2M053, Module 3: Power Generation and Distribution Systems

Module 3 of career development course (CDC) 2M053, Missile and Space Facilities Journeyman, provides an in-depth look at the missile alert facility (MAF) and launch facility (LF) power generation and distribution systems and the LF wastewater removal systems, and closes with an introduction to hydraulic and pneumatic systems. Lesson 1 provides an introduction into internal combustion engine and operating principles. There are detailed lessons on the components that make the engine operate, as well as auxiliary systems that help the engine perform its function on the missile facilities. This lesson also explores generators to see how they produce voltage and link with the diesel engine.

Lesson 2 presents information on the function and operation of the Minuteman power processor (MPP) as well as the automatic switching unit (ASU) that houses the MPP. We will cover the power contactors that allow power to flow into the power distribution system function, and the components that power flows to within the MAF and LF power distribution systems. Lesson 3 provides information on LF sump pump (SP) systems SP–102 and SP–103, which remove unwanted water from the bottom of the launch tube as well as the launcher support building. We will cover specific operating principles of sump pump system SP–102, as well as how to troubleshoot this system if problems occur. This lesson concludes with an introduction to hydraulic and pneumatic systems and their basic operating principles. Code numbers on figures are for preparing agency identification only. The use of a name of any specific manufacturer, commercial product, commodity, or service in this publication does not imply endorsement by the Air Force.

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Lesson 1. Internal Combustion Engine Systems

Main Points

1. Internal combustion engine components and operation
2. Engine starting, running, and stopping
3. Auxiliary engine systems and equipment
4. Generators, exciters, and voltage regulators

As a technician on a periodic maintenance team, you are preparing to operate the diesel electric unit (DEU) at a launch facility (LF) in order to bring the engine to operating temperature before you change the oil. When you press the manual pushbutton on the Minuteman power processor (MPP) to start the engine, it cranks and begins to run, but then quickly shuts down. After 10 seconds, it attempts another start; after four failed attempts, the MPP locks the engine out and makes no further attempts to start it. This lesson focuses on familiarizing you with how an internal combustion diesel engine operates as well as some of the engine's components. You

will learn about some auxiliary systems and added equipment that enhances the engine's operation. Lastly, this lesson will cover how a generator produces electricity as well as how a voltage regulator maintains the proper voltage output.

Click here to begin Lesson 1 of Module 3.

Internal Combustion Engine Components and Operation

An internal combustion diesel engine is the core of the power generation system at the missile alert facility (MAF) and LF, and provides the auxiliary power needed to operate some of the support vehicles and equipment on which you will use or perform maintenance. No matter where the engine is physically located, the same fundamental principles apply to how it starts and continues to operate. This lesson focuses on some basic components of an internal combustion diesel engine as well as how a four-stroke engine operates.

The DEUs at Malmstrom Air Force Base (AFB), Wing 1, are different from the ones at Minot and F.E. Warren AFBs, Wings 3 and 5. The following lessons will note these differences. While all DEUs at all wings operate using the same fundamentals, the DEUs at Wing 1 LFs and MAFs were replaced with modernized generator sets during a recent modification. The look and control are different from the DEUs that you performed maintenance on during your technical training. Take a moment to familiarize yourself with the general look and design of each of the DEUs (fig 1–1).

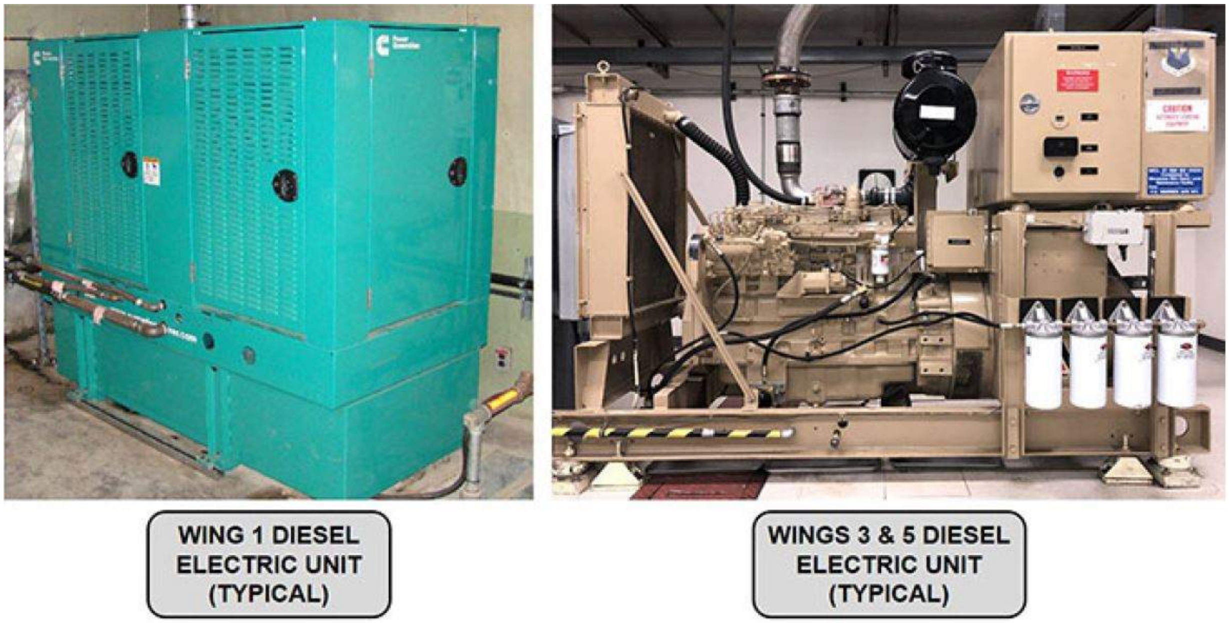


Figure 1–1. Wing 1 and Wings 3 and 5 Diesel Electric Units.

Engine Components

An internal combustion engine has many moving parts that must be synchronized properly to ensure it starts and continues to operate. Before we explore engine design and discuss the different strokes involved in engine operation, let's review the parts and components used in an internal combustion engine. Refer back to these terms if needed during the discussion on engine operation.

Click on each number to learn about the different engine components.

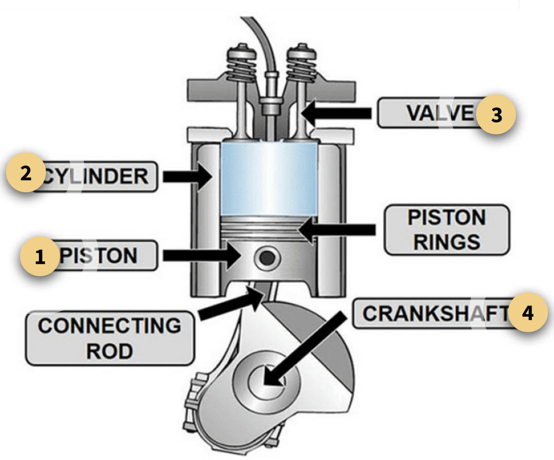


Figure 1–2. Engine components.

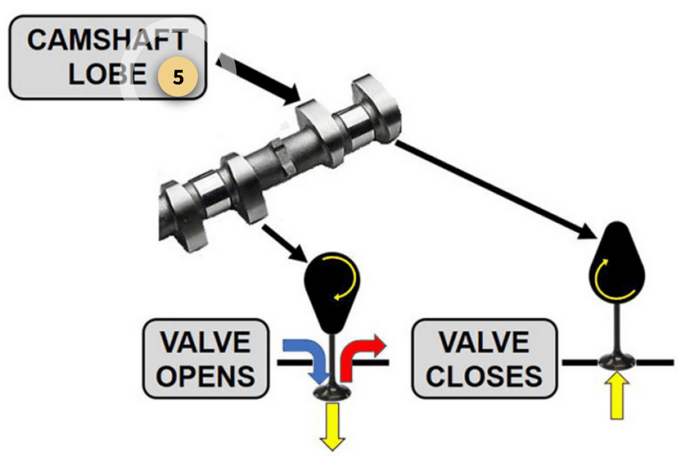


Figure 1–3. Engine camshaft.

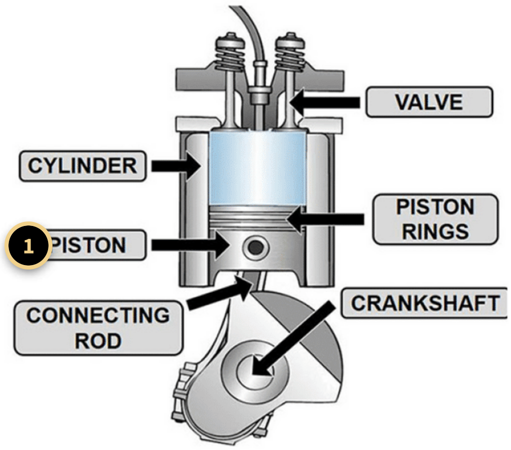


Figure 1–2. Engine components.

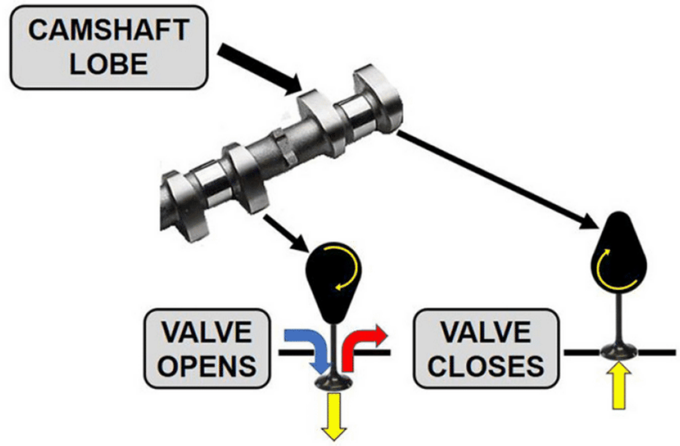


Figure 1–3. Engine camshaft.

Piston

A piston (fig 1–2) is a cylindrical object that fits neatly inside the engine's cylinder to create a nearly airtight seal. You can compare a piston inside of a cylinder to the plunger inside a syringe. The downward force of combustion is applied to the top of the piston, which is transferred through the piston's connecting rod and into the crankshaft. Since the piston and the cylinder are both made of metal, lubricating oil must be injected constantly between the two. There are several rings around the body of the piston, and some engines use more or fewer rings than others. The rings near the top of the body of the piston are called compression rings, and they aid in creating an airtight seal between the piston and the cylinder. The rings near the bottom of the body of the piston are called oil rings, and their purpose is to scrape oil off the cylinder wall and back down into the crankcase sump where it is again circulated by the oil pump. The piston continuously reciprocates, and each stroke performs a different function to keep the engine running. You will read about this cycle of events later in the lesson.

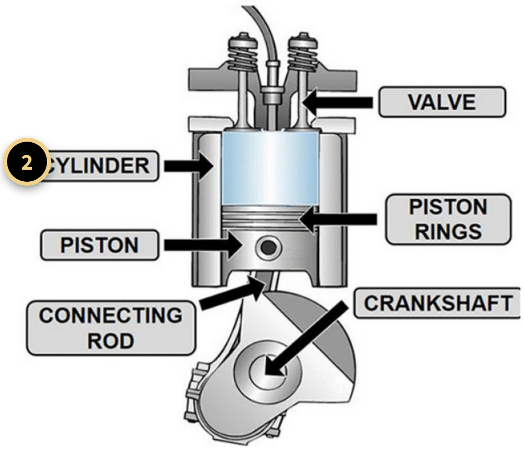


Figure 1–2. Engine components.

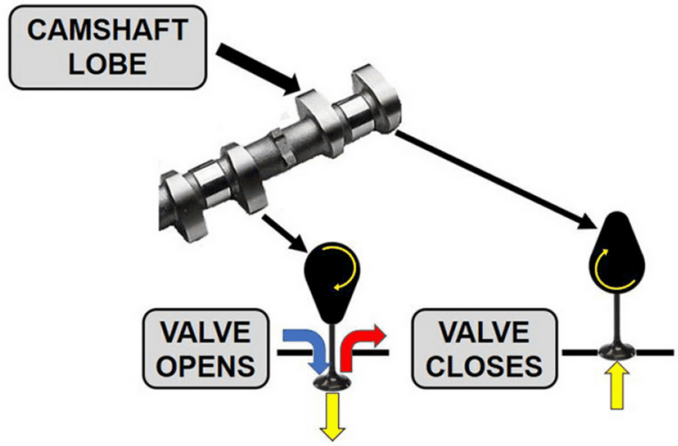


Figure 1–3. Engine camshaft.

Cylinder

The cylinder is a passage bored into the engine block that houses the piston. An engine needs at least one cylinder to make power. A good example of this is the single cylinder used in a lawn mower or weed trimmer. Some high-performance cars and trucks have as many as twelve cylinders, and some may have even more. An engine with more cylinders is able to generate more horsepower and torque.

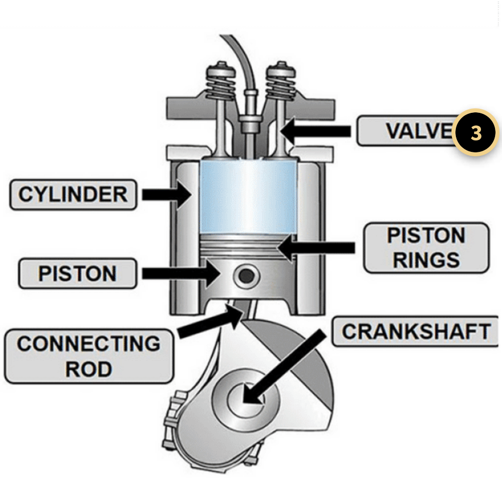


Figure 1–2. Engine components.

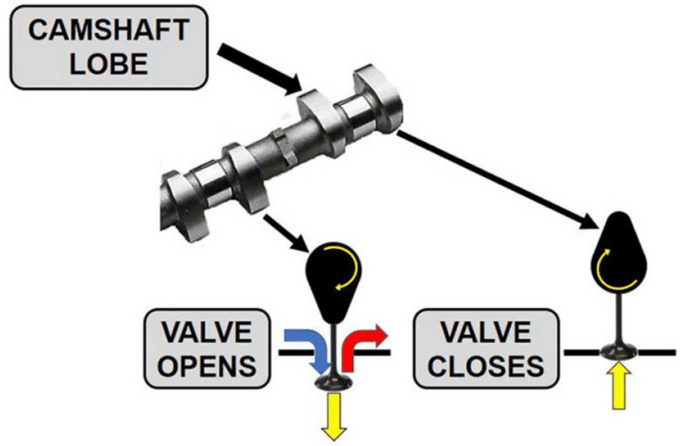


Figure 1–3. Engine camshaft.

Valve

An engine's intake and exhaust valves allow intake air to be drawn in and burned exhaust gases to be expelled from cylinder. Valves are pressed open by the camshaft at specific times in the cycle depending on what stroke (intake, compression, power, exhaust) the cylinder is in.

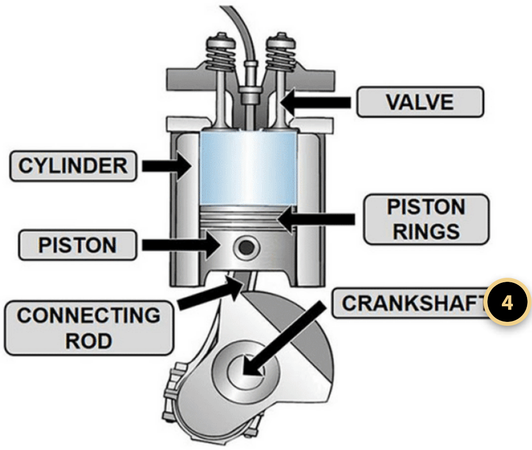


Figure 1–2. Engine components.

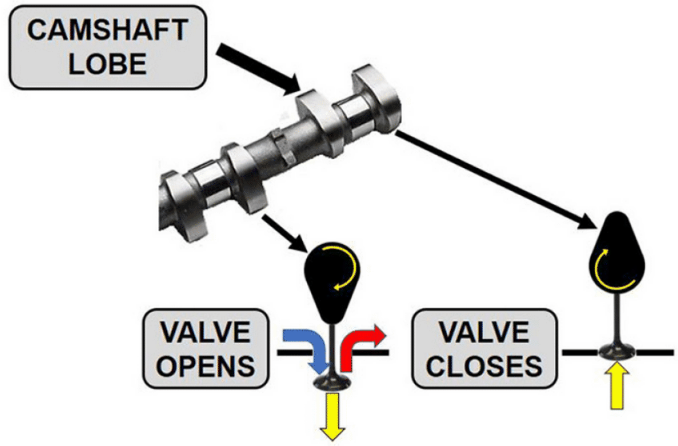


Figure 1–3. Engine camshaft.

Crankshaft

The crankshaft is the component in the internal combustion engine that converts the reciprocating (up and down) motion of the pistons into a rotary (turning) motion. This rotary motion turns an auxiliary component, such as the transmission in your car, or the generator on the LF diesel engine or payload transporter (PT) auxiliary power unit (APU).

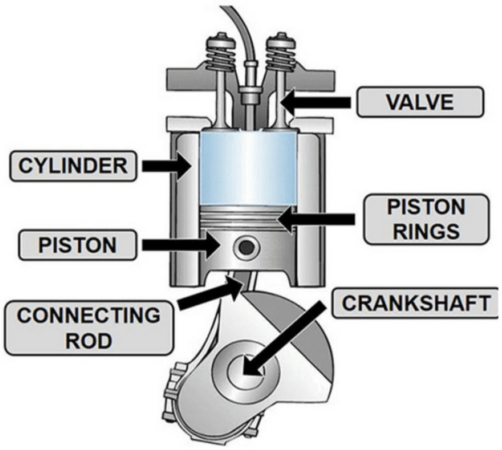


Figure 1–2. Engine components.

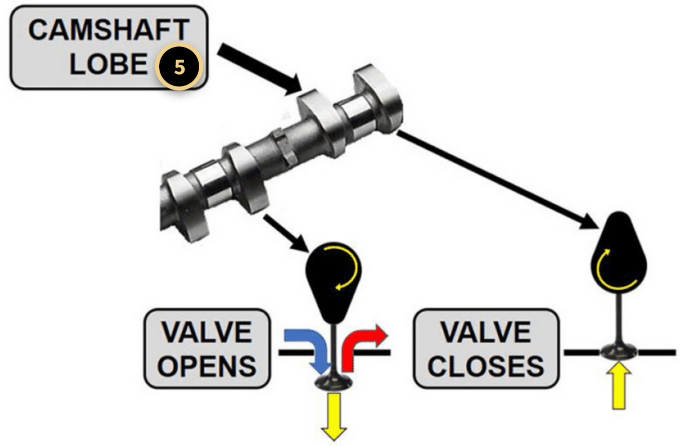


Figure 1–3. Engine camshaft.

Camshaft

The crankshaft drives the camshaft, and typically, the two are meshed by a gear, chain, or heavy-duty cogged belt. The camshaft has many "lobes" whose purpose is to press the valve open at very specific times in the engine's cycle (fig. 1–3). A heavy spring pushes and holds the valve closed when it is not being pressed open.

Flywheel

The flywheel is a weighted metal plate attached to the crankshaft that serves two major purposes. The flywheel's mass and weight smooth out engine operation by keeping the crankshaft spinning between combustion pulses. It also enables initial startup of the engine because the teeth on the engine's starter engage with the teeth on the circumference of the flywheel to rotate the crankshaft.

Complete the content above before moving on.

Four-Stroke Diesel Engines

Reciprocating engines convert the reciprocating motion of a piston to the rotary motion of a crankshaft. In a four-stroke engine, the complete cycle of events requires four-piston strokes and two crankshaft revolutions. The four-stroke cycle of events consists of intake stroke, compression stroke, power stroke, and exhaust stroke.

All diesel engines need air, fuel, and heat (ignition) to begin the combustion process and to continue to operate. If you remove one of those elements, the engine will not start or will stop if it is already operating. Each element is provided during one of the engine's strokes.

NOTE: Diesel engines do not use spark plugs to ignite the air/fuel mixture like gasoline engines do.

All missile sites and support equipment use four-stroke engines. Refer to figure 1–4 for an illustration of the cycle of events as we go through them.

Click on each number to learn about the different cycles of a four-stroke diesel engine.

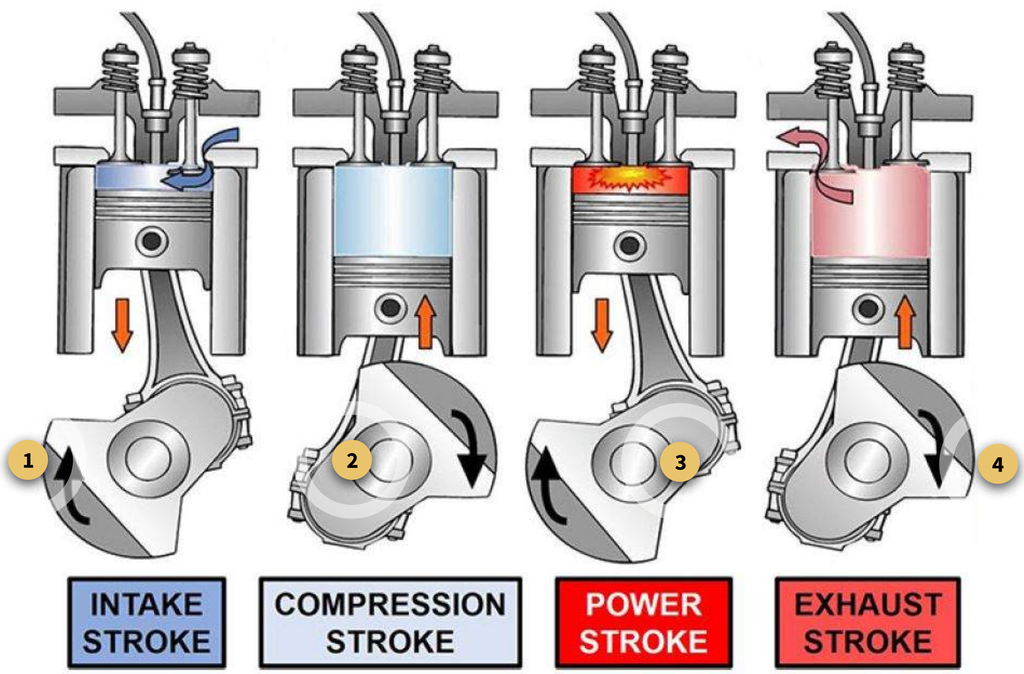


Figure 1–4. Four-stroke engine operation.

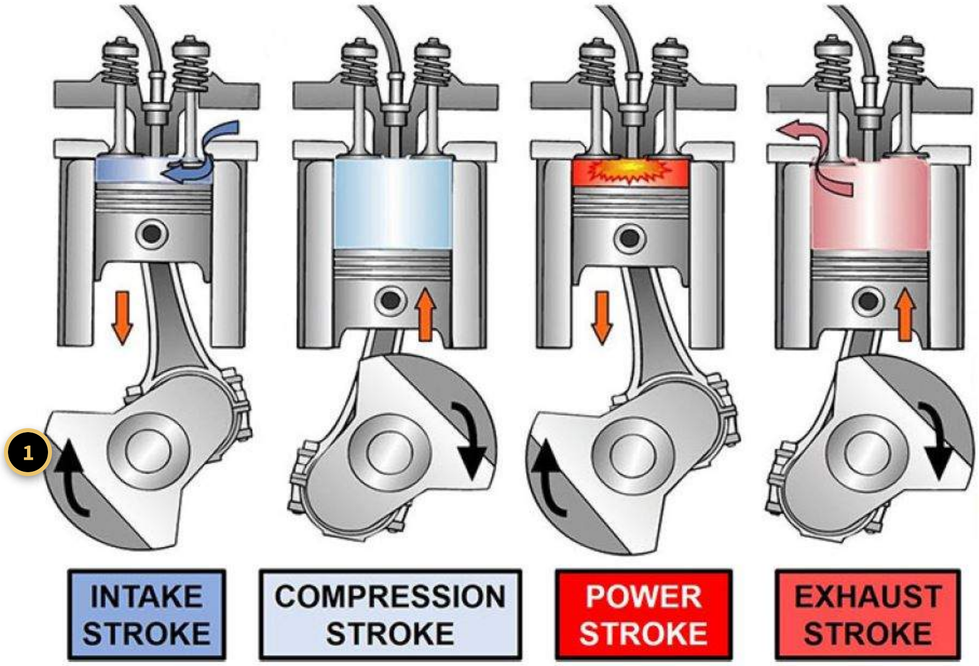


Figure 1–4. Four-stroke engine operation.

Intake Stroke

The downward motion of the piston creates a vacuum that pulls fresh air in past the open intake valve and into the cylinder. The intake valve is timed to close just as the piston nears the bottom of the cylinder. The cylinder is now filled with fresh air, which is the first element that the engine needs to operate.

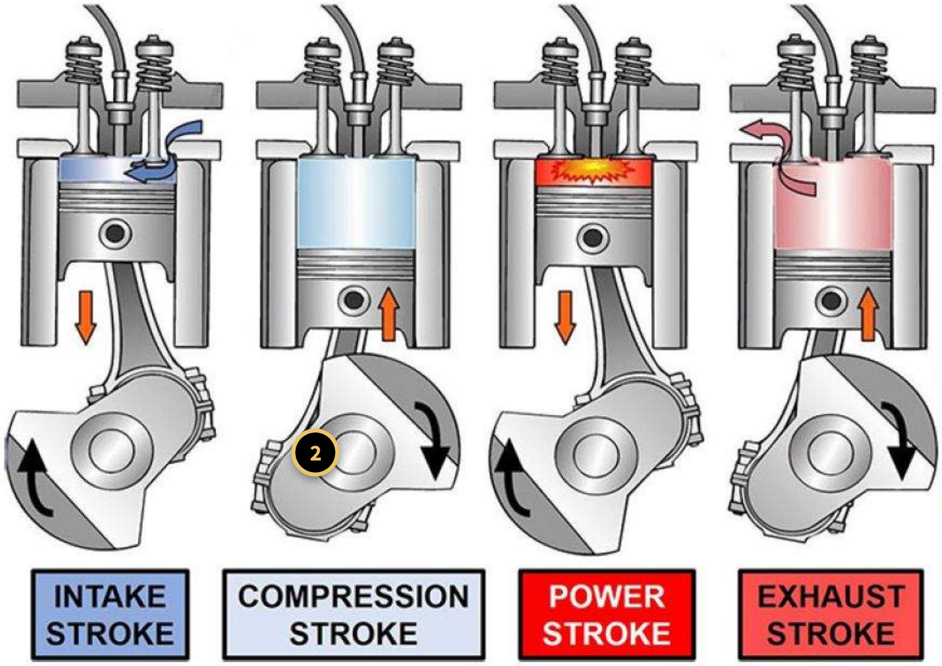


Figure 1–4. Four-stroke engine operation.

Compression Stroke

The spinning motion of the crankshaft created by the last power stroke forces the piston upward, which compresses the volume of air that has just been pulled into the cylinder. The pressure and temperature of the intake air increase as the piston moves upward toward the top of the cylinder. Two of the necessary elements for engine operation are now in place—air and heat.

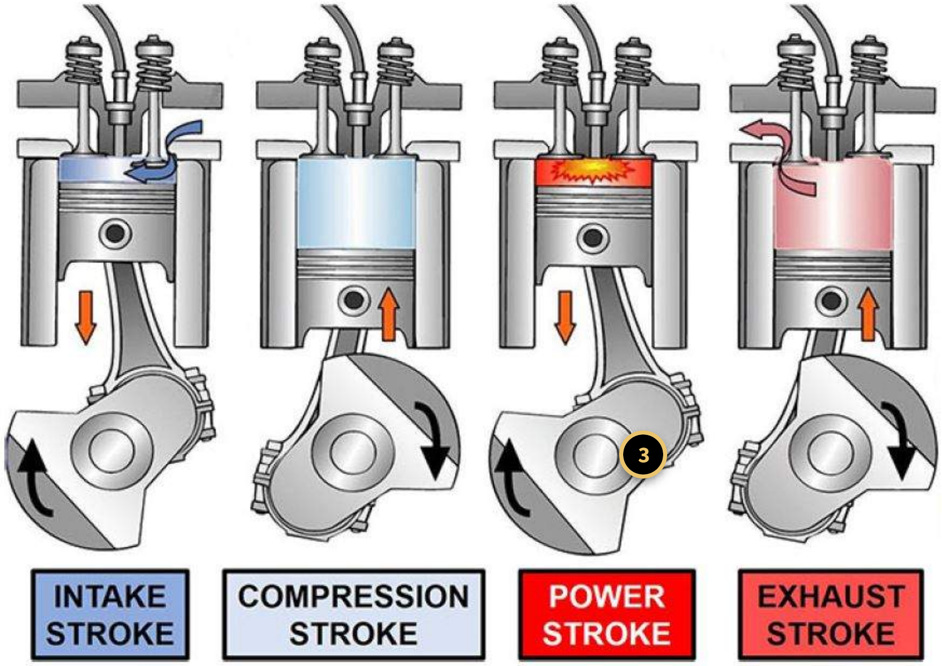


Figure 1–4. Four-stroke engine operation.

Power Stroke

As the piston nears the top of the cylinder, a perfectly timed jet of diesel fuel is injected into the hot mass of air, which adds the third and final element that the engine needs to operate. The sheer temperature of the air combined with the fuel causes the mixture to ignite. This controlled explosion forces the piston down and causes the crankshaft to rotate.

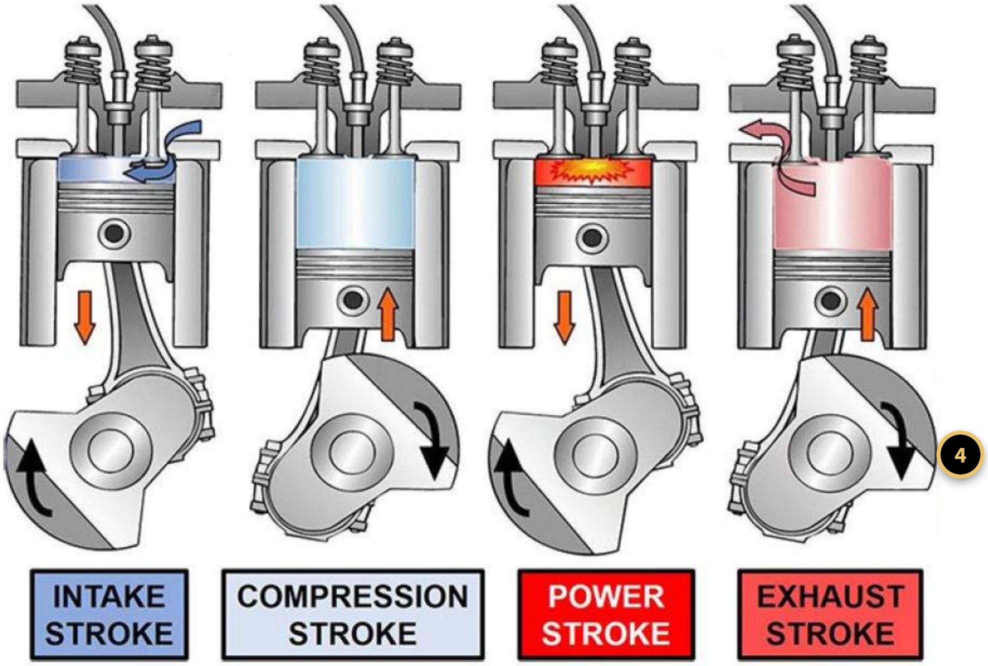


Figure 1–4. Four-stroke engine operation.

Exhaust Stroke

Now the cylinder is full of exhaust gases that were created when the air and fuel mixture burned. The camshaft pushes the exhaust valve open, while the intake valve remains closed. The crankshaft pushes the piston back upward, which expels the exhaust gases past the open exhaust valve and out of the cylinder.

This cycle of events happens hundreds or even thousands of times per minute, depending on the rotational speed of the engine, which is annotated in revolutions per minute (rpm). The power stroke is the only stroke where the piston is driving the crankshaft, and the inertia created by the flywheel is the force that keeps the crankshaft spinning between power strokes.

Up to this point, we have discussed the events that occur inside the cylinder during an internal combustion engine's cycle of events. Several systems must work together to start the engine and sustain its operation. For the most part, the systems are the same from one engine to the next, but the components vary somewhat between applications. In the following paragraphs, we will discuss the function and operation of the following LF diesel engine systems:

- Starting
- Air intake
- Fuel injection
- Exhaust

- Lubricating oil
- Cooling

Complete the content above before moving on.

Starting System

The engine's starting system must rotate the crankshaft until the cycle begins and the engine runs on its own. There are several ways an engine can be started—in fact, you may have seen pictures or movies of an old Ford Model T being started with a hand crank. All the diesel engines you will work on as a 2M0X3 technician use electric starters powered by a battery or set of batteries. You may already be familiar with this system from your technical training; it's the same system used on most cars and trucks, too.

The engine starting system operates in nearly the same fashion regardless of whether you are at a MAF, LF, or working on a transporter-erector (TE) APU diesel engine. A starter is simply an electric motor, which is why you will often see it referred to as a starter motor.

When the starter is energized, a plunger inside of it extends and meshes the teeth on the starter's gear with the teeth on the engine's flywheel. The starter motor begins to spin which causes the flywheel and crankshaft to spin. The plunger on the starter automatically retracts once the engine is running under its own power. If the starter stayed engaged with the flywheel while the engine was running at full operating speed, the starter would be damaged.

Air Intake System

The purpose of an engine's air intake system is to supply fresh, filtered air that the engine will use for combustion. The air intake system consists of an air filter, charge air cooler (Wing 1 only), the compressor side of the turbocharger, and all associated piping between these components.

Click on each (+) sign to learn about the associated piping of air intake system.

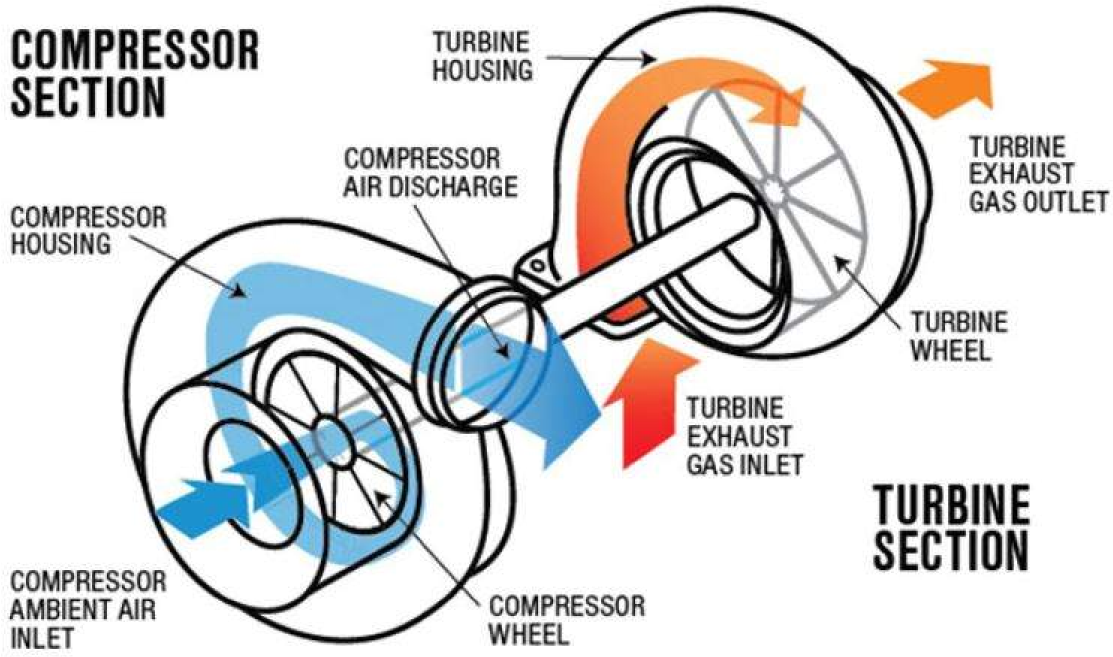
Air Filter

The first component in the air intake system is the air filter, and its purpose is to prevent unwanted foreign matter from being pulled into the cylinders. Air filters are commonly made of a pleated paper mesh, which filters out dust, dirt, and debris that could cause the cylinder walls and piston rings to wear prematurely.

Turbocharger

The purpose of a turbocharger is to use the force of the hot exhaust gases leaving the cylinders to provide compressed air for the engine's cylinders. This may sound a bit confusing, but understand that a turbocharger is made up of two different sides—one side is located in the intake system, and one side is located in the exhaust system (fig 1–5). Exhaust gases turn a turbine that is linked mechanically to the compressor wheel on the intake side; therefore, the turbocharger is often considered part of both the intake and exhaust systems.

The more air and fuel that an engine can burn per power stroke, the more horsepower and torque it can create. Air and fuel entering an engine must be mixed at a certain ratio, meaning that extra fuel must be injected to compensate for the extra air that is being forced in by the turbocharger. The engine is more powerful because of the extra fuel and air being burned, which can make larger engines more efficient and smaller engines capable of doing more work.



Charge Air Cooler (Wing 1 only)

When air is compressed by a turbocharger it becomes hotter and less dense, which is why a charge air cooler, or intercooler, is sometimes added to remove heat from the intake charge before it enters the cylinders. The charge air cooler is nothing more than a large radiator that the intake air runs through. External air then blows across the radiator—usually supplied by the engine's radiator fan, which pulls the heat from the intake air and expels it elsewhere. The result is a cool, dense charge of intake air that can be mixed with more fuel than hot, less dense air. Charge air coolers are not used at Wings 3 and 5 because the turbochargers on these engines only provide a few pounds per square inch (psi) of boost, which does not cause enough of a change in air temperature or density.

Complete the content above before moving on.

Fuel Injection and Governor Systems

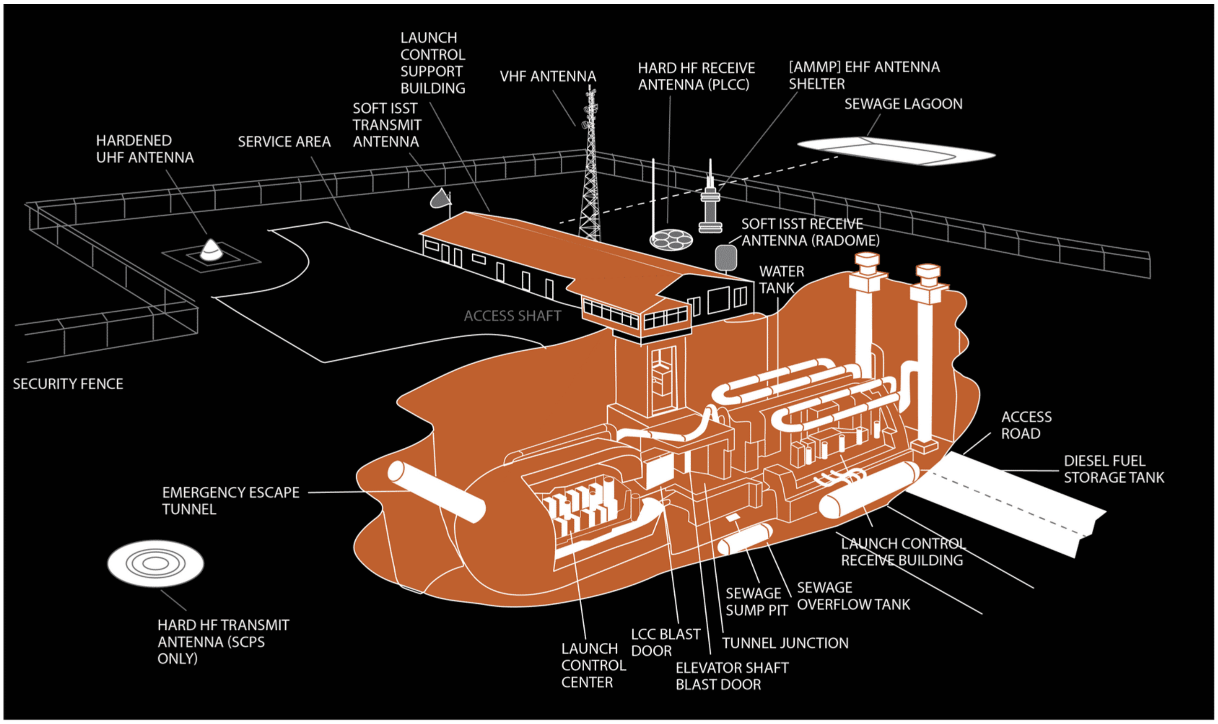
The fuel injection system on a diesel engine delivers clean, high-pressure fuel that is needed for the combustion process. Fuel tanks that supply the engines you perform maintenance on can sometimes sit unused for long periods of time; this increases the amount of debris and water condensation that could be in the fuel as it is drawn up for use by the engine. This is why a robust system of particulate filters and water separators are used on the systems you work on.

