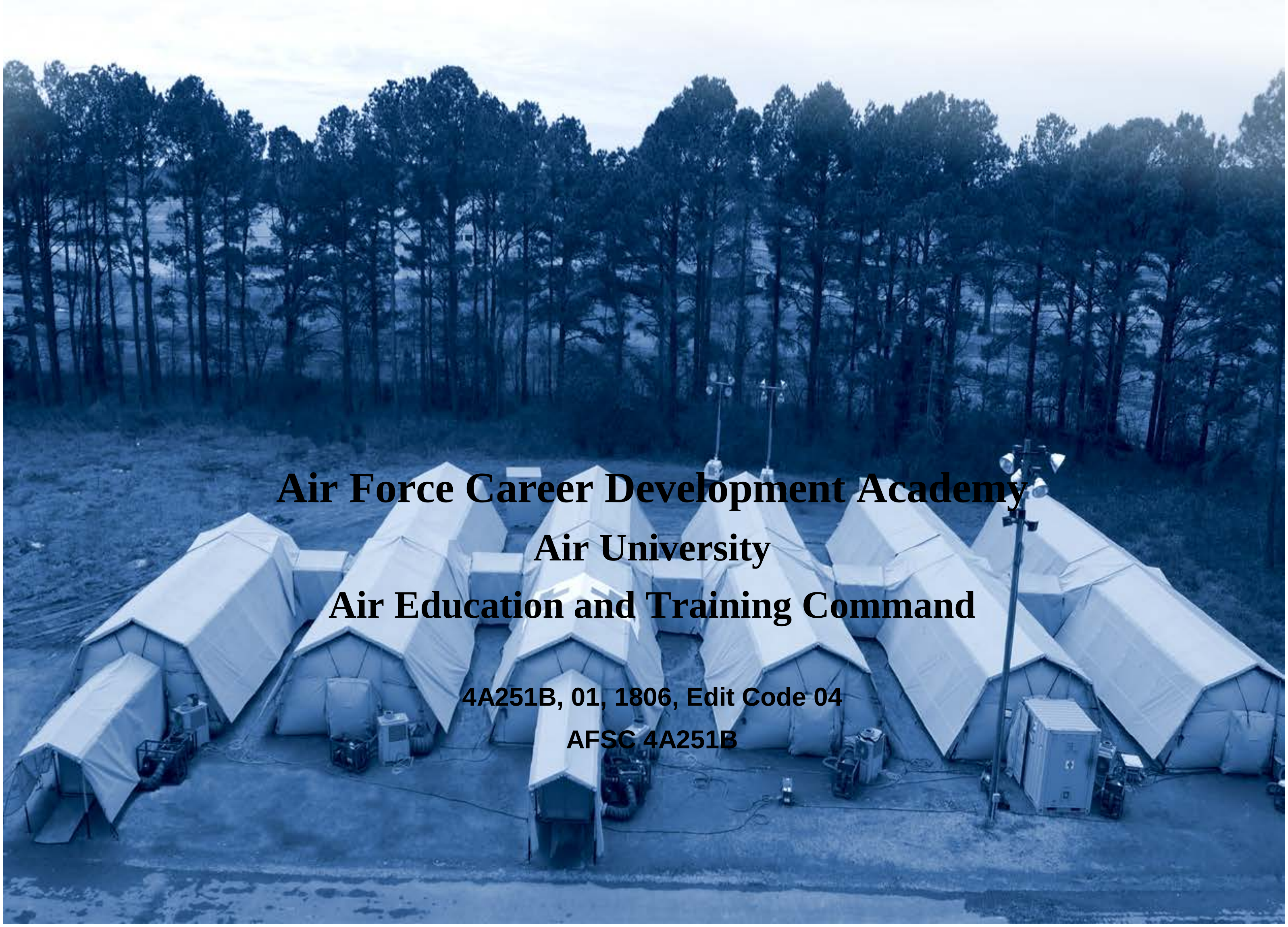
CDC 4A251B

Biomedical Equipment Journeyman

Volume 1. Facility and Equipment Interface and Medical Readiness



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Author: MSgt Matthew J. Colica, CBET, Sec+
MSgt Jason E. Johnson, CBET, Sec+
382nd Training Squadron
59th Training Group (AETC)
382 TRS/TRR
3068 William Hardee Rd, MIF 1-Bldg 899
JBSA Ft Sam Houston, TX 78234
DSN: 420–1775
E-mail address: matthew. j.colica.mil@mail.mil
Jason.e.johnson1.mil@mail.mil

Instructional Systems Specialist: Dr. Kenith Isreal

Editor: Chad Williams

Air Force Career Development Academy (AFCDA)
Air University (AETC)
Maxwell AFB, Gunter Annex, Alabama 36114–3107

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THIS FIRST VOLUME of CDC 4A251B, Biomedical Equipment Journeyman, provides the foundational instruction you need to comprehend facility infrastructure and your role in deployment operations.

Unit 1 provides the foundation of power production principles including transformers, conductors, and protective devices. It also breaks down facility management concepts and familiarizes you with building utility systems and how they apply to your daily duties.

Unit 2 explores your roles beyond in-garrison operations. This unit transitions the power generation and distribution concepts from Unit 1 to expeditionary capabilities. Here you will also learn shelter and environmental systems used in the field as well as various oxygen capabilities.

A glossary is included for your use.

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This volume is valued at 12 hours and 4 points.

Acknowledgment

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Company	Literature	CDC Figure Number
Genesis J.I.T.	Expeditionary Medical Support 800 AMP Power Distribution Unit Manual Number: 614–9999–0003	2–6 and 2–7
UTS Systems	Shelter Distribution Box (SDB) Technical Manual 610–9999–0001 Rev.: IR	2–9
	Expeditionary Medical Support (EMEDS) “Single Skin” Operators Manual, Model TM60 Tall, 2014	2–14 and 2–15
Pacific Consolidated Industries	Expeditionary Deployable Oxygen Concentration System 120B Service Manual P/N 793720–001	2–20
	Hospital Oxygen Backup System Manual 350061F 2008	2–24
	Mobile Oxygen Storage Tank Technical Manual 350003K, 2009	2–25
	Patient Oxygen Distribution System & Surgical Suite Oxygen Distribution System Manual 350112 Rev. B 2013	2–26
Carleton Life Support Systems Inc. (CLSS)	DOGS-M Commercial-off-the-shelf Manual P/N OMMC–045-000P-00, 2013	2–21
	DOGS-M Training Presentation 2009	2–22 through 2–23
Essex Industries	Oxygen Generator Liquefier (OGL) Service Manual Part No. 50C–0103–5	2–27
	NPTLOX Manual TO 15X2–5–22 Feb 13	2–28

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.

Page

Unit 1. Utility Systems and Facility Management

YOUR JOB CONSISTS OF MORE THAN just maintaining the existing medical equipment within your facility. Biomedical Equipment Technicians (BMET) are vital to the equipment procurement process and your knowledge as a subject matter expert (SME) plays a major role in that process. Part of evaluating new equipment requirements is determining if your facility can currently support the specifications, and what modifications you need to accommodate the new equipment. This service is invaluable to every department within your medical facility. Preplanning prior to equipment purchase eliminates equipment sitting for months awaiting installation due to a utility not being available. Important utilities needed for equipment can include things such as electrical power, plumbing (water, steam, etc.) supply and drainage, medical gases, and ventilation requirements. Almost every piece of equipment requires some form of power, and you are the link that ensures the right power is there.

1–1. Power Production System and Components

Your electrical power distribution system is comprised of many components (e.g., the power source, distribution transformer, distribution panels, and conductors). Usually, your facility power comes from a commercial power plant. Sometimes, overseas locations have a generator dedicated to the facility to ensure that the voltage and frequency provided meets the specifications required for the equipment inside. If you have ever plugged a 110-volt piece of equipment into a 220-volt wall supply, you quickly learned the need for ensuring proper power. More often than not, commercial power is your primary mode of power and a generator is your backup mode. This power comes down from a pole or through a ground conduit to your building's service entrance. This service entrance usually has a bank of transformers, known as distribution transformers, which provide the needed power at the proper voltages throughout the hospital.

In this unit, we discuss transformers and their various configurations. Then, we cover emergency power and how the essential electrical system fits into the plan. Finally, we cover the rules involved in conductor (wiring) connection and selection for use within the facility. Remember, all of these components comprise a power distribution system, and you need to be able to speak confidently and knowledgeably about them. Now, let's get started by discussing one of the components that we have control over—the transformer.

001. Description and classification of transformers

You learned about various types of transformers in Career Development Course 4A251A, so we will now go into their applications within a medical facility. Transformers require little care and maintenance because of their simple, durable construction. Their high efficiency is responsible for the extensive use of alternating current (AC). Each type of transformer has its advantages and disadvantages, but we want to discuss the transformers that supply power to your building (fig. 1–1). Far more essential to you is the makeup of the transformers used in power plants. I'm sure you have seen the transformers we are going to talk about. They are usually located on a pad outside, mounted on a pole near a building, stored in a hospital basement, or found in rooms throughout your hospital dedicated to the power plant.

General construction features of a transformer

The typical single-phase transformer has two windings electrically insulated from each other. These windings wrap a common magnetic circuit made of laminated sheet steel. The following table describes the principal parts of a transformer:

Part	Description
Core	Provides a circuit of low reluctance for the magnetic flux.
Primary winding	Receives the energy from the AC source.
Secondary winding	Receives the energy by mutual induction from the primary winding and delivers it to the load.
Enclosure	Protects the transformer from physical damage and helps to channel the flow of cooling air past the transformer unit.

When a transformer steps up the voltage, the low-voltage winding is the primary. When a transformer steps down the voltage, the high-voltage winding is the primary (see figure 1-1 for a transformer wiring breakdown). The primary always connects to the source of power, and the secondary always connects to the load. It is common practice to refer to the windings as the primary and secondary, rather than the high-voltage and low-voltage windings.

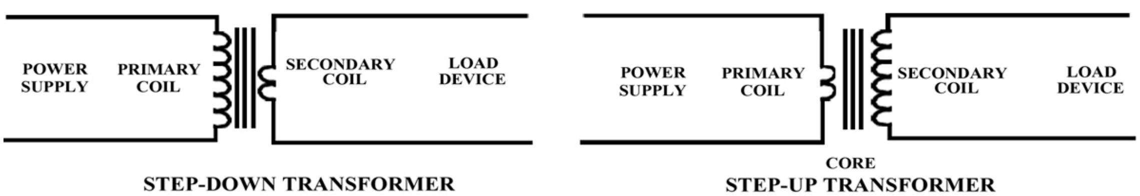


Figure 1–1. Types of transformers.

Because the primary and secondary coils are not very efficient by themselves, you must have some part that positions the coils in place and provides a path for magnetic flux lines. A transformer has a laminated silicon steel core to provide the path for magnetic lines of flux and positioning of the coils. Iron is usually the metal of choice. Iron has little resistance to magnetic lines and allows nearly all of the magnetic field of the primary to flow through the iron core and cut the secondary. The iron core increases the efficiency of the transformer to 98 or 99 percent.

The complete core and coil assembly sit in a steel tank. In larger transformers, the complete assembly is usually immersed in a special mineral oil to insulate and cool the unit. Other installations consist of single-phase, air-cooled transformers mounted in drip-proof enclosures.

Transformers categorize as single-phase and three-phase units. While a single phase transformer has one winding, a three-phase transformer consists of a separate insulated winding for each of the different phases wound on a three-legged core capable of establishing three magnetic fluxes displaced 120° in time phase. In some installations where continuity of service is a necessity, three separate, single-phase, delta-connected transformers are installed to supply low-voltage service. Then, if one transformer is damaged or goes out of service, it can be removed and the remaining two transformers operate in open delta to supply the three-phase service—but at a reduction in the original load capacity of the transformer bank.

Classifications of transformers

A transformer is classified according to service, purpose, and method of mounting and cooling. Power, distribution, and instrument are the main service-type transformers you will see in your facility. The purpose of a transformer determines its use in a circuit.

The following table describes the different transformers:

Transformer	Description
Constant-potential	A constant-potential transformer changes the voltage level of a system. Its primary connects across a steady voltage supply and provides a steady secondary voltage that is the same from no load to full load. Power and distribution transformers are this type. The current in the primary and secondary changes when the load changes.
Varying-potential	A varying-potential transformer varies the secondary voltage when connected to a constant primary voltage. Voltage regulators or ballasts for mercury-vapor lamps use this type of transformer.
Current	This type of transformer changes the current of a system. Its primary winding connects in series with the circuit desiring the current change. The voltage on the primary and secondary changes with a change in current in the system. This is common in instrument transformers.
Constant-current	A constant-current transformer supplies a constant secondary current to a system no matter what the load is. The primary connects to a constant voltage, but the secondary voltage varies according to the load. Series street lighting and airfield lighting systems use this type of transformer. Another common name for this unit is a constant-current regulator.

Transformers rate according to their voltage capacity and current-carrying capability. The insulation value of the coils, bushings, and oil determine the voltage a transformer is able to carry. The size of the wire in the coils and the size of the terminal connections determine the current or amperage a transformer can carry. The voltage and current combine into a volt-ampere (VA) rating. Because the VA rating is usually over 1,000, the transformers generally rate in kilovolt-ampere (kVA).

002. Types of transformer connections

Transformer connections vary according to the type of transformer and type of system in which they are connected. Different connections vary based on the specific load demands of a particular circumstance. The types of transformer connections we describe are single-phase, three-phase, and isolation.

Single-phase transformers

Single-phase transformer connections vary according to the demand. They connect differently for lighting loads only, or for combination lighting and power loads. If the demand is for a small lighting load only, the secondary windings (the low-voltage windings) connect in parallel, as the schematic diagram in figure 1–2 shows. The result is 120 volts for lights. As you know, if a transformer draws a greater load than it is rated to handle, the transformer burns out. To be certain of having the correct transformer for the demand, use the following formula to convert the apparent power from the transformer providing 120 volts for lights into kVA:

$$\mathrm{kVA} = \mathrm{L} = \frac{\mathrm{I} \times 120}{1000}.$$

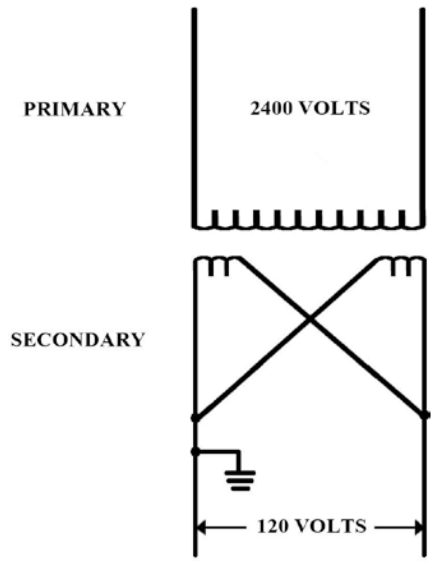


Figure 1–2. Transformer connection for lights.

The "L" represents the kVA load, "I" represents the current in amperes, and 120 is the amount of voltage. Current multiplied by voltage gives VA. Since transformers rate in kVA, we need to express the load in kVA. Remember, the prefix "kilo" means thousand; by this method, divide the VA by 1,000 to express the load in kVA. For example, with a single-phase transformer connected so it produces 120 volts for lighting, let's assume the current available is 100 amperes. Using the formula we just gave you to determine the kVA, the equation looks like this:

$$\text{kVA} = \text{L} = \frac{100 \times 120}{1000} = 12\ \text{kVA}.$$

As we mentioned previously, the transformer rating should equal the kVA of the demand. The load determines the size of the transformer required, but the power factor of the load determines the amount of usable power. The kVA placed into the system is greater than the kilowatt (kW) that can be taken out of the system. Ammeters and voltmeters indicate total current and voltage regardless of the power factor, while the wattmeter indicates the effective product of the instantaneous values of voltage and current. A wattmeter indicates the true power.

The schematic diagram in figure 1–3 shows the single-phase connection for light and power. A three-wire system makes it possible to serve 120-volt lighting and 240-volt power loads simultaneously. The transformer, as you remember, has two secondary windings; in this case, they connect in series. To determine the load for coil No 1 use:

$$\text{L}_1 = \frac{\text{I}_1 \times 120}{1000}.$$

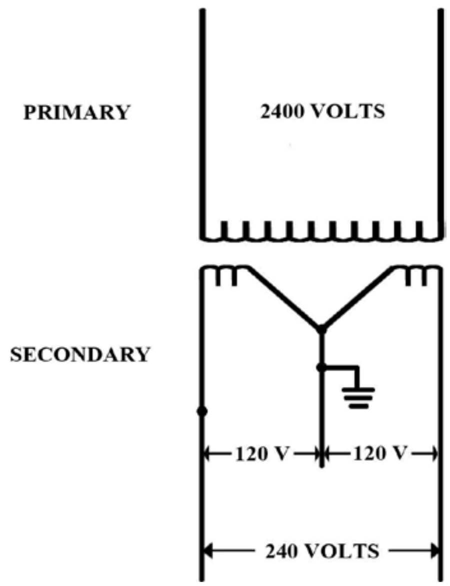


Figure 1–3. Transformer connection for lights and power.

The same is true of the other secondary coil, except the subscript (L_2) is changed to show it is the other secondary coil. The load for coil No. 2 is:

$$L_2 = \frac{I_2 \times 120}{1000}.$$

Since the two secondary windings connect in series, the total load formula reads:

$$L_T = L_1 + L_2.$$

When the two secondary windings connect in series, their voltages add together; when the secondary windings connect in parallel, their currents add together. For example, if the rating of each secondary winding is 120 volts and 100 amperes, the series-connection output rating is 240 volts at 100 amperes, or 24 kVA. The parallel-connection output rating is 120 volts at 200 amperes, or 24 kVA.

To find the kVA rating for a three-phase bank of transformers (which we will cover in the next topic), use this formula:

$$kVA = \frac{E \times 1.732}{1000}.$$

Three-phase transformers

There are many reasons why three-phase power is used. Heavy-duty motors operate more efficiently from a three-phase circuit. To obtain greater power, hook up three single-phase transformer coils for three-phase voltage. To supply three-phase service, you must have a three-phase distribution system.

The Air Force uses three basic types of distribution systems—a delta, an ungrounded wye, and a grounded wye. The type of system obtained depends on the connection of the three windings of the generator and secondary winding connections of the substation transformers.

Delta

To obtain a delta system, the windings of the generator and the secondary connections of the substation transformers must connect in series. Only one voltage exists in a delta system. Figure 1–4 shows the delta system is a three-phase, three-wire configuration. Since there is no neutral in a delta system, there is no potential from any energized phase to neutral or ground as long as the delta system remains pure (no grounds). The letters A, B, and C designate the energized phases. This phase designation applies to all systems. You can obtain system voltage between any two of the three phases: A and B, B and C, or C and A. This phase-to-phase voltage is line voltage.

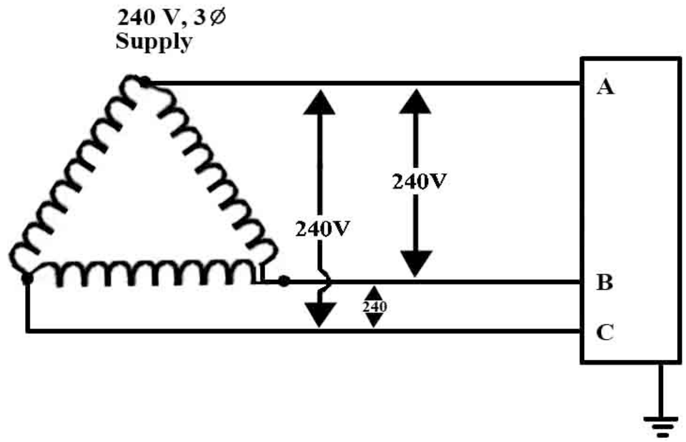


Figure 1–4. Three-phase delta transformer.

Ungrounded wye

The ungrounded wye system (fig. 1–5) is a star system (Y) with a neutral point, which is similar to the delta system in that it is a three-phase, three-wire system. The main difference in the two systems is the ungrounded wye system has two-system voltage potentials (phase and line) due to the nature of the connection. If you take a reading between ground and any of the three phases—A, B, or C—the voltage of that phase is measured. This voltage is phase voltage, which is possible because the common point (neutral) of the windings at the substation connects to the ground using the Earth to complete the path for return. If you take a voltage reading between any two of the three phases—A to B, B to C, or C to A—then it indicates a different value. This is line voltage and is 1.73 times the phase voltage. Why won't this voltage be twice the phase voltage since you are measuring the voltage in two phases? The reason is in the nature of the way a generator creates the voltage. Remember, no two phases can be at maximum at the same time, because their peaks are 120° apart. This difference in peak voltage results in the constant 1.73 number. The situation results in the two voltage potentials: line and phase.

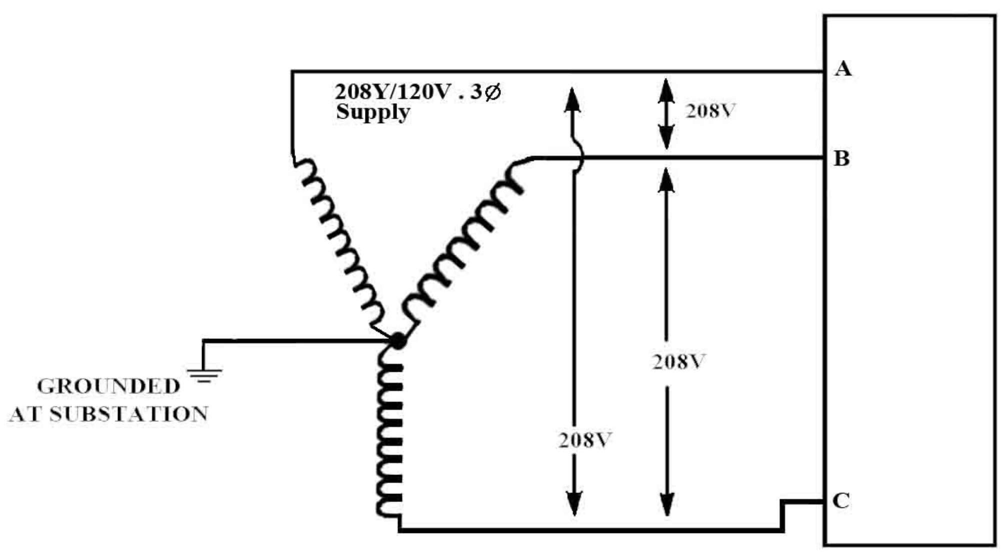


Figure 1–5. Three-phase ungrounded wye transformer.

Grounded wye

The last of the three systems is the grounded wye, which is a star system (Y) with a common return or neutral wire system (fig. 1–6). This is a three-phase, four-wire system, and it is the preferred system of the Air Force. Phase voltage is possible because the common point (neutral) of the windings at the substation connects to ground, using the Earth to complete the path for the return.

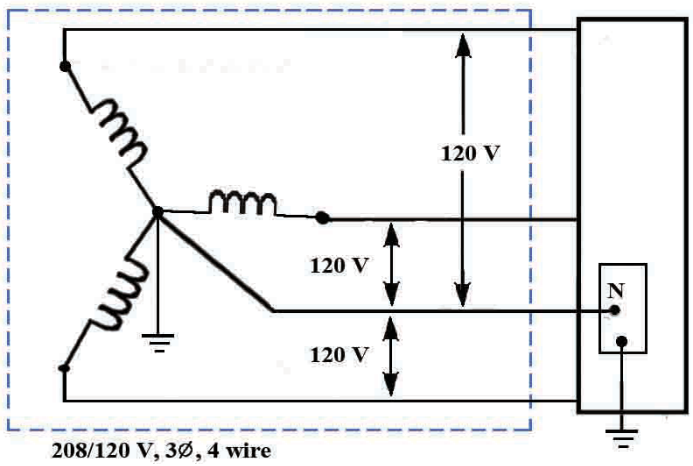


Figure 1–6. Three-phase grounded wye transformer.

The wye system has two voltage potentials like the ungrounded wye system. You obtain phase-to-phase (line) voltage between any two of the three energized phases. You can also obtain phase-to-neutral (phase) voltage from any one of the three energized phases and neutral. The neutral conductor is the fourth wire of this system, designated with the letter "N." The neutral connects to the ground at predetermined locations throughout the distribution system to ensure the neutral remains a deenergized conductor. Earth also serves as an alternate path back to the source if the neutral conductor happens to break its path. The neutral is not an energized conductor, but always treat it as such since certain accidental conditions have the potential to energize the neutral.

Isolation transformers

There is one other transformer we need to discuss—the isolation transformer. The intended design of an isolated power system is to eliminate spark hazards where you would use flammable anesthetics, but this type of electrical system also provides added protection from electrical shock. In an isolated power system, an isolation transformer gets electrical current from the usual ground-referenced power source for the hospital and convinces the electrons that it, not the generator, is the power source. Electron flow then returns to the isolation transformer. Since the isolated power system does not use ground as a path back to the isolation transformer, the current is no longer seeking ground as in the ground-referenced system. Instead, a wire in the electrical system provides the electrons with a pathway back to the transformer. Figure 1–7 shows a typical isolated system.

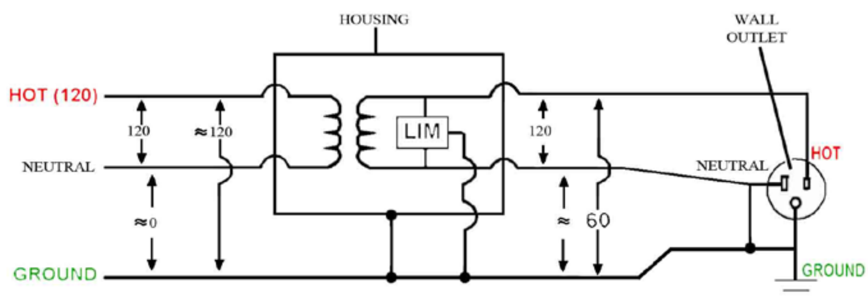


Figure 1–7. Isolation transformer configuration.

Advantages

Isolated systems offer some important advantages over ground-referenced power. Any equipment faults that allow electrons to accumulate on the case of a device are less of a shock hazard. This is because most of these electrons do not seek paths to ground. In the wet environment of the operating room (OR), this is very important. Another advantage of isolated power is, in some cases, malfunctioning equipment may continue to operate rather than cease functioning as would normally happen in a ground-referenced power system. If the malfunctioning unit is critical for life-support, this is a valuable characteristic of isolated power.

Limitations

Unfortunately, the isolation transformer is not perfect in convincing electrons it is their source. A small percentage of the electrons circulating in the system remain ground seeking. As long as the total number of ground-referenced electrons is small, the isolation system effectively functions as a further safeguard. As more of these transformers used in the system to supply electrical devices increases, the number of ground-referenced electrons also increases. This may cause a gradual loss in the effectiveness of the isolation. Even though there may be sufficient ground-referenced electrons in the isolation system to pose a microshock threat, another fault or unsafe action must take place before any shock hazard is actually present.

Line isolation monitors

Isolated power systems must include a line isolation monitor (LIM), which are typically located in the OR. This is a test instrument designed for continually checking the balanced and unbalanced impedance from each line of an isolated circuit to ground, and is equipped with a built-in test circuit to exercise the alarm without adding to the leakage current hazard. This unit ensures the integrity of the isolation transformer. The sole purpose of the LIM is to count the number of ground-referenced electrons present in the system at any given moment. As long as the total number of ground-seeking electrons remains small, the LIM indicates a green “safe” light and remains silent. If the LIM counts a total that exceeds an established limit, the LIM warns you by sounding an alarm and turning on its red “hazard” light. Remember, the alarm is only informing you the LIM has counted a number of ground-seeking electrons that exceeds the established limit. In other words, the isolation system degraded to some extent that it is only being partially ground-referenced. The alarm does not mean a shock is occurring.

Two general situations usually lead to a LIM alarm:

- Accumulated leakage current from the use of many properly functioning electrical devices.
- Equipment faults or failure that may cause isolated electrons to revert into ground-seeking electrons.

LIMs require periodic maintenance and testing by either the hospital’s facility management (FM)/maintenance team or the local BMET. National Fire Protection Association (NFPA) 99, *Health Care Facilities Code*, requires testing of LIMs at intervals not to exceed 1 month by actuating the LIM test switch. If the LIM is equipped with automated self-test and self-calibration capabilities, then it is to be tested at intervals of not more than 12 months. In addition, be sure to test the LIM after any repair or renovation to an electrical distribution system.

003. Description of the essential electrical system

Emergency power systems provide a hospital or clinic with enough power to support essential functions during a commercial or main power failure. These systems are necessary to prevent hazards associated with power failures. Power loss to life-support equipment or patient care areas during delicate procedures could prove disastrous. NFPA 70, the *National Electrical Code (NEC),* Art. 517, provides the requirements for essential electrical systems. A common acronym for the code is NEC.

The essential electrical system consists of three separate branches capable of supplying a limited amount of lighting and power service considered essential for life safety and effective hospital operation. This system activates during interruption of the normal electrical service. These three branches are the:

- Life safety branch.
- Critical branch.
- Equipment branch.

Figure 1–8 is an example of a typical essential electrical distribution system. It includes the normal source of power (usually a transformer fed from a power station) and a service entrance feeding overprotected circuits that supply power to the life safety branch, critical branch, and equipment system.

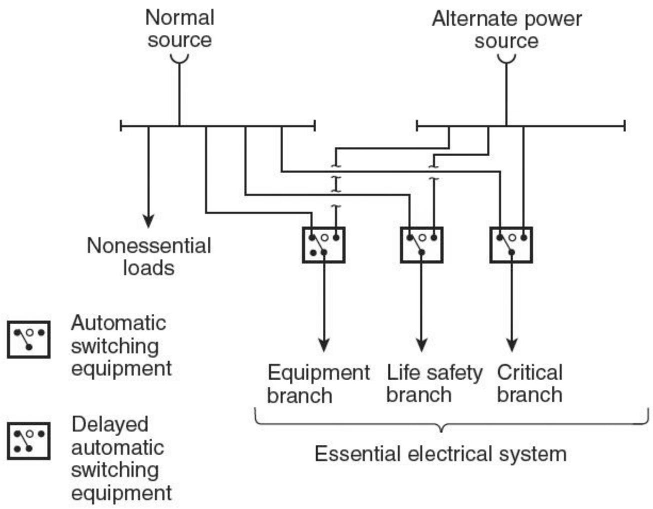


Figure 1–8. Large hospital essential electrical system (minimum requirement greater than 150 kVA).

Life safety branch

The life safety branch supplies power for the following lighting, receptacles, and equipment:

- Illumination of means of egress and exits (e.g., lighting required for corridors, passageways, stairways, landings at exit doors, and all necessary approaches to exits).
- Exit signs and exit directional signs.
- Hospital communication systems when used for issuing instructions during emergency condition.
- Generator set task illumination areas, select receptacles at the generator set location and essential electrical system transfer switch locations, battery charger for emergency battery-powered lighting unit(s).
- Elevator cab lighting and control, communication, and signal systems.
- Electrically powered doors used for building egress.
- Fire alarms and auxiliary functions of fire alarm combination (e.g., fire alarms and alarms used for piped medical gas systems).

Figure 1–8 shows the life safety branch requires automatic switching equipment. Therefore, if power is lost from the normal source, your switching panel automatically senses it and transfers the load to the alternate source—in your case, a generator. The life safety and critical branches automatically restore to operation within 10 seconds.

Critical branch

NFPA 99 permits subdividing the critical branch into two or more branches if necessary. The critical branch supplies power for task illumination, fixed equipment, selected receptacles, and special power circuits serving the following areas and functions related to patient care:

- Critical care spaces that utilize anesthetizing gases, task illumination, selected receptacles, and fixed equipment.
- Isolated power systems in special environments.
- Task illumination and select receptacles in the following: patient care spaces, including infant nurseries, selected acute nursing areas, psychiatric bed areas (omit receptacles), and ward treatment rooms; medication preparation spaces; pharmacy dispensing spaces; nurses' stations (unless adequately lighted by corridor luminaires).
- Additional specialized patient care task illumination and receptacles where needed.
- Nurse call systems.
- Blood, bone, and tissue banks.
- Telephone equipment rooms and closets.
- Task illumination, selected receptacles, and selected power circuits in the following areas: general care beds with at least one duplex receptacle per patient bedroom, and task illumination as required by the governing body of the health care facility; angiographic and cardiac catheterization labs; coronary care units; hemodialysis rooms or areas; emergency room treatment areas (selected); human physiology labs; intensive care units; and post-operative recovery rooms (selected).
- Additional task illumination, receptacles, and select power circuits needed for effective facility operation, including single-phase fractional horsepower motors, permitted to be connected to the critical branch.

The intention of the critical branch is to serve a limited number of receptacles and locations to reduce the load and minimize the chances of a fault condition. The critical branch requires an automatic switching device when normal power is lost so alternate power immediately becomes available. You can place receptacles for corridors in general patient care areas on the critical branch circuit, as long as you identified them as such.

Equipment branch

The equipment branch is installed and connected to the alternate power source so it can be either automatically or manually restored to operation after a time lag period following the energizing of the life safety and critical branches.

The following equipment automatically activates with the equipment branch:

- Central suction systems serving medical and surgical functions, including controls, with such suction systems permitted to be placed on the critical branch.
- Sump pumps and other equipment required to operate for the safety of major apparatus, including associated control systems and alarms.
- Compressed air systems serving medical and surgical functions, including controls, with such air systems permitted to be placed on the critical branch.
- Smoke control and stair pressurization systems.
- Kitchen hood supply or exhaust systems, or both, if required to operate during a fire in or under the hood.
- Supply, return, and exhaust ventilating systems for the following: airborne infectious/isolation rooms; protective environment rooms; exhaust fans for laboratory fume

hoods; nuclear medicine areas where radioactive material is used; ethylene oxide evacuation; anesthetic evacuation.

- Supply, return, and exhaust ventilating systems for operating and delivery rooms.
- Supply, return, exhaust ventilating systems, and/or air conditioning systems serving telephone equipment rooms and closets and data equipment rooms and closets.

The following equipment is set up for automatic or manual activation (as selected) with the equipment branch:

- Heating equipment used to provide heating for operating, delivery, labor, recovery, intensive care, coronary care, nurseries, infection/isolation rooms, emergency treatment spaces, and general patient rooms; and pressure maintenance pump(s) for water-based fire protection systems.
- Heating of general patient rooms during disruption of the normal source shall not be required under any of the following conditions: (a) Outside design temperature is higher than –6.7°C (+20°F); (b) Outside design temperature is lower than –6.7°C (+20°F), where a selected room(s) is provided for the needs of all confined patients [then only such room(s) need be heated].
- Elevator(s) selected to provide service to patient, surgical, obstetrical, and ground floors during interruption of normal power.
- Hyperbaric facilities.
- Hypobaric facilities.
- Autoclaving equipment arranged for either automatic or manual connection to the alternate source.
- Controls for equipment connected to the critical equipment branch.
- Other selected equipment

The reason this type of equipment is on a time delay is so the generator can start, warm up, and then have a large load placed on it. Air conditioning and heating systems are famous for the large amperage loads they place on a generator. If the generator is not ready to receive this heavy load, it can bog down and drop the entire load off line. This would cause the critical branch and life safety branch to also lose power. You can also place heating equipment on line using a manual switch over. This is sometimes preferable so you can control when that large load hits the generator, depending on what your requirements are at the time.

If you have an emergency generator, you are required to provide on-site fuel storage, a preventive maintenance (PM) program, and a generator exercise schedule. Your facilities requirements for on-site fuel storage depend upon experiences; considering the duration and frequency of outages, weather, and geographical location. NFPA 70 and NFPA 101, the *Life Safety Code*; require that you have at least 2 hour's worth of full-demand onsite fuel supply. The hospital's facility maintenance contract or the power production section at base civil engineering (BCE) provides generator PM, but it is the facility manager's responsibility to ensure completion and documentation of the maintenance.

Finally, there is the generator exercise program. We are not talking about cross fit for the generator. We are talking about running (operating) the generator under load for no less than 30 minutes at least once per month. If you don't run the generator under a full load, you won't know whether it will operate in an emergency condition. The facility manager is responsible for overseeing the completion of generator maintenance and reporting the information to the environment of care committee (EOCC) (covered later in this unit).

In outpatient clinics and other noncritical areas, you can use battery-powered systems to power emergency electrical needs. Batteries are required to provide power to essential lighting, alarms, and any equipment necessary for patient care. The batteries shall maintain the total lamp load associated with the unit for not less than 1 1/2 hours without the voltage falling below 87.5 percent of normal voltage or 60 percent of the initial emergency illumination. You have seen this type of emergency lighting mounted in the hallways and various rooms throughout your facility. They plug into a wall receptacle and, when power is lost, automatically turn on providing light for the hallways, rooms, and exits.

As you can see, nonessential equipment and loads do not warrant consideration in the grand scheme of things. Therefore, it is extremely important that when doing a preprocurement survey, you place the equipment you purchase on the proper branch of the essential electrical system.

Similar rules apply for smaller hospitals, but on a smaller scale. Figure 1–9 shows a small hospital configuration providing the appropriate power—supplied by the normal power source or alternate power source—to all branches. One thing to note is that in the small hospital configuration (minimum requirement 150 kVA or less) all three branches share one transfer switch. This means that the equipment branch is no longer set up on a delayed automatic switch (as it is in figure 1–8), and will resume operations within 10 seconds with the life safety and critical branches.

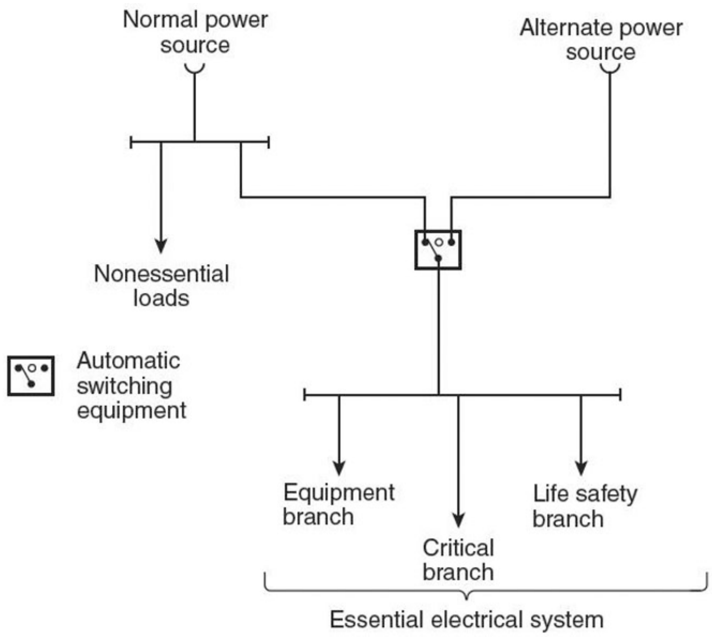


Figure 1–9. Small hospital essential electrical system (minimum requirement 150 kVA or less).

004. Characteristics of conductors

This lesson is about conductors—the wiring system, materials, assemblies, and construction methods used to deliver power to outlets, lights, and machines. The knowledge gained here will help you install new systems and repair existing systems properly and efficiently.

Installation of branch and feeder circuits

Electrical circuits installed in a building are branch or feeder circuits. Branch circuits run between the final overcurrent devices and the outlets for connecting electrically operated equipment. You can describe feeder circuits as those that deliver power to the final overcurrent devices. Think of the B-box, or branch box, that you learned about in the tech school field course. The B-box distributes power to the tent outlets forming a branch circuit. Now the B-box is “fed” from the generator and power distribution panel (PDP) forming a feeder circuit. Figure 1–10 shows typical feeder and branch circuits.

