitor, the display will show "diSC."

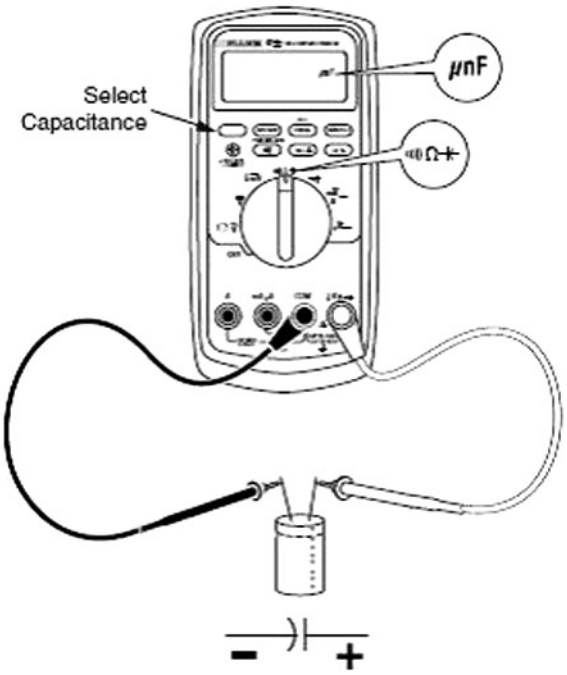

Figure 3–8. Measuring capacitance. (Printed with permission, Fluke Corporation).

Diode testing

Use the diode test to check diodes, transistors, silicon controlled rectifiers (SCR), and other semiconductor devices. To perform the test, set up the meter as shown in figure 3–9. For forward-bias

readings on any semiconductor component, place the *red* test lead on the component's *positive* terminal and place the *black* lead on the component's *negative* terminal.

In a circuit, a good diode should produce a forward bias reading of 0.5 volts (V) to 0.8 V; however, the reverse-bias reading can vary depending on the resistance of other pathways between the probe tips. A short beep sounds if the diode is good (< 0.85V) (fig. 3–9). A continuous beep sounds if the reading is ≤ 0.100 V. This reading would indicate a short circuit. The display shows "OL" if the diode is open (fig. 3–9).

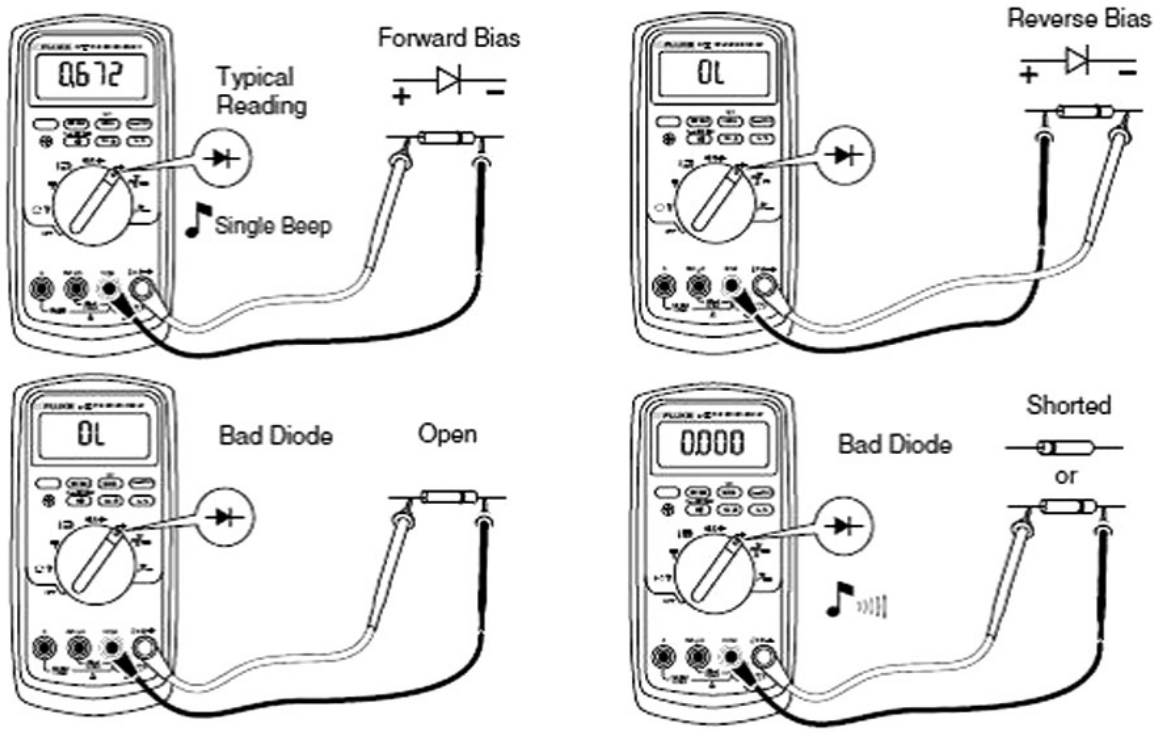

Figure 3–9. Diode testing. (Printed with permission, Fluke Corporation).

218. Oscilloscopes

You will sometimes need measurements that the multimeter cannot provide, such as noise, frequency, amplitude, or a characteristic that changes over time. This is when you will need to use an oscilloscope. We will now discuss using an oscilloscope to make measurements and analyze waveforms. First, we will cover some oscilloscope principles.

You will see different oscilloscope models during your career. Learning principles common to all of them will help you when it comes time to use these different models. This lesson was adapted from the manual, *The XYZs of Oscilloscopes*, Copyright 2016 Tektronix, Inc., reproduced with permission.

Oscilloscope principles

The oscilloscope is a graph-displaying device—it draws a graph of an electrical signal. In most applications, the graph shows how signals change over time: the vertical (Y) axis represents voltage and the horizontal (X) axis represents time. The intensity, or brightness, of the display is the Z-axis (fig. 3–10).

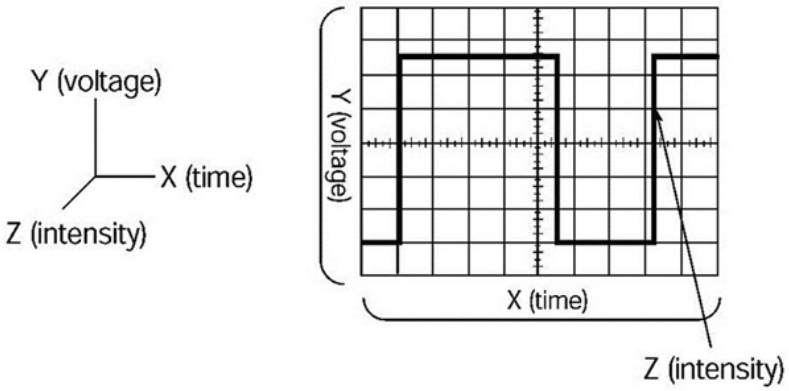

Figure 3–10. Waveform components.
(Copyright 2016 Tektronix, Inc. All rights reserved—Reproduced by permission).

This simple graph can tell you many things about a signal, such as:

- time and voltage values of a signal;
- frequency of an oscillating signal;
- frequency with which a particular portion of the signal is occurring relative to other portions;
- whether a malfunctioning component is distorting the signal;
- how much of a signal is DC or AC; and
- how much of the signal is noise and whether the noise is changing with time.

An analog oscilloscope works by applying the measured signal voltage directly to the vertical axis of an electron beam that moves from left to right across the oscilloscope screen—usually a cathode ray tube (CRT). The backside of the screen is treated with luminous phosphor that glows wherever the beam hits it. The signal voltage deflects the beam up and down, proportionally, as it moves horizontally across the display, tracing the waveform on the screen. The more frequently the beam hits a particular screen location, the brighter it glows.

In contrast to an analog oscilloscope, a digital oscilloscope uses an analog-to-digital converter (ADC) to convert the measured voltage into digital information. It acquires the waveform as a series of samples, and then stores these samples until it accumulates enough samples to describe a waveform. The digital oscilloscope then reassembles the waveform for display on the screen.

You will most likely encounter digital oscilloscopes throughout your career unless your shop has an older analog model still on inventory. Analog oscilloscopes still have a functional use for analyzing certain types of signals, but digital is more suitable for the circuits you will be troubleshooting as a BMET. That is why we will focus on digital oscilloscopes in this lesson.

Oscilloscope systems and controls

A basic oscilloscope consists of four different systems—display system, vertical system, horizontal system, and trigger system, and various controls. Understanding each will enable effective use of oscilloscopes to obtain the specific measurements you need. Each system contributes to the oscilloscope’s ability to reconstruct a signal.

Display system and controls

An oscilloscope’s front panel includes a display screen with knobs, buttons, switches, and indicators used to control the signal acquisition and display. The display screen will have grid markings, which create the graticule (fig. 3–11).

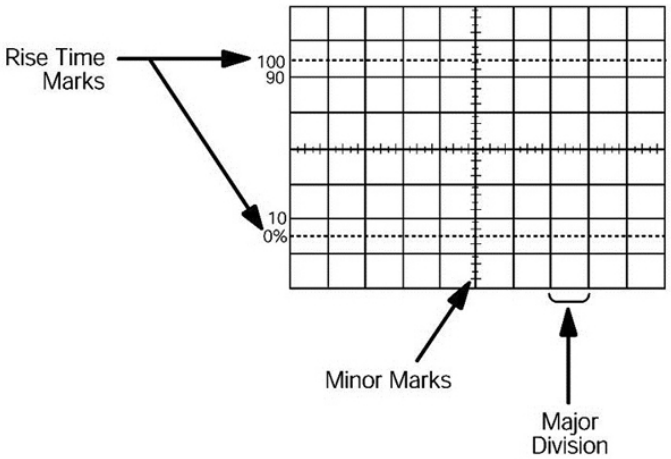

Figure 3–11. Oscilloscope graticule.
(Copyright 2016 Tektronix, Inc. All rights reserved—Reproduced by permission).