Diesel fuel is injected directly into the cylinder as the piston is nearing the top of its compression stroke. This means that the fuel must be injected at a much higher pressure than the pressure inside the cylinder—or it simply will not go in. An example of this is trying to blow more air into a balloon that is already full. Powerful fuel injection pumps driven by the crankshaft are installed on most of the diesel engines on which you will perform maintenance.

Click on each (+) sign to learn about the different components associated with the fuel injection system.

Underground Fuel Storage Tank —

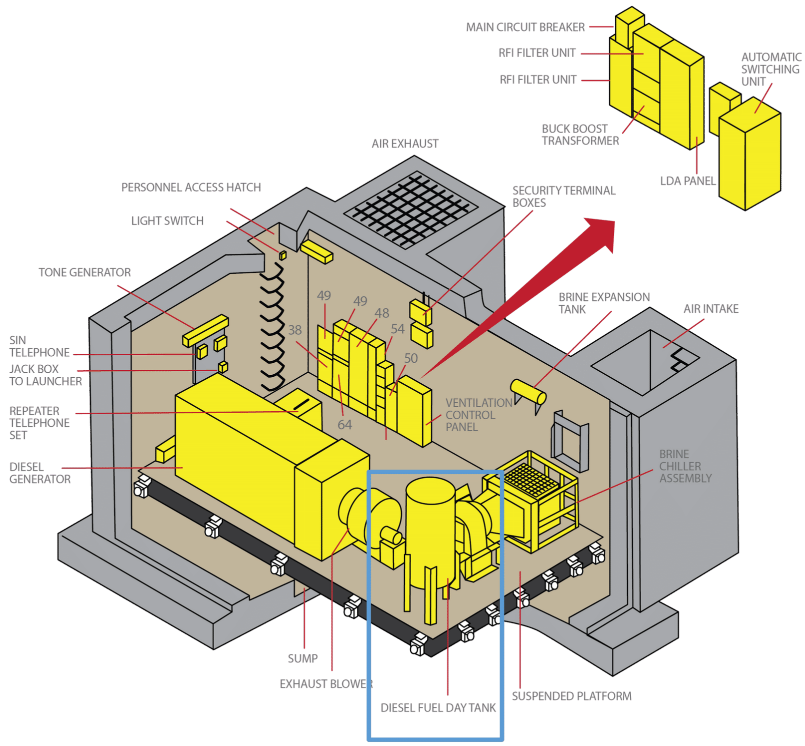
All MAFs and LFs in the missile field have large underground storage, or main tanks, which is where the fuel starts it journey to the engine's cylinder, and where we will begin. These tanks hold thousands of gallons of fuel to ensure that the DEU can run for as long as possible, and are double-walled to prevent fuel from seeping into the ground should a leak develop. Every MAF and LF utilizes an electronic leak detection system that is designed to alert the proper personnel of a suspected leak. In addition, an alarm is initiated when the tank has low fuel, at which point a commercial fuel delivery truck and a maintenance team dispatch to top it off.



Fuel Day Tank

The fuel day tank is a large tank inside of the LSB that draws its fuel from the larger underground fuel storage tank. The fuel day tank is located in the base of the DEU at Wing 1 sites, and is a large cylindrical tank bolted to the floor of the LSB at Wings 3 and 5.

The fuel day tank automatically refills itself from the underground storage tank using an electric pump that energizes when the tank hits a low level and shuts off when the tank is filled. All three wings utilize a hand pump that must be cranked manually in the event that power is not available or the electric pump is malfunctioning. An alarm will report to the MAF if the fuel level in the day tank drops too low.



Fuel Filters —

It is important for the diesel fuel to be free of sediment and other particles that may have settled at the bottom of either of the fuel tanks because this loose debris might eventually clog the fuel injectors. DEUs at all three wings use commercially available filters to handle this task.

Fuel Injection Pump —

The crankshaft drives the fuel injection pumps at all three wings. The purpose of the fuel injection pump is to pressurize the fuel being sent to the engine's fuel injectors. Wing 1 diesels use a "common rail" system where the injection pump provides pressurized fuel to a fuel rail where it waits to be let through by the injectors. Fuel pressure builds up equally behind all of the injectors, and then the engine's computer sends an electronic pulse at the correct instant in order to open the injector's solenoid to let fuel through into the cylinder.

Wings 3 and 5 fuel injection pumps work differently since they send pressurized fuel to each injector through an individual line. These injection pumps must be timed precisely to deliver bursts of pressurized fuel at just the right moment. The steel lines that run from the injection pump to the individual injectors must all be the same length; therefore, you will notice that the lines running to injectors closer to the pump may coil around several times to use up the slack.

Complete the content above before moving on.

Exhaust System

The purpose of the exhaust system is to route spent exhaust gases out of the cylinder and away from the engine, and they generally consist of a muffler and any required piping. Ideally, exhaust gas should be expelled to a location where it will not be inhaled by any technicians in the area or be pulled back in through the engine's intake system. A muffler dampens the loud sound generated by the engine while it is running, but you will still generally be required to wear hearing protection.

Lubricating Oil System

The main purpose of the lubricating oil system is to reduce friction between moving parts, but it also removes heat from the engine and cleans the engine internal parts over which it flows. Since the DEUs at all wings may need to run for days or weeks at a time, external tanks have been added to ensure that the engine has more oil available than just the amount that is normally in the crankcase.

Click on each tab to learn about the different components associated with the lubricating oil system.

LUBRICATING OIL TANK | OIL LEVEL REGULATOR | OIL PUMP | OIL FILTERS | O

The engine normally circulates the oil from its own crankcase, but the DEU will eventually run out of oil and seize up if it is burning or leaking oil. The lubricating oil tank is an external tank that will provide an extra 50 to 150 gallons depending on the wing.

LUBRICATING OIL TANK | OIL LEVEL REGULATOR | OIL PUMP | OIL FILTERS | O

A device called an oil level regulator (fig 1–6) is installed on every DEU in the missile field. Its purpose is to allow extra oil to flow in from the external lubricating oil tank into the engine crankcase if necessary. If the engine is burning or leaking oil, a float inside the regulator will drop to allow additional oil to flow into the engine's crankcase. The float moves back up to stop oil from flowing in once the crankcase level is high enough.

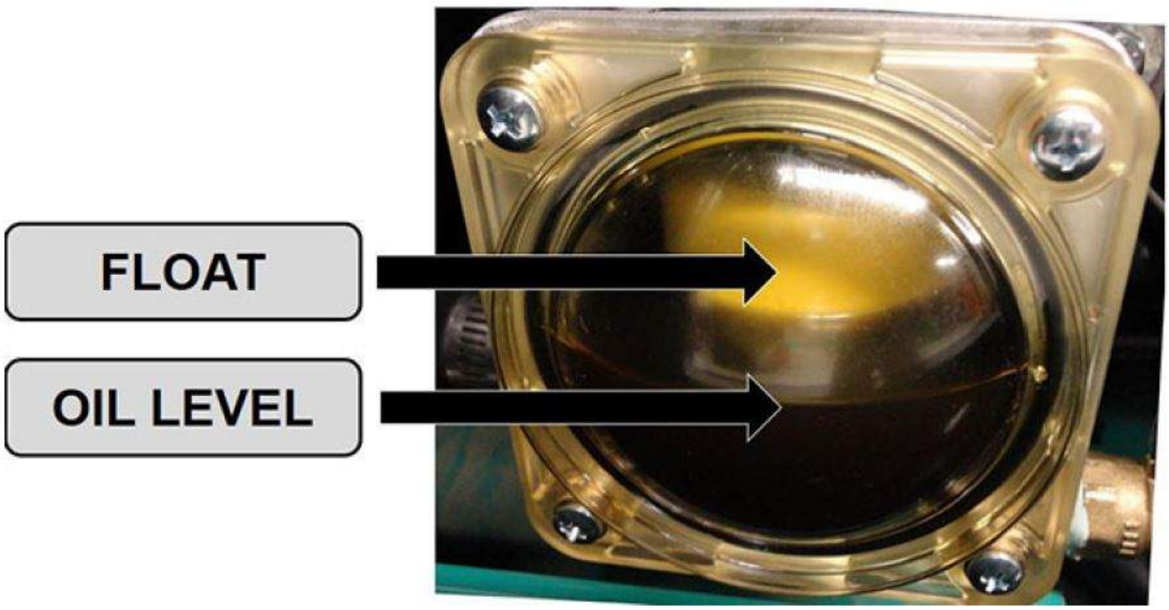


Figure 1–6. Oil level regulator.

LUBRICATING OIL TANK | OIL LEVEL REGULATOR | OIL PUMP | OIL FILTERS | O

The crankshaft also drives the oil pump, and its purpose is to pull oil in from the engine's crankcase, pressurize it, and then send it out through oil galleries to the moving parts of the engine. A gallery is a passage cut or bored into the engine block and cylinder head.

LUBRICATING OIL TANK	OIL LEVEL REGULATOR	OIL PUMP	OIL FILTERS	O

Earlier you learned that lubricating oil helps to clean internal engine parts. The oil filter removes the foreign matter that the oil collects while it is circulating through the engine. The DEUs at different wings use different numbers and configurations of oil filters, but their purpose is still the same.

LUBRICATING OIL TANK	OIL LEVEL REGULATOR	OIL PUMP	OIL FILTERS	C

You also learned earlier that oil removes heat from the engine as it circulates. This heat is removed from the oil through an oil-to-engine coolant heat exchange that happens inside of a component called an oil cooler. The oil and coolant circulate in close proximity to each other inside of a heat exchanger but do not mix, which is the process that allows the oil to transfer heat to the engine coolant.

Complete the content above before moving on.

Cooling System

All internal combustion engines generate heat; this is a result of the combustion itself as well as friction between moving parts inside of the engine. Different engine types use different types of cooling systems, to include air cooling and liquid cooling. All the engine types on which you will perform maintenance as a 2M0X3 technician are cooled by liquid.

Click on each (+) to learn about the different components associated with the cooling system.

Coolant —

Engine coolant removes heat from engine components by gathering heat as it moves through galleries in the engine block and cylinder head. Engine coolant is typically a 50/50 mixture of water and propylene glycol, which both increases its boiling point and reduces its freezing point.

NOTE: Lubricating oil and engine coolant flow through separate galleries and passages inside the engine. They do not mix.

Coolant Filter —

A coolant filter removes sediment, scale, and other solids from the coolant, which prevents these abrasives from flowing through the water pump therefore reducing the effectiveness of the cooling system. Coolant filters also add chemicals to the coolant as it passes through, which helps to reduce the acidity within the cooling system. Not all engines you work on use a coolant filter.

Water Pump —

The purpose of the water pump is circulate coolant through the engine's galleries and hoses. It is belt-driven and operates whenever the engine is running.

Thermostat

A thermostat is a component that is located in cooling system between the engine block and the radiator. An engine must operate at a certain temperature in order to run efficiently, and it will take much longer to reach this operating temperature if the coolant is allowed to flow freely to the radiator. When the engine is below operating temperature, the thermostat will prevent most of the coolant from flowing into the radiator in order to build up heat. The thermostat modulates to an open position to allow coolant in the engine block to flow to the radiator once the engine is at its operating temperature.

Radiator

The purpose of a radiator is to remove the heat that the coolant picked up while flowing through the engine. Coolant is circulated through the radiator once the engine has reached operating temperature, and air blows across the fins of the radiator. Since heat flows from a hotter substance to a cooler one, heat is transferred from the coolant to the outside air. Wing 1 DEUs use built-in, belt-driven radiator fans. Conversely, air is pulled across the radiator of Wings 3 and 5 DEUs by a large external ventilation fan. Both configurations serve the same purpose, which is to remove heat from the coolant as it flows through the radiator.

Immersion Heater –

The diesel engines you will perform maintenance on sometimes need to start and operate in very cold and harsh conditions. Since diesel engines do not use spark plugs, they rely on heat created by the piston compressing air in the cylinder. If the cylinder is too cold for combustion to occur, the engine will fail to start and a maintenance team will be dispatched for troubleshooting. The function of an immersion heater is to keep an engine warm when it is not operating, which allows the engine to start easier and develop its rated power faster in very cold conditions.

Complete the content above before moving on.

You have reached the self-test questions. Answer each question before moving forward to the next set of questions. For the fill-in the blank questions, you will need to add (.) periods to the end of the sentences.

Click here to answer the self-test questions pertaining to the internal combustion engine components and operation.

1. What is the purpose of the compression and oil rings on the engine's piston?

Type your answer here

SUBMIT

1

2. Give a definition of an engine's cylinder.

Type your answer here

SUBMIT

2

3. What function do engine valves perform?

Type your answer here

SUBMIT

3

4. What two major purposes does an engine's flywheel serve?

Type your answer here

SUBMIT

4

5. What events occur during an internal combustion engine's power stroke?

Type your answer here

SUBMIT

5

6. Explain how a charge air cooler (intercooler) operates.

Type your answer here

SUBMIT

6

7. How is the LF fuel day tank refilled?

Type your answer here

SUBMIT

7

8. What is the purpose of an internal combustion engine's exhaust system?

Type your answer here

SUBMIT

8

9. How does an internal combustion engine's oil pump operate?

Type your answer here

SUBMIT

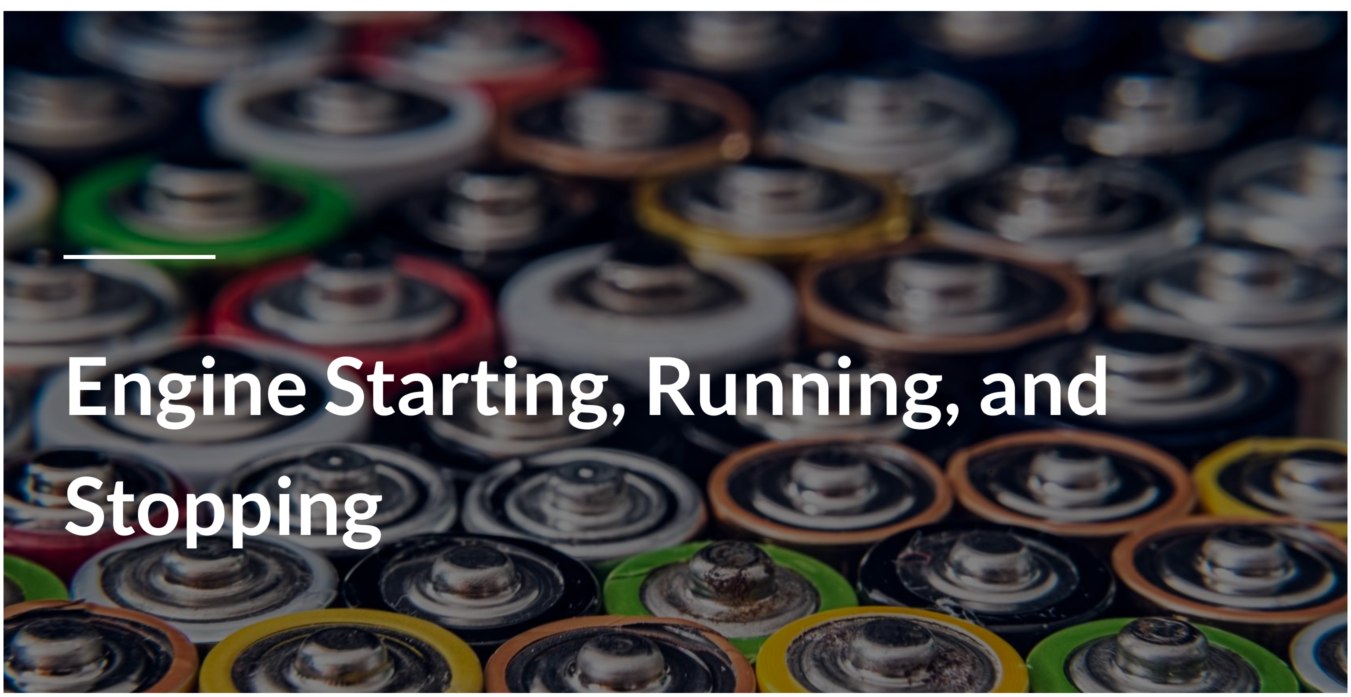
9

10. How does an engine's thermostat react once the coolant inside the engine reaches the proper temperature?

Type your answer here

SUBMIT

Click through each tab before moving forward in the lesson.



Engine Starting, Running, and Stopping

The previous lesson focused on how an internal combustion diesel engine operates as well as the engine systems that support operation. This lesson focuses on how the DEU at an MAF or LF is started, what components keep it running, and how the DEU is shut down when it no longer needs to be running.

Start Batteries

The systems you perform maintenance on at the MAF, LF, or missile support base (MSB) all use electric starters that receive electricity from a battery or set of batteries. Wing 1 DEUs use a 12-volts direct current (VDC) system that consists of two 12-VDC batteries in a parallel configuration. Wings 3 and 5 use a 24-VDC configuration consisting of four 6-VDC batteries in a series configuration (fig 1–7).

NOTE for Wing 1 only: The yellow 6-VDC batteries and battery charger at the MAF and LF were relocated during the DEU replacement program. They now serve as the batteries and battery charger for the MPP. Since the new DEU uses a 12-VDC starting system, the DEU starting batteries no longer have the ability to aid the MPP batteries.

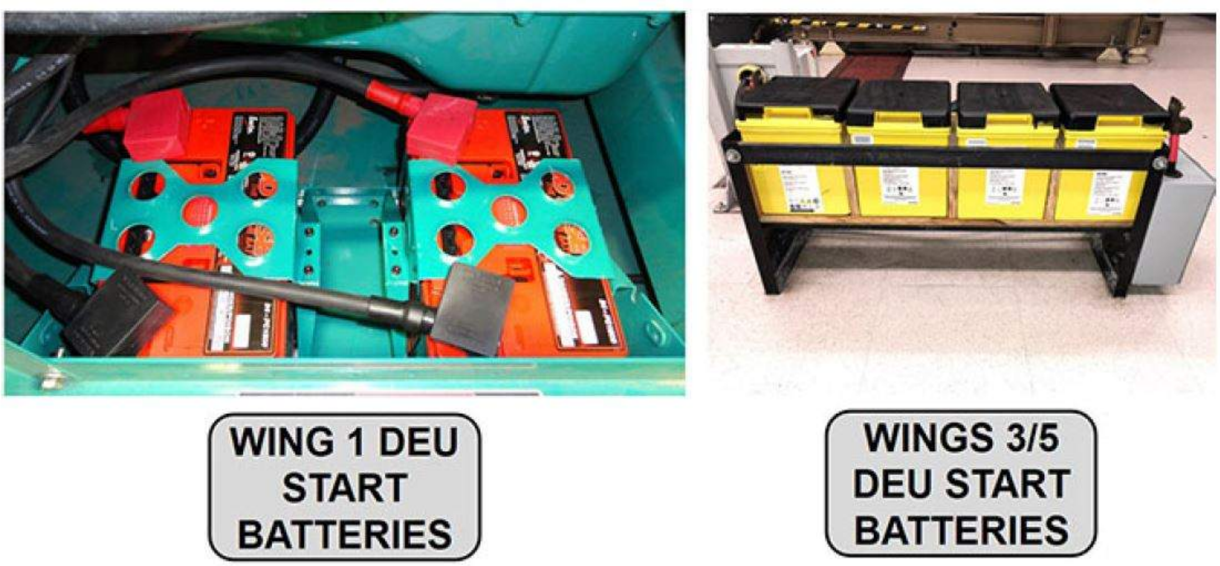


Figure 1–7. Diesel Electric Unit Starting Batteries

Battery Charging System

The starting batteries used in the systems you perform maintenance on have a system to recharge them, just like the battery in your car, truck, or cell phone. The purpose of the battery charger is to maintain the batteries at full charge so they are ready to supply power to the starter when the DEU needs to start (fig 1–8). A float charge compensates for small voltages that are lost on a day-to-day basis; an equalizing charge provides much higher current after a battery has experienced a significant voltage drop from a load being placed on it.

Wing 1 DEU starting batteries are recharged by a battery charger when the DEU is not running and by an alternator when it is running. Conversely, a battery charger only charges the DEU starting batteries on the Wing 3 and 5 sites.

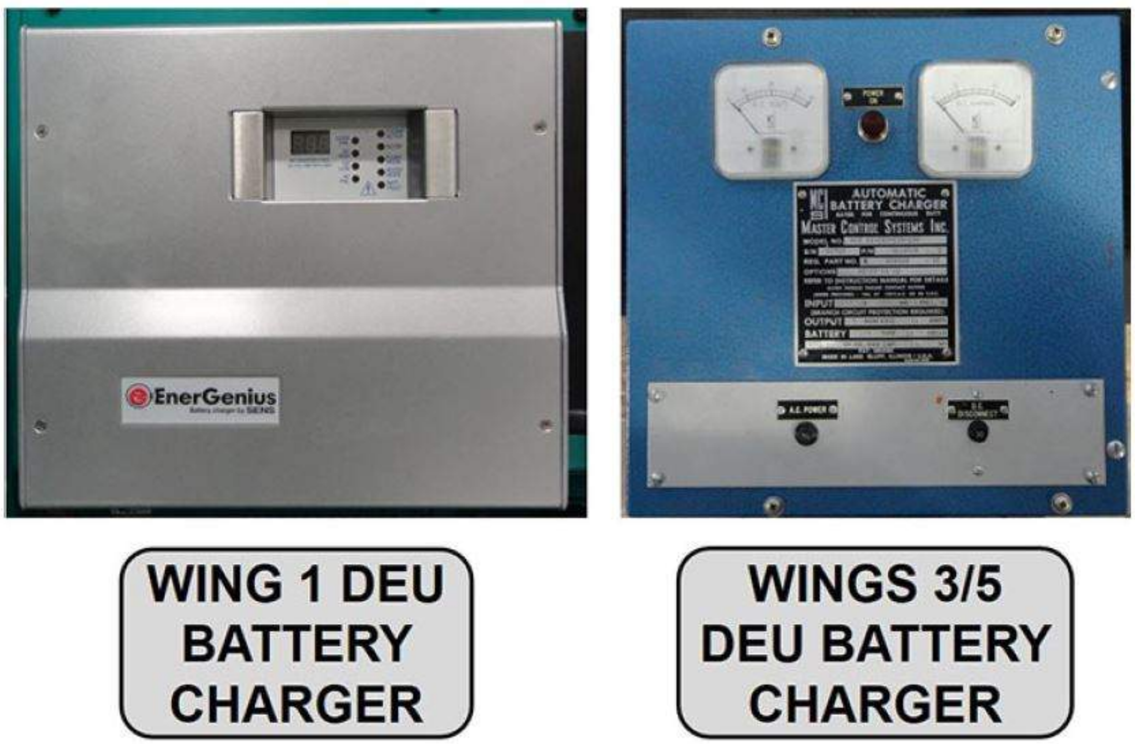


Figure 1–8. Diesel Starting Battery Charger.

Engine Starting

The MPP starts the Wing 1 DEU by sending a signal to the power command control (PCC) panel on the DEU, which then handles all starting and running operations. The MPP starts the Wing 3 and 5 DEU manually by opening the fuel solenoid and then energizing the engine's starter. Fuel flows to the injection pump and the starter turns the engine to start the cycle of events.

Now that you know how the DEU is started, let's discuss the different events that will cause the MPP to start it. Click on each (+) sign below to begin.

Commercial Power Failure —

The MPP automatically disconnects the site from commercial power if it falls outside of operational connect limits. If commercial power does not return to satisfactory connect limits within five minutes (four minutes and forty-five seconds plus a fifteen second 'test' period), the MPP will run the site off DEU power. The MPP will run the site off DEU power for a minimum of three hours before attempting to reconnect to commercial power.

Test Mode —

A technician runs the DEU in test mode after maintenance is complete in order to verify that the DEU will operate properly. This mode disconnects commercial power and intentionally runs the site using the power generated by the DEU. A technician puts the DEU in test mode by pressing the TEST pushbutton on the MPP.

Manual Mode —

A technician or team uses manual mode in order to run the DEU, but without any load. Typically, manual mode is used when the DEU needs to be operated for a troubleshooting procedure. The site still operates on commercial power when the DEU is running in this mode. A technician puts the DEU in manual mode by pressing the manual pushbutton on the MPP.

Periodic Exercise

The DEU may run rarely if a MAF or LF goes for long periods without a commercial power failure. The reason the MPP runs a periodic exercise on the DEU every 30 days is to exercise the DEU and to ensure that problems with the standby power system are discovered as soon as possible. Otherwise, a problem with the system might go unnoticed until the next time commercial power failed—which could potentially be a very long time. This 30-day timer resets automatically if the DEU was connected successfully to the site during a recent commercial power failure.

Load Bank Test

It is important for diesel engines to be regularly 'exercised' under a 100 percent of their rated capacity annually to prevent carbon and other deposits from building up in the cylinders and exhaust system. Even when the full load of the MAF or LF is placed on the DEU, it still is not running at full capacity. During a load bank test, a large bank of resistors is connected to the generator and the DEU is then run under full load for one hour. This resistor bank is of sufficient capacity to place the DEU under a 100 percent load.

Complete the content above before moving on.

Governor System

Any engine will experience different load conditions depending on what type of load it drives. The engine in your car or truck is placed continually under different loads depending on how and where you are driving (e.g., accelerating from a stoplight or maintaining a cruising speed). Your foot modulates the gas pedal at different rates depending on what the car needs to do.

The engines you work on at the MAF, LF, and MSB use a governor that automatically controls engine speed. The DEU requires more fuel to maintain the same 1,800 rpm under a load than it does if it is running unloaded, just as your car uses more fuel to accelerate than it does when idling at a stoplight. The governor maintains an engine speed of 1,800 rpm, regardless of engine load, by simply delivering different amounts of fuel to the cylinders. The Wing 1 DEU is governed differently than Wings 3 and 5 DEU.

The Wing 1 DEU is governed differently than Wings 3 and 5 DEU. Click on each tab to learn about the DEU at the Wings.

WING 1 DEU

WINGS 3 AND 5 DEU

The PCC computer controls the Wing 1 DEU and utilizes a common-rail fuel system. If the DEU rpm is too low, the PCC adds more fuel to the cylinders by commanding the electronic fuel injectors to stay open longer. When the engine rpm is too high, the computer commands the injectors to do the opposite. The same engine rpm is maintained under all load conditions.

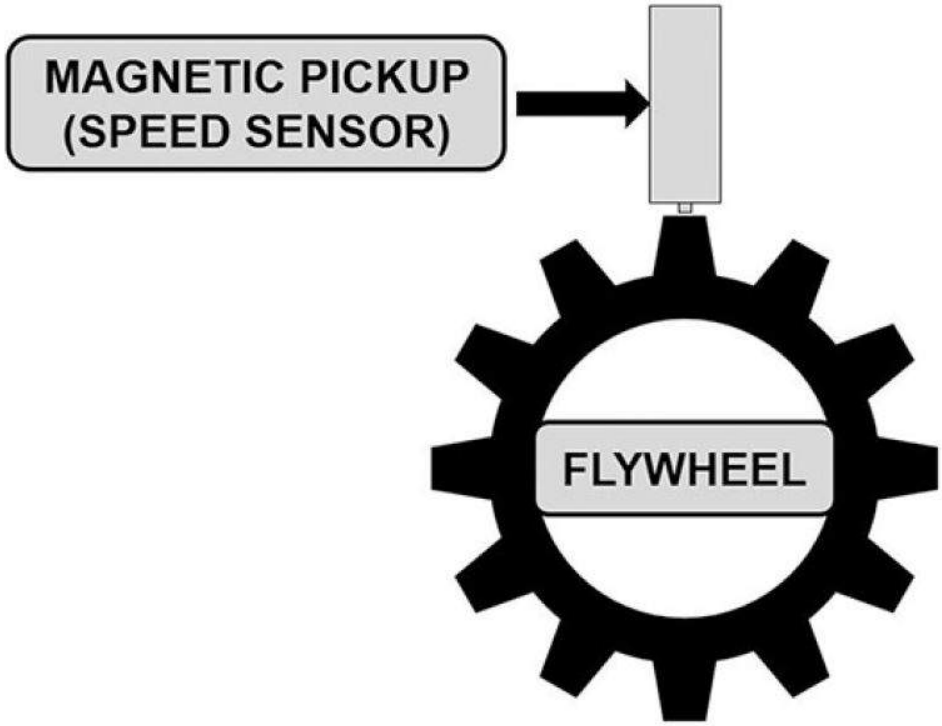
WING 1 DEU

WINGS 3 AND 5 DEU

The DEUs at Wings 3 and 5 use a different system that accomplishes the same function. The engine's magnetic pickup (speed sensor) counts the teeth on the flywheel as they pass under it (fig 1–9). Each tooth sends a high signal, and the valley between each of the teeth sends a low signal. This registers to the electronic governor controller as a constant flow of alternating high and low signals.

The governor controller translates this data to determine the engine's rpm. For instance, if the frequency the flywheel's teeth pass under the speed sensor decreases, the governor controller knows that the engine rpm is dropping.

The governor controller uses this data to send commands to the governor actuator, which is linked to the fuel injection pump mechanically. The governor actuator forces the injection pump to supply more fuel if engine rpm is too low and less fuel if the engine rpm is too high. These actions all happen very quickly in real time to maintain 1,800 rpm under all load conditions.



Complete the content above before moving on.

Engine Stopping

The MPP shuts down the Wing 1 DEU by sending a signal to the PCC panel, which then commands the fuel injectors to stop delivering fuel to the cylinders. The DEU stops running because it has been starved of fuel.

The MPP shuts down the Wings 3 and 5 DEU by closing the fuel solenoid, which starves the diesel of fuel.

The DEU at Wings 3 and 5 can be shut down manually by setting the DEU switch on the MPP to DISABLE. The Wing 1 DEU can be shut down using the same method, but a technician can also shut the engine down by pressing the EMERGENCY STOP button on the PCC, or by switching the O-MANUAL-AUTO (off-manual-automatic) switch to O (fig. 1–10).

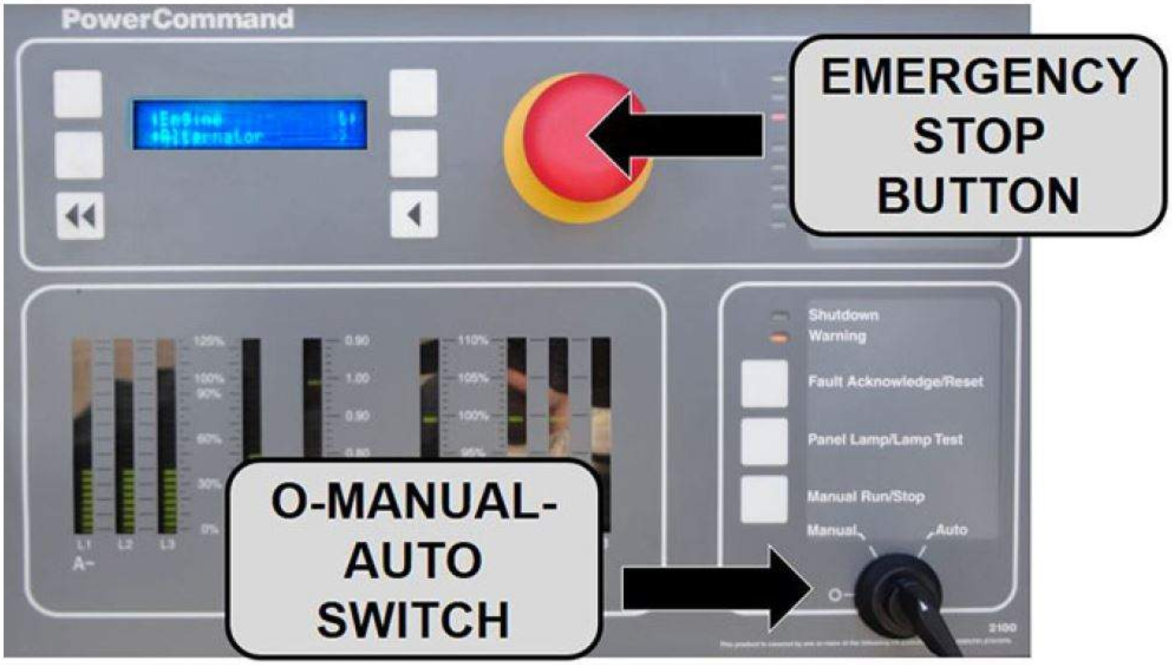


Figure 1–10. Wing 1 DEU Emergency Stop Button.

Click here to begin the self-test questions.

KNOWLEDGE CHECK TIME!

You have reached the self-test questions. Answer each question before moving forward to the next set of questions. For the fill-in the blank questions, you will need to add (.) periods to the end of the sentences.

Click here to answer the self-test questions pertaining to the engine starting, running, and stopping.

1. After a commercial power failure, and a successful connection to standby power, how long will the MPP run the site off standby power before attempting to return to commercial power?

- ◯ Thirty minutes.
- ◯ One hour.
- ◯ Three hours.
- ◯ Two hours.

SUBMIT

10

2. What is the purpose of running the DEU in manual mode?

Type your answer here

SUBMIT

11

3. What is the purpose of performing a load bank test on the DEU?

Type your answer here

SUBMIT

12

4. How does the Wing 1 DEU PCC panel increase engine rpm?

Type your answer here

SUBMIT

13

5. How do the Wings 3 and 5 DEU maintain a constant 1,800 rpm?

Type your answer here

SUBMIT

Complete the self-test questions above before moving on in the lesson.

Auxiliary Engine Systems and Equipment

The 90th MXG standing next to the last Cummins diesel engine to replace the nearly 50-year-old back-up power supply in the missile field.

The previous lesson focused on the core systems needed for an internal combustion engine to operate. Several other systems are also necessary to ensure that a malfunctioning DEU shuts down as quickly as possible in order to prevent further damage. The various equipment items and cabinets attached to the engine serve a vital role as well, so we will explore those items. This lesson will cover the following systems and equipment:

- Engine safety and alarm devices
- Engine and generator control panels
- Generators
- Voltage regulators

Engine Safety and Alarm Devices

Several conditions can cause the MPP to shut down a running DEU in order to prevent equipment damage:

- Low oil pressure
- Engine overspeed
- High coolant temperature

NOTE: The PCC panel on the Wing 1 DEU monitors several additional parameters and can shut down the DEU independently of the MPP. There are too many other parameters to discuss in this lesson, but you can

locate the exact cause of a Wing 1 DEU fault by navigating to the correct menu on the PCC panel's digital display (fig 1–11).

A Note on Differences Between Switches and Sensors

A *switch* opens or closes when a predetermined high or low limit is met and sends either voltage or no voltage—there is no middle ground.

A *sensor* detects a wide range of pressures, temperatures, and so forth, and sends varying voltages based on what it is sensing.

Engine Oil Pressure Monitoring

An oil pressure switch or sensor monitors an engine's oil pressure and sends a signal if the oil pressure falls below a set threshold. The two main causes of low oil pressure are worn bearings and/or lack of oil supply. This parameter is monitored because low oil pressure damages the engine.

The sensor on the Wing 1 DEU uses different resistance values based on the oil pressure it senses. A constant voltage is applied to the sensor—the sensor then sends a voltage value back to the PCC panel based on the oil pressure. If the oil pressure falls below 34 psi, the PCC panel shows a warning light and message but does not shut the engine down. If the oil pressure falls below 30 psi, the PCC panel immediately shuts the engine down and the MPP indicates a low oil pressure condition.

The oil pressure switch on the DEU at Wings 3 and 5 does not sense a range of pressure values—it is either open or closed. The switch closes when the DEU is not operating and opens when the engine runs and builds oil pressure. If the engine is creating enough oil pressure to keep the switch open, all is well. If the oil pressure falls below 12 ±2 psi, the switch closes to complete a circuit. This closed circuit allows voltage to flow to the MPP telling it to shut down the engine. The MPP ignores the signal from the oil pressure switch for 30 seconds after engine startup in order to allow enough time for oil pressure to build.

Engine Overspeed Monitoring

All engines are designed to operate at a certain optimal rpm, and mechanical damage occurs if the engine's rpm gets too high. An overspeed switch, or sensor, monitors rpm and sends a signal to shut the engine down if it exceeds a certain speed threshold.

The Wing 1 DEU uses an electronic speed sensor that sends real-time engine rpm data to the PCC panel, which then controls engine speed by commanding the fuel injectors to either add fuel if the engine rpm is too low or subtract fuel if the rpm is too high. If the engine computer loses the ability to subtract fuel, and the rpm continues to rise, the computer initiates an engine overspeed shutdown. Remember, the MPP does not directly control the DEU on Wing 1 sites; it communicates through the PCC panel.

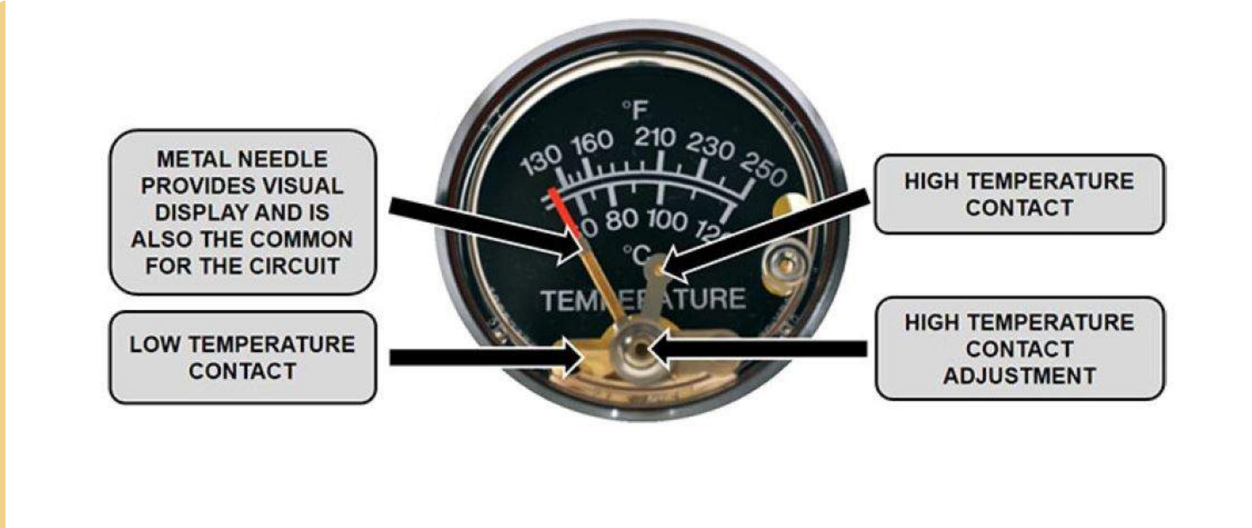
The Wings 3 and 5 DEUs utilize an electronic speed switch, which uses data sent from the same magnetic sensor used by the engine governor. The electronic speed switch sends a signal to the MPP to initiate shutdown if the engine's speed exceeds 2010 ±60 rpm.