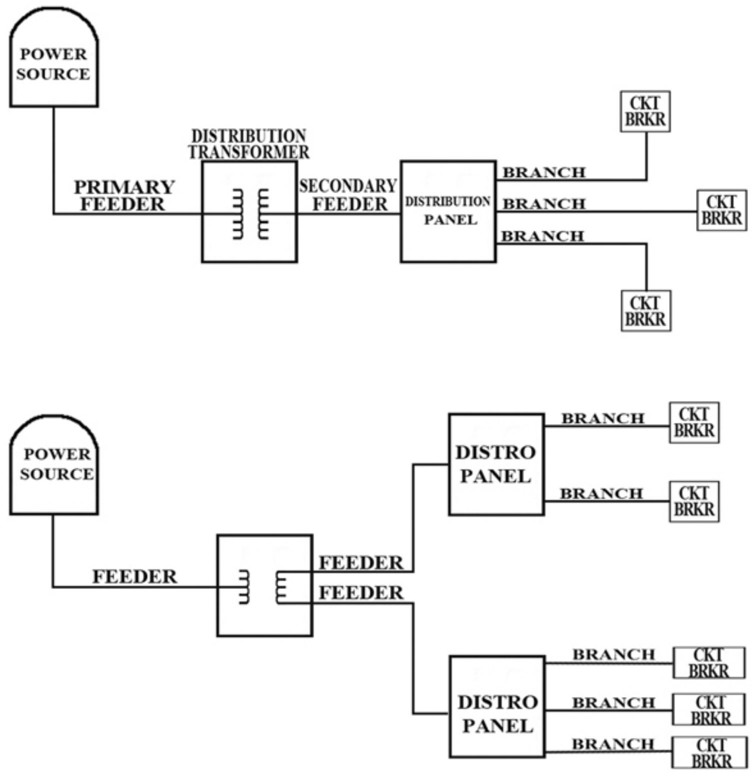


Figure 1–10. Typical power distribution system.

Small buildings

Small buildings usually have one main distribution panel board to which the branch circuits are connected. When the distribution panel combines with the service equipment, there is no need for a feeder circuit. However, when the distribution panel is separate, you need a feeder circuit to establish power between the service equipment and the distribution panel.

Large buildings

Large buildings require more than one panel board to meet their power needs. You can install feeder circuits to supply power from the main panel board to panel boards installed elsewhere in the building. Although you can use the main panel board for branch and feeder circuits, it is usually limited to feeder circuits. A separate panel board (located near the main panel board) for needed branch circuits is normally preferred to dual usage. Most of the panel boards served by a feeder circuit are used for branch circuits. In some cases, a panel board at the end of a feeder circuit becomes a junction point, attaching subfeeders. These subfeeders in turn, supply branch circuit panel boards. Consequently, through the installation of feeder circuits, it is possible to use a single set of large conductors to replace several long-length small conductors required when all branch circuits connect to the main entrance panel board. Feeder circuits allow panel boards to be specifically located, which greatly reduces the wiring needed for branch circuits. Generally, such circuit arrangements reduce voltage loss in the conductors, and save material and labor.

You can install branch and feeder circuits by any method approved by the NEC for the installation of electrical circuits. The main objective of installing circuits is to keep problems and hazards at a minimum, consistent with existing conditions. Use nonmetallic cable for circuits where it is not subject to damage or excessive dampness. Install circuits in metal raceways, rigid nonmetallic raceways, and cable trays. You can install feeder circuits with a common neutral to serve two or three sets of three-wire feeders, or two sets of four- or five-wire feeders. Feeders installed in a metal raceway and using a common neutral must have all the conductors involved enclosed in the same raceway. A feeder that supplies branch circuits having grounded conductors must provide a grounding means to which the branch circuit grounding conductors are connected.

Conductor terms

As soon as you start to work with an electrician, you find a new language is used. This is true of any trade that has material peculiar to the work done. In the electrical trade, two terms often used to mean the same thing are "wire" and "conductor." There is nothing wrong with this, but there are times when it is necessary to be more specific. The following table defines terms you should learn:

Term	Definition
Wire	A thin rod of hard or soft drawn metal. In electrical work, this metal is one that conducts easily (e.g., copper or aluminum).
Conductor	As applied to interior wiring, a bare or insulated wire or group of wires not insulated from each other and suitable for carrying an electrical current.
Solid conductor	A bare or insulated single wire.
Stranded conductor	A group of wires twisted together to form a single conductor that may be bare or insulated.
Cable	Two or more solid or stranded conductors insulated from each other that may or may not be contained in a common outer covering.
Cord	Small, stranded, flexible cable, usually rubber covered.

The amount of current a conductor carries safely depends on four things:

- The metal used.
- The size of the wire.
- The type of insulation.
- The location of the conductor.

Consider each of these when you select the type of conductor to use for a job.

Composition and sizes of wire

Today there are several materials or combinations of these materials used to make wires. The most common metals used are copper, copper alloy, aluminum, copper-clad aluminum, and silver. Copper is the standard in electrical conductors, second only to silver in conductivity, but far more plentiful and therefore economical. If using an aluminum or copper-clad aluminum wire in place of a copper wire, it must be one size larger to carry the same current safely. If you are going to use this type of wire to power a piece of medical equipment, you need to verify with the manufacturer that it is appropriate to do so. There have been reports of heat damage and fire due to aluminum and copper-clad aluminum wire. The problem was so bad that X-ray manufacturer's state in their literature not to use the aluminum or copper-clad aluminum wire.

To work with different size wires, you must know something about the scheme used in wire numbering. Instead of referring to wires by the diameter or area of the wire, the industry uses numbers to represent sizes. The American Wire Gauge (AWG) numbers represent the different wires sizes. The range of the AWG is from No. 40 (the smallest) to No. 4/0 (the largest). The diameter of the conductor determines the associated number.

Figure 1–11 shows you the various sizes of wire (not drawn to scale) in the AWG. Note that at the bottom of the chart, the last conductor is marked 350 kcmil (thousands of circular mils). All conductors larger than No. 4/0 AWG receive size ratings according to the cross-sectional area in circular mils, designated as kcmil. A circular mil is the area of a circle one-thousandths of an inch in diameter. The 350-kcmil conductor on the chart has a cross-sectional area of 350,000 circular mils. Conductors made in kcmil sizes range from 250 kcmil to 2,000 kcmil.

SIZE				
NUMBER	NATURAL SIZE	DIAMETER (INCHES)	NO. OF WIRES	WEIGHT (FEET PER POUND)
40	TOO SMALL TO SHOW ACCURATELY	.0031	SOLID	33,410.
36		.0050		13,210.
30		.0102		3,287.
24		.0201		817.6
18		.0403		203.4
16		.0508		127.9
14		.0640		80.44
12		.0808		50.59
10		.1018		31.82
8		.1284	SOLID	20.01
6		.184	7	12.58
4		.232	7	7.91
2		.292	19	4.97
1		.332	19	3.94
1/0		.373	19	3.13
2/0		.419	19	2.48
3/0		.470	19	1.97
4/0		.528	19	1.56
350 Kcmil		.681	37	0.925

Figure 1–11. Conductor sizing chart.

Note also on the chart that the larger AWG sizes list as stranded conductors. Sizes larger than No. 6 AWG would be very stiff and hard to handle if they were solid. Therefore, when using anything larger than No. 6 AWG—and even some that are smaller—stranded wire provides flexibility. The most common sizes of conductors you will work with are No. 14 AWG through No. 4/0 AWG. Fixture wiring, appliance controls, signal and alarm circuits, or motor windings use smaller sizes, such as No. 16 AWG and below. You must remember that the size of a conductor references the diameter or cross-sectional area of the wire, which does not include the insulation.

Types of insulation

Where the wire is used determines the type of insulation needed. For example, you would not use a rubber or plastic-insulated wire in places where there are very high temperatures. On the other hand, you would not install an asbestos-insulated wire where it might get wet. The NEC covers the types of insulation and associated locations. The code also requires manufacturers of wire and cable to identify their product properly. They must show the size of wire, type of insulation, maximum working voltage, and manufacturer's name or trademark. You can find this information on the outer surface of the insulation. You can also learn a great deal about wire or cable by just reading the markings. The following table shows some of the common letters used to indicate a type of insulation or a characteristic:

Letter	Type of insulation
A	Asbestos.

Letter	Type of insulation
H	Heat resistant.
R	Rubber.
T	Thermoplastic.
V	Varnished cambric.
W	Moisture resistant.

These letters, or combinations of, indicate the insulation type. For example, TW indicates moisture-resistant thermoplastic used in dry or wet locations. The combination RHW indicates heat and moisture-resistant rubber used in dry or wet locations.

Conductor location

As mentioned before, the location of a conductor also has an effect on its current-carrying capacity. A conductor used in free air will safely carry more current than the same conductor installed along with other conductors in conduit or cable. The reason for this is the conductor in free air is able to get rid of the heat caused by current flow much faster than if it was positioned in conduit or cable. The number of conductors installed in conduit also has an effect on the current-carrying capacity. The more conductors there are, the lower the safe current-carrying capacity. To determine the amount of current a specific size and type of conductor used in a certain location can carry, you must refer to NFPA 70, *National Electronic Code*.

Types of wiring systems

The types of electrical systems installed inside a building are determined mostly by what the building is to be used for and the type of electrical equipment to be operated. Generally speaking, electrical loads divide into three categories. The first of these consists mostly of lighting requirements with some need for motor operation. The second category consists of a fairly heavy lighting load combined with a moderate requirement for power equipment. The third class consists mostly of power equipment with a relatively small lighting load. Under normal conditions, the power needed to meet the use requirements comes from the distribution transformer system, or more specifically, the secondary of the transformer.

Two-wire, single-phase system

The simplest wiring system is a two-wire, single-phase type used in small structures where the main need is for lighting. This wiring initiates from a single-phase transformer or a three-phase transformer wired to provide single-phase power as discussed in the transformer section. It can also operate 120-volt appliances and motors. A two-wire system consists of one ungrounded, insulated conductor and one identified (grounded) conductor (fig. 1–12). The ungrounded or “hot” conductor is black or any other color except white, natural gray, or green. The identified conductor called the neutral is white or natural gray in color. This system is limited to operation of 120-volt equipment and relatively light loads of about 50 amperes or less. Larger loads require the use of larger, more expensive conductors. Another type of system can better serve such loads. The two-wire system requires the use of an equipment-grounding conductor, which may be a separate conductor, conduit, or other recognized means of grounding.

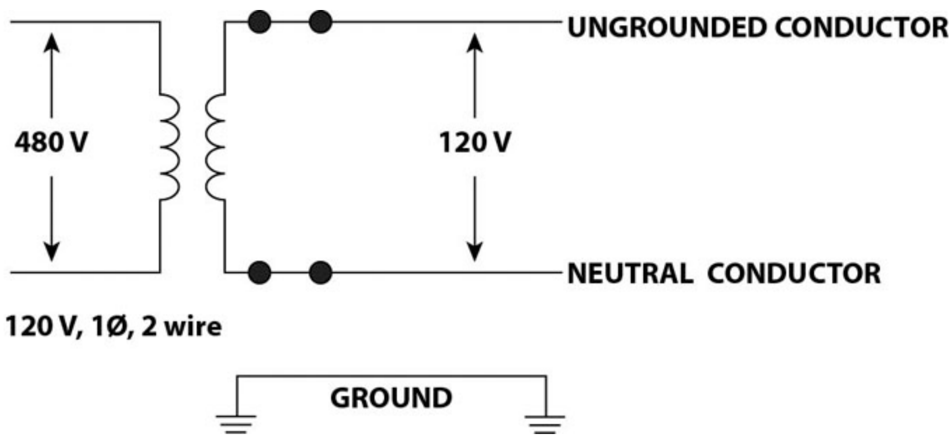


Figure 1–12. Two-wire, single-phase wiring system.

Three-wire, single-phase system

Another wiring system is the three-wire, single-phase type used for lighting and power. This system (fig. 1–13) uses two ungrounded conductors and a neutral conductor. The neutral conductor is grounded. This system provides 120 volts between each ungrounded conductor and the neutral. It also provides 240 volts between the two ungrounded conductors. Lighting loads and 120-volt appliances and motors connect between either of the ungrounded conductors and the neutral. Heavier loads (e.g., air conditioners, heating equipment, and larger powered equipment) connect between the ungrounded conductors to take advantage of the greater efficiency of 240-volt operation. This system provides up to twice the power that is available from a two-wire system with the same size conductors and a balanced load between the two ungrounded conductors. It is the most common system used today due to its flexibility. This system also requires the use of a separate ground for equipment.

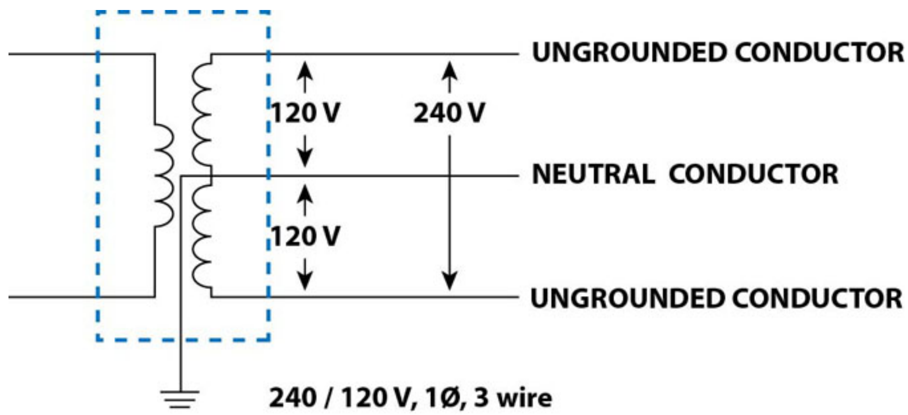


Figure 1–13. Three-wire, single-phase wiring system.

Three-phase, three-wire system

The three-phase, three-wired system is the second type of three-wire system used when the load requirement is for power. This system (fig. 1–14) uses three ungrounded conductors, each of which is a phase and fed by a delta or ungrounded wye transformer. It furnishes power, usually 240 volts, to installed equipment. If there is a need for lighting, you can install 240-volt fixtures and bulbs. This type of system can also achieve higher voltages (i.e., 480 or 600 volts) when requiring substantial amounts of power.

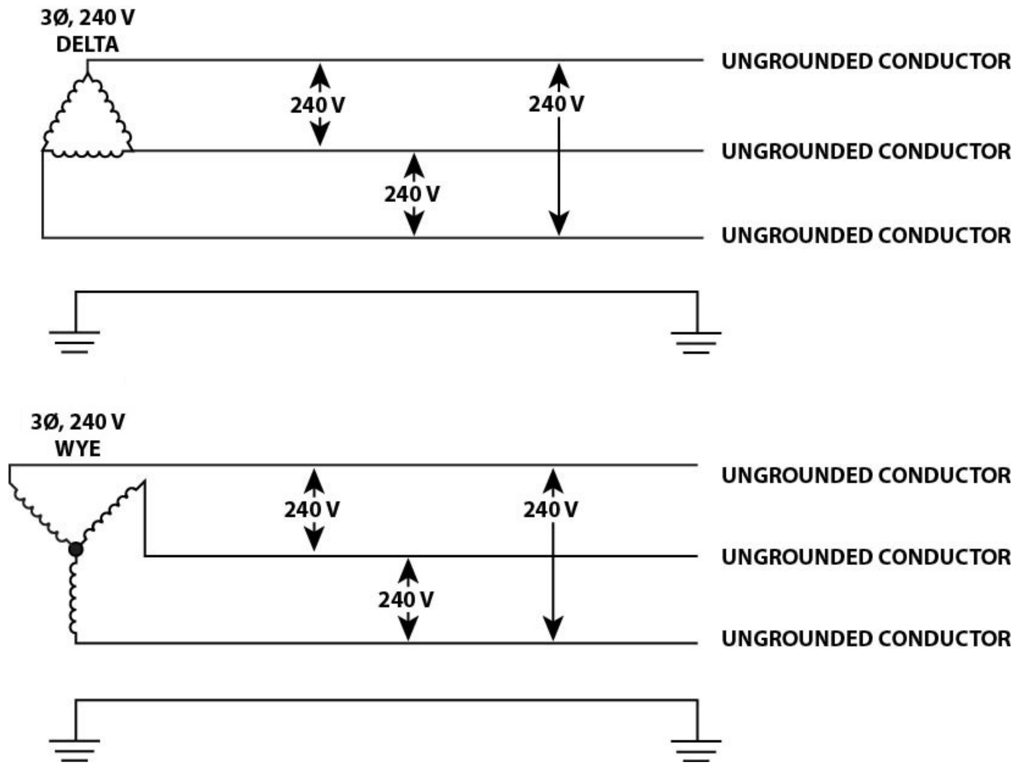


Figure 1–14. Three-phase, three-wire system.

Three-phase, four-wire system

The last type of wiring system in common use is the three-phase, four-wire system. This system has three ungrounded phase conductors, plus a grounded neutral (fig. 1–15). It is a combination light and power system, and offers quite a cost reduction over a three-wire, single-phase system for the same amount of power. The usual voltages are 120/208 or 120/240, depending on the type of transformer connections used. A wye transformer hookup provides 208 volts phase to phase; that is, between any two ungrounded conductors and 120 volts from any phase to neutral. This is the only three-phase, four-wire system allowed in Air Force medical facilities.

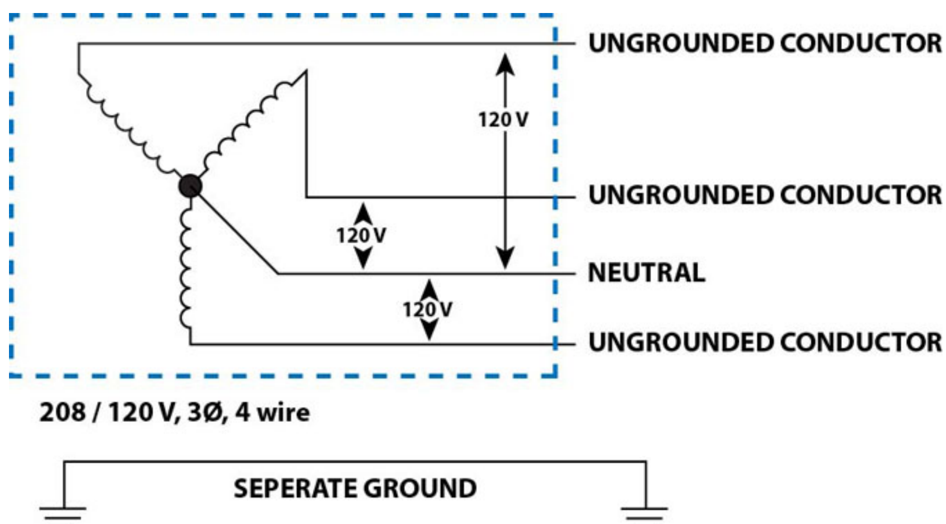


Figure 1–15. Acceptable three-phase, four wire system.

Self-Test Questions

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

001. Description and classification of transformers

1. Why do transformers require little care and maintenance?

2. Name the four principal parts of a transformer.

3. Which winding is the primary when the transformer steps up voltage? Steps down the voltage?

4. What are larger transformers immersed in to insulate and cool the unit?

5. How does a three-phase transformer differ from a single-phase transformer?

6. How are transformers classified?

7. What remains constant in the system when using a constant-potential transformer? What changes?

8. What type of transformer would you use for the ballast of a mercury-vapor lamp?

9. Which transformer would you use if you wanted the current in the secondary to remain constant?

10. The voltage that a transformer can carry depends on what factors?

002. Types of transformer connections

1. How would you connect the secondary winding for a small, lighting load?

2. What happens if a transformer draws a greater load than it is rated to handle?

3. If your lighting current were 120 amperes for a 120 volt system, would your 12 kVA transformer be large enough to handle the load? If not, how large a transformer would you need?

4. When two secondary windings are connected in series, how is the voltage effected? When the secondary windings are connected in parallel, how is the current effected?

5. Name the three basic types of three-phase transformers used by the Air Force.

6. What are the two types of voltage provided by the ungrounded wye?

7. Which three-phase configuration does the Air Force prefer?

8. What ensures the integrity of the isolation transformer line?

9. What two conditions cause a LIM alarm?

10. What are the LIM testing intervals required by NFPA 99, *Health Care Facilities Code*?

003. Description of the essential electrical system

1. What are the three branches of the essential electrical system?

2. Hospital communication systems connect to which branch?

3. How is critical branch supply power used?

4. What is the intended purpose of the critical branch?

5. Which branch provides power for the supply, return, and exhaust ventilating systems?

6. Why does the equipment system activate on a time delay?

7. What three things should you provide if you have a backup generator on site?

8. Who is ultimately responsible for maintenance and testing on the emergency generator?

9. Why would you test a generator under a full load?

10. What method, other than the generator, can you use for emergency lighting in outpatient clinics and other noncritical areas?

11. What is the *minimum* total lamp load time requirement for battery-powered systems?

12. What should you consider when performing a preprocurement survey?

004. Characteristics of conductors

1. Where do branch circuits run?

2. When the distribution panel is separate from the service equipment, what do you need to establish power between them?

3. When a feeder supplies branch circuits that have grounded conductors, what *must* that feeder circuit provide?

4. What four things effect how much current a conductor can carry?

5. What metal is the *best* standard for creating electrical conductors?

6. What type measurement standard lists wire sizes that run from No. 40 to No. 4/0?

7. What does kcmil stand for?

8. What is the size range for kcmil?

9. What does the NEC require wire and cable manufacturers use to identify their product properly?

10. When working with insolation, what would the combination of THW mean?

11. Where does the heat come from in a conductor?

12. What load does a two-wire, single-phase system support?

13. What voltages do a 240-volt, three-wire, single-phase system provide?

14. Which wiring configuration is the *most* common system used today? Why?

15. What two transformers can provide a three-phase, three-wire system?

1–2. Electrical System Protection and Devices

We discussed how you bring power into the building, send it through distribution transformers, and then send it through various conductors to the specific load. What we have not talked about are the distribution panels, circuit breakers, and various other protective devices that monitor our power and keep us safe. These devices are as simple as a circuit breaker that pops when the amperage gets too high, and as complex as special devices designed to keep power clean and usable. In this section, we first discuss how your distribution panels provide easier access to conductors from the transformer. Then we explain how to balance a transformer load properly using the panel boards. Next, we cover the different types of fuses and circuit breakers available to perform overcurrent protection. Moving further into safety, we look at some built-in circuit protection that medical equipment uses to provide added protection to the operator and patient. Lastly, we will address the operation and uses of uninterruptable power supplies.

005. Types of circuit protection

Once you bring power into the building, you must divide it and send it out to various points. A distribution panel, as its name implies, serves as a center or point in the electrical system where the power feeds the branch circuits. There is only one distribution panel in a building when the requirement is for lighting and power, and the building is not too large. On the other hand, several panels may be required in a large building or one in which quite a lot of electrically powered equipment is to be operated (i.e., a medical facility).

Distribution panels

A distribution panel consists mainly of a metal cabinet that houses bus bars and individual circuit protective devices. The protective devices (fuses and circuit breakers) protect the circuits against excessive current flow. Distribution panels divide into categories according to the purpose and intended use of the circuits. The type of protective devices used within the panel also effects their classification.

Distribution panel boards are generally lighting and appliance panels, power panels, or feeder panels. Any panel board that has *more than* 10 percent of its overcurrent devices rated at 30 amperes or less, and has provisions for neutral connections, classifies as a lighting and appliance panel. These panel boards provide connections for branch circuits used for lighting and power purposes. Power panel boards mainly provide power for the operation of electrical equipment. Most of the branch circuits from a power panel are 240 or 480 volts, which may also provide some lighting circuits. Feeder panel boards distribute power to other panel boards located at various points in a building. These other panel boards can be power panels, or lighting and appliance panels. These added panel boards allow installation of branch circuits where they are most useful, with an overall savings in material.

Panel boards must be rated at least as high as the feeder capacity required for the load. They are marked by the manufacturer with the voltage, current rating, and number of phases for which they are designed. This information, plus the manufacturer’s name or trademark, must not be obstructed by interior parts or wiring after the panel board is installed. According to the NEC, lighting and appliance panel boards cannot have more than 42 overcurrent devices besides the mains. Two-pole and three-pole circuit breakers count as two and three overcurrent devices, respectively.

According to the NEC, each lighting and appliance panel board must be protected from current flow on the supply side by not more than two main circuit breakers or two sets of main fuses having a combined rating no greater than that of the panel board. This protects not only the feeders, but also the panel board bus bars. The panel board does not need individual protection if the panel board feeder has overcurrent protection no higher than the panel board rating. To prevent overheating of the conductor, the total load on any single overcurrent device in a panel board must not exceed 80 percent of its capacity where, in normal use, the load continues for three hours or longer.

Grounding is required for panel board cabinets. A terminal bar provides for attachment of feeder and branch circuit equipment-grounding conductors where nonmetallic raceway or cable is used. This terminal bar bonds to the cabinet, but not to the neutral bar, except in service equipment.

Three-phase panel boards supplied by a four-wire, delta-connected system, which has the midpoint of one phase grounded, must have the higher voltage-to-ground conductor or bus bar marked. This high-voltage conductor should have an orange outer finish or be clearly tagged. Any point where you can make a connection and the neutral conductor is present requires identification. The phase arrangement on a three-phase panel board is A, B, C, from left to right or top to bottom, when viewed from the front. The B phase is the phase that has the higher voltage to ground.

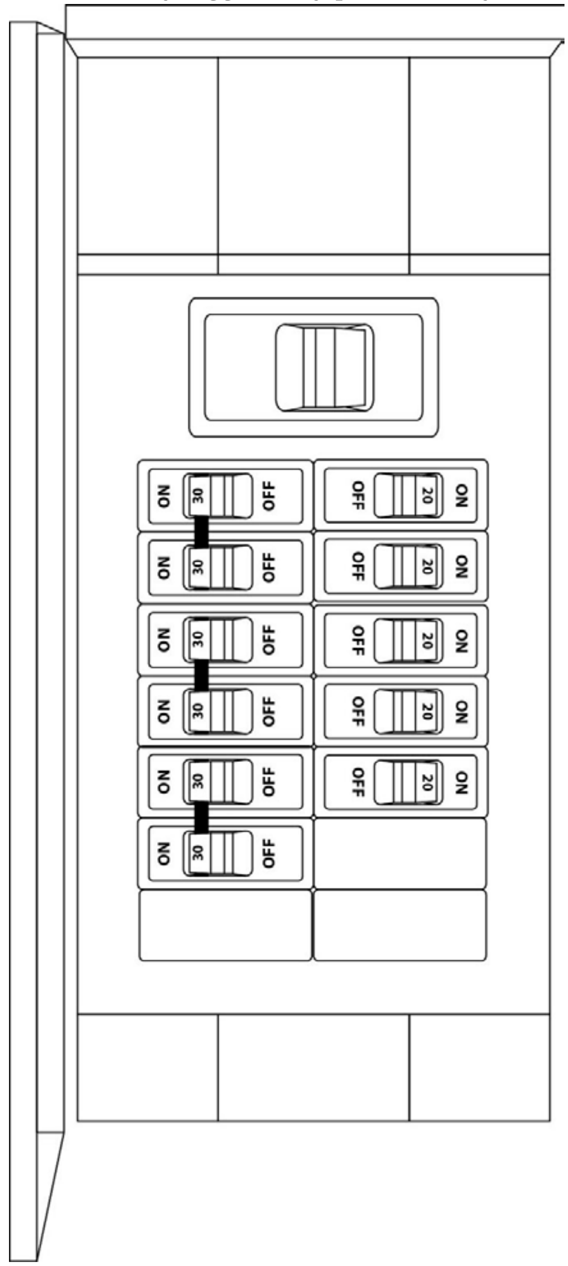


Figure 1–16. Distribution panel.

Fuse panels

Fuse panels, as the name implies, contain fuses for protection of each circuit. There are many designs of fuse panels, varying in size, capacity (amperage and voltage), and type of installation. The ampacity of the panel's bus bars determines the capacity of the panel. Whether it is a single-phase or three-phase panel determines the number of bus bars used.

A fuse panel can be surface or flush-mounted. The cabinet or case has knockouts so you can attach conduit or cable connectors directly to it. Panels supplying power to general branch circuits must be of the "dead front" design. This prevents live parts from exposing when the door on the panel is open. You must remove the cover from the panel to gain access to the interior parts.

Fuse panels use plug, cartridge, or knife-blade fuses, or a combination of these. Fuse panels used in medical facilities are the ferrule or knife-blade fuses, depending on the capacity of the panel. We will describe these two types of fuses later in the lesson.

Circuit breaker panels

Circuit breaker panels serve the same purpose as fuse panels. Generally, they resemble fuse panels, except for the protective devices used in the circuits. Figure 1–16 shows the front of a breaker panel with exposed reset levers. Circuit breaker panels are preferred over fuse panels because a circuit breaker only needs resetting after being tripped by an overload condition. Fuses, on the other hand, require replacement after they are blown. An added convenience of the circuit breaker is the ability to manually disconnect the circuit from its power source, like a switch. Circuit breaker panels must be of the dead front design, the same as fuse panels. Replacement of individual circuit breakers requires removing the front cover.

Protective devices

Before you can hook up branch circuits to a panel board, you must select the protective devices in the form of fuses and circuit breakers. These devices provide protection for the circuit conductors and equipment connected to the circuit.

Cartridge fuses

There are two types of cartridge fuses: the ferrule and the knife-blade (Fig. 1–17). Both types are available with replaceable or non-replaceable fuse links. Ferrule-type fuses are available in ampere ratings from 0.5–60. Fuse panels that use ferrule-type fuses have specially designed fuse clips in which only ferrule types fit. Fuse diameter and length increase as amperage and voltage increase. You can use Ferrule-type fuses in circuits up to 600 volts.

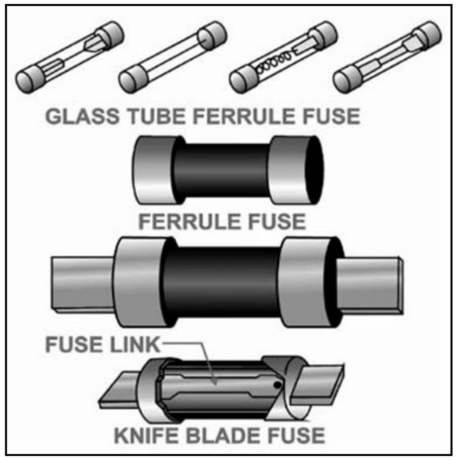


Figure 1–17. Fuses.

Fuse panels that provide distribution for high-capacity circuits use knife-blade fuses for protection. Like the ferrule fuses, the knife-blade fuse clips only hold knife-blade fuses. Knife-blade fuses are available in ampere ratings of 61–6,000. The maximum voltage rating for knife-blade fuses is 600 volts.

Two factors must be considered when selecting fuses for circuit protection—total current flow and the voltage of the circuit in which the fuse is to be installed. Since the purpose of the fuse is to protect the circuit, it must be the weakest point in the circuit. Thus, the fuse rating cannot exceed the lowest rated component requiring protection. Before installing a fuse in a panel, check the condition of the fuse holders or clips. They must be clean and hold each fuse firmly.

Not all fuses operate the same way. Some instantly break the circuit connection to prevent any overcurrent conditions, while others allow for some variance before severing the connection. The following are some different fuse characteristics:

Fuse Type	Characteristic
Fast Blow	Opens the moment the current flow exceeds the designated rating.
Slow Blow	Designed to tolerate spikes in current (initial surges).
Time Delay	Similar to slow blow, but designed to open only after the exceeded current rating is maintained for a specific amount of time.

Circuit breakers

One of the newer types of protective devices, used more often than fuses because of the way it reacts to an overload, is the circuit breaker. A circuit breaker trips on an overload, but can reset to complete the circuit again without having to remove or replace it. To reset a tripped breaker you must turn it to the fully OFF position and then back ON again. Circuit breakers classify according to their operating principle. They are thermal, magnetic, or combination thermal-magnetic. Figure 1–18 shows typical circuit breakers with one, two, and three poles. Multi-pole breakers open all grounded conductors in a circuit at the same time.

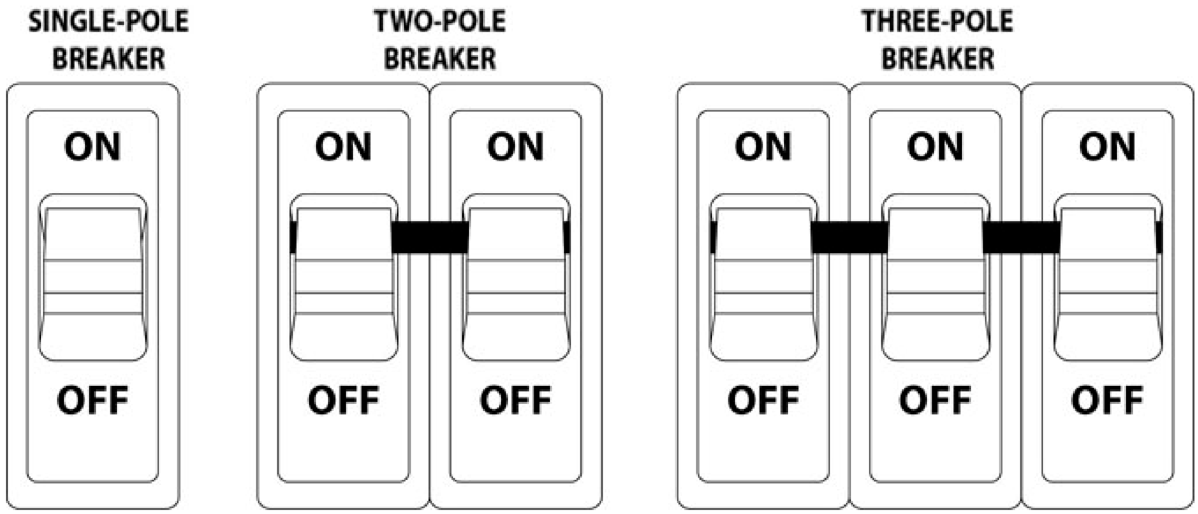


Figure 1–18. Circuit breakers.

A thermal-type circuit breaker has a bimetallic element within the breaker that responds to temperature change. The bimetallic element consists of two strips of dissimilar metal fused together. Each strip has a different expansion rate when heated. Current flowing through the breaker generates heat, which increases as the flow increases. The heat causes the bimetallic element to bend and act against a latch. The breaker mechanism adjusts so that when the current flow reaches a set level, the element bends enough to trip the latch. This action opens a set of contacts to break the circuit. Another common name for the thermal-type circuit breaker is a time lag breaker, because the breaker does not open immediately when an overload occurs. The bimetallic element requires a short time (length depends on the size of the overload) to respond to the heat generated by the overload current.

A magnetic-type circuit breaker responds instantaneously when an excess of current flows through the breaker. A small electromagnet actuates the breaker mechanism. Whenever a predetermined amount of current flows through the electromagnet, it creates enough magnetic flux to attract a small armature. As the armature moves, the breaker mechanism trips and opens the circuit.

The thermal-magnetic circuit breaker, as the name implies, combines the features of the thermal and magnetic types. Of the three, the thermal-magnetic circuit breaker is preferred for general use. A small overload actuates the bimetallic strip to open the circuit on a time delay, while a large overload or short circuit actuates the magnetic trip to open the circuit instantaneously.

Circuit breaker ratings are the same as fuses, amperes and volts, and you select them on the same basis. Circuit breakers are sealed units, so never attempt to adjust the ampere capacity or repair them. You must remove and replace a defective breaker.

A ground-fault circuit-interrupter (GFCI) is a thermal-magnetic breaker with an additional internal circuit that detects a current leak from the hot wire to ground and opens the breaker if that current reaches a set amount. This leakage cannot be more than 5 (±1) milliamperes to ground. Most of these breakers have a test button used to check the GFCI to see if it trips when there is a fault.

To install the GFCI, you connect the circuit hot wire to the breaker the same as you do on a standard breaker. The circuit neutral connects to another terminal on the GFCI, instead of to the neutral bar in the panel. The GFCI comes with an attached white neutral wire you connect to the neutral bar. The NEC requires GFCIs be installed for several circuits used in the hospital. These circuits include all 120-volt, single-phase, 15- and 20-ampere receptacles in bathrooms, wet locations, and outdoors. You can also use a GFCI elsewhere when there is a need for the added protection.

Surge suppressors

A surge suppressor, sometimes called a clipper, protects equipment from high intensity impulse voltages. Suppressors prevent equipment damage; they can convert impulses to ground noise, which cause data corruption and loss. All of your hospital computers, along with all the laboratory equipment and other sensitive medical equipment, have surge suppressors and protectors. They look like multistrip outlets with circuit breakers built into them, but do not confuse the two as they do not offer the same levels of protection. They help to screen out the voltage problems caused by lightning, elevators, computer power supplies, air conditioning controls, light switches, dimmer switches, and other electrical issues that could cause momentary power spikes.

006. Uninterruptible power supplies

Uninterruptible power supplies, commonly referred to as UPS units, are another type of circuit protection as well as a backup power source. These generally self-contained battery back-up units have a variety of uses such as providing emergency power to a whole building or individual piece of equipment; providing clean power by limiting noise produced from electromagnetic/radio frequency interference, frequency instability and harmonic distortion; as well as regulating voltage spikes between the main power source and the equipment connected to it. These power supplies provide AC power to a load for some period in the event of a power failure. UPS can provide power from a couple seconds to a couple of hours, depending on the size of the UPS, the load and its intended purpose.

Types of UPS technologies

There are three categories of static UPS systems consisting of on-line, line-interactive, and standby systems. An on-line UPS uses a method of double conversion to take the AC from the wall, rectify it to direct current (DC) for charging the battery and then inverting back to 120V/230V AC for powering the protected equipment. The online UPS provides the highest level of power protection available.

A line-interactive UPS places the inverter in line with the circuit and charges the battery, while also compensating for over/under voltage situations introduced from mains AC power. This type uses a variable-voltage autotransformer to sense voltage fluctuations and adjust to the proper voltage, providing clean power to the equipment. When a full power loss incurs, the unit switches to the battery and inverts the energy back to AC power. The line-interactive UPS provides better filtering and output voltage boost than a standby system.

A standby or off-line system is the most basic of the three and provides surge protection and battery back-up. In a standby system, the load receives power directly by the input power and the backup power circuitry only initiates when the main utility power fails. Most UPS below 1 kVA tend to be line-interactive or standby, as these are generally less expensive.

Another type of UPS system is a rotary system, which unlike the static UPS, uses mechanical rotating components such as a flywheel or motor to provide power. Rotary units either use a flywheel to provide temporary kinetic energy until the generator warms up, batteries to power an onboard motor/generator, or are engine-coupled with a small diesel engine attached. The concept of a rotary UPS is any UPS whose output sine wave is the result of rotating generation. Even though these units might have self-contained energy generation, the intended purpose is still to sustain operations until the backup generator comes up to full speed.

System applications

You can use UPS in a variety of applications. They can be stand-alone or rack based units. The most common application that you will see is the small under desk unit used to provide backup power to a workstation computer. Although you might see them conveniently used as a footrest, which is not why they are under your desk. The stand-alone UPS unit is not intended to provide long term energy during a power outage, but to sustain operations long enough to properly power down sensitive equipment and save critical information. You will commonly see these units attached to equipment such as telemetry, central patient monitoring, radiology or facilities workstations, as well as sensitive lab equipment.

Rack based UPS are used to provide backup power to many systems vital to the hospital communications infrastructure. Think of all of the communications closets and server rooms located within your facility. You will find rack mounted UPS systems powering server applications such as internet, Defense Medical Logistics Standard Support (DMLSS), telemetry, or Picture Archiving and Communication System (PACS) servers.