The graticule is in an 8 x 10 or 10 x 10 division pattern. The oscilloscope control labels (such as volts/div and sec/div) always refers to major divisions. The tick marks on the center horizontal and vertical graticule lines are minor divisions, which divide the major divisions into smaller, more accurate increments. Most oscilloscopes display the number of volts each vertical division represents, and the number of seconds each horizontal division represents, on the screen. The front panel (fig. 3–12) is usually divided into three main sections labeled horizontal, trigger, and vertical (your oscilloscope may contain other sections depending on the model and type).

Figure 3–12. Oscilloscope front panel.
(Copyright 2016 Tektronix, Inc. All rights reserved—Reproduced by permission).

You need to adjust the three systems to accommodate an incoming signal as follows in the table:

System	Function
Vertical	The attenuation or amplification of the signal. Use the volts/div control to adjust the amplitude of the signal to the desired measurement range.
Horizontal	The time base. Use the sec/div control to set the amount of time per division, represented horizontally across the screen.
Trigger	The oscilloscope triggering. Use the trigger level to stabilize a repeating signal or to trigger on a single event.

Vertical system and controls

Vertical controls position and scale the waveform vertically, set the input coupling, and adjust other signal conditioning. The common vertical controls we will discuss are the position and volts per division, input coupling, and bandwidth limit.

Position and volts per division

The vertical position control allows you to move the waveform up and down to exactly where you want it on the screen. The volts-per-division setting (usually written as volts/div) varies the size of the waveform on the screen. A good general-purpose oscilloscope can accurately display signal levels from about 4 millivolts (mV) to 40V. The volts/div setting is a scaling factor that varies the size of the waveform on the screen.

If the volts/div setting is 5V, then each of the vertical divisions represents 5V and the entire screen can display 40V from bottom to top, assuming a graticule with eight major divisions. If the setting is 0.5 volts/div, the screen can display 4V from bottom to top, and so on. The maximum voltage you can display on the screen is the volts/div setting multiplied by the number of vertical divisions.

Note that the probe you use, 1X or 10X (discussed in more detail later), also influences the scale factor. You divide the volts/div scale by the attenuation factor of the probe if the oscilloscope does not do it for you. Often, the volts/div scale has either a variable gain or a fine gain control for scaling a displayed signal to a certain number of divisions. Use this control to assist in taking rise time measurements.

Input coupling

Coupling refers to the method used to connect an electrical signal from one circuit to another. In this case, the input coupling is the connection from your test circuit to the oscilloscope. The coupling can be set to DC, AC, or ground.

DC coupling shows all of an input signal. AC coupling blocks the DC component of a signal so that you see the waveform centered on zero volts. Figure 3–13 shows this difference. The AC coupling setting is useful when the entire signal (AC + DC) is too large for the volts/div setting.

The ground setting disconnects the input signal from the vertical system, which lets you see where zero volts are located on the screen. With grounded input coupling and auto trigger mode, you see a horizontal line on the screen that represents zero volts. Switching from DC to ground and back again is a handy way of measuring signal voltage levels with respect to ground.

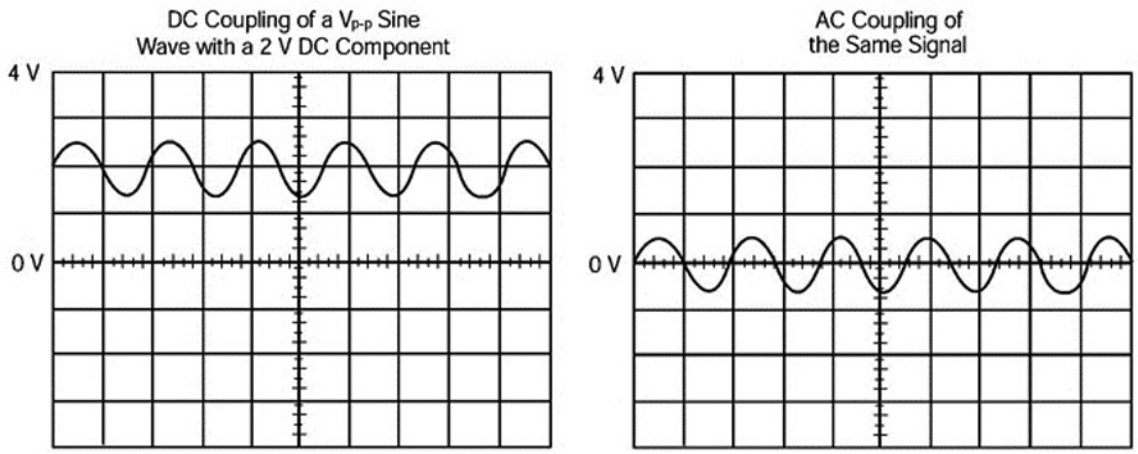

Figure 3–13. AC and DC input coupling.
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Bandwidth limit

Most oscilloscopes have a circuit that limits the bandwidth. By limiting the bandwidth, you reduce the noise that sometimes appears on the displayed waveform, resulting in a cleaner signal display. Note that, while eliminating noise, the bandwidth limit can also reduce or eliminate high-frequency signal content.

Horizontal systems and controls

An oscilloscope's horizontal system is most closely associated with its acquisition of an input signal—sample rate and record length are among the considerations here. Horizontal controls position and scale the waveform horizontally. The common horizontal controls we will cover are acquisition modes, position and seconds per division, and time-base settings.

Acquisition modes

Acquisition modes control how waveform points are produced from sample points. Sample points are the digital values derived directly from the ADC. The sample interval refers to the time between these sample points. Waveform points are the digital values that are stored in memory and displayed to construct the waveform. The time-value difference between waveform points is the waveform interval. The sample interval and the waveform interval may, or may not, be the same.

Because of this, there are many acquisition modes where one waveform point is comprised of several sequentially acquired sample points. Additionally, waveform points can be created from a composite of sample points taken from multiple acquisitions, which provides another set of acquisition modes.

Position and seconds per division

The horizontal position control moves the waveform left and right to exactly where you want it on the screen. The seconds-per-division setting (sec/div) lets you select the rate at which the waveform is drawn across the screen (also known as the time-base setting or sweep speed). This setting is a scale factor. If the setting is 1 millisecond (ms), each horizontal division represents 1ms and the total screen width represents 10ms, or ten divisions. Changing the sec/div setting enables you to look at longer and shorter input signal time intervals. As with the vertical volts/div scale, the horizontal sec/div scale may have variable timing, allowing you to set the horizontal time scale between the discrete settings.

Time-base settings

Your oscilloscope has a time-base, or main-time base. Many oscilloscopes also have what is called a delayed time base—a time-base with a sweep that can start (or be triggered to start), relative to a pre-determined time on the main time-base sweep. Using a delayed time-base sweep allows you to see events more clearly and to see events that are not visible solely with the main time-base sweep. The

delayed time-base requires a time delay to be set and the possible use of delayed trigger modes and other settings, which we will not discuss in this lesson. Refer to the manual supplied with your oscilloscope for information on how to use these features.

Trigger system and controls

An oscilloscope's trigger function synchronizes the horizontal sweep at the correct point of the signal, which is essential for clear signal characterization. Trigger controls allow you to stabilize repetitive waveforms and capture single-shot waveforms. The trigger makes repetitive waveforms appear static on the oscilloscope display by repeatedly displaying the same portion of the input signal. Imagine the jumble on the screen that would result if each sweep started at a different place on the signal, as seen in figure 3–14.

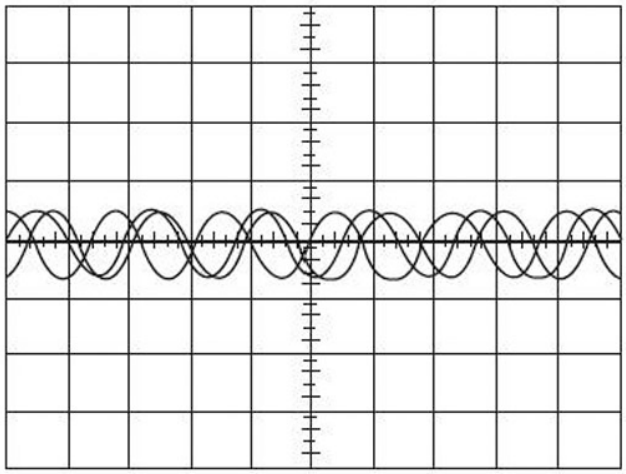

Figure 3–14. Untriggered display.
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Edge triggering is the basic and most common type. In addition to threshold triggering, many digital oscilloscopes offer a host of specialized trigger settings not offered by analog instruments. These triggers respond to specific conditions in the incoming signal, making it easy to detect; for example, a pulse that is narrower than it should be. Such a condition would be impossible to detect with a voltage threshold trigger alone.

Your oscilloscope may have some advanced trigger controls that enable you to isolate specific events of interest to optimize the oscilloscope's sample rate and record length. You can trigger on pulses defined by amplitude, qualified by time, and delineated by a logic state or pattern (logic triggering).

Trigger level and slope

The trigger level and slope controls provide the basic trigger point definition and determine how a waveform is displayed (fig. 3–15). The trigger circuit acts as a comparator. You select the slope and voltage level on one input of the comparator. When the trigger signal on the other comparator input matches your settings, the oscilloscope generates a trigger. The slope control determines whether the trigger point is on the rising or the falling edge of a signal. A rising edge is a positive slope and a falling edge is a negative slope. The level control determines where on the edge the trigger point occurs.