Engine High/Low Temperature Monitoring

The function of any device that monitors engine temperature is to initiate a shutdown if the engine gets too hot. Excessive temperatures cause the engine's parts to expand, which reduces bearing clearances and increases friction. If left long enough, eventually the engine will seize because bearings will fuse and pistons will expand to be too large for their cylinders.

The Wing 1 DEU's coolant temperature sensor is installed directly into the engine block; a continuous flow of data is sent from the temperature sensor to the PCC panel. A warning is initiated at 225 degrees Fahrenheit (°F). The PCC panel shuts the DEU down completely if the coolant temperature rises to 233 °F. You can check the coolant temperature using the PCC panel's digital display.

The DEUs at Wings 3 and 5 use a temperature switch gauge (fig 1–12) connected to a sensor that is installed into the engine block. The switch gauge gives you a visual indication of the coolant temperature and also houses two electrical contacts. One contact is on the low temperature side of the switch gauge. The needle on the temperature display is metallic and provides the common, or ground, for the two circuits. If the temperature of the engine falls to approximately 90 °F, the needle will touch the low side contact and cause the FUEL MAIN TANK indicator light to illuminate on the MPP; typically, this indicates that the immersion heater system has failed. If the engine temperature reaches 220 ±5 °F, the temperature needle will touch the gauge's high temperature contact, which will send a signal to the MPP to shut down the DEU. The high temperature contact set point is adjustable, while the low temperature contact set point is not.



Complete the content above before moving on.

Engine and Generator Control Panels

Several panels around the engine contain all the auxiliary equipment needed to control the engine and the generator. Inside these panels, you find wiring, terminal boards, fuses, and other important components that are necessary for engine operation and power generation. The Wing 1 and Wings 3 and 5 DEU will be broken down separately because there are major differences between the various panels (fig 1–13).

Panel	Wing 1 DEU	Wings 3 and 5 DEU
Power Command Control	✓	✗
DEU interface	✓	✗
DEU circuit breaker	✓	✗
Battery charger	✗	✓
Generator control	✗	✓
Engine cranking / monitor & alarm	✗	✓

Figure 1–13. Wing 1 and Wings 3 and 5 DEU Panel Comparison.

Wing 1 Power Command Control (PCC) Panel

The PCC panel (fig 1–14) is a microprocessor-based control system for the generator set, and all control functions are contained on the motherboard. The PCC software governs engine speed, regulates generator output, and controls and monitors the entire DEU. Statistics, faults and fault history, operating parameters, generator output, and a multitude of other data can be viewed on the PCC panel's digital display.

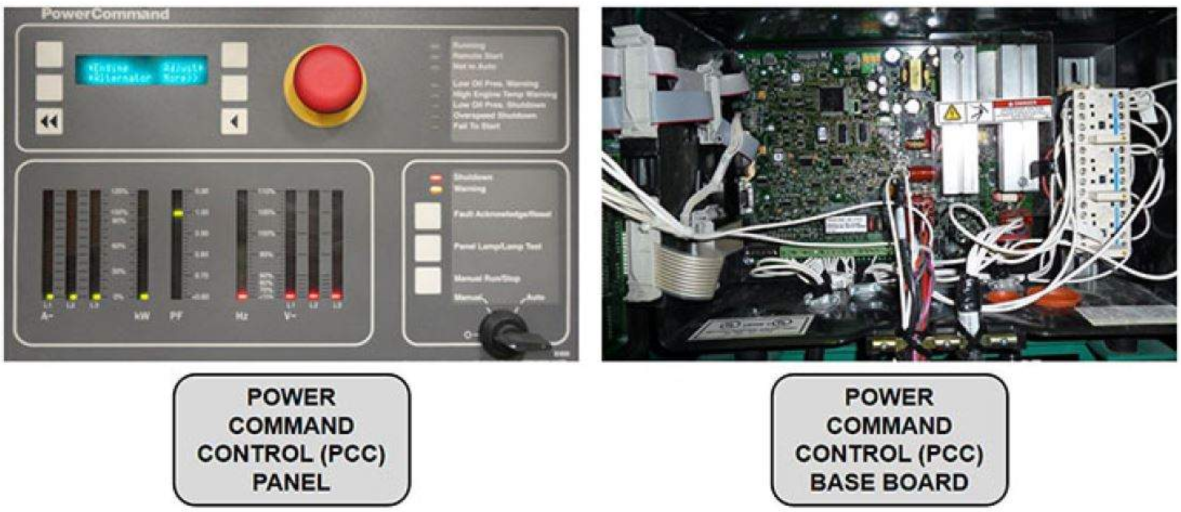


Figure 1–14. Wing 1 DEU power command control panel.

Wing 1 DEU Interface Panel

The interface panel on the MAF DEU looks differently and is located in a different area of the engine than the LF DEU (fig 1–15); however, both serve essentially the same purpose.

Figure 1–15. Wing 1 LF DEU interface panel.

MAF DEU Interface Panel

The MAF DEU interface panel houses the major components that act as an interface between the DEU and the site. The following lists the four major interfacing components:

- Terminal board A (TBA)
- Terminal board B (TBB)
- ON and OFF switches
- Push/pull circuit breakers (CB)–1 and CB–2.

TBA is where all direct current (DC) voltage wiring interfaces between the site and the DEU, which consist primarily of signals to and from the MPP. Plug P1 is the quick-disconnect that interfaces with jack J1 on the panel. Figure 1–16 illustrates the quick disconnect plug and jack system used on all Wing 1 DEUs.

TBB is where all alternating current (AC) voltage wiring interfaces between the site and the DEU, and P2 is the quick-disconnect plug that interfaces with jack J2 on the panel.

ON/OFF switches for the DEU immersion heater, day tank fuel transfer pump, and DEU radiator damper actuator are located on the interface panel.

Push/pull circuit breakers CB–1 and CB–2 provide circuit protection for the DEU roof damper and DEU radiator damper operator, respectively. Air is drawn in through the roof damper above the DEU and exhausted through the wall damper (located in front of the DEU radiator).

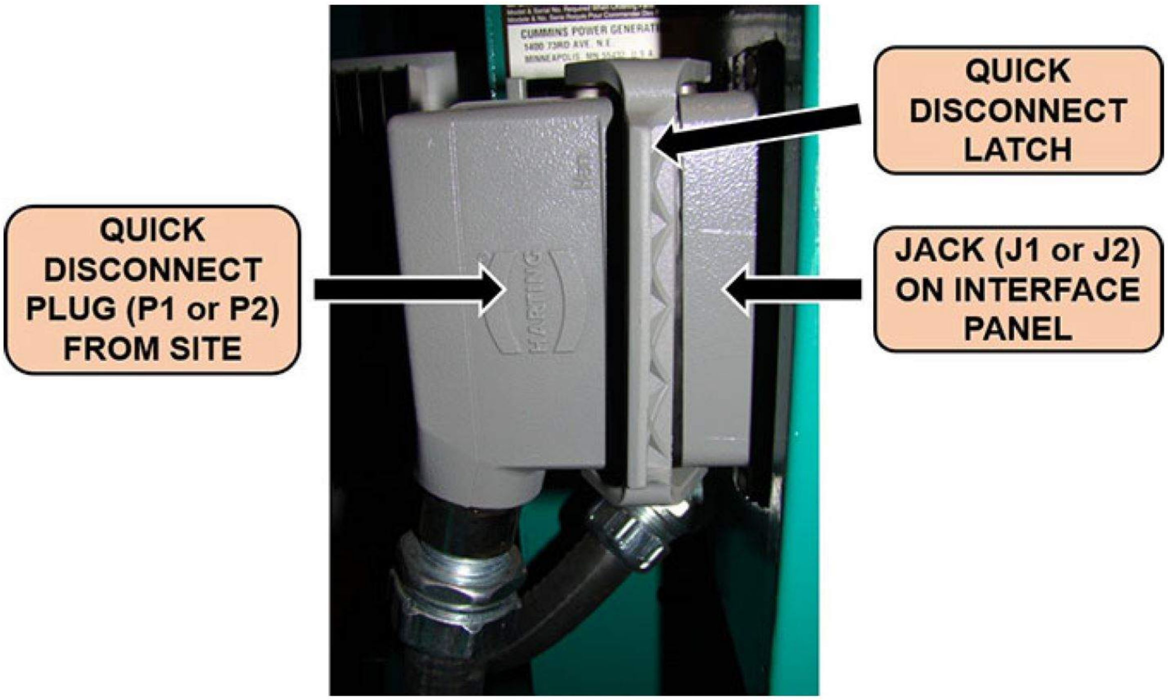


Figure 1–16. Wing 1 DEU Interface Panel Jack and Plug System.

LF DEU Interface Panel

The LF DEU interface panel houses only three major interfacing components since it does not contain any push-pull circuit breakers.

TBA is where all DC voltage wiring interfaces between the site and the DEU, and consists mainly of signals sent to and received from the MPP. Quick-disconnect plug P1 interfaces with jack J1 on the panel.

TBB is the location where all AC voltage wiring interfaces between the site and the DEU. A quick-disconnect plug interfaces with jack J2 on the panel. The DEU battery charger and immersion heater are two of the AC loads that run through TBB/P2/J2.

ON/OFF switches for the DEU immersion heater, day tank fuel transfer pump, and DEU battery charger are located on the interface panel.

Complete the content above before moving on.

Wing 1 DEU Circuit Breaker Panel

The DEU circuit breaker panel (fig 1–17) houses the standby power main circuit breaker and the large power cables that run from the generator to the automatic switching unit (ASU) or power transfer switch (PTS) cabinet.

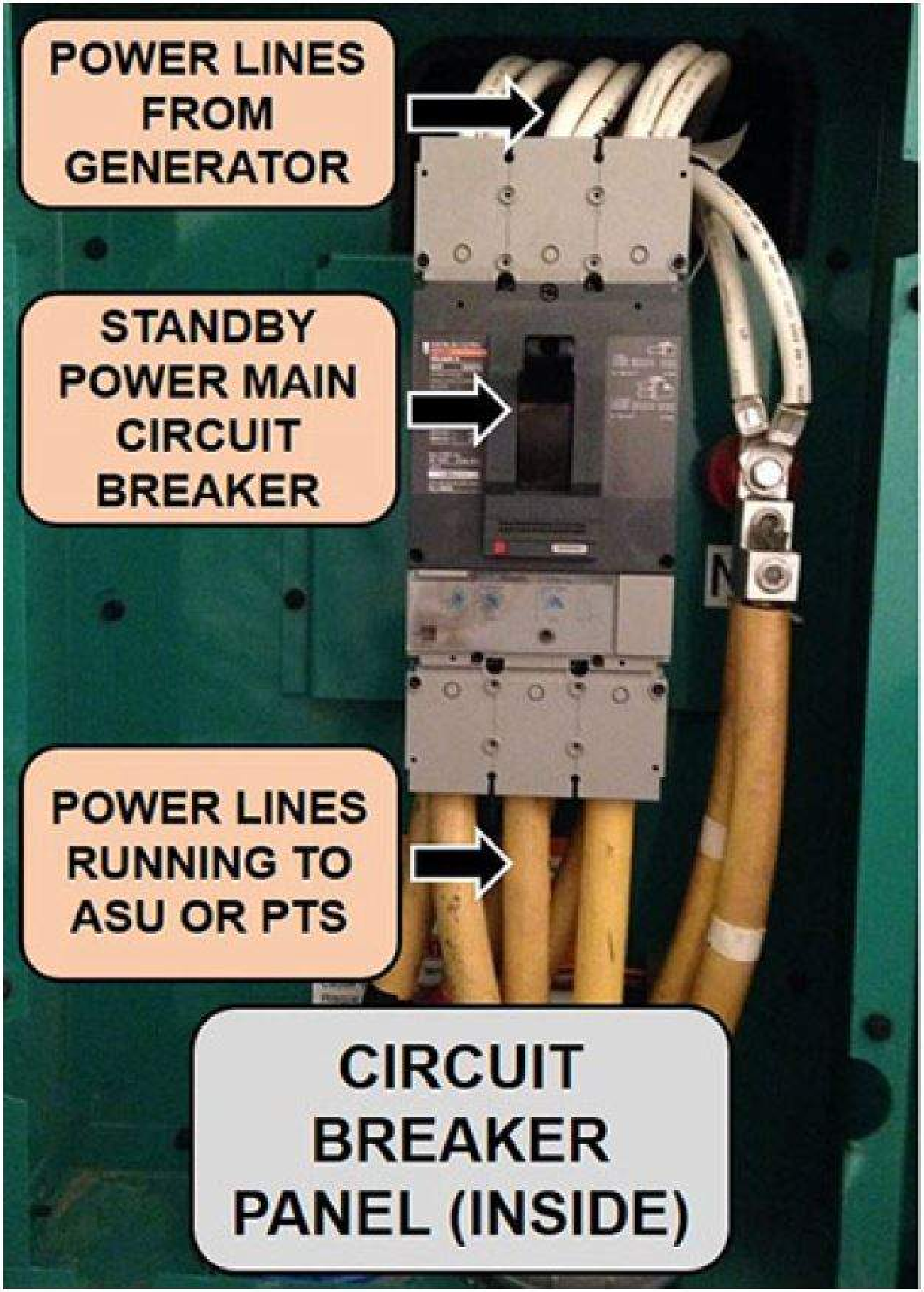


Figure 1–17. Wing 1 DEU Circuit Breaker Panel (front panel removed) (typical).

Wings 3 and 5 Engine Cranking and Monitor and Alarm Panel

The engine cranking and monitor and alarm panel (fig 1–18) houses the electronic speed switch and the governor controller, as well as other important terminal boards, fuses, and wiring. The function and operation of the electronic speed switch and governor controller were discussed earlier.

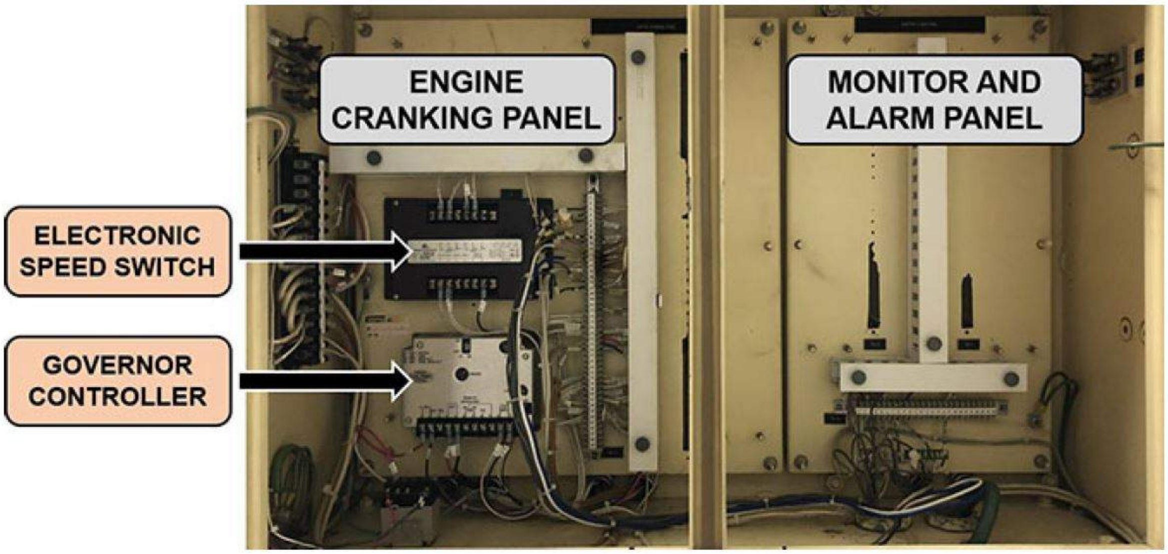


Figure 1–18. Wings 3 and 5 Engine Cranking and Monitor & Alarm Panel (doors open).

Wings 3 and 5 Generator Control Panel

The generator control panel contains a variety of components that monitor and control the output of the generator. Inside the panel you will find a main circuit breaker, voltage regulator, voltage adjust rheostat, frequency test receptacle, and elapsed time meter (fig 1–19).

The standby power main circuit breaker's function is to open (trip) in order to protect the generator if the site loads draw too much current. The breaker does not automatically reset, which means that a maintenance team will need to dispatch to troubleshoot the cause of the over current condition.

The purpose of the voltage regulator is to maintain the same generator voltage output automatically regardless of engine speed. The voltage regulator is covered in more detail in the next lesson.

The voltage adjust rheostat is electrically attached to the voltage regulator, and its purpose is to allow a technician to adjust the voltage output of the generator.

A frequency test receptacle is nothing more than a wall outlet socket that allows you to attach a multimeter to check the frequency output of the generator. Typically, this is done by either inserting the multimeter leads directly into the socket or by using a locally manufactured frequency meter cord. This cord is simply a standard three-prong wall outlet plug that is attached to positive and negative male multimeter leads.

The elapsed time meter displays the number of hours that the DEU has run since its last overhaul. Each DEU must be removed and overhauled at certain intervals, which is why you or your team chief will record this number before leaving site.

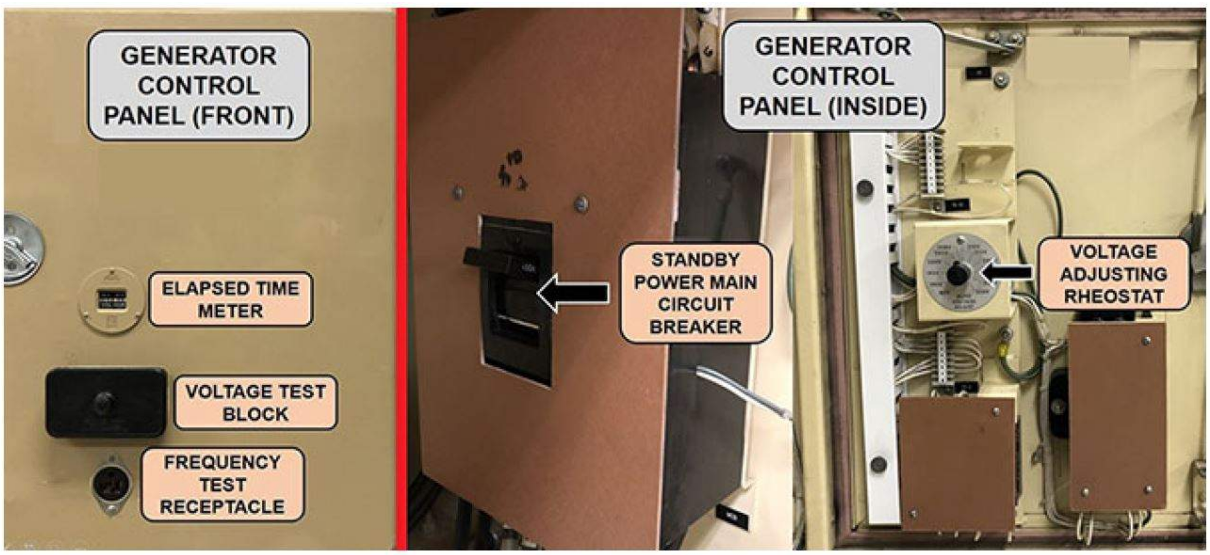


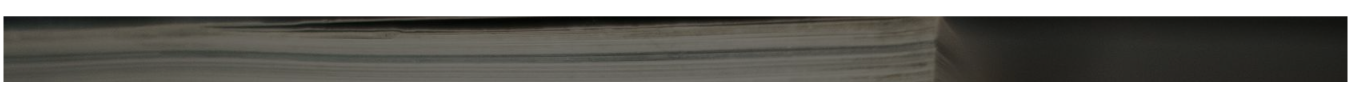
Figure 1–19. Wings 3 and 5 Generator Control Panel.

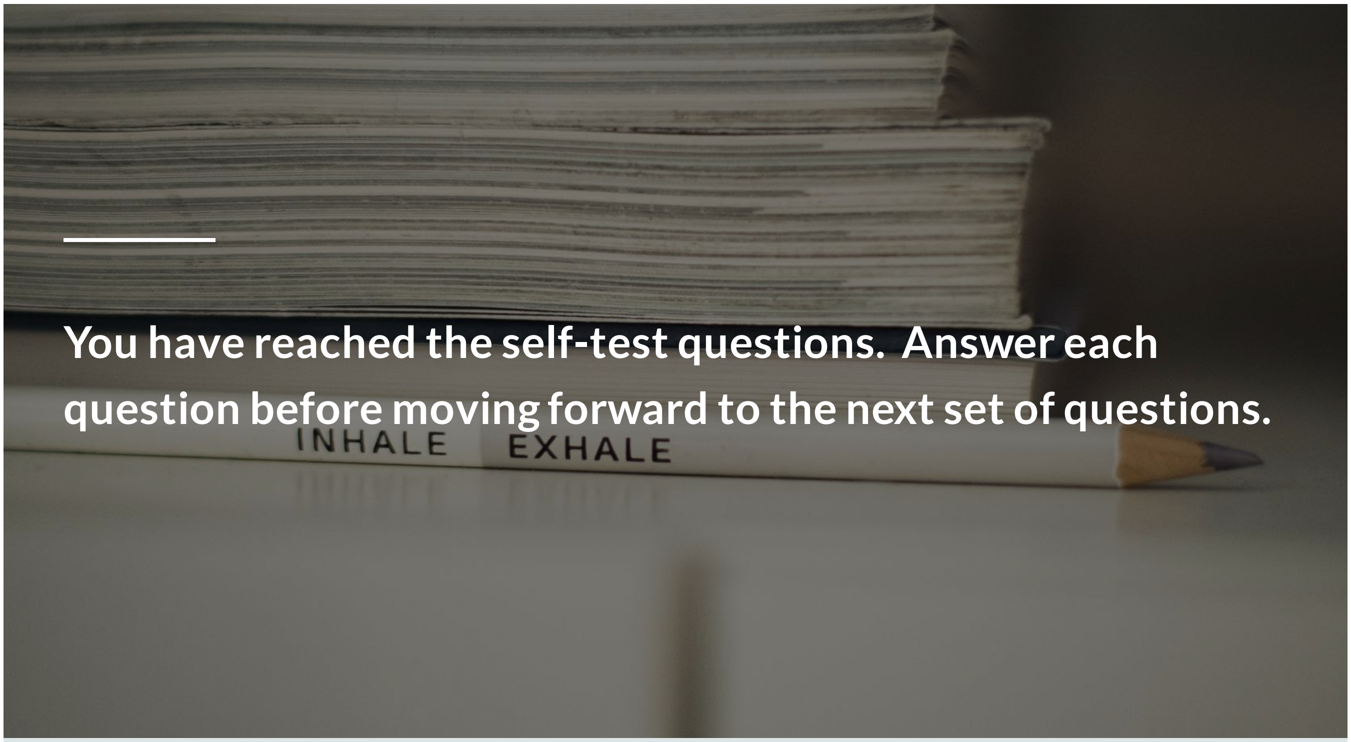
Wings 3 and 5 Battery Charger Panel

The battery charger panel (fig 1–20) is relatively straight forward—it houses the battery charger that maintains the charge on the DEU starting batteries discussed earlier in the unit.

Figure 1–20. Wings 3 and 5 DEU Starting Battery Charger Panel.

Click through each tab before moving forward in the lesson.





You have reached the self-test questions. Answer each question before moving forward to the next set of questions.

KNOWLEDGE CHECK TIME!

For the fill-in the blank questions, you will need to add (.) periods to the end of the sentences.

Click here to answer the self-test questions pertaining to the auxiliary engine systems and equipment.

1. What is the difference between a switch and a sensor?

Type your answer here

SUBMIT

14

2. What happens if an engine's rpm gets too high?

Type your answer here

SUBMIT

15

3. What sequence of events occurs if the Wings 3 and 5 DEU reach 2010 ±60 rpm?

Type your answer here

SUBMIT

16

4. What sequence of events occurs if the Wings 3 and 5 DEU reach 220 ±5 °F?

Type your answer here

SUBMIT

17

5. What engine and generator control panels exist at the Wing 1 LF? Select the answer(s) that best answers this question.

- [ ] PCC panel
- [ ] Voltage test block.
- [ ] DEU interface panel.

☐ DEU circuit breaker panel.

SUBMIT

18

6. What components are found in the Wings 3 and 5 generator control panel?

○ Main control alarm panel, voltage regulator, voltage adjust rheostat, frequency test receptacle, and elapsed time meter.

○ Main circuit breaker, voltage regulator, voltage battery tester, frequency test receptacle, and elapsed time meter.

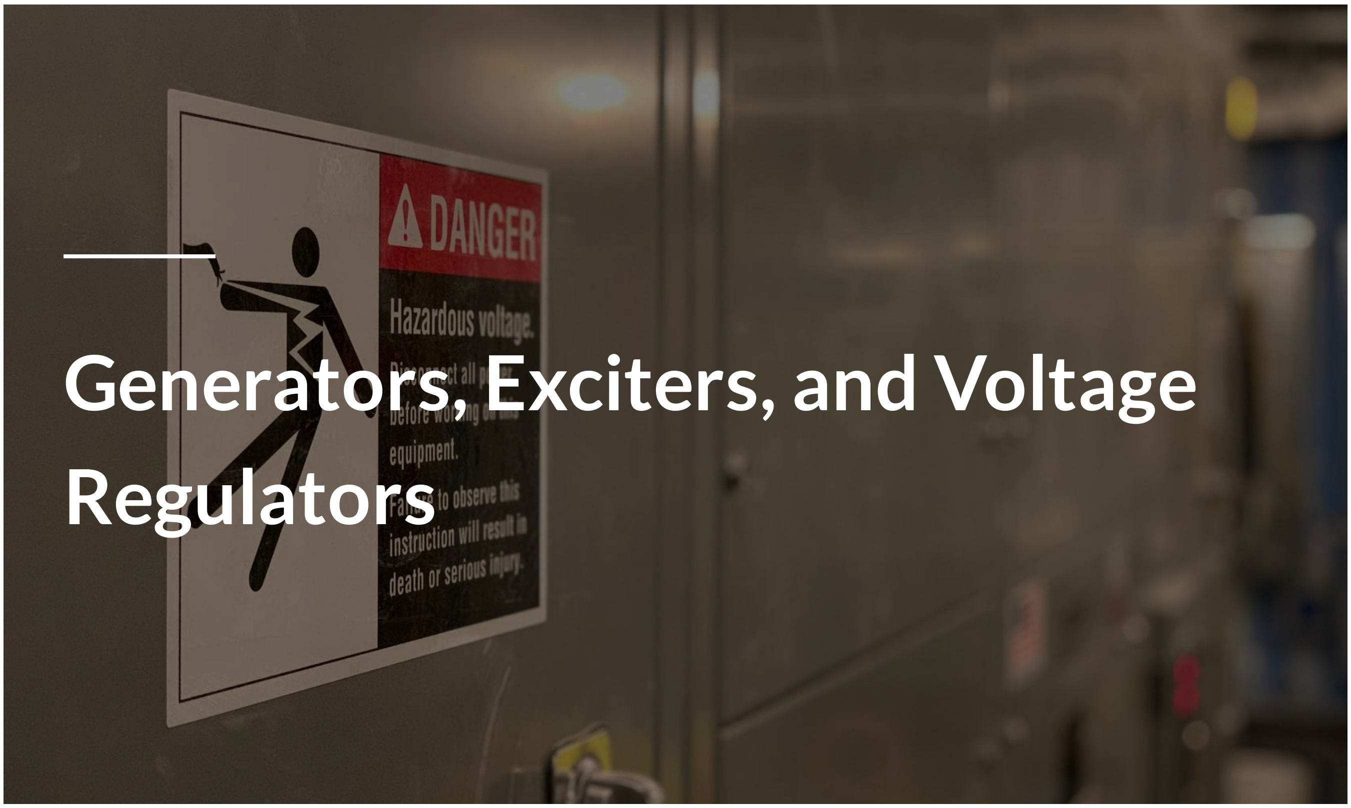
○ Main circuit breaker, voltage regulator, voltage adjust rheostat, and frequency test receptacle.

○ Main circuit breaker, voltage regulator, voltage adjust rheostat, frequency test receptacle, and elapsed time meter.

SUBMIT

Click through each tab before moving forward in the lesson.

Generators, Exciters, and Voltage Regulators



The lessons you have just read focused primarily on the starting, running, and stopping of the diesel engine itself—but why does it need to run and what is it turning? This lesson focuses on the electricity created when the diesel engine spins the generator, how the generator creates electricity, and how the voltage and frequency output of the generator are regulated.

The generators you perform maintenance on convert the rotary motion of the diesel engine's crankshaft into electricity that will supply power to the MAF or LF when no commercial power is available. The same is true of the generators you might perform maintenance on that are located on the PT, TE, or a periodic maintenance team (PMT) van—these vehicles can accomplish all their normal functions even when they are not connected to site or facility power. Diesel engines with generators are installed in facilities such as hospitals that need to have a backup source of power. A hospital needs to have electricity available at all times in order to operate life support and other equipment. The MAF and LF must also have electricity at all times in order to maintain the ability to accomplish their missions.

The complete package of a generator connected to a diesel engine at a MAF or LF is called the diesel electric unit, or DEU, a term with which you are already familiar. A DEU on a PT, TE, or PMT van is known as an auxiliary power unit, or APU. There is even a small APU in the portable air conditioner you may perform maintenance on as a power, refrigeration, and electrical (PREL) shop technician. The generators on these different pieces of equipment all exist to generate electricity.

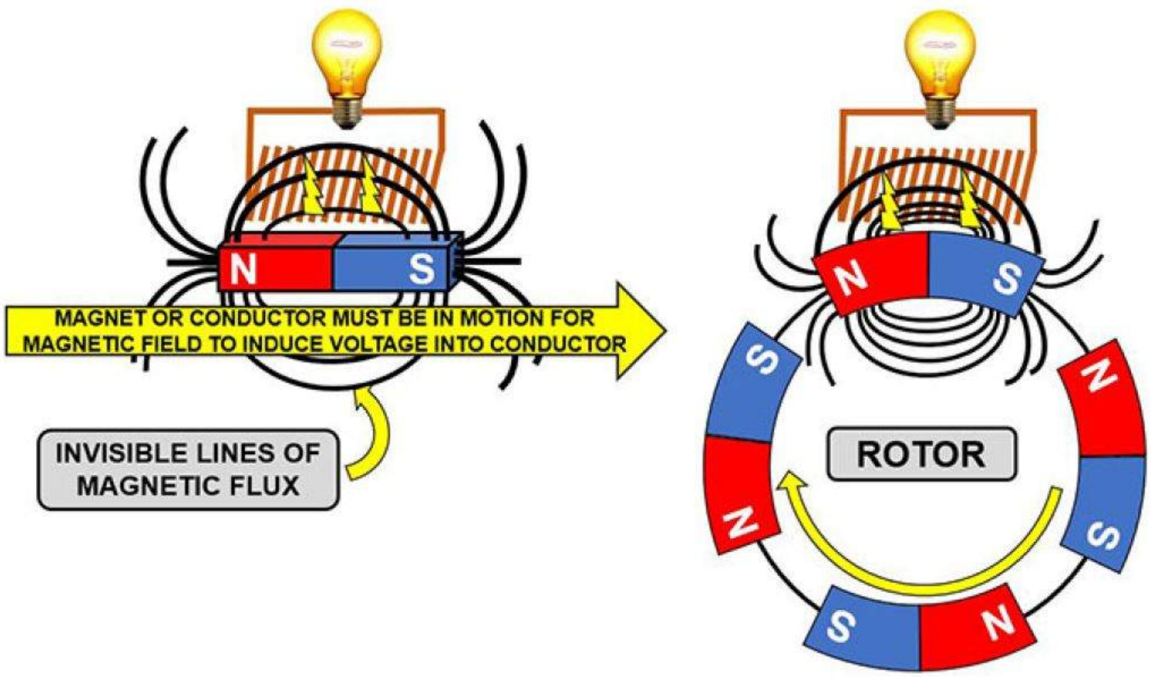


Figure 1–21. Magnetic Flux (magnetic field).

Electromagnetic Induction

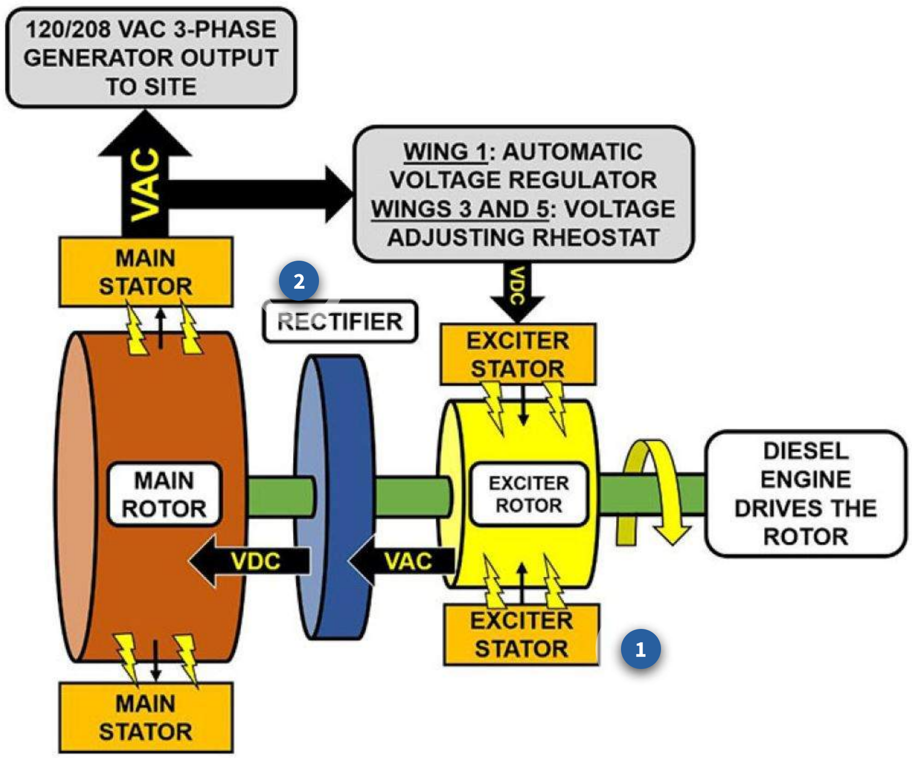
You will need to be familiar with some theory of electromagnetic induction before we get into the series of events that eventually creates the electricity. In a nutshell, an electrical current will be induced into any conductor that is passed through a changing magnetic field (fig 1–21). It makes no difference whether the magnet is moving or the conductor is moving, but the conductor must pass through the alternating magnetic fields created by the magnet's north and south poles.

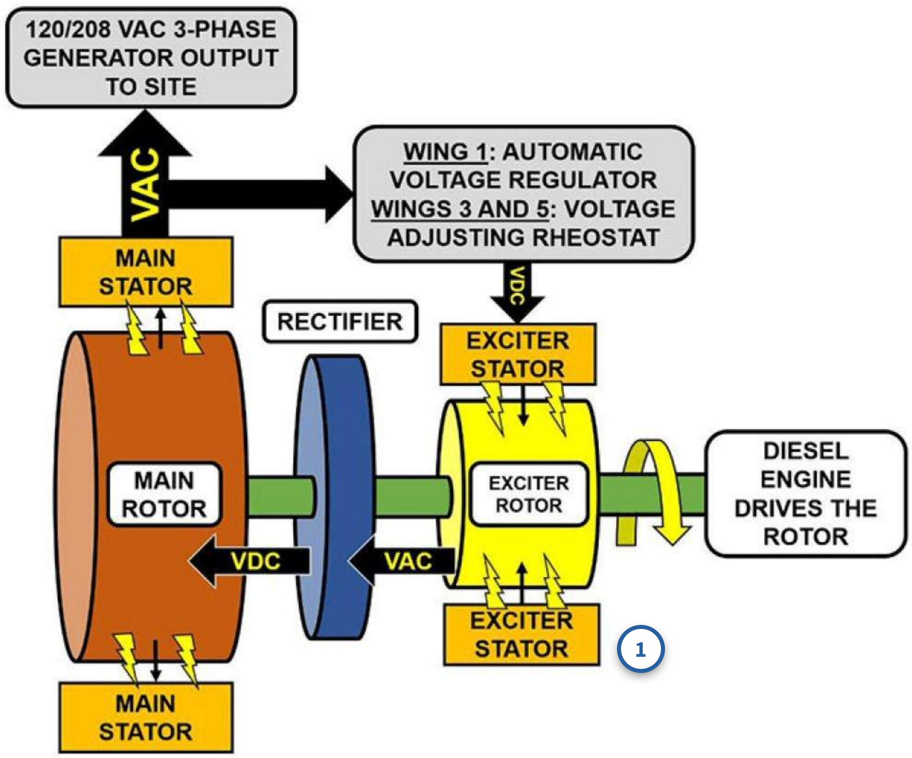
The strength of an electromagnetic field can be adjusted by changing how much current is supplied to the electromagnet. A stronger magnetic field will induce more current, and a weaker magnetic field will induce less current. Electromagnets are used throughout the generator, and the strength of these electromagnets can be adjusted to change the voltage output of the generator.

Generator Operation

Refer to figure 1–22 as we discuss the operation of the generator. You have started the diesel engine, and it is running at the proper rpm. A generator consists of two major assemblies—the stationary portion called the stator, and the rotating portion called the rotor.

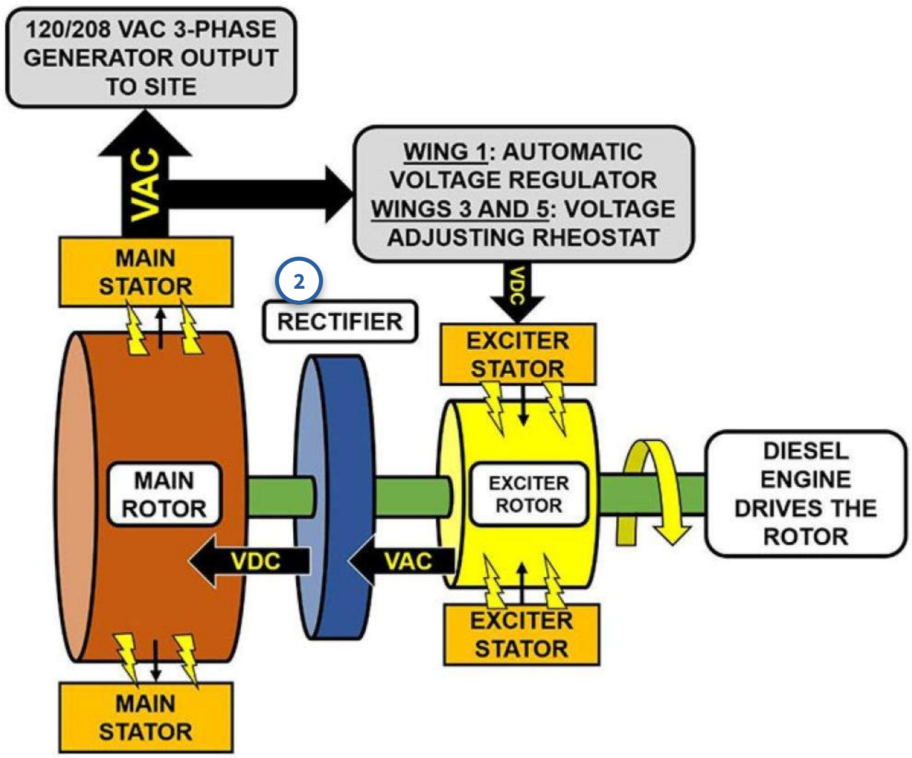
The exciter rotor, rectifier, and main rotor are all connected mechanically and are rotated by the crankshaft of the diesel engine. Click on each number before moving forward in the lesson.