While those are relatively smaller UPS units by comparison, you will also see UPS units on a much larger scale. Some applications employ large banks of batteries designed to power heavier loads such as computed tomography (CT), magnetic resonance imaging (MRI) or nuclear medicine units. In a field deployment setting, you might even see a dedicated UPS building wired between the field generator and the tactical shelter powering a CT or MRI unit. Such sensitive and expensive equipment requires clean power to prevent damage as well as a battery backup to safely power down the equipment. Can you imagine losing power while you have a patient still stuck in the bore of a cramped MRI machine? Having a means to safely retract the patient table and save all patient data and images is critical.

007. Grounding types and installation

Grounding is probably one of the least thought of, but more important, tasks in any career field that deals with electricity. Why is grounding so important? Probably the most important aspect is it can save your life. An electrical system must provide for the protection of life as well as property when faults develop from system breakdown, lightning, and failure of equipment and appliances connected to the system. Consequently, all metal parts and enclosures of the wiring system, plus the neutral conductors, tie together, and then ground to Earth reducing the electrical potential to zero. Electrical grounding consists of four types: system grounds, equipment grounds, static grounds, and lightning grounds. As you have already covered the importance of electrostatic discharge and static grounding in your A set, we will focus on systems, equipment, and lightning.

System grounding

System grounding consists of connecting the neutral conductor to the Earth. The purpose of this connection is to get rid of any high voltages that inadvertently enter the system from lightning strikes, a breakdown in transformer insulation, or accidental contact between the service drop and nearby high-voltage lines. Such voltages are often in the range of 2,300 volts. This voltage is high enough to break down the insulation on system wiring in an ungrounded system. On an ungrounded system, a breakdown of insulation can result in heat generation, which will set fire to any surrounding flammable material. In addition, if these high voltages do not find a way to reach ground and remain on the line, they present a serious shock hazard.

When you properly ground the system through an adequately sized low-resistance conductor, these high-voltage currents bleed off to the Earth immediately. As a result, the danger of fire or shock reduces to a minimum. Figure 1–19 shows how the system ground hooks up to the service entrance. The sizes of the service conductors determine the size of the system grounding conductors. On a normal installation, service conductors that are No. 2 or smaller need a No. 8 grounding conductor. The NEC specifies the size of the conductor used with various sizes of service conductors, but it may not be smaller than 12.5 percent of the area of the largest service conductor.

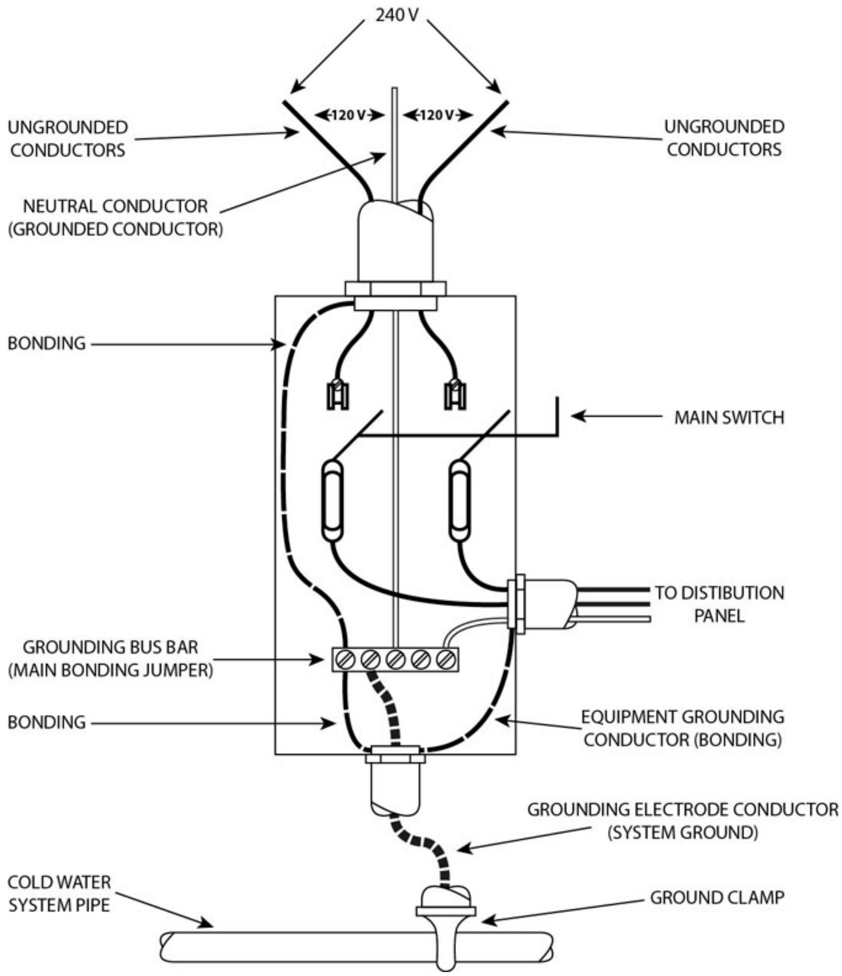


Figure 1–19. Service entrance grounding.

Equipment grounding

Equipment grounding consists of connecting all exposed, noncurrent-carrying metal parts of the electrical system to the Earth (fig. 1–20). This includes conduit or other raceways, outlet boxes, switch and panel board enclosures, and electrical equipment with exposed metal parts. Grounding reduces the possibility of shock or injury to people in case a live conductor contacts any of these conductive parts.

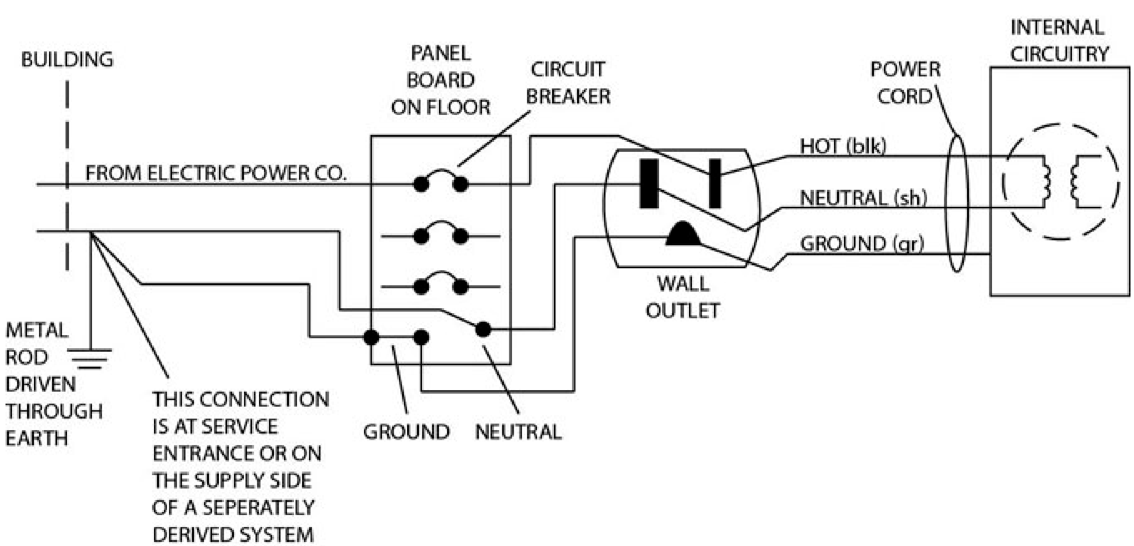


Figure 1–20. Ground wiring integrity.

The metal conduits entering the enclosure are bonded together. These conduits are then bonded to the grounding bus bar. The conduit entering at the right of the enclosure also serves as an equipment-grounding conductor for the remainder of the electrical system. The bonding jumper, from the grounding bus bar to this conduit, grounds the service entrance conduit in addition to being an equipment ground. Bonding jumpers are made of copper. Those that bond service equipment are sized the same as the grounding electrode conductor. The ones used for equipment grounding are sized the same as the equipment grounding conductors.

The ground will maintain as the conductors run to the outlets, even if you remove an outlet in one area (fig. 1–21). This redundant grounding is an extremely important safety factor in a medical facility.

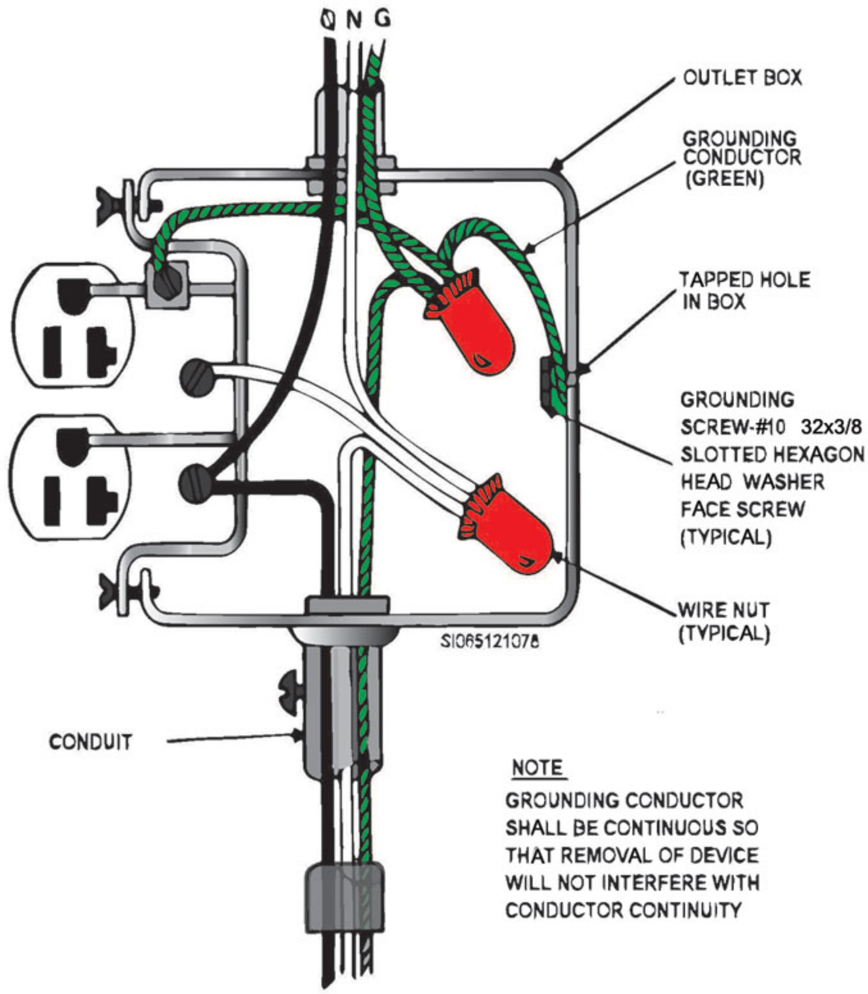


Figure 1–21. Receptacle box wiring.

Lightning grounds

The purpose of a lightning ground is for safely dissipating lightning strikes into the earth. This presents a hazard to personnel and equipment in the vicinity; under some conditions, lightning strikes 3–20 miles away can induce up to 60,000 volts on ungrounded equipment. Manufacturers design lightning grounds to carry large currents for short time periods. Lightning conductors are as short and straight to ground as feasible. Equipment in hazardous areas must have at least 1/0 AWG. This is one of the several parts that make a complete lightning protection system. A complete lightning protection system usually consists of air terminals (lightning rods), down conductors, arresters, and other connectors or fittings. The lightning protection system protects the building, its occupants, and its contents from the thermal, mechanical, and electrical effects of lightning.

System ground installations

An effective ground for an electrical system must provide continuity, adequate capacity, and permanence. The NEC specifies the types of grounding electrode systems that meet all of these requirements.

Normal ground electrodes

When available, a metal underground water pipe, which has direct contact of 10 feet or more with the Earth, serves as the primary grounding electrode. If the piping system contains a water meter, insulated joints, or nonmetallic sections; you must install bonding jumpers around these units to ensure continuity. The underground water pipe requires supplementing with at least one other grounding electrode. This added electrode can be the effectively grounded metal frame of a building; a steel reinforcing bar in the bottom of a concrete foundation or footing (at least 20 feet of No. 2 or larger solid copper conductor buried 2.5 feet deep); or a made electrode. The two electrodes bond together so they have the same ground potential.

Alternate ground electrodes

When the preceding electrode system is not available for grounding, one or more other electrodes may be used. These may be some type of installed system or a made electrode. In addition, other metal underground systems or structures (i.e., a heating system or an underground tank) make suitable electrodes. Items *not* permitted for use as grounding electrodes are metal underground gas piping systems, aluminum, or the structures or structural reinforcing steel used in underground pool systems.

You can make electrodes from pipes, rods, or plates. Pipe and rod electrodes cannot be less than 8 feet long. Pipe or conduit should be ¾″ or more in diameter, and galvanized if made of iron or steel. Steel and copper or zinc coated steel rod electrodes should be ⅝″ or larger in diameter. Nonferrous rods can be as small as ½″ in diameter. When using metal plates for electrodes, they should have at least 2 square feet of area exposed to the Earth. Steel plates should be at least ¼″ thick, while nonferrous plates can be as thin as 0.06″. Aluminum electrodes are prohibited.

You should drive pipe or rod electrodes to a depth of 8 feet unless underlying rock interferes. Use a driving point on the end of the pipe to ease driving. A protective cap prevents damage to the pipe top from the sledgehammer. When rock is less than 4 feet deep, you must dig a trench below the permanent moisture level and bury at least 8 feet of electrode in the trench. You also need to bury plate electrodes below the permanent moisture level, which normally means at least 2.5 feet deep. Where soils are corrosive, use electrodes made of copper or other corrosion-resistant metal. The durability of galvanized steel is too unpredictable to use under such conditions. You must remove paint, lacquer, paraffin, or other protective coatings from electrodes before you install them.

Ground electrode resistance

Be sure to check the resistance after installing ground electrodes. You can perform a reasonably accurate check connecting an ohmmeter between the electrodes and taking a reading of the resistance. When checking a single made electrode, drive a second ground rod 6 feet from the made electrode and take an ohmmeter reading between them. The resistance between the electrodes and the Earth must be 25 ohms or less. A resistance higher than this requires the installation of one or more additional electrodes to bring the resistance down. Any additional electrodes must be 6 feet or more from the existing electrodes.

Grounding electrode conductor

The grounding electrode conductor connects the grounding bus bar of the service equipment with the grounding electrode. The grounding electrode conductor can be of copper, aluminum, or copper-clad aluminum. It must be resistant to any existing corrosive condition. This conductor can be solid or stranded; insulated, covered, or bare; and must not have any joints or splices. The grounding electrode conductor must have a protective covering (i.e., metal conduit or cable armor) if it is smaller than No. 6. You can install a No. 6 conductor without a protective cover, if you fasten it rigidly to the construction and is not subject to damage. Number 4 and larger conductors do not need a protective covering unless installing them where severe damage may occur. You must firmly anchor the grounding electrode conductor to the grounding electrode. One method is to use a clamp assembly. Be sure to remove any paint, wax, or other nonconductive material before installing the clamp onto the grounding electrode. Ensure the protective covering and grounding electrode conductor attach securely to the grounding clamp.

Protective metal enclosures for grounding electrode conductors must be electrically continuous from the service equipment cabinet to the grounding electrode. A break in the protective covering requires that you bond each end of the break to the grounding conductor. Never use solder to make any connection in an electrical grounding system. Never install aluminum or copper-clad aluminum grounding conductors in direct contact with a masonry surface, the Earth, or where corrosive conditions exist. Also, never install these conductors closer than 18 inches to the Earth when used outside.

Equipment grounds

You can use equipment-grounding conductors made of copper or other corrosion-resistant material; solid or stranded; insulated, covered, or bare. This conductor can be wire, any shape bus bar, any form of metallic conduit, armor of armored cable, or any other type of raceway approved for this purpose. You must install equipment-grounding conductors of the preceding types with approved fittings and terminations tightened with suitable tools. A separate grounding conductor is required in nonmetallic cable, which you can run with other conductors in a raceway.

Bare equipment-grounding conductors do not need further identification. Covered or insulated grounding conductors should be green or green with one or more yellow stripes. If you use conductors with other than a green finish as equipment grounds, you must strip the covering at every accessible point; or the exposed covering must be colored green, or have green-colored tape or adhesive labels applied.

Self-Test Questions

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

005. Types of circuit protection

1. What is the function of a distribution panel?

2. What are three classifications of distribution panels?

3. How are power panels used?

4. What are the usual voltage ratings from a power panel?

5. What information *must* the manufacturer place on a panel board?

6. A three-pole circuit breaker counts as how many overcurrent devices?

7. If a load on an overcurrent device in a panel board continues for three hours or longer, what max capacity limit should *not* be exceeded?

8. What type of fuse panels can you use in medical facilities?

9. Why are circuit breaker panels preferred over fuse panels?

10. What causes fuse diameter and length to increase?

11. Why is the fuse the weakest link in the circuit?

12. Name the three types of circuit breakers.

13. Which type of circuit breaker is preferred for general use?

14. How much current leakage to ground would cause a GFCI to trip?

15. Where would you find a GFCI in a medical facility?

16. Why are surge suppressors used?

006. Uninterruptible power supplies

1. Describe the uses of UPS systems.

2. How long can a UPS provide power? What determines this length?

3. What are the three categories of static UPS systems?

4. Which UPS system provides the *highest* level of power protection available?

5. How does UPS technology use a line-interactive variable-voltage autotransformer?

6. What advantages does a line-interactive system provide over a standby system?

7. What does a rotary UPS system use to provide power?

8. What is the most common UPS application used in the field?

9. According to the text, what applications would you use a rack-mounted UPS system to power?

007. Grounding types and installation

1. What are the four types of grounding?

2. Why does system grounding connect the neutral conductor to Earth?

3. Where would you look to find what size grounding conductor is needed for system grounding?

4. What four examples are provided of devices that require Earth grounding.

5. What does equipment grounding do?

6. From what material is bonding jumpers made?

7. In a medical facility, what is an *extremely* important safety factor regarding grounding?

8. What is the purpose of a lightning ground?

9. What components make up a complete lightning ground system?

10. What are the three criteria of an effective ground?

11. What serves as the *primary* grounding electrode in a medical facility?

12. Which items cannot be used as electrodes? What are the permitted options?

13. How deep should you drive a pipe or rod electrode into the ground?

14. What must you do if the rod you are using has a protective coating?

15. When checking a single made electrode, what is the required resistance between the electrode and the Earth?

16. What is a grounding electrode conductor?

17. What colors are used for equipment grounding conductors?

1–3. Facility Management

As a biomedical equipment technician (BMET), you might find yourself working in FM at some point in your career. Depending on the size of the facility, you could be running projects, leading the department as the noncommissioned officer in charge (NCOIC) or possibly even be the facility manager of your military treatment facility (MTF). In this section, we will discuss the overall operation and personnel in FM and the Joint Commission (TJC) requirements, as well as blueprints and structural considerations.

008. Facilities program overview

The FM program encompasses many different key elements to operating an MTF. Most BMETs tend to shy away from working outside of the shop, but the opportunity to immerse yourself in how these programs operate and the regulatory requirements could help you be a better-rounded BMET down the road. Let's discuss some of the personnel and programs that fall under the facilities umbrella.

Facility manager

The facility manager is the person responsible for the daily operations and the overall facility upkeep. They can be duel-hatted as many other positions in facilities such as the safety officer or quality assurance evaluator (QAE) over the maintenance and housekeeping contracts. In larger FM programs however, these would each be separate positions. Some facility manager responsibilities entail:

- Serves as the real property building manager and member of the medical facility utilization board.
- Responsible for FM, financial planning, programming, budgeting, and monitoring of expenses.
- Develops and maintain a long-range master facility improvement plan (MFIP).
- Maintains a written interim life safety measures (ILSM) policy detailing how the facility will protect patients, staff, and visitors during temporary periods that do *not* meet NFPA 101, Oversees fire prevention/protection programs and coordinates fire drill requirements, in accordance with (IAW) NFPA 101, with BCE and base fire chief or alternate.
- Acts as or oversees the safety officer, and serves as a member of the EOCC or function.
- Assigns or acts as the surveillance monitor to oversee contracted housekeeping services through the hospital aseptic management services (HAMS) contract.
- Reviews BCE and/or Air Force Medical Support Agency (AFMSA) centralized contracts that provide the MTF with refuse collection, elevator maintenance, hood and return/outside air duct cleaning, and other contractual services.
- Manages the MTF and grounds maintenance programs. (Including snow and ice removal).
- Develops and manages the energy conservation program.
- Oversees contract for removal, treatment, storage, and disposal of regulated medical waste (RMW).
- Serves as member of the infection control committee.
- Serves as a member or advisor of the equipment review and authorization activity (ERAA).

As you can see the facility manager have a lot of responsibility and serve on many different committees and boards to determine policy and implement corrective actions within an MTF.

Safety officer

The MTF safety officer serves as the FM point of contact for all safety-related matters, in the case where the FM is not also dual appointed as the safety officer. The MTF commander appoints the safety officer in writing IAW TJC guidelines. In dealing with safety matters, they coordinate actions with other organizations such as the installation safety office, bioenvironmental engineering (BEE), BCE, public health, BMET, patient safety office, and infection control. The safety officer is responsible to:

- Serve as the area fire marshal IAW AFI 32–2001, *Fire Emergency Services (FES) Program*, and local procedures.
- Oversee fire exit drills. Conduct inspections to verify proper alarm transmission, smoke and fire containment procedures, evacuation to areas of refuge, fire extinguisher use, and evacuation preparation.
- Develop local written procedures to control the use of patient-owned electrical devices in patient care environments, and approve the use of power strips/surge protectors used with non-medical equipment.
- Submit mishap reports IAW AFI 91–204, *Safety Investigations and Reports* to the installation safety office.
- Ensure all medical facility personnel receive initial and annual refresher safety training and that supervisors document all related safety training on AF Form 55, Employee Safety and Health Record, IAW AFI 91–203, *Air Force Consolidated Occupational Safety Instruction*.
- Assist with development and annual review of departmental safety briefings and newcomer's orientation programs.
- Ensure staff members submit AF Form 765, Medical Treatment Facility Incident Statement, to the patient safety office/risk manager for reportable incidents involving patients, visitors, or staff.
- Annually present safety program, including results of inspections by outside agencies at EOC meetings.
- Review waste handling procedures to ensure compliance with federal, state, and local hazardous materials and RMW management.

Facility maintenance

Specialized personnel maintain the medical facility just like the medical equipment. Depending on the scope and size of your facility, either BCE or an independent hospital facilities contract conducts these actions. In the case of BCE, FM is the liaison between the organizations and places the work requests. When an in-house service contract services the hospital, the FM or QAE will oversee the contract and track the performed work. Facility maintenance includes aspects such as power distribution and emergency generator maintenance and testing, plumbing, medical gas lines, heating ventilation, and air conditioning (HVAC), maintaining the HVAC and badge access servers and physical upkeep of the facility, just to name a few. Depending on how your facility writes the contract, there could be more or less of these services included.

Housekeeping

Housekeeping is vital to maintaining a clean and reputable facility. It ensures compliance with infection control standards as well as contributes to the operational flow of an MTF. Think about the turnover rate of an OR suite and the level of disinfection involved. Without a thorough and expedient housekeeping staff, we would not be able to sustain a rapid ops tempo and would have to cancel or reschedule services. Housekeeping services, along with linen services and infection control criteria fall under the HAMS contract. FM is responsible to oversee the housekeeping contact and perform inspections as well as handle write-ups and complaints that might arise. The facility manager or designated QAE is in charge of this function.

Linen

Just like housekeeping, a proper linen service is important to keep the facility running. The linen service handles the sanitation of items such as scrubs, hospital bed sheets, lab coats, etc. As some linens are soiled or damaged beyond repair, ensuring a constant supply and replacement analysis with logistics is key to ensuring the facility has what it needs to operate on hand at all times. The linen supply officer can be either a facilities or a logistics function.

009. Environment of care

The environment of care (EOC) is something you might already be familiar with as a BMET. You might have attended an EOC committee meeting or worked on some processes that report to the committee. The EOC governs a lot of programs and metrics that fall within the BMET wheelhouse. In this section, we will discuss some of the functions and responsibilities that you will have as a BMET in regards to the EOC.

Environment of care committee

The EOCC is composed of various members of the hospital staff and focuses on safety and efficiency throughout daily operations. The MTF hospital administrator, or delegated support commander, generally chairs the committee. Voting committee members also include the MTF functional commanders (squadron or group based on the size of your facility). The sections that report to the committee include, but are not limited to, BMET, logistics, facilities, safety, infection control, and security. The committee reviews metrics from these sections to ensure compliance with standards set by TJC.

As a BMET, you are responsible for briefing elements of equipment maintenance such as:

- Shop monthly completion metrics of both life safety and other PMs.
- Medical equipment recalls and status updates.
- Unable to locate (UL) equipment.
- EOC safety walkthrough inspection findings.
- Medical equipment incident investigations.

As a FM function, reportable metrics include:

- Monthly generator testing schedules and results.
- Housekeeping compliance and observations.
- Linen status.
- Facility maintenance work order completion rates.
- Safety metrics such as personnel injury reports, fire drill schedule and results, motorcycle safety training stats and EOC safety walkthrough inspection findings to name a few.
- Funded and unfunded facility projects

Environment of care management plans

TJC's EOC are standards that require organizations to develop management plans in six functional areas. These areas are:

- Safety.
- Security.
- Hazardous materials and waste.
- Fire safety.
- Medical equipment.
- Utilities.

TJC also requires organizations to have a written emergency operations plan, but these have different parameters than management plans. The medical contingency response plan (MCRP) addresses emergency management.

Management plan focus

Although FM might not develop each management plan, they are the overall authority responsible for overseeing and reporting the plans for each of these functions. Each management plan must address the following topics:

- Risk assessment.
- Staff development.
- Emergency response and procedures.
- Inspection, testing, and maintenance.
- Information collection and evaluation.
- Performance monitoring.
- Annual evaluation.

Medical equipment management plan

As you might assume, the BMET shop is responsible for developing the medical equipment management plan. This management plan describes the framework to manage medical equipment risks and continuously improve program performance. Although you might be involved in helping to develop some of the other plans, let's focus on the equipment aspect. Your shop plan will detail your overall operation and procedural guidance in some of the following areas:

Area	Focus
Scope	The scope of responsibility that the program is responsible for (i.e. all buildings and clinics serviced by the medical equipment maintenance function).
Safety risks	Management of equipment recalls through authorities such as the Food and Drug Administration (FDA), Emergency Care Research Institute (ECRI), medical materiel quality control (MMQC) or the original equipment manufacturer (OEM).
Equipment procurement	Medical equipment procurement processes such as technical equipment evaluation and ERAA.
Equipment inventory	Accountability of equipment assets, categorized by physical risk assessment.
Equipment maintenance	Defined intervals for inspecting, testing, and maintaining high risk and non-high risk medical equipment based on OEM recommendations and risk levels.
Incident investigations	Established process for evaluating and reporting medical equipment suspected in or attributing to death, serious injury or serious illness of any individual, as required by the Safe Medical Device Act (SMDA) of 1990.
Sterilizer testing	Sterilizer testing and maintenance, separately tracked from standard preventive maintenance (PM) based on biological hazards and indicators.
Water testing	The chemical and biological testing of water sources used in hemodialysis procedures.

These are some, but not all, of the key areas determined by the EOC's elements of performance (EP). Medical equipment management plans might differ slightly between organizations, but the intent of a management plan is to be consistent with civilian accreditation applicable standards of TJC.

Master facility improvement plan

The facility manager is responsible to develop and maintain a long-range MFIP, and annually brief the plan to the MTF executive staff. The MFIP documents ongoing preventive and corrective facility maintenance activities and condition assessment of existing infrastructure. It also identifies current and future sustainment, restoration, and modernization (SRM) requirements to support the MTF mission within existing facilities. The MFIP includes areas such as; future year defense plan (FYDP), + 2 years unfunded requirements for military construction (MILCON) or operations and maintenance (O&M). A proper MFIP also consists of the following reports:

- Facility inventory.
- Facility assessment study (FAS).
- Contracts supporting facility operations.
- Energy star rating.
- Monthly PM and contract maintenance (CM) completion rates.
- Five-year review of projects for each facility.
- Three-year requirements for each facility.
- MFIP.

Having a basic knowledge on how FM works and what functions and personnel fall under its purview, will help you understand how to best collaborate on renovation and equipment projects. It will also ensure that you understand what goes into some of our requirements behind the scenes, and prepare you with some preliminary knowledge if you ever have the opportunity to work in FM.

010. Architectural and engineering requirements

Construction blueprints are a means for the owner, architect, and builder to communicate ideas and relate specific directions. Blueprints detail what is to be built, what materials are to be used, and how the job is to be done. A set of blueprints or working-drawings form the basis of agreement and understanding that a building will be built as it was planned.

Blueprint reading is the gathering of information from a blueprint. It involves two principal elements: visualization and interpretation.

Visualization is the ability to see or envision the size and shape of an object from a set of blueprints that shows several views of a building. Another important aspect of blueprint reading is the ability to interpret lines, symbols, dimensions, notes, and other information on the print.

This lesson will familiarize you with the basic components of structural requirements, blueprints, and blueprint interpretation. This will help you gain insight into the amount of thought and work that goes into your facility before the ground is ever broken for construction.

Structural requirements

As a BMET, you usually become involved with the blueprints on the interpretation level; that is, after the building is completed and you need to interpret specific information. This information might be the size of wire used in power distribution, the location of outlet circuit breakers and shutoff valves for gas and water lines, or the weight-bearing capabilities of walls and floor. However, many BMETs work in FM; with that job comes the responsibility of new construction or renovation projects. In either case, you are required to read blueprints to ensure your building meets specifications or to interpret information related to equipment requirements. When evaluating new equipment procurement or facility renovation projects structural requirements are a vital part of this process. Each section of a building has a weight capacity rating based on the structural support in place. You could not install a large MRI system or a bank of sterilizers in an area that does not meet the load bearing requirements. The effects of a mistake like that could be catastrophic. In some cases, it might be appropriate to reinforce the support in certain sections to meet a project’s requirements.

Similarly, rooms that house equipment capable of ionizing radiation have special requirements for lead lined walls. This ensures radiation is limited to minimize any unnecessary exposure. During construction projects, lead lining is a requirement that you need to address based on the projected intent and equipment used in that room. Some general areas that could warrant lead lining are standard x-ray rooms, OR suites (such as Cysto or Hybrid), Cath labs, mammography rooms, or CT rooms for instance. The health physicist is responsible for determining additional shielding requirements beyond minimum requirements established in the unified facilities criteria (UFC).

A facility's blueprints should be able to convey the elements you need from weight bearing capacity, to electrical layout, medical gas supplies, and even HVAC capabilities.

Blueprint components

A blueprint is a copy of a drawing that tells the owner, architect, and builder what the structure should look like when it is completed. For many years, the blueprint was the only type of reproduction used. It consisted of a print with white lines on a blue background. Today, the term "blueprint" is widely used to refer to all types of copies of construction drawings. The prints have changed to dark lines on a light background, referred to as whiteprints. These prints have symbology and a language unique unto themselves. For the purpose of this lesson, we will continue to refer to construction drawings as blueprints.

Symbology

Architects and engineers use symbols and abbreviations in blueprints to simplify their work. It would be extremely time consuming to draw out every little detail, and then explain specifically what it is. This alone would create stacks of blueprints three times as high as we have now. These symbols and abbreviations are adopted by the United States (US) of America Standards Institute. The symbols used are universal, ensuring all contractors using the blueprints understand each symbol and abbreviation. However, many architects and engineers like to customize some of the symbols. When using customized symbols, a legend is included to explain the meaning of nonstandardized symbols. You should be able to understand each symbol; not necessarily memorize each one, but know what material or component the symbol represents. The following table explains the seven symbol categories we are going to look at:

Category	Description
Material	Material symbols represent the different materials that may be used when constructing a building. Materials symbols are most often used on elevation views and floor plans.
Electrical	Electrical drawings use symbols and abbreviations extensively. Sometimes a symbol combines with an abbreviation further clarifying a component. In electrical drawings, circles and squares usually denote an electrical load. A letter placed inside of it indicates the type of electrical load or electrical device. Many of the symbols shown are very similar to one another; therefore, the easiest way to remember the symbol is to look closely at the basic symbols, and then look at the different lines and abbreviations added to that basic symbol that cause the symbol to change its meaning. When learning the electrical symbols, it might help to look at an electrical supply company catalog. Then, you can compare the symbol to the actual component. You will find there are often similarities between the component and symbol. The schematic is the engineer's blueprint of an electrical circuit. It differs from a builder's blueprint in it does not show the actual location of the electrical devices used in the circuit, but only the electrical relationship of one device to another. You are familiar with schematics, since you encountered them throughout the basic course and in your on-the-job training.
HVAC	HVAC units must be shown on HVAC drawings, as well as detailing the ductwork and piping required for these systems. The piping symbols for HVAC systems are the same as for plumbing blueprints.
Plumbing	In addition to showing all the piping necessary for a particular building, plumbing blueprints must include symbols indicating all fixtures, valves, and fittings.
Elevation and floor plan	Elevation views and floor plans are the most common types of blueprint used. The symbols encountered between these two types can vary. In an elevation view, it is customary for the component to look like the actual component, rather than using a symbol. Since this is not feasible in a floor plan, it is more common to use symbols.

Category	Description
Construction	Construction symbols illustrate the actual components required to support a structure. This helps the contractor know exactly what kinds of beams, studs, tubes, and so forth are necessary for a particular building.
Reference	Reference symbols are extremely important in identifying each blueprint. You can find these symbols on virtually every blueprint. These symbols are important because blueprints are jam packed with a lot of information. The symbols tell you where you can find the detail of the areas they are pointing.

Lines

A line in a blueprint is like a symbol. Lines are similar to symbols in that lines come in many weights and styles. The style and weight of a line depends on the particular construction method or meaning indicated in a certain blueprint.

Lines can be tricky symbols because their meanings change from field to field, or even engineer to engineer. For example a broken line (**- - - -**) can represent an object located behind another object on a blueprint; therefore, it is invisible. In an electrical blueprint, the broken line can represent wiring installed in the field by a service technician or electrician. A thin broken line can indicate low voltage wiring; a thick broken line can indicate high voltage. For this reason, you must look at the legend on the blueprint because the slightest difference in thickness or style can entirely change the meaning of the line.

Scales

There are three basic types of scales used for construction blueprints: architect, metric, and engineer. All three scales convey information concerning the dimensions of the building to people who are constructing the building.

Architect scale

When drawing a blueprint to scale, the architect reduces all lines in the drawing by the same ratio. For example, an architect may use a ¼″ line in the drawing to represent an actual 1-foot segment of the building. Think of dimensions on the drawing in terms of the actual dimensions of the building. The scale is always shown on the blueprint and looks something like this: SCALE: ¼″ = 1′–0″. Most architects use a certain distance to represent 1 foot. The distance the architect selects divides into 12 equal sections, each of which then equals 1 inch. Not all blueprints need to be drawn to scale. Normally a drawing marked “not to scale” shows some unusual feature or installation procedure. This type of drawing may be drawn to a different scale than the rest of the blueprints, and the dimension measurements are full size.

Metric scale

Architectural drawings often use a metric scale. The metric scale uses the meter (m) to measure distance, the kilogram (kg) to measure weight, and the liter (L) to measure volume. This includes prefixes representing multi- or sub-meters. A decameter equals 10 m and a hectometer equals 100 m; a centimeter is $^{1}/_{100}$ of a meter and a millimeter (mm), which is the most commonly used subdivision, is $^{1}/_{1,000}$ of a meter.

The main difference between a metric scale and an architect scale is the metric scale uses increments of 10, rather than increments of 12 as used in an architect scale. Architects sometimes use dual measurements in a drawing. This simply means the blueprint shows both the metric scale and the standard US dimensions. This eliminates the need for conversion. If dual dimensions are not used, a metric conversion chart often accompanies the drawings.

Engineer scale

When creating site plans, an engineer scale (also known as a civil engineer scale) is most often used. This scale differs from the architect scale in each inch in an engineer scale is divided into 10, 20, 30, 40, 50, or 60 equal units. These units can be inches, feet, yards, miles, or whatever else the engineer desires. The unit chosen usually depends upon the drawing size; however, in all cases, the unit chosen must be divisible by a power of 10 (i.e., the engineer scale may be 1 inch = 100 feet, 1 inch = 1,000 feet, etc.).

When an engineer creates a site plan, he or she places the engineer scale along the direction of the measurement needed (i.e., the property line). If the drawing is already created, you can obtain the length of the property line by simply reading the measurement on the scale. When using the engineer scale, just as with the architect scale, consider the drawn object as full size.

It is important you understand the scale you are dealing with when reading a blueprint or when trying to obtain accurate measurements from one. It is also important to understand the written language used on blueprints.

Blueprint interpretation

Your medical facility's blueprints may be in the facility manager's office or at BCE. As we have said, these blueprints are required for you to perform your job above and beyond the common mechanic. They provide a vast amount of information useful during preprocurement, installation, room modification, valve locating, sizing wires, and so forth. Unfortunately, that stack of blueprints can be quite daunting to someone who does not know exactly what to look for.

Blueprint categories

Blueprints, sometimes referred to as working-drawings, provide the details of size and shape description, materials used, finish, and other special details of construction. A complete set of blueprints is usually comprised of eight categories—site plan, foundation plan, floor plan, elevation drawings, sectional drawings, structural framing plans, mechanical plans, and electrical plans.

Site plan

A site plan (fig. 1–22) shows a view of the building on the property as seen from overhead. This plan is drawn to scale, and details the sidewalks, trees, and any other existing features. There are two types of site plans that can be drawn—land surveyor and architect.

The land surveyor typically prepares the initial site plan, based on the property deed. This initial plan shows only the lengths of the property boundaries. Sometimes, a complete field study is performed in addition to the property survey, and includes land characteristics (i.e., whether the land is wooded, hilly, etc.).

When an architect draws a site plan, it is normally very detailed. This plan usually includes property lines, existing and new contour lines, water and telephone lines, and electrical power lines. The architect may include precise notes concerning which side of the building faces north, the names of the property owners surrounding the building, monuments, and so forth. The architect also provides a legend, which is a list and description of symbols appearing on the site plan.

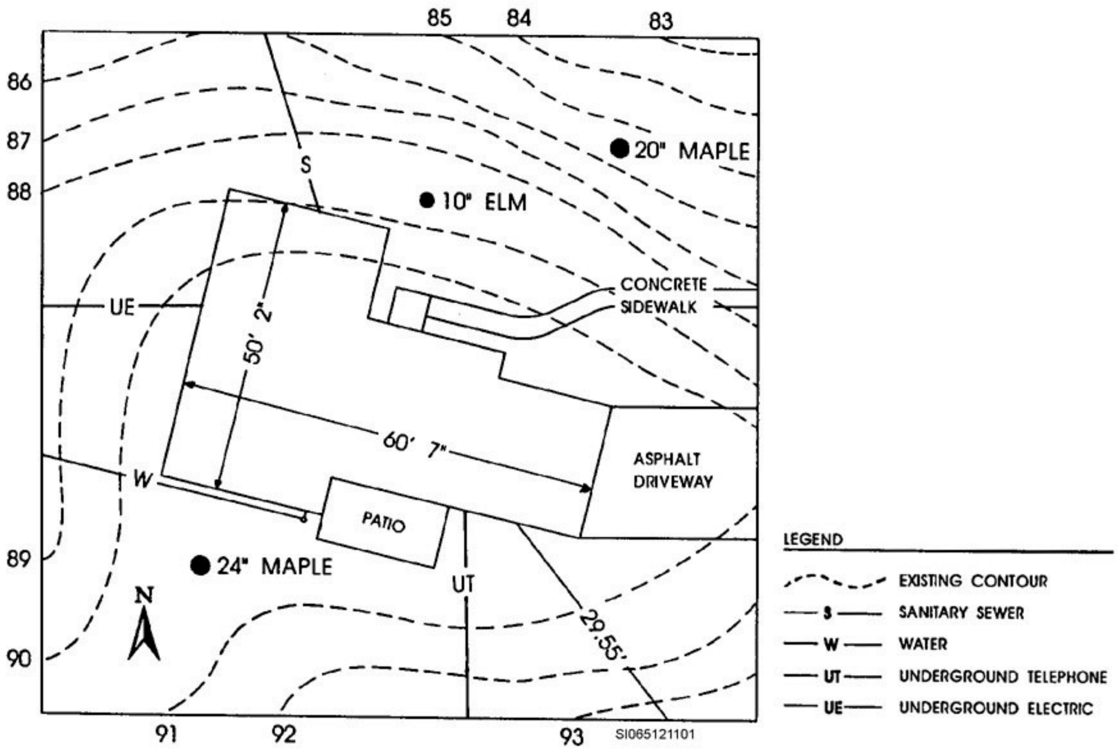


Figure 1–22. Site plan.