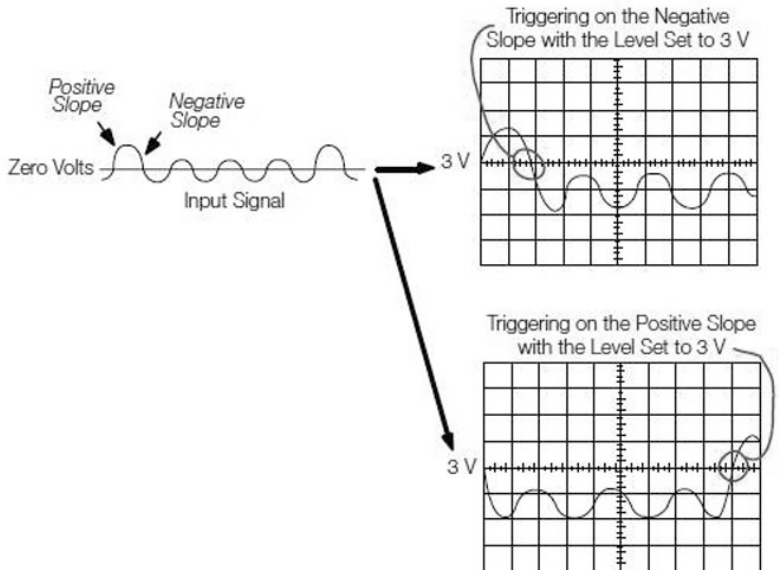

Figure 3–15. Positive and negative slope triggering.
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Trigger modes

The trigger mode determines whether the oscilloscope draws a waveform based on a signal condition. Common trigger modes include normal and auto. In normal mode, the oscilloscope only sweeps if the input signal reaches the set trigger point; otherwise, the screen freezes on the last acquired waveform. Normal mode can be disorienting since you may not see the signal at first if you do not adjust the level control correctly. Auto mode causes the oscilloscope to sweep, even without a trigger. If no signal is present, a timer in the oscilloscope triggers the sweep.

Trigger holdoffs

Sometimes getting an oscilloscope to trigger on the correct part of a signal requires great skill. Many oscilloscopes have a special feature known as trigger holdoff to make this task easier. Trigger holdoff is an adjustable period after a valid trigger where the oscilloscope cannot trigger. This is useful when you are triggering on complex waveform shapes, so that the oscilloscope only triggers on an eligible trigger point. Figure 3–16 illustrates how this feature helps create a usable display.

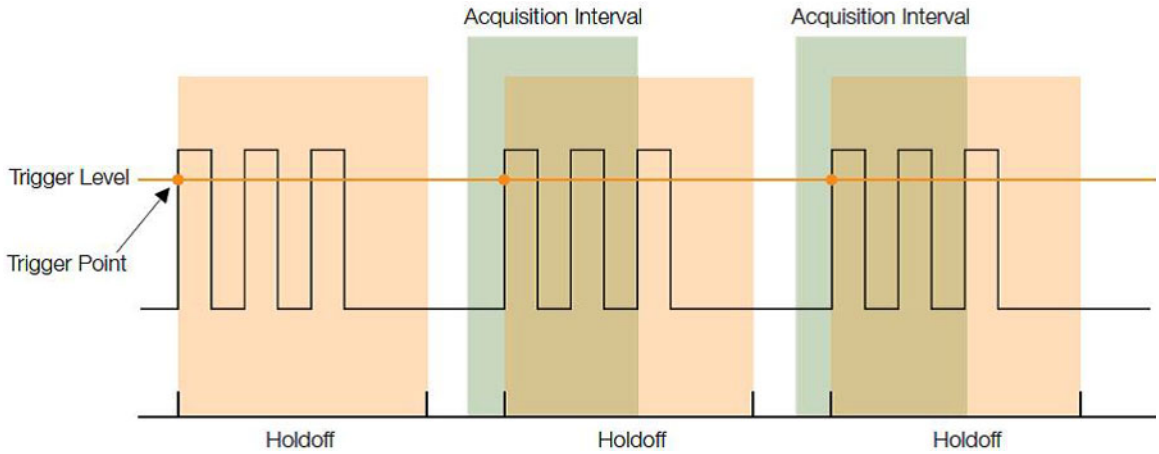

Figure 3–16. Trigger holdoff feature.
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Analyze waveforms

The generic term for a pattern that repeats over time is a wave. Sound waves, brain waves, ocean waves, and voltage waves are all repetitive patterns. An oscilloscope measures voltages waves. One cycle of a wave is the portion of the wave that repeats. A waveform is a graphic representation of a wave. A voltage waveform shows time on the horizontal axis and voltage on the vertical axis.

Waveform shapes reveal a great deal about a signal. Once you see a change in the height of the waveform, you know that the voltage has changed. Any time there is a flat, horizontal line, you know that there is no change for that length of time. Straight, diagonal lines mean a linear change—rise or fall of voltage at a steady rate. Sharp angles on a waveform indicate sudden change. Figure 3–17 shows examples of common waveforms.

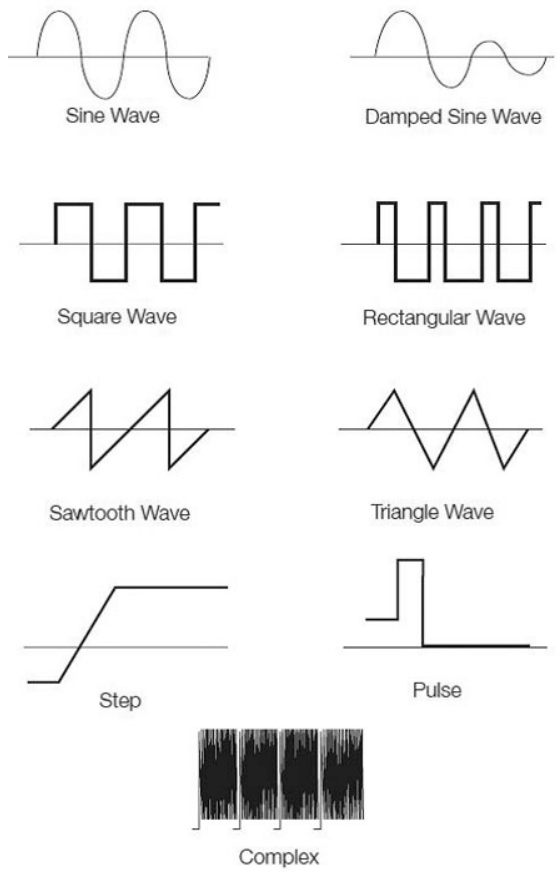

Figure 3–17. Common waveforms.
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Types of waves

You can classify most waves into the following types with their descriptions in the table below:

Waveform	Description
Sine	The fundamental wave shape. The voltage in your wall outlet varies as a sine wave. Most AC power sources produce sine waves, which is due to its physical properties.
Square and Rectangular	A square wave is a voltage that turns on and off (or goes high and low) at regular intervals. It is the standard wave for testing amplifiers. Television, radio, and computer circuits use square waves for timing signals. The rectangular wave is like the square wave except that the high/low time intervals are not of equal length. It is particularly important

Waveform	Description
	when analyzing digital circuitry.
Sawtooth and Triangle	These result from circuits designed to control voltages linearly, such as a television raster scan. The transitions between voltage levels of these waves change at a constant rate. These transitions are known as ramps.
Step and Pulse	A step indicates a sudden change in voltage, similar to the voltage change you would see if you turned on a power switch. A pulse indicates sudden changes in voltage; similar to the voltage changes you would see if you turned a power switch on and then off again. A pulse might represent one bit of information traveling through a computer circuit or it might be a glitch, or defect, in a circuit. A collection of pulses traveling together creates a pulse train. Digital components in a computer communicate with each other using pulses. These pulses may be in the form of serial data stream or may use multiple signal lines to represent a value in a parallel data bus. Pulses are also common in x-ray and communications equipment.
Complex	This combines the characteristics of sines, squares, steps, and pulses to produce complex wave shapes. The signal information may be embedded in the form of amplitude, phase, and/or frequency variations.

Waveform measurements

Common oscilloscope measurements you will make include frequency and period, voltage, amplitude, and phase.

Frequency and period

If a signal repeats, it has frequency. You measure frequency in Hz, and it equals the number of times the signal repeats itself in one second, which is referred to as cycles per second. A repetitive signal also has a period—the amount of time it takes the signal to complete one cycle. Period and frequency are reciprocals of each other, so that period equals the frequency and 1/frequency equals the period. For example, the sine wave in figure 3–18 has a frequency of 3Hz and a period of 1/3 second.

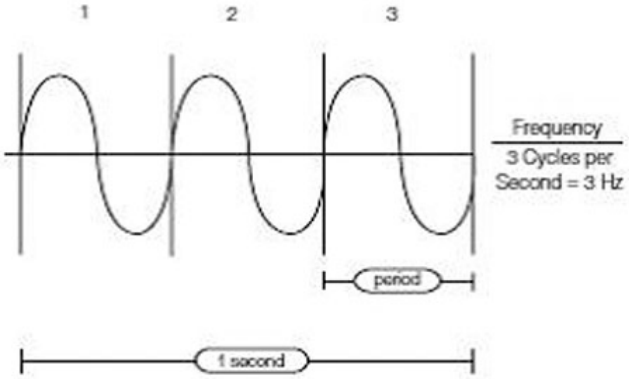

Figure 3–18. Sine wave frequency and period.
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Voltage

Voltage is the amount of electrical potential, or signal strength, between two points in a circuit. Usually, one of the two points is ground, or zero volts, but not always. You may need to measure the voltage from the maximum peak to the minimum peak of a waveform. This is referred to as the peak-to-peak voltage.

Amplitude

Amplitude refers to the amount of voltage between two points in a circuit. Amplitude commonly refers to the maximum voltage of a signal measured from ground, or zero, volts. The waveform shown in figure 3–19 has an amplitude of 1V and a peak-to-peak voltage of 2V.