120/208 VAC 3-PHASE GENERATOR OUTPUT TO SITE
VAC
WING 1: AUTOMATIC VOLTAGE REGULATOR WINGS 3 AND 5: VOLTAGE ADJUSTING RHEOSTAT
MAIN STATOR
2
RECTIFIER
VDC
EXCITER STATOR
MAIN ROTOR
EXCITER ROTOR
DIESEL ENGINE DRIVES THE ROTOR
VDC
VAC
EXCITER STATOR
1
MAIN STATOR



Exciter

The exciter supplies the AC voltage needed in order for the main rotor to produce a desired generator final output voltage. Less excitation will cause the generator to produce less voltage, and more excitation will have the opposite effect. The strength of the electromagnet inside the exciter stator is determined by the amount of power supplied to it by the automatic voltage regulator on the Wing 1 DEU, or the voltage-adjusting rheostat on the Wings 3 and 5 DEU. The exciter stator generates the magnetic field that induces AC voltage into the conductors on the exciter rotor.



Rectifier

The AC voltage from the exciter is sent to the rectifier, where diodes convert the AC voltage to DC voltage. This DC voltage then energizes the electromagnets along the circumference of the main rotor. The electromagnets on the spinning main rotor induce AC voltage into the stationary conductors on the main stator. The power produced by the main stator is the generator's final output voltage, which is sent through conductors to the ASU or PTS, and then distributed to site loads.

Complete the content above before moving on.

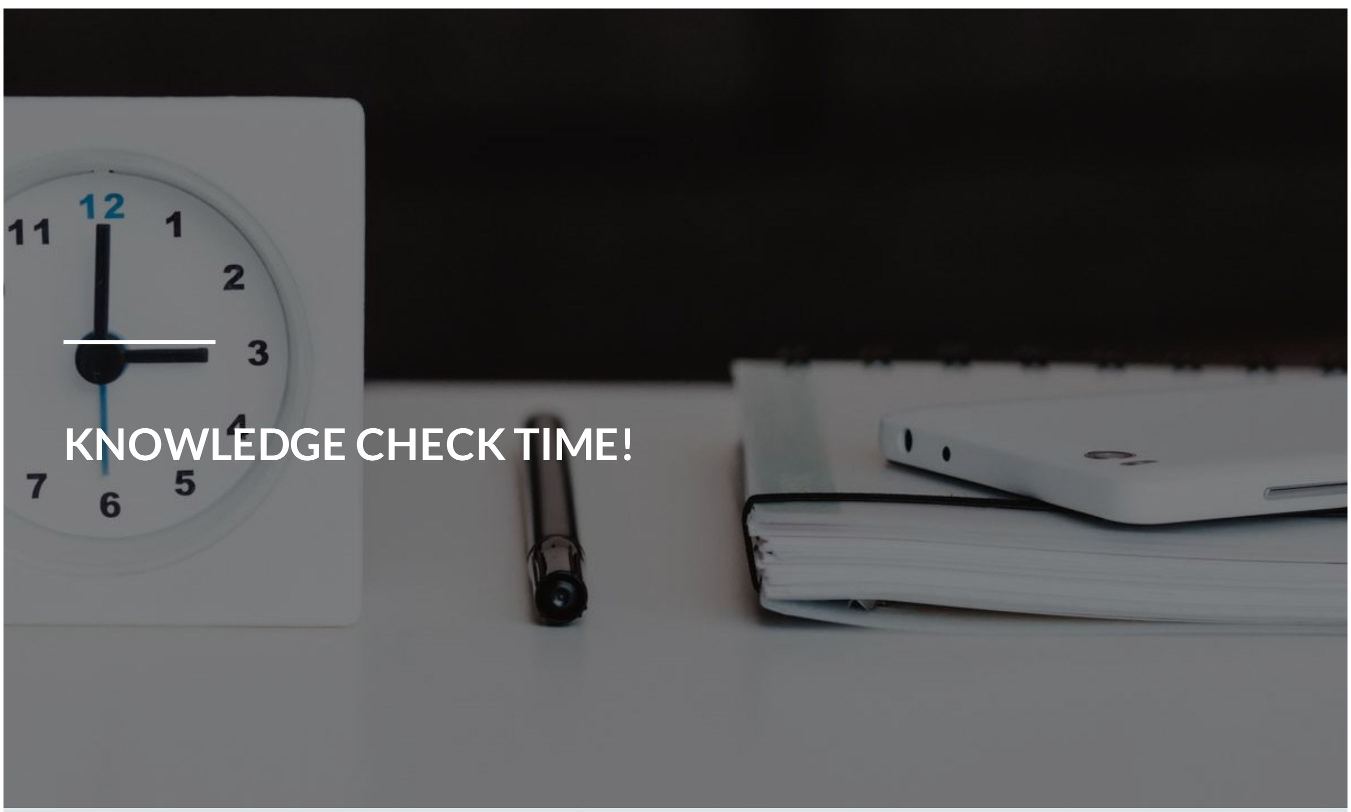
Voltage Regulator

The voltage regulator is the component that allows you to modify the final output voltage of the generator. Wing 1 DEUs utilize an automatic voltage regulator that is fed by the output of the main stator, and as you might guess, automatically adjusts the generator voltage output by sending more or less voltage to the exciter. If the voltage output of a Wing 3 or 5 DEU is not correct, a technician must manually adjust the voltage-adjusting rheostat. Regardless of which wing you are at, the voltage regulator causes the exciter to increase or reduce the amount of voltage that is fed to the electromagnets on the main rotor.

Changing Generator Output Frequency

The output voltage of the generator can be changed by changing the amount of voltage that flows from the exciter to the main rotor. What if you need to change the frequency output of the generator? This is accomplished by increasing or decreasing the rpm of the engine. If the engine is rotating faster, the electromagnets in the main rotor will pass the conductors on the main stator faster, which will cause an increase in frequency with no change in voltage output. The opposite will be true when the engine is rotating slower. It should be noted, however, that there is a mechanical malfunction with either the stator or the rotor if the generator's output frequency is substantially higher or lower than it should be with the engine running at 1,800 rpm.

The diesel engine's sole purpose is to turn the generator to create electricity. This standby power source is vitally important because our MAFs and LFs must still be able to accomplish their missions even when no power from the commercial power company is available. Some of the engines you perform maintenance on provide power so that support vehicles can accomplish their missions without the need for external facility power.



You have reached the self-test questions. Answer each question before moving forward to the next set of questions. For the fill-in the

blank questions, you will need to add (.) periods to the end of the sentences.

Click here to answer the self-test questions pertaining to generators, exciters, and voltage regulators.

1. What is electromagnetic induction?

Type your answer here

SUBMIT

2. How is the strength of an electromagnetic field changed?

Type your answer here

SUBMIT

20

3. What parts of a generator are rotated by the crankshaft of the diesel engine?

Type your answer here

SUBMIT

21

4. What is the purpose of a generator's exciter?

Type your answer here

SUBMIT

22

5. How is the power produced by a generator's main stator used?

Type your answer here

SUBMIT

23

6. How is the frequency output of a generator changed?

Type your answer here

SUBMIT

This completes Lesson 1. You can find the answers to the self-test questions in the Module 3 table of content.

Lesson 2. Power Systems

Main Points

1. Minuteman Power Processor and Automatic Switching Unit
    a. Minuteman power processor function and operation
    b. Automatic switching unit function and operation
2. Launch Facility and Missile Alert Facility Power Distribution Systems
    a. Launch facility commercial and standby power contactor function and operation
    b. Missile alert facility and launch facility power distribution systems

Performing maintenance on the power generation and distribution system is a fundamental task that all facilities maintenance technicians will spend a considerable amount of time doing. This lesson covers the power systems at the MAF and LF and ends with a discussion on the MPP, which is the heart of the power distribution

system. A firm understanding of these lessons will solidify your knowledge of the power system and make you more effective at maintaining and troubleshooting it.

Click here to begin Lesson 2 of Module 3.

Minuteman Power Processor and Automatic Switching Unit

The previous unit focused on the DEU, and we covered the components and operation of an internal combustion engine. We covered how the generator creates the electricity the MAF or LF use when no commercial power is available. Power comes in on power lines from the commercial power company or the DEU generates it. This section adds to your knowledge by concentrating on how these two power sources are monitored for quality and then are sent to the power distribution system.

Minuteman Power Processor Function and Operation

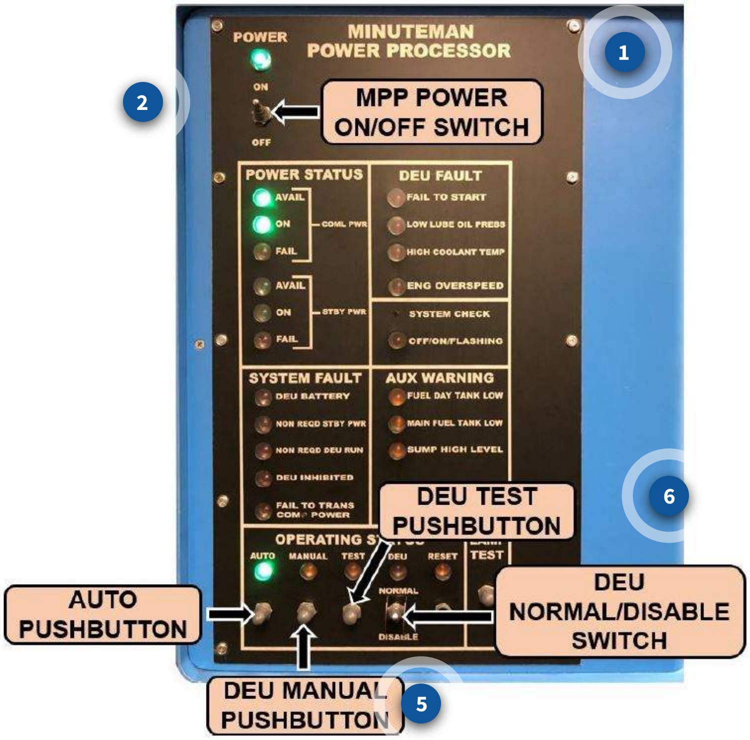
Recall from your technical training that electricity is supplied to the MAF or LF from the commercial power company over power lines or is generated on-site by the DEU, where it then waits to be let through to the power distribution system by the MPP. This lesson focuses on the basic functions and operation of the MPP. The MPP is a low-powered computer installed at each MAF and LF, and it serves the following major purposes:

- Monitors commercial and standby power for specific quality standards, selects which power source is connected to the site, and immediately disconnects power if it falls outside the quality standards.
- Starts the DEU, monitors its running parameters, and stops the DEU when the power that it supplies is no longer needed or it is malfunctioning.

Refer to figure 2–1 as we look at the parts of the MPP.

Click on each number to learn more about the Minuteman power

processor.



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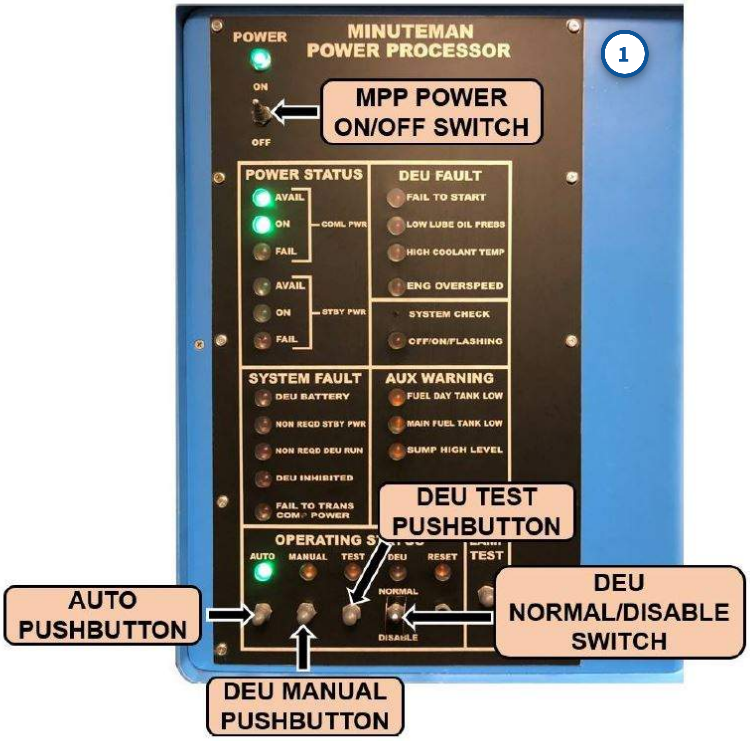
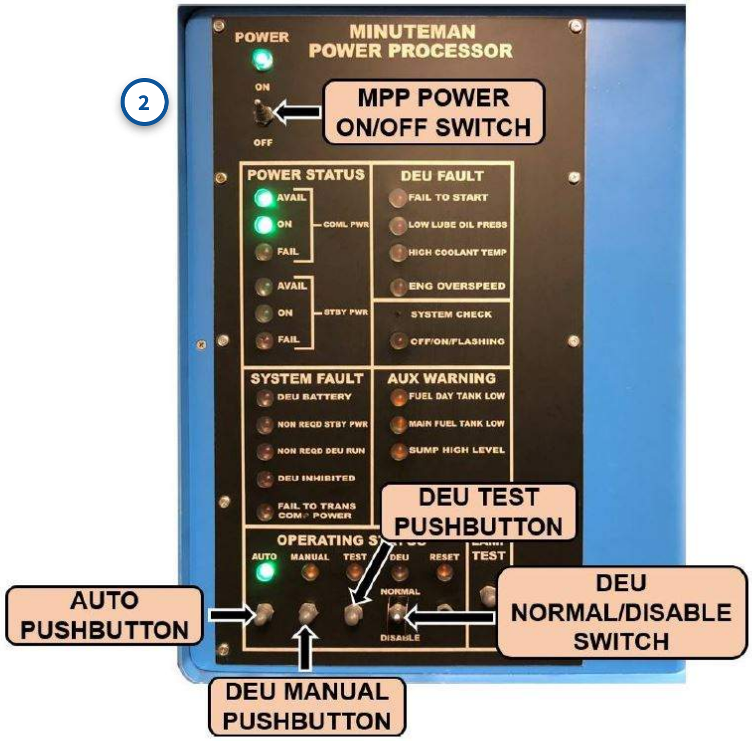


Light Emitting Diode Indicators

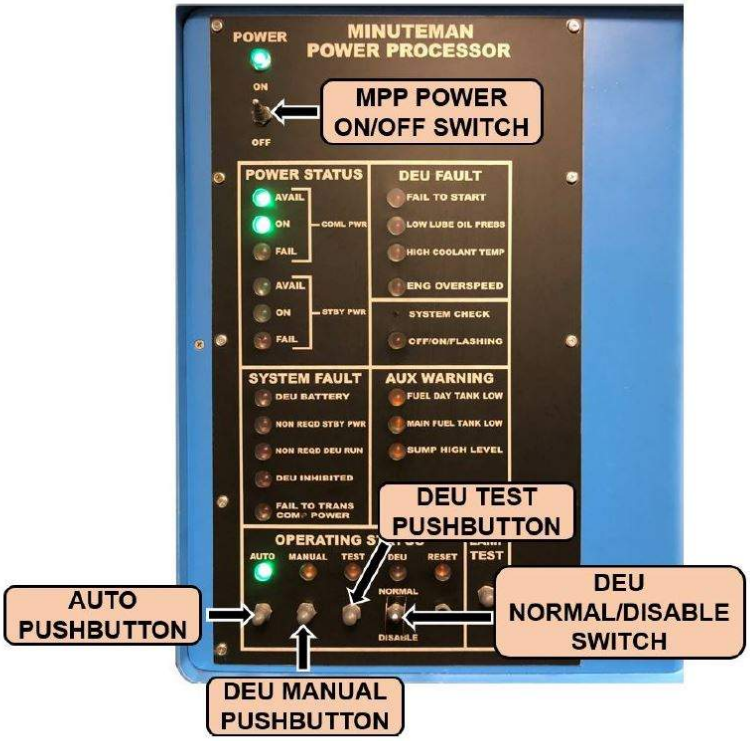
The front face of the MPP has 26 light emitting diode (LED) indicator lights. The function of each is labeled near it in white letters. The purpose of the LEDs is to provide a visual indicator of the status of commercial and/or standby power and any faults that may be present. For example, the LEDs on the MPP in figure 2–1 indicate the MPP is on, in automatic mode, and commercial power is available and connected to the MAF or LF.



Power ON/OFF Switch

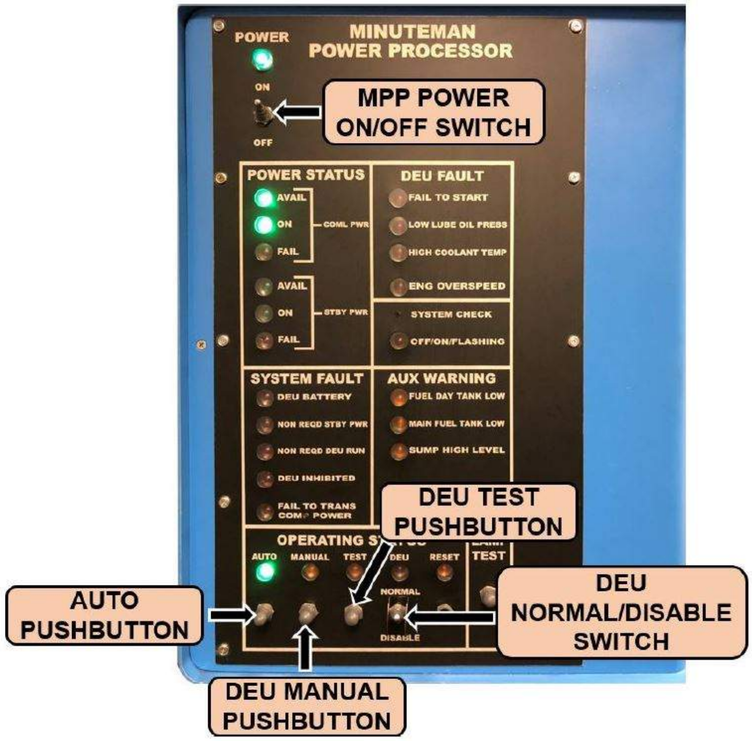
The power ON/OFF switch is located on the top-left of the front face of the MPP, directly under the POWER indicator light. The MPP is energized when the switch is in the ON or upward position, and is deenergized when the switch is in the OFF or downward position.

3



AUTO Pushbutton

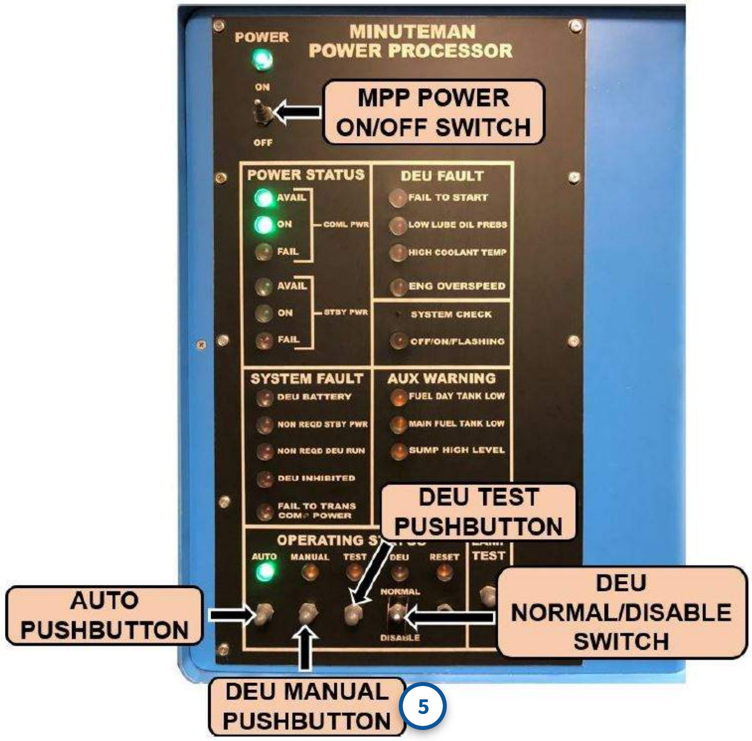
This AUTO pushbutton is located at the bottom-left of the front face of the MPP, directly under the AUTO indicator light. The purpose of this pushbutton is to return the MPP to automatic mode from any other mode that it may currently be in.



4

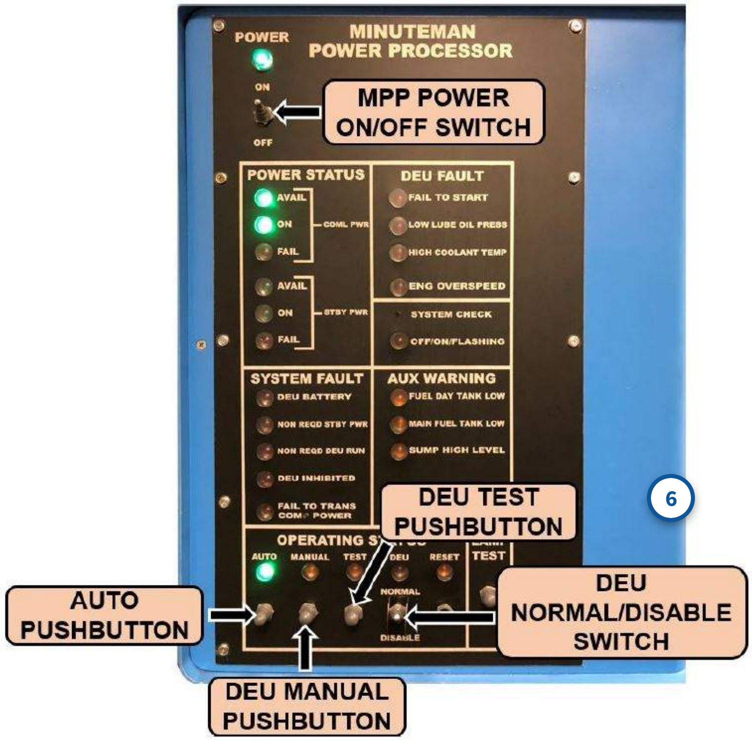
Diesel Electric Unit NORMAL/DISABLE Switch

This switch has two positions––upward for normal and downward for disable. The switch is set to NORMAL on a regular, day-to-day basis. However, if there is a problem with the DEU or you are performing maintenance on it, the DEU should be DISABLED so that it cannot be started manually or automatically. DEU manual and test modes cannot be entered if this switch is set to DISABLE. Moving the switch to DISABLE when the DEU is already running will cause it to shut down immediately.



Diesel Electric Unit MANUAL Pushbutton

The DEU MANUAL pushbutton is located on the bottom of the face of the MPP, directly under the MANUAL indicator LED. Pressing this pushbutton will cause the DEU to start in manual mode, meaning it will be running without a load placed on it, and the site will still be operating on commercial power. Pressing this button will have no effect if the DEU normal/disable switch is set to DISABLE. Manual mode is especially useful for running the DEU so that you can troubleshoot it.



Diesel Electric Unit TEST Pushbutton

This pushbutton is used specifically to "test" if the DEU is in proper operating condition and capable of providing electricity to the MAF or LF in the event that commercial power is not available. Pressing this pushbutton will cause the MPP to disconnect the site from commercial power, start the DEU, and then operate the site off the power being supplied by the DEU. Pressing this button will have no effect if the DEU NORMAL/DISABLE switch is set to DISABLE.

Complete the content above before moving on.

Lamp TEST Pushbutton

This pushbutton is located at the bottom-right of the face of the MPP. Pressing this button will cause each of the LED indicators on the face of the MPP to illuminate one at a time so that you can verify that each is working correctly.

Jacks J1 and J2

The MPP must have hardware installed so that it can communicate with the electronics on the MAF or LF. This is accomplished through jacks J1 and J2 (not pictured) which are located on the right side of the MPP, toward the top. You will disconnect plugs P1 and P2 from the corresponding jacks on the MPP any time your technical order directs you to remove a faulty MPP and replace it with a working unit.

Shock Mounts

The MPP is mounted inside the ASU using four shock mounts (not pictured). One shock mount is located on each of the four corners of the rear of the MPP. The mounts feature a rubberized portion that allows the MPP to move slightly in the event that any seismic activity hits the site.

The MPP is the sole authority on selecting which power source (electricity from either the power company or the DEU) will supply electricity to the MAF or LF. Commercial power is the preferred source, and the MPP will keep this connected at all times as long as it meets the MPP's power standards. Regardless of whether power is supplied by the commercial power company or the DEU, it must meet the following basic parameters in order for the MPP to allow it to flow to the various electrical loads at the MAF or LF:

- Proper voltage
- Proper frequency
- Proper phase sequence (A, B, C)

A typical residential home does not have any standards for incoming electricity, and whatever the local power company sends out is what will flow directly to your appliances. This is not the case with MAFs and LFs in the missile complex. Since millions of dollars' worth of damage and many lost man hours can result from poor power flowing to the electronic components at an MAF or LF, the MPP is not only the gatekeeper for connecting power in the first place, but it will also instantaneously disconnect power if it does not continue to meet strict requirements.

If the power being supplied by the commercial power company does not meet standards, the MPP will disconnect it and start the DEU. The MPP will then monitor the power that is being generated by the DEU to ensure it meets the standards. If DEU power is within tolerance, the

MPP will allow the electricity from the DEU to flow through to the various components on site that require it.

If commercial or standby power are both out of tolerance, neither source will be connected to the site. The site will be dark and quiet for the most part, and equipment required to launch the missile will run off battery power supplied by emergency storage batteries set in the launch control center (LCC) at the MAF or the launcher equipment room (LER) at the LF. The site will not be left in this powerless condition for very long because a maintenance team will be dispatched immediately to troubleshoot the cause of both the commercial power and DEU failures. Like other computers, the MPP needs power to operate. If both commercial and DEU power are not within acceptable limits, then where does the MPP get its power? The answer to that is battery power.

It is understood the MPP could not operate off either commercial or DEU power because those two sources are not necessarily always available on site. Different missile wings have different MPP battery configurations, but the MPP requires 24 VDC to operate, regardless of which wing you are at.

In addition to monitoring the quality of the power being generated by the DEU, the MPP will shut the engine down immediately if it detects that the coolant temperature is too high or the oil pressure is too low. The MPP does this because both of these conditions could cause damage to the engine.

Complete the content above before moving on.

Automatic Switching Unit Function and Operation

Since you have already learned about the DEU and the MPP, the next logical step in your journey through the power generation and distribution system is the ASU. This lesson will focus on the major components housed inside the ASU.

The ASU houses the MPP and power transfer contactors, and its primary purpose is to perform power transfer functions (fig 2–2). It houses terminal boards, wiring, fuses, test points, relays, contactors, many other items, and is where the MPP, MPP batteries, battery charger (Wings 3 and 5 only), and remote start unit (RSU) are located.

The ASU you learned about during your technical training at Vandenberg space force base (SFB) is the type found at Wings 3 and 5. The ASU at Wing 1 sites is slightly smaller but has the same outward-swinging doors and MPP access door.

NOTE: At a Wing 1 MAF only, the ASU is called the power transfer switch or PTS cabinet. The PTS cabinet will not be discussed in detail because it houses the same components and functions the same way that an ASU does.

Since the main purpose of the MPP is to monitor and transfer between commercial and standby power sources, it makes sense the large contactors that allow power to be sent to the distribution system are located in this same cabinet.

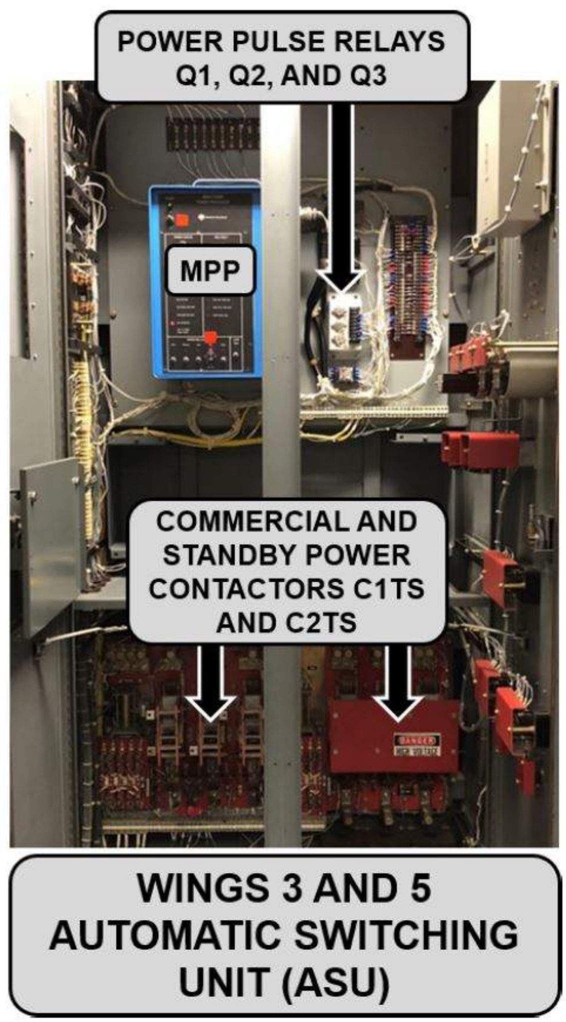


Figure 2–2. Automatic Switching Unit.

Automatic Switching Unit Batteries and Battery Charger (Wing 1)

The Wing 1 ASU batteries and battery charger are located outside of the ASU. The four yellow 6-VDC sealed lead-acid batteries previously used as the DEU starting batteries were relocated to the floor next to the right side of the ASU during the DEU replacement program, and now serve as the MPP batteries. The four 6-VDC batteries are wired in series to meet the 24-VDC power requirement of the MPP. The battery charger that formerly charged the DEU starting batteries is still used but it has been mounted to the right (external) side of the ASU.

Minuteman Power Processor Batteries and Battery Charger (Wings 3 and 5)

Two small, grey 12-VDC batteries wired in series supply a total of 24-VDC to the MPP. The batteries are maintained at a full charge by a battery charger that is powered by 120-volts alternating current (VAC) power whenever commercial or standby power is connected. Both the batteries and the charger are located inside of the ASU and held in place by retainers.

Commercial and Standby Power Contactors

The power contactors are the devices the MPP commands to allow power to flow or be removed from the power distribution system. For now, all you need to know are their names—you will focus on how they actually operate in another volume.

The Wing 1 MAF and LF contactors have different names than their Wings 3 and 5 counterparts, so they will be discussed separately. It may help you to remember that no matter if you are at the MAF or LF, the power contactor for commercial power has the number 1 in its name, and the power contactor for standby power has the number 2 in its name. The MAF and LF power contactors at all three wings are located in the lower portion of the ASU (or PTS cabinet).

Listed below are the MAF and LF power contactors at all three wings. Click on the icon in the lower right to flip the card to learn the location of each power contactor.

Wing 1 Missile Alert Facility Power Contactors

The power contactors in the Wing 1 MAF PTS cabinet are designated transfer switch (TS) 1 for commercial power and TS2 for standby power.

Wing 1 Launch Facility Power Contactors

The power contactors in the Wing 1 LF ASU are simply designated K1 for commercial power and K2 for standby power.

Wings 3 and 5 Launch Facility and Missile Alert Facility Power Contactors

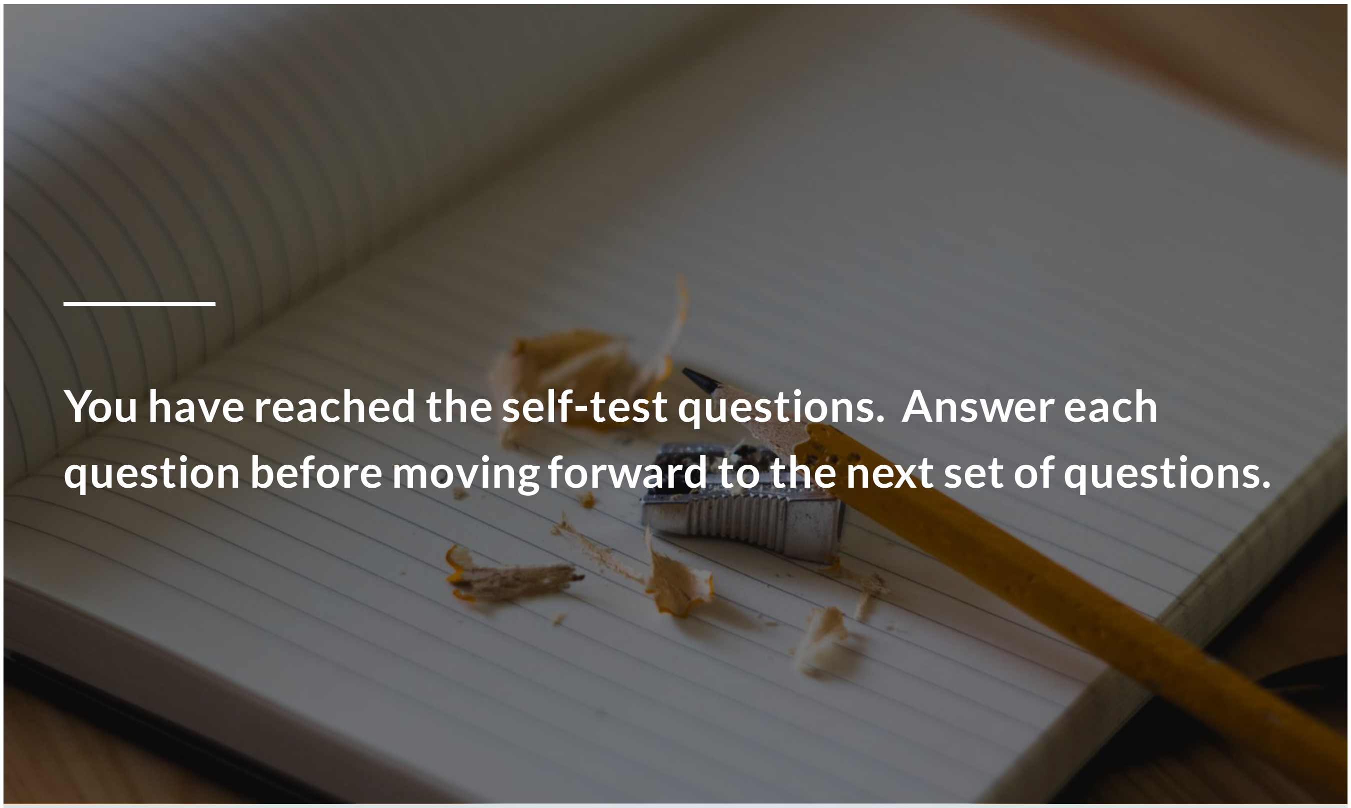
The power contactors at Wings 3 and 5 MAF and LF are designated contactor 1 transfer switch (C1TS) for commercial power, and contactor 2 transfer switch (C2TS) for standby power.

Figure 2–3. Remote Start Unit.

Remote Start Unit

The RSU located inside of the ASU, provides the ability to use a remote signal to start the LF DEU (fig 2–3). The MCC does this by sending a 19 ±5 second telephone ring tone over the support information network (SIN) line. Sending another 19 ±5 second tone will cause the LF to transfer from standby power back to commercial power.

Complete the content above before moving on.



KNOWLEDGE CHECK TIME!

For the fill-in the blank questions, you will need to add (.) periods to the end of the sentences.

Click here to answer the self-test questions pertaining to the Minuteman power processor function and operation.

1. What is the purpose of the LED indicators on the face of the MPP?

Type your answer here

SUBMIT

1

2. Why is running the DEU in manual mode especially useful?

Type your answer here

SUBMIT

2

3. What actions does the MPP take if commercial power no longer meets quality standards?

Type your answer here

SUBMIT

Complete the content above before moving on.

Click here to answer the self-test questions pertaining to the automatic switching unit function and operation.

1. What is the ASU at a Wing 1 MAF called?

Type your answer here

SUBMIT

3

2. What are the designators for the commercial and standby power contactors in the Wing 1 LF ASU?

Type your answer here

SUBMIT

4

3. What line does the MCC send the 19 ±5 second telephone ring tone over to start the DEU remotely at the LF?

Type your answer here

SUBMIT

Complete the content above before moving on.

Launch Facility and Missile Alert Facility Power Distribution Systems

This section focuses on the events that occur after the MPP has issued the command to connect commercial or standby power. It will also cover how and where the power is distributed throughout the MAF and LF power distribution systems.

Launch Facility Commercial and Standby Power Contactor Function and Operation

Up to this point you have read about the two types of primary power—commercial and standby—and you have a basic understanding of how the MPP monitors power quality and decides which source of power is connected to the loads at the MAF or LF. This lesson will further your knowledge of the LF power distribution system by explaining the major functions and operations that occur after the MPP's microprocessor has made the decision to let power flow through.

You might believe that the MPP is a one stop shop that both monitors power quality and then allows it to pass through—however, commercial and DEU power do not flow directly through the MPP. Small wires tap off the main commercial and standby power sources and are routed through jacks J1 and J2, which are connected to plugs P1 and P2 on the MPP. In other words, the MPP only gets a 'sample' of the incoming power. If this sample meets the standards, the MPP sends a signal out through other components within the system, and power is connected to the site eventually. Let's discuss the basics of those major components now.

Launch Facility Commercial and Standby Power Contactor Function and Operation

How The Minuteman Power Processor Sends Primary Power Connect/disconnect Commands

To make this easier to understand, imagine yourself in a formation that is preparing to march somewhere. The Airman issuing the flight commands shouts *Forward, Harch!*, and your flight begins to march. In order to emphasize a point, pay attention to the fact that the Airman does not continue to command *Forward, Harch!* time after time—he only says it once. The MPP operates in the same way when it sends the command to connect or disconnect commercial or standby power—it sends a brief, one-time pulse. If you had a multimeter connected to that circuit at the instant that the MPP sent the command pulse, you would only see a very brief blip on the meter screen. Let's learn about the process behind connecting commercial power.

Launch Facility Commercial and Standby Power Contactor Function and Operation

How The Minuteman Power Processor Connects Commercial Power

At this point, the MPP has already monitored the incoming commercial power for proper quality, and has made the decision to allow it to pass through into the power distribution system. The MPP sends a brief pulse directly to COMMERCIAL POWER ON relay K3 on a Wing 1 site, or COMMERCIAL POWER ON transistor Q3 on a Wing 3 or 5 site. Relay K3 and transistor Q3 both serve the same function, which is to relay the POWER ON pulse from the MPP to the power contactor. However, this happens a bit differently depending on which wing you are at.

How The Minuteman Power Processor Connects Commercial Power

Commercial Power ON Pulse Relay K3 (Wing 1)

The following is a simplified chain of events that occurs when the MPP chooses to allow commercial power to flow to the site:

- The MPP sends a brief 24-VDC pulse that flows to and energizes the coil of relay K3.
- A set of contacts inside of relay K3 close to allow 120 VAC to flow to the coil of commercial power contactor K1.
- The three contacts (one for each phase of power) inside of power contactor K1 close; this is the instant when commercial power is allowed to flow through to the site.

It is important to note that the coil of contactor K1 requires a constant supply of 120 VAC in order to keep commercial power connected to the site. This is important because it contrasts the fact that the commercial power contactor C1TS on a Wing 3 or 5 site only needs a brief pulse to cause it to reposition.

At this point in the Wing 1 system, a set of auxiliary contacts open on commercial power contactor K1 that makes it impossible for power to flow to the coil of standby power contactor K2. This is why both commercial and standby power cannot be connected at the same time. Both can be available (e.g., commercial power can be coming in and the DEU can be running) but only one of these sources can actually be connected to the site at any given time.

How The Minuteman Power Processor Connects Commercial Power

Commercial Power ON Pulse Transistor Q3 (Wings 3 and 5)

Again, the following list is a simplified chain of events that occurs once the MPP chooses to allow commercial power to flow to the power distribution system:

- The MPP sends a brief 24-VDC pulse that biases the base of transistor Q3.
- While transistor Q3's base is biased, a pulse of 24 VDC flows from the collector of transistor Q3 to its emitter.
- The 24-VDC pulse supplied from the emitter of transistor Q3 flows to and energizes the coil of commercial power contactor C1TS.
- The three contacts (one for each phase of power) of commercial power contactor C1TS close, allowing commercial power to flow through to the site.