Foundation plan

This type of plan shows the contractor where to locate the footings, foundation walls, sills, columns, and girders.

Footings distribute the weight of a building over a sizable area. The material most often used for footings is concrete, as it can withstand heavy weights and does not decay. If needed, you can use steel to reinforce the concrete. Footings basically provide the support for the building under the ground line.

Foundation walls support the weight of the building above the ground. This weight transfers to the footings. Foundation walls are generally made of concrete; however, suitable substitutes consist of items like stone or brick. If the building has a basement, then the foundation walls are also the basement walls on the foundation plan.

Sills are normally made of wood and fastened to the foundation with anchor bolts. The main purpose of sills is to provide a base to which the exterior walls can attach to the foundation. Most local codes require installation of a sill with some sort of termite protection, as the sill is made of wood and located near the ground line.

Columns are normally made of wood, brick, or concrete, and used to support the floor. In some types of construction, columns may be the only support structure. Foundation wall also use columns.

Girders are horizontal supports placed underneath the floor. They rest on columns and secure to the foundation wall. Wood is the typical construction material for girders.

Floor plan

A floor plan is a very important blueprint as it contains the most information concerning the design of a building. Floor plans are basically complete views of each floor as they appear from overhead. These plans include the locations of all doors, windows, walls, and so forth. The floor plan covers every item located between the floors and ceiling. Floor plans also show HVAC, electrical, and plumbing systems. Use these type plans as templates for various other plans (i.e., plumbing and wiring). There are two types of floor plans: general design and working-drawing floor plans (composite):

- The general design floor plan shows only the basic layout and arrangement of the area. Since it doesn't include much detail, it is primarily used for sales purposes. There is insufficient information on general design floor plans to be used in construction, however, they are drawn to scale and include the dimensions of each room. These features assist a facility manager to determine the square footage of an area which is needed when writing a housekeeping contract, or creating a template for fire evacuation, or as a basis for future remodeling (i.e., carpet replacement, painting, or wall coverings).
- The working-drawing floor plan (or composite floor plan) is used during construction and is far more detailed than the general design. The main purpose of these drawings is to provide the contractor with the information necessary to correctly interpret the architect's design. These floor plans diminish the confusion that may exist between the architect and contractor.

Large medical facilities have several floor plan sheets. There is usually a floor plan for each separate floor; if the building is split into zones, each zone has a floor plan. That makes it much easier to show the amount of detail required for construction.

Elevation drawings

Elevation drawings depict the exterior or interior walls of a building. Usually, there are four elevation drawings needed to show the design of a building from all sides. Hence, there are right, left, front, and rear elevations. More elevation views are required for buildings of unusual design (i.e., those with more than four sides or internal courtyards).

When floor plans represent the horizontal arrangement of a building, interior and exterior elevations will depict the vertical design of a building or walls. Often, interior elevation drawings will indicate cabinets, including height and depth. Interior elevation drawings are sometimes prepared with the floor line on the bottom of the drawing.

Sectional and detail drawings

Sectional drawings show the construction of walls, stairs, or other details not clearly shown on the elevation, floor plan, or framing drawings. These sectional views are known as detail sections and usually are drawn to a scale larger than that used for the elevation and floor plan drawings. Detail dimensions showing the thickness of finished and sub-floor materials, joist sizes, molding location, and so forth provide essential construction information. Sectional views can be drawn as transverse or longitudinal. A transverse view takes you through the narrow width of an entire building; longitudinal takes you through the long dimension of the section you are viewing.

Detail drawings are required when performing special or unusual construction. Frequently, these are detailed views of some special feature (i.e., an arch, cornice, doors, windows, or retaining wall) drawn to a larger scale to clearly describe the manner in which the construction is to be performed.

Structural and framing plans

These plans show the many elements needed to provide a building with strength and support. No matter what materials or techniques are employed, the principles used in structural design never change from one building to the next. The footings support foundation, which supports the walls, which support the roof. Every building requires many different types of framing plans (i.e., floor, wall, and roof framing plans).

Framing plans depend on the type of weight each element will carry once the building is complete. This weight can be classified into two categories—live weight and dead weight.

- Live weight varies from building to building, depending on where the building is located and how it is used. Wind, snow, rain, people, and furniture are types of live weight.

- Dead weight consists of the weight of the materials used to construct the building. This weight does not vary once the building is complete unless there is a building modification.

Mechanical plans

These plans include the information needed to install the HVAC and plumbing systems, including the complete layout of those systems, as well as other drawings to illustrate the mechanical systems. Basically, the mechanical plans cover the areas that affect the comfort level of the people occupying the building.

Electrical plans

The architect does not actually create the electrical plans; instead, the architect hires an engineer to design the electrical system. Like the mechanical plans, these plans are normally comprised of several types of plans already discussed (i.e., site, floor, and elevation plans). To read electrical blueprints, you must have a working knowledge of electrical circuits and symbols.

Blueprint storage and care

Until recently, all record drawings were hard copies stored in flat file drawers in a room with reinforced walls and a heavy steel door. Some of your units will still have these rooms. The reason for the special location of drawings is that many of these documents have significant historical and legal value. In addition, these drawings are often the only record of how a facility was put together. When an engineer has to plan an addition to a building or someone in the shops needs to troubleshoot an electrical problem, the record drawings are usually the first place they look. Now, a handful of installations have fully electronic vaults with no hard copies at all. Most installations have a mixture of computer aided drafting (CAD) drawings, scanned drawings, and traditional hard copy drawings.

Blueprints and related specification sheets are as important as the tools you use. With proper care, hardcopy blueprints can be kept usable for a long period of time. Rules of care you should observe are:

- Never write on a print unless authorized to make changes.
- Keep prints clean and free of dirt and oil.
- Fold, roll, or hang prints carefully to avoid tearing.
- Do not lay sharp tools or pointed objects on prints.
- While in use, lay prints in a safe and secure place to avoid being stepped on or damaged.
- When not in use, store prints in a clean, dry place.

Self-Test Questions

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

008. Facilities program overview

1. Who is responsible for daily operations and overall facility upkeep?

2. What is detailed in the Interim Life Safety Measures (ILSM) policy?

3. Describe the MTF safety officer’s role.

4. Who appoints the safety officer in writing IAW TJC guidelines?

5. The safety officer coordinates actions with which organizations?

6. Who conducts facility maintenance in an MTF?

7. Who oversees the facility maintenance contract?

8. What Air Force contract governs housekeeping services for medical facilities?

009. Environment of care

1. What is the focus of the EOCC?

2. Who generally chairs the EOCC?

3. As a BMET, what equipment maintenance statuses are you responsible to brief the EOCC?

4. List the six functional areas of TJC’s EOC management plans.

5. What topics must each management plan address?

6. What does the medical equipment management plan describe?

7. What source authorities can you use to manage medical equipment recalls?

8. What determines intervals for inspecting, testing and maintaining high risk and non-high risk medical equipment?

9. What is the purpose of the MFIP?

010. Architectural and engineering requirements

1. What do blueprints detail?

2. What are the two principal elements of blueprint reading?

3. Why do rooms that house equipment capable of ionizing radiation require lead lined walls?

4. Who is responsible for determining additional shielding requirements beyond minimum requirements established in the UFC?

5. Why are symbols and abbreviations used on blueprints?

6. Where would you find the explanation of a nonstandardized symbol?

7. What are the seven symbol categories?

8. What is a schematic? How is it different from a builder's blueprint?

9. What are the *most* common types of blueprints?

10. What are the three basic types of scales used on blueprints?

11. What is the *main* difference between an architect scale and a metric scale?

12. When is an engineer scale most often used?

13. Name the eight categories of blueprints.

14. What type of plan shows the contractor where to locate the footings, foundations, columns, sills, walls, and girders?

15. What blue print contains the most information concerning the design of a building and serves as a template for other drawings?

16. Briefly describe the two types of floor plans.

17. How many elevation drawings would you need to show the design of the whole building?

18. What is the principle of structural design?

19. What are the two types of weight? Describe what you would consider in each weight.

20. Who designs the electrical system and plans?

21. What are the six rules of care for a blueprint?

1–4. Building Utility Systems

Imagine, if you will, that the MTF is a human body. Building systems are the blood flowing through the MTF. Like the blood flowing through your veins, you know it's there, but you can't see it. Let the blood stop flowing and you have serious problems. The same is true of a MTF's medical gas, HVAC, or plumbing systems. If one of these systems fails, you have serious problems, ranging from the comfort of patients and staff, to the inability to perform surgery because of a lack of gas or airflow. Understanding the basics will help you to communicate with the BCE, contractors, or MTF commander when necessary.

As a BMET working in FM, you will be responsible for coordinating repairs and inspections, and ensuring compliance with the regulatory agencies for various building systems. As a BMET working in the maintenance shop, you may need to locate a valve to shut off oxygen to a treatment room so you can replace a quick disconnect or a water valve when installing a sterilizer or scope washer.

This section will familiarize you with the basic principles and components of central gas, HVAC, and plumbing systems.

011. Central gas systems

Every MTF has some type of central gas system, which is composed of three major components:

- A central supply of gas (i.e., oxygen [O_2]).
- Pipelines that transport the gases to the various end points in the MTF (i.e., surgery).
- Connectors at the end points to which equipment that use the gases are connected (i.e., an anesthesia machine).

The system might be in the form of liquid oxygen (LOX) bulk systems at a large MTF, or a manifold system using individual cylinders in a small MTF. In this lesson, we will focus on the O_2 systems. See Figure 1–23 below for an in-depth flow map of how the medical gas systems you will learn about interrelate with each other from central supply to common endpoints.

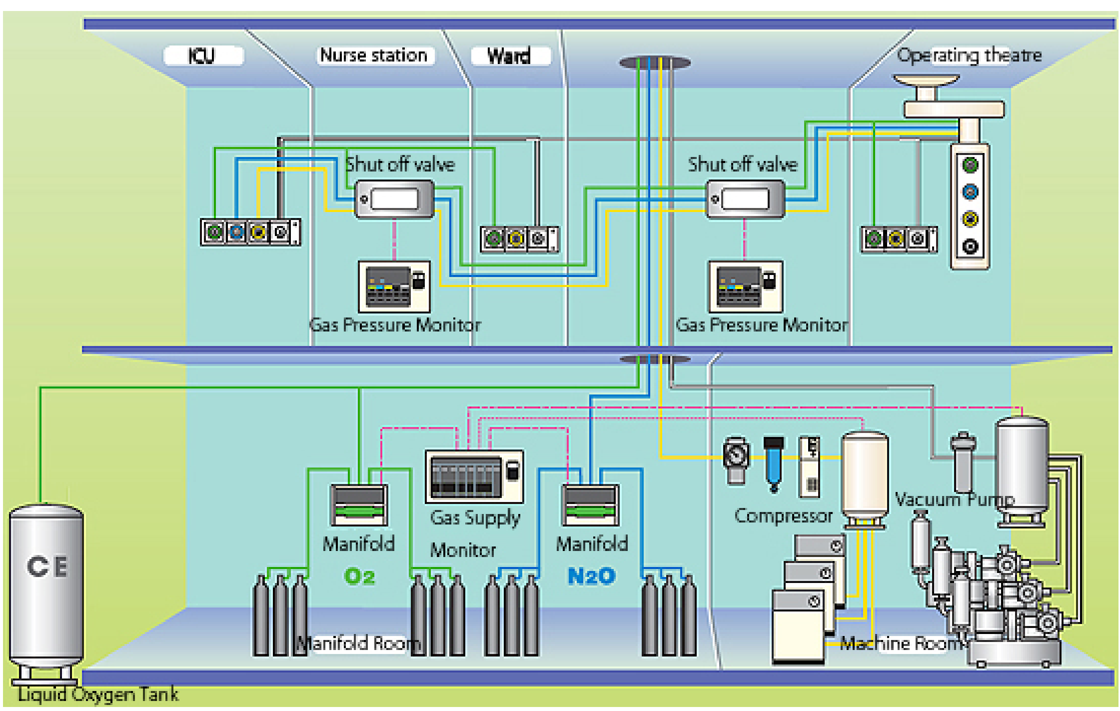


Figure 1–23. Medical gas flow map.

Let's take a closer look at the two types of central gas systems.

Bulk storage system

If an MTF uses a large volume of O_2, then it generally has a bulk storage system. Bulk systems are the most cost effective method for supplying large amounts of O_2. The storage tanks are located outside of the MTF, away from flammable materials and public areas. The reason we consider these bulk storage systems economical is because they use LOX. As LOX warms to room temperature, one cubic foot of LOX expands to 860 cubic feet of O_2 gas. One cubic foot of LOX is equal to 3½ H-cylinders of O_2 gas. Smaller MTFs use replaceable LOX cylinders.

LOX is stored in special two-layer containers that use insulation and near vacuum to keep the LOX at –297°F and at a pressure of approximately 85 pounds per square inch (psi). LOX converts to O_2 gas in two different ways, depending on the volume of use. Here is a simplistic overview of how LOX becomes O_2 gas (fig. 1–24). During normal use, the gaseous O_2 is pulled off the top of the container. It then passes through a super heater that warms the gas, and then onto the pressure regulator where the pressure is reduced to 50–55 psi for use in the MTF. During periods of high use, the system pulls LOX directly from the bottom of the tank. The LOX passes through a vaporizer that converts the LOX to O_2 gas. The O_2 gas goes through a super heater, then through the 50–55 psi regulator, and, finally, to the MTF.

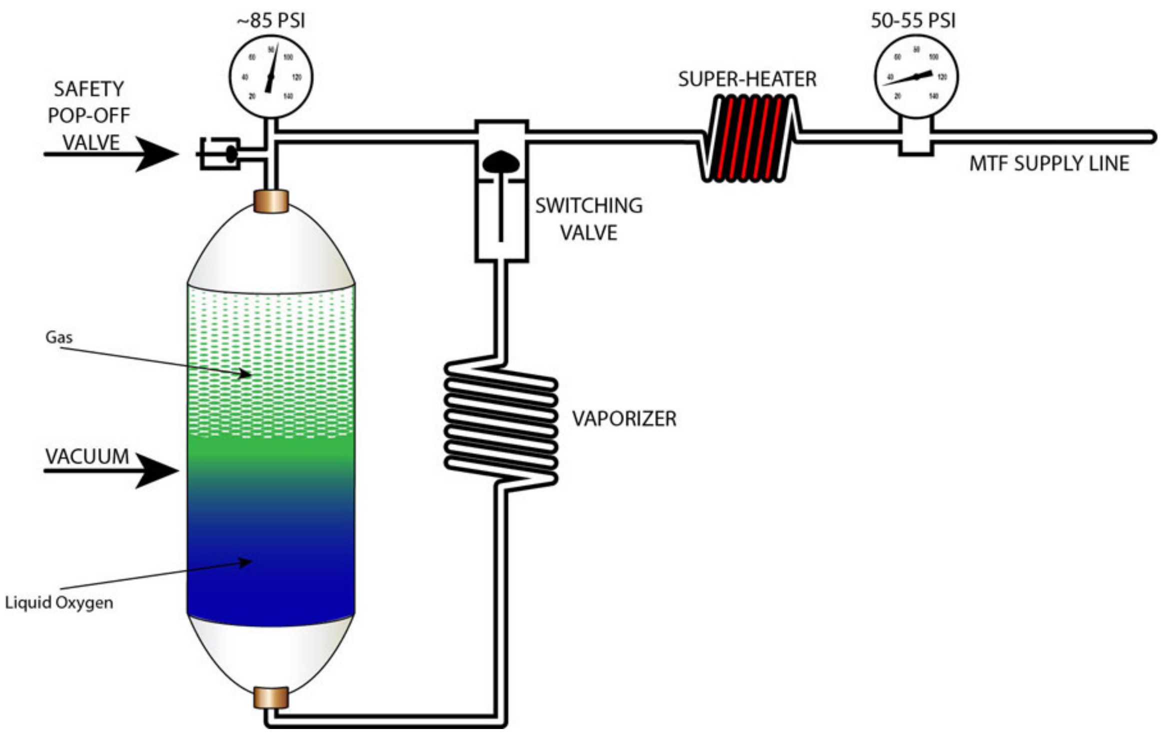


Figure 1–24. Bulk liquid oxygen storage.

As with any medical system, you must look at some safety aspects. Fire is the biggest danger; although LOX is not flammable, it does support combustion, making a small fire into an inferno. You can also receive freeze burns if you come into direct contact with LOX or touch an uninsulated pipe carrying LOX.

Manifold system

The manifold system can use LOX cylinders or standard H-size O_2 gas cylinders. The H-size O_2 gas cylinder has 2,200 psi when full. These cylinders are connected to the primary and secondary banks of a manifold. The primary and secondary banks are identical and interchangeable by design. Do not confuse the secondary bank with a separate reserve system, which we will discuss later. Since we have already looked at how the LOX from a bulk system gets into the MTF, let’s take a simplistic look at how O_2 gas from the H-cylinder gets into the MTF (fig. 1–25). The O_2 gas flows through a switching valve to a regulator that reduces the O_2 gas to 50–55 psi for use in the MTF. The manifold uses automatic switching to change from the primary bank to the secondary bank. Only one bank is in use at any one time. If the manifold can hold eight O_2 gas cylinders, four cylinders will connect to the primary bank and four to the secondary bank. As the gas used in the primary bank depletes, the system automatically switches over to the secondary bank.

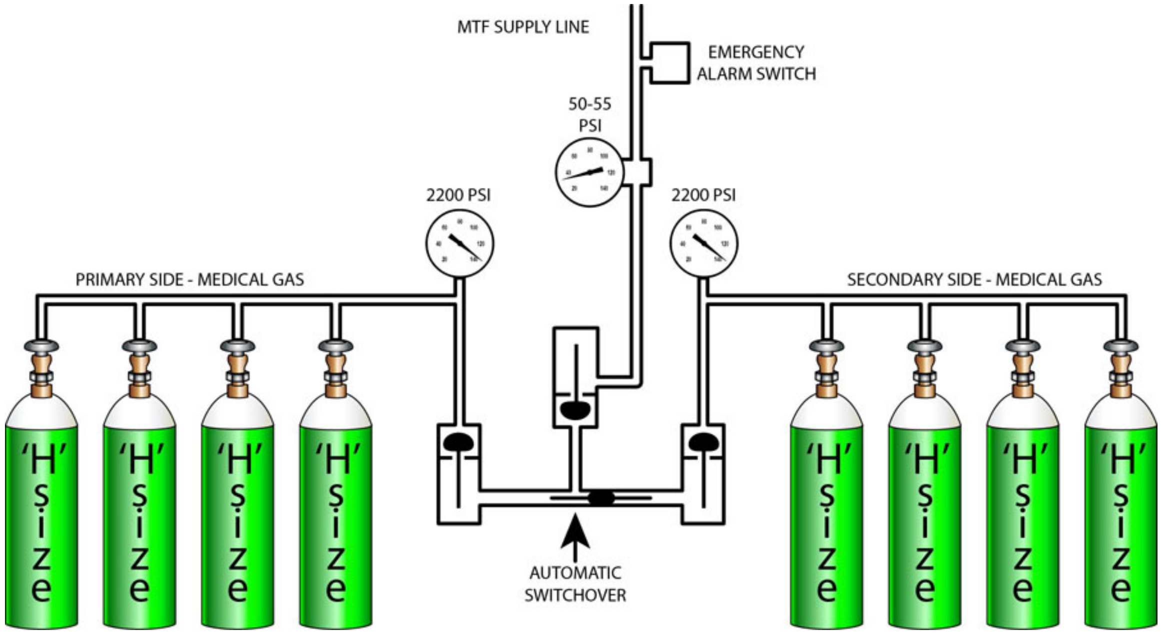


Figure 1–25. H-cylinder manifold system.

Safety features

All O_2 central gas systems have a multitude of built-in safety devices. There are alarms that activate when the supply is low, pressure alarms that activate when the pressure varies by ±20 percent from the normal operating pressure of 50–55 psi, and pressure relief valves that open if the pressure in the system exceeds the normal level by more than 50 percent.

The alarms should be located in three different places in the MTF. There should be a local alarm at the site of use, an alarm in FM, and an alarm in a location manned 24 hours a day (e.g., the emergency room).

Reserve systems

MTFs are required to have a reserve system in case of a catastrophic failure or running out of O_2. Large MTFs are required to have a reserve LOX system. Smaller MTFs with the bulk systems might use the LOX cylinders (fig. 1–26) or the H-cylinders in a manifold setup. Regardless of the type of reserve system, MTFs are required to keep a reserve supply of O_2 on hand equal to the average daily use of O_2 in that facility.

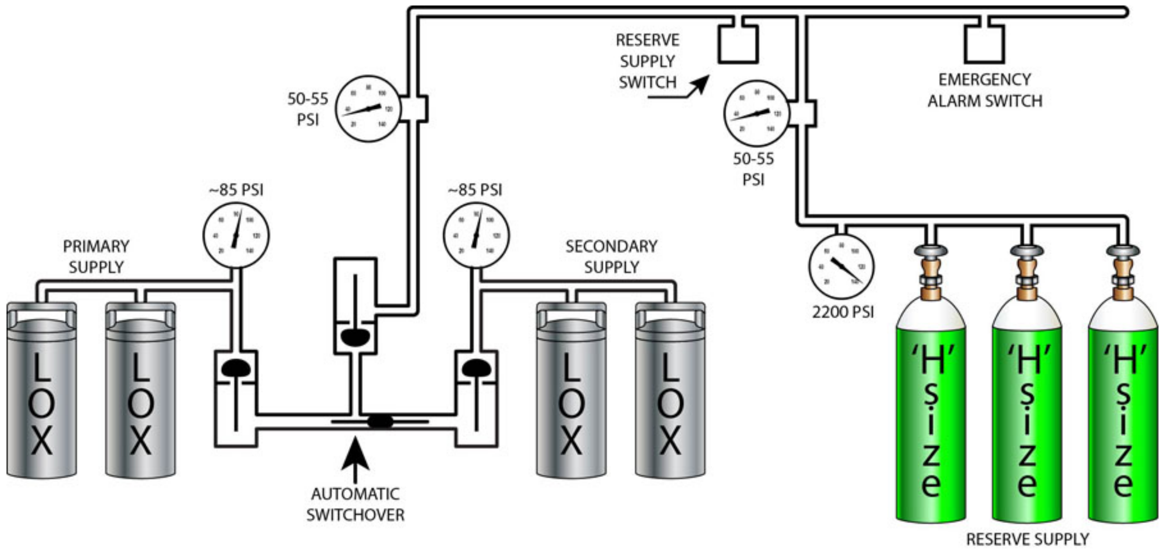


Figure 1–26. LOX manifold system with reserve.

Zones

The zones of the MTF are set up according to the basic design of the building. Think of it as spokes on a wagon wheel. The hub of the wheel is the source of the gas pipeline and the spokes are the actual pipeline. Cutoff valves are located on these spokes to isolate the different areas for servicing. In case of an emergency (i.e., fire), the cutoff valves allow the area affected to be shut off, while other unaffected areas still receive O_2. Surgery, which is generally the largest consumer of gases, is located at the end of the line.

Inspection, certification, and testing

When would you perform an inspection and certification of a gas system? According to the National Fire Protection Association's *NFPA 99: Health Care Facilities*, all new gas systems require inspection. If you make any additions or repairs to the current gas system, the system (including purging the system with an inert gas) requires re-certification.

You should thoroughly test the system to ensure the line pressure maintains at the proper level (50 – 55 psi for O_2). Ensure the pressure relief valve vents when pressure exceeds the 50 percent of normal operating pressure. Be sure to test the high- and low-pressure alarms, as well as the various cutoff valves. All of these valves and alarms should be marked on a facility map.

You are also required to perform a medical gas concentration test. This ensures purity of the medical gases measured at the source and outlet. To test the concentration, you should use an instrument designed to measure the specific gas. Medical gases (i.e., O_2, nitrous oxide N_2O, and nitrogen) should be at least 99 percent pure. Medical air must be between 19.5 and 23.5 percent O_2. All other gases should be ±1 percent of the manufacturer's labeling.

Connection

To interface the medical gas system with medical equipment, you need some type of connector. There are two basic types of connectors in use today. The first of the connectors is called a quick-disconnect or quick-coupler. This type of connection allows the medical technician to rapidly connect or disconnect the equipment from the gas system. The connections are color coded, and also keyed or pinned to prevent mix-ups. The second type of connector is the diameter index safety system (DISS), which you already learned about in the 4A251A set. Using this system, each gas line has non-interchangeable threads that are gas specific.

Other piped systems

Let's take a brief look at some of the other medical gas systems you will find in an MTF.

Medical air

The O_2 concentration of medical grade air ranges from 19.5 to 23.5 percent O_2. You can obtain medical grade air (21 percent O_2 and 79 percent nitrogen) from cylinders containing medical-quality filtered air, air compressors, or very complex mixing systems that mix O_2 and nitrogen from a central source. It travels from the source to a pressure regulator, on to the piping system, and finally, the termination point. Compressors are the most common, so let's look at them.

The medical air compressor system requires two separate compressors—each can meet the MTF's medical air needs. The compressor's air intake is located away from streets or any potential source of carbon monoxide or other forms of exhaust, including the hospital's vacuum and waste anesthetic gas disposal (WAGD) exhaust or plumbing vents. The system dries the input air to remove water vapor, and then filters it to remove oil, dirt, and other contaminates. Keep the piping above freezing temperatures. The piping system also includes the same types of alarms and valves as the O_2 pipeline.

Nitrogen

The nitrogen pipeline system is used primarily to power instruments in the surgical suite. This system uses H-size nitrogen tanks and follows the same principle as the manifold system mentioned earlier. The general components and inspection criteria remain the same.

Nitrous oxide

MTFs that have a greater need for N_2O than the cylinders attached to an anesthesia machines provide, will use N_2O pipeline systems. Like the O_2 system, it is a banked manifold system with an automatic switchover. Naturally, the same rigid requirements for valving and inspections apply.

Central vacuum

The MTF's central vacuum system is not really a source of medical gas, but it is no less important than the gas systems mentioned previously. Central vacuum systems require the same type of attention as any medical gas system. You find a central vacuum in several places in the MTF (e.g., surgery, minor surgery, emergency rooms, special care units, maintenance shop, etc.).

Like the medical air system, central vacuum systems must have two independent pumps—each capable of maintaining the peak vacuum load. There is automatic switching from one pump to the other in case one of the pumps fails. The system must connect to emergency power, if it is available. The pumps should be located away from the medical air compressor intake, and the O_2 and N_2O storage areas. The traps that collect solid and liquid contaminants require cleaning periodically and proper waste disposal. The pipeline requires protection from low temperatures to prevent condensation in the lines.

Surgery has a vacuum requirement to be able to remove 99 L of air per minute, while areas outside of surgery only have an air removal requirement of 28–57 L of air per minute. How far away the end point is located from the source and the total flow in the system will determine the amount of vacuum generated in any particular part of the MTF.

For an in-depth study into medical gas systems, refer to NFPA 99: *Health Care Facilities* and NFPA 50: *Standard for Bulk Oxygen Systems at Consumer Sites*.

012. Heating, ventilation, and air conditioning

The HVAC system in the MTF maintains a comfortable working environment for patients and staff members. The HVAC system also meets standards and regulatory requirements by providing the required room air exchanges in places like the clinical laboratory, surgery, nuclear medicine, and patient isolation areas. In MTFs, we use chilled water systems for central air conditioning because of the ease with which water circulates in the system. If we piped refrigerant throughout the facility, it would cost a great deal of money to charge the system and could lead to an environmental disaster if that amount of refrigerant leaked into the atmosphere. Figure 1–27 shows a representation of a basic HVAC system.

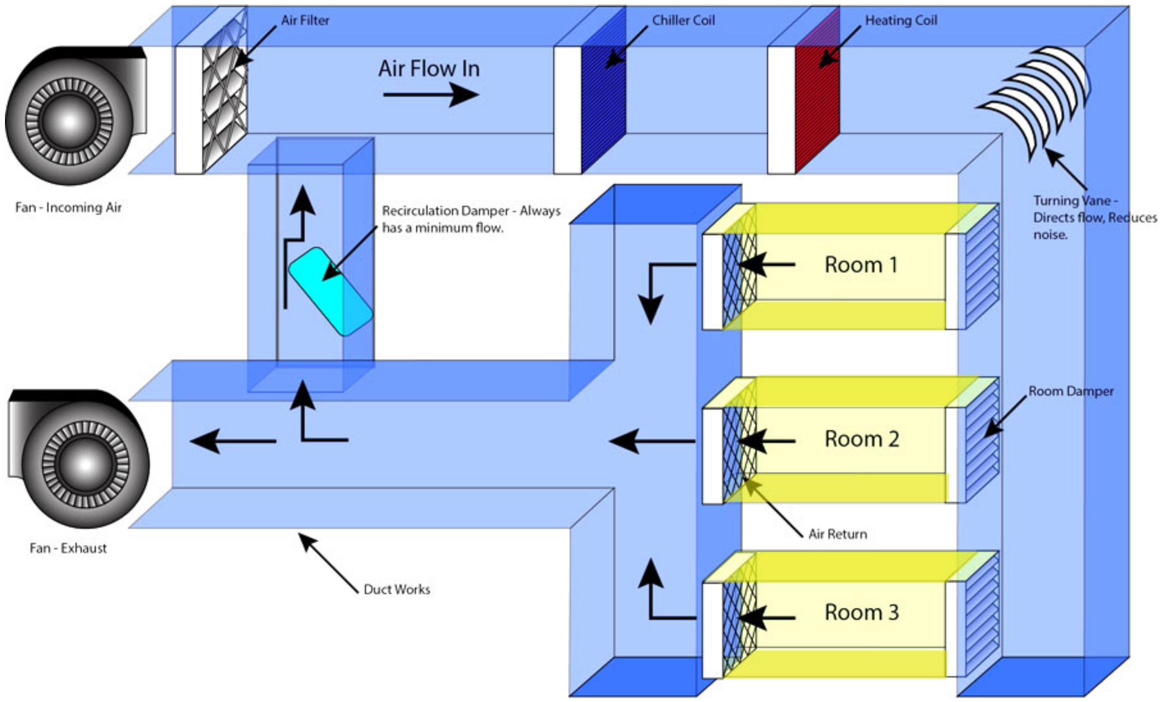
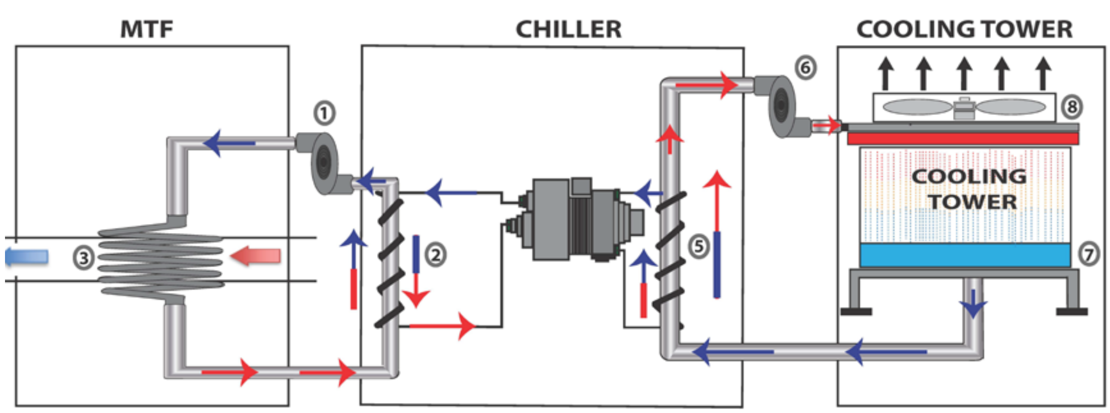


Figure 1–27. Basic HVAC system.

Chiller operation

The whole function of a chiller is to remove heat. To get an idea of how a chiller works, you must first think of a system with two closed water loops, and then add in a closed refrigeration loop with an evaporator, condenser, compressor, and refrigerant. Last, you have a treatment room, office, corridor, or surgical suite in the MTF that needs to be cooled. In this discussion of the chiller, please refer to figure 1–28.



1. Recirculation pump.
2. Evaporatation coil - absorbs heat from water, chilling the water.
3. Chiller coil - located in the ducts in the MTF.
4. Compressor.
5. Condenser coil - heat is absorbed from the refrigerant by the water.
6. Circulation pump.
7. Cooling tower - releases heat from the water into the surrounding air.
8. Fan - blows air through the cooling tower to help cool the water.

Figure 1–28. Chiller operation.

The first water loop flows through a circulation pump, to the chiller, and across the evaporator coil, which absorbs the heat from the water, chilling the water. The water then flows through chiller coils located in air handlers or induction units somewhere in the MTF. Unconditioned air blows across the chiller coil and the chilled water in the coil absorbs the heat cooling the air. Then, the water goes through the system again. Where does the heat absorbed by the evaporator coil go? The refrigerant in the evaporator absorbs the heat, and the refrigerant then passes through the compressor and on to the condenser coil. At the condenser coil, the heat in the refrigerant is absorbed and transferred to the water flowing across it. This is the second water loop. The water in this loop, once heated by the condenser coil, goes to a circulation pump, which sends it to the cooling tower. At the cooling tower, the water is exposed to outside air, which, aided by large fans, absorbs the heat. After the water has cooled, it goes through the cycle again.

Boiler

In a large MTF, a boiler typically supplies the heat. The boiler has two sides—waterside and fireside. The boiler uses natural gas or oil as a heat source. The boiler tank has an input water supply line, an output steam main line, and a condensate return line. In most cases, the boiler produces high-pressure steam at 100 psi.

NOTE: Any steam pressure above 15 psi is classified as high-pressure steam. Conversely, any steam pressure at 15 psi or lower is low-pressure steam.

The 100-psi steam then branches off where pressure regulators reduce it for use in various areas of the MTF (i.e., 60-psi steam for autoclaves, 15-psi steam for various kitchen equipment, and 5-psi steam for heating).

As stated, the 5-psi steam is used for heating. The heating is done by passing steam through a heating coil in the air handlers or induction units located somewhere in the MTF, and then blowing unconditioned air past the coil. The air absorbs the heat from the heating coil, which, in turn, cools the steam. As the steam cools, it starts to condense and flows as hot water back to the boiler.

Air handling unit

The air handling unit (AHU) is a mechanical system consisting of:

- An enclosed housing.
- Supply air fan(s).
- Heating and cooling coils (evaporator).
- Filters.
- Return air dampers.
- Return air fan(s).
- Relief air dampers.

Fans inside the AHU accomplish that actual movement of the air.

Distribution system

The distribution system is what disperses the tempered air to the rooms or areas. The distribution system contains several components, including the ducts and dampers.

Ducts

The ducts are the channels that carry the air from the AHUs to the area requiring the tempered air. Duct sizing varies according to the heat load of the area requiring tempered air, as well as how far from the source of the tempered air the area is located. Ducts also return the air to the AHU.

Dampers

The dampers are pieces of equipment in the duct system that controls the flow of air through the system. Depending on how far the damper is open determines how much air flows.

There are also types of dampers that control smoke and fire. When the AHU detects smoke or fire, it shuts off through control circuits and these dampers close immediately. Smoke dampers activate with a photoelectric eye, while fire dampers operate on a fusible link or electronic circuit. These two dampers prevent the spread of smoke and fire through the duct system. Without these dampers, the duct system becomes an excellent chimney.

Cooling tower

All cooling towers work in a similar manner; they dissipate the heat gained in the condenser through evaporation. As the water moves through the tower, the surface area of the water is increased and air is pulled across the water to enhance the evaporation. The different methods used to increase the surface area of the water are part of what makes one cooling tower different from another.

Energy management and control systems

Energy management and control systems (EMCS) is a BCE section located on base that monitors and controls the MTF's heating and cooling needs. Through the use of computers, EMCS can detect problems with the AHU and correct them.

The term EMCS is another name for the hospital's control system. While it is mostly used by the civilian hospital industry, you might hear it used at your MTF.

Terms

The following table provides a list of terms you should be familiar with:

Term	Definition
HEPA filter	High-efficiency particulate air (HEPA) filter.
Return	Airflow out of a room, back through the ducts, to the AHU.
Positive pressure	When the air pressure inside a room or building is higher than the air pressures outside the room or building. This creates airflow out of the room or building. This is a desirable condition in surgical suites, newborn intensive care rooms or when a patient has a compromised immune system where protecting them from germs, viruses, and dangerous substances is important. Positive pressure is undesirable in a tuberculosis isolation room.
Negative pressure	When the air pressure inside a room or building is lower than the air pressure outside the room or building. This creates outside airflow into the room or building and prevents airborne contaminants from escaping. This is undesirable in a surgical suite, but is normally required in areas with airborne contagious diseases such as tuberculosis, measles or chickenpox isolation rooms, or nuclear medicine hot labs. Negative pressure keeps germs, viruses, and harmful substances confined in an area, protecting the staff and other patients.
Air changes	The number of times the volume of air in a given space is completely replaced in a given period of time.

013. Plumbing systems

Over the course of your career, you will need to understand how plumbing systems work and how that applies to your duties. In this section, we discuss the basic knowledge of piping, including the different types of pipes as well as the medical equipment applications.

Types of pipe and tubing

There are many different types of pipe, tubing, and fittings used in plumbing. The types of pipe used most often in hot and cold water systems are galvanized steel, plastic, and copper. Always make sure you are using materials designed for the system you are working on. This lesson will cover some of the more common types currently used. This is by no means an all-inclusive list. As older piping systems made of iron, clay and asbestos-cement require repairs; we are instead replacing them with the newer, safer, and more cost-efficient materials available today.

Plastic pipe

Water, waste, and gas systems use hard and flexible plastic pipe. It is commonly available in sizes from ½ –18 inches in diameter. Rigid pipes usually come in 20 foot lengths. Flexible forms come in different lengths or long coils for large and smaller pipe. It is easy to use and will not rust, rot, or corrode.

There are many types of plastic pipe. You can find some in the table below:

Type	Use
Acrylonitrile-butadiene-styrene (ABS)	ABS is a rigid pipe used for building drain, waste, and vents (DWV).
Polyvinyl chloride (PVC)	PVC is a rigid pipe normally used in water distribution systems (WDS). PVC piping typically comes in schedule 40, schedule 80, and DWV. Schedule 80 PVC is thicker and stronger than schedule 40. Use DWV in sanitary waste systems only.
Chlorinated polyvinyl chloride (CPVC)	CPVC is a rigid pipe similar to PVC but special development allows it to withstand higher temperatures than other plastics. It is normally rated for 180°F at 100 psi. Because of its excellent resistance to chemicals, CPVC is now available in larger sizes for DWV applications. Hot WDS typically use CPVC.
Polybutylene (PB)	PB is flexible tubing used for cold water building supply and underground sprinkler systems. PB is widely used in mobile homes due to its expansion/contraction characteristics.
Polypropylene (PP)	PP is rigid piping used for industrial applications (water and wastewater treatment) involving corrosive media. PP may be used at temperatures to 150°F, in continuous pressure service, and at temperatures to 180°F, with gravity flow conditions. PP is very lightweight, and has good chemical resistance. PP is commonly available in schedule 40 and 80.
Polyethylene (PE)	PE is flexible piping used for industrial piping systems, as well as for buried gas and water pipelines. The major benefits of PE are that it is virtually unbreakable due to impact and low temperatures, exceptionally resistant to abrasion, and good chemical resistance. PE typically comes in three strengths low, medium, and high density.