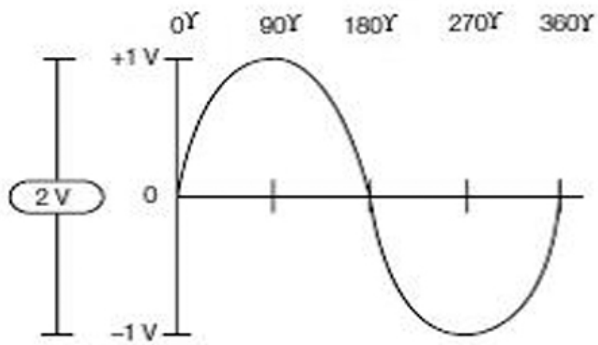

Figure 3–19. Sine wave amplitude and degrees.
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Phase

It is easiest to learn phase by looking at a sine wave. The voltage level of sine waves is based on circular motion. Given that a circle has 360°, one cycle of a sine wave has 360°. Using degrees, you can refer to the phase angle of a sine wave when you want to describe how much of the period has elapsed. Phase shift describes the difference in timing between two otherwise similar signals. The waveforms in figure 3–20 are said to be 90° out of phase with each other, since the waves reach similar points in their cycles exactly one-fourth of a cycle apart (360°/4 = 90°). Phase shifts are common in electronics.

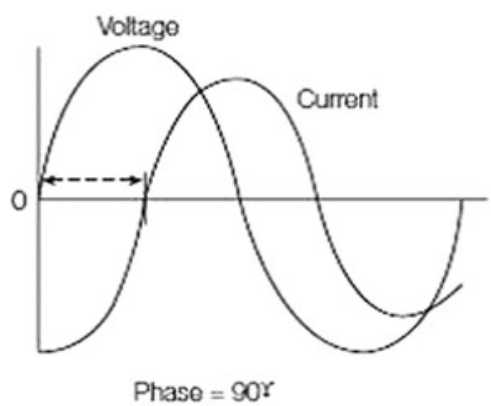

Figure 3–20. Phase shift.
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Using an oscilloscope

Setting up the oscilloscope properly is the first step to using one. You will start by grounding the oscilloscope, then setting the controls in standard positions, and finally, using the oscilloscope probes to take measurements.

Grounding

Proper grounding is an important step when preparing to take measurements or to work on a circuit. Properly grounding the oscilloscope protects you from a hazardous shock, and grounding yourself protects your circuits from damage.

To ground the oscilloscope means to connect it to an electrically-neutral reference point, such as earth ground. Ground your oscilloscope by plugging its three-pronged power cord into an outlet grounded that is earth ground. Grounding the oscilloscope is necessary for safety. If a high voltage contacts the case of an ungrounded oscilloscope—any part of the case, including knobs that appear insulated—it can shock you. However, with a properly grounded oscilloscope, the current travels through the grounding path to earth ground rather than through you to earth ground.

Grounding is also necessary for taking accurate measurements with your oscilloscope. For accurate measurements, it is important that the oscilloscope share the same ground as the circuit you are testing. If you are working with integrated circuits (IC), you also need to ground yourself. Integrated circuits have tiny conduction paths that can be damaged by static electricity that builds up on your body. You can ruin an expensive IC by simply walking across a carpet and then touching the IC leads. To solve this problem, wear a grounding strap. This strap safely sends static charges on your body to earth ground.

Setting the controls

After plugging in the oscilloscope, look at the front panel. As previously described, the front panel has three main sections that are labeled vertical, horizontal, and trigger. Your oscilloscope may have other sections, depending on the model and type—whether analog or digital. Most oscilloscopes have at least two input channels, and each channel can display a waveform on the screen. Multiple channels are useful for comparing waveforms.

Some oscilloscopes have AUTOSET and/or DEFAULT buttons that can set up the controls in one step to accommodate a signal. If your oscilloscope does not have this capability, it is helpful to set the controls to standard positions before taking measurements.

General instructions to set up the oscilloscope in standard positions are as follows:

1. Set the oscilloscope to display channel 1.
2. Set the vertical volts/div scale and position controls to mid-range positions.
3. Turn off the variable volts/div.
4. Turn off all magnification settings.
5. Set the channel 1 input coupling to DC.
6. Set the trigger mode to auto.
7. Set the trigger source to channel 1.
8. Turn trigger holdoff to minimum or off.
9. Set the intensity control to a nominal viewing level, if available.
10. Adjust the focus control for a sharp display, if available.
11. Set the horizontal time/division and position controls to mid-range positions.

Using oscilloscope probes

Now you are ready to connect a probe to your oscilloscope. An oscilloscope can only be as precise as the data that goes into it. A probe matched to your oscilloscope, and to the device you are testing, not only allow the signal to go to the oscilloscope cleanly, it also amplifies and preserves the signal for the greatest integrity and measurement accuracy.

Probes actually become part of the circuit by introducing resistive, capacitive, and inductive loading that inevitably alters the measurement. For the most accurate results, ideally select a probe with minimal loading.

There is a variety of probes available, but the most common is the passive probe. Most passive probes have some attenuation factor, such as 10X and 100X. The 10X attenuator probe is an excellent general-purpose probe. The 10X attenuator probe improves the accuracy of your measurements but

also reduces the signal's amplitude at the oscilloscope input by a factor of 10. Because it attenuates the signal, the 10X attenuator probe makes it difficult to look at signals less than 10 mV peak-to-peak.

The 1X probe is similar to the 10X attenuator probe, but it lacks the attenuation circuitry. Without attenuation, the circuit under test will have more interference. Use the 10X attenuator probe as your general-purpose probe, but keep the 1X probe accessible to measure slow-speed, low-amplitude signals.

Some probes have a feature for switching between 1X and 10X attenuation at the probe tip (fig. 3–21). If your probe has this feature, make sure you are using the correct setting before taking measurements. Many oscilloscopes can automatically detect whether you are using a 10X or 100X probe and adjust their screen readouts accordingly. However, with some oscilloscopes, you must set the type of probe you are using or read it from the proper 1X or 10X marking on the volts/div control.

Figure 3–21. Probe attenuation switch.
("How to use an oscilloscope" by SparkFun is licensed by CC BY SA 4.0).

The 10X attenuator probe works by balancing the probe's electrical properties against the oscilloscope's electrical properties. Before using a 10X attenuator probe, you need to adjust this balance for your particular oscilloscope. This adjustment is called compensating the probe.

You should get into the habit of compensating the probe every time you set up the oscilloscope. A poorly adjusted probe can make your measurements less accurate. Figure 3–22 illustrates the effects on a 1 megahertz (MHz) test signal when a probe is not properly compensated and when it is properly compensated.

Most oscilloscopes have a square-wave reference signal available at a terminal on the front panel that is used to compensate the probe. General steps to compensate the probe are as follows:

1. Attach the probe to a vertical channel.
2. Connect the probe tip to the probe compensation (i.e., square-wave reference signal).
3. Attach the ground clip of the probe to ground.
4. View the square-wave reference signal.
5. Make the proper adjustments on the probe so that the corners of the square wave are squared.

When you compensate the probe, always attach any accessory tips you will use and connect the probe to the vertical channel you plan to use. This will ensure the oscilloscope has the same electrical properties as it does when you take measurements.

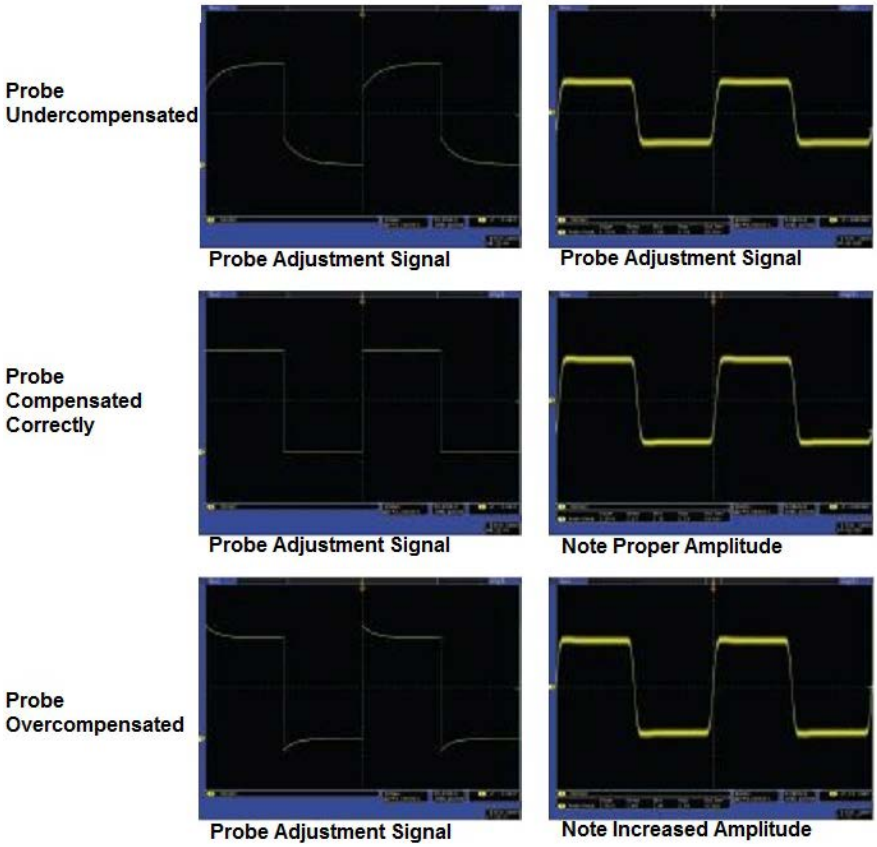

Figure 3–22. Probe compensation effects.
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Making oscilloscope measurements

Measuring a signal requires two connections: the probe tip connection and the ground connection. Probes come with an alligator-clip attachment for grounding the probe to the circuit under test. Probe tips exist in a variety of form factors, such as fine point, spring-loaded clip, and hooks; try to use one that does not require you to hold it in place during the measurement. In practice, you attach the grounding clip to a known ground in the circuit, such as the metal chassis, and connect the probe tip to a test point in the circuit. Your signal should now be on the screen. You may have to adjust your horizontal and vertical controls to be able to view your signal clearly.