At this point in the Wings 3 and 5 system, a set of auxiliary contacts open so that power cannot physically flow to the coil standby power contactor C2TS, and this same process happens on Wing 1 sites. Power cannot flow to the opposite contactor in order to prevent both commercial and standby power from being connected at the same time.

Now you know the fundamental difference between connecting commercial power at the three different wings. Power contactors on Wing 1 sites need a constant source of electricity in order to remain energized. Power contactors on Wings 3 and 5 sites only need a pulse in order to reposition. This means that the contactor will need another pulse in order to reposition again.

Complete the content above before moving on.

How the Minuteman Power Processor Connects Standby (DEU) Power

The same processes are used to connect standby power to the site, so we will not be taking such an in depth look at them.

Standby Power ON Pulse Relay K4 (Wing 1)

The MPP sends a 24-VDC pulse to relay K4, which in turn allows 120 VAC to flow to standby power contactor K2. Standby power will flow through to the site as long as contactor K2 remains energized. Auxiliary contacts on contactor K2 open to prevent power from ever flowing to contactor K1.

Standby Power ON Pulse Transistor Q1 (Wings 3 and 5)

In this scenario, the MPP again sends a 24-VDC pulse, but this time it is sent to the standby power on pulse transistor Q1. Twenty-four VDC then flows from the collector to the emitter of transistor Q1 and then to the standby power contactor C2TS. Contactor C2TS only needs a single pulse in order to reposition, and now standby power is connected to the site. A set of contacts opens so that commercial power contactor C1TS cannot receive a pulse.

You can see that the pattern is exactly the same for connecting either commercial or standby power, with the exception that the MPP sends the 24-VDC pulse to a different relay (Wing 1) or transistor (Wings 3 and 5). Lastly, let's cover how the MPP disconnects commercial or standby power from the site.

Complete the content above before moving on.

How the Minuteman Power Processor Disconnects Power From Site

If you think about it, the MPP must disconnect standby power from the site in order to connect commercial power, and the opposite is true if the MPP wants to switch from commercial to standby. It makes no sense to have two sources of power connected at the same time, and you have already read about the interlocks that are built into the power system at all wings to prevent this from occurring.

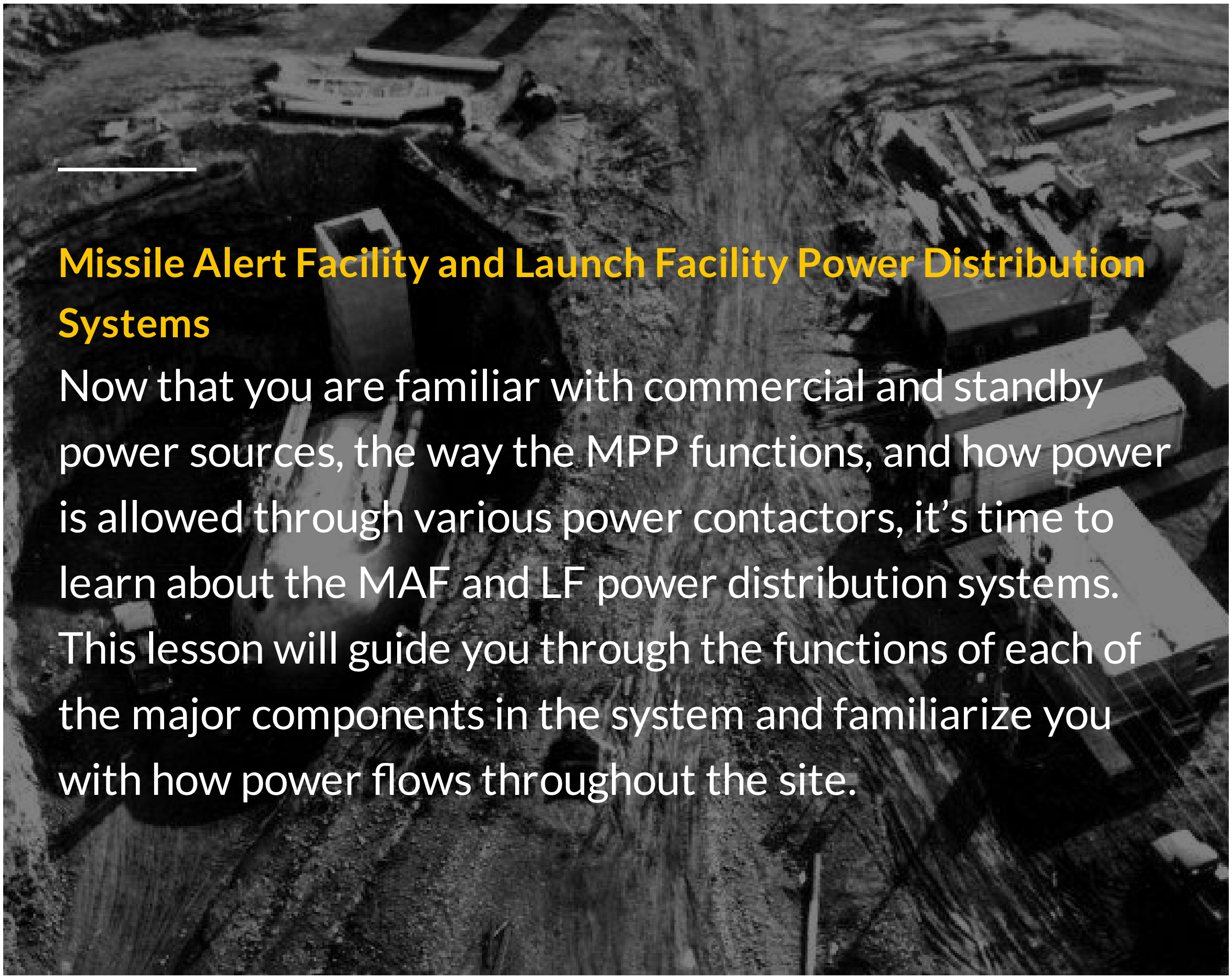
Commercial/standby Power OFF Pulse Relay K5 (Wing 1)

Relay K5 is used to disconnect whichever power source (commercial or standby) is currently connected to the site. The MPP sends a 24-VDC pulse to relay K5, and in turn relay K5 removes power from the circuit that is sending the constant supply of 120 VAC to either contactor K1 or contactor K2. Once the coil of either power contactor no longer has a supply of electricity, the contacts open up and power can no longer flow through to the site.

Commercial/standby Power OFF Pulse Transistor Q2 (Wings 3 and 5)

Just like relay K5 in the Wing 1 system, transistor Q2 is used to disconnect whichever source of power is currently connected to the site. You will remember that the commercial and standby power contactors on a Wing 3 or 5 site (C1TS and C2TS, respectively) only change position one time for each pulse they receive. That being said, the MPP sends a 24-VDC pulse to transistor Q2, which in turn sends a 24-VDC pulse from its emitter. Remember from above that the pulse from Q2 can only physically flow to whichever contactor is currently in use. Therefore, if commercial power is online, it gets disconnected, and if standby power in online, it gets disconnected. The MPP decides when to connect power, but remember that the power contactors that open and close to control the flow of power are separate physical components.

Complete the content above before moving on.



Missile Alert Facility and Launch Facility Power Distribution Systems

Now that you are familiar with commercial and standby power sources, the way the MPP functions, and how power is allowed through various power contactors, it's time to learn about the MAF and LF power distribution systems. This lesson will guide you through the functions of each of the major components in the system and familiarize you with how power flows throughout the site.

Missile Alert Facility Power Distribution System

The MAF power distribution systems at all wings perform the same two major functions:

- Distributes commercial AC power to the electrical equipment in the launch control support building (LCSB) (Wing 1), launch control equipment building (LCEB) (Wings 3 and 5), tunnel junction, and LCC.
- Automatically generates and distributes standby AC power if commercial power fails.

The name of some of the major components that comprise the MAF power distribution system differs between the Wing 1 and Wings 3 and 5 MAF, but the main objective is for you to understand the functions of the different components.

Listed below are the MAF power distribution system functions of the different components.

Service Disconnect Breaker and Commercial Power Main Circuit Breaker

The service disconnect breaker at a Wing 1 MAF and the commercial power main circuit breaker at a Wing 3 or 5 MAF all serve the same purpose. They are the first entry point of commercial power into the MAF power system, and their purpose is to trip (break) the circuit if the amperage draw of the system downstream becomes too high. Usually, an amperage draw large enough to trip the facility main breaker is caused by a power fault or short where electricity is running straight to ground. These types of large amperage draws generally create a large amount of heat in a circuit, which would eventually cause wires and other conductors to melt. Replacing these components costs time and money, and this or any breaker is designed to open the circuit before any major damage occurs.

Source Region Electromagnetic Pulse Electrical Surge Arrestor

The source region electromagnetic pulse (SREMP) electrical surge arrestor (ESA) is designed to protect the electrical equipment in the facility from a large surge of power that could be caused by a lighting strike or even the electromagnetic pulse (EMP) induced into incoming power lines by a low-altitude nuclear blast.

Power Line Protection Assembly

The power line protection assembly (PLPA) has the same basic function as the SREMP ESA, which is to prevent EMP, lightning, and other high voltage or high current electrical disturbances from damaging electronic equipment in the MAF. The PLPA panel includes four large power filters—one each for A, B, and C phases of power as well as one for the neutral bus. These filters absorb voltage spikes and transients and provide a smooth output of power, much like a capacitor.

Automatic Switching Unit and Power Transfer Switch Cabinet

The PTS cabinet at a Wing 1 MAF and the ASU at a Wing 3 or 5 MAF both serve the same purpose, which was described in detail earlier in this unit. However, for the context of this lesson, the PTS cabinet and ASU send commercial or standby AC power to the launch control distribution panel A (LCDA) (Wing 1 MAF) or the launch control distribution panel S (LCDS) (Wing 3 or 5 MAF). The MPP monitors commercial and standby power and will not allow either source to flow through to the power distribution system unless operational connect limits are met.

Launch Control Distribution Panel A and Launch Control Distribution Panel S

Panel LCDA at a Wing 1 MAF and panel LCDS at a Wing 3 or 5 MAF are large panels that contain many individual circuit breakers, and they are the only panels that receive power directly from the PTS cabinet or ASU, respectively. The circuit breakers in the LCDA or LCDS distribute commercial or standby power to many other areas, panels, or individual components at the MAF.

Continue on to learn about the functions of the different components.

Buck Boost Transformer

The buck boost transformer raises the line voltage flowing from the LCDS panel to the launch control power panel A (LCPA) at a Wing 3 or 5 MAF approximately 5 to 6 volts, which compensates for voltage that is lost when power passes through various feeders and line filters.

Radio Frequency Interference Filter and Power Line Filter

The radio frequency interference (RFI) filter at a Wing 1 MAF and the power line filter at a Wing 3 or 5 MAF are the next point of filtration for power leaving the LCDA or the buck boost transformer on its way to the LCC. Any transient voltage or voltage spikes that could cause damage to critical circuitry in the LCC will be smoothed out or directed to ground.

Junction Box

The junction box (located in the LCC at all MAFs) houses three metal-oxide varistors (MOV)––one for each phase of power. The MOV absorbs large power spikes and the MOV is destroyed when this happens; however, a voltage spike stops here instead of flowing into the electrical system and causing damage to equipment.

Launch Control Distribution Panel B and Launch Control Power Panel A

Launch control distribution panel B (LCDB) at a Wing 1 MAF and LCPA at a Wing 3 or 5 MAF are located in the LCC, and their purpose is to distribute power to all loads in the LCC. They are just like panels LCDA and LCDS, and contain many circuit breakers that serve individual components. The Wing 1 MAF has some different components and follows a slightly different flow than power at a Wing 3 or 5 MAF, which makes it necessary to break each down individually.

Complete the content above before moving on.

Wing 1 Missile Alert Facility Power Flow

Now that you are familiar with the major components in the Wing 1 MAF power distribution system, use figure 2–4 to follow the power flow.

Commercial power comes in over power lines and passes through the service disconnect breaker and PLPA before arriving to the PTS cabinet, and standby (DEU) power passes through its own internal circuit breaker before it enters the PTS cabinet. Primary power (commercial or standby) passes through the PTS cabinet and into distribution panel LCDA, where it is distributed to all topside MAF loads. The Wing 1 DEU supplies power to the entire MAF, to include the topside and the LCC.

Power from panel LCDA passes through an additional RFI filter and lightning arrester in the LCC access shaft, as well as a junction box in the LCC, before reaching distribution panel LCDB. Panel LCDB distributes primary power to all LCC loads.

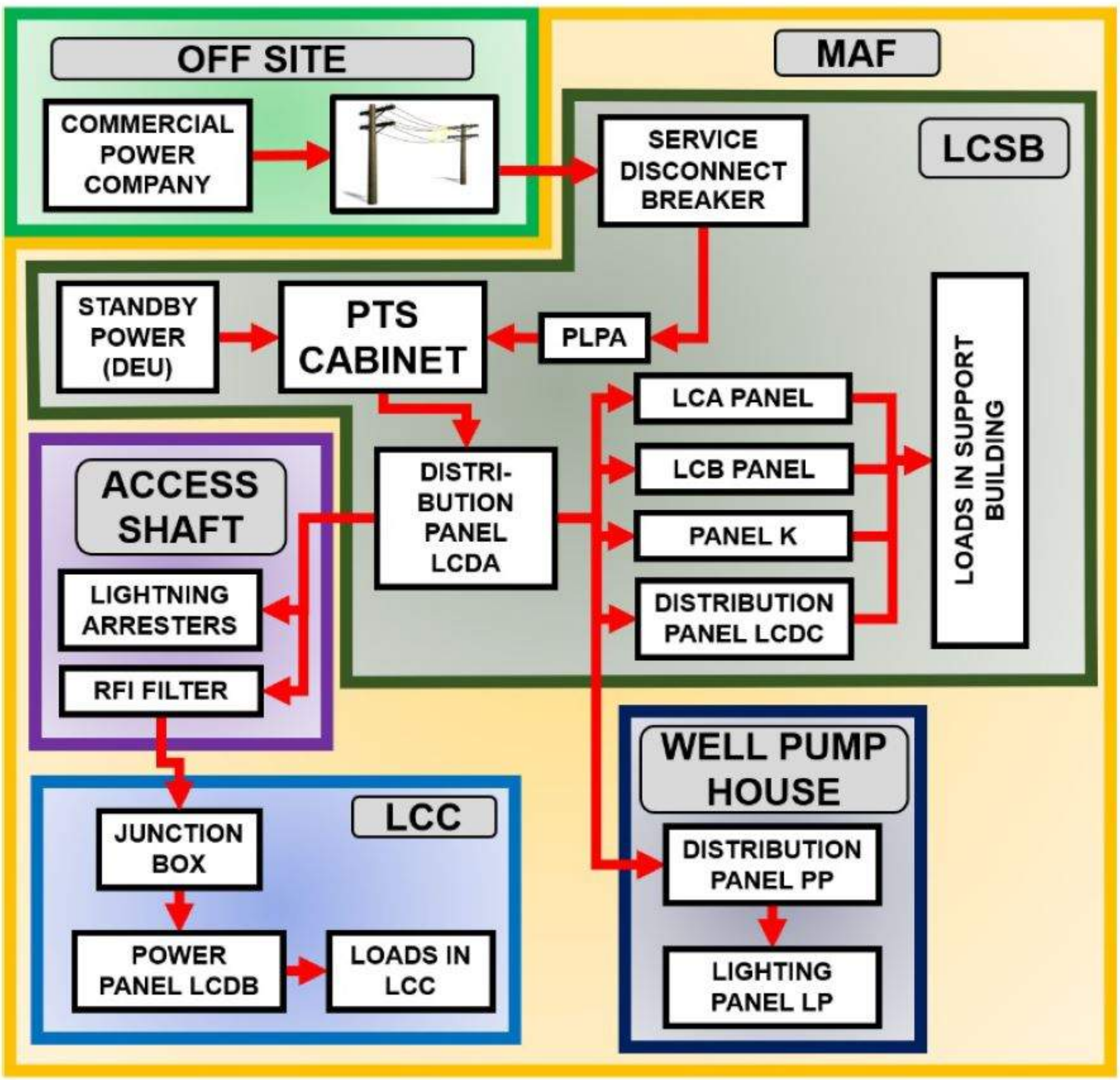


Figure 2–4. Wing 1 MAF Power Distribution Diagram.

Wings 3 and 5 Missile Alert Facility Power Flow

Now that you are familiar with the major components in the Wings 3 and 5 MAF power distribution system, use figure 2–5 to follow the power flow.

Commercial power comes in over power lines and passes through the main circuit breaker or service disconnect breaker, SREMP ESA, and PLPA before arriving to the ASU. Standby (DEU) power passes through its own internal circuit breaker before entering the ASU. Primary power (commercial or standby) passes through the ASU and into an additional circuit breaker built into distribution panel LCDS, where it is distributed to all LCEB and other below-grade loads. The DEU in the LCEB at a Wing 3 or 5 MAF does not supply power to the topside personnel areas—a separate topside generator exists for this purpose, and the MAF facility manager must start this generator manually.

Power from panel LCDS passes through an additional power line filter in the LCEB and junction box in the LCC before reaching distribution panel LCPA. Panel LCPA distributes primary power to all LCC loads.

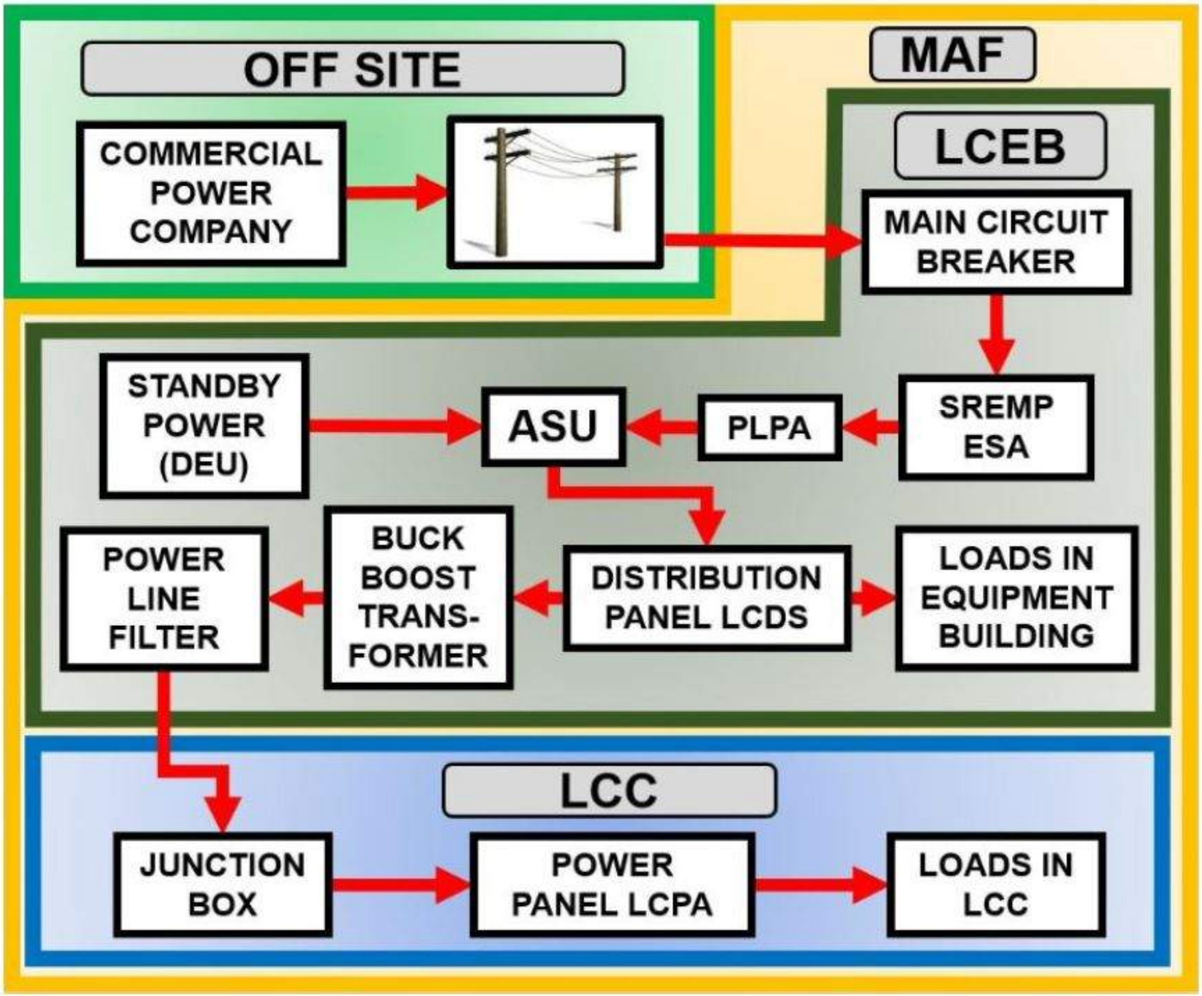


Figure 2–5. Wings 3 and 5 MAF Power Distribution Diagram.

Launch Facility Power Distribution System

The LF power distribution system performs the same two major functions at all wings:

- Distributes commercial AC power to the electrical equipment in the LCEB, tunnel junction, and LCC.
- Automatically generates and distributes standby AC power if commercial power fails.

The main circuit breaker, SREMP ESA, PLPA, ASU, and buck boost transformer in the LF power distribution system serve the same purpose and have the same names as the components in the MAF power distribution system, so they will not be explained again in order to avoid redundancies. The major power distribution panels located on the LF are the LSB launcher distribution panel A (LDA) in the support building and the launcher distribution panel B (LDB) in the LER.

Launch support building distribution panel

The LDA panel is in the support building and is where all power from the ASU is sent for distribution. It houses many circuit breakers that distribute power to all components in the support building, and contains the sole circuit breaker that sends primary power to the LDB panel in the LER.

Launcher distribution panel B

Power coming from the LDA panel in the support building flows through a primary power filter in the LER and then enters the LDB panel. The LDB panel is the sole source of primary power for the LER and this is where you will find the circuit breakers for equipment that 2M0X3 technicians commonly

Complete the content above before moving on.

Launch Facility Power Flow

Let's use figure 2–6 to follow the flow of power through the LF power distribution system.

Commercial power comes in over power lines and passes through the main circuit breaker, SREMP ESA, and PLPA before arriving at the ASU. Standby (DEU) power passes through its own internal circuit breaker before entering the ASU. Primary power (commercial or standby) passes through the ASU and into distribution panel LDA, where it is distributed to all support-building loads.

Power from panel LDA passes through the buck boost transformer, enters the LER, and then passes through the primary power filter before entering distribution panel LDB. Panel LDB distributes primary power to all of the electrical loads inside of the LER.

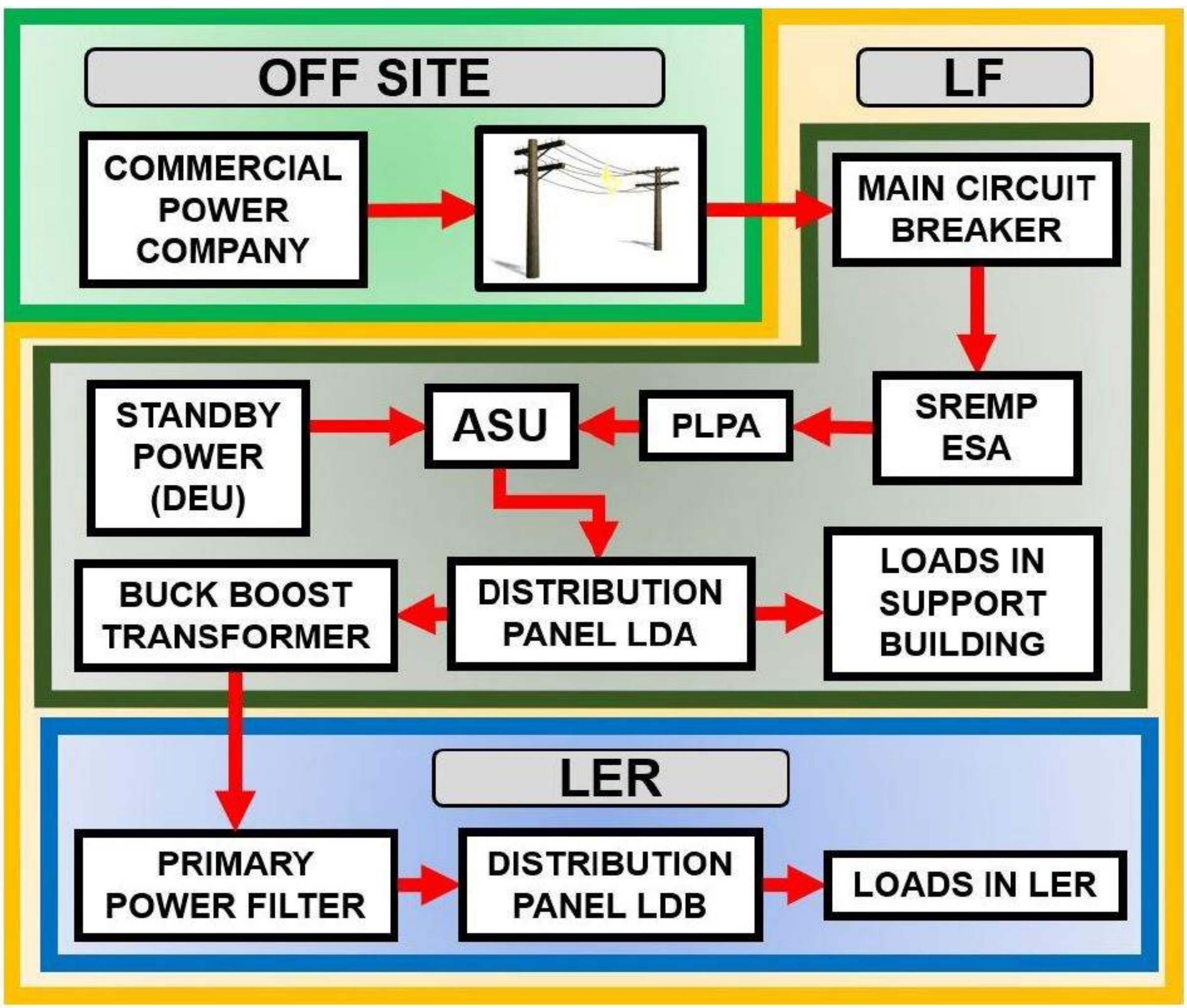
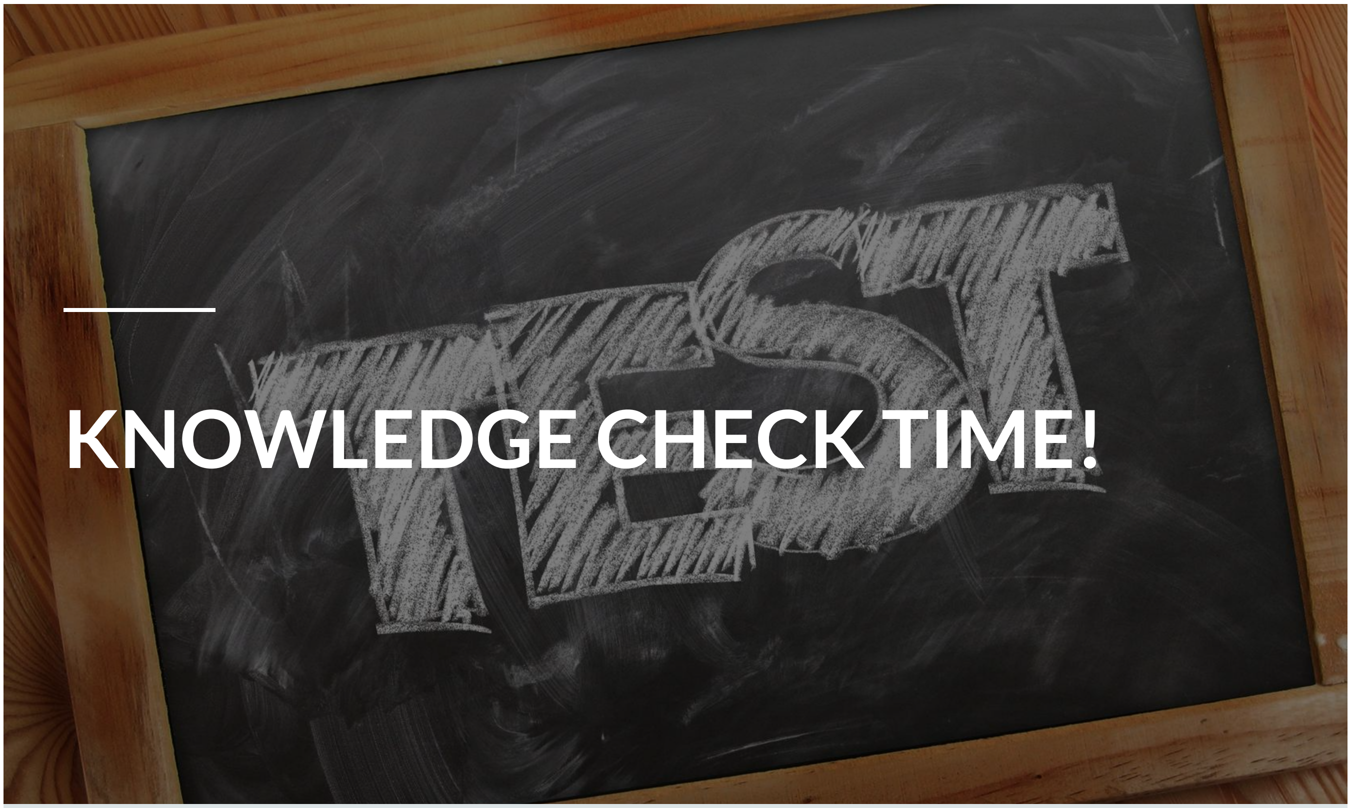


Figure 2–6. LF Power Distribution Diagram (all wings).

Complete the content above before moving on.



KNOWLEDGE CHECK TIME!

You have reached the self-test questions. Answer each question before moving forward to the next set of questions. For the fill-in the blank questions, you will need to add (.) periods to the end of the sentences.

Click here to answer the self-test questions pertaining to the launch facility commercial and standby power contactor function and operation.

1. On a Wing 1 LF, what component does the MPP send a pulse directly to in order to begin the process of connecting commercial power?

- ◯ Commercial power on transistor Q3.
- ◯ Commercial/standby power off relay K5.
- ◯ Commercial power on relay K3.
- ◯ Commercial/standby power off transistor Q2.

SUBMIT

2. On a Wing 3 or 5 LF, what component does the MPP send a pulse directly to in order to begin the process of connecting commercial power?

- Commercial power on transistor Q3.
- Commercial/standby power off relay K5.
- Commercial power on relay K3.
- Commercial/standby power off transistor Q2.

SUBMIT

3. On a Wing 1 LF, what component does the MPP send a pulse directly to in order to disconnect whichever source of primary power is currently connected?

- Commercial/standby power off transistor Q2.
- Commercial/standby power off relay K5.

Commercial power on relay K3.

Commercial power on transistor Q3.

SUBMIT

7

4. On a Wing 3 or 5 LF, what component does the MPP send a pulse directly to in order to disconnect whichever source of primary power is currently connected?

Commercial/standby power off transistor Q2.

Commercial/standby power off relay K5.

Commercial power on transistor Q3.

Commercial power on relay K3.

SUBMIT

Complete the content above before moving on.

Click here to answer the self-test questions pertaining to missile alert facility and launch facility power distribution systems.

1. What is the first point of entry for commercial power at a Wing 3 or 5 MAF?

Type your answer here

SUBMIT

2. For what is each of the four power filters inside the power line protection assembly used?

Type your answer here

SUBMIT

9

3. What areas of the Wing 1 MAF are powered by the DEU?

Type your answer here

SUBMIT

10

4. How is the DEU at a Wing 3 or 5 MAF started?

Type your answer here

SUBMIT

11

5. What purpose does LDB panel in the LER serve?

Type your answer here

SUBMIT

This completes Lesson 2. You can find the answers to the self-test questions in the Module 3 table of content.

Lesson 3. Wastewater Disposal and Hydraulic and Pneumatic Systems

Main Points

1. Launch Facility Wastewater Disposal Systems
   a. Launch facility wastewater disposal system familiarization
   b. Sump pump system SP–102 operation
   c. Troubleshooting sump pump system SP–102
2. Hydraulic and Pneumatic System Theory and Operation
   a. Hydraulic systems
   b. Pneumatic systems

The sole reason the facilities you learned about in the previous volumes of this career development course (CDC) exist is for the protection and security of the missile. Since the entire LF is located below ground level, water from rain, melting snow, and possibly a

high water table continuously penetrates the structure. As a facilities maintenance technician, you are responsible for the maintenance and troubleshooting of the waste disposal systems that kick into action whenever water accumulates in either the launcher support building (LSB) or the bottom of the launch tube.

This lesson introduces you to the LF wastewater disposal system, and its operation. We also cover some essential troubleshooting tactics. The second portion of this lesson covers the fascinating world of hydraulic and pneumatic systems. We'll cover how these systems make it possible for us to lift loads and accomplish work that we normally would not be able to do.

Click here to start the last lesson in Module 3.

Launch Facility Wastewater Disposal Systems

A house or building that is above ground level is not very susceptible to flooding; however, we know this is not the case with Minuteman III LFs. The LSB and LER are buried beneath the ground to help protect them from the effects of a nuclear detonation; however, this comes at the cost of ground water penetrating into these structures. Two pumping systems were built into the LF—one in the LSB and one in the bottom of the launch tube—whose purpose is to send water up and out of these areas. Let's begin with a familiarization of the LF wastewater disposal system.

Launch Facility Wastewater Disposal Systems

Launch Facility Wastewater Disposal System Familiarization

Due to the sensitivity of the equipment and the fact that we do not want electrical panels filling up with water, the LF employs a robust system of pumps, plumbing, and accompanying electronic circuitry designed to remove wastewater before it has the chance to cause damage. This lesson focuses on the different systems used at the LF and their operation.

Wastewater System Terminology

The LF wastewater disposal system has its own terminology. It is important that you become familiar with the terms in the following paragraphs.

GROUND MAINTENANCE RESPONSE–29 | **GROUND MAINTENANCE RESPONSE–5** | **SOURCES OF WASTE WATER**

A ground maintenance response (GMR)–29 is the fault alarm associated with sump pump system SP–102 in the launch tube, and it indicates the system is malfunctioning or the water level in launch tube has risen to the alarm probe. This and all other fault alarms report to the MCC at the MAF who then notifies the missile maintenance operations center (MMOC). The MMOC notifies the facilities maintenance work center who generates a dispatch to the LF soon afterwards to troubleshoot the cause of the fault.

GROUND MAINTENANCE RESPONSE–29 | **GROUND MAINTENANCE RESPONSE–5** | **SOURCES OF WASTE WATER**

A GMR–5 is the fault alarm associated with sump pump system SP–103 in the support building, and it indicates the system is malfunctioning or the water level in the sump pit has risen to the alarm float switch. There are several other faults that also use the GMR–5 circuit; sometimes this makes it difficult to pinpoint whether this is a fault with the sump pump or another piece of equipment.

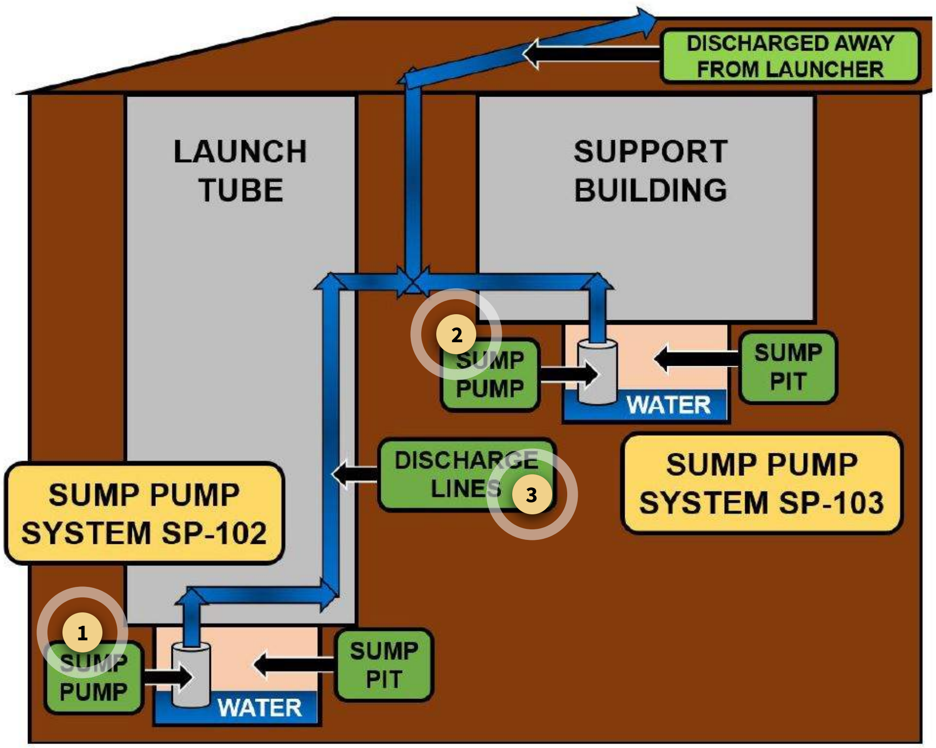
GROUND MAINTENANCE RESPONSE–29 | **GROUND MAINTENANCE RESPONSE–5** | **SOURCES OF WASTE WATER**

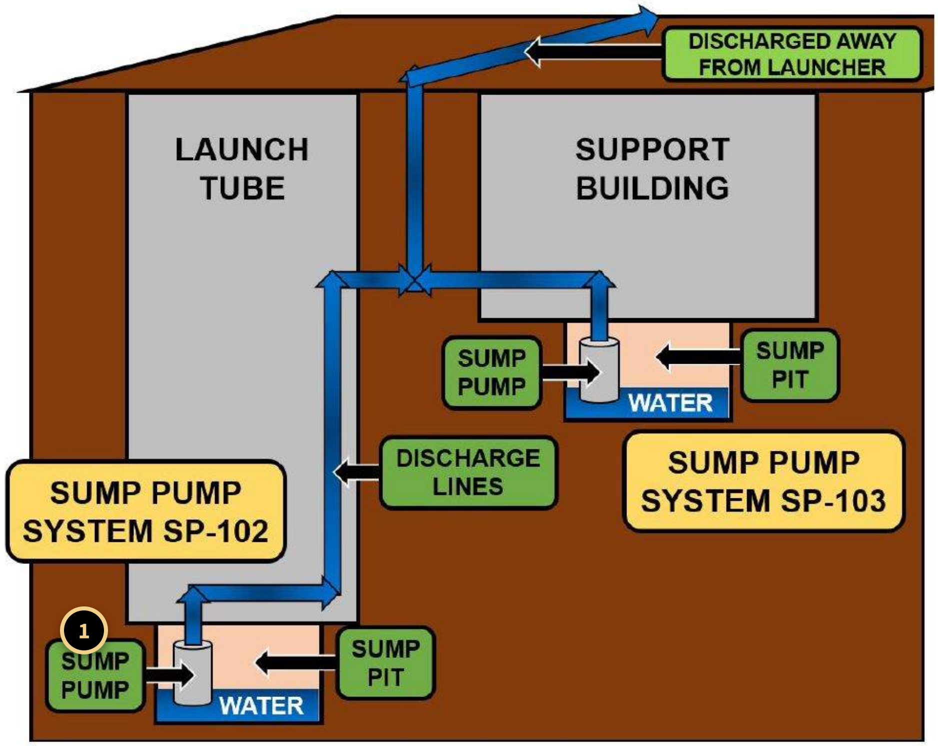
The missile complexes at all three wings cover many thousands of square miles, and all of them are in areas that receive rain and seasonal snowfall. Some LFs are built in “dry” areas, while others are built in wetlands or marshlands that have much higher water tables. The water table is the depth at which the ground is saturated in water. A high water table would be ideal if you were looking to dig a well, for example. It is not ideal in the case of our MAFs and LFs, however, because a higher water table increases the amount of water intrusion into these structures.