Cross-linked polyethylene pipe

Cross-linked polyethylene or PEX pipe is the newest plastic type used for plumbing in North America. Although not yet widely used, Europe implemented PEX for several years without problems. It is very flexible and capable of making turns greater than 90 degrees, therefore using fewer fittings. PEX pipe works well for both hot and cold service and, with the proper fittings, can easily connect to existing pipes of varied materials.

Copper

Water supply and drainage systems are the biggest uses of Copper tubing. It is lightweight, easily installed, and resists corrosion. The type of tubing you use depends on the system and location of installation. Hard- drawn copper tubing is available in 20 foot lengths or less and soft-drawn (sizes up to 1inch diameter only) in 25- to 100-foot coils. Copper tubing interconnects by soldering or by compression-type fittings.

Steel pipe

Steel pipe comes in two basic types: galvanized and black iron. Black-iron pipe is actually steel pipe painted black. Its name carried over from when the pipe was first made of only iron. Steel is composed of an iron-carbon alloy, which increases its strength. Black-iron uses include natural gas distribution lines and fuel system piping. Galvanized pipe is primarily for cold and hot WDS, drainage systems, and vent installations in buildings. Steel pipe is manufactured in standard lengths of 21 feet with diameters from 1/8 inch–24 inches. Galvanizing extends the pipe's life span by reducing corrosion, such as rust. However, galvanizing does not strengthen the pipe itself. Steel pipe is threaded for assembly. The threads on the pipe, as well as those in the fittings, are tapered to assure a tight joint.

Stainless steel pipe
Stainless steel pipe's iron-carbon chromium alloy composition allows it to carry liquids that are corrosive to other metals. It is a common application in newer hydrant fuel systems, but because of its cost, you will rarely see it in water and waste systems.

Ductile iron pipe
Ductile iron pipe generally is available in diameters from 2–48 inches and lengths to 20 feet. It is used for water distribution or drainage systems. The advantages of ductile iron pipe include long laying lengths, tight joints, higher corrosion resistance than cast iron, ability to withstand relatively high-pressures, and easy to work with.

Cast-iron soil pipe
Use cast-iron soil pipe in drainage systems. Manufacturers produce cast-iron soil pipe in service weight and in extra heavy weights. Each section is usually 5 or 10 feet long and joined with bell and spigot or hubless joints. The pipe extends diameters of 2–15 inches.

Causes of pressure loss
Capacity loss is a decrease in the carrying capacity of pipelines (over time). Common causes are increased friction in the system like a partially closed valve or buildups in the interior of the pipe, which decreases the interior diameter. The causes of increased roughness or decreased line size are corrosion, pitting, tuberculation or small "mounds" of rust inside the pipe, sediment deposits, slime growths, and air accumulation at high points in the system.

Leaks
Leaks are a major cause of pressure loss in the WDS. Most of the time leaks will eventually surface. Sometimes pressure loss in the distribution system will lead you to leaks that are not so apparent. After discovering a leak, always remember to turn off the valve to the water source before attempting to work on the leak.

Corrosion in water systems
Corrosion and its products eat away at the metal walls of a pipe and cause leakage. Briefly stated, the theory of corrosion is the tendency for metal to return to its natural state. Energy was supplied during the refining of the original ores, mostly oxides, which were the source of the steel pipe. When this pipe sits buried in the soil, it tends to surrender the energy and return to its original state—iron oxide. The rate that metal corrodes depends upon the moisture coming into contact with it, the acidity of a solution that touches it, the motion of the metal, the change in temperature, the aeration of the water, or the presence of bacteria. In any case, metal corrodes easily in the presence of acids, salts, hydrogen sulfide, soot, ashes, and dust. Electrochemical reaction is what causes corrosion, which is (in relation to metals) an induced flow of electrons through a metallic path. The return of any formed material to complete disorganization (through corrosion or decomposition) is part of nature.

Plumbing applications
Many medical equipment devices use piped water or steam in daily operations such as; sterilizers, ultrasonic washers, and scope washing systems. While sweating pipe or installing water systems is not a daily practice for most BMETs, it is important to understand the concepts of how plumbing systems work. When planning equipment installations, you will need to know if your current plumbing infrastructure can support the new demand. Going from one sterilizer to three in a department can increase the draw within the system and reduce the supply pressure for all equipment

in that area. You might have to coordinate a modification to increase the diameter of the existing supply line prior to installation. This is why the FM team is critical to the equipment planning phase.

A general rule of thumb when it comes to utility systems is that everything contained within the wall tends to fall in the scope of facilities, while plumbing connections outside of the wall can fall on the BMET for installations and repairs. If the manufacturer does not cover it during an equipment purchase, you might be responsible for installing plumbing connections between the equipment and the wall. This could include additional items such as carbon or ultraviolet filters, external water heaters, or onboard steam generators.

Water quality

The quality of the water supplied to your facility makes a big difference in how you approach medical equipment. Different regions of the country have varying water quality, from hardness to power of hydrogen (pH) levels. This comes into play when establishing PM schedules as well as planning requirements for new procurement. In areas with hard water, you could need additional filtration systems. Some facilities even employ reverse osmosis systems to feed their equipment. Another way to overcome bad water is a more aggressive PM schedule than manufacturer recommendations, such as replacing filters at more frequent intervals.

Self-Test Questions

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

011. Central gas systems

1. What are the three major components of a central gas system?

2. In a MTF, what kind of storage system uses a large volume of O_2?

3. At an MTF, where are the bulk storage tanks located?

4. Why are bulk storage systems considered to be economical?

5. What happens to LOX when it is warmed to room temperature?

6. One cubic foot of LOX is equal to how many H-cylinders of O_2 gas?

7. Describe the container and temperature in which LOX is stored.

8. Describe how LOX converts to gaseous O_2 during normal use.

9. What are some of the hazards associated with LOX?

10. What kind of cylinders can a manifold system use?

11. The standard H-size O_2 gas cylinders has how much pressure when full?

12. What is the regulated pressure range of O_2 used in the MTF?

13. What happens when the O_2 in the primary bank of a manifold depletes?

14. When should the pressure alarms in a pipeline system activate?

15. When should the pressure relief valve in a pipeline system open?

16. Where should the alarms for a pipeline system be located?

17. Why are MTFs required to have a reserve system?

18. How much O_2 should a reserve supply maintain?

19. What is the purpose of the cutoff valves?

20. When should you conduct an inspection on a gas pipeline system? Recertification?

21. What is the medical gas concentration test? How would you perform this test?

22. Describe the two types of medical gas connectors in use today.

23. What is the O_2 concentration range of medical air?

24. What are some considerations when choosing the location of the medical air compressor intake?

25. What is the *primary* use of the nitrogen pipeline system?

26. How is N_2O supplied?

27. Where would you expect to find central vacuum in an MTF?

28. What is the vacuum requirement for surgery? Areas outside of surgery?

012. Heating, ventilation, and air conditioning

1. What is a HVAC system used for in a MTF?

2. Why are chilled water systems used in MTFs?

3. What is the purpose of the chiller?

4. What level of steam pressure is classified as high-pressure steam?

5. What level of steam pressure is classified as low-pressure steam?

6. In an MTF, for what is 5-psi steam used?

7. Name five components of the AHU.

8. What is the function of ducts?

9. What is the function of dampers?

10. What do the smoke and fire dampers prevent?

11. What is the basic principle of operation of all cooling towers?

12. What makes one cooling tower different from another?

13. What is the EMCS?

14. What does the acronym HEPA identify?

15. Define return.

16. Define positive pressure.

17. Define negative pressure.

18. Define air changes.

013. Plumbing systems

1. What types of pipe are the *most* common applications for hot and cold water systems?

2. What actions would you take as older piping systems made of iron, clay and asbestos-cement require repairs?

3. What are the *commonly* available sizes of plastic pipe?

4. What are some advantages to using plastic pipe?

5. For what application would you use PVC pipe?

6. Describe the construction and applications of CPVC.

7. Describe the advantages to using PEX pipe.

8. What are the *largest* uses of copper tubing?

9. How would you interconnect copper tubing?

10. What are the two basic types of steel pipe?

11. What effect does galvanizing have on a pipe?

12. What is the intended use for stainless steel pipe?

13. What are the advantages of using ductile iron pipe?

14. List some common causes of pressure loss due to increased roughness or decreased line size.

15. After discovering a leak, what should you always remember to do before working the issue?

16. Briefly describe the theory of corrosion.

17. When planning equipment installations, what plumbing considerations do you need to know?

18. What are some ways to overcome hard or bad water?

Answers to Self-Test Questions

001

1. Because of their simple, durable construction.
2. (1) Core.
   (2) Primary winding.
   (3) Secondary winding.
   (4) Enclosure.
3. Low-voltage; high-voltage.
4. Special mineral oil.
5. The three-phase transformer has a separate insulated winding for each one of the phases wound on a three-legged core; a single phase unit has one winding.
6. Service, purpose, and method of mounting and cooling.
7. Voltage; current.
8. Varying-potential.
9. Constant-current.
10. The insulation value of the coils, bushings, and oil.

002

1. In parallel.
2. The transformer burns out.
3. No; one that carries at least 14.4 kVA.
4. They add; they also add.
5. (1) Delta.
   (2) Ungrounded wye.
   (3) Grounded wye.
6. (1) Phase.
   (2) Line.
7. Grounded wye.
8. A LIM.
9. (1) Accumulated leakage current from the use of many properly functioning electrical devices.
   (2) Equipment faults or failures that may cause isolated electrons to revert into ground-seeking electrons.
10. (1) If manually tested, at intervals not to exceed 1 month.
    (2) If equipped with automated self-test and self-calibration capabilities, at intervals of not more than 12 months.
    (3) After any repair or renovation to an electrical distribution system.

003

1. (1) Life safety.
   (2) Critical.
   (3) Equipment.
2. Life safety.
3. Task illumination, fixed equipment, selected receptacles, and special power circuits serving areas and functions related to patient care.

4. To serve a limited number of receptacles and locations to reduce the load and minimize the chances of a fault condition.
5. Equipment.
6. So the generator can be started, warmed up, and prepared for the large equipment load to be placed on it.
7. (1) On-site fuel storage.
   (2) Preventive maintenance (PM) program.
   (3) Generator exercise schedule.
8. Facility manager.
9. To ensure it operates under its intended load during an emergency.
10. Battery-powered systems.
11. Not less than 1 1/2 hours without the voltage falling below 87.5 percent of normal voltage or 60 percent of the initial emergency illumination.
12. The equipment item is placed on the proper branch of the essential electrical system.

004

1. Between the final overcurrent devices and the outlets for connecting electrically operated equipment.
2. A feeder circuit.
3. A grounding means to which the branch circuit grounding conductors connect.
4. (1) Metal used.
   (2) Size of the wire.
   (3) Type of insulation.
   (4) Location of the conductor.
5. Copper.
6. AWG.
7. Thousands of circular mils.
8. 250–2,000 kcmil.
9. The size of wire, type of insulation, maximum working voltage, and manufacturer’s name or trademark.
10. Heat and moisture-resistant thermoplastic.
11. Current flow.
12. Relatively light loads of about 50 amperes or less.
13. Two 120-volt lines and a 240-volt line.
14. Three-wire, single-phase system; due to its flexibility.
15. (1) Delta.
    (2) Ungrounded wye.

005

1. It serves as a center or point in the electrical system where power is fed to the branch circuits.
2. (1) Lighting and appliance.
   (2) Power.
   (3) Feeder.
3. Mainly to provide power for the operation of electrical equipment.
4. 240 or 480 volts.
5. The voltage, current rating, number of phases for which they are designed, and name of manufacturer and trademark.
6. Three.
7. 80 percent.
8. Ferrule or knife-blade type fuse panels.

9. Because a circuit breaker needs only to be reset after it is tripped by an overload condition, while fuses must be replaced after they are blown; the circuit breaker also provides a means for manually disconnecting a circuit from its power source.
10. An increase in amperage and voltage.
11. If a problem occurs within the circuit, the fuse blows before the rest of the circuit is damaged.
12. (1) Thermal.

    (2) Magnetic.

    (3) Thermal-magnetic.
13. Thermal-magnetic.
14. Any value greater than 5 (±1) milliamperes.
15. Bathrooms, wet locations, and outdoors.
16. To prevent equipment damage from high-intensity impulse voltages.

006

1. (1) Providing emergency power to a whole building or individual piece of equipment.

   (2) Providing clean power by limiting noise produced from electromagnetic/radio frequency interference, frequency instability and harmonic distortion.

   (3) Regulating voltage spikes between the main power source and the equipment connected to it.
2. A couple of seconds to a couple of hours; depending on the size of the UPS, the load and its intended purpose.
3. (1) On-line.

   (2) Line-interactive.

   (3) Standby (off-line).
4. On-line.
5. To sense voltage fluctuations and adjust to the proper voltage, providing clean power to the equipment.
6. Better filtering and output voltage boost.
7. Mechanical rotating components such as a flywheel or motor.
8. The small under desk unit used to provide backup power to a workstation computer.
9. Server applications such as internet, DMLSS, telemetry, or PACS servers.

007

1. (1) System.

   (2) Equipment.

   (3) Static.

   (4) Lightning.
2. To get rid of any high voltages that inadvertently enter the system from lightning strikes, breakdown in transformer insulation, or accidental contact between the service drop and nearby high-voltage lines.
3. The NEC.
4. (1) Conduit or other raceways.

   (2) Outlet boxes.

   (3) Switch and panel board enclosures.

   (4) Electrical equipment with exposed metal parts.
5. It reduces the possibility of shock or injury to people in case a live conductor contacts any conductive parts.
6. Copper.
7. Redundant grounding.
8. For safely dissipating lightning strikes into the earth.
9. (1) Air terminals (lightning rods).

   (2) Down conductors.

(3) Arresters.
(4) Other connectors or fittings.

10. (1) Continuity.
(2) Adequate capacity.
(3) Permanence.
11. A metal underground water pipe.
12. Metal underground gas piping systems, aluminum or the structures or structural reinforcing steel used in underground pool systems; Pipe, rods, or plates.
13. 8 feet.
14. Remove the coating.
15. 25 ohms or less.
16. It connects the grounding bus bar of the service equipment with the grounding electrode.
17. Green, or green with one or more yellow stripes.

008

1. Facility manager.
2. How the facility will protect patients, staff, and visitors during temporary periods that do not meet NFPA 101, *Life Safety Code*.
3. Serves as the FM point of contact for all safety-related matters, in the case where the FM is not also dual appointed as the safety officer.
4. MTF commander.
5. (1) Installation safety office.
(2) BEE.
(3) BCE.
(4) Public health.
(5) BMET.
(6) Patient safety office.
(7) Infection control.
6. Either BCE or an independent hospital facilities contract.
7. Facility manager or QAE.
8. Hospital Aseptic Management System (HAMS).

009

1. Safety and efficiency throughout daily operations.
2. MTF hospital administrator, or delegated support commander.
3. (1) Shop monthly completion metrics of both life safety and other PMs.
(2) Medical equipment recalls and status updates.
(3) UL equipment.
(4) EOC safety walkthrough inspection findings.
(5) Medical equipment incident investigations.
4. (1) Safety.
(2) Security.
(3) Hazardous materials and waste.
(4) Fire safety.
(5) Medical equipment.
(6) Utilities.
5. (1) Risk assessment.
(2) Staff development.

(3) Emergency response and procedures.
(4) Inspection, testing, and maintenance.
(5) Information collection and evaluation.
(6) Performance monitoring.
(7) Annual evaluation.

6. The framework to manage medical equipment risks and continuously improve program performance.
7. (1) FDA.
   (2) ECRI.
   (3) MMQC.
   (4) OEM.
8. OEM recommendations and risk levels.
9. Documents ongoing preventive and corrective facility maintenance activities and condition assessment of existing infrastructure. It also identifies current and future sustainment, restoration, and modernization (SRM) requirements to support the MTF mission within existing facilities.

010

1. What is to be built, what materials are to be used, and how the job is to be done.
2. (1) Visualization.
   (2) Interpretation.
3. To ensure radiation is limited to minimize any unnecessary exposure.
4. The health physicist.
5. To simplify the architect’s and engineer’s work, and keep the number of blueprints required to a minimum.
6. In a legend.
7. (1) Material.
   (2) Electrical.
   (3) HVAC.
   (4) Plumbing.
   (5) Elevation and floor plan.
   (6) Construction.
   (7) Reference.
8. An engineer’s blueprint of an electrical circuit; it does not show the actual location of the electrical devices used in the circuit, but only their electrical relationship with one another.
9. Elevation views and floor plans.
10. (1) Architect.
    (2) Metric.
    (3) Engineer.
11. The architect scale is based on increments of 12, rather than increments of 10 as used in the metric scale.
12. When creating site plans.
13. (1) Site plan.
    (2) Foundation plan.
    (3) Floor plan.
    (4) Elevation drawings.
    (5) Sectional drawings.
    (6) Structural framing plans.
    (7) Mechanical plans.
    (8) Electrical plans.
14. Foundation.

15. Floor.
16. (1) A general design floor plan shows only the basic layout and arrangement of the area.

    (2) A working-drawing floor plan (or composite floor plan) is used primarily for the actual construction and is far more detailed.
17. Usually four; there may be more if the building is of unusual design or has interior courtyards.
18. The footings support foundation, which supports the walls, which support the roof.
19. (1) Live weight varies from building to building and can include wind, snow rain, people, and furniture.

    (2) Dead weight consists of the materials used to construct the building.
20. An engineer.
21. (1) Never write on a print unless you have been authorized to make changes.

    (2) Keep prints clean and free of dirt and oil.

    (3) Fold, roll, or hang prints carefully to avoid tearing.

    (4) Do not lay sharp tools or pointed objects on prints.

    (5) While in use, lay prints in a safe and secure place to avoid being stepped on or damaged.

    (6) When not in use, store prints in a clean, dry place.

011

1. (1) A central supply of gas.

   (2) Pipelines, which transport the gas.

   (3) Connectors at the end points.
2. Bulk.
3. Outside the MTF, away from flammable materials and public areas.
4. They use LOX.
5. One cubic foot of LOX expands to 860 cubic feet of gaseous O_2.
6. 3½.
7. In special two-layer containers that use insulation and near vacuum to keep LOX at –297°F at a pressure of approximately 85 psi
8. The gaseous O_2 is pulled off the top of the container, passes through a super heater that warms the gas, and then on to the pressure regulator where the pressure is reduced to 50–55 psi for use in the MTF.
9. Fire and burns.
10. LOX or standard H-size O_2 gas.
11. 2,200 psi.
12. 50–55 psi.
13. The system automatically switches over to the secondary bank.
14. When the pressure varies by ±20 percent from the normal operating pressure of 50–55 psi.
15. When the pressure in the system exceeds the normal level by more than 50 percent.
16. They should be at the site of use, in FM and another in a location that is manned 24 hours a day.
17. In case of a catastrophic failure or running out of O_2.
18. The amount equal to the average daily use of O_2 in that facility.
19. To isolate the different areas of the pipeline for servicing.
20. All new gas systems require inspection; if you make any additions or repairs to the current gas system.
21. A test to ensure the purity of medical gases; with an instrument designed to measure the specific gas at the source and outlet.
22. (1) Quick-disconnect or quick-coupler, which allows the medical technician to rapidly connect or disconnect the equipment from the gas system. The connections are color coded, and also keyed or pinned to prevent mix ups.

    (2) DISS, which is based on each gas line having non-interchangeable threads that are gas specific.

23. Between 19.5 and 23.5 percent.
24. Keep away from streets or any potential source of carbon monoxide or other forms of exhaust, including the hospital's vacuum and WAGD exhaust or plumbing vents.
25. To power instruments in the surgical suite.
26. Through a banked manifold system with an automatic switchover.
27. Surgery, minor surgery, emergency rooms, special care units, maintenance shop, etc.
28. Able to remove 99 L of air per minute; able to remove 28–57 L of air per minute.

012

1. Maintain a comfortable working environment for patients and staff members; also meets standards and regulatory requirements by providing the required room air exchanges in places like the clinical laboratory, surgery, nuclear medicine, and patient isolation areas.
2. Because of the ease with which water can be circulated in the system. Charging the system to pipe refrigerant throughout the facility would cost a great deal of money; also, leaking such an amount of refrigerant into the atmosphere would lead to an environmental disaster.
3. Remove heat.
4. Any steam pressure above 15 psi.
5. Any steam at 15 psi or lower.
6. Heating.
7. Any five of the following:
   (1) Enclosed housing.
   (2) Supply air fan(s).
   (3) Heating and/or cooling coils (evaporator).
   (4) Filters.
   (5) Return air dampers.
   (6) Return air fan(s).
   (7) Relief air dampers.
8. Carry the air from the AHUs to the area requiring the tempered air.
9. Control the flow of air through the system.
10. The spread of smoke and fire through the duct system.
11. Dissipate the heat gained in the condenser through evaporation.
12. The different methods used to increase the surface area of the water.
13. A BCE section located on base that monitors and controls the MTF's heating and cooling needs.
14. High-efficiency particulate air filter.
15. Air flow out of a room, back through the ducts, to the AHU.
16. When the air pressure inside a room or building is higher than the air pressures outside the room or building, this creates air flow out of the room or building.
17. When the air pressure inside a room or building is lower than the air pressure outside the room or building, this creates air flow into the room or building and prevents airborne contaminants from escaping.
18. The number of times the volume of air in a given space is completely replaced in a given period of time.

013

1. Galvanized steel, plastic, and copper.
2. Replacing them with the newer, safer and more cost-efficient materials available today.
3. ½–18 inches in diameter. Rigid pipes usually come in 20 foot lengths. Flexible forms come in different lengths or long coils for large and smaller pipe.
4. It is easy to use and will not rust, rot, or corrode.
5. Water distribution systems (WDS).

6. CPVC is a rigid pipe similar to PVC but special development allows it to withstand higher temperatures than other plastics. It is normally rated for 180°F at 100 psi. Because of its excellent resistance to chemicals, CPVC is now available in larger sizes for DWV applications. Hot water distribution systems (WDS) typically use CPVC.
7. It is very flexible and capable of making turns greater than 90 degrees, therefore using fewer fittings. PEX pipe works well for both hot and cold service and, with the proper fittings, can easily connect to existing pipes of varied materials.
8. Water supply and drainage systems.
9. Soldering or compression-type fittings.
10. (1) Galvanized.
    (2) Black iron.
11. Extends the pipe's life span by reducing corrosion, such as rust.
12. To carry liquids that are corrosive to other metals. Is a common application in newer hydrant fuel systems.
13. Long laying lengths, tight joints, high corrosion resistance, ability to withstand relatively high-pressures, and easy to work with.
14. Corrosion, pitting, tuberculation or small "mounds" of rust inside the pipe, sediment deposits, slime growths, and air accumulation at high points in the system.
15. Turn off the valve to the water source.
16. The tendency for metal to return to its natural state.
17. If your current plumbing infrastructure can support the new demand.
18. Additional filtration systems, reverse osmosis systems, or a more aggressive PM schedule than manufacturer recommendations, such as replacing filters at more frequent intervals.

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 Air Force Career Development Academy (AFCDA).

1. (001) How are *large* transformers cooled?
   a. Immersion in oil.
   b. Fan circulating air.
   c. Free flowing water.
   d. Stationary air conditioner.

2. (001) In a three-phase transformer, how many degrees is each phase displaced?
   a. 30°.
   b. 90°.
   c. 120°.
   d. 180°.

3. (001) How are transformers classified?
   a. Power, distribution, and instrument.
   b. Power, purpose, distribution, and cooling.
   c. Service, purpose, and method of mounting and cooling.
   d. Kilo-volt amperage rating, transformer configuration, and method of installation.

4. (001) Which type of transformer provides a steady secondary *voltage* from no load to full load?
   a. Current.
   b. Constant-current.
   c. Varying-potential.
   d. Constant-potential.

5. (002) What instrument do you use to measure *true* power?
   a. Ammeter.
   b. Voltmeter.
   c. Wattmeter.
   d. Multimeter.

6. (002) Besides delta, what are the other two types of three-phase transformers used by the Air Force?
   a. Wye and grounded delta.
   b. Wye and ungrounded wye.
   c. Grounded wye and ungrounded wye.
   d. Grounded wye and ungrounded delta.

7. (002) The Air Force prefers which three-phase distribution system?
   a. Ungrounded delta.
   b. Ungrounded wye.
   c. Grounded delta.
   d. Grounded wye.

8. (002) Between which points would you measure to obtain *line* voltage in a wye system transformer?
   a. Ground to neutral.
   b. Any phase to neutral.
   c. Any phase to ground.
   d. Any two of the three phases.

9. (002) Which type of transformer eliminates spark hazards where flammable anesthetics are used and gives added protection from electrical shock?
   a. Delta.
   b. Isolation.
   c. Grounded wye.
   d. Ungrounded wye.

10. (002) What is used to count ground-referenced electrons in an isolated power system?
    a. Ground-referenced circuit-interrupter.
    b. In-line metering system.
    c. Line isolation monitor (LIM).
    d. Circuit breaker.

11. (003) What three branches make up the *essential* electrical system?
    a. Emergency, utilities, and equipment.
    b. Critical, equipment, and emergency.
    c. Life safety, utilities, and equipment.
    d. Life safety, critical, and equipment.

12. (003) What *minimum* full-demand fuel supply are you required to have onsite for an emergency generator?
    a. 1 hours' worth.
    b. 2 hours' worth.
    c. 5 hours' worth.
    d. 8 hours' worth.

13. (003) How often should you exercise an emergency generator under full load?
    a. 30 minutes at least once quarterly.
    b. 60 minutes at least once quarterly.
    c. 30 minutes at least once monthly.
    d. 60 minutes at least once monthly.

14. (004) What type of circuit provides power to the *final* overcurrent devices?
    a. Branch.
    b. Feeder.
    c. Primary.
    d. Secondary.

15. (004) The amount of current a conductor can safely carry depends on the metal used, wire size, type of insulation, and
    a. length of the wire.
    b. type of load device.
    c. type of wiring system.
    d. location of the conductor.

16. (004) What type of wiring system includes wire sizes No. 40 to No. 4/0?
    a. Micro-critical manner (MCM).
    b. American Wire Gauge (AWG).
    c. Thousands of circular mils (kcmil).
    d. National Electrical Code (NEC).

17. (004) Which wiring system would you use in small structures where the *main* need is for lighting?
    a. Three-wire, single-phase.
    b. Two-wire, single-phase.
    c. Three-phase, three-wire.
    d. Three phase, four-wire.

18. (004) Which wiring system uses two ungrounded conductors and one neutral conductor to provide power *and* light?
    a. Three-wire, single-phase.
    b. Two-wire, single-phase.
    c. Three-phase, three-wire.
    d. Three-phase, four-wire.

19. (004) What three-phase, four-wire system does the Air Force permit for use in medical facilities?
    a. Star-powered.
    b. Wye-powered.
    c. Delta-powered.
    d. Grounded delta-powered.

20. (005) What types of fuses would you use in medical facilities?
    a. Cartridge and plug.
    b. Cartridge and ferrule.
    c. Knife-blade and plug.
    d. Knife-blade and ferrule.

21. (005) What type of circuit breaker is *best* for general use?
    a. Electric.
    b. Thermal.
    c. Magnetic.
    d. Thermal-magnetic.

22. (005) How are circuit breakers rated?
    a. Size and volts.
    b. Poles and volts.
    c. Poles and amperes.
    d. Volts and amperes.

23. (005) What type of protective device is often found in bathrooms and wet locations within a medical facility?
    a. Ground-fault circuit-interrupter.
    b. Uninterrupted power supply.
    c. Line isolation monitor.
    d. Surge suppressor.

24. (006) Which is *not* a category of static uninterruptable power supply?
    a. Line-interactive.
    b. Standby.
    c. Rotary.
    d. On-line.

25. (006) Which application would you use a stand-alone uninterruptable power supply?
    a. Internet server.
    b. Telemetry workstation.
    c. Defense Medical Logistics Standard Support (DMLSS) server.
    d. Picture Archiving and Communication System (PACS) server.

26. (006) What is the purpose for using a flywheel in a rotary uninterruptable power supply?
    a. Provides temporary kinetic energy until the generator warms up.
    b. Starts the onboard motor/generator during power loss.
    c. Provides clean power by limiting noise interference.
    d. Recharges the backup battery bank.

27. (007) Connecting all exposed, noncurrent-carrying metal parts of an electrical system to the Earth is what type of grounding?
    a. Equipment.
    b. Electrical.
    c. Facility.
    d. System.

28. (007) Which example is a *primary* normal ground electrode?
    a. A 10-foot metal underground water pipe with unbonded joints.
    b. A 15-foot metal underground gas pipe with unbonded joints.
    c. A 15-foot metal underground water pipe with bonded joints.
    d. A 10-foot metal underground gas pipe with bonded joints.

29. (007) If a made electrode fails the ground resistance test, an additional ground electrode must be placed *at least* how far away from the existing electrodes?
    a. 4 feet.
    b. 6 feet.
    c. 8 feet.
    d. 10 feet.

30. (007) An insulated grounding conductor wire is green or green with what color stripes?
    a. Yellow.
    b. Orange.
    c. White.
    d. Black.

31. (008) In a medical facility, who is responsible for the daily operations and overall facility upkeep?
    a. Facility maintenance contractor.
    b. Base civil engineering (BCE).
    c. Facility manager.
    d. Senior BMET.

32. (008) Who is responsible for appointing the military treatment facility (MTF) safety officer in writing in accordance with (IAW) the Joint Commission (TJC) guidelines?
    a. Medical logistics flight commander (MLFC).
    b. Installation safety officer.
    c. MTF commander.
    d. Facility manager.

33. (008) What Air Force centralized contract governs housekeeping services?
    a. Hospital aseptic management service (HAMS).
    b. Hospital aseptic management system (HAMS).
    c. Housekeeping aseptic management service (HAMS).
    d. Housekeeping aseptic management system (HAMS).

34. (009) As a BMET, you are responsible to brief the environment of care committee (EOCC) on subjects such as shop completion metrics, medical equipment recalls, and
    a. projected preventative maintenance schedules.
    b. medical equipment maintenance contracts.
    c. generator testing schedules and results.
    d. unable to locate (UL) equipment.

35. (009) Which is *not* one of the functional areas of environment of care (EOC) management plans?
    a. Hazardous materials and waste.
    b. Emergency operations.
    c. Fire safety.
    d. Security.

36. (010) What information can you find on a schematic?
    a. Component name, materials, location, and electrical relationship between components.
    b. Only electrical relationships between components.
    c. Circuit board component layout.
    d. Only component locations.

37. (010) Which is *not* a typical scale used in blueprint production?
    a. Architect.
    b. Engineer.
    c. Metric.
    d. Linear.

38. (010) What scale deals with increments of 12?
    a. Architect.
    b. Engineer.
    c. Metric.
    d. Linear.

39. (010) Which document serves as a template for other plans?
    a. Floor plan.
    b. Working-drawing.
    c. Elevation drawing.
    d. Sectional drawing.

40. (010) What are the two types of floor plans?
    a. Working and composite.
    b. General and composite.
    c. Basic and working.
    d. Basic and general.

41. (010) Which document is used to depict the exterior or interior walls of a building?
    a. Floor plan.
    b. Detailed drawing.
    c. Elevation drawing.
    d. Sectional drawing.

42. (010) Which statement describes *improper* care of blueprints?
   a. They can be hung on a rack in the closet.
   b. They can be laid out on the floor while investigating a problem.
   c. They must be kept away from food, drink, and tools while in use.
   d. They can have a new approved transformer drawn on the plans by an authorized person.

43. (011) What is *not* a major component of a central gas system?
   a. Central supply of gas.
   b. Air handler.
   c. Connectors.
   d. Pipelines.

44. (011) What is the pressure level of a full H-size cylinder of oxygen (O_2)?
   a. 2,200 pounds per square inch (psi).
   b. 2,300 psi.
   c. 2,400 psi.
   d. 2,500 psi.

45. (011) In an MTF, a regulator is used to reduce the oxygen (O_2) pressure to what safe operating range?
   a. 45–50 pounds per square inch (psi).
   b. 50–55 psi.
   c. 55–60 psi.
   d. 60–65 psi.

46. (011) Oxygen (O_2) pressure relief valves open if the pressure in a pipeline system exceeds the *normal* level by more than
   a. 30 percent.
   b. 40 percent.
   c. 50 percent.
   d. 60 percent.

47. (011) Medical air must be between
   a. 18.5–22.5 percent oxygen.
   b. 19–23 oxygen.
   c. 19.5–23.5 oxygen.
   d. 20–24 percent oxygen.

48. (011) What are the liters of air per minute vacuum requirement for the surgery department?
   a. 28.
   b. 57.
   c. 65.
   d. 99.

49. (012) Which is *not* part of the chiller's refrigeration loop?
   a. Condenser.
   b. Evaporator.
   c. Compressor.
   d. Cooling tower.

50. (012) Boilers *normally* operate at what steam pressure?
   a. 90 psi.
   b. 95 psi.
   c. 100 psi.
   d. 105 psi.

51. (012) What is the steam pressure used for heating the military treatment facility (MTF)?
   a. 5 psi.
   b. 15 psi.
   c. 60 psi.
   d. 100 psi.

52. (012) Which is *not* part of an air handling unit (AHU)?
   a. Fans.
   b. Ducts.
   c. Filters.
   d. Dampers.

53. (012) How does the cooling tower dissipate heat?
   a. Vacuum.
   b. Absorption.
   c. Evaporation.
   d. Condensation.

54. (012) Which of the following rooms would normally require a *negative* pressure environment?
   a. Rooms where a patient has a compromised immune system.
   b. Newborn intensive care rooms.
   c. Nuclear medicine hot labs.
   d. Surgical suites.

55. (013) The following are types of pipe used most often for hot and cold water applications *except*
   a. galvanized steel.
   b. stainless steel.
   c. copper.
   d. plastic.

56. (013) Due to its ability to withstand higher temperatures than other plastics, which pipe is rated 180°F at 100 pounds per square inch (psi) and typically used in hot water distribution systems (WDS)?
   a. Chlorinated polyvinyl chloride (CPVC).
   b. Polyvinyl chloride (PVC).
   c. Polybutylene (PB).
   d. Polyethylene (PE).

Please read the unit menu for unit 2 and continue ➔

Unit 2. Deployable Medical Systems

THE US HAS ONE OF THE LARGEST deployable footprints of any country in the world. We deploy personnel across a variety of continents in support of both peacetime as well as wartime missions. From battlefield Air Force theater hospitals (AFTH) to global crisis response units and even humanitarian assistance missions that better the health of developing countries, the Air Force is continually engaging its deployment platforms across the world. Our mission as a BMET is to set up and maintain the field power and structures as well as medical equipment that provide necessary medical treatment.

You may find yourself as a member of an expeditionary medical support (EMEDS) unit or inspecting war reserve materiel (WRM). Whatever your mission, how you accomplish it will directly affect the quality of treatment provided by those facilities. What makes a BMET's role so important to the field is the versatility that our scope of responsibility entails. When you deploy, not only are you responsible for the equipment inside the EMEDS, but you are now the facilities, power, O_2 person, and relative "jack of all trades." Your role in deployment operations is critical to the success of medical mission sustainment. This unit explores the complete EMEDS setup, including the fundamental equipment requirements for the site. Whichever job you find yourself in, this information will be invaluable.

2–1. Power Requirements

When you arrive in the middle of a field environment with a group of people and equipment, one of the first considerations you will have is "Where am I going to get the power I need?" If you deploy to an underdeveloped area, most likely commercial power will not be readily available or possibly not reliable. The answer is simple…bring your own power. We talked extensively about power in unit 1 of this volume; now is your chance to apply that information to a bare bones setup. We start this section by explaining the need for generators to provide power and power distributions panels (PDP) to reach all of your assets. Let's get started with generating some power.

014. Generator components and maintenance

Each configuration of an EMEDS has specific power requirements. Fortunately, the size of the configured load has already been determined for you with the appropriate size generator. In rare cases the deployment footprint can be modified based on mission requirements, so it is always a good idea to double check your specs and make sure you are bringing enough power to meet the demand.

The generators are usually assigned to the BMETs (your shop), and you are responsible for the overall maintenance. When they are in storage or not activated, you should negotiate an agreement between the MTF and BCE, requesting BCE perform all maintenance and provide user training on the generators. This helps to keep your generators in top-notch condition until a deployment is necessary. This agreement can also stipulate that BCE provide preshipment packing and generator preparation for deployment. However, once you are in the field, the responsibility for the generator is yours.

Terms

Let's review some basic terms used in conjunction with generators by using the following table:

Term	Description
Tactical quiet generator (TQG)	The TQG is a common term referring to a field deployable generator. The TQG comes in various models and sizes. This design creates less noise hazards than its predecessors such as the MEP–7A model.
Mobile electric power (MEP)	MEP is the acronym that precedes the generator's model number (i.e., MEP–807A). This device generates 3-phase power using a diesel engine and an alternator. When mounted on a trailer, this same model is designated PU–807A.
Load bank	A load bank is a balanced resistive load that maintains the generator up to 50 percent of its rated load to prevent excessive engine carbonizing due to light loads. You have probably heard the adage that a generator likes to run at its capacity. The harder it works, the better it likes it. Light loads cause the generator to build up excessive carbon waste due to inefficient fuel consumption. Your car performs in a similar way. It gets better gas mileage when you are traveling on the highway for a distance, rather than when you make short trips in town. The load bank is a selectable size load that adds to the actual load, allowing the generator to run more efficiently. This is of concern to you more at night when you have most of the equipment turned off throughout the camp and only the light bulbs are on.
Generator set	This is the "official" name of the device that produces three-phase AC electrical power at selectable ranges. The TQG can be configured for 120/208 volts of alternating current (VAC) or 240/416 VAC operation for 50 Hz or 60 Hz.
Battle short	This is an emergency bypass of most fault conditions that can occur within a generator. The battle short switch allows you to continue to operate the generator through critical events requiring electrical power. You must understand however, that continuing to operate it in this mode causes damage and breakdown.
Dead crank switch	The dead crank switch allows you to crank the engine without starting it.
Paralleling	This is where you connect two or more generators in sync with one another to share the same load.

Generator operation

Once started, generators continue to run as long as they have the proper lubrication and enough fuel. The tank holds 66 gallons of fuel and can run on either diesel or JP8 jet fuel (giving you options in the field). The optimal load capacity that a generator should operate is 80 percent. At an 80 percent load and a full fuel tank, a generator can run for about 8 hours. The more load…the less time, so be sure to monitor fuel consumption and plan deliveries accordingly.

This leads us to the following important considerations for the continued use of the generator:

- Schedule timely refueling to mitigate the interruption of power.
- Maintain a fuel reserve in case there is a delay in the scheduled refueling.
- Keep a class "C" fire extinguisher near the generator site.
- Complete the required generator inspections and paperwork.
- If the deployment is long-term, perform PM at appropriate intervals with a minimum loss of power availability.

Major components

Figures 2–1 through 2–3 show examples of a standard skid-mounted generator with the basic components you need to know identified. We discuss each of the basic components that you will interact with on an operational level.