The two most basic measurements you can take are voltage and time measurements. We will discuss methods for taking measurements visually with the oscilloscope screen. This is a common technique with analog instruments, and it may be useful for an “at-a-glance” interpretation of digital oscilloscope displays. Note that most digital oscilloscopes include automated measurement tools. You should also know how to take measurements manually since this method will help you understand and check the automatic measurements using digital oscilloscopes or taking measurements with older model oscilloscopes.

Voltage measurements

Speak—from the maximum point of a signal to its minimum point. When discussing voltages, you must be careful to specify which voltage you mean. The oscilloscope is primarily a voltage-measuring device.

Once you have measured the voltage, other quantities (e.g., current, resistance, and power) are just a calculation away. We will not go into detail on these calculations here since that is part of the next volume (Electronic Principles) you will study. Figure 3–23 shows voltage peak and voltage peak-to-peak.

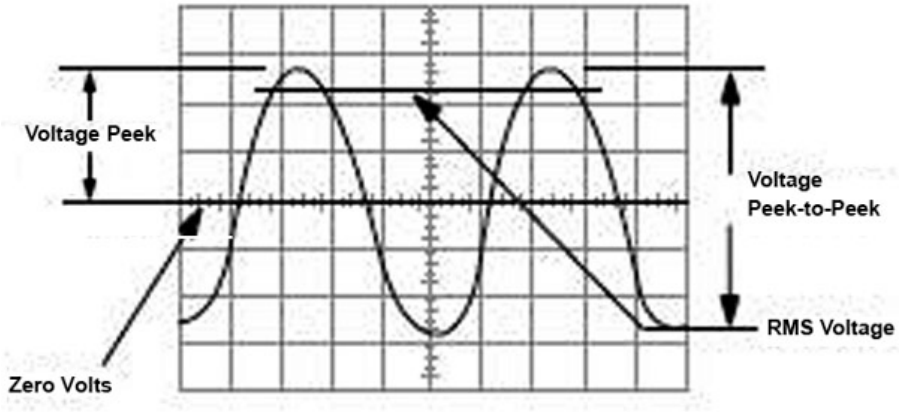

Figure 3–23. Voltage peak and voltage peak-to-peak.
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The most basic method of taking voltage measurements is to count the number of divisions a waveform spans on the oscilloscope's vertical scale. Adjusting the signal to cover most of the screen vertically makes for the best voltage measurements. The more screen area you use, the more accurately you can read from the screen. You should always measure on the center vertical graticule line (fig. 3–24) when measuring voltage to ensure accuracy.

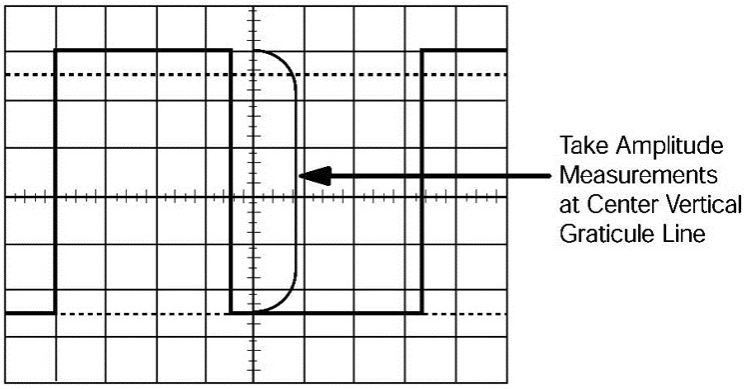

Figure 3–24. Proper voltage measurement.
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Many oscilloscopes have on-screen line cursors that let you make waveform measurements automatically on-screen, without having to count graticule marks. You can move two horizontal cursor lines up and down to bracket a waveform's amplitude for voltage measurements, and you may move two vertical lines move right and left for time measurements. A readout shows the voltage or time at their positions. However, you may sometimes find yourself using an older model oscilloscope and will need to know how to make measurements the "old-fashioned" way, or manually.

DC voltage measurements present a slight problem when determining their voltage. On an AC measurement, the entire signal shows on the screen, so counting the divisions from one point of the waveform to another is simple. When DC voltage applies to the vertical input, the existing reference line is gone, leaving only the input DC voltage line appearing on the screen. To determine the voltage, you must know where the reference line was before the input DC voltage was applied. You can use one the following procedures to find the position of the reference line:

- You can momentarily move the AC-ground (GND)-DC switch from the DC position to the GND position with the incoming signal applied. This will cause the DC voltage to disappear and the original reference line to reappear on the display. Make note of the division line that the reference falls on (the position can now be adjusted to any major division line), and return

the AC-GND-DC switch to the DC position. When the DC voltage line reappears, count the number of divisions from the reference line to the DC voltage line.

- You can preset the reference line to an identified division line before applying the DC input. Calculate the number of divisions covered by the voltage from the known reference line to the DC voltage line after the signal is applied.

In either case, you will have several divisions between the reference line and the DC voltage line. Use this value together with the volts/div switch setting to determine the incoming DC voltage value.

Another factor to consider when making DC voltage measurements is the polarity of the incoming signal. For a positive DC voltage, position the reference line on or near the bottom division line on the oscilloscope screen, allowing the input to drive the oscilloscope image in a positive direction up the screen. For a negative voltage, position the reference line on or near the top division line on the screen to allow a downward (negative) deflection. A polarity factor is also used in the formula for calculating the DC voltage. If the signal is measured from the bottom graticule and moved upward, the polarity is positive and a (+1) is used in the calculation. If the reference line was at the top of the screen, with the incoming signal creating a downward movement, the polarity is negative and a (–1) is used in the calculation.

Use the following formula when calculating DC voltage:

Voltage = Number of vertical divisions × volts/div setting × polarity

Let us use an example and put this formula to work. Assume that you took a DC voltage reading with a 100X probe, that the volts/div switch was set to 2, the polarity was positive (the signal moved upward from the reference line), and the signal moved 4.6 vertical divisions. With these figures, you would have the following solution:

Voltage = 4.6 × 2 × 1 = 9.2 volts

The following procedures show how to measure peak-to-peak AC voltage. To find the peak-to-peak value with an oscilloscope:

1. Connect the signal you are measuring to the oscilloscope's input connector.
2. Set the volts/div switch to display the largest waveform possible (ensure the entire peak-to-peak waveform is visible).
3. Obtain a stable image, which displays several cycles of waveform.
4. Turn the vertical and horizontal position controls so that the waveform's lower extremity coincides with the lowest horizontal graticule line and that one of the peaks is on or near the vertical centerline (fig. 3–25).
5. Measure the vertical divisions.

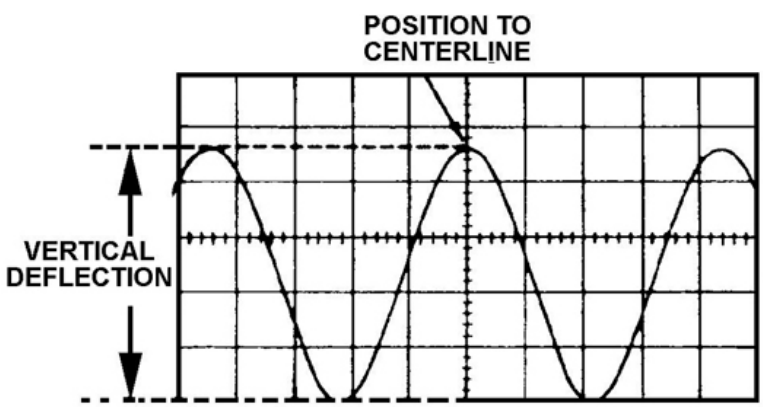

Figure 3–25. Peak-to-peak AC voltage measurements.

From this point on, the rest of the measurement is a mathematical problem. The formula you should use is:

Peak-to-Peak Volts = Number of vertical divisions (vertical deflection) × volts/div setting

The vertical deflection is the number of major and minor divisions counted on the oscilloscope screen for the waveform being measured and the volts/div setting is read from the 1X or 10X position on the oscilloscope, depending on the probe you are using.

Assuming, for this example, that you are using a 10X probe, that the volts/div switch is set to 5 (indicated adjacent to the 10X mark on the knob), and reading the waveform illustrated in figure 3–24, you would have the following solution:

Peak-to-Peak Volts = 4.6 × 5 = 23 volts peak-to-peak

After determining the peak-to-peak value, you can use a mathematical process to determine peak, or root mean square (RMS), values (peak-to-peak divided by 2 equals peak value, and peak value times 0.707 equals the RMS value). RMS is the effective voltage value of AC, which is equivalent to DC.

Time and frequency measurements

You can make time measurements using the oscilloscope's horizontal scale. Time measurements include measuring the period (or time) and pulse width of pulses. Frequency is the reciprocal of the period, so once you know the period, the frequency is one divided by the period. Like voltage measurements, time measurements are more accurate when you adjust the portion of the signal you are measuring to cover a large area of the screen. Also, make your measurements on the center horizontal graticule line to ensure accuracy (fig. 3–26).

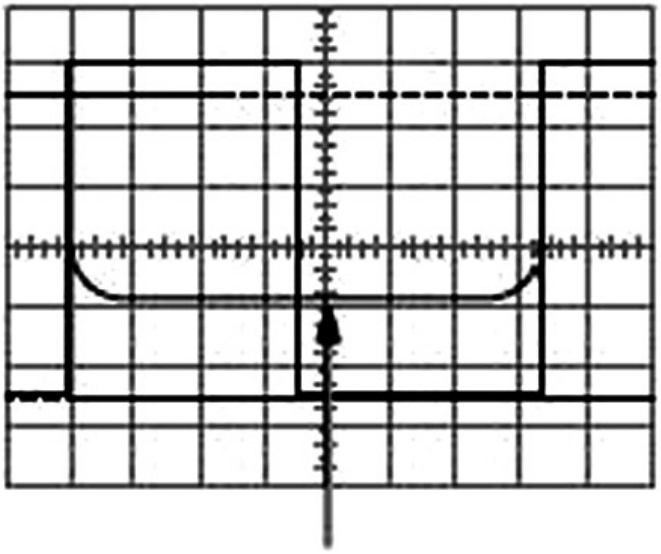

Figure 3–26. Properly measuring frequency.
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You determine time duration and frequency similar to determining voltage measurements. The exception is that the deflection of the signal is on the horizontal division lines and is multiplied by the sec/div setting. Follow these procedures to determine the time duration of a selected signal:

1. Connect the signal you are measuring to the oscilloscope's input connector.
2. Set the volts/div switch to display several waveform divisions.
3. Set the sec/div switch to display the portion of the waveform you are measuring, as illustrated in figure 3–27.