Every LF is built so that water will naturally flow downhill and away from the launcher and LSB; however, water intrusion cannot be avoided 100 percent of the time. This is especially true during heavy rainstorms and large amounts of quickly melting snowfall.

Complete the content above before moving on.

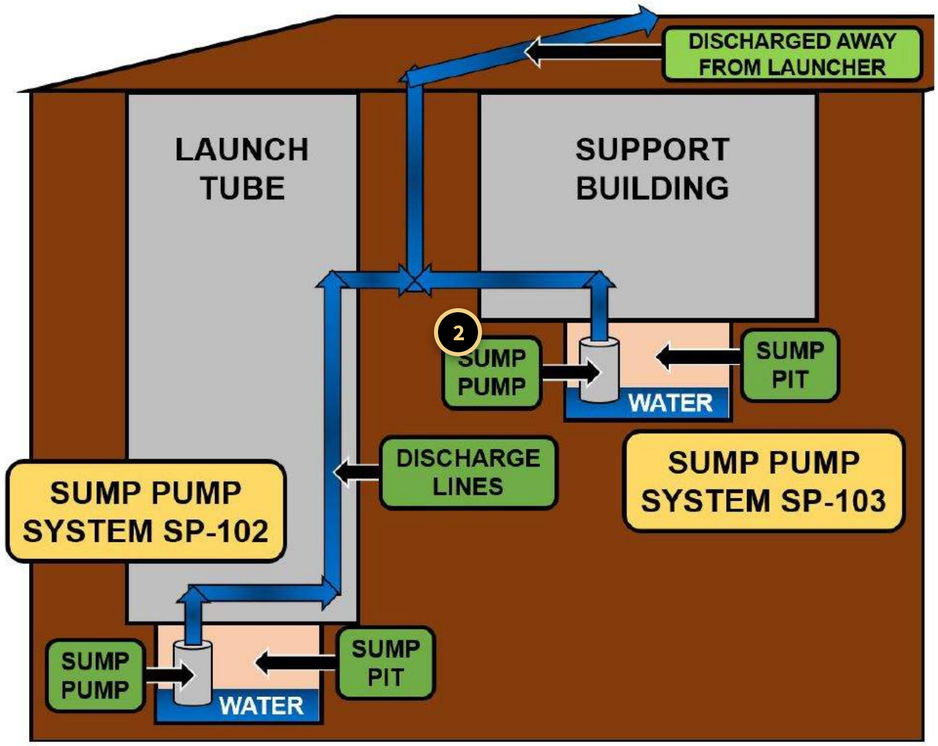
Click on each number to learn more about the LF wastewater removal components.





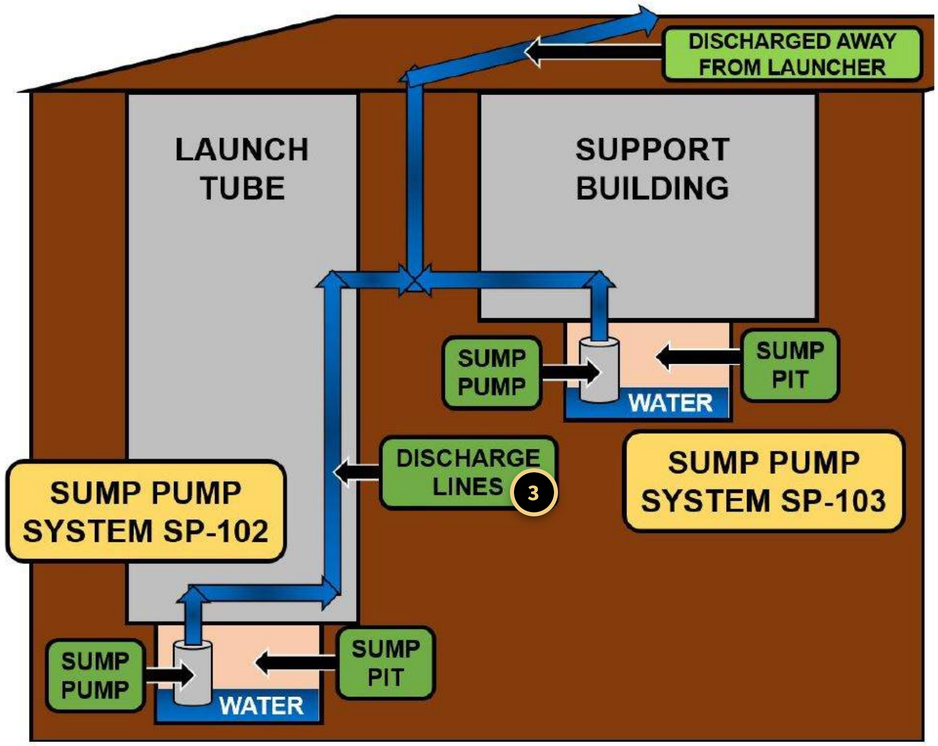
Sump Pit

A sump pit (fig 3–1) is a basin or area constructed specifically to collect wastewater. There is one at the bottom of the launch tube, which is the lowest part of the launcher and the entire LF. The second sump pit you should be familiar with is the one in the support building. Water will naturally accumulate in these two sump pits because they reside at the lowest point in their respective structures.



Sump Pump

The sump pump (fig 3–1) is a powerful submersible liquid pump whose purpose is to pump liquid out of and away from the bottom of the sump pit through piping or discharge lines. The pump only runs when the liquid level in the sump pit rises to the start probe or float, and then shuts off again once the liquid falls below the stop probe or float.



Discharge Line

Each sump pump ejects water through plumbing called a discharge line (fig 3–1). The discharge line for sump pump system SP–102 travels up the launch tube wall and combines with the discharge line from sump pump system SP–103 several feet below ground level. This single discharge line then runs to the edge of the site so that wastewater is discharged away from the launcher.

Complete the content above before moving on.

Float Switch

A float switch (fig 3–2) is just that—a switch inside an object that floats in certain liquids.

The LF wastewater disposal system uses two different types of floating switches. The first type is a bubble-shaped float tethered to a pole by an electrical wire. The second type is a doughnut-shaped float that rides up and down on a fixed rod.

Tethered Float

When the water level rises to a point where the float is parallel, the switch inside the float closes and allows power to flow through. This flowing power can start a pump or send an alarm, depending on where the float is placed. This type of float switch comes in two different types: differentiating and non-differentiating.

Tethered Float Switches	
Differentiating	**Non-differentiating**
Only used for sump pump system SP–103 start and stop float switches.	Only used for the sump pump system SP–103 alarm float.
Only floats on water. This ensures the sump pump will not start if sump pit of sump pump system SP–103 if is full of fuel or oil.	Floats on any liquid. It only will initiate a GMR fault alarm and will not start the pump.

Fixed Rod Float

The fixed rod float switch (fig 3–3) rises with the liquid level, and hits its stopping point when the water level in the sump pit rises to a predetermined level. Hitting the stopping point completes a circuit and power flows through.

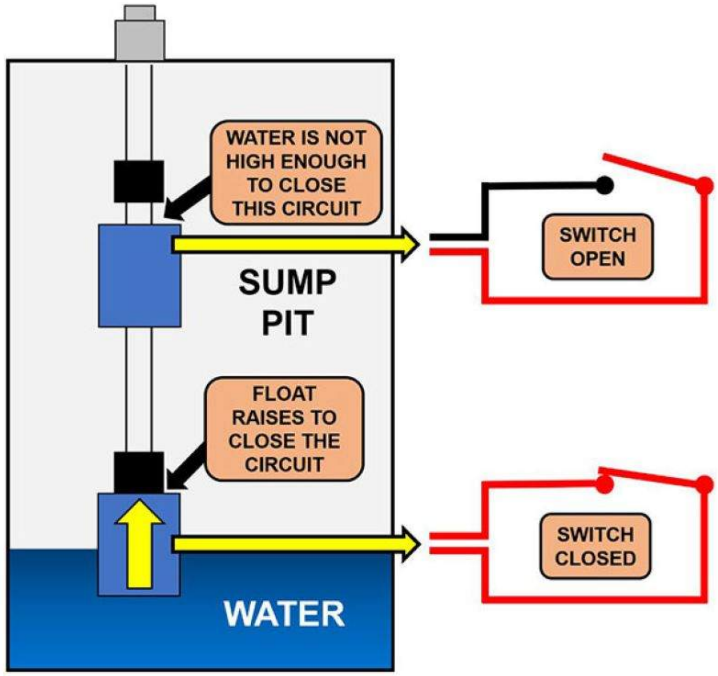


Figure 3–3. Sump pump system SP—102 float switches (Wings 3 and 5).

Liquid Level Probe

A liquid level probe (fig 3–4) has the same purpose as a float switch but operates differently. A probe will have a small amount of voltage waiting on it or will be the ground for another probe; the water is what actually completes the circuit between two probes or an energized probe and ground. Sump pump systems SP–102 and SP–103 at all three missile wings use a combination of float switches and probes.

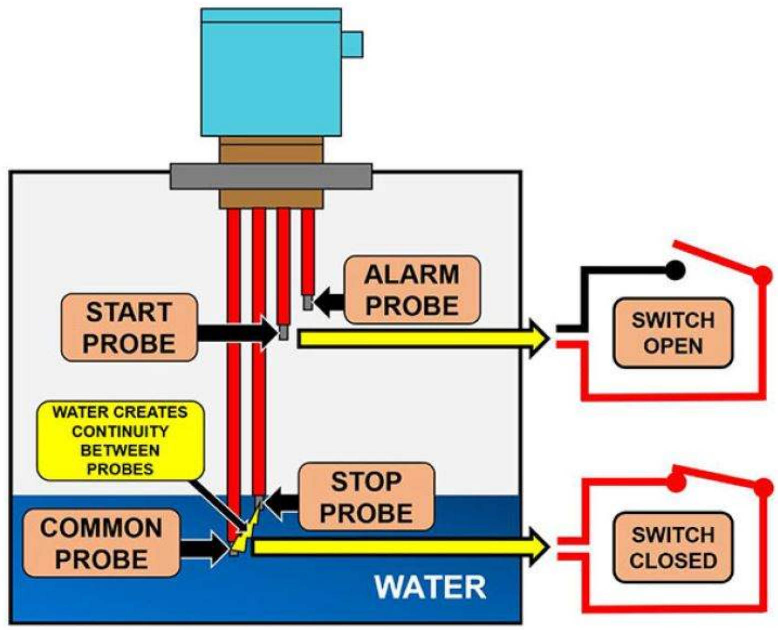


Figure 3–4. Sump pump system SP–102 probe assembly (Wing 1).

Complete the content above before moving on.

Click on each (+) sign below is continue learning about the wastewater system terminology.

Sump Pump System SP–102

Sump pump system SP–102 is responsible for removing wastewater that has accumulated in the sump pit at the bottom of the launch tube. All LFs at all wings use this system.

Sump Pump System SP–103

Sump pump system SP–03 is responsible for removing wastewater that has accumulated in the sump pit at the bottom of the support building. All LFs at all wings use this system.

Sump Pump System SP–104 (Select Sites Only)

A select few sites (those that have an abnormal amount of water accumulation in the front of the launcher closure) use a third sump pump system called sump pump system SP–104. A heated drainage trench at the end of the launcher closure rails collects water and diverts it to another sump pit that is only a few feet below the ground. This water is then discharged away from the launcher.

Water Diverter System (Select Sites Only)

Many sites use a water diverter system that consists of a rubber ring around the top of the launch tube that channels water into two receptacles on the north and south sides of the launcher. Water then runs down to the sump pit of sump pump system SP–102 through plastic tubing attached to the launch tube wall and is pumped out and away from the launcher by the pump of sump pump system SP–102. The water diverter system prevents water from running under the launcher closure lid and directly down on top of the missile.

Dewatering Well (Select Sites Only)

The LF dewatering well is limited to only a few sites throughout all three missile complexes. The dewatering well is a narrow 100-foot-deep hole drilled into the ground whose purpose is to keep the ground water level low enough to where it cannot intrude into the LER. A pumping system near the bottom of the well pumps water up through a discharge line that runs through the ground all the way to the outside of the LF security fence, where it typically discharges water next to the site’s access road.

Lower Launcher Equipment Room Floor Sensor Probe (Select Sites Only)

This system consists of an additional probe that is slightly above floor level in the lower LER. Water that floods the lower LER floor will contact the probe and cause a GMR–29 fault alarm to report to the LCC.

Launcher Equipment Room Rattlespace Sensor (Select Wing 1 Sites Only)

This system consists of an additional sensor placed inside the rattlespace at select Wing 1 sites. Any water that floods the rattlespace will also contact the probe and generate a GMR–29 fault alarm.

Complete the content above before moving on.

Sump Pump System SP–102 Operation

You can see that there are many facets to the LF wastewater disposal system. This lesson focuses solely on sump pump system SP–102 and its operation.

Sump pump system SP–102 is different from nearly any other system you will work on at an MAF or LF because its control panel is located in the lower LER, while the pump, float switches, and liquid level probes are much further down at the bottom of the launch tube. This means the only way you will know the system is operating correctly will be to observe indications you will see inside the control panel of sump pump SP–102.

Water being discharged on the topside of the LF is another prime indicator that the system is working correctly. Therefore, knowing how this system operates will enable you to 'see' what the system is doing, per se, without physically being at the bottom of the launch tube.

There are essentially four states sump pump system SP–102 can operate in when set to auto mode, no matter at which wing you are:

1. Water is below the start probe (Wing 1) or below the start float (Wings 3 and 5).
2. Water is touching the start probe (Wing 1) or elevating the start float switch (Wings 3 and 5).
3. Water is touching the alarm probe (all wings).
4. Water is touching the LER floor sensor (all wings, select LFs).

The schematics and descriptions you will find in Civil Engineering Manual (CEM) 21–SM80A-2-24-2, *Water Supply, Distribution, and Waste (Wing 1)*, 21–SM80B-2-24-2 (Wing 3), or 21–SM80B-2-24-4 (Wing 5) are sometimes confusing and do not tell the entire story. The paragraphs and diagrams that follow will explain step-by-step how sump pump system SP–102 operates in auto mode during each of the four states listed above. We will use the system at F.E. Warren AFB (Wing 5), but the concepts you learn are applicable to all three wings.

Note that the sump pump system SP–102 HAND-OFF-AUTO (H-O-A) switch is set to AUTO in all of the following scenarios.

Water Level Below Low Water Level Float Switch and not Touching Launcher Equipment Room Floor Probe (Wings 3 and 5)

On a day-to-day basis, as long as the sump pump system SP–102 is functioning correctly, the water level in the sump pit will be below the low water level float switch and no water will be touching the LER floor sensor probe. Figure 3–5 illustrates this.

A three-pole circuit breaker in the LDB panel supplies 120 VAC that enters the control panel for sump pump system SP–102, and waits on the line side of motor starter M1.

The control panel of sump pump system SP–102 and all its components are powered by one phase of 120 VAC supplied by the LDB panel that branches off pin 1 of terminal board (TB) 2 and then runs to pin 1 of TB1. Power then runs all the way to the bottom of the launch tube to pin 4-4 of TB4. Power runs through the closed stop/lockout switch, back to pin 4-5 of TB4, and then all the way back up the launch tube to pin 2 of TB1.

The 120 VAC on pin 2 of TB1 branches out to two different locations:

The 120 VAC on pin 2 of TB1 branches out to two different locations:

- Power runs through the H-O-A switch located on the front of the sump pump system SP–102 control panel, and then flows to pin 5 of TB1.
- Power runs to pin 5 of relay R1 and waits.

The 120 VAC on pin 5 of TB1 branches out in three different directions:

- Power travels down to the bottom of the launch tube, into the junction box, through pin 4-8 of TB4, and exits the junction box. It then flows into the low water level float switch and waits.
- Power travels to pin 1 of relay R3, which energizes the coil of the relay. When the coil of relay R3 is energized, contacts 3/4 and 5/6 inside the relay R3 reposition, and the following actions occur:
  - Contacts 5/6 of relay R3 open, but this does not cause anything to happen yet.
  - Contacts 3/4 of relay R3 close to allow DC power from the GMR–29 fault alarm circuit to flow through. The GMR–29 fault alarm circuit must be closed in order for the fault to clear. A good way to remember this is the phrase “break to make”—breaking the GMR circuit makes the alarm report.

- The third location power flows from pin 5 of TB1 is to pin 1 of relay R4, energizing the coil of the relay. When the coil of relay R4 is energized, contacts 3/4 close to allow DC power from the GMR–29 fault alarm circuit to flow through. Since contacts 3/4 on both relays R3 and R4 are now closed, the GMR circuit is complete, and the GMR–29 fault alarm is not reporting.

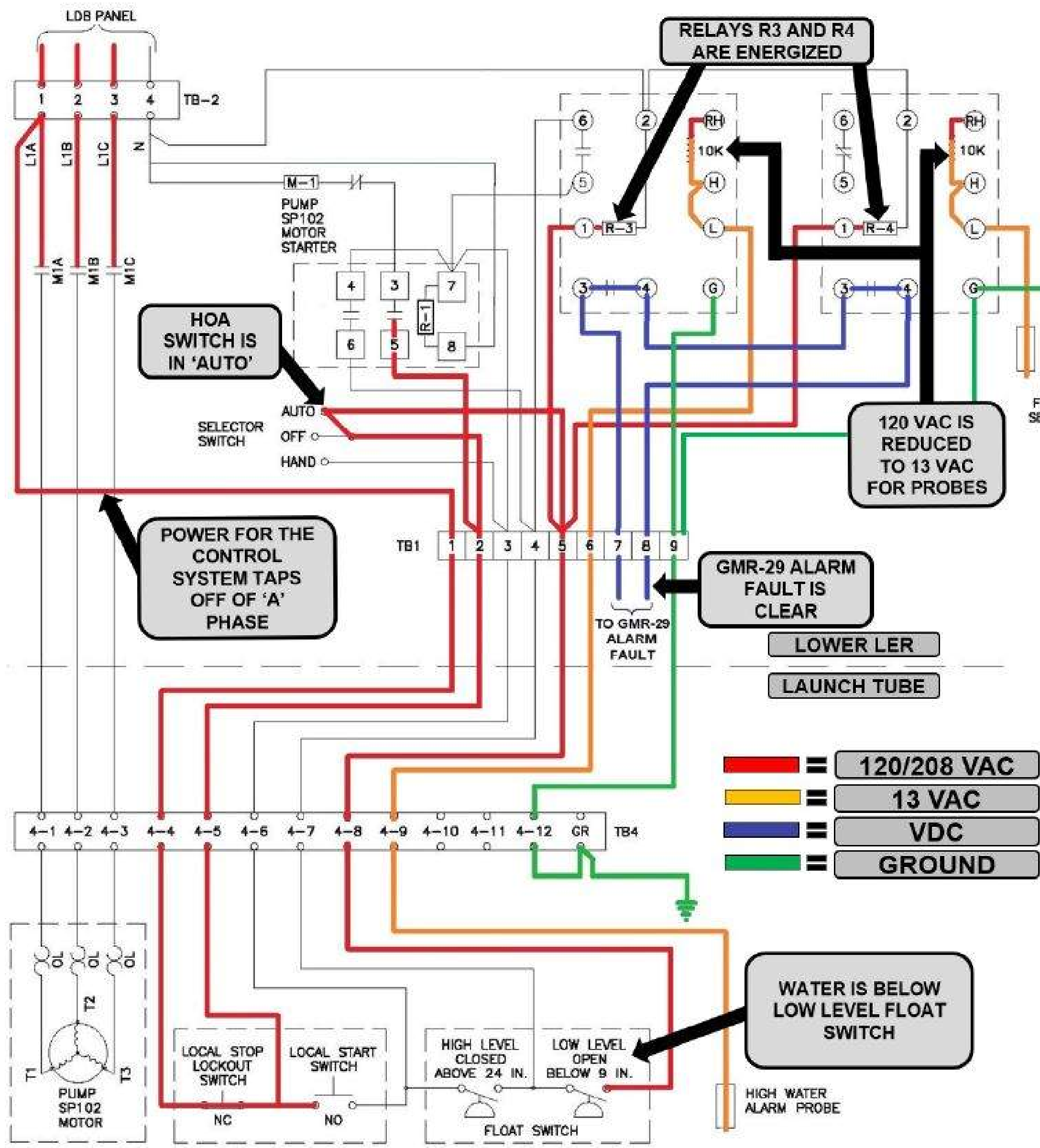


Figure 3–5. Water Level Below Low Water Level Float Switch.

Next, we cover how relays R3 and R4 handle the inputs from the high liquid level alarm probe in the sump of sump pump system SP–102 and the floor sensor in the LER.

120 VAC from pin RH of relay R3 is reduced to 13 VAC by a 10,000-ohm resistor. Voltage then flows to pin H of relay R3, through a jumper wire and into pin L of relay R3, and then flows out of the relay and into pin 6 of TB1.

From pin 6 of TB1, 13 VAC flows all the way down the launch tube, into the junction box, and to pin 4-9 of TB4. The 13 VAC then flows from pin 4-9 of TB4, out of the junction box, and waits on the high water level alarm probe.

A ground wire also runs from pin G on both relays R3 and R4, where the two wires join on pin 9 of TB1. A single ground wire then runs from pin 9 of TB1 all the way down the launch tube to pin 4-12 of TB4 in the junction box. This ground wire then jumps to pin GR of TB4, exits the junction box, and creates a ground point in the sump pit. This point provides a path to ground for the 13 VAC that is waiting on the high water level alarm probe. Later in this lesson, you will find out how the 13 VAC initiates a GMR–29 fault alarm.

120 VAC from pin RH of relay R4 is reduced to 13 VAC by a 10,000-ohm resistor. Voltage then flows to pin H of relay R4, through a jumper wire into pin L of relay R4, and then flows out the relay and waits on the LER floor sensor probe.

A ground wire also runs from pin G of relay R4 down to a spot near the LER floor sensor probe where it acts as the ground for the LER floor sensor in the same way that the ground for the high water level alarm probe in sump pit of sump pump system SP–102 works. Any water that pools on the LER floor will create continuity between the LER floor sensor and its ground, which will allow the 13 VAC to "ground out." Later in the lesson, you will find out how relay R4 reacts to this.

Again, the water level is still below the low water level float switch and not touching the high water level alarm probe or the LER floor sensor probe; the system exists in this state the majority of the time.

Click to continue with the lesson.

Water Level at Low Water Level Float Switch and not Touching LER Floor Sensor Probe

When the water rises high enough to close the low water level float switch, 120 VAC is allowed to pass through where it waits on one side of the high water level float switch and flows to pin 4-7 of TB4 inside of the junction box (fig 3–6). This power then flows up the launch tube and to pin

4 of TB1 located inside of the sump pump system SP–102 control panel. From pin 4 of TB1, power branches off in two separate directions:

- Power flows to pin 6 of relay R3, where it waits to flow through contacts 5/6 later on as a “last attempt” to start the sump pump.
- Power flows to pin 6 of relay R1, where it waits to flow through contacts 4/6 later on to establish the “holding” circuit for relay R1.

These are the only actions that occur when water reaches the low water level float switch.

Water Level at High Water Level Float Switch and not Touching LER Floor Sensor Probe

In a properly functioning sump pump system SP–102, the sump pump will only begin to operate once the water level in the sump pit reaches the high water level float switch. Figure 3–7 illustrates this process.

120 VAC flows through the closed contacts of the high water level float switch and to pin 4-6 of TB4 inside of the junction box. From there it flows up the launch tube and to pin 3 of TB1 in the control panel, and from there flows to the coil of relay R1.

When the coil of relay R1 is energized, contacts 4/6 and 3/5 of relay R1 both close, which causes the following actions:

- When contacts 3/5 of relay R1 close, power flows to the coil of sump pump motor starter M1, which closes contacts M1A, M1B, and M1C inside of motor starter M1. Power flows through contacts M1A, M1B, and M1C and down the launch tube to pins 4-1, 4-2, and 4-3 of TB4 in the junction box. From here, power flows out of the junction box and energizes the sump pump. At this point water will start to discharge on the topside of the LF, and the water level in the sump pit will start to drop.
- Contacts 4/6 of relay R1 close to create the “holding” circuit that prevents relay R1 from deenergizing even after the water level drops below the high water level float switch. If the holding circuit is not established and maintained, the sump pump will stop running immediately after the water level drops below the high water level float switch. Once the holding circuit has been properly established, the sump pump will only stop running after the water level drops below the low water level float switch. These actions prevent the

sump pump from repeatedly turning on and then shutting off (short cycling). Short cycling causes unneeded wear and tear on components that can lead to premature failure.

Sump pump system SP–102 continues to pump water to the topside of the LF until water drops below the low water level float switch.

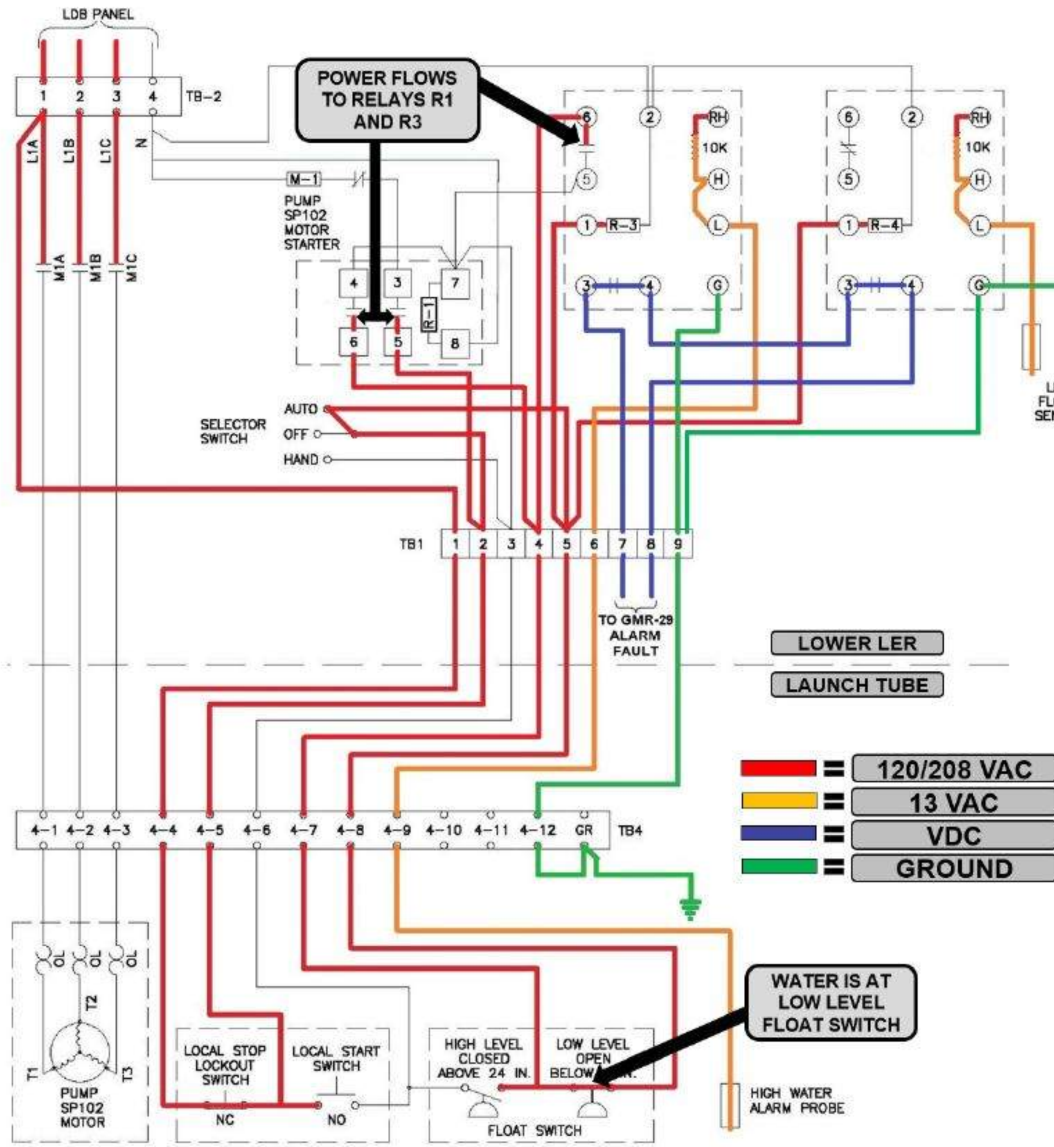
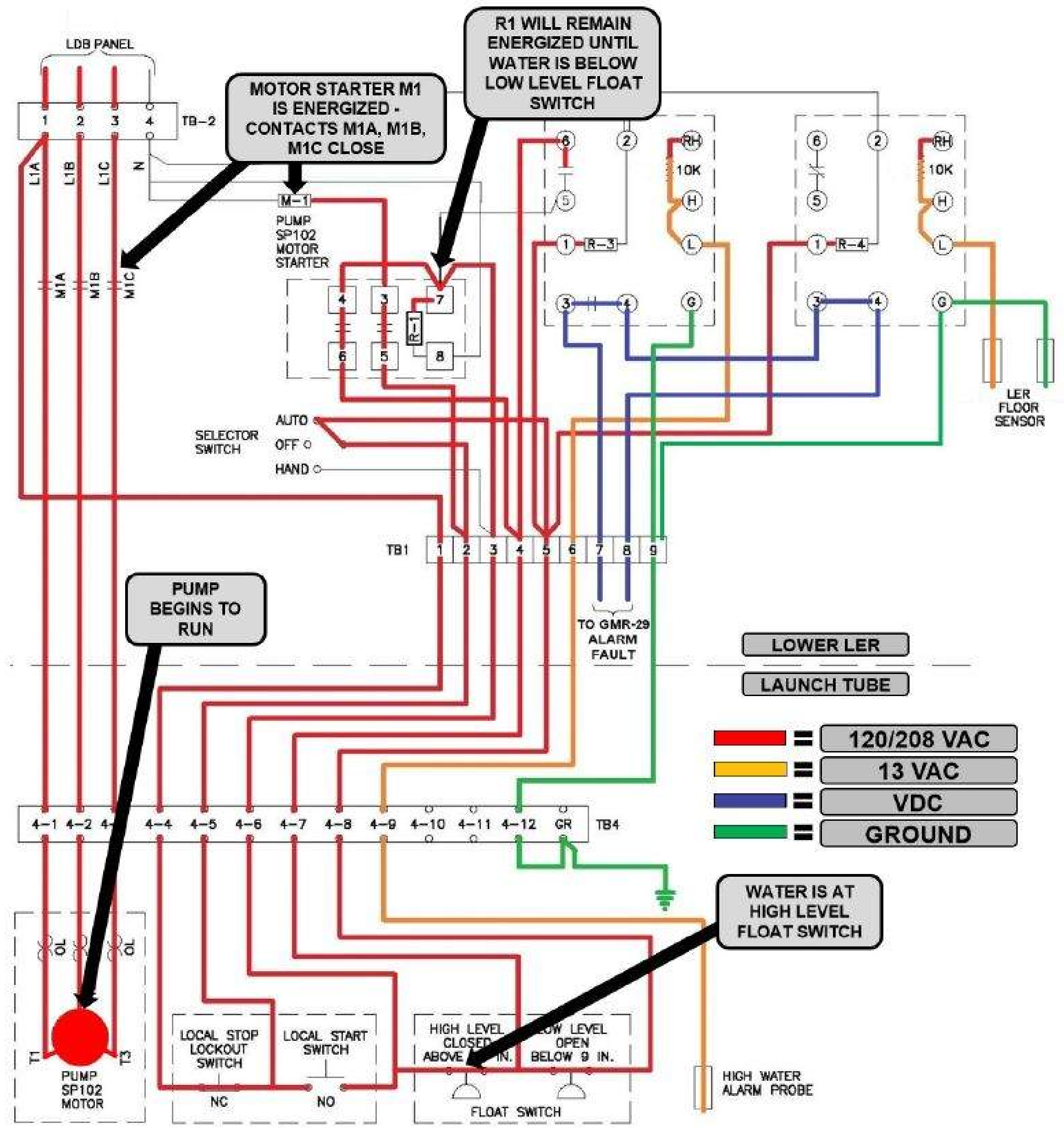


Figure 3–6. Water Level at Low Water Level Float Switch.



Water Level Reaches High Water Level Alarm Probe

If sump pump system SP–102 is malfunctioning, or if water is flowing into the sump pit faster than the sump pump can remove it, water eventually will rise to touch the high water level alarm probe. Figure 3–8 illustrates this condition.

When the water level in the sump pit reaches the high water level alarm probe, a circuit is completed between the probe and the ground point coming from pin G of relay R3 up in the control panel. Relay R3 senses that 13 VAC is returning on the ground circuit, and the contacts 3/4 and 5/6 of relay R3 reposition. The following two events will occur:

1. Contacts 3/4 of relay R3 open to break the GMR–29 fault alarm circuit, which initiates a GMR–29 fault alarm to the LCC. A maintenance team will be sent to troubleshoot because water is not being pumped out of the pit.

2. The sump pump system makes one final attempt to start the sump pump by closing contacts 5/6 of relay R3. Doing so sends power to pin 7 of relay R1 with the intent of energizing its coil, and therefore energizing sump pump motor starter M1. If this final attempt does cause the pump to start, this indicates the high water level float switch is malfunctioning.

If the system is able to start the pump using the “final attempt” method, the water level in the sump pit will fall, the GMR–29 fault alarm will clear, and the pump will stop once the water level falls below the low water level float switch. However, this is only a temporary solution. If water is actively flowing into the pit (e.g., snowmelt or rainstorm), the water level will again rise to the high water level alarm probe, and the process will repeat itself. This cycle of water filling the pit and then being pumped out is referred to as a “cycling GMR–29,” and although the fault does clear, a maintenance team will likely be sent to troubleshoot.

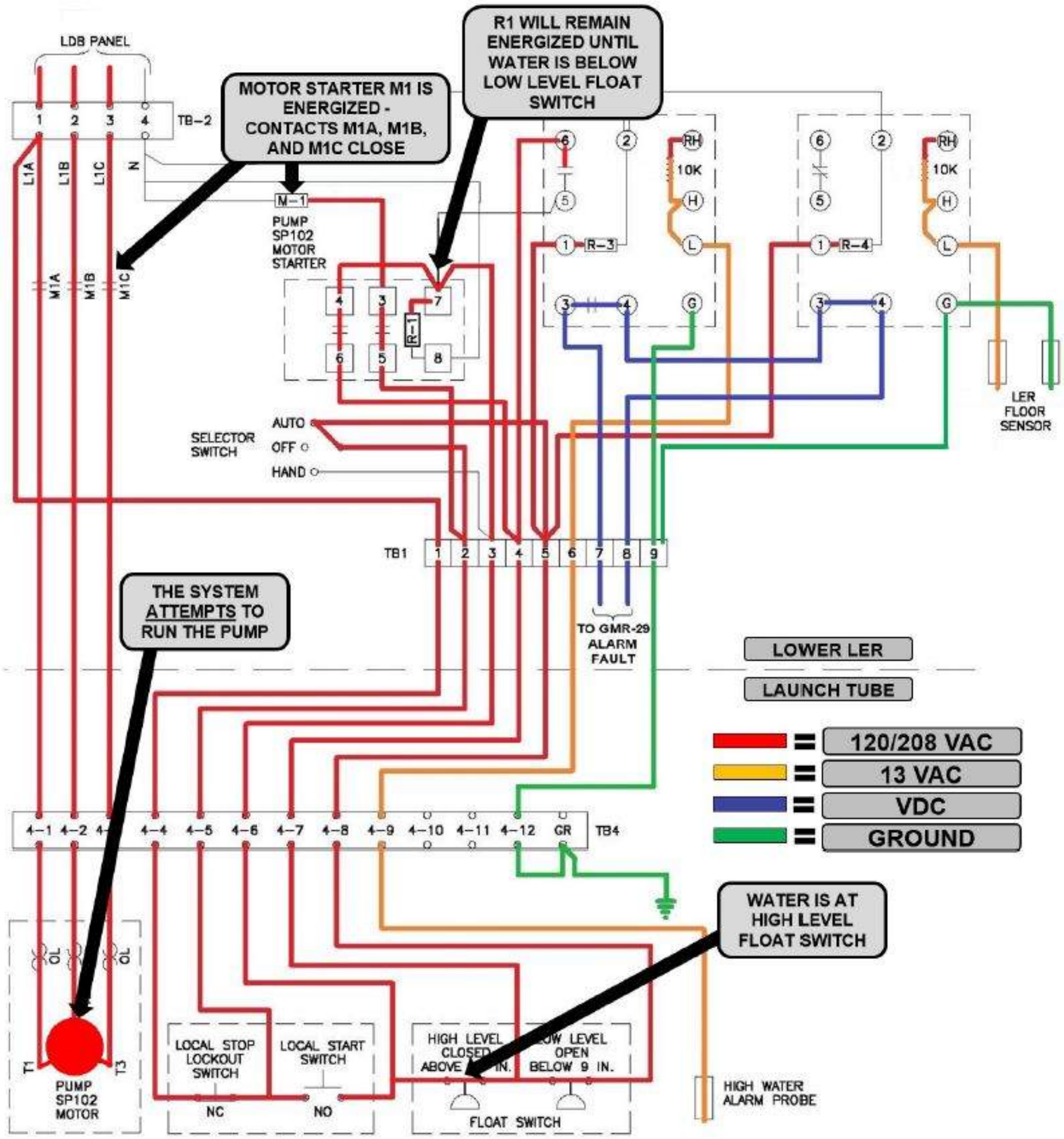


Figure 3–8. Water Level at High Water Level Alarm Probe.

Water Touching Launcher Equipment Room Floor Sensor Probe

The lower LER floor might flood if condensation runoff from the air handler is not running to the bottom of the launch tube or if water is somehow penetrating the rattle space and it begins to overflow (fig 3–9). When water touches the LER floor sensor probe, a circuit is completed between the probe and the ground point coming from pin G of relay R4 in the control panel of sump pump system SP–102. Relay R4 senses that 13 VAC is returning on the ground circuit, and deenergizes the coil of relay R4. Contacts 3/4 of relay R4 open to break the GMR–29 fault alarm loop, which sends a GMR–29 fault alarm to the LCC. A maintenance team will be sent to troubleshoot because water has flooded the lower LER.