The electronic modular control panel (EMCP) (Fig. 2–1) contains controls and indicators for monitoring TQG operation. This is the information center of the generator. Here you can monitor and adjust voltages, frequencies, alarms, fuel level, and start/stop/warm up/cool down the generator. It also contains an emergency push to stop button, which shuts down the TQG immediately when pushed. The AC circuit interrupter switch is a control, which allows you to manually send power to the load once voltage and frequency reach stability. This ensures that you are only sending power from the source at the intended ranges once the generator is warmed up enough to handle a load. This panel is where you will find the battle short to override fault conditions and continue operation of the generator. Only use the battle short in critical situations where the need for immediate power now is more important than the health of the generator.

The paralleling receptacles are located next to the EMCP. They pair the generator sets together in order to share the load across one feed. When you attach two or more generators together using the paralleling cables, you can sync them together ensuring they operate at the same voltage and frequency and evenly distribute the load. Be sure to follow the directions in the manual, as an improper set up can damage the generator. The 100 kW TQG can be paralleled with either another 100 kW or a 200 kW generator set of the same family. This panel also houses two convenience receptacles rated 120 VAC, 15A and are available at all times during generator operation.

The load board (Fig. 2–2) connects load cables to the TQG with five heavy-duty connector lugs and nuts. These cables route to your PDP. The reconnection board changes the generator output voltage for different load applications. The TQG can be configured for 120/208 VAC or 240/416 VAC operation for 50 Hz or 60 Hz by changing the direction of the board.

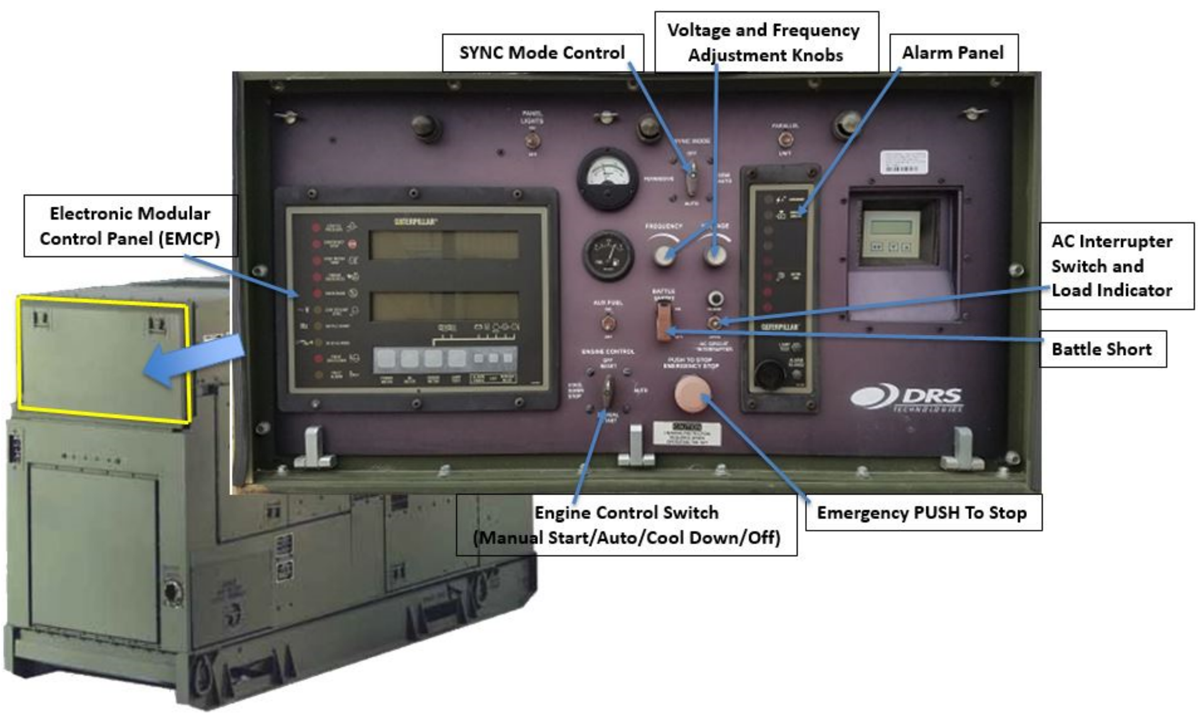


Figure 2–1. MEP–807a tactical quiet generator, control panel.

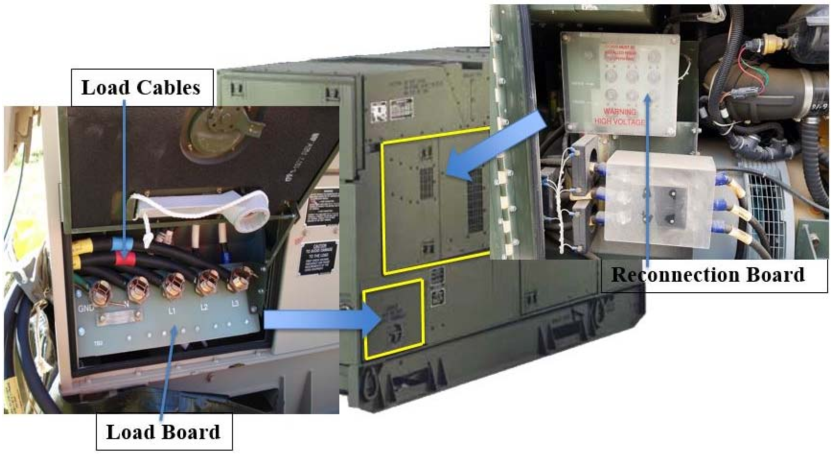


Figure 2–2. MEP–807a tactical quiet generator, load connections.

Figure 2–3. MEP–807a TQG, front.

Figure 2–3 shows the other sides of the generator and illustrates some additional components that will be useful for standard operation of the generator. The battery compartment houses two sealed 12 volts of direct current (VDC) batteries connected in series. The batteries provide 24 VDC power for EMCP controls, engine starting, and to the North Atlantic Treaty Organization (NATO) slave receptacle. There is also a battery disconnect switch to easily remove the batteries from the circuit or redirect the path to the NATO slave receptacle. The NATO slave receptacle allows you to connect to another generator to easily jump-start one another if the batteries in either unit are depleted. Inside the battery compartment door pockets, you will find the field manual, grounding rods, and paralleling cables. You can also find the compartment housing the dead crank switch on the same side as the NATO slave receptacle.

Installation

Once you get to the field, you need a ten thousand pound (10k) forklift to move the generators. Each EMEDS site should have two 100 kW generators for uninterrupted power. You should place the generators near a road for refueling and maintenance. Be sure to install the generator on a level site and ground prior to operation. When determining a ground source, in order of preference, choose an underground metallic water piping system, driven metal rod, or a buried metal plate. A ground rod must have a minimum diameter of ⅝″ if solid or ¾″ if using a pipe, and a minimum drive depth of 8 feet. A ground plate must have a minimum area of 9 square ft. and buried at a minimum depth of 4 ft. The ground lead must be at least No. 6 AWG copper wire, and must bolt or clamp to the rod, plate, or piping system. Connect the other end of the ground lead to the generator ground terminal stud. The most common grounding method in a field site is the metal grounding rod.

Operational inspection

You should perform PM checks on generators before, during, and after operation of the unit. Some of the steps in the PM occur more than once. The applicable maintenance manual has the step-by-step procedure for the PM process. The first step in a PM check is to ensure the ground cable is secure. Perform this step first as a safety precaution. Check all additional cables to ensure they are secure (if connected), with no cracking or fraying. Cables include items such as the NATO slave connector, parallel, load and battery cables. Check the output load terminal and reconnection boards for damage or loose connections. Inspect all lights, alarms, and functions on the control panel assembly using the lamp test or applicable indicators. Check for leaks, damage, or corrosion in the fuel system and cooling system. Inspect the engine oil and the coolant for proper fluid levels. Do not forget to check the fuel level as well….no fuel …no power. Check the control panel to ensure the gauges read within the proper ranges using the engine meter button. The oil pressure gauge should read between 35–70 pounds per square inch gauge (psig) and coolant temperature gauge should read between 170°F–200°F. Check the battery system for the required electrolyte level. Make sure to check the air intake system for excessive dirt.

Always allow the engine to warm up at no load for approximately 5 minutes or until coolant temperature reaches 100°F. Once the engine is running smoothly, fine-tune the voltage and frequency to the desired settings using the adjustment knobs on the EMCP. When powering down the generator, set the engine control knob to cool down/stop. This will allow the generator set to operate with no load applied for 5 minutes. The generator set will shut down automatically once the cool down is complete. In critical situations only, you can use the push to stop emergency button if needed.

Organizational maintenance

Organizational maintenance on the generator requires quarterly, semi-annual, and annual maintenance actions according to the preventative maintenance checks and services (PMCS) checklist. The list for the PMCS covers many items, including those already listed in the operational inspection. Using the following table, let's review some of the common tasks for the quarterly checks and services not already listed:

Interval	Maintenance Action
Quarterly or 300 hours	Check the entire housing, to include doors, panels, latches, and hinges.
	Change engine oil and oil filter.
	Check oil pan magnetic plug for metal particles.
	Replace fuel filter.
	Clean auxiliary fuel pump strainer.
	Replace water separator filter element.
	Check muffler for leaks, restrictions, accumulation of carbon deposits, and loose hardware. Replace muffler if required.
	Check generator for damage, wear, rust, corrosion, missing parts, and secure mounting.
	Visually inspect battery-charging alternator for damage, arching, and corrosion.
	Inspect cylinder head for cracks and seepage.
	Drain sediment/water from fuel tank.
	Inspect belts for proper routing and that belts firmly seat in the pulley grooves.
Semi-annually or 750 hours	Check crankcase ventilation filter for cleanliness, damage, and secure mounting.
	Check air cleaner for cleanliness, damage, and secure mounting.
Semi-annually or 4000 hours	Inspect belt tensioner for worn or loose bolts.
	Inspect the engine vibration damper for damage.
Annually	Replace fan belts.
	Drain, clean, and flush cooling system.
	Inspect engine mounts.

Interval	Maintenance Action
	Clean engine exterior. Replace bearing when failed or after 2,500 hours. Internally clean and leak test the after cooler core. Inspect to see if the measurement of the valve lash is in the acceptable range.

Now, take a look at a typical generator setup at an EMEDS site (Fig. 2–4). The generators sit as far from the site as possible. Generators can be set up on either end of the EMEDS, depending on what is best for general mission operations. Things to consider when establishing a camp layout include patient flow, noise levels in relation to patient care or command tent, ease of fuel delivery access, and average wind direction. Although winds tend to change, it is best to try to avoid exhaust fumes continually blowing across the MTF if possible.

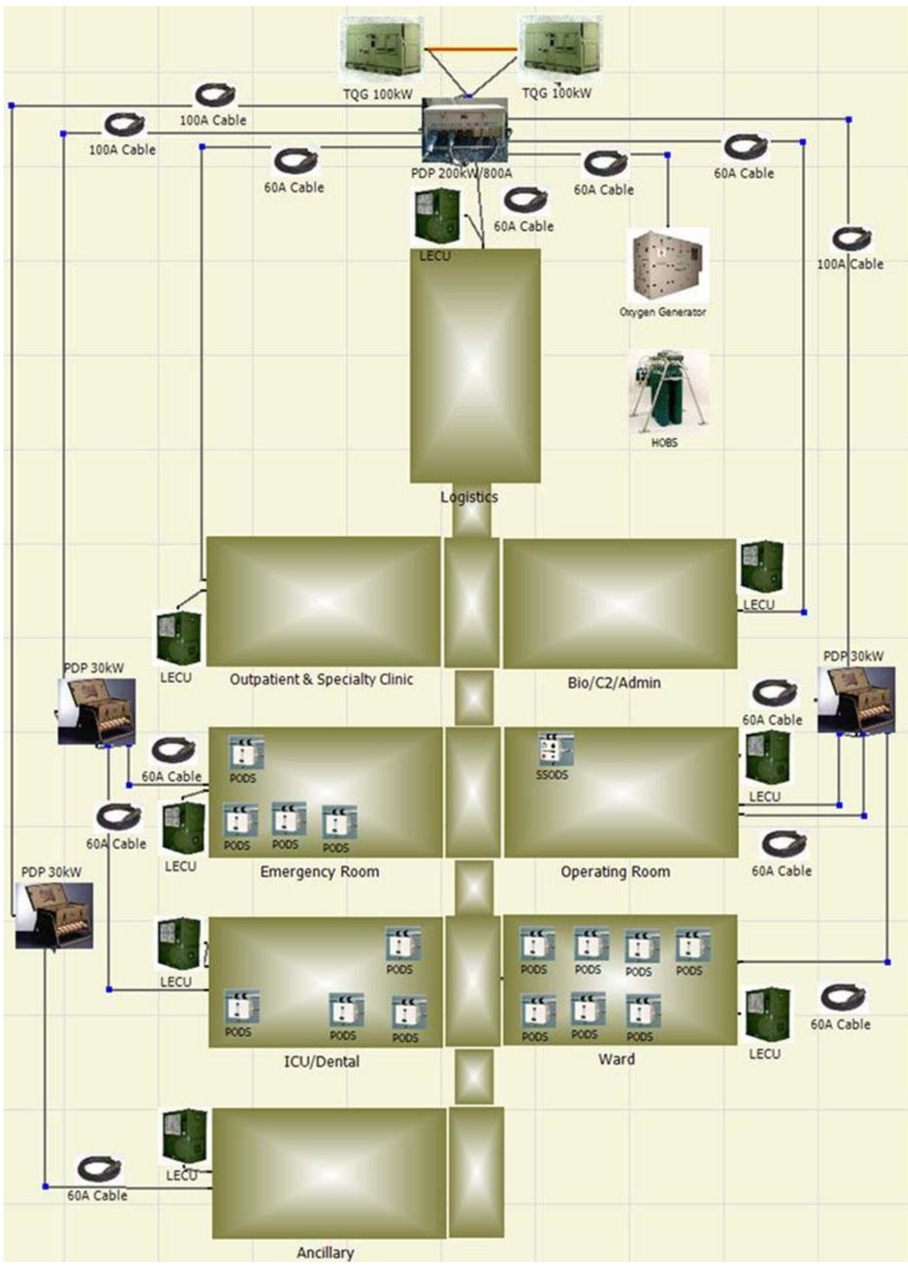


Figure 2–4. EMEDS generator setup.

015. Distribution of electrical power

Now that you have power, you need to get it to the users. Similar to the distribution concepts discussed in unit 1, this is where you would use the power distribution center (PDC) to be able to bridge power from the generator to its desired location. These centers are also referred to as PDPs or power feeders. You usually use the term “feeder” when you use more than one PDC in the same line of distributed power. Refer to figure 2–5, a standard EMEDs +10 power distribution setup. The generators (No. 1) supply power to the feeder. The feeder (No. 2) is the larger PDC that feeds two smaller PDCs (No. 3), which, in turn, feed the user through branch distribution boxes located inside the tent (No. 4).

PDCs

The PDCs control the safe, orderly distribution of electrical power in a field environment. They are the link between the generators and users. The PDCs and feeders are located strategically to provide power to the encampment. The total kW demand load of your EMEDS site determines the size of the PDC required. Each assemblage assigned has recalculated loads for the size of your EMEDS site. The PDCs come in the following load sizes—15 kW, 100 kW, and 200 kW. Although they are rated by total kW, the unit nomenclatures are referred to by amperage capacity (i.e. 100 kW PDC = 400A and 200 kW PDC = 800A).

A larger kW-rated PDC feeds the smaller kW-rated feeders. These systems follow the same rules you learned about conductors. The larger one *always* feeds the smaller one. Let’s assign some values to the PDCs in figure 2–5 for a clearer understanding. Assume the No. 2 feeder is 200 kW and the No. 3 PDC is 100 kW. You should never have the situation where No. 2 is smaller than No. 3.

The PDC is a portable system designed for rapid deployment. It weighs approximately 305 pounds (lb.), so be sure to adhere to the necessary handling safety precautions (i.e., two-person lifting; using your legs, not your back; etc.). The following table shows the PDC number and size requirements for an EMEDS site. We will start with the smallest configuration being the health response team (HRT), which replaced the EMEDS basic package.

PDP	HRT	EMEDS +10	EMEDS +25
100 kW (400A)	1	2	2
200 kW (800A)	X	1	1

Figure 2–6 shows what a typical PDC looks like. It has several receptacles for power distribution to the user. The PDC also includes circuit breakers to turn power on and off each branch, phase indicators that visually confirm power from the generator, load lines connected in-phase, and a main circuit breaker that turns power off to the whole PDC. You can easily turn power off by switching the main circuit breaker to the off position.

Internal configuration

Figure 2–7 shows the internal configuration of the typical PDC. The generator load lines (L1, L2, and L3) hook up to A, B, and C respectively. There is a place for the neutral (N) to hook up and a separate ground (G). You will also find a main circuit breaker on each input (rated at 400 amps). It can disconnect the incoming power from all of the branch lines. The main bus runs through the center of the PDC and powers each individual branch. As you can see, each branch has its own circuit breaker for individual power activation or deactivation. There are three types of outputs for this unit. The first type is two cam series 5-wire phase cables to further distribute power to smaller 400A PDCs. There are also combinations of 100A and 60A receptacle connectors called cannon plugs. This allows for the properly keyed connection of the phases and provides protection from the elements. Lastly is a single 20A/120VAC GFCI outlet for direct power connection to the PDC.

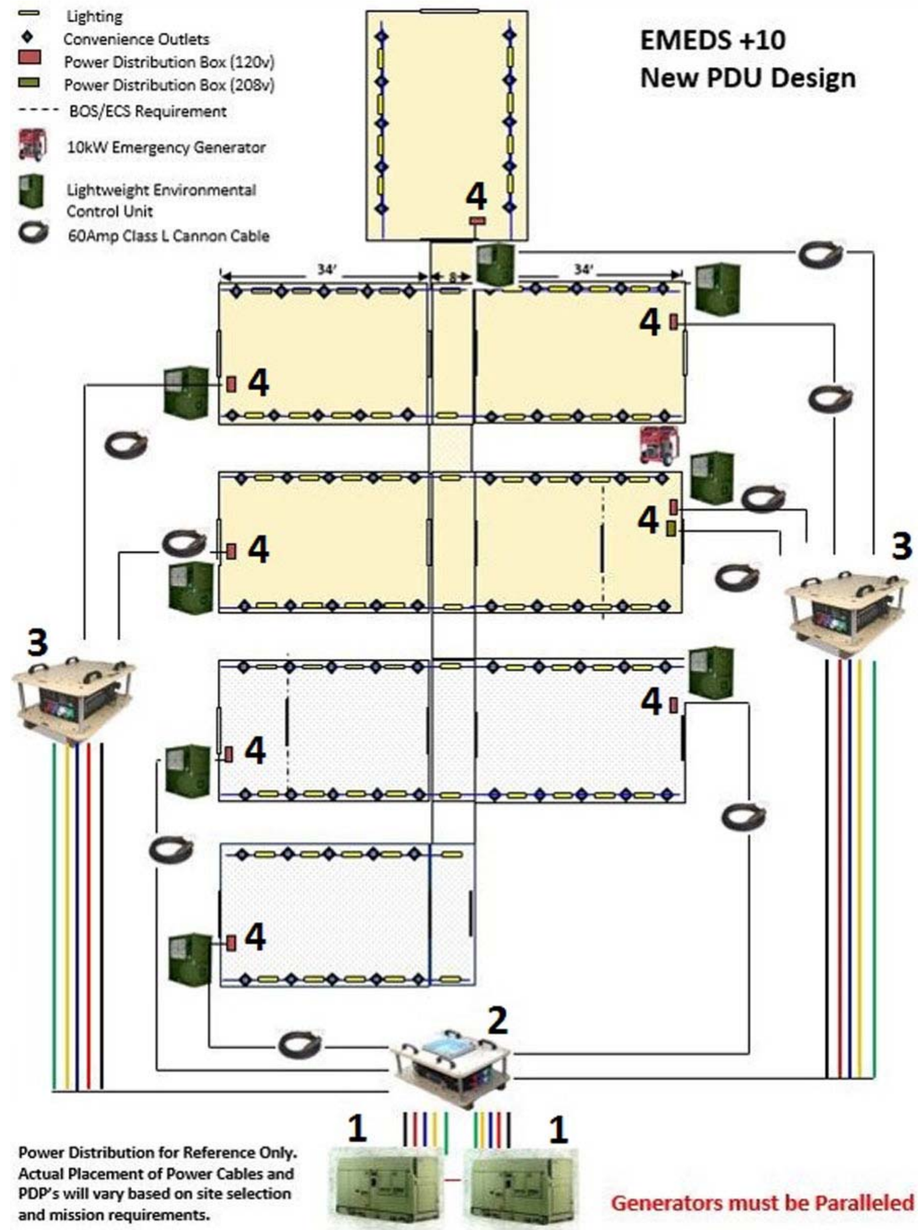


Figure 2–5. Site power distribution.

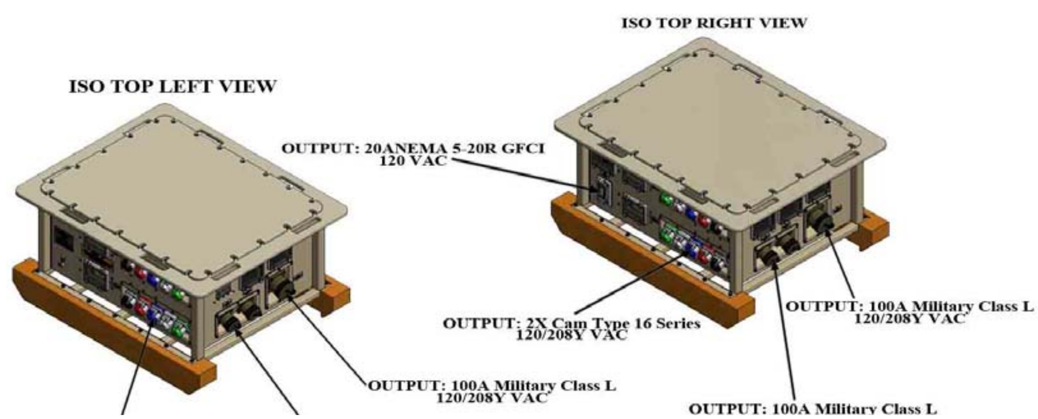


Figure 2–6. Power distribution center, 800A.

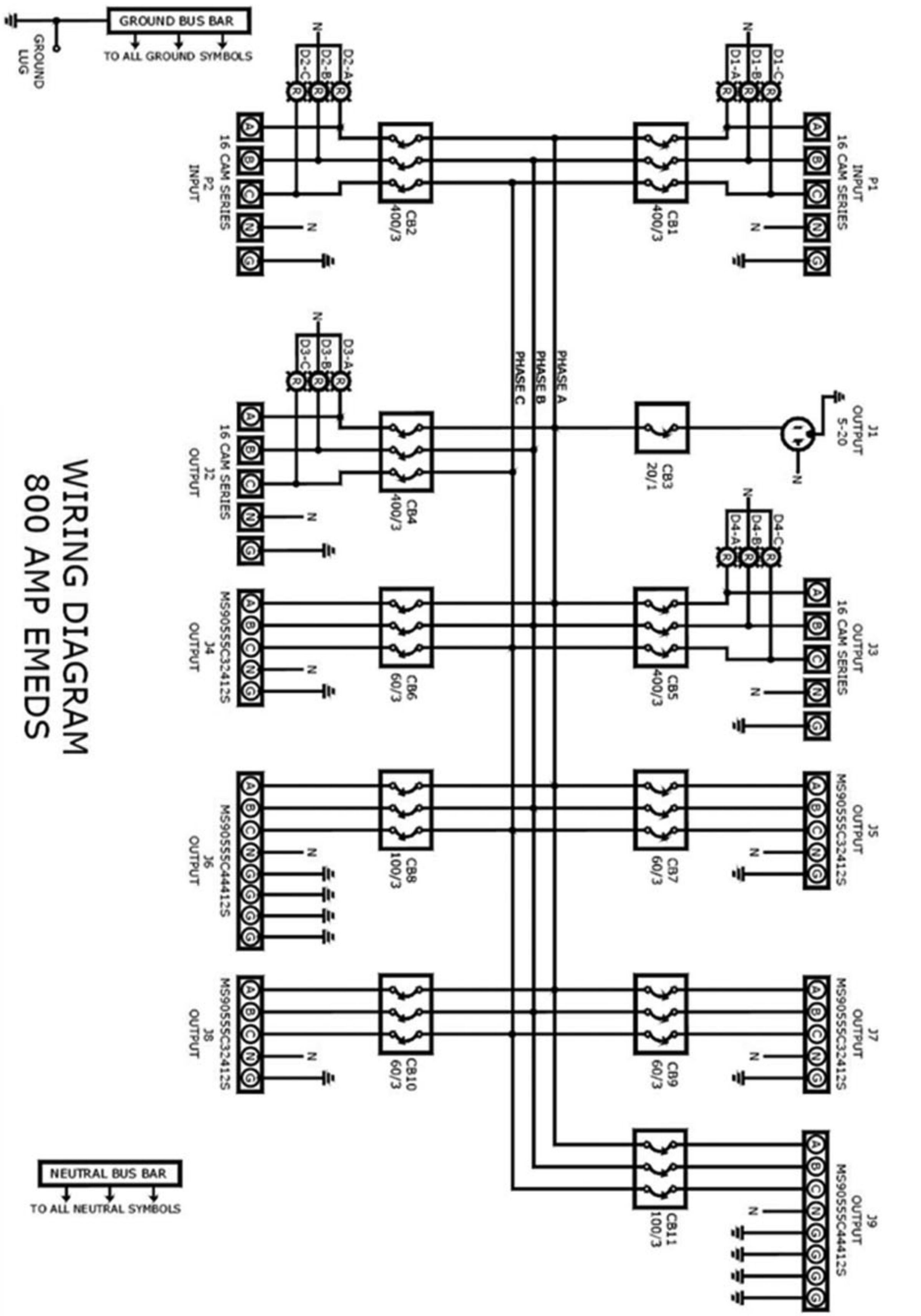


Figure 2–7. Internal schematic of a PDC.

Conductors

The only way power can get to the PDC is through conductors (wiring) from the generator. Figure 2–8 shows the cables or conductors that come with the PDC. Notice the larger cable (Fig. 2–8C), 350A, 50 ft., does not have cannon plugs on the end. You hook these wires directly to the load terminal board of the generator. The terminal board connectors resemble large clamps. You run the wire between the clamping mechanisms, and then tighten the clamp. As each cable is hooked up (L1, L2, L3, L0 (N), and ground) to the generator, the other end should be attached to the appropriate clamp at the PDC (i.e., you hook up L1 at the generator, and then hook the other end of the cable to A (L1) on the PDC). Do not cross the cables when making connections. Two things can happen:

- Two large cables pulling full capacity can induce voltage into the other by creating magnetic fields.
- Not hooking each end as you go could cause you to connect L1 from the generator to L2 (B) or L3 (C) of the PDC. This causes your power to be out-of-phase and could damage the PDC as well as the equipment the PDC feeds.

It is *extremely* important that you turn off all power before making any of these connections. Verifying proper cable connection is not redundant—it is smart!

The next cable you should look at in figure 2–8 is the cable with cannon plugs. These come in 60A (Fig. 2–8A) or 100A (Fig. 2–8B) capacities and 50 ft. or 100 ft. lengths. This is the cable connected to the receptacles leading from the PDC, especially if you are feeding another PDC. The 100A version generally connects one PDC to another. Since it carries a higher amperage capacity, it can feed another PDC, which further distributes power down the line. The 60A cables feed the end users from the PDCs (i.e. tents, ECUs, or O_2 concentration systems). From the generator down to the user, cables should always feed larger ratings to smaller (305A–100A–60A).

Figure 2–8. Conductors (wiring) for PDCs and feeders.

You could use the 100A wire for the tent lighting, but it is not recommended. That wire has a lot higher rating than the 60A wire to feed tent lights. So, if an electrical problem occurs when using the 100A wire, the conductor carries up to those 100 amps. By that time, your bulbs will have burned up, along with any lower-rated wire within the tent. The 60-amp wire carries only 60 amps, any amperage above that blows the circuit breaker. This can be quite a significant difference in damage, depending on the load.

Branch box

Figure 2–9 is an example of the distribution box located in the tent.

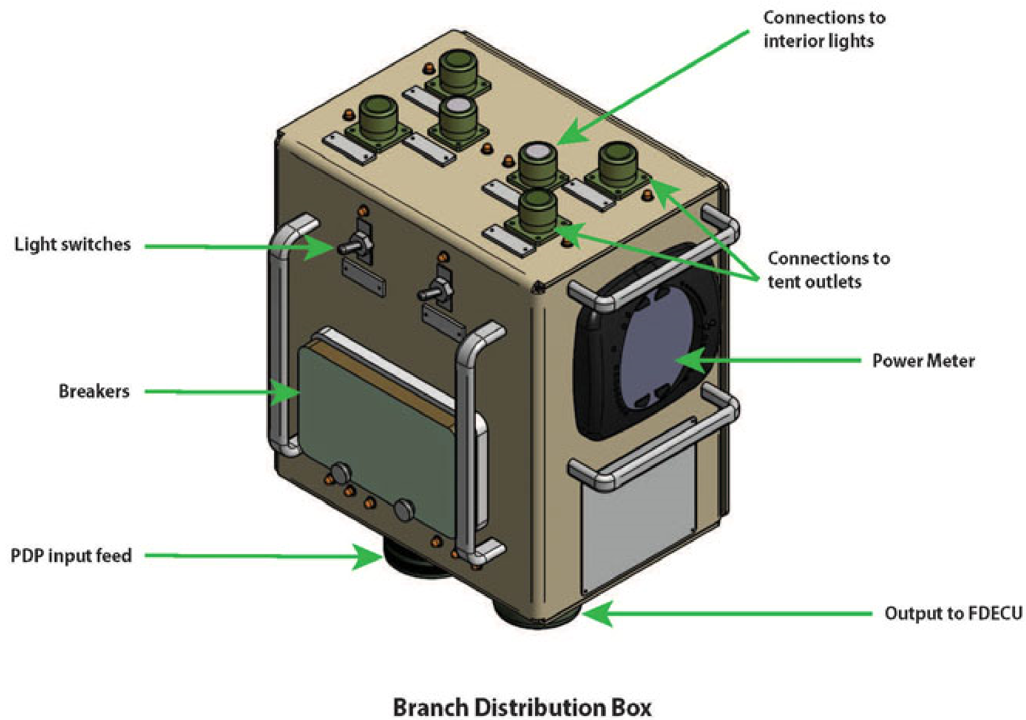


Figure 2–9. Branch distribution box.

The branch box provides power and light distribution within a tent or structure. The cannon plug-type connector hooks into the bottom of the B-box where it says “power in.” It also has a 60A output cannon plug to power the environmental control unit (ECU). The B-box provides additional hook ups for the lights and outlet receptacles, which are connected with cannon plugs into the top of the box. Outlets are available on the left side of the B-box for direct connection to equipment and accessories. These are standard receptacles typically seen throughout your home and medical facility. They accept the standard three-prong plug. The right side of the unit contains a power meter to monitor incoming and outgoing power status.

The front of the B-box has switches for the right and left lights, and set up circuit breakers—one for each output. These circuit breakers flip if the circuit is overloaded. You can reset them, but if the overload condition still exists, the circuit breaker will not reset or it may reset and then immediately pop again. These boxes mount to the tent pole.

PDC PM procedures

The following table illustrates the sequence for PM procedures on a PDC for operation:

Interval	Location	Procedure
Before operation	Enclosure	Check for damage to the enclosure or door assemblies.
Before operation	Enclosure	Inspect the cover assembly.
Before operation	Enclosure	Check the drainage openings.
Before operation	Top panel	Check for damaged circuit breakers.
Before operation	Top panel	Check the indicator lights for damage.
Before operation	Connectors	Inspect the connectors for damage.
Before operation	Connectors	Inspect the connector covers.
Before operation	Cable assemblies	Check for damaged cable connectors.
Before operation	Cable assemblies	Check for split, cut, or damaged insulation.
Before operation	Ground wires	Check the ground wires for security.

Interval	Location	Procedure
Before operation	Connectors	Ensure to cap unused connectors.
During operation	Top panel	Ensure indicator lights glow when power is applied.
After operation	Top panel	Clean the face of the circuit breakers with a dry rag.
After operation	Connectors	Ensure to cap unused connectors.
After operation	Cable assemblies	Clean assemblies with a rag soaked in mild detergent.

Now that we have power generation, and distribution systems are making the power accessible, let's make use of the power and hook it up to buildings and equipment!

Self-Test Questions

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

014. Generator components and maintenance

1. Who should the hospital have an agreement with for the maintenance of stored generators?

2. What is a load bank?

3. What allows an emergency bypass of all generator malfunctions and forces the unit to go on line with the load?

4. What fuels operate the generator?

5. How long does the generator fuel last with a full tank at 80 percent load?

6. Name the five important things to consider when using a generator.

7. Which component is the information center of a TQG?

8. How would you manually send power from the generator to the load once voltage and frequency are stable?

9. In what situation should you use the battle short?

10. Where is the load cable connected to the generator?

11 What sources can you use for generator grounding? Which is the *most* common?

12. What are the minimum requirements for grounding sources?

13. What is the *first* step performed in a PM check?

14. How would you check all lights, alarms, and functions on the control panel?

15. How long should you let the generator warm up before placing a load on it? How long should the unit cool down with no load?

16. How often should you change the engine oil and filter?

015. Distribution of electrical power

1. When are the PDCs referred to as power feeders?

2. Given three PDCs rated at 100 kW, 200 kW, and 15 kW, how should you connect them if the intent was for them to feed each other, and then feed the user?

3. What precautions should you adhere to prior to moving the PDC?

4. What is the *smallest* EMEDS configuration (which replaced the EMEDs basic layout)?

5. On the PDC, what tells you the load lines connected in-phase from the generator?

6. Name the two things that can happen if you cross the cables coming from the generator to the PDC.

7. What should you always do before making any connections to the generator or PDC?

8. Where does the cable from the PDC tie in to the tent to provide power?

9. What is the safety feature on the B-box for an overloaded condition?

10. What should you check for during operation when performing a PM on a PDC?

2–2. Tactical Shelters

Now that you have set up all of the power requirements to generate some juice, it is time to tie it into the facility that you will be using. Although tactical shelters are more of a structure than medical equipment, they are no less vital to your daily duties. Ensuring that the shelters are set up correctly and properly maintained, falls under your scope of responsibility as a deployed BMET.

016. International Organization for Standardization shelters

In the previous lessons, you learned about generators and electrical power distribution. Now is the time to apply some of those concepts to the tactical shelters included in an EMEDS. A shelter, just as the name implies, provides protection (or shelter) from the outside elements. Once powered from the generator and PDCs, these structures allow us to perform medical operations in more desirable conditions. The official military name for the International Organization for Standardization (ISO) shelter is shelter, tactical, expandable.

ISO shelter system application

ISO shelters have rigid walls to maintain a controlled environment and facilitate all-weather operation. They are simple to set up and easy to maintain. There are external connections for the ECU and electrical power. They can operate under blackout conditions with door switches that cut off the lights when the door opens. They have two configurations—the one-sided (2:1) shelter and the two-sided (3:1) shelter. When either shelter is in its closed shipping configuration (Fig. 2–10), its dimensions are 8′ wide × 8′ high × 19′10½″ long. This tactical shelter size conforms to the ISO guidelines for shipping containers, which is why we commonly call it the ISO shelter.

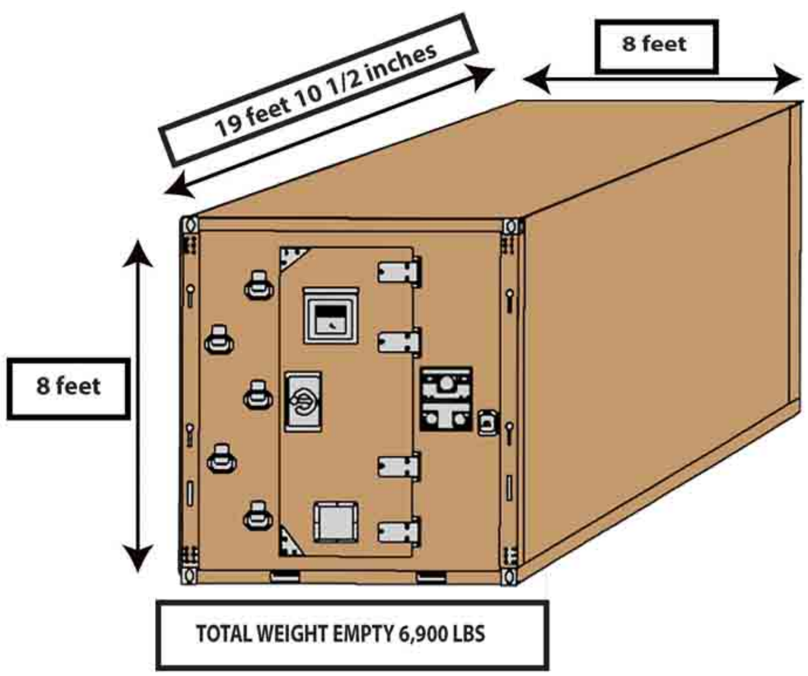


Figure 2–10. ISO shelter configured for shipment.

When fully expanded, the one-sided (2:1) shelter (Fig. 2–11) has 271 sq. ft. of usable floor area, with the height and length staying the same, but the width expanding to 14′10″. The 2-sided (3:1) shelter (Fig. 2–12) has 400 sq. ft. of usable floor area, with the height and length staying the same, but the width expanding to 21′10″ wide. The weight of the ISO shelters range from 6,900 lb. empty to over 15,000 lb., depending on the configuration.

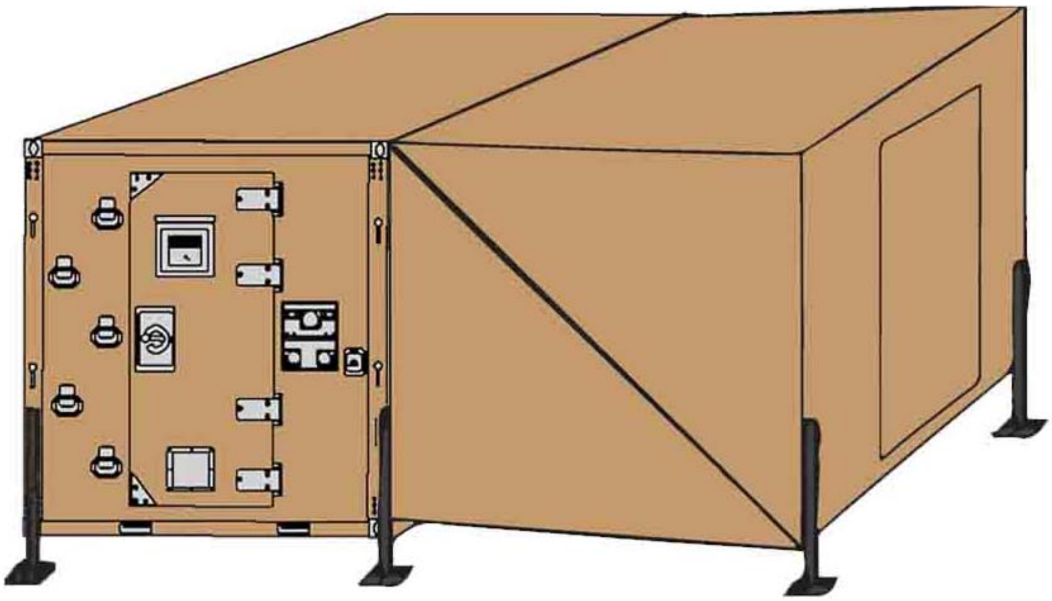


Figure 2–11. 2:1 ISO shelter.

Figure 2–12. 3:1 ISO shelter.