4. Obtain a stable image.
5. Adjust the vertical position control to move the measurement points to the horizontal centerline (fig. 3–27).
6. Measure the horizontal distance between the measurement points on the horizontal centerline.

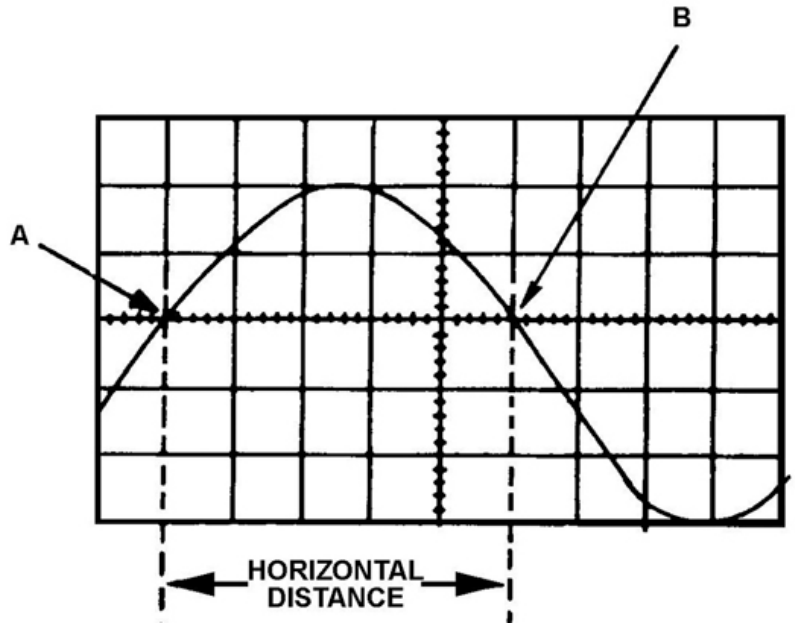

Figure 3–27. Measuring time duration.

Calculate the frequency of the area under test with the following formula:

Time = Horizontal deflection × sec/div setting.

Using the data represented in figure 3–26, and a sec/div setting of 2 ms, you have:

Time duration = 5 × .002 (2ms/2 × 10^{-3}) = 10ms

If you wanted to figure out the frequency for the above figure you would use the formula:

Frequency = 1/Time

Using the data from the previous example, you have:

Frequency = 1/10 ms = 100 Hz

Pulse width and rise time measurements

The details of a pulse's shape are important. Pulse width is the amount of time the pulse takes to go from low to high and back to low again. Pulses can become distorted and cause a digital circuit to malfunction, and the timing of pulses in a pulse train is often significant. Standard pulse measurements are pulse rise time and pulse width.

Rise time is the amount of time a pulse takes to go from a low to a high voltage. By convention, the rise time is measured from 10 percent to 90 percent of the full voltage of the pulse—this eliminates any irregularities at the pulse's transition corners. Pulse width is the amount of time the pulse takes to go from low to high and back to low again. By convention, the pulse width is measured at 50 percent of full voltage. Figure 3–28 illustrates these measurement points.

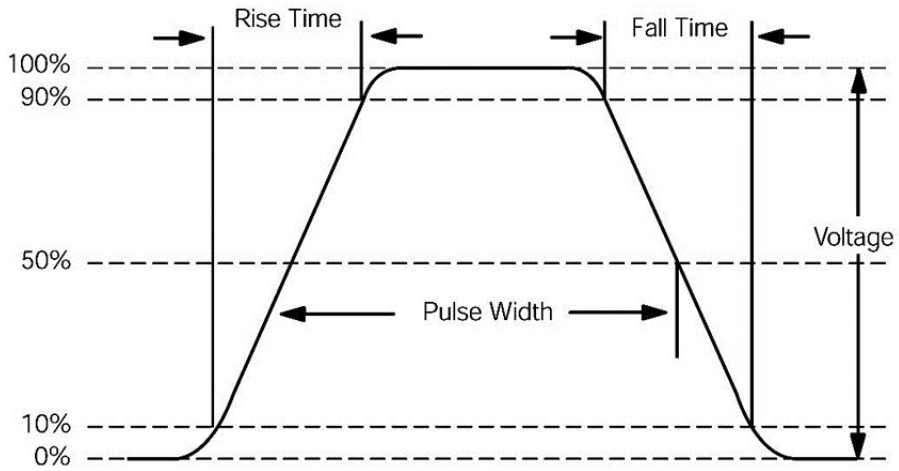

Figure 3–28. Pulse rise time and pulse width measurement points.
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Pulse measurements often require you to fine-tune the triggering. To become an expert at capturing pulses, learn how to use the trigger holdoff and how to set the digital oscilloscope to capture pretrigger data, as described here. Horizontal magnification is another useful feature for measuring pulses, since it allows you to see the fine details of a fast pulse.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

217. Using multimeters

1. Describe the difference between chassis ground and signal ground.

2. What problems can you cause by taking a meter measurement in an isolated circuit while the meter common lead is connected to a chassis ground?

3. What is the *safest* way to measure voltage?

4. Describe one-handed troubleshooting.

5. How does one-handed troubleshooting help prevent shock?

6. What is the *main* concern with using multimeter probes in circuits?

7. Explain what happens if you try to take a voltage reading with a meter configured for a current measurement.

8. How do you use the meter to measure current?

9. How do you safely discharge a capacitor?

10. Why is a clamp-on meter safer than a multimeter for measuring current?

11. How do multimeters determine the resistance of a component?

12. Why is it important to isolate a component before measuring resistance?

13. How is the REL mode used on the multimeter when measuring capacity?

14. How many volts should you measure in a good forward-bias diode?

218. Oscilloscopes

1. What are the three axes of an oscilloscope reading, and what do they represent?

2. Identify the four oscilloscope systems.

3. Which system would you adjust for the amount of time per division?

4. How do you change the size of the waveform on the screen?

5. How can you find the max voltage than can be displayed on the screen?

6. How can you reduce noise from your displayed waveform?

7. What is the function of the seconds-per-division setting?

8. What enables you to stabilize repetitive waveforms?

9. Which type of trigger is the *most* common?

10. Briefly explain trigger holdoff.

11. Which waveform is typically used in x-ray and communications equipment?

12. Explain the relationship between frequency and period.

13. Which term is used to refer to the amount of voltage between two points in a circuit?

14. How must you set up the oscilloscope ground for accurate measurements?

15. When selecting a probe to use with an oscilloscope, which type should you choose?

16. How do you compensate a probe?

17. How must you position the reference line when measuring DC voltage?

18. What would be the value of a measured DC voltage that caused a 5.6 division deflection, with a volts/div setting of 2, and positive polarity?

19. If a signal has a vertical deflection of 4.8 divisions and the volts/div switch is set in the 5 position, what is the peak-to-peak value of the AC signal being measured?

20. Determine the time if a signal has a horizontal distance of 2.8 divisions and a sec/div switch setting of 2ms.

21. If the time duration in the previous question were for one full cycle of a sine wave, what would the frequency of the sine wave be?

22. Describe pulse width.

3–2. Other General Test Equipment

We will conclude this unit by covering some other general test equipment you need to be familiar with as a BMET. While not as frequent as the multimeter, you will use routinely use manometers and electrical safety analyzers in your duties.

219. Manometers

Manometers are devices used to measure the positive or negative pressure (vacuum) of a component or system. There are many different variations of analog and older liquid manometers, but your shop will more than likely use digital models.

Digital manometers consist of models designed to measure gas, liquid, or possibly both. Most manometers will have a single input port, but some may have dual input ports to enable connecting two systems to read its differential pressure (compares two values simultaneously). Manometers are extremely simple to operate, but you should be aware of some precautions prior to use, which are as follows:

1. Check the pressure range of the manometer. You can damage the manometer if the system you are trying to test goes past the maximum pressure the manometer can handle. In contrast, if the pressure you are trying to test is too low, the manometer will not be able to read it. You need to use the operating range of the system you are trying to test to properly check it against the manometer's range.
2. Ensure you can use the manometer for the type of media you are measuring. A quick way to destroy your manometer is to connect a water line to its input pressure port designed to measure a gas.

Now you are ready to operate the manometer, so follow these steps:

1. Turn on the manometer.
2. Zero out the manometer; make sure it reads zero when vented to atmosphere. (**NOTE:** If you do not perform this step before taking a measurement, you may get inaccurate readings.)
3. Connect the manometer inlet port tubing from the system to be measured (could be as simple as a sample port or you may have to configure a connection with tubing and connectors to tie into the system). Hospital-grade tubing can be used for most measurements, but rigid tubing should be used for negative (vacuum) pressure measurements.
4. Pressurize the system you are measuring. The pressure readout will be on the digital display.

If your manometer measures liquid pressure, be sure to verify in the user's manual which types of liquids are compatible. The manometer may have a potential of hydrogen (pH), or corrosive, restriction.