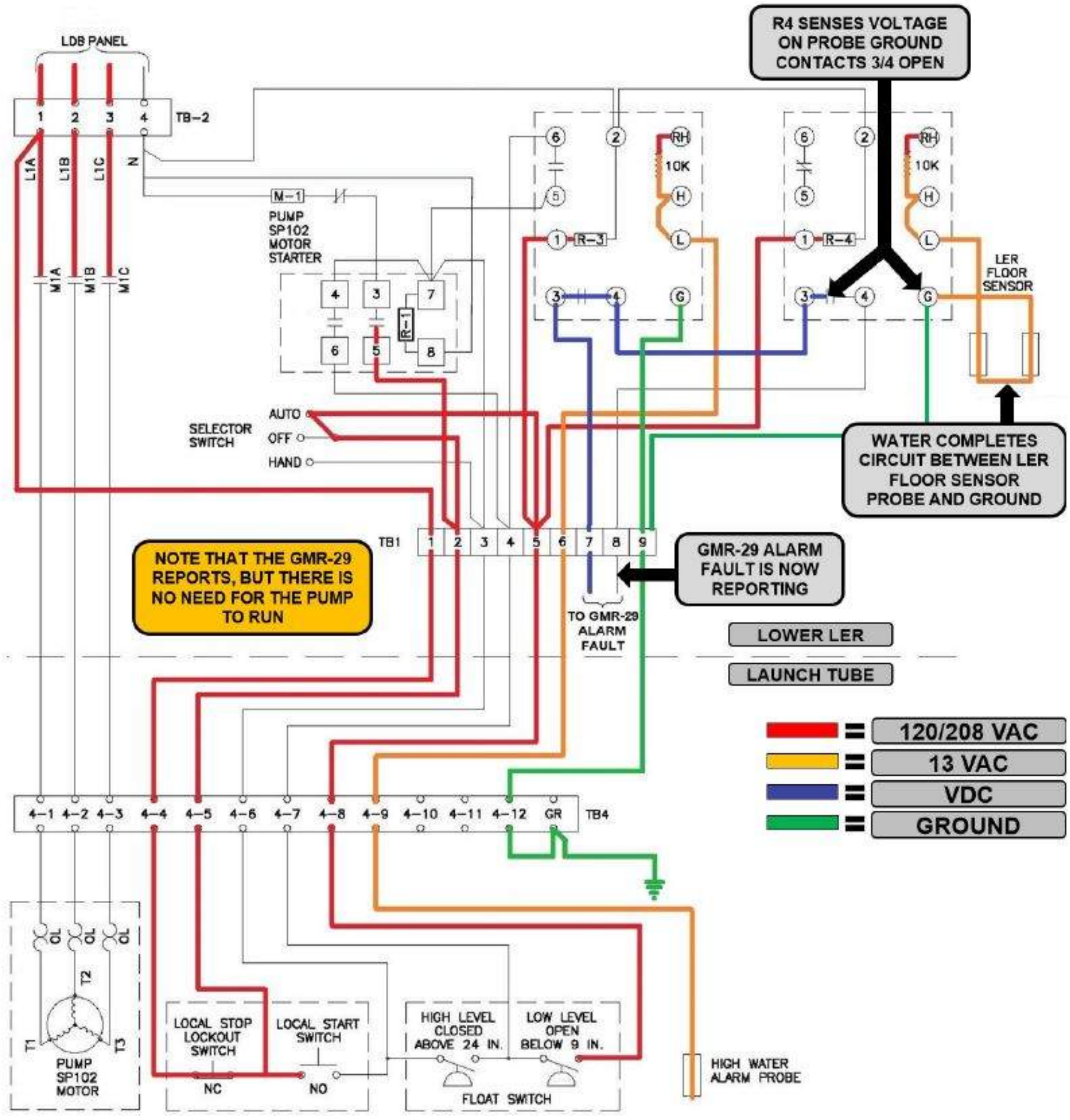
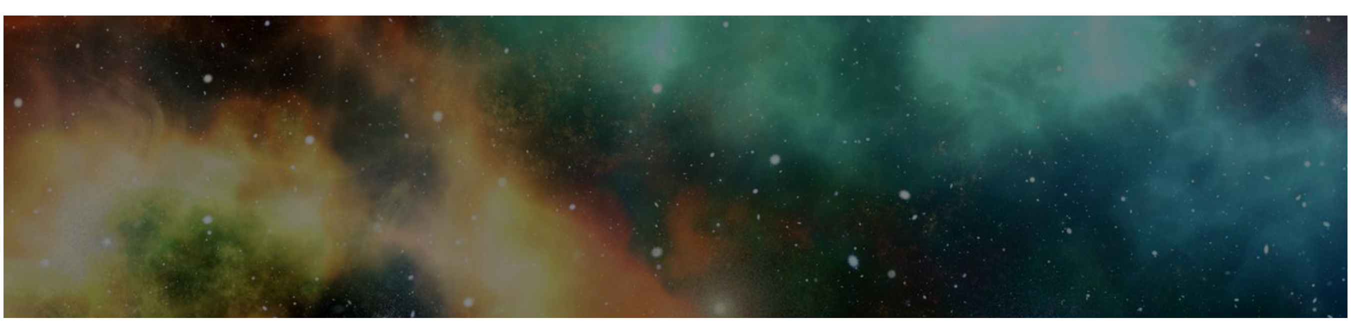


Figure 3–9. Water Touching LER Floor Sensor Probe.



Troubleshooting Sump Pump System SP–102

This lesson covers troubleshooting sump pump SP–102. As you saw in the last lesson, this system has several modes, and troubleshooting can be daunting since a portion of the system is located underground in the bottom of the launch tube. This lesson will provide you with the tools you will need to troubleshoot problems with sump pump system SP–102 as quickly as possible.

Airmen with the 91st Missile Maintenance Squadron facilities maintenance section empty water from a water tank at Minot Air Force Base, ND., Oct. 24, 2016. The FMS Airmen use the water tanks to fill a launch-tube sump pump in order to test its operation. (U.S. Air Force photo/Airman 1st Class Jonathan McElderry)

Troubleshooting Techniques

When examining a malfunctioning sump pump system SP–102, remember these key ideas from our lesson on troubleshooting:

- Use troubleshooting procedures and schematics hand-in-hand; doing so tells you not only what you are checking, but also why you are checking it.
- Perform a preliminary check and use your senses. Look and smell for components or wiring that may have overheated in the control panel. Look to see if water has been discharged from the line on the topside of the LF recently or if there is an obstruction in the discharge line.

You will be surprised to see how many problems are detected and solved by simply performing the operational checkout of sump pump system SP–102. If you are dispatching as a PMT technician, you will have a large tank full of water on your trailer to aid in troubleshooting. Pouring water into the pit and then discharging it out topside proves the full function of the system. If you are dispatching as a facilities maintenance team (FMT) technician, you will not have enough water on your truck to fill the sump pit. Luckily, if you are dispatching to troubleshoot a GMR–29 fault alarm that is reporting because the sump pit is full, you already have the water you need—you must use it sparingly though.

Electrical Troubleshooting

If you have not already noticed from tracing the schematics, sump pump system SP–102 is complex. Luckily, there are simple tests you can accomplish with your multimeter that will provide a definite indication of whether a component is faulty or not.

The electrical components of missile alert facility chiller are shown, which the power, refrigeration and electrical laboratory team participating in the 2021 Global Strike Challenge was tasked to repair July 26, 2021 at Malmstrom Air Force Base, MT. PREL is a facilities maintenance career field, which is a branch of missile maintenance that specializes in electrical and refrigeration troubleshooting and repair. (U.S. Air Force photo by Airman Elijah Van Zandt)

Sump Pump Motor Windings Open or Shorted (All Wings)

Two of the electrical modes of failure for the sump pump of sump pump system SP–102 are open or shorted motor windings.

Open Motor Winding

The pump utilizes three different motor windings––one for each phase of power. An open in a winding is a physical break where current cannot pass through (fig 3–10), and an open in any pump winding will cause the pump to have sluggish performance or possibly not run at all.

You can use the following steps to test the condition of the pump's motor windings, and you can do this from the comfort of the lower LER:

- Turn off the breaker to sump pump system SP–102 in the LDB panel, and use a multimeter to verify the absence of AC power in the control panel.
- Isolate the pump motor windings by removing the phase wires from sump pump motor starter M1. Make note of where the wires were so you can return them to the proper configuration.
- Set your multimeter to read resistance and test each of the pump's phase wires to the other two wires (fig. 3–11) (A to B, A to C, B to C), and write down the resistance reading the meter shows for each of the three tests.
- Your multimeter will show a resistance reading for the winding(s) you are testing. A serviceable winding will show some amount of resistance, but it will not be too much (i.e. kilo ohms, mega ohms, or over limit). The key to remember is all three readings should have approximately the same resistance value, and a reading where you see a different value will show you the culprit.
- You will know a motor winding is open because you will not get the same resistance reading for all three tests (fig 3–12). Note that the resistance numbers in the figure are only examples.

The wiring that runs from the control panel of sump pump system SP–102 to the bottom of the launch tube can be well over 100 feet long. A break in any of the wires between motor starter M1 and the sump pump will display a similar resistance reading to that of an open motor winding. For this reason, always perform a final resistance test on the motor windings from the bottom of the launch tube prior to replacing the pump. The only corrective action for an open motor winding is to replace the pump.

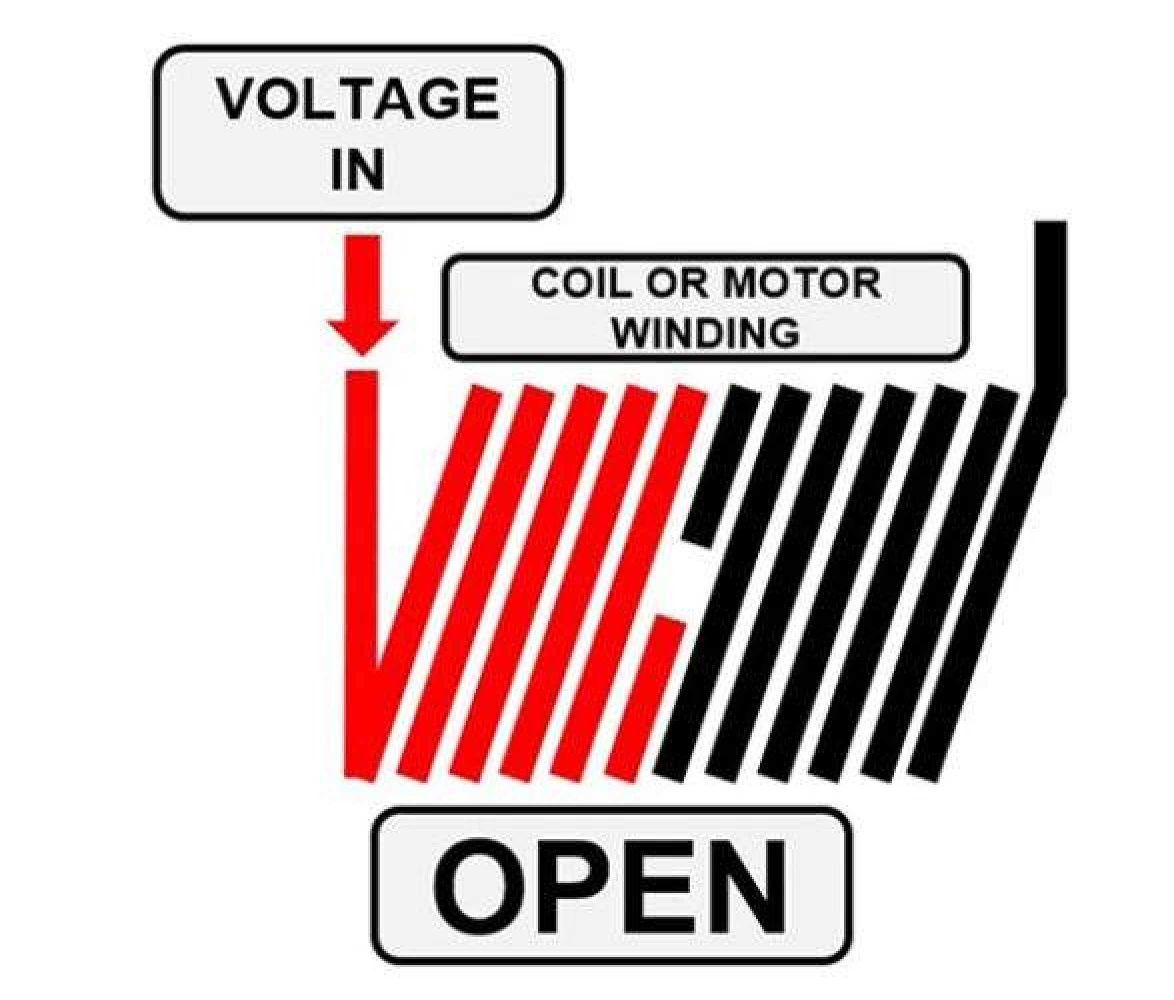


Figure 3–10. Open Motor Winding or Coil.

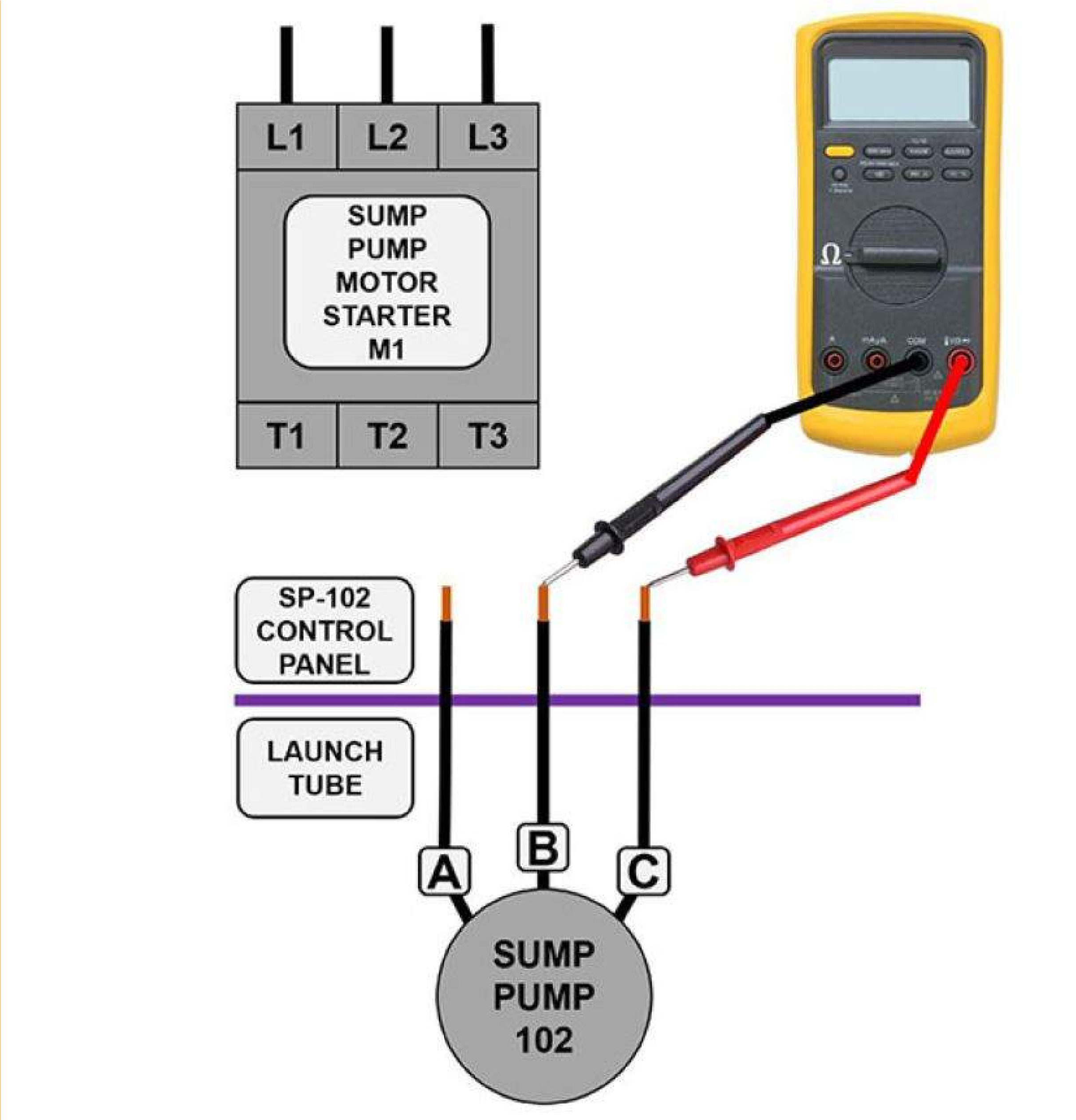


Figure 3–11. Testing a Motor Winding.

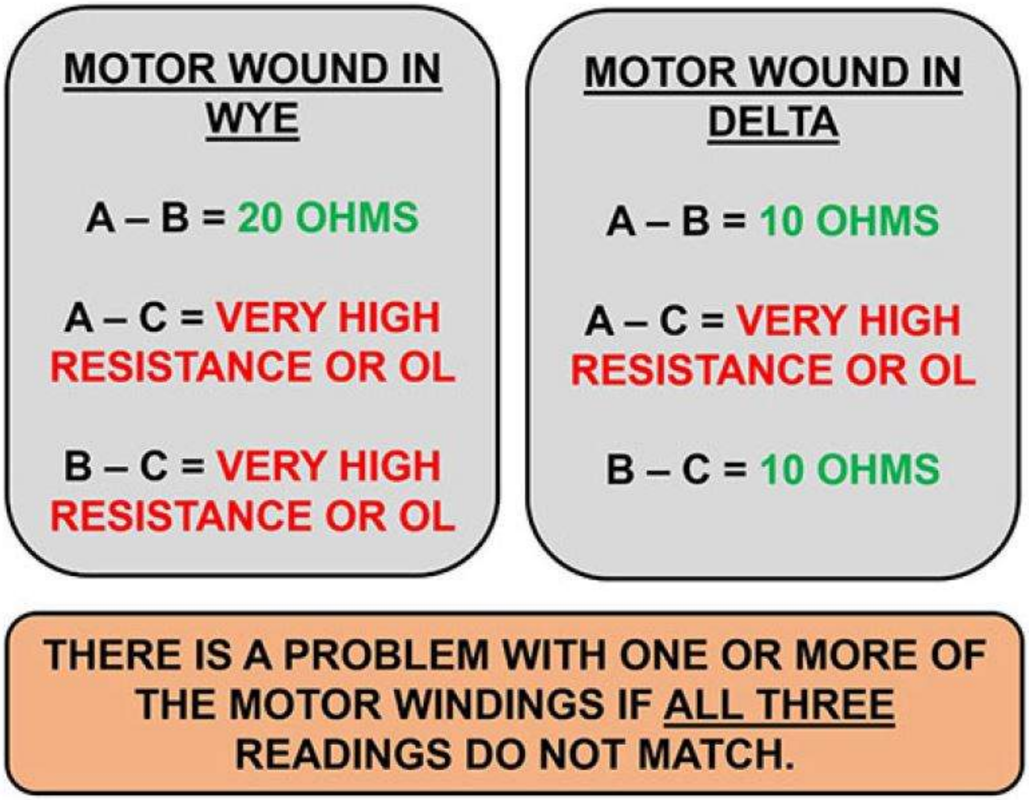


Figure 3–12. Multimeter Readings for an Open Motor Winding.

Scroll through each image before moving forward in the lesson.

Shorted Motor Winding

A short in a motor winding can appear in one of three ways:

- Winding is shorted to itself (individual winds of the same winding shorted together).
- Winding is shorted to another winding (winding A is shorted to winding B).
- Winding is shorted directly to ground (winding shorted to the metal case of the sump pump).

You can test for shorted motor windings the same way you tested for an open motor winding:

Isolate the pump phase wires and perform resistance checks between each of the three wires—A

– B, A – C, and B – C. There should be some resistance on each of the three tests, and the number should be the same.

Note that taking only resistance readings between motor windings might not indicate there is a problem, even if one does exist. It is for this reason you should also test each motor winding phase wire to ground as well. If there is a motor winding shorted to the outer case of the sump pump, your multimeter will display very low resistance (continuity) between that motor winding phase wire and ground. Resistance between a motor winding and ground should always be very high or over limit, and any other reading indicates a short. Remember to test all three motor windings to each other (phase-to-phase) and to ground (phase-to-ground) to ensure detection of all possible motor winding issues.

Click on each (+) sign to learn about the possible motor winding issues.

Start Relay R1 Defective (Wing 5) —

With both float switches closed, voltage should be present on pin 3 of TB1. If there is power at this point and motor starter M1 is not energizing, check voltage directly on the coil of relay R1. R1 has a defective coil if it is receiving power but not repositioning.

If the coil is not receiving power check for loose wiring between pin 3 of TB1 and the coil of relay R1. If the coil of relay R1 is receiving power and energizing, but motor starter M1 is not energizing, either the 3/5 contact of relay R1 is stuck open or the coil of motor starter M1 is defective.

Lastly, if contacts 4/6 of relay R1 fail to close, then the coil of relay R1 will deenergize as soon as the high-level float opens because the holding circuit was not established.

Motor Starter M1 Defective —

The pump of sump pump system SP–102 will not operate if motor starter M1 is defective in any way. When the motor starter engages, you should hear an audible ‘click’ in the panel and the operating light on the panel should come on. If it does not, verify the motor starter coil is receiving power. If it is receiving power, but not repositioning, then the motor starter is likely defective. Isolate the coil of motor starter M1 and take a resistance measurement. If the multimeter indicates over-limit, the coil is open and the motor starter must be replaced. If the multimeter indicates an extremely low resistance, the coil is shorted. If the multimeter reads a normal resistance, then make another resistance check between the ground side of the coil and a panel ground. If you check ground-to-ground and your multimeter shows a very high resistance or over-limit, then you must find the loose or broken wire between the ground side of the coil and where it should be grounded. Remember that coils and all other electrical loads only operate correctly if they are grounded. A functional coil that is receiving adequate power still will not work without a ground, and the same logic can be applied to any electrical circuit.

If the coil of motor starter M1 is working correctly and the contacts are indeed repositioning, the next step is to perform a voltage check on all three of the incoming and outgoing phase wires. Your multimeter should read approximately 120 VAC when testing each point to ground. If one of the three phases of power going into the top of motor starter M1 does not show 120 VAC, there is an issue with power coming from the LDB panel. If all three phases of power flowing into the top of motor starter M1 are 120 VAC, but one of the phases exiting M1 is less than 120 VAC, there is a problem with M1's internal power contactors. The 120 VAC should be supplied to and exiting motor starter M1; therefore, M1's power contactors are likely dirty, corroded, or malfunctioning if less than 120 VAC is exiting motor starter M1.

Defective Float Switches (Wing 5)

A defective low or high water level float switch is very easy to troubleshoot because it is a series circuit that should be open when the water level is low and closed when the water level reaches a predetermined point. A float switch can malfunction two ways:

1. The switch stays closed even after the water level in the sump pit has dropped to a sufficient level.
2. The switch stays open even after the water level in the sump pit has risen to the predetermined level.

If a GMR–29 fault alarm is reporting for a high water level in the sump pit, you know that both the low water level float switch and high water level float switch should be closed. Resistance checks are the most effective and foolproof way to test if the float switches are opened or closed. Use the following steps to test whether the low water level float switch is open or closed:

- Turn off the breaker to sump pump system SP–102 in the LDB panel, and use a meter to verify the absence of AC power in the control panel.
- Remove the wires from pins 4 and 5 of TB1 in the control panel.
- Use your multimeter to take a resistance reading between the two wires. Zero or very low resistance indicates that the float switch is closed, and very high resistance or over-limit indicates the switch is open.

A low water level float switch stuck in the closed position will cause the sump pump to continue to run even after there is no longer any water in the sump pit.

Use the following steps to test whether the high water level float switch is open or closed:

- Turn off the breaker to sump pump system SP–102 in the LDB panel, and use a meter to verify the absence of AC power in the control panel.
- Remove the wires from pins 3 and 4 of TB1 in the control panel.
- Use your multimeter to take a resistance reading between the two wires. Zero or very low resistance indicates that the float switch is closed, and very high resistance or over-limit indicates the switch is open.

If the high water level float switch remains open (stuck) even with a high water level, the pump will not start and water will continue to rise toward the high water level alarm probe. If the high water level float switch stays closed (stuck) even when the water level is low, this also indicates that it is defective and there will need to be a trip down to the bottom of the launch tube to replace it. Do not get tunnel vision though—a switch permanently open or closed, regardless of water level in the sump pit, can also be caused by a loose or broken wire or a short. Those are many of the ways you can use electrical checks to troubleshoot sump pump system SP–102. Now, let's look at some mechanical troubleshooting techniques.

Complete the content above before moving on.

Mechanical Troubleshooting

At times, you will find that all of the electrical portions of sump pump system SP–102 are operational, but water still will not pump to the topside of the LF. Here are some common mechanical problems that can cause this to happen.

Sump Pump Seized (Both Systems)

It is not uncommon for the sump pump motor to seize; typically, this is identified by a tripped circuit breaker in the LDB panel. If the circuit breaker is reset and the H-O-A switch is set to the HAND position, the seized pump would try to operate, draw excessive amperage for a short while, and then the circuit breaker will eventually trip again. A foreign object might be obstructing the sump pump impeller, so it is a good idea to use the following steps to attempt to run the pump in reverse before condemning it:

- Turn off the breaker to sump pump system SP–102 in the LDB panel, and use a meter to verify the absence of AC power in the control panel.
- Swap any two of the phase wires exiting motor starter M1, set the H-O-A switch to OFF, and then set the sump pump system SP–102 breaker in the LDB panel to ON.
- Set a clamp-on ammeter to AC amperage and place it around one of the sump pump phase wires that were swapped in the previous step.
- Set the H-O-A switch to HAND and then check the reading on the clamp-on ammeter.
    - If the amperage draw is consistently higher than 10 amps for approximately 10 seconds, set the H-O-A switch to OFF. The pump is seized and it will need to be replaced.
    - If the amperage draw settles in the single digits—roughly 3 to 8 amps—and the circuit breaker in the LDB panel does not trip again, the pump is no longer seized.
- If the pump ran correctly in the reverse direction, shut off the sump pump system SP–102 breaker in the LDB panel, swap the phase wires back to the normal configuration, and perform a functional checkout of sump pump system SP–102. A functional checkout should always be performed after discovering and eliminating an issue with the system in order to prove that the system is fully functional and that there are no other faults.

If the motor seizes up again when you run it in the correct direction, a trip to the bottom of the launch tube will be necessary to check for a physical obstruction and/or replace the sump pump.

Shorted Probes (Wing 1)

Since sump pump system SP–102 on a Wing 1 site only uses probes, many malfunctions can occur if the probes are shorted together artificially in any way. There are typically two ways that these probes can become shorted together:

1. Debris or corrosion caused by sump water on the metal probes can build up to the extent that it shorts two or more probes together.
2. If the launch tube has recently flooded, the small control box that all of the probes screw into may be full of water—this water will act the same as a full sump pit because it shorts all four probes together (fig 3–13).

There will be no indication of the common and stop probes being shorted together, but the sump pump will run if the start probe becomes shorted. Any residual water below the stop probe will be pumped out of the sump pit, and the sump pump will run 'dry' after that and eventually fail. Again, there will be no indication that this is happening if no team is already on site. Evidence of the failed pump will only reveal itself once the water level in the sump pit rises to the high water level alarm probe and a resulting GMR–29 fault reports.

You can find out which probes are shorted together by measuring resistance with your meter. Turn off the breaker to sump pump system SP–102 in the LDB panel, and use a meter to verify the absence of AC power in the control panel. Pins 3, 4, 5, and 6 on terminal board TB2 in the control panel correspond to the START, COMMON, STOP, and ALARM probes, respectively, in the sump pit. Tag and remove the wires, and then start performing resistance checks. If there is water in the box that the probes screw into, each probe will appear to be shorted to each of the other three probes even though there is no water in the sump pit.

If there is debris or corrosion shorting the probes together, all four or some combination of the four probes will appear to be shorted together. Remember, you would not have been sent to the site unless the high water level alarm probe was shorted to the common probe–– that is what would cause the GMR–29 fault alarm to report.

A trip to the bottom of the launch tube will be necessary to remedy the issue whether there is water in the top of the probe assembly or corrosion connecting the probes.

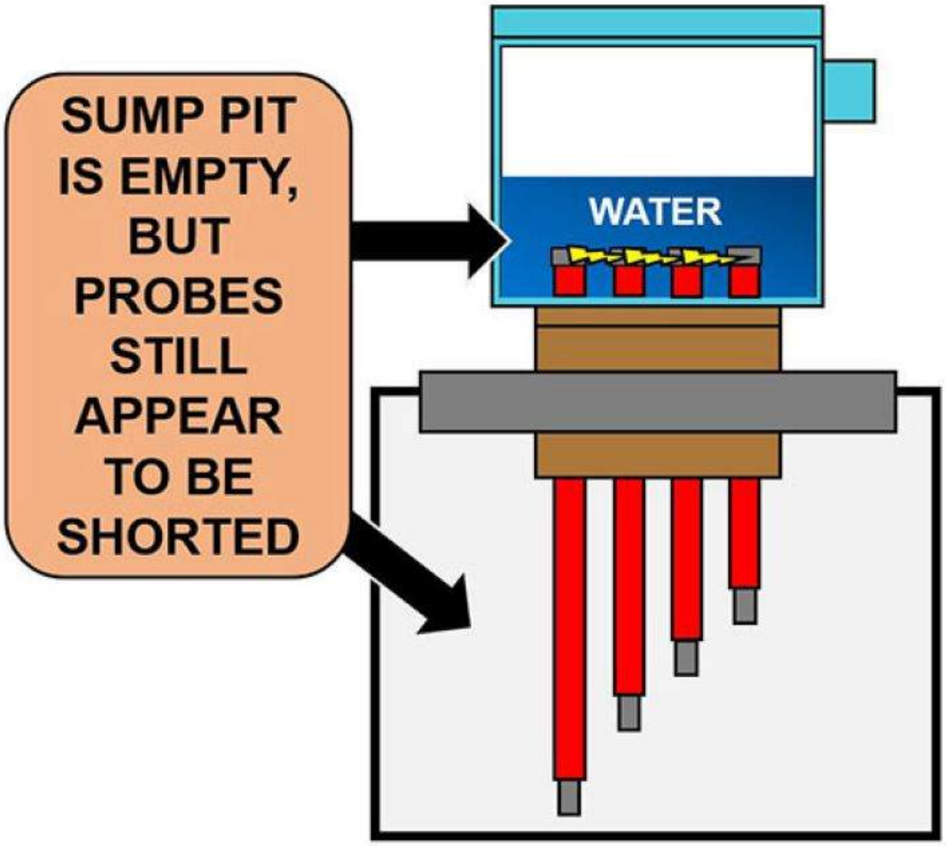


Figure 3–13. Probes Shorted by Water in Top of Probe Assembly (Wing 1).

Discharge Obstruction

An obstruction in the discharge line will prevent water from being pumped out of the sump pit even though the entire system is functioning correctly. This could typically occur several ways:

Topside Discharge Outlet Crushed Closed

It will be visually obvious if the discharge outlet has been crushed closed and GMR–5 and GMR–29 fault alarms will likely be reporting since the sump pits of both sump pump systems SP–103 and SP–102 are full of water. Unless the outlet is 100 percent crushed, you will still see water seeping out and possibly hear audible noises from water trying to escape.

Check Valve in the Discharge Line After the Sump Pump is Stuck Closed

There is a one-way check valve (fig 3–14) in the discharge line of sump pump system SP–102, several feet after the pump. As you know, the discharge lines for the two sump pump systems combine into a single main discharge line. Check valves are installed in the discharge lines so that neither sump pump can pump water into the other sump pump's pit—water can only exit either discharge line through the main line.

These check valves serve an important purpose, but they can also become stuck closed and prevent water from being removed from the sump pit. The check valve for sump pump system SP–102 is located at the bottom of the launch tube, and you will need to install a work cage in order to troubleshoot it.

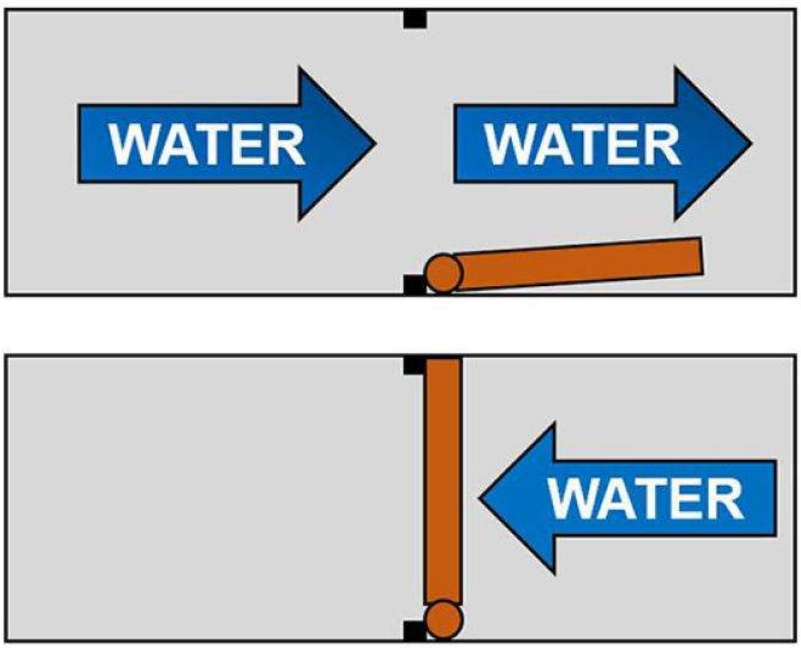


Figure 3–14. Check valve (one-way valve) operation.

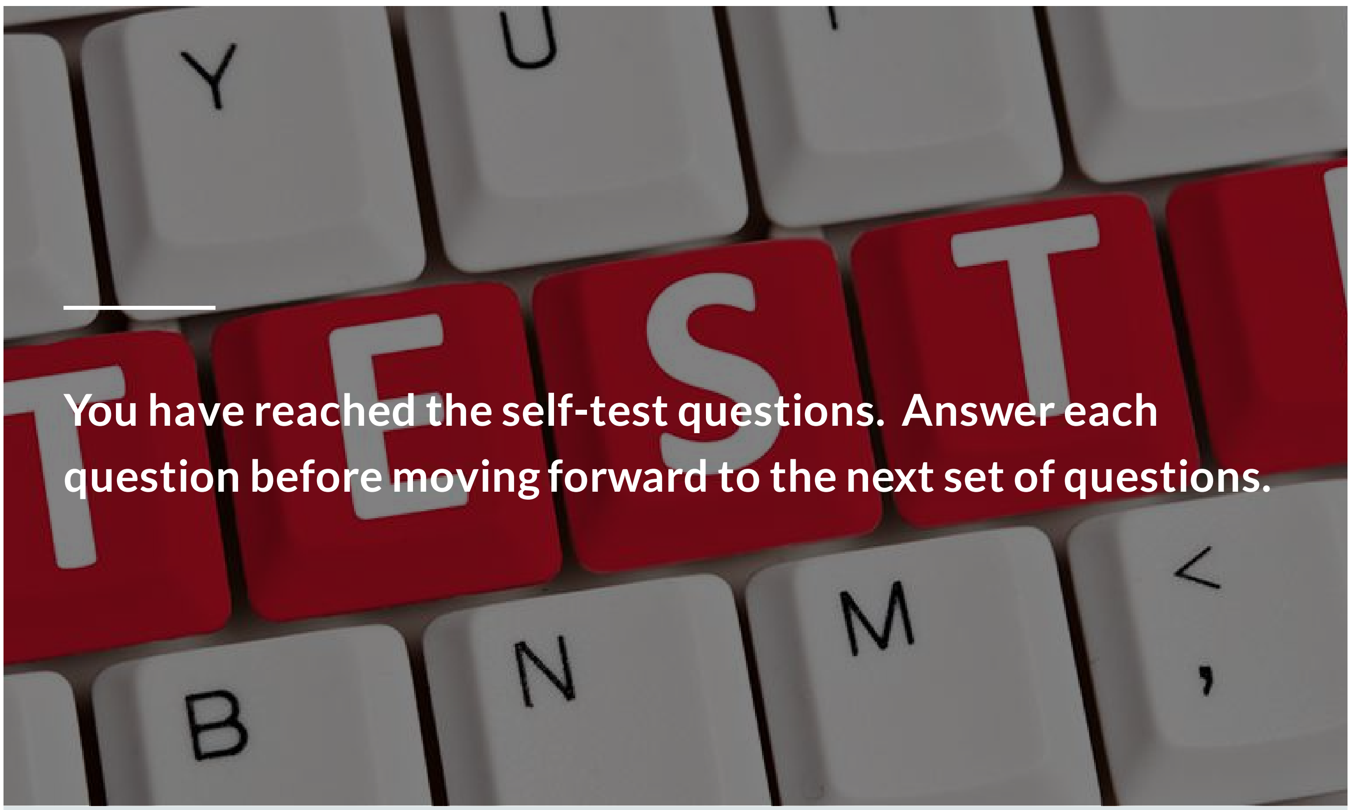
An Object or Debris Has Been Sucked Into the Sump Pump Inlet

This malfunction is typically very rare, and a trip to the bottom of the launch tube will be necessary to remove the obstruction.

An Underground Portion of the Discharge Line Has Collapsed

The LFs were built many decades ago, and buried metal sump pump discharge lines are constantly exposed to moisture from wastewater on the inside and ground water on the outside. If a discharge line has collapsed, it must be excavated to be repaired.

Complete the content above before moving on.



You have reached the self-test questions. Answer each question before moving forward to the next set of questions.

KNOWLEDGE CHECK TIME!

For the fill-in the blank questions, you will need to add (.) periods to the end of

the sentences.

Click here to answer the self-test questions pertaining to the launch facility wastewater disposal system familiarization.

1. Why is it sometimes difficult to determine if a GMR–5 is related to a malfunction in sump pump system SP–103?

Type your answer here

SUBMIT

2. What purpose do the LF sump pump systems serve?

Type your answer here

SUBMIT

3. How is the discharge line for sump pump system SP–102 routed to the topside of the LF?

Type your answer here

SUBMIT

4. Why is it acceptable to use a non-differentiating float switch as the tethered float in the sump pit of sump pump system SP–103?

Type your answer here

SUBMIT

5. Sump pump system SP–103 is responsible for which function?

Type your answer here

SUBMIT

6. Where does the LF dewatering well discharge the water that it collects?

Type your answer here

SUBMIT

Complete the content above before moving on.

Click here to answer the self-test questions pertaining to sump pump system SP–102 operation.

1. Why is sump pump system SP–102 different from nearly any other system on which you will work?

Type your answer here

SUBMIT

2. (T /F) Does the terminal board 2 panel supplies power to the sump pump system SP–102 control panel.

- ○ True.
- ○ False.

SUBMIT

3. In the Wings 3 and 5 sump pump system SP–102, which contacts must be closed in order for a GMR–29 to not be reporting?

Type your answer here

SUBMIT

4. In a normally functioning sump pump system SP–102 at Wings 3 and 5, what actions will occur when both low and high water level float switches are submersed under water?

Type your answer here

SUBMIT

5. What actions will occur when water comes in contact with the high water level alarm float located in the sump pit of sump pump system SP–102?

Type your answer here

SUBMIT

6. What actions will occur when water comes in contact with the LER floor sensor probe?

Type your answer here

SUBMIT

Complete the content above before moving on.

Click here to answer the self-test questions pertaining to the troubleshooting sump pump system SP–102.

1. Why should troubleshooting procedures and schematics be used hand-in-hand when troubleshooting sump pump system SP–102?

Type your answer here

SUBMIT

2. What will you have as a PMT technician that will aid you greatly in your troubleshooting efforts?

Type your answer here

SUBMIT

3. How much resistance should a serviceable motor winding show when performing resistance checks with a multimeter?

Type your answer here

SUBMIT

4. What two checks should you always perform on a motor's windings when troubleshooting for a possible open or short?

Type your answer here

SUBMIT

5. In the Wings 3 and 5 sump pump system SP–102, what will occur if contacts 4/6 of relay R1 fail to close after the sump pump has started running?

Type your answer here

SUBMIT

6. What must be swapped in order to run the sump pump of sump pump system SP–102 in reverse?

Type your answer here

SUBMIT

7. In the sump pump system SP–102 control panel, what pins on terminal board TB2 correspond to the START, COMMON, STOP, and ALARM probes in the sump pit?