When deployed, ISO shelters ship by air, land, or sea. The shelters ship as a complete package, ready for setup and use. While the ISO shelter does a great job of protecting you from the elements, it will not protect you from bullets, bombs, or chemical agents.

Site preparation

The site that will house the ISO shelter should allow for reasonable maneuvering of vehicles used for hauling or hoisting the shelter. The terrain should be firm, well drained, and relatively free of surface rocks or stones. The slope of the terrain should not exceed 18″ over the projected floor area of the expanded shelter.

Install

To lift the ISO shelter into place, use a dolly set M832 mobilizer if the shelter system is 10,000 lb. or less. If the gross weight of the shelter system is over 10,000 lb., then use the dolly set XM1022 or hoisting sling (with a cable breaking strength of 35,000 lb.). When using a forklift, ensure it has a minimum tine length of six feet. Use the inner slots for fork lifting an empty shelter only. Follow the manufacturer's instructions for proper hoisting and set-up of the ISO shelter.

Organizational maintenance

Step-by-step procedures for organizational maintenance on the ISO shelter are in the appropriate technical order. Performing specific tasks may require special tools (e.g., a hand blind riveter, portable electric router, snap ring pliers, box end or adjustable pliers, multimeter, portable electric drill, and crimping tool). Maintenance may include the checkout and replacement of light bulbs and circuit breakers, or utility power checks.

Specific ISO shelters

Now that you have an idea what an ISO shelter is, let's look at the radiology, surgery, and laboratory ISO shelters.

Radiology

The radiology ISO shelter uses the 2:1 configuration. The following is a partial list of equipment found in a radiology ISO shelter:

- Fixed high-frequency radiographic unit.
- Mobile A/C radiographic unit.
- Radiographic film illuminator.

Surgery

The surgery ISO shelter uses the 3:1 configuration. The following is a partial list of equipment found in a surgery ISO shelter:

- LOX converter.
- Surgical suction.
- Anesthesia apparatus.
- Anesthesia ventilator.
- Vital signs monitor.
- Pulse oximeter.
- Defibrillator/monitor.
- Volume ventilator.

Laboratory

The laboratory ISO shelter uses the 3:1 configuration. The following is a partial list of equipment found in a laboratory ISO shelter:

- Blood bank refrigerator.
- Water purification system.
- Clinical chemistry analyzer.
- Laboratory centrifuges.
- Blood cell counter.
- Microscope.

017. Tentage

Let's turn our attention to the types of tents used for deployed medical facilities. The two types of systems widely used on Air Force medical assemblages are the Alaska Medical Shelter System (AKMSS) and the UTS System®. These both include ORs, supply, dental, pre-op, surgery, and wards, which protect medical personnel from extreme heat and cold conditions.

AKMSS

Figure 2–13. AKMSS, EMEDS site.

The design of the AKMSS (Fig. 2–13) will last for 10 years when erected and has a shelf life of 20 years when stored. They are available in tan or green, and hold up in all types of terrain and in all types of weather. The design allows you to erect the structure with a group of four people, but due to the size and weight of the braces and cross sections, that is not realistic to meet EMEDS rapid deployment timelines. The AKMSS can accommodate string lighting with six sockets; each socket can handle 150 watts of light operation at 120 volts, 60 Hz with the receptacles rated at 15 amps each. The shelter includes a 20′ wide × 32.5′ long × 10′ high free-span shelter, a 20′ × 8′ × 10′ high extension shelter, a 7′ × 8′ × 9′ vestibule shelter, quick-connect wiring harness, and a 463L palatable transport container. Each shelter has a lightweight, structural aluminum frame system and a high-strength aluminum base covered with a military specification vinyl fabric.

UTS shelter system

Figure 2–14. UTS EMEDS layout.

The UTS System® (Fig. 2–14), formerly known as the Utilis system, is the replacement concept to the Alaska medical shelter. As this is the newer system that we use across AF platforms, we will discuss the details for installing and employing this version throughout this lesson. The shelter consists of a frame, shelter fabric with integrated liner and electrical, side arches (10 per shelter), one electrical pole, a thermal fly, hanging rigid bars (4) and a staking kit. The UTS System has two power distribution circuits on each side (left and right) of the shelter for a total of four circuits. One power distribution circuit has three each quad-con 4 outlet boxes, two each quad-con 4 outlet boxes and an extension piece. The shelter includes a 21′ wide × 36′ long × 10′ TM60 Tall shelter, a 21′ × 7′ × 10′ TM15 Tall four-way connector, a 7′ × 6′ × 9′ SM5 Vestibule.

The UTS System® made some improvements in designing the TM60, taking into account feedback from the field. In addition, the TM60 tall has a plenum pre-installed and there are pre-labeled removable signs (e.g., dental, emergency room) to designate each shelter. The SM5 Vestibule is equipped with electrical cord channels making running power smoother. The frame attaches on the exterior of the tent underliner, which helps reduce wear and tear on the shelter fabric. The *most* important advantage the UTS System® has over the older Alaska system is the time and people it takes to set up each tent. An experienced team can set up a UTS single tent, operational with staked frame and underliner with five people in around five minutes. This plays a significant role in meeting the Air Force's expeditionary deployment timelines.

Collectively protected-expeditionary medical support

The chances of encountering nuclear, biological, and chemical (NBC) warfare agents in the field are high, so the EMEDS shelter has the capability to protect against these agents. Collectively protected-expeditionary medical support (CP-EMEDS) equipment packages deploy into areas with a NBC threat. When in place, CP-EMEDS allows continued operations after a NBC incident without requiring a change to the shelter layout. Be sure to install the CP components during the initial EMEDS setup. The CP-EMEDS (Fig. 2–15) equipment consists of CP liners, chemically hardened ECU, filtered-air blowers, airlocks, and pressure alarm systems. A water distribution system provides potable water flow and wastewater recovery to all areas of the medical facility that need support.

In CP mode, the connection of the double track flange is one key element to ensure the hospital remains a toxic free area (TFA). It also allows the connection of other CP shelters, like the collectively protected expeditionary latrine (CPEL) to be complexed to the hospital. When the hospital does not need to be in a CP mode, the hospital commander has the option to have the double track flange connected to alleviate water, dust, and vermin penetration.

Figure 2–15. Collectively protected shelter.

Prepare site

The site must have at least 82′ by 94′ of space for an EMEDS HRT configuration utilizing a UTS System®. The area must be free of any debris and be made as smooth as possible. The ground should be level so the floors do not slope in either direction. It should be located as close to the road as possible to allow the forklift to set the container base down.

Installation

Once the container is at the site, the shelter is ready for installation. It is important to inventory the container to ensure all of the items are available. Lay the items out on the floor in the order you plan to use them. There are also items needed for installation that are not part of the inventory. These can include a sledgehammer, ladder, masonry bit, and a 50′ tape measure. Place the ECU on the left corner of the shelter. Set up the shelter in the following sequence:

1. Clear an area approximately 5 feet larger than the shelter to be set up.
2. Unfold the ground cloth found in the shelter accessory carry bag.
3. Place the roof frame carry bag in the center of the ground cloth. Open the carry bag and lay flat.
4. Open the roof frame assembly by unfolding the roof arches.

5. Raise the roof frame upright so it is resting on the eave angles.
6. Deploy the roof frame by grasping two roof arches, lifting off the ground, and pulling away from the center.
7. Grab the two pieces of the ridge purlin and slide the male connector into the corresponding piece of the ridge purlin. (Roof is complete).
8. Pre-position the side arches, cleats facing up and with the feet away from the shelter.
9. Raise one entire side of the roof assembly and insert the side arches onto the black male ends on the angles. Secure with lynch pins.
10. Roll out the outer fabric the length of the roof assembly under the frame below the ridge hinge.
11. Run the outer fabric black ropes up through the ridge pulleys on the frame and secure to cleats. (Corner ropes feed through the eyebolt).
12. Pull the thermal fly over the roof frame and lace up the endwall thermal fly starting with the ridge.
13. Raise the other side of the roof assembly and insert the side arches onto the black male ends.
14. Connect wind lines to the angle eyebolts with the 'S' hook.
15. Deploy the foot extensions.
16. Attach the catch plates to the frame feet.
17. Raise the ridgeline and eaves of the outer fabric and secure to arches.
18. Stake the tent. (Structure is complete).

Organizational maintenance

The following table contains the maintenance criteria for the UTS:

Item	Inspection	Corrective Action
Exterior fabric	Inspect for any build-up of dirt and foreign matter.	Clean as required.
Covers, end panels, floors, and liners	Inspect for small tears and worn areas every 30 days while in use.	Clean the area and patch, if necessary.
Electrical cable assemblies	Inspect for kinked, nicked, or cracked cable assemblies every 30 days.	Repair as required.
Containers	Inspect while in use, prior to packing, and prior to shipment.	Clean as required.

NOTE: Use only soap and water to clean the shelter.

Prepare for shipment

When preparing for shipment, tear down the shelter in reverse order of setup. Inspect all items for damage. All items must be dry and free of rodents and bugs before packing. Clean all parts and repackage them into their appropriate container in the order listed in the maintenance instructions. This ensures all parts fit into the container and prevents repacking.

Self-Test Questions

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

016. International Organization for Standardization shelters

1. What is the official military name for the ISO shelter?

2. Name the two ways ISO shelters are configured.

3. What are the dimensions of an ISO shelter when it is configured for shipping?

4. Where does the name “ISO shelter” originate?

5. When fully expanded, the one-sided (2:1) shelter provides how much usable floor space?

6. What are the dimensions of the fully expanded one-sided (2:1) shelter?

7. When fully expanded, the two-sided (3:1) shelter provides how much usable floor space?

8. What are the dimensions of the fully expanded two-sided (3:1) shelter?

9. What are the terrain requirements when preparing the site for installation?

10. What equipment should you use to move an ISO shelter if the gross weight of the shelter system is over 10,000 lb.?

11. What configuration does the radiology ISO shelter use?

12. Name three equipment items found in the radiology ISO shelter.

13. What configuration does the surgery ISO shelter use?

14. Name five equipment items found in the surgery ISO shelter.

15. What configuration does the laboratory ISO shelter use?

16. Name four equipment items found in the laboratory ISO shelter.

017. Tentage

1. What is the shelf life of an AKMSS?

2. What is the structural content of the AKMSS?

3. What is the replacement concept to the AKMSS?

4. What does the structural content of the UTS System® include?

5. When would you install CP components on an EMEDS?

6. What does a collectively protected version of the UTS System® include?

7. What is one of the key elements to ensure the hospital remains a TFA?

8. What is the *minimum* space requirement for an EMEDS HRT configuration using a UTS System®?

9. What is an important task to perform before beginning installation of a UTS® shelter system?

10. How often should you check the floors and liners for small tears?

11. How often are the electrical cable assemblies inspected for cracks?

2–3. Environmental Control

When you deploy, you must be ready to survive in all weather conditions. That means you must bring everything but the kitchen sink to ensure you are prepared. It would be a shame to save someone's life with our medical skills, only to have him or her die of frostbite or heat stroke because you did not make the treatment environment survivable. This section walks you through the various equipment items needed to provide heating and air-conditioning to your facility. It also discusses some special environmental requirements for NBC conditions. Remember, you must be able to adapt to any situation you encounter, so the more you know about these items, the better asset you are to the team.

018. Environmental control functions

Climate control is one of the most essential parts of a deployed environment. Some deployment locations have weather that varies from one extreme to another, and depending on the time frame of your deployment, you could see both ends of the scale. For instance, Afghanistan is known for having summers that can reach in excess of 120 degrees, but did you know that the winters could drop to –9 degrees? Proper climate control can be the difference between effective mission operations, and a bad story to write home about (if you can even write home with frostbite). Either way, comfort indoors is extremely important to you and your patients. Let's begin by discussing the ECU.

ECU

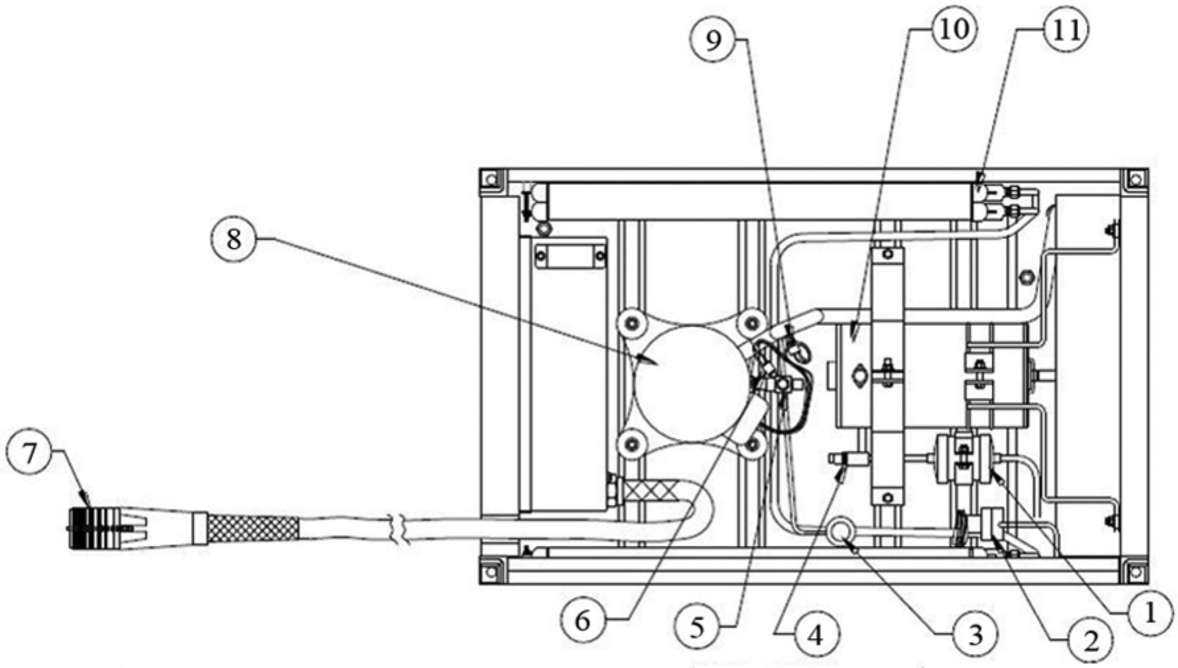
This unit is an air conditioner and a heater rolled into one. Figure 2–16 shows a basic ECU you may encounter. There are various models of ECUs, but all operate in the same manner. They provide environmental control to each temporary facility they connect to. The lightweight environmental control unit (LECU) weighs approximately 550 lb., which is significantly less than the weight of its predecessor the field deployable environmental control unit (FDECU), which weighed 800 lb. This makes a big difference when having to adjust the position of the ECU during install, after the forklift drops it off by the tent. Not only weight, but also the size difference and stackable design of the LECU doubles the amount of ECUs that you can fit on a single aircraft pallet. A lighter, more mobile expeditionary force increases mission capabilities.

Figure 2–16. Environmental control unit.

Figure 2–17 below shows the internal configuration of the LECU. The following table discusses common ECU components and their functions:

Component	Function
Evaporator	Device in which the refrigerant evaporates while absorbing heat. You could single out the evaporator as the one component that actually accomplishes the purpose of this system – the cooling of air.
Evaporator fan	Pulls air through a filter and across the evaporator coil.
Evaporator fan motor	Provides the means to spin the evaporator fan.
Evaporator drain	Consists of two ½" hose barbs fittings with plastic plugs and drain tubes to run evaporated liquid away from the shelter and ECU.
Supply air duct	Five foot long duct with a sewn in band clamp that supplies air to the shelter.
Return air duct	Seven foot long duct with a sewn in band clamp that pulls return air from the shelter.
Charging valve	Used for adding liquid refrigerant.
Condenser coil	Transfers heat picked up from the evaporator to outside air.

Component	Function
Condenser fan motor	Draws outside air through the finned condenser coil and delivers hot air outside.
High/Low-pressure cutout	Switches off the electrical circuit when refrigerant pressure is too high. Protective devices, which sense the suction and discharge pressures of the refrigerant within the compressor. High pressure breaks at 475 psig, low breaks at 5 psig.
High-temperature cutout	Switches off the electrical circuit when the temperature is too high. Automatic reset limit control set to open at 180°F and close at 140°F.
Power cord	A cannon plug cable that provides 208 volts, 3-phase power to the unit from the PDC at a maximum of 35 amps.
Compressor	Takes low-pressure, low-temperature refrigerant and delivers high-pressure refrigerant to the condenser.
Sight glass	Provides a visible indication of the fluid state of the refrigerant.
Hot gas valve	The hot gas valve's purpose it prevent condensate on the evaporator coil from freezing during low load conditions by keeping the suction pressure above 52 PSIG (33° F).
Thermostatic expansion valve (TEV)	This valve controls the flow of liquid refrigerant into the evaporator. Varying load conditions change the operating forces in the expansion valve. The changing forces cause the expansion valve to open or close.
Thermostat control	The thermostat is a two-stage temperature controller that incorporates a liquid filled remote sensing element.
Heater	Six rod heating elements are located on the evaporator grill. When air passes through the evaporator, it crosses the heating elements, and then passes to the discharge duct for space warming.
Air filter	Captures solid airborne contaminants before they enter the ECU.



1. Filter/drier
2. Main Termostatic Expansion Valve (TEV)
3. Thermostat
4. Receiver service valve
5. Compressor sevice valve
6. High pressure cutout switch
7. Power cable (cannon connection to B-box)
8. Compressor
9. Low-pressure cutout switch
10. Condenser fan motor
11. Condenser coils

Figure 2–17. ECU components.

Heating process

There are two stages of the heating process (high and low). The heaters have a high temperature cutout switch mounted in close proximity to the heater elements. In case of any condition which would cause low airflow, and therefore, high element temperature, the cutout switch would open and deactivate the heater by removing control circuit voltage from the heater contactor. The high temperature cutout switch is a snap disc automatic reset limit control set to open at 180°F and close at 140°F. The remote sensing bulb is located on the suction line at the outlet of the evaporator. This return air duct contains a sample of the air temperature within the structure.

The first low temperature stage switches on a set of three wire heating elements should the return air temperature drop below the thermostatic set point (i.e., if the thermostatic set point is 70°F, and the return air temperature drops to 69°F, then the heating elements turn on because the return air temperature dropped below the set point). When the return air drops below the set point, the elements turn on, heating the supply air as it passes through the evaporator. The unit then delivers the heated air to the discharge duct by the evaporator blower.

If the ECU does not heat the area quickly enough and the temperature continues to drop according to the remote sensing bulb, then a second set of heating elements turns on. The first set of elements stays on continuously, and the second set cycles ON and OFF in relation to the return air temperature.

When the selector switch is set to heating mode and the conditioned space is sufficiently heated, the thermostat causes the low-heat/high-heat contactor to deenergize, shutting off heating.

Air conditioning process

The air conditioning process is a one stage cooling system. The compressor circulates refrigerant through the system by creating a pressure differential. The compressor has a discharge service valve and suction access valve, which are important during various maintenance functions.

After refrigerant gas leaves the compressor it enters the condenser and hot gas solenoid (L1). Refrigerant gas entering the condenser compresses to a pressure/temperature condition well above the ambient air temperature. When the condenser fan draws cooler ambient air through the condenser coil, the refrigerant gas will condense into a liquid.

The liquid refrigerant then enters the receiver, which is a liquid holding tank ensuring a steady liquid flow into the filter drier and provides a place for storage of refrigerant. The filter/drier removes particulate contaminants such as metal filings and brazing slag from the system, and it retains soluble elements such as water and acid.

The TEV is the next component in the liquid line of the refrigeration system. This valve controls the flow of liquid refrigerant into the evaporator. When liquid refrigerant leaves the expansion valve, its pressure/temperature reduces because of the pressure drop across the expansion valve. This liquid pressure/temperature is lower than the temperature of the return air drawn through the evaporator by the circulating (evaporator) fan. The evaporator absorbs heat and reduces the temperature of the air on the leaving side of the evaporator. You could single the evaporator out as the one component that actually accomplishes the purpose of this system – the cooling of air.

When the selector switch is set to cooling mode and the conditioned space reaches the intended range, the thermostat causes the compressor and condenser fan contactors to deenergize, shutting off the cooling operation.

Collective protection

We discussed CP-EMEDS in an earlier lesson, but what truly protects you from outside contaminants is collective protection provided by the ECU. You can outfit the ECU for use during direct exposure to a hazardous environment. It operates using filter blower overpressure systems developed for use in NBC environments.

Collectively protected ECU

The LECU can operate with a filter blower unit (FBU) or a fan filter assembly (FFA) blower. Essentially these units provide NBC filtration as well as positive pressure capabilities to ensure a contamination free zone. Make sure to install the NBC hardening kit in order to use the system in NBC protection mode. This kit consists of an NBC return air adapter, chemically hardened return and supply ducts, and a filtered make-up air blower assembly.

FAA–400

You can use the 400-cubic feet per minute (cfm) unit (FFA–400, Fig. 2–18) in conjunction with an LECU or FDECU in order to provide clean filtered make-up air to the shelter. It attaches to the ECU via an NBC adapter collar and two 4” hoses. The power requirements are 120/208 VAC, 3 phase, 50/60 Hz. The FFA 400’s receive power by connecting their “Y-”cable to the J1 and J2 plugs on the ECU control panels. The two main functions of FFA blowers are to provide air filtration and a positive pressure environment to prevent contaminants from entering.

The FFA–400-cfm blower features two gas particulate NBC filters. It comes with a low-pressure alarm placed within the shelter, designed to monitor the interior pressure of the TFA and provides an audible alarm if the pressure rises too high or drops too low. This unit also includes a plastic tube sensor that runs outside of the shelter to monitor ambient pressure in relation to the pressure inside the TFA. It is equipped with LCD readout indicating the shelter pressure, a low and high pressure LED, and an audio on/off switch. The alarm activates when the pressure of the system drops below 0.40 inches of water gauge (iwg) or rises above 0.85 iwg. There is a switch to silence the alarm; however, the red LED warning light will illuminate until you correct the condition. Once the pressure of the shelter has risen above 0.45 iwg or dropped below 0.75 iwg, the alarm will automatically reset itself. You can either mount the low-pressure alarm on the electrical distribution box attached to the light box pole, or simply place it on a table. The low-pressure alarm uses a standard 110V plug.

Figure 2–18. Chemically hardened FDECU with FFA–400-cfm blower.

FFA–580 and bump-through door airlocks

Part of a CP EMEDS is having a means to enter and exit in order to provide patient care, while also ensuring that you maintain a contaminant free zone. Personnel entering must go through the bump-through door airlock system. The NBC protective liners install internally, the system is pressurized by external FFA–580 (600-cfm) blowers. This all-weather portable positive pressure NBC filtration system provides clean breathable air to the shelters and forces air flow outward from the shelter. It allows for a greater recirculation of the air within the airlock, thus reducing the purge time. The unit is modular in design and allows you to combine multiple units for requirements greater than 600 cfm. The unit uses three sets of 200 cfm gas particulate standard type-classified M56 filters. As you can see in figure 2–19, the shelter appears to be “puffed out” because the blower creates positive pressure inside the tent preventing contaminants from entering.

It provides a high flow rate of filtered air to ensure a rapid purge of airborne contaminants during entry and exit. Two 12-inch diameter flexible ducts, made of chemical agent resistant cloth, each 9 ft. long, convey air from the filter unit to the airlock and back. It has a gauge panel assembly that attaches directly to the frame of the inner door. It consists of two pressure gauges with tubing (pressure reference lines), a timer, and an incandescent lamp. One pressure gauge measures the pressure inside the TFA, referenced to the outside. The second measures the pressure in the airlock. This device is manually set to time a 3-minute period when a person enters or exits the airlock. Although the airlock itself maintains a positive pressure environment, it manages pressure at a lower level than the attached structure, ensuring that airflow moves away from the safe zone.

Figure 2–19. Bump-through door airlock with FFA–580.

019. Installation and maintenance of ECUs

Site selection

The place that you set up an ECU needs to meet the following criteria:

- Position the LECU on a level surface (at least four (4) feet from any obstruction).
- If the terrain is uneven, ensure the raised corner of the unit is not higher than 5″ above the lower corner.
- Place the unit about 6′ – 7′ away from the structure requiring environmental control.
- Point the front of the unit toward the structure.
- Position the unit so the ducts are free of kinks or sharp bends.
- Leave a minimum of 2′ at the rear of the unit for condenser air circulation.
- Place the unit on the generator side of the site to reduce the distance of cable runs.

Installation

Perform the set-up of the LECU in the following manner:

1. Release three latches and open top cover.
2. Lift the cover and support it by hand, manually insert the prop rod into the receptacle to secure in the open position.
3. Remove air ducts, drain line, cable, return air duct collar, and remote box.
4. Unwind power cable and guide through the notched area on the top of the side panel.
5. Remove metal duct cover and store using quarter turn fasteners.

6. Plug remote control cable into connector located inside the supply air duct collar.
7. Pass the cable and remote control box through the supply duct.
8. Connect the five-foot long duct to the LECU supply duct collar and secure with the attached band clamp.
9. Pass the cable and remote control box through the shelter opening and connect the supply air duct to the shelter.
10. Position remote control box approximately five feet above the floor, away from supply air and midway on the shelter wall, if possible.
11. Release the eight quarter-turn fasteners and remove the return air cover plate from the front of the LECU.
12. Connect the return air collar to the LECU.
13. Connect the seven-foot long duct to the LECU return air duct collar. Secure with the attached band clamp.
14. Before starting the LECU, fully open the condenser fan storage panel.
15. Release quarter-turn fasteners, swing cover down and secure in the open position with lanyards and pin.
16. Close and secure top lid.
17. Remove the drain plugs with lanyard and connect drain line two places at rear of the LECU and route to appropriate drainage area.
18. Ensure drain line outlet is lower than the LECU for proper drainage.
19. Remove the left side condenser coil storage panel and secure to top of the LECU with four quarter-turn fasteners.
20. Remove the right side condenser coil storage panel and secure to top of the LECU with four quarter-turn fasteners
21. Connect power cable to a three phase, 208 VAC, 50/60Hz power supply with neutral and ground.

Operational inspection

The following table shows the procedures required to ensure efficient operation of the LECU:

Interval	Maintenance Action
Before operation	Inspect the flexible ducts for worn or torn spots, and for secure attachment.
Before operation	Inspect the outside coil for dirt or obstruction.
Before operation	Ensure the outside fan is secured.
Before operation	Inspect for foreign objects in fan wheel.
Before operation	Check the liquid indicator sight glass for cracks and note its color.
Before operation	Check the control panel for damage.
During operation	Check the liquid indicator for constant bubbles or foam and its color.
During operation	Check the condensate drain hose, when in cooling mode.
Weekly	Inspect the power cable for damage.
Weekly	Inspect the wiring for damage.
Monthly	Check the covers, screens, and panels for dirt or obstruction.
Monthly	Check the air filter, clean, or replace as necessary.
Monthly	Inspect the outside of the unit for damage.
Monthly	Ensure the identification plate is secure.

Organizational maintenance

The following table shows the tasks required for proper organizational maintenance of the LECU:

Interval	Item	Procedure
Quarterly	Top compartment fan.	Clean the top compartment fan as necessary and inspect it for damage.
Quarterly	Condensate drain hose.	Remove the supply panel, fill drain pan with two gallons of water, and examine the hose drains free of any obstruction.
Semi-annually	Wires, cables, harnesses, and electrical connections.	Open the cover and panel, and inspect these items for breaks, cuts, or frayed insulation. Ensure the electrical connections are secure.
Semi-annually	Electrical system components.	Open the cover and panels, and inspect these items for damage or evidence of overheating.
Semi-annually	Refrigeration system components, tubing, and fittings.	Open the cover and panels, and inspect this system for damage or evidence of a refrigerant leak. Check the tube and fittings for damage.
Semi-annually	Top compartment coil.	Check for any visible damage or evidence of leaking.
Semi-annually	Electric box wiring.	Open electric box door and electric box panel. Inspect for frayed or damaged insulation over visible portion of wires. Check for loose electrical connections.

Preparation for storage

There are several steps involved in preparing the unit for storage:

1. Open access panels and inspect unit thoroughly for broken wires, broken controls, or other damage that may have occurred during operation.
2. Visually check inside the unit to verify that the return air filter is clean and in place, that there are no refrigerant leaks, and that there are no loose or broken wires and other physical damage.
3. Locate remote control box and unplug remote control cable. Install the remote control box inside of the LECU top cover and secure with four (4) quarter-turn fasteners.
4. Loosen the band clamp and remove the five (5) foot long duct. Collapse and secure with the draw straps.
5. Install the supply air cover plate and secure the four (4) quarter-turn fasteners.
6. Loosen the band clamp and remove the seven (7) foot long duct. Collapse and secure with the draw straps.
7. Loosen the eight (8) quarter-turn fasteners and remove the return air duct collar.
8. Remove the air return air cover plate from the top cover, then install the plate and secure the (8) quarter-turn fasteners.
9. Attach the return air duct collar to the inside of the LECU top cover by fastening four (4) of the eight (8) quarter-turn fasteners.
10. Remove the drain lines and roll up for storage inside the LECU.
11. Plug drain openings with plastic drain plugs.
12. Coil the power cable clockwise around the inside of the unit.
13. Place the return duct (collapsed and secured) in the back left side of the LECU.
14. Place the supply duct (collapsed and secured) in the front left side of the LECU.
15. Ensure you install components in a manner that the top cover will be able to close and secure with the three latches without being forced.
16. Place the remote box cable in the front right side and the drain line in the back right side of the LECU.

17. Close the top cover and secure the three (3) latches.
18. Close the condenser exhaust cover and secure with two (2) quarter-turn fasteners.
19. Remove the front side condenser storage panel from the top of the LECU and secure over the front side condenser coil with four (4) quarter-turn fasteners.
20. Remove the rear side condenser storage panel from the top of the LECU and secure over the rear side condenser coil with four (4) quarter-turn fasteners.
21. Close and/or replace all access panels and covers.

Self-Test Questions

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

018. Environmental control functions

1. What are the two basic functions that the ECU provides?

2. How much does an LECU weigh? FDECU?

3. What is the job of the compressor on the ECU?

4. What does the TEV control?

5. How many heating rods are there? Where are they located?

6. What is the function of the air filter?

7. What are the two stages of the heating process?

8. How does the compressor circulate refrigerant through the system?

9. Where does the heat exchange occur in the ECU during the air conditioning process?

10. What truly protects you from outside contaminants in a CP-EMEDS?

11. What are the roles of FBU and FFA blowers?

12. When does the pressure alarm activate on the FFA–400-cfm blower?

13. How does the bump-through door airlock ensure that airflow moves away from the safe zone?

019. Installation and maintenance of ECUs

1. How much room do you need for condenser air circulation when installing the ECU?

2. Where should you position the remote control box during installation on an LECU?

3. When installing an LECU, what step should you take before starting the unit?

4. How often should you inspect an ECU for foreign objects in the fan wheel?

5. What steps would you take to PM the condensate drain hose? How often should you perform this task?

6. What is the *first* step you should take when preparing the LECU for storage?

2–4. Oxygen Requirements

The previous discussions covered power and environmental requirements for a deployment site. This section will cover O_2 systems, which are very important in maintaining an efficient EMEDS site. O_2 systems provide life support capabilities for patient care.

020. Oxygen concentration systems

O_2 deployment in the field is a huge undertaking. It requires shipping, storage, and distribution throughout various EMEDS sites; some of the supply may be lost before it reaches its final destination. There have been many improvements made to these delivery systems over the years, encompassing feedback from experiences in the field. At the forefront to these changes are the O_2 generation systems, such as the Expeditionary Deployable Oxygen Concentration System (EDOCS) and the Deployable Oxygen Generation System – medium (DOGS-M). Units such as the mobile oxygen storage tank (MOST) and the Hospital Oxygen Backup System (HOBS) supply O2 storage functions. The distribution systems for EMEDS are the Patient Oxygen Distribution System (PODS) and Surgical Suite Oxygen Distribution System (SSODS). Let's take a more in-depth look at these units.

EDOCS

The EDOCS 120 and 120B (Fig. 2–20) have been the bedrock of O_2 generation over the past couple of decades. The EDOCS 120B generates 120 liters per minute (lpm) of 93% ± 3% pharmacological O_2. This O_2 is then delivered to the hospital distribution system at 100 psi. A built-in boost compressor receives this gas and compresses it to 2,250 psi. The high-pressure gas is then stored in four cylinders to provide a two-hour back-up supply. A vacuum pump is included with this system to evacuate the cylinders prior to filling. The system can supply 10 patients at 11 lpm by respirator or 55 patients at 2 lpm by nasal cannula. It can operate 24 hours a day and takes approximately 16.5 hours to fill one HOBS.

DOGS-M

The DOGS-M (Fig. 2–21) is a more recent O_2 concentration system mobilized across EMEDS assemblages, and as such, we will use this model as the focus for concepts in this lesson. The overall concept operates similar to that of the EDOCS products. This unit can operate over a temperature range of – 25ºF–120ºF, and employs a centrifugal separator and series of cabinet and air compressor inlet filters to allow operation in dusty environments. The DOGS-M generates 120 lpm of 93% ± 3% pharmacological O_2. It delivers a low pressure O_2 supply at an adjustable pressure range of 50–100 psig for patient ambulatory use, and a high-pressure supply up to 2250 psig to fill tanks.

Other features of the system include the capability of evacuating storage cylinders to 25 inches of mercury (inHg) before filling, integral back-up storage, an active thermal management system, and a communication port for system monitoring.

O_2 generation system

The O_2 generation system in the DOGS-M uses a pressure swing adsorption (PSA) process to separate out O_2 and argon from the inlet air. This differs from the EDOCS, which uses a vacuum swing adsorption (VSA) process. Normal atmospheric air consists of approximately 20.9% O_2, 78% nitrogen, 0.9% argon, and a variety of trace gases such as carbon dioxide. Typical product gas from an O_2 PSA system contains about 93% O_2, 5% argon, and 2% nitrogen.

The PSA system used in the DOGS-M consists of a water separator and coalescing filter (to remove as much liquid water from the compressed air as possible before it enters the sieve beds), solenoid valves, and two beds of adsorptive material (molecular sieve), which are pressurized in a cyclic regenerative process.

Figure 2–20. EDOCS 120B.

Figure 2–21. DOGS-M.

Compression systems

The main air compressor used in the system (Fig. 2–22) is a two stage blower and works by internal volume contraction using the claw principle. The claw pump consists of two rotors, which turn in opposite directions, synchronized with a precision gear.

The low-pressure O_2 compressor (Fig. 2–22) boosts the product gas pressure from about 20 psig to an internal storage pressure of about 130 psig. The motor drive controls the speed of the low-pressure compressor and varies according to system demand. It conserves product gas that leaks past the piston seals by means of a feedback line that connects the crankcase to the compressor inlet. After exiting the low-pressure compressor, the product gas cools using a heat exchanger and routes to the high pressure compressor and the low pressure delivery system.

The high-pressure O_2 compressor (Fig. 2–23) boosts the product gas from 110 psig to at least 2250 psig. It refills the cylinders or high-pressure storage devices connected to the high-pressure port, as well as the back-up storage cylinders inside the unit.

Cylinder evacuation system

The DOGS-M cylinder evacuation system utilizes an oil-less piston vacuum pump, which can provide 28 inHg maximum vacuum and 1.7 cfm of flow. The pump can evacuate an H cylinder to 25” inHg vacuum in less than 10 minutes.

Back-up storage system

The back-up storage system (Fig. 2–23) includes two DOT 3AA–2400 approved cylinders with shut off valves and integral burst disks to protect the cylinders from overpressure. These cylinders require hydrostatic testing every ten years. When fully charged, the back-up system has enough capacity to deliver 102 lpm of product gas for over two hours through the low-pressure delivery port. It takes the back-up storage system four hours to recharge.

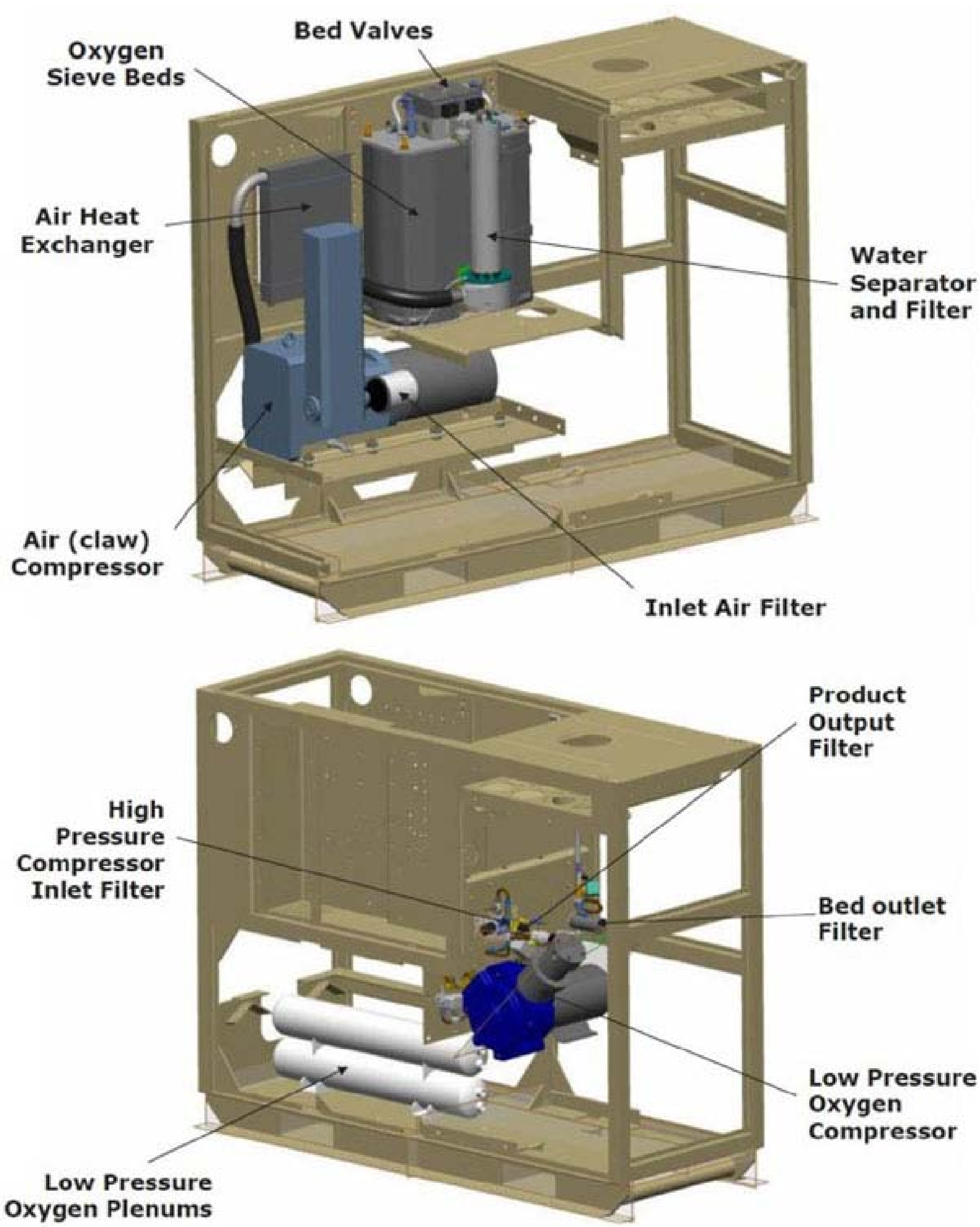


Figure 2–22. DOGS-M concentration components.