220. Electrical safety analyzers

Use electrical safety analyzers to perform equipment electrical safety inspections. The analyzer simulates the conditions required for each test, and it is able to measure small values of current, voltage, and resistance. The accuracy of the electrical safety analyzer is critical, so ensure that the analyzer's calibration is current prior to its use. Your local Precision Measurement Equipment

Laboratory (PMEL), or the equipment manufacturer (if PMEL is not available), must calibrate your safety analyzers at least annually. There are special precautions to take when using electrical safety analyzers.

Precautions and hazards

When measuring extremely small current, voltage, and resistance values, it is important to limit external influences, since it may affect the readings. Avoid any contact with the device under test as you are taking readings. Touching the device or allowing any part of another device (e.g., cable, lead, etc.) to touch it may introduce external factors that can affect the test results. Here are some general precautions and hazards to follow when using electrical safety analyzers:

- Never connect the analyzer to equipment connected to a patient.
- Do not use electrical safety analyzers in wet locations or dust.
- Inspect analyzer and test leads before use. Do not use it if you note any abnormal conditions, including a faulty display, broken case, or damaged test lead insulation.
- Use only a power supply outlet that has a protective earth ground. Do not use a two-conductor adapter or extension cord.
- Do not touch metal parts of the device you are testing. Consider the device under test an electrical shock hazard when connected to the analyzer because some tests involve high voltages, high currents, and/or the removal of the ground of the device under test.

Using electrical safety analyzers

There is no standard, specific electrical safety analyzer model that Air Force medical equipment repair shops must use, so you will see and use multiple ones. Each analyzer's numerous operations and methods of connecting vary. Follow the manufacturer's guidance closely to ensure correct and accurate results, to prevent damage to the analyzer and the device under test. The general steps that apply for setting up all electrical safety analyzers are as follows:

1. Connect an electrical safety analyzer to line power that is properly grounded.
2. Connect the device you wish to test to the analyzer. There are many ways to connect, depending on the analyzer and the device you are testing. See figure 3–29 for connection examples.
3. Turn the analyzer on and wait for it to initialize.

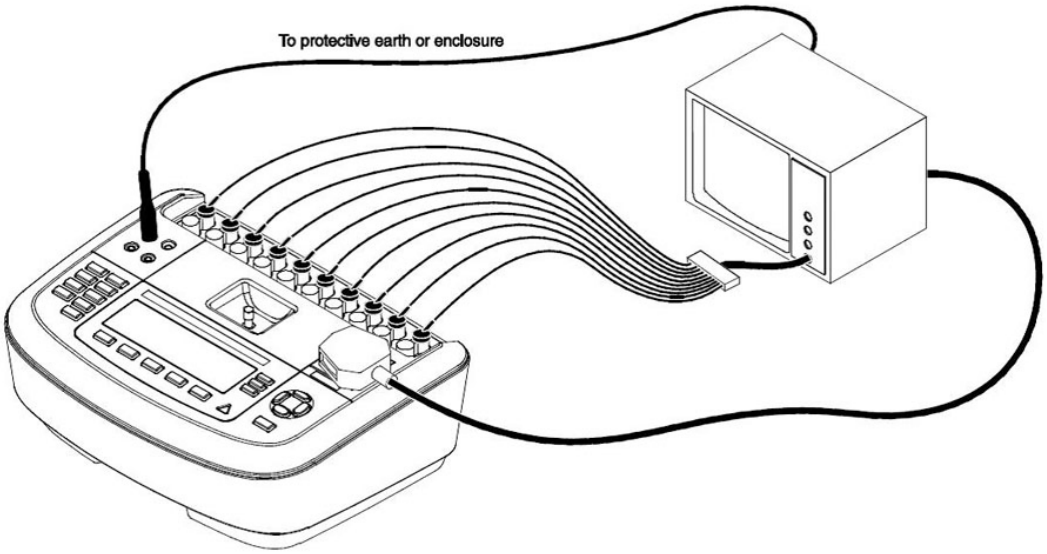

Figure 3–29. Electrical safety analyzer connections. (Printed with permission, Fluke Biomedical).

Conducting electrical safety inspections

Performing electrical safety inspections is a key responsibility of BMETs. You perform this test to make sure faulty equipment or leads will not inadvertently shock a patient or staff member. NFPA 99, *Health Care Facilities Code*, establishes minimum electrical safety testing requirements. It only requires electrical safety tests be performed before putting equipment into service for the first time and after any repair or modification that might have compromised its electrical safety.

The term *leakage current* refers to currents, not intended for patients, which flow from exposed conductive portions of a device. The following table gives a brief description of the required tests and procedures for equipment in patient care areas.

Test	Description
Ground resistance	Measures the ohm value from the ground prong on the power cord to the device chassis ground. The chassis ground point on the device may be a metal subframe, exterior panel, or a screw or connector that physically connects to the device grounding system. The correct measurement is from the point of least resistance found on the device. The limit is 0.5 ohms.
Chassis leakage current (touch current)	This test measures the current flowing between the devices' enclosure and ground. Most analyzers are capable of measuring many configurations, but leakage-current measurements are only required as follows: normal polarity, open ground mode, and device under test both on and off. The limit is 500µA.
Lead leakage current	Measures the current flowing between leads; only required to measure all leads connected together to ground (open and closed). Individual lead-to-ground or lead-to-lead leakage testing is *not* required. The limit is 100µA for closed ground and 500µA for open ground.

Once you set up your analyzer, these required tests are easy to perform. You simply adjust parameters to the required test settings and record the results. Always perform the ground resistance test *before* any of the leakage tests.

Other safety inspection test considerations

In the following situations, standard safety inspection tests are impractical or ineffective.

1. Hard-wired devices are checked for current leakage levels prior to the connection of the ground wire during the initial installation.
2. Double-insulated devices are items that have no exposed conductive surfaces and covers are usually made with plastic. They do not require electrical safety analyzer testing. However, visually inspect these devices to ensure they are in compliance with the below:
   a. They are identified as double insulated on an UL sticker attached to the unit. See figure 3–30 for an example.
   b. There are no conductive surfaces present.

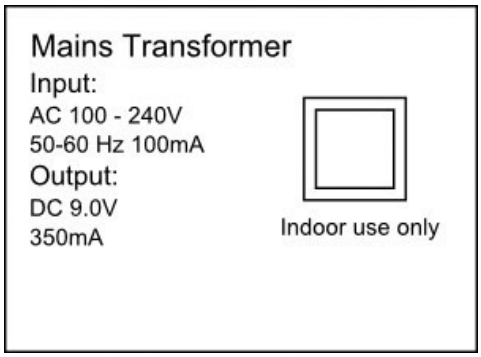

Figure 3–30. UL double-insulation symbol example.

3. Battery-powered devices are checked for leakage current if they are capable of operating while connected to the charger. Connect the charger to the analyzer receptacle with the device attached to the charger in the normal operating configuration.
4. Some device systems are set up to operate in a packaged arrangement. The components of the system all fit on a cart, or in a movable enclosure, and all of the components get their power from a single power strip. When this power method is used, check the devices for leakage and ground continuity as an assembly. (**NOTE:** Connect a power strip to the analyzer's receptacle and connect each device to the strip's receptacles for testing.) In addition, check each device capable of stand-alone operation individually.
5. For a device that utilizes an approved extension cord, perform the electrical safety test with the extension cord in the circuit.
6. High-current draw equipment, such as warming cabinets, hypo/hyperthermia units, or ultrasound therapy devices, may exceed the chassis leakage current limits, so they may use a *redundant ground* for an additional layer of safety. A redundant ground is an additional external ground wire permanently fastened between the chassis of the equipment, normally to the screw of the outlet cover plate. If the unit has fixed (permanently secured), redundant grounding, perform the electrical safety inspections as normal with the redundant ground left intact in accordance with NFPA 99 (2015), paragraph 10.3.5.3.1. Document the work order/EDF and clearly label the redundant ground wire with a note such as: "This is a redundant ground and must not be removed; if equipment needs moved, contact Medical Maintenance at 867–5309."

Electrical safety standards have the possibility of changing around every three to five years. Always follow the guidance provided by AFMOA and refer to AFI 41–201, *Managing Clinical Engineering Programs*, and/or NFPA 99, to confirm requirements. One final note, always document the results of your electrical safety inspection on the applicable work order.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

219. Manometers

1. What is the purpose of a manometer?

2. What are some dual-port manometer models capable of measuring?

3. What are two precautions to use when operating manometers?

220. Electrical safety analyzers

1. List at least three general precautions for electrical safety analyzers.

2. What guidance establishes the *minimum* electrical safety-testing requirement?

3. When must you perform electrical safety testing of equipment per NFPA 99?

4. What is the limit of the ground resistance check?

5. Which configuration settings are you required to check chassis leakage current in? What is the limit?

6. When do you check hard-wired devices for leakage current?

7. What is a double-insulated device?

8. Briefly describe how you test a system of several devices powered by a single power strip for electrical safety.

9. How do you test an equipment item that has an approved extension cord?

10. Explain the purpose of a redundant ground.

11. If you have questions concerning electrical safety tests, who or what should you consult?

Answers to Self-Test Questions

217

1. Chassis ground is the metal chassis serving as a ground for the entire unit; signal ground is internal circuits that uses a ground isolated from the chassis ground.
2. (1) The readings taken are not accurate because of the improper reference point; (2) you may damage the equipment being tested by connecting the isolated circuit to chassis ground through the multimeter circuitry.
3. By turning off power to the unit under test, connecting the meter lead, reconnecting power to the unit, and then taking the reading.
4. Having only one hand on or near a device under test while the power is on.
5. With only one hand, you do not present an easy path for current to flow.
6. There is a possibility of shorting components.
7. There is damage due to the low resistance of the ammeter circuitry that allows large amounts of current to shunt around the component and through the meter.

8. (1) Turn off the circuit to be tested, (2) connect probes in series with the circuit, (3) turn the power on, (4) take the reading, (5) power off, and (6) disconnect probes.
9. Provide a conducting path with sufficient resistance, such as a resistor or light circuit, across the leads.
10. It is noninvasive and provides information on current without interrupting the circuit.
11. It produces an internal current to use for measuring.
12. The internal current that the meter produces flows through all possible paths between the probes and the resistance reading represents the total resistance of all paths.
13. To improve accuracy of measurements less than 1000 nF by subtracting the residual capacitance of the meter and leads.
14. 0.5–0.8V.