Type your answer here

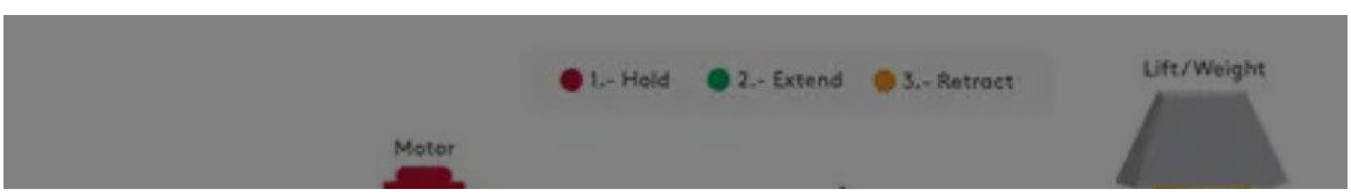
SUBMIT

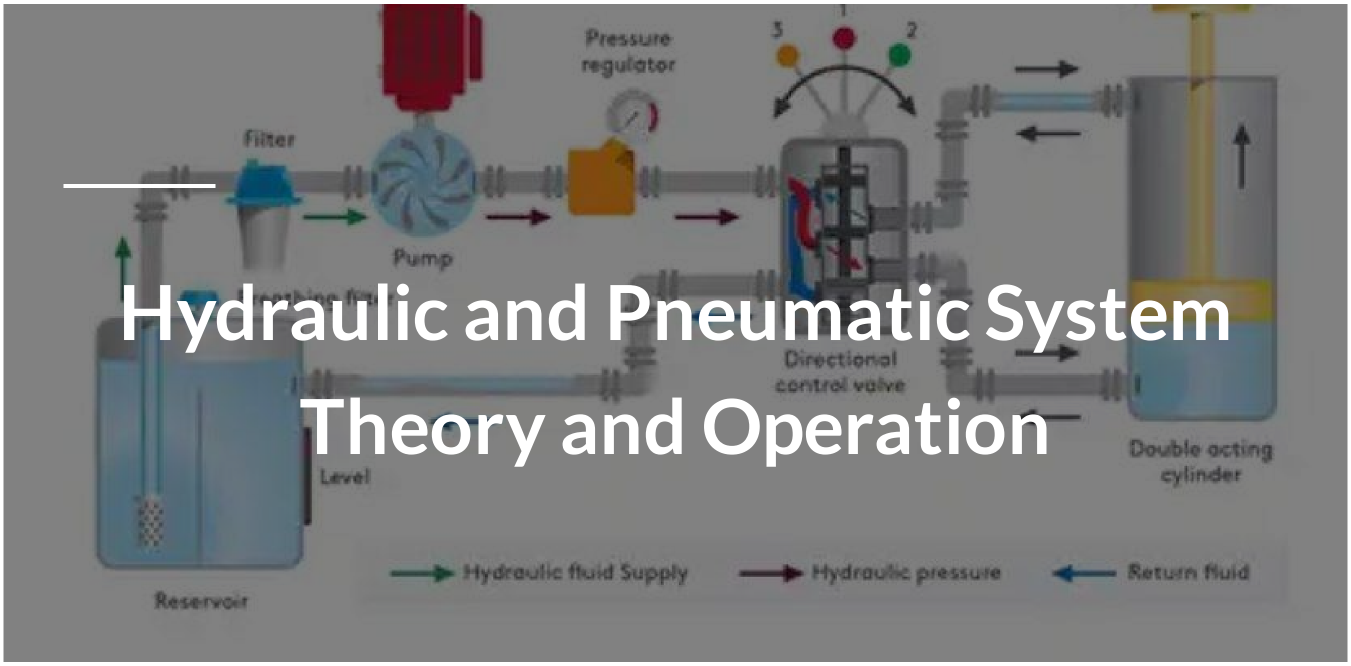
8. Why are check valves installed in the discharge lines?

Type your answer here

SUBMIT

Complete the content above before moving on.





Hydraulic and Pneumatic System Theory and Operation

Not very long ago, lever and pulley systems were the only way to physically lift or move any object that was too heavy for a person to move manually. Lucky for us, technology progressed and systems were invented that gave us the ability to multiply our input effort hundreds of times, and get work done that was previously impossible. The following lessons on hydraulic and pneumatic systems will provide you with a strong foundation on both the theory behind them as well as how they operate.

Figure 3–15. Hydraulic Automobile Jack.

Hydraulic Systems

Have you ever wondered how a small hydraulic car jack (fig 3–15) can lift the immense weight of an automobile simply by pumping the jack's handle? Have you ever seen construction equipment move many tons of dirt and rocks with ease? Hydraulic systems are the tools that make this possible, and in this lesson, we will focus on the fundamentals of how these systems operate.

Hydraulic System Theory

Hydraulic systems operate on the principle that a liquid cannot be compressed, and a force applied anywhere within a confined body of liquid will be transferred equally throughout all parts of that body of liquid (fig 3–16). The hydraulic system must be completely sealed from the atmosphere and be free from leaks to be fully effective.

As you can see in figure 3–16, downward pressure on the piston on the left side of the hydraulic system transfers through the liquid and over to the bottom of the piston on the right side of the system, forcing it upward. Simple, right?

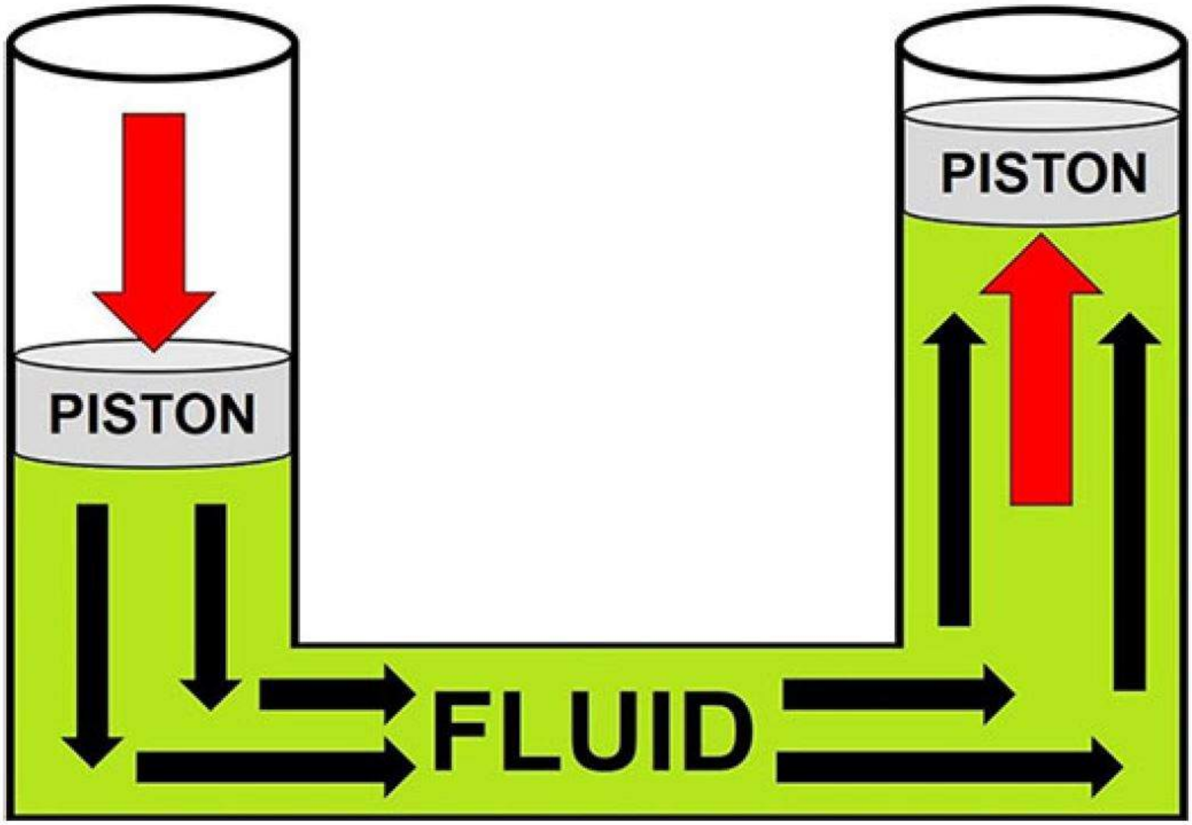


Figure 3–16. Simple Hydraulic System.

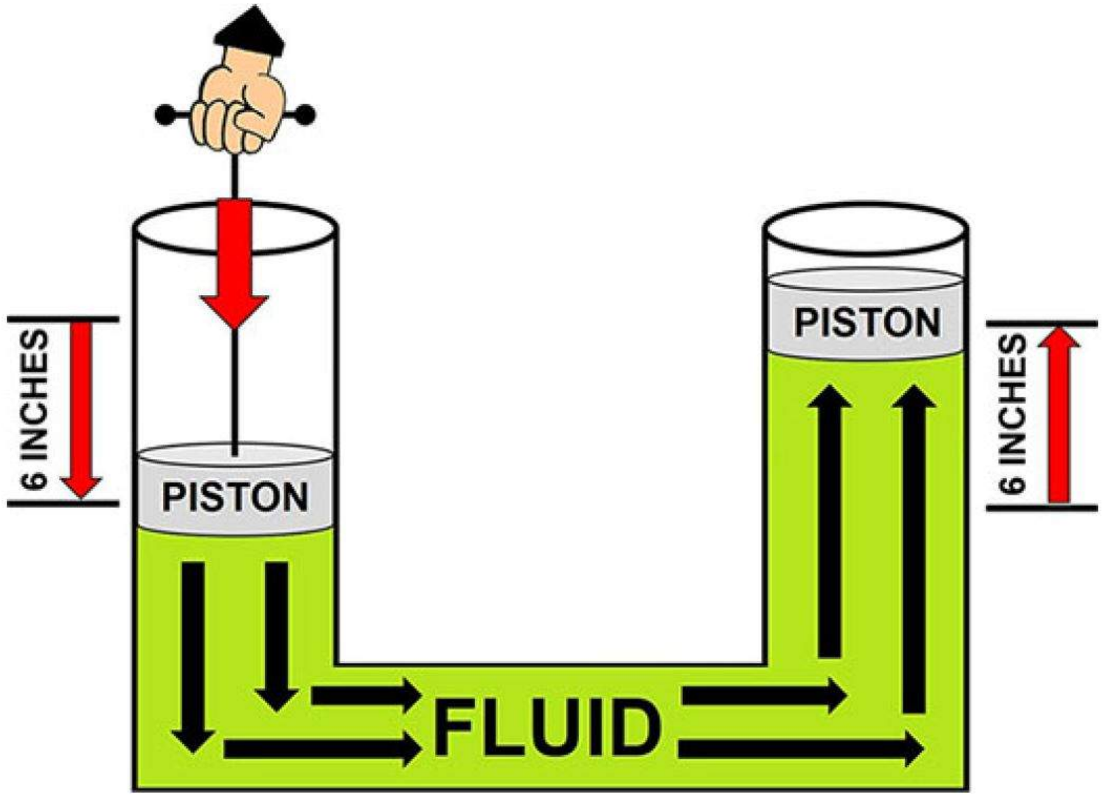


Figure 3–17. 1 to 1 Ratio Hydraulic System.

Hydraulic System Operation

As you have seen, hydraulic system theory is simple. Pressure on one part of a confined body of fluid is transferred to all parts of the body of fluid in equal amounts.

The two pistons in figure 3–17 have exactly the same dimensions and surface area, and the cylinders they move up and down in have the same dimensions as well. This means the exact amount of force applied to one side of the system is transferred to the other side of the system. The output piston moves exactly as far as the input piston. As an example, if the piston on the left is pressed downward a distance of 6 inches, the piston on the right will move upward exactly 6 inches. This hydraulic system would have a 1 to 1 (1:1) ratio, and the purpose of this particular configuration only exists to illustrate the very basics.

If the output piston only moves as far and with as much force as the input piston, what is the point? How can pumping the handle of the car jack with only the weight of a person's upper body lift an automobile that weighs 500 pounds? The primary function that a hydraulic system provides is to act as a force multiplier, and any tool that reduces the force needed to perform a task is considered the same. In order to answer the questions posed at the beginning of this paragraph, let's dig deeper into the attributes of a hydraulic system that allows it to actually multiply the input force.

The hydraulic system, in figure 3–18, is one where force is being multiplied, meaning the output force is greater than the input force. To accomplish this, the area of the input piston must be smaller than the area of the output piston. We are going to apply 100 pounds of force to the input piston, which has an area of two square inches 100 pounds of force divided by the two square inch area of the input piston equals 50 psi. This 50 psi of force is exerted equally throughout the entire body of the fluid, and applied to the larger 12 square inch area of the output piston.

Some quick math will reveal that 50 psi of force, multiplied by the 12 square inch area of the output piston, equals 600 pounds of lifting force exerted by the output piston. You have created 600 pounds of upward force, which will overcome the automobile's weight of 500 pounds. Note that 500 pounds of force would not be adequate to lift the automobile because the input force would not be greater than the weight of the automobile; the two forces would be equal. If you would like to research this subject further, this information is derived from Pascal's law.

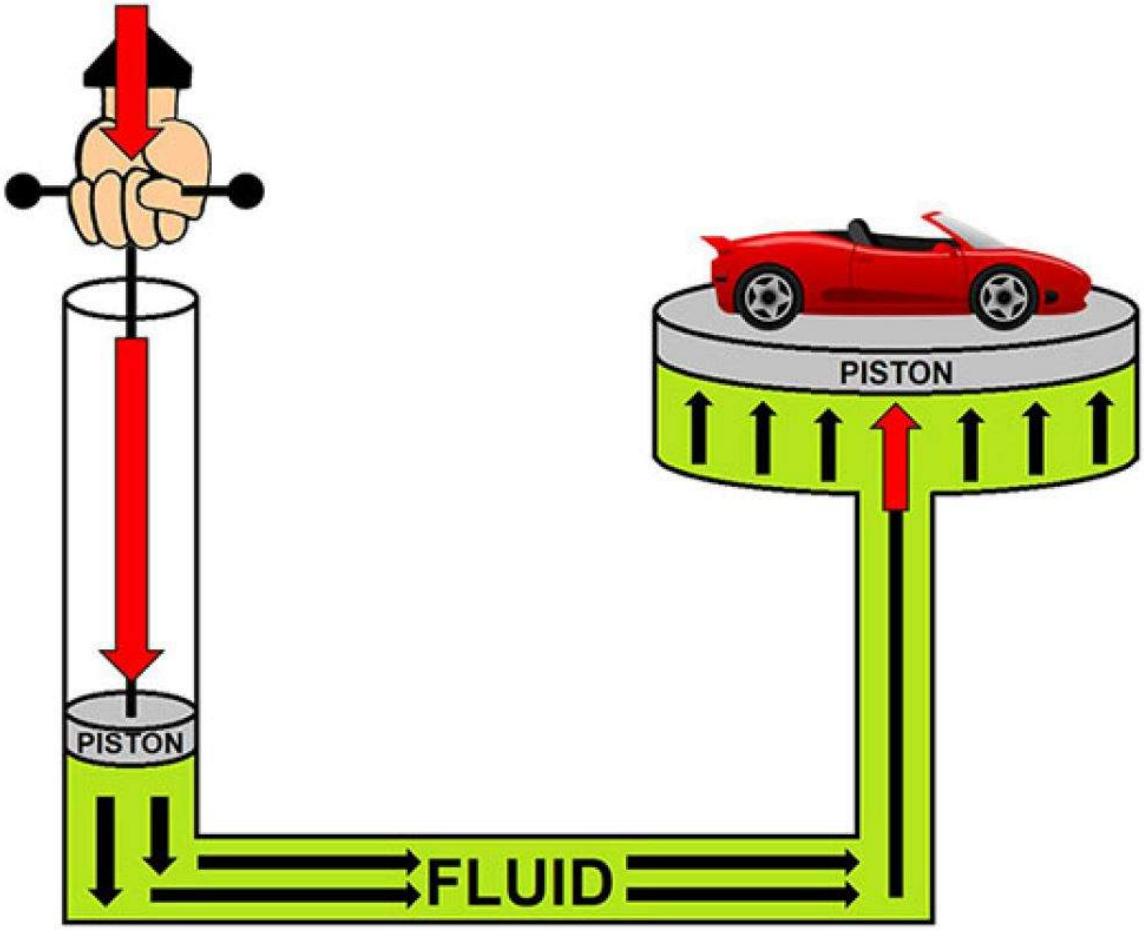


Figure 3–18. Multiplication of Effort Within a Hydraulic System.

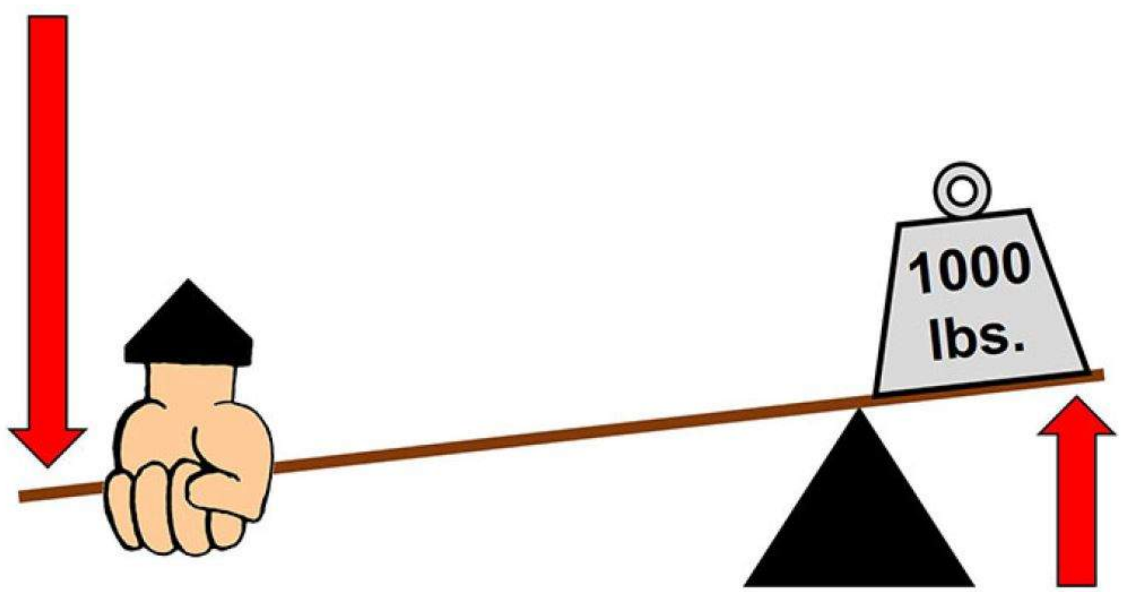


Figure 3–19. Lever System.

Due to the difference in area between the input and output pistons, the output piston will only move a fraction of the distance the input piston moves. To find this ratio, divide the area of the larger piston by the area of the smaller piston. The 12 square inch area of the output piston, divided by the 2 square inch area of the input piston, equals six, or a 6:1 ratio. Now you know that in order for the output piston to move just one inch, the input piston will need to move six inches. If you wanted to raise your automobile five inches, your jack handle would need to move 30 inches! This is impractical, which is why hydraulic jacks have been designed to be pumped many times versus the handle needing to move several feet.

The same concept is demonstrated using a lever on a fulcrum to lift a heavy weight (fig 3–19). Notice how the user must move the lever a very far distance, but the 1,000-pound weight only moves upward a very short distance. The input piston moves a farther distance than the output piston; the side of the lever to which force is applied travels farther than the object being lifted by the lever. This enables the user to move heavy objects that they could never have moved using their own strength.

Figure 3–20. Hydraulic Actuators on Heavy Equipment.

The automobile jack is a great example of a hydraulic system in action, but not all systems are operated by hand. For example, construction equipment (fig 3–20) uses motor driven hydraulic pumps that actuate complex systems capable of lifting many tons. You will learn about complex hydraulic systems in your 7-level career development course.

When working with hydraulic systems, there are certain precautions that you and your team members should be made aware. These systems use fluid under extreme pressures to perform work, and these pressures may be high enough to puncture skin. If you discover a leak while the system in operation, never attempt to plug the leak or cover it with another object, such as tape or a cloth. Remove power from the system or discontinue its use, and let your task supervisor know that the system is leaking.

If the need arises to clean up hydraulic oil, be sure to use the proper personal protective equipment (PPE), and dispose of soiled rags and absorbent material in accordance with your technical orders or other appropriate guidance.

Hydraulic System Precautions

Complete the content above before moving on.

Figure 3–21. Bicycle Pump.

Pneumatic Systems

Pneumatic systems use principles similar to hydraulic systems. However, instead of using fluid pressure to do work, pneumatic systems use a pressurized gas. A bicycle pump (fig 3–21) is a great example of a simple pneumatic system at work.

Note that throughout this lesson the terms gas and air are used interchangeably.

Click on each (+) sign below to learn about pneumatic theory, operation, and precautions.

Pneumatic System Theory —

Pneumatic systems operate on the same principles hydraulic systems do; however, a gas (usually air) is used as the medium to accomplish the work. Unlike a liquid, air can be compressed into a smaller volume––for example, you inflate a football, basketball, bicycle tube, or even a balloon. You take the pressure of the outside air, and then compress it into a smaller volume inside of the inflatable object. In the simplest of terms, pneumatic systems perform work by using pressurized gas in a confined area to apply force to an object (fig 3–22).

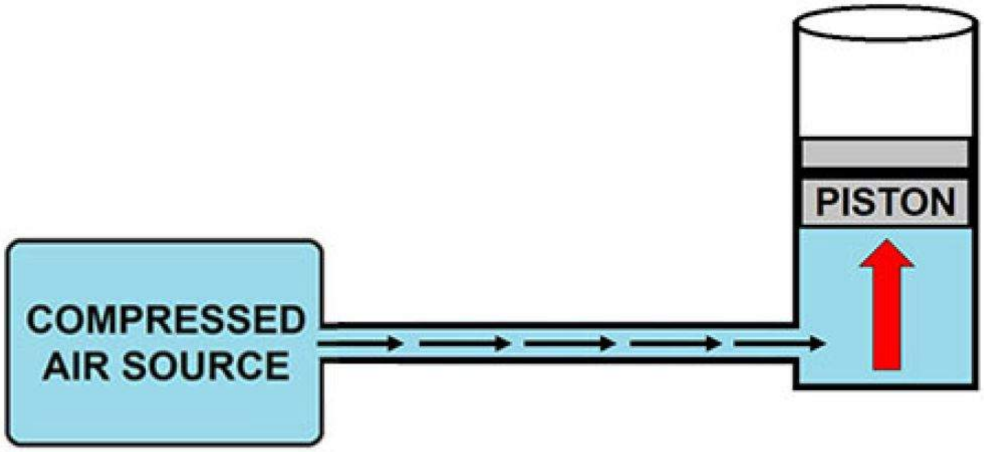


Figure 3–22. Basic pneumatic system.

Pneumatic System Operation (1)

The input force in a pneumatic system is equal to the pressure of the compressed air source. The compressed air source used in pneumatic systems is typically at a constant pressure. Let's use 25 psi as an example, which is then applied evenly throughout the confined system. A valve or other metering device will allow the air pressure to pass through and actuate whatever tool you are using to perform the work. When a pneumatic system is at rest (i.e. not performing work), there is no path between the compressed air source and the mechanism that would be actuated by the compressed air (fig 3–23). For example, the fluid in a hydraulic system only transfers force. A compressed gas, on the other hand, will only continue to exert force until it equalizes with atmospheric pressure.

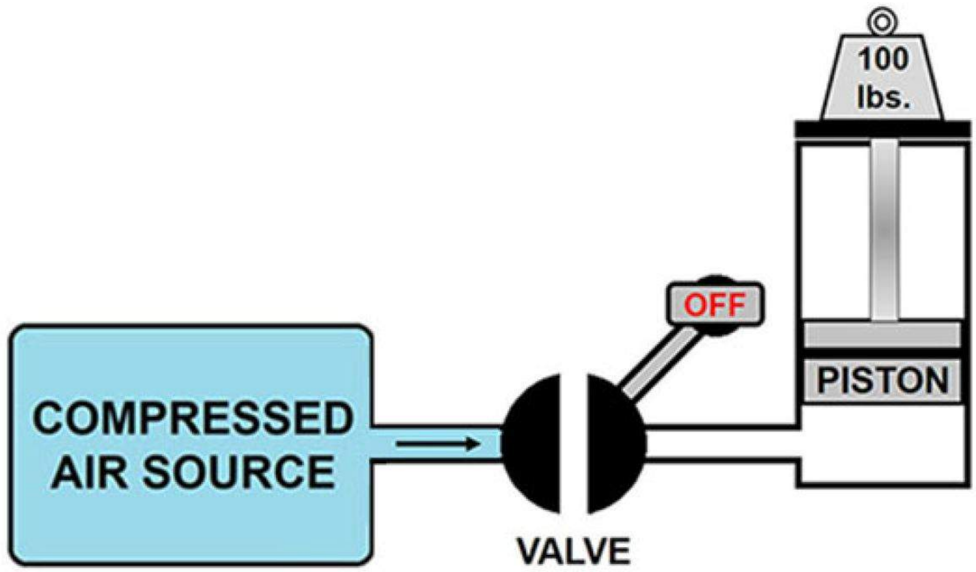


Figure 3–23. Pneumatic system at rest.

Pneumatic System Operation (2)

When air pressure is needed to actuate the mechanism performing the work, the valve or metering device will allow the compressed air to flow through (fig 3–24). If a pneumatic system is being used on an assembly line in a factory, for example, this process could happen several times per second. Speed of actuation is where pneumatic systems outshine hydraulic systems. Pneumatic systems can actuate much quicker because a gas is much less resistant to flow than a fluid. Pneumatic systems are used typically in factories and processing plants where quick, precise, and repetitive motions are needed.

A key item to remember is typically, there is no “back and forth” flow of air in a pneumatic system. The air used to perform the work is vented to the atmosphere once it has performed the work, and new compressed air is supplied by the compressed air source. This venting is what makes pneumatic systems much louder than hydraulic systems. Good examples of this are the pneumatic drill that your dentist uses and the pneumatic impact wrench used in mechanic’s shop. Both produce high levels of noise. You can apply some of the same math from Pascal’s law to the pneumatic system in figure 3–24. To move the 100-pound weight upward, more than 100 pounds of force will need to be applied to the bottom of the output piston.

Let’s say the compressed air source supplies a constant 25 psi of pressure throughout the system. If the piston has an area of two square inches, you would have 25 psi of pressure acting on those two square inches, 25 multiplied by two equals 50. Fifty pounds of force is not enough to lift the 100-pound weight. Even if you increased the area of the piston to four square inches, the weight would not move. The reason for this is 100 pounds of force will only equal the weight to be lifted. Just like with the hydraulic car jack in the last lesson, the upward force must be greater than the downward force being exerted by the object you are trying to move. If a piston with a five square inch area were used, multiplied by the 25 psi supplied by the compressed air source, 125 pounds of force would be applied to the bottom of the piston. The 125 pounds of upward force will slowly, but surely, move the 100-pound weight. The greater the difference between the applied force and the force required, the faster the work will be accomplished.

As an example, think of yourself pushing a broken down automobile down a flat road. Alone, you can probably provide enough force to get the car rolling very slowly. However, if five of your friends join you behind the automobile to help, it would get rolling much easier, and you could get it rolling at a faster speed as well.

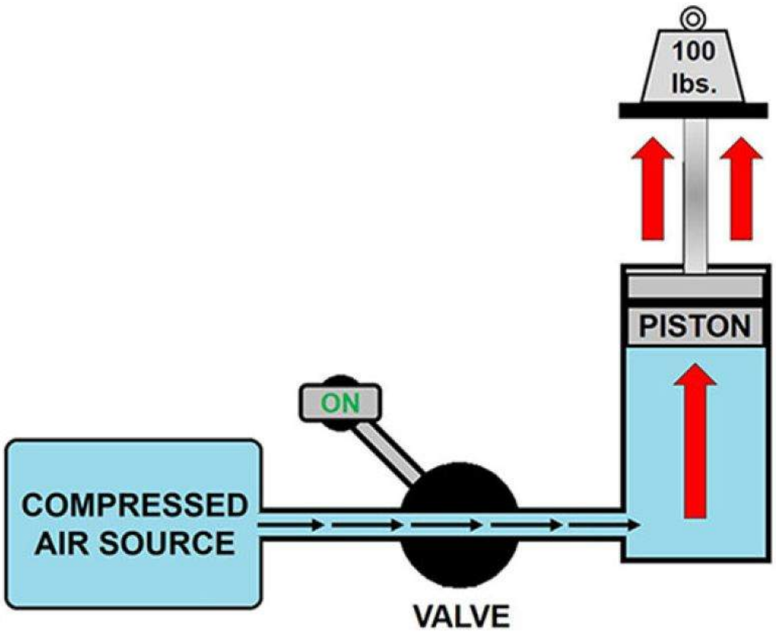
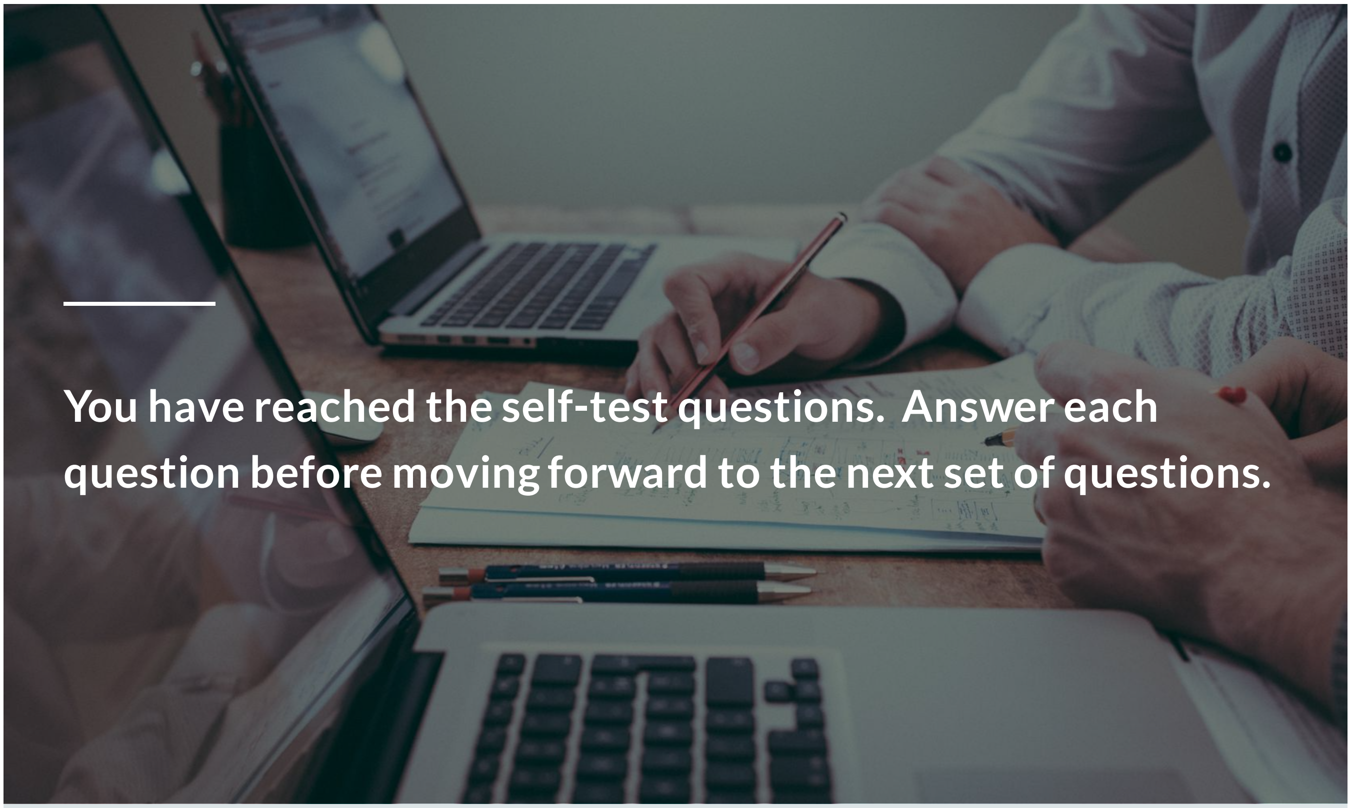


Figure 3–24. Pneumatic system performing work.

Pneumatic System Precautions

There are dangers inherent to pneumatic systems you and your team members should be made aware. If you discover a leak in a pressurized air line, never attempt to cover or repair it. Remove power from the system or discontinue its use, and let your task supervisor know that you have discovered a leak. Pressurized air can stir up dust and debris, can accelerate objects to high speeds, and can be very loud. You may even use compressed air for cleaning. Always be sure to use the PPE prescribed in your technical orders, such as eye and hearing protection. Compressed air, even at low pressure, should never be used to remove debris from skin or clothing. The reason for this is that small air bubbles may enter even perfectly healthy skin because it is porous; cuts or wounds increase the likelihood. These air bubbles can then make their way to the heart or brain, and may cause personnel injury or death.

Complete the content above before moving on.



You have reached the self-test questions. Answer each question before moving forward to the next set of questions.

KNOWLEDGE CHECK TIME!

For the fill-in the blank questions, you will need to add (.) periods to the end of the sentences.

Click here to answer the self-test questions pertaining to the hydraulic systems.

1. What attributes must a hydraulic system possess to be fully effective?

Type your answer here

SUBMIT

2. What characteristics would a 1:1 ratio hydraulic system possess?

Type your answer here

SUBMIT

3. Why would 100 pounds of downward force on one side of a hydraulic system fail to move a 100-pound weight on the output side of the system?

Type your answer here

SUBMIT

4. In what ways are a lever and a fulcrum similar to a hydraulic system?

Type your answer here

SUBMIT

5. If you discover a leak in a hydraulic system, what should you never attempt to do?

Type your answer here

SUBMIT

Complete the content above before moving on.

Click here to answer the self-test questions pertaining to the pneumatic systems.

1. What happens to a volume of air when it is compressed?

Type your answer here

SUBMIT

2. Where does the compressed air or gas in a pneumatic system go after it has performed work?

Type your answer here

SUBMIT

This completes Lesson 3. You can find the answers to the self-test questions in the Module 3 table of contents.

Module 3: Self-Test Question Answers

Lesson 1: Internal Combustion Engine Systems

401. Internal Combustion Engine Components and Operation

1. Compression rings aid in creating an airtight seal between the piston and the cylinder. Oil rings scrape oil off the cylinder walls.

2. A passage bored into an engine block to house the piston.

3. Allow intake air to be drawn in and burned exhaust gases to be expelled from cylinder.

4. Its mass and weight smooth out engine operation by keeping the crankshaft spinning between combustion pulses. It also enables initial startup of the engine because the teeth on the engine's starter engage with the teeth on the circumference of the flywheel to rotate the crankshaft.

5. The controlled explosion that results from the heated air and fuel mixture forces the piston downward and causes the crankshaft to rotate.

6. Hot intake air from the turbocharger goes through the charge air cooler. Air from an external source blows across the charge air cooler and removes heat.

7. By either an electric pump that turns on and shuts off automatically, or a hand-driven manual pump.

8. Route spent exhaust gases out of the cylinder and away from the engine.

9. Draws oil in from the engine's crankcase, pressurizes it, and then sends it out through oil galleries.

10. It opens to allow coolant in the engine block to flow to the radiator.

402. Engine Starting, Running, and Stopping

1. Three hours.

2. The DEU runs with no load placed on it. Useful for troubleshooting.

3. The DEU is exercised at 100 percent of its rated capacity once a year in order to prevent the buildup of carbon and other deposits.

4. It commands the electronic fuel injectors to stay open longer, which adds more fuel to the cylinders.

5. If the teeth on the flywheel are passing by the magnetic pickup too slowly, fuel is added to increase rpm. If the teeth are passing the pickup too fast, fuel is reduced, which reduces engine rpm.

403. Auxiliary Engine Systems and Equipment

1. Switches open or close when a predetermined high or low limit is met and send either voltage or no voltage. Sensors detect a wide range of pressures, temperatures, and so forth, and send varying voltages based on what it is sensing.

2. Mechanical damage.

3. The electronic speed switch sends a signal to the MPP to initiate shutdown.

4. The needle in the temperature switch gauge will touch high side contact, which will signal the MPP to shut down the DEU.

5. PCC panel, DEU interface panel, DEU circuit breaker panel.

6. Main circuit breaker, voltage regulator, voltage adjust rheostat, frequency test receptacle, and elapsed time meter.

404. Generators, Exciters, and Voltage Regulators

1. An electrical current induced into any conductor passed through a changing magnetic field.

2. Change the amount of current supplied to the electromagnet.

3. Exciter rotor, rectifier, main rotor.

4. Provide the amount of AC voltage required for the main rotor to produce a desired final generator output voltage.

5. To power site loads because this is the generator’s final output voltage.

6. Change the engine rpm.

Lesson 2: Power Systems

405. Minuteman Power Processor Function and Operation

1. Provide a visual indicator of the status of commercial and/or standby power and any faults that may be present.

2. It is especially useful for running the DEU so that you can troubleshoot it.

3. Commercial power is disconnected and the DEU is started.

406. Automatic Switching Unit Function and Operation

1. PTS cabinet.

2. K1 for commercial power, and K2 for standby power.

3. SIN line.

407. Launch Facility Commercial and Standby Power Contactor Function and Operation

1. Commercial power on relay K3.

2. Commercial power on transistor Q3.

3. Commercial/standby power off relay K5.

4. Commercial/standby power off transistor Q2.

408. Missile Alert Facility and Launch Facility Power Distribution Systems

1. Commercial power main circuit breaker.

2. One each for phases A, B, and C, and one for the neutral bus.

3. All areas of the MAF, to include the topside and the LCC.

4. The facility manager must start it 5. It is the sole source of primary power for the LER.

Lesson 3: Wastewater Disposal and Hydraulic and Pneumatic Systems

409. Launch Facility Wastewater Disposal System Familiarization

1. There are several other faults that also use the GMR–5 circuit; sometimes this makes it difficult to pinpoint whether this is a fault with the sump pump or another piece of equipment.

2. Pump liquid out of and away from the bottom of the sump pit.

3. It runs up the launch tube wall and combines several feet below ground level with the discharge line from sump pump system SP–103.

4. Because the tethered float only initiates a GMR fault alarm and does not cause the pump to run.

5. Removing wastewater that has accumulated in the sump pit at the bottom of the support building.

6. Outside the LF security gate, usually next to the access road.

410. Sump Pump System SP–102 Operation

1. Because its control panel is in the lower LER, while the pump, float switches, and liquid level probes are much further down at the bottom of the launch tube.

2. False. LDB.

3. Contacts 3/4 of both relays R3 and R4.

4. The sump pump will energize and empty the sump pit.

5. Contacts 3/4 of relay R3 open to break the GMR–29 fault alarm loop and initiate a GMR–29 alarm fault.

6. Relay R4 senses that 13 VAC is returning on the ground circuit, which deenergizes the coil of relay R4. Contacts 3/4 of relay R4 open to break the GMR–29 fault alarm loop, which sends a GMR–29 fault alarm to the LCC.

411. Troubleshooting Sump Pump System SP–102

1. So that you not only know what you are checking, but why you are checking it.

2. A tank full of water on your trailer.

3. Some resistance––not too low but not extremely high or over limit.

4. Phase-to-phase resistance checks and phase-to-ground resistance checks.

5. The coil of relay R1 will deenergize as soon as the high-level float opens because the holding circuit for relay R1 was not established.

6. Any two phase wires.

7. Pins 3, 4, 5, and 6, respectively.

8. So that neither sump pump can pump water into the other sump pump's pit.

412. Hydraulic Systems

1. The system must be completely sealed from the atmosphere and have no leaks.

2. The exact amount of force that was applied to one side of the system would be transferred to the other side of the system. The output piston would move exactly as far as the input piston.

3. Because the input force would be equal to the weight of the object, but would not be enough to actually move the object in the opposite direction.

4. The input piston will move a farther distance than the output piston; the side of the lever that force is applied to will travel farther than the object being lifted by the lever.

5. Never attempt to plug the leak or place an object over it.

413. Pneumatic Systems

1. The volume of air becomes smaller.

2. Typically, the air or gas is vented to the atmosphere; the compression source provides more compressed air or gas.

This is the end of the self-test answers for Module 3.