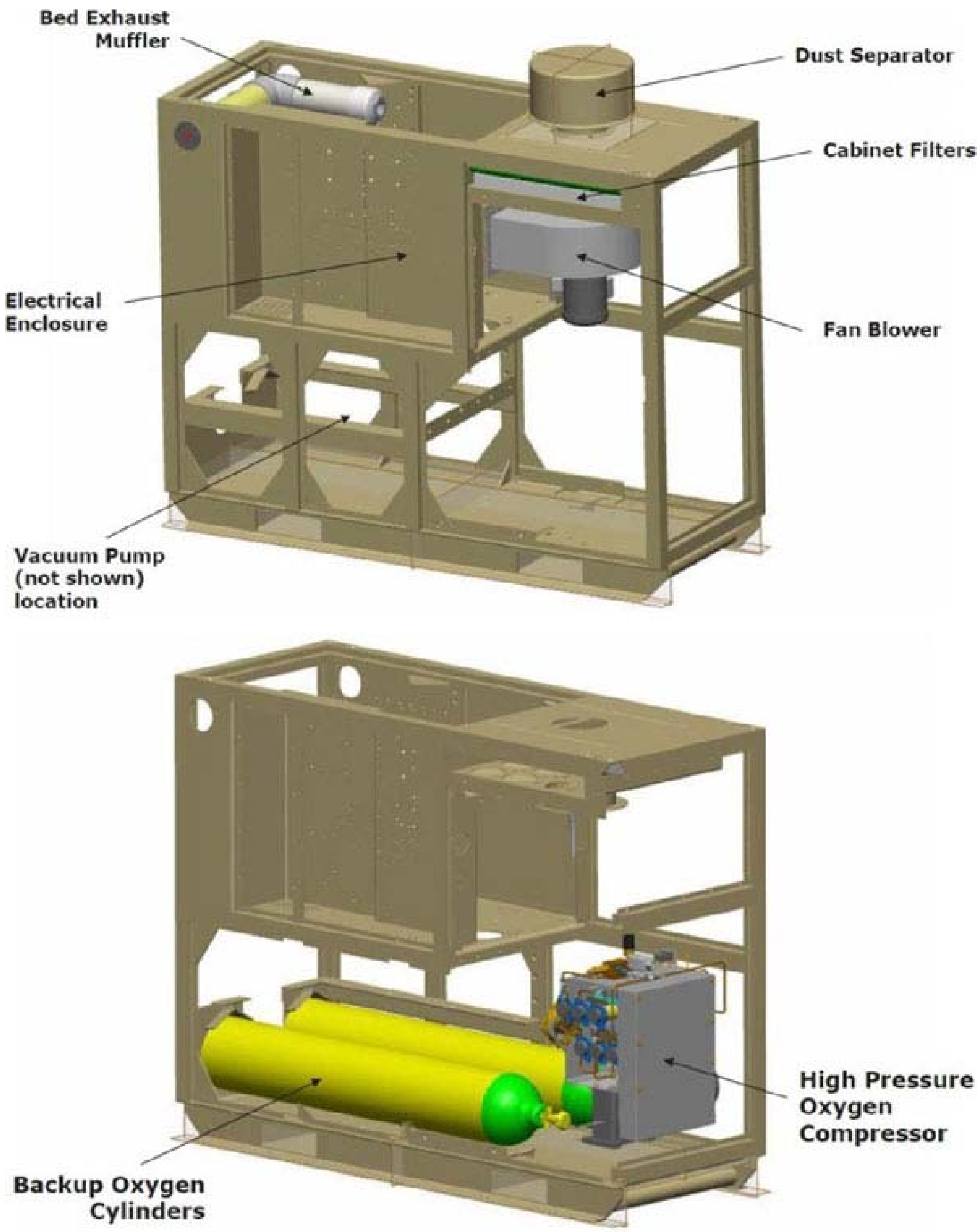


Figure 2–23. DOGS-M delivery components.

Installation

Utilize the following procedures to set up/install the DOGS-M:

1. Position the system away from the exhaust of any internal combustion engines, heaters, and other sources of carbon monoxide, hydrocarbon fumes, or other contamination sources.
2. Allow adequate room for the compressor and cabinet ventilation fans to draw in fresh air and to exhaust the cabinet cooling air. There should be at least five (5) feet of clearance around the system for air circulation, and to allow access for operation and maintenance activities.
3. Position the system in a reasonably level area, no more than 6 degrees of slope.
4. Visually inspect the unit to verify that no damage to the system has occurred during transit.
5. Replace rain cover with inlet air dust separator.

6. Open/secure heat exchanger cover.
7. Open /secure control panel cover.
8. Install product gas hoses as required.
9. With power off, connect the main power cable from the generator to the unit.
10. Verify that the following switches are set to these positions:

- Control panel power switch SW1 is in the OFF position
- Mode selection switch SW2 is in the LOW PRESSURE DELIVERY ONLY position.
- Control panel regulator RGLTR1 is fully adjusted out.
- Valve V1 is in the VENT/EVACUATE position.

11. Depress the system power switch SW1 on the front control panel to the ON position and verify that the power failure alarm comes on. Move the power switch SW1 back to the OFF position and verify that the alarm goes off.
12. Apply power to the system from the generator main breaker, turn the circuit breaker handle on the DOGS-M main breaker CB1 to the ON position, and verify that the power available light is illuminated on the control panel. This completes the equipment setup.

Preventative maintenance

The following table shows the procedures and requirements to ensure efficient preventative maintenance of the unit:

Interval	Maintenance Action
After first 100 hours	Inspect sieve bed outlet filter (FLTR5).
1,000 hours	Replace cabinet inlet air pre-filter.
1,000 hours	Replace cabinet inlet air particulate filter.
2,000 hours	Replace main air compressor inlet filter (FLTR1).
8,000 hours	Replace O_2 bed inlet filter (FLTR2).
8,000 hours	Replace water separator drain filters (FLTR3, 4).
8,000 hours	Replace O_2 bed outlet filter (FLTR5).
8,000 hours	Replace high-pressure O_2 compressor inlet filter (FLTR6).
8,000 hours	Replace low-pressure O_2 outlet filter (FLTR7).
1,000 hours	Inspect drain holes in lower four corners of frame.
2,500 hours	Grease main air compressor motor bearings.
4,000 hours	Replace main air compressor gear oil.
4,000 hours	Remove and replace LP O_2 compressor for overhaul.
500 hours (high pressure compressor hour meter)	Inspect high-pressure O_2 compressor chain and sprockets.
2,000 hours (high pressure compressor hour meter)	Remove and replace high-pressure O_2 compressor for overhaul.
1000 hours	Lubricate sieve bed solenoid valves.
16,000 hours	Replace sieve bed solenoid valves.
20,000 hours	Remove and replace main air compressor.
20,000 hours	Replace failure alarm batteries.
No interval specified. As or if required.	Remove and re-install sieve beds.

Calibration

Most of the maintenance on O_2 concentration systems is keeping up with good preventative maintenance to ensure the units run clean and smooth with proper lubrication. Now let's discuss some of the performance aspects requiring periodic calibration verification.

O_2 sensor

The O_2 sensor requires accuracy verification every 12 months. You can accomplish this by sampling the product gas with a calibrated analyzer and comparing the O_2 concentration display reading on the control panel against the output of the calibrated analyzer. If the difference is greater than the O_2 analyzer tolerance plus 1%, the O_2 sensor is out of calibration and requires replacement.

Pressure transducer

You can check the pressure transducer calibration by connecting the test pressure gauge supplied with the unit to valve V6 and comparing the reading to the output through the RS–232 connection. There is not a field procedure for adjusting the calibration on the pressure transducer. The recommendation is to replace the transducer if the two numbers vary by more than 15 psi.

High pressure compressor/switch

The high-pressure switch on the high-pressure compressor allows adjustment if the compressor does not fill cylinders to 2300 psig +/- 50 psig before turning off. This can be adjusted by loosening the setscrews on the black switch housing and rotating it to adjust the pressure switch setting. Clockwise rotation will increase the pressure setting, and counterclockwise rotation will decrease the pressure setting.

Common malfunctions

Some common malfunctions that you might see in O_2 concentration systems are:

- Low O_2 purity.
- Loss of mains power.
- Temperature ranges out of limits.
- Pressure ranges out of limits.

021. Oxygen delivery systems

Once you have harnessed the ability to produce O_2, now you need a means of storing and delivering this critical gas to the facility and the patients. This lesson discusses some of the common equipment used to establish the O_2 link between concentration and consumption.

HOBS

HOBS (Fig. 2–24) consists of a manifold supported by four legs that has two banks of four stations to support eight H-cylinders. Each station has a shut-off valve, flexible pigtail, and CGA540 connector for connecting the cylinders. This is a passive system, which has no moving parts or power requirements. This system provides eight hours of additional back-up O_2 using an average flow rate of 120 lpm at 75 psi. The HOBS is capable of reaching a peak flow rate of 240 lpm, yet when the average flow rate is doubled, it also reduces the supply time by one half (down to 4 hours). It can also refill 10 E- or D-sized cylinders. You can evacuate the cylinders by using the vacuum pump on the DOGS-M or EDOCS. Two people can set up the HOBS in around 10 minutes. The HOBS automatically senses when the primary source of O_2 depletes and switches over to the secondary source.

Figure 2–24. HOBS.

MOST

MOST (Fig. 2–25) is a portable O_2 system designed to provide O_2 to patients in remote locations or in transit. It is a lightweight O_2 storage and distribution system, which contains two brass-lined cylinders in a rugged case. The case also contains the regulators and hoses for patient use. The MOST provides 10,000 liters of O_2 at 2,250 psig. This system is capable of distributing 150 lpm at 50 psig. This is a wheel-based system that weighs 200 lb. when fully charged, and has eight handles that allow easy transport for two people.

Figure 2–25. MOST.

PODS

PODS (Fig. 2–26) is the O_2 distribution system within the EMEDS. It is a system of flow regulators and hoses fitted with quick-disconnect fittings that deliver regulated pressure O_2 to up to six patient beds for each PODS package. It consists of low-pressure alarms, flow meter stations, hoses, and fittings that can be adapted for use according to the EMEDS configuration.

Figure 2–26. PODS.

SSODS

SSODS is similar to the PODS configuration and is designed to deliver O_2 to the surgical suite of the EMEDS. The SSODS contains enough hose, fittings, and flow meters to support one surgical suite per SSODS package.

022. Liquid oxygen generation and distribution

Just like the lessons in the previous FM unit, O_2 supplies utilize both gas and liquid concepts. While gas concentration systems are the main supply feeders to the expeditionary facilities, the field also uses liquid O_2 generation systems to provide O_2 supply for more mobile applications due to its size and expansion properties. This lesson will go over some of the equipment used in providing a supply of liquid O_2 to the field.

O_2 generator and liquefier system

The oxygen generator and liquefier (OGL) system (Fig. 2–27) has a similar overall function as the concentration systems from the previous lesson. It extracts O_2 from the atmosphere and uses it to fill and supply delivery equipment for patient use. The difference is that the OGL converts it to a liquid form, which can be compacted into much smaller containers.

The OGL is a portable LOX system, which generates 93% United States Pharmacopoeia (USP) O2 and liquefies it into LOX at approximately 1 liter per hour (lph). It can store up to 40 liters of LOX in an onboard storage tank, also known as the Dewar. As long as the OGL has power and is in the Make LOX/Standby mode, the system prevents any loss of LOX contained in the storage tank. The LOX can transfer into any portable LOX storage device with a standard CRU–50/A fill valve, with the use of the attached transfer hose. This includes:

- Dismounted Medical Oxygen System (DMOS).
- Mounted Medical Oxygen System (MMOS).
- Backpack Medical Oxygen System (BMOS).
- BMOS filling station (BMOS-FS).
- Portable Therapeutic Liquid Oxygen (PTLOX) System.
- Next-Generation Portable Therapeutic Liquid Oxygen (NPTLOX) System.

While the main purpose of this unit is to supply LOX to various field distribution equipment, the OGL can also supply up to 11 lpm (7–10 psig) of 93% USP O_2 gas to an external O_2 booster pump for filling high-pressure cylinders. This unit was not designed to primarily fill gas cylinders and supply an EMEDS demand (like the EDOCS or DGOG-M), but it can perform some O_2 gas functions as needed in critical situations. The OGL requires 200–240 VAC 50/60 Hertz power on a 30 amp single-phase power. This unit has three modes of operation; make LOX/standby, transfill, and O_2 gas.

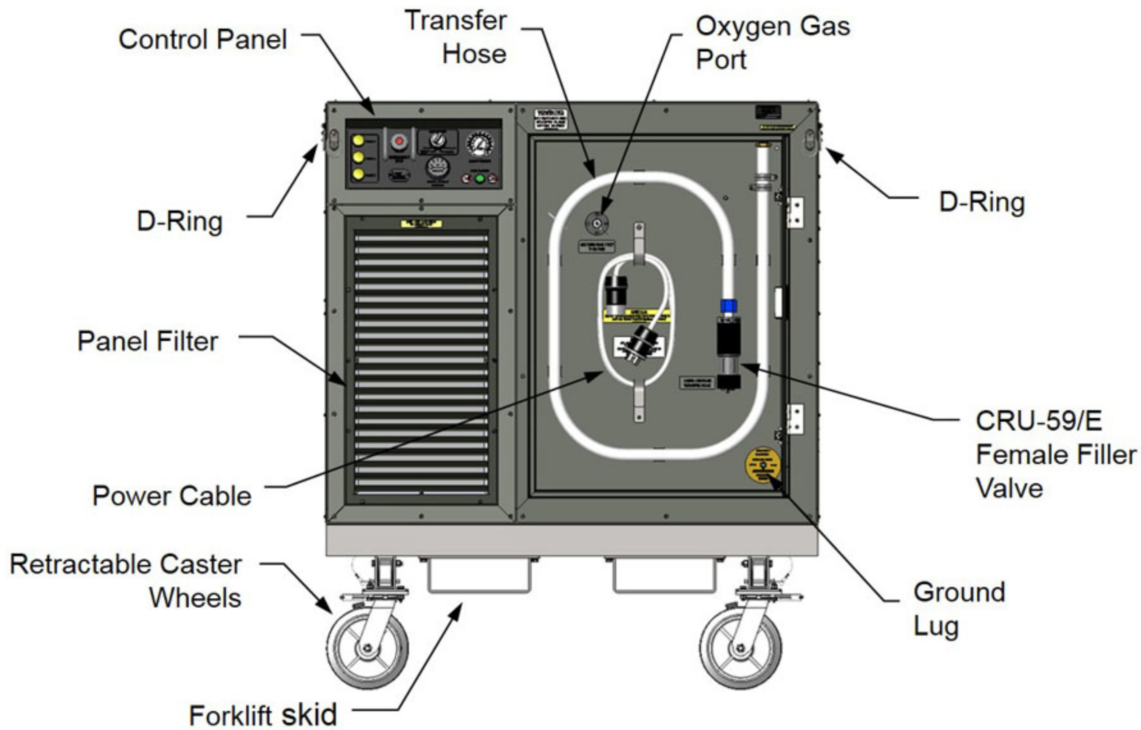


Figure 2–27. OGL system.

Make LOX/Standby mode

In make LOX mode, the OGL is capable of generating an average of 1 liquid lph. Once the system begins operation, it will take 2–3 hours to cool the Dewar enough for LOX to start accumulating. This only occurs when the system starts in a warm/empty state (no LOX). Once the system reaches over 90 percent O_2 concentration and a pressure inside the Dewar of 25 psig, the helium compressor/cold head will turn on and start liquefying gas. When the Dewar reaches capacity, the system will go into standby.

Transfill mode

In transfill mode, the OGL is capable of transferring LOX into storage devices and LOX storage/gas conversion systems. It uses a liquid O_2 transfer hose with a CRU–59/E female filler valve that conforms to MIL-PRF–38201 on the end capable of mating with CRU–50/A fill valves. This mode is simple; inspect it for damage, hook it up to the LOX vessel, and begin transfill.

O_2 gas mode

In O_2 gas mode, the OGL is capable of supplying gaseous O_2 at up to 11 lpm at 7–10 psig. The O_2 gas port for the O_2 gas mode is a DISS 1240 style fitting with an integral check valve. The O_2 gas port can connect to an external high-pressure booster pump to fill high-pressure cylinders.

NPTLOX system

One of the most common storage units transfilled by the OGL is the NPTLOX system (Fig. 2–28). As a BMET, this is a unit that you will most likely see when working in a WRM section. When filled with LOX, the NPTLOX will provide for an uninterrupted supply of therapeutic O_2 to meet and achieve Air Mobility Command/Surgeon General (AMC/SG) aeromedical evacuation (AE) mission requirements. As the expansion capability of LOX allows us to supply large amounts of O_2 in a small compact space, as well as the unit having “safe to fly” aerovac certifications, it makes this unit the ideal source of O_2 supply for AE missions. The expansion ratio of LOX to O_2 gas is roughly 1:850, depending on the atmospheric pressure. With the NPTLOX capable of holding twenty liters of LOX, it can deliver up to 17,000 liters of gaseous O_2 to the patient. This is approximately two and a half times the capacity of a single H cylinder at a fraction of the size. The unit humidifies and delivers gaseous O_2 at a controlled flow rate to up to six patients at once. It has a delivery rate of up to 66 lpm at 50±5 psig for use with critical care air transport (CCAT) ventilators. Electrical power consists of two 9V lithium batteries, given that much of the unit runs on pressure and pneumatics.

Figure 2–28. NPTLOX.

When transferring LOX from the OGL to the NPTLOX (or any other delivery system), personnel should *always* wear proper personal protective equipment (PPE) such as head covering, eye goggles, face shield, gloves, apron, coveralls, cuffless trousers, long sleeve shirt, jacket, and shoes which fit closely around the top, with rubber soles and heels. All items shall be clean and free of grease, oil, and fuel. Remember; *always* keep away from exposure to oil and grease. Do *not* handle O_2 with greasy hands or clothing. Do *not* let fittings, hoses, or any O_2 equipment come in contact with oil, grease, hydraulic fluid, or dirt.

Self-Test Questions

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

020. Oxygen systems

1. What does the EDOCS concentrator generate?

2. How many hours of back up O_2 does the EDOCS provide?

3. What components on the DOGS-M allow the unit to operate in dusty environments?

4. At what pressure ranges does the DOGS-M deliver low-pressure O2? High pressure?

5. How does the O_2 generation system in the DOGS-M differ from the EDOCS?

6. What are the gas concentrations that make up normal atmospheric air?

7. What does the PSA in the DOGS-M consist of?

8. Describe how the main air compressor works.

9. Describe how the claw pump operates.

10. To what pressure does the low-pressure O_2 compressor boost the product gas?

11. How often do the back-up storage cylinders on the DOGS-M require hydrostatic testing?

12. Where should you position the DOGS-M during installation?

13. How many feet of clearance around the system should you allow for air circulation and access for maintenance activities?

14. When should you inspect the sieve bed outlet filter?

15. When should you grease the main air compressor motor bearings?

16. At what intervals should you verify the O_2 sensor accuracy?

17. How would you check the pressure transducer calibration accuracy?

18. Describe how you would adjust the high-pressure compressor switch.

19. List some common malfunctions that you might see dealing with O_2 concentration systems.

021. Oxygen delivery systems

1. Describe the configuration of a HOBS unit.

2. How many hours of additional backup O_2 does the HOBS provide using an average flow rate of 120 lpm?

3. What happens when the HOBS senses that the primary source of O_2 has depleted?

4. What is the MOST?

5. What are the elements of a PODS?

6. What section of the hospital would you connect the SSODS?

022. Liquid oxygen generation and distribution

1. How does the OGL system differ from gaseous oxygen ($O_{2)}$ concentration systems?

2. What is the rate and purity that the OGL system produces LOX?

3. List the portable LOX storage devices that the OGL system can transfill.

4. What are the three modes of operation on the OGL?

5. How long does it take to cool the Dewar enough for LOX to start accumulating?

6. When does the helium compressor/cold head turn on to start liquefying gas?

7. Describe how the OGL system produces high pressure O_2 for filling cylinders.

8. What is the *most* common unit the OGL transfills with LOX?

9. Why is the NPTLOX the ideal source of O_2 supply for AE missions?

10. Explain the expansion properties of LOX as it relates to gaseous O_2.

11. What is the O_2 gas capacity of an NPTLOX unit versus an H cylinder?

12. What types of personal protective equipment (PPE) should you wear when handling LOX?

Answers to Self-Test Questions

014

1. BCE.
2. A balanced resistive load that maintains the generator up to 50 percent of its rated load to prevent excessive engine carbonizing due to light loads.
3. The battle short.
4. Diesel or JP8 jet fuel.
5. About 8 hours.
6. (1) Schedule timely refueling to mitigate the interruption of power.
   (2) Maintain a fuel reserve in case there is a delay in the scheduled refueling.
   (3) Keep a class "C" fire extinguisher near the generator.
   (4) Complete the required generator inspections and paperwork.
   (5) If the deployment is long-term, perform preventive maintenance (PM) at appropriate intervals with a minimum loss of power availability.

7. The electronic modular control panel (EMCP).
8. Activate the AC interrupter switch.
9. Only in critical situations where the need for immediate power now is more important than the health of the generator.
10. At the load terminal board.
11. Underground metallic water piping system, driven metal rod, or a buried metal plate; metal grounding rod.
12. A minimum diameter of ⅝″ if solid or ¾″ if using a pipe, and a minimum drive depth of 8 ft. A ground plate must have a minimum area of 9 square ft. and buried at a minimum depth of 4 ft. The ground lead must be at least No. 6 American Wire Gauge (AWG) copper wire, and must bolt or clamp to the rod, plate, or piping system.
13. Ensure the grounding cable is secure.
14. By using the lamp test or applicable indicators.
15. Approximately 5 minutes or until coolant temperature reaches 100°F; 5 minutes.
16. Quarterly or 300 hours.

015

1. When they feed power to another PDC.
2. 200 kW feeds the 100 kW, which feeds the 15 kW, which feeds the user.
3. The proper lifting techniques.
4. The health response team (HRT).
5. The phase indicators.
6. (1) Two large cables pulling full capacity can induce voltage into the other by creating magnetic fields.
   (2) Not hooking each end as you go could cause you to hook the wrong wire to the connections, thus causing the voltage to be out of phase and destroying the PDC or user equipment.
7. Turn off all power.
8. The bottom of the B-box where it says “power in.”
9. Circuit breakers.
10. Ensure indicator lights glow when you apply power.

016

1. Shelter, tactical, expandable.
2. (1) The one-sided (2:1) shelter.
   (2) The two-sided (3:1) shelter.
3. 8′ wide × 8′ high × 19′10½″ long.
4. It meets the ISO guidelines for shipping containers.
5. 271 square feet.
6. 14′10″ wide × 8′ high × 19′10½″ long.
7. 400 square feet.
8. 21′10″ wide × 8′ high × 19′10½″ long.
9. The terrain should be firm, well drained, and relatively free of surface rocks or stones. The slope of the terrain should not exceed 18″ over the projected floor area of the expanded shelter.
10. The dolly set XM1022 or hoisting sling (with a cable breaking strength of 35,000 lb.).
11. 2:1 configuration.
12. (1) Fixed high-frequency radiographic unit.
    (2) Mobile A/C radiographic unit.
    (3) Radiographic film illuminator.
13. 3:1 configuration.
14. Any five of the following:

(1) LOX converter.
(2) Surgical suction.
(3) Anesthesia apparatus.
(4) Anesthesia ventilator.
(5) Vital signs monitor.
(6) Pulse oximeter.
(7) Defibrillator/monitor.
(8) Volume ventilator.

15. 3:1 configuration.
16. Any four of the following:
    (1) Blood bank refrigerator.
    (2) Water purification system.
    (3) Clinical chemistry analyzer.
    (4) Laboratory centrifuges.
    (5) Blood cell counter.
    (6) Microscope.

017

1. 20 years.
2. The shelter includes a 20′ wide × 32.5′ long × 10′ high free-span shelter, a 20′ × 8′ × 10′ high extension shelter, a 7′ × 8′ × 9′ vestibule shelter, quick-connect wiring harness, and a 463L palletable transport container.
3. UTS System, formerly known as the Utilis system.
4. The shelter includes a 21′ wide × 36′ long × 10′ TM60 Tall Shelter, a 21′ × 7′ × 10′ TM15 Tall Four-way Connector, a 7′ × 6′ × 9′ SM5 Vestibule.
5. During the initial EMEDS setup.
6. CP liners, chemically hardened environmental control units (ECU), filtered-air blowers, airlocks, and pressure alarm systems.
7. The connection of the double track flange in collective protection (CP) mode.
8. At least 82′ by 94′ of space.
9. Inventory the container to ensure all of the items are available.
10. Every 30 days while in use.
11. Every 30 days.

018

1. (1) Air conditioning.
   (2) Heating.
2. Approximately 550 lb.; 800 lb.
3. It takes low-pressure, low-temperature refrigerant and delivers high-pressure refrigerant to the condenser.
4. The flow of liquid refrigerant into the evaporator.
5. Six; on the evaporator grill.
6. Captures solid airborne contaminants before they enter the ECU.
7. (1) High.
   (2) Low.
8. By creating a pressure differential.
9. In the evaporator.
10. Collective protection (CP) provided by the ECU.
11. To provide NBC filtration as well as positive pressure capabilities to ensure a contamination free zone.

12. When the pressure of the system drops below 0.40 inches of water gauge (iwg) or rises above 0.85 iwg.
13. It maintains a positive pressure environment relative to the outside ambient air, yet manages pressure at a lower level than the attached structure.

019

1. At least 2′ at the rear of the unit.
2. Approximately five (5) feet above the floor, away from the supply air and midway on the shelter wall, if possible.
3. Fully open the condenser fan storage panel.
4. Before operation.
5. Remove the supply panel, fill drain pan with two (2) gallons of water, and examine the hose drains free of any obstruction; quarterly.
6. Open access panels and inspect unit thoroughly for broken wires, broken controls, or other damage that may have occurred during operation.

020

1. 120 lpm of 93% pharmacological O_2.
2. Two.
3. A centrifugal separator and series of cabinet and air compressor inlet filters.
4. Low pressure O_2 supply at an adjustable pressure range of 50–100 psig for patient ambulatory use; high-pressure supply up to 2250 psig to fill tanks.
5. The DOGS-M uses a pressure swing adsorption (PSA) process to separate out oxygen (O_2) and argon from the inlet air. This differs from the EDOCS, which uses a vacuum swing adsorption (VSA) process.
6. Approximately 20.9% oxygen (O_2), 78% nitrogen, 0.9% argon and a variety of trace gases such as carbon dioxide.
7. A water separator and coalescing filter, solenoid valves, and two beds of adsorptive material (molecular sieve).
8. The main air compressor used in the system is a two stage blower and works by internal volume contraction using the claw principle.
9. The claw pump consists of two rotors, which turn in opposite directions, synchronized with a precision gear.
10. 20 psig to an internal storage pressure of about 130 psig.
11. Every ten years.
12. Away from the exhaust of any internal combustion engines, heaters, and other sources of carbon monoxide, hydrocarbon fumes, or other contamination sources.
13. At least five feet.
14. After the first 100 hours.
15. After 2,500 hours.
16. Every 12 months.
17. By connecting the test pressure gauge supplied with the unit to valve V6 and comparing the reading to the output through the RS–232 connection.
18. Loosening the setscrews on the black switch housing and rotating it. Clockwise rotation will increase the pressure setting, and counterclockwise rotation will decrease the pressure setting.
19. (1) Low oxygen (O_2) purity.
    (2) Loss of mains power.
    (3) Temperature ranges out of limits.
    (4) Pressure ranges out of limits.

021

1. A manifold supported by four legs that has two banks of four stations to support eight H-cylinders. Each station has a shut-off valve, flexible pigtail, and CGA540 connector for connecting the cylinders.

2. Eight.
3. It switches over to the secondary source.
4. A portable O_2 system designed to provide O_2 to patients in remote locations or in transit.
5. (1) Low-pressure alarms.
   (2) Flow meter stations.
   (3) Hoses.
   (4) Fittings that can be adapted for use according to the EMEDS configuration.
6. The surgical suite.

022

1. It converts oxygen extracted from the atmosphere to a liquid form, which can be compacted into much smaller containers.
2. 93% United States Pharmacopoeia (USP) oxygen at approximately 1 liter per hour (lph).
3. (1) Dismounted Medical Oxygen System (DMOS).
   (2) Mounted Medical Oxygen System (MMOS).
   (3) Backpack Medical Oxygen System (BMOS).
   (4) BMOS filling station (BMOS-FS).
   (5) Portable Therapeutic Liquid Oxygen (PTLOX) System.
   (6) Next-Generation Portable Therapeutic Liquid Oxygen (NPTLOX) System.
4. (1) Make LOX/Standby.
   (2) Transfill.
   (3) O_2 gas.
5. Two to three hours.
6. Once the system reaches over 90% oxygen (O_2) concentration and a pressure inside the Dewar of 25 psig.
7. In O_2 Gas mode, the OGL is capable of supplying gaseous oxygen (O_2) at up to 11 lpm at 7–10 psig. The oxygen gas port can connect to an external high-pressure booster pump to fill high-pressure cylinders.
8. The Next-Generation Portable Therapeutic Liquid Oxygen (NPTLOX) System.
9. Because the expansion capability of LOX allows us to supply large amounts of O_2 in a small compact space, as well as the unit having “safe to fly” aerovac certifications.
10. The expansion ratio of LOX to O_2 gas is roughly 1:850, depending on the atmospheric pressure.
11. With the NPTLOX capable of holding twenty liters of LOX, it can deliver up to 17,000 liters of gaseous oxygen (O_2) to the patient. This is approximately two and a half times the capacity of a single H cylinder at a fraction of the size.
12. (1) Head covering.
    (2) Eye goggles.
    (3) Face shield.
    (4) Gloves.
    (5) Apron.
    (6) Coveralls.
    (7) Cuffless trousers.
    (8) Long sleeve shirt.
    (9) Jacket.
    (10) Shoes which fit closely around the top with rubber soles and heels.

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.

57. (014) Whose responsibility is it to maintain the generators when *in use*?
    a. Medical logistics.
    b. Power production.
    c. Base civil engineering.
    d. Biomedical equipment technician.

58. (014) What component on the generator, when activated, allows you to operate the unit through fault conditions for a critical event?
    a. Override switch.
    b. Prime mover.
    c. Battle short.
    d. Load bank.

59. (014) Which component allows you to jump-start another generator that has a depleted battery?
    a. North Atlantic Treaty Organization (NATO) slave receptacle.
    b. Paralleling cables.
    c. Load cables.
    d. Battle short.

60. (014) The *first* step in a preventive maintenance check is to
    a. check the air intake system for excessive dirt.
    b. check the engine for proper oil level.
    c. ensure the ground cable is secure.
    d. check the oil pressure gauge.

61. (015) What determines the size of the power distribution center (PDC) required at an expeditionary medical support (EMEDS) site?
    a. Number of tents and equipment.
    b. Number of personnel and equipment.
    c. Kilowatt demand load of the EMEDS.
    d. Voltage requirements of site equipment.

62. (015) How can you easily disconnect all main power from the power distribution center (PDC) at an expeditionary medical support (EMEDS) site?
    a. Disconnect all load lines from the generator.
    b. Disconnect the branch lines from the PDC.
    c. Flip each branch circuit breaker.
    d. Switch off the main circuit breaker.

63. (015) What provides power and light distribution within a tent at an expeditionary medical support (EMEDS) site?
    a. Power distribution feeder.
    b. Receptacle connector.
    c. Circuit breaker box.
    d. Branch box.

64. (016) The expanded one-sided International Organization for Standardization (ISO) shelter provides how many square feet of usable floor space?
   a. 251.
   b. 261.
   c. 271.
   d. 281.

65. (016) The expanded two-sided International Organization for Standardization (ISO) shelter provides how many square feet of usable floor space?
   a. 300.
   b. 350.
   c. 371.
   d. 400.

66. (017) How long is an Alaska Medical Shelter System (AKMSS) designed to last when erected or stored?
   a. 10 years; 30 years.
   b. 10 years; 20 years.
   c. 20 years; 30 years.
   d. 20 years; 20 years.

67. (017) What are the dimensions for a UTS System TM60 Tall shelter?
   a. 21′ × 36′ × 10′.
   b. 21′ × 36′ × 15′.
   c. 36′ × 50′ × 10′.
   d. 36′ × 50′ × 15′.

68. (017) When preparing a field site using the UTS System, what is the *minimum* space required to set up an expeditionary medical support (EMEDS) health response team (HRT) configuration?
   a. 64′ × 82′.
   b. 75′ × 82′.
   c. 82′ × 94′.
   d. 85′ × 94′.

69. (017) The electrical cable assemblies on a UTS System *should* be checked for kinks or cracks every
   a. 30 days.
   b. 60 days.
   c. 120 days.
   d. 180 days.

70. (018) What is the approximate weight of the lightweight environmental control unit (LECU)?
   a. 350 lb.
   b. 550 lb.
   c. 700 lb.
   d. 800 lb.

71. (018) On the environmental control unit (ECU), what component takes low-pressure, low-temperature refrigerant, and delivers high-pressure refrigerant to the condenser?
   a. Thermostatic expansion valve (TEV).
   b. Charging valve.
   c. Quench valve.
   d. Compressor.

72. (018) On an environmental control unit (ECU), what component could you single out as the one that actually accomplished the task of cooling air?
    a. Thermostatic expansion valve (TEV).
    b. Condenser coil.
    c. Compressor.
    d. Evaporator.

73. (018) Which of these connects to the bump-through door airlock to provide nuclear, biological and chemical (NBC) filtration as well as positive pressure capabilities to ensure a toxic free zone?
    a. FFA–400 (400–cfm) blower.
    b. FFA–580 (600–cfm) blower.
    c. Filter blower unit (FBU).
    d. NBC hardening kit.

74. (019) When installing an environmental control unit (ECU), you should leave a *minimum* of how much unobstructed room for condenser air circulation?
    a. 6 feet.
    b. 4 feet.
    c. 3 feet.
    d. 2 feet.

75. (020) How many liters per minute of 93% pharmacological oxygen (O_2) can the Expeditionary Deployable Oxygen Concentration System (EDOCS) 120 generate?
    a. 30.
    b. 60.
    c. 120.
    d. 300.

76. (020) What process does the Deployable Oxygen Generation System –medium (DOGS-M) use to separate out oxygen (O_2) and argon from the inlet filter?
    a. Pressure swing adsorption (PSA).
    b. Pressure sealed adsorption (PSA).
    c. Vacuum swing adsorption (VSA).
    d. Vacuum sealed adsorption (VSA).

77. (020) How often do the back-up oxygen (O_2) cylinders in the Deployable Oxygen Generation System – medium (DOGS-M) require hydrostatic testing?
    a. Every 10 years.
    b. Every 6 years.
    c. Every 2 years.
    d. Every year.

78. (021) How many hours of back-up oxygen (O_2) can the Hospital Oxygen Backup System (HOBS) provide?
    a. 2.
    b. 8.
    c. 10.
    d. 24.

79. (022) At what rate can the oxygen generator and liquefier (OGL) system produce liquid oxygen (LOX)?
    a. 10 liters per minute (lpm).
    b. 10 liters per hour (lph).
    c. 1 lpm.
    d. 1 lph.

80. (022) Which of the following is *not* an oxygen (O_2) system that can be transfilled by the oxygen generator and liquefier (OGL) system?
    a. Next-Generation Portable Therapeutic Liquid Oxygen (NPTLOX) System.
    b. Dismounted Medical Oxygen System (DMOS).
    c. Patient Oxygen Distribution System (PODS).
    d. Backpack Medical Oxygen System (BMOS).

Do not return your answer sheet to the Air Force Career Development Academy (AFCDA).

Glossary

Terms

ABS	Acrylonitrile-Butadiene-Styrene
AC	alternating current
AE	aeromedical evacuation
AFMSA	Air Force Medical Support Agency
AFTH	Air Force theater hospital
AHU	air handling unit
AKMSS	Alaska Medical Shelter System
AMC/SG	Air Mobility Command/Surgeon General
AWG	American Wire Gauge
BCE	base civil engineering
BEE	bioenvironmental engineering
BMET	biomedical equipment technician
BMOS	Backpack Medical Oxygen System
BMOS-FS	backpack medical oxygen system filling station
CAD	computer aided drafting
CCAT	critical care air transport
cfm	cubic feet per minute
CM	contract maintenance
CP	collectively protected
CPEL	collective protection expeditionary latrine
CP-EMEDS	collectively protected-expeditionary medical support
CPVC	chlorinated polyvinyl chloride
CT	computed tomography
DC	direct current
DISS	Diameter Index Safety System
DMLSS	Defense Medical Logistics Standard Support
DMOS	Dismounted Medical Oxygen System
DOGS-M	Deployable Oxygen Generation System – medium
DWV	drain, waste, and vent
ECRI	Emergency Care Research Institute
ECU	environmental control unit

EDOCS	Expeditionary Deployable Oxygen Concentration System
EMCP	electronic modular control panel
EMCS	energy management and control systems
EMEDS	expeditionary medical support
EOC	environment of care
EOCC	environment of care committee
EP	elements of performance
ERAA	equipment review and authorization activity
FAS	facility assessment study
FBU	filter blower unit
FDA	Food and Drug Administration
FDECU	field deployable environmental control unit
FFA	fan filter assembly
FM	facility management
ft.	foot
FYDP	future year defense plan
GFCI	ground-fault circuit-interrupter
HAMS	hospital aseptic management services
HEPA	high-efficiency particulate air
HOBS	Hospital Oxygen Backup System
HRT	health response team
HVAC	heating, ventilation, and air conditioning
IAW	in accordance with
ILSM	interim life safety measures
inHg	inches of mercury
ISO	International Organization for Standardization
iwg	inches of water gauge
Kg	kilogram
kVA	kilovolt-ampere
kW	kilowatt
L	liter
lb	pound
LECU	lightweight environmental control unit
LIM	line isolation monitor
lph	liters per hour
lpm	liters per minute

LOX	liquid oxygen
MCRP	medical contingency response plan
MEP	mobile electric power
MFIP	master facility improvement plan
MILCON	military construction
m	meter
mm	millimeter
MMOS	Mounted Medical Oxygen System
MMQC	medical materiel quality control
MOST	mobile oxygen storage tank
MRI	magnetic resonance imaging
MTF	military treatment facility
NATO	North Atlantic Treaty Organization
NBC	nuclear, biological, and chemical
NCOIC	noncommissioned officer in charge
NEC	National Electrical Code
NFPA	National Fire Protection Association
N_2O	Nitrous oxide
NPTLOX	next-generation portable therapeutic liquid oxygen
O&M	operations and maintenance
OEM	original equipment manufacturer
OGL	oxygen generator and liquefier
OR	operating room
O_2	Oxygen
PACS	Picture Archiving and Communication System
PB	polybutylene
PDC	power distribution center
PDP	power distribution panel
PE	polyethylene
PEX	cross-linked polyethylene
pH	power of hydrogen
PM	preventive maintenance
PMCS	preventative maintenance checks and services
PODS	Patient Oxygen Distribution System
PP	polypropylene
PPE	personal protective equipment

PSA	pressure swing adsorption
psi	Pounds per square inch
psig	pounds per square inch gage
PTLOX	portable therapeutic liquid oxygen
PVC	polyvinyl chloride
QAE	quality assurance evaluator
RMW	regulated medical waste
SMDA	Safe Medical Device Act
SME	subject matter expert
SRM	sustainment, restoration, and modernization
SSODS	Surgical Suite Oxygen Distribution System
TEV	thermostatic expansion valve
TFA	toxic free area
TJC	The Joint Commission
TQG	tactical quiet generator
UFC	unified facilities criteria
UL	unable to locate
UPS	uninterruptible power supply
US	United States
USP	United States Pharmacopoeia
VA	volt-ampere
VAC	volts of alternating current
VDC	volts of direct current
VSA	vacuum swing adsorption
WAGD	waste anesthetic gas disposal
WDS	water distribution system
WRM	war reserve materiel

Student Notes

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