218

1. The vertical (Y) axis (represents voltage), the horizontal (X) axis (represents time), and the (Z) axis (represents intensity, or the display brightness).
2. Display, vertical, horizontal, and trigger.
3. Horizontal.
4. By using the volts/div setting.
5. Using the volts/div setting multiplied by the number of vertical divisions.
6. By limiting the bandwidth.
7. Allows you to select the rate at which the waveform is drawn across the screen.
8. Trigger controls.
9. Edge triggering.
10. It is an adjustable time after a valid trigger when the oscilloscope cannot trigger, which is useful when you are triggering on complex waveform shapes to only trigger at an eligible point.
11. Pulse.
12. Frequency is the number of times a signal repeats in one second; period is the amount of time it takes for the signal to complete one cycle.
13. Amplitude.
14. It must share the same ground as the circuit under test.
15. One with minimal loading.
16. (1) Attach the probe to a vertical channel.
    (2) Connect the probe tip to the probe compensation.
    (3) Attach the ground clip of the probe to ground.
    (4) View the square wave reference signal.
    (5) Make the proper adjustments on the probe so that the corners of the square wave are squared.
17. For a positive DC voltage, position the reference line on or near the bottom division line on the oscilloscope screen, allowing the input to drive the oscilloscope image in a positive direction upward. For a negative voltage, position the reference line on or near the top division line on the screen to allow a downward deflection.
18. DC voltage = $5.6. \times 2 \times (1) = 11.2$ volts.
19. $4.8 \times 5 = 24$ volts peak-to-peak.
20. Time duration = $(2.8 \times 2 \times 10^{-3}) = 5.6$ ms.
21. Frequency = 1/5.6 ms = 178.57 Hz.
22. The amount of time a pulse takes to go from low to high and back to low again.

219

1. To measure a component or system's positive or negative pressure (vacuum).
2. Differential pressure of two systems.
3. (1) Check the manometer's pressure range; (2) ensure you can use the manometer for the type of media you are measuring.

220

1. Any three of the following: (1) never connect the analyzer to equipment connected to a patient; (2) do not use electrical safety analyzers in wet locations or dust; (3) inspect analyzer and test leads before use; (4) use a power supply outlet that has a protective earth ground; (5) do not touch metal parts of the device you are testing.
2. NFPA 99.
3. Before putting equipment into service the first time and after any repair or modification that may have compromised its electrical safety.
4. 0.5 ohms.
5. Normal polarity, open ground mode, and device under test both on and off; limit is 500µA.
6. Prior to connection of the ground wire during the installation.
7. Items that have no exposed conductive surfaces, usually constructed of plastic.
8. They are checked for leakage and ground continuity with the power strip attached (the power strip will be connected to the analyzer's receptacle, and each device will then be connected to the strip's receptacles for testing). Also check each device capable of stand-alone operation individually.
9. With the cord in the circuit.
10. It is an additional, external ground wire permanently fastened between the chassis of the equipment to the screw of the outlet cover plate normally.
11. Contact AFMOA; reference AFI 41–201, *Managing Clinical Engineering Programs*, and NFPA 99.

Complete the unit review exercises.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter. When you have completed all unit review exercises, transfer your answers to the Field-Scoring Answer Sheet.

Do not return your answer sheet to the AFCDA.

63. (217) This characteristic of a multimeter that is set to measure current makes it susceptible to damage.
    a. Only one lead is used to take current measurements.
    b. It is connected in parallel to the circuit under test.
    c. The ammeter setting has very low resistance.
    d. It induces a voltage to the circuit under test.

64. (217) When using a multimeter to measure resistance, always
    a. connect in parallel to component.
    b. de-energize the circuit under test.
    c. connect in series to component.
    d. energize the circuit under test.

65. (218) Which *wave* type would you *most* likely use to test an amplifier circuit?
    a. Sine.
    b. Square.
    c. Triangle.
    d. Sawtooth.

66. (218) If you are using an oscilloscope probe with a 10X attenuation factor, you can expect signals less than this peak-to-peak voltage level to be difficult to see.
    a. 100 millivolts (mV).
    b. 50 mV.
    c. 20 mV.
    d. 10 mV.

67. (218) You are taking a direct current (DC) voltage measurement with an oscilloscope and a 1X probe. The volts (V)/division setting is set at 5 and your signal moves *upward* 3 vertical divisions. What is the signal voltage?
    a. 150 V.
    b. 100 V.
    c. 15 V.
    d. 5 V.

68. (218) You are taking a direct current (DC) voltage measurement with an oscilloscope and a 1X probe. The volts (V)/division setting is set at 2 and your signal moves *downward* 4.2 vertical divisions; therefore, the signal voltage is
    a. –8.4 V.
    b. +8.4 V.
    c. –84 V.
    d. +84 V.

69. (218) You need to determine the duration of a waveform with an oscilloscope and a 1X probe. The seconds/division setting is set at 2 milliseconds (ms) and the waveform covers 4 division lines. What is the waveform duration?
    a. 4 ms.
    b. 8 ms.
    c. 16 ms.
    d. 24 ms.

70. (218) The waveform frequency with a time duration of 15 milliseconds (ms) is
    a. 6.67 hertz (Hz).
    b. 66.67 Hz.
    c. 666.67 Hz.
    d. 6666.67 Hz.

71. (218) To *eliminate* any irregularities at the pulse transition corners, you measure the pulse's rise time when it is at this percentage of full voltage.
    a. 10 to 90.
    b. 25 to 75.
    c. 50.
    d. 90.

72. (219) Which type of tubing should you use with the manometer to read vacuum pressure measurements?
    a. Rigid tubing.
    b. Hospital grade tubing.
    c. Nylon tubing.
    d. No leak tubing.

73. (220) You *must* ensure that the safety analyzers in your shop are calibrated at *least* every
    a. 6 months.
    b. 12 months.
    c. 24 months.
    d. 36 months.

74. (220) When conducting electrical safety inspections, different values are recorded at several locations around the equipment chassis during a ground resistance test. Now, this is the correct action to take.
    a. Use the average of all readings.
    b. Use the reading from the point of least resistance.
    c. Use the reading from the point of greatest resistance.
    d. Use the difference of the greatest and least resistance.

75. (220) When *must* you perform electrical safety tests on battery-powered equipment?
    a. If it is capable of operating while connected to the charger.
    b. If no conductive surfaces exist.
    c. Only during installation.
    d. Never.

Glossary of Abbreviations and Acronyms

°	degrees
µA	microampere
AAMI	Association for the Advancement of Medical Instrumentation
AC	alternating current
ACS	American Chemical Society
ADC	analog-to-digital converter
AED	Automated External Defibrillator
AFI	Air Force instruction
AFMOA	Air Force Medical Operations Agency
AFOSH	Air Force Occupational Safety and Health
AFRC	Air Force Reserve Command
AGR	Active Guard and Reserve
AIDS	Acquired Immune Deficiency Syndrome
ANG	Air National Guard
ANSI	American National Standards Institute
ASIMS	Aeromedical Services Information Management System
ASTM	American Society for Testing and Materials
BE	Bioenvironmental Engineering
BMET	biomedical equipment technician
CE	civil engineering
CFR	Code of Federal Regulations
CGA	Compressed Gas Association
CLSI	Clinical and Laboratory Standards Institute
COM	communication (terminal)
CPAP	continuous positive airway pressure
CRT	cathode ray tube
DC	direct current
DISS	Diameter Index Safety System
DLA	Defense Logistics Agency
DMLSS	Defense Medical Logistics Standard Support
DOD	Department of Defense
DOT	Department of Transportation
DRMO	Defense Reutilization and Marketing Office
DSCP	Defense Supply Center, Philadelphia

EDF	equipment data file
EOC	Environment of Care
F	Fahrenheit
FDA	Food and Drug Administration
FDAMA	Food and Drug Administration Modernization Act
GND	ground
HAZCOM	hazardous communication
HIPAA	Health Insurance Portability and Accountability
HMR	Historical Maintenance Record
HVAC	heating, ventilation, and air conditioning
Hz	hertz
IC	integrated circuits
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IMR	Individual Medical Readiness
Li-Ion	lithium ion
LOTO	lockout/tagout
mA	milliampere
MAJCOM	major command
MDR	Medical Device Reporting
MEMO	Medical Equipment Management Office
MERC	Medical Equipment Repair Center
MHz	megahertz
MLFC	Medical Logistics Flight Commander
MMQC	Medical Materiel Quality Control
ms	millisecond
MTF	military treatment facility
mV	millivolts
NCOIC	noncommissioned officer in charge
NCRP	National Council on Radiation Protection
NEMA	National Electrical Manufacturers Association
nF	nano farad
NFPA	National Fire Protection Association
NiCad	nickel cadmium
Ni-MH	nickel-metal hydride
OEHWG	Occupational & Environmental Health Working Group

OEM	original equipment manufacturer
OIC	officer in charge
OSHA	Occupational Safety and Health Administration
pH	potential of hydrogen
PH	public health
PISS	Pin Index Safety System
PMEL	Precision Measurement Equipment Laboratory
PPE	personal protective equipment
PVC	polyvinylchloride
QA	quality assurance
REL	relative
RF	radio frequency
RM	risk management
RMS	root mean square
rpm	revolutions per minute
SCR	silicon controlled rectifiers
SDS	safety data sheet
SF	standard form
SMDA	Safe Medical Device Act of 1990
TB	Tuberculosis
TLD	thermoluminescent dosimeter
UL	Underwriter’s Laboratories
V	volt
USAMMA	US Army Medical Materiel Agency
WAG	waste anesthetic gas
WRM	war reserve materiel

Student Notes

Student Notes

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