

## **Fuel System**

### **Screen 1:**

#### **Welcome Screen:**

Welcome to the Fuel System module of the ES44AC/DC Mechanical Systems Advanced course.

### **Screen 2:**

#### **Introduction to Fuel System:**

In this module, you will learn how to inspect and maintain the components of the fuel system in a running repair environment.

At the end of this module, you will be able to:

- State the purpose and location of the major components of the fuel system.
- Describe how diesel flows through the fuel system.
- Describe the abnormal operating condition detection strategies used in the fuel system.
- Describe how to check and adjust the fuel supply pressure.
- Describe how to remove and install the fuel filter elements.

### **Screen 3:**

#### **Disclaimer:**

Please note that this module is for training use only. For complete details of inspecting and maintaining the components of the fuel system, refer to customer-specific drawings, manuals, and procedures.

### **Screen 4:**

#### **Components of the Fuel System:**

The fuel system in an ES44AC/DC locomotive serves two purposes. The primary purpose is to provide fuel to the engine for combustion, and the secondary purpose is to lubricate and cool the high-pressure fuel equipment. A few major components that comprise the fuel system are the fuel tank, fuel transfer pump, fuel manifold.

### **Screen 5:**

#### **Fuel Tank:**

Located on the underside of the locomotive platform between the trucks, the fuel tank holds the fuel supply for the diesel engine.

### **Screen 6:**

#### **Fuel Transfer Pump:**

Located in the radiator cab on the Engineer's side, the fuel transfer pump circulates a near-constant supply of fuel through the fuel system.

**Screen 7:****Fuel Manifold:**

Mounted on the end of the fuel filter assembly, the fuel manifold contains a heater and a thermostatic valve to heat cold diesel fuel. Diesel fuel tends to gel when cold, and the fuel manifold helps to prevent the filters from clogging caused by this condition.

**Screen 8:****Components of the Fuel System (Cont'd):**

The other major components of the fuel system are fuel filter assembly, high-pressure fuel equipment, regulating valve.

**Screen 9:****Fuel Filter Assembly:**

Located in the radiator cab adjacent and below the combustion air filter compartment, the fuel filter assembly removes contaminants larger than 5 microns from the fuel. This protects the engine's high-pressure fuel equipment.

**Screen 10:****High-Pressure Fuel Equipment:**

Located on each power assembly on the engine, the high-pressure equipment includes high-pressure pumps, high-pressure lines, and injectors. This equipment takes the low-pressure fuel from the fuel tank, increases the pressure, and supplies it to the power assemblies as governed by the Engine Control Unit (ECU).

**Screen 11:****Regulating Valve:**

Mounted on the left side of the engine below the L1 power assembly, the regulating valve provides backpressure in the fuel lines for the high-pressure fuel pumps. This ensures sufficient filling of the high-pressure pumps and helps prevent cavitation in the pumps.

**Screen 12:****Sensors of the Fuel System:**

The fuel system consists of two sensors.

**Screen 13:****Engine Fuel Temperature Sensor (EFT):**

Located in the fuel line that crosses over the Integrated Front End (IFE) cover of the engine, the EFT sensor measures the temperature of the fuel supplied to the engine and provides the temperature information to the ECU.

**Screen 14:****Engine Fuel Pressure Sensor (EFP):**

Located in the fuel line connected to the regulating valve, the EFP sensor measures the pressure of the fuel supplied to the engine and provides the pressure information to the ECU.

**Screen 15:****Fuel Flow Path through the Fuel System:**

So, how does fuel flow through the fuel system of an ES44AC/DC locomotive? The fuel system can be divided into four functional sections: suction, low-pressure supply, high-pressure supply, and return/regulating section. First, an electrically driven fuel transfer pump draws the fuel from the fuel tank in the suction section. The fuel pump is turned on prior to the engine running to prime, or pressurize, the fuel system. All of the fuel system is normally pressurized except for the suction side of the fuel transfer pump. If there is a leak on the suction side of the piping, the result would be air entering the fuel supply, which could be indicated by a loss of suction pressure. The location of the leak would be in the suction or supply side piping that runs between the fuel tank connection, which is located on the Engineer's side of the locomotive, and the fuel transfer pump inlet connection. A leak anywhere else in the system would be indicated by the presence of leaking fuel.

**Screen 16:****Fuel Flow Path through the Fuel System (Cont'd):**

Under normal operating conditions, the fuel transfer pump provides an output flow rate of 12.75 GPM at Low Idle engine speed.

**Note:** The fuel transfer pump contains an internal pressure relief valve, which protects the pump if the output pressure exceeds 130 psi.

For example, if the fuel filter elements become dirty or clogged, the pressure at the pump outlet rises. When the pressure exceeds 130 psi, the relief valve opens and diverts approximately 4.75 to 8.75 GPM of fuel back to the tank. From the fuel transfer pump outlet, the low-pressure fuel is sent to the fuel manifold. The manifold contains a fuel heater and a thermostatic mixing valve. The fuel first flows through the fuel heater, which uses water from the split cooling water system to heat the fuel. This is necessary because the cold diesel fuel tends to wax and become thick and slushy. The thermostatic mixing valve regulates the outlet fuel temperature. The thermostatic valve is normally open, and the fuel flows from the fuel heater through the valve until the main flow temperature reaches 75°F. At this point, the valve starts to close, causing cold fuel from the fuel tank to mix with the warmer fuel from the fuel heater. When the fuel temperature reaches 85°F to 87°F, the valve closes fully, and the fuel flow bypasses the fuel heater. From the fuel manifold, the fuel flows to the fuel filter assembly. The fuel filter assembly consists of two tanks, or canisters, and each tank contains a three-piece filter element. The filter elements remove contaminants larger than 5 microns from the fuel. From the

fuel filter assembly, the fuel flows to each of the 12 high-pressure pumps on the engine by means of a circular low-pressure supply header. The supply header ensures that the fuel is equally distributed to each high-pressure pump.

#### **Screen 17:**

##### **Fuel Flow Path through the Fuel System (Cont'd):**

The high-pressure (HP) pumps are piston-type pumps that are driven from the camshaft at each power assembly. These pumps take fuel from the low-pressure supply header, pressurize it up to 23,000 psi, and send it to the injectors through the high-pressure fuel lines. The ECU governs the timing and amount of fuel delivered by each HP pump by opening and closing a solenoid located on the pump. When an HP pump is not pressurizing the fuel for the injection process, the solenoid on the HP pump is open. This allows the fuel from the low-pressure supply header to pass through the HP pump to the low-pressure return header. The return header runs parallel and under the low-pressure supply header to a regulating valve. The regulating valve is normally set to 90 psi with the engine at low idle. It provides backpressure in the low-pressure fuel lines to the HP pumps. A certain amount of pressure or restriction ensures sufficient filling of the HP pumps and helps prevent cavitation or loss of suction in the HP pumps. Fuel from the regulating valve drains back to the fuel tank. In addition, two gravity drain headers are located on each side of the engine. A small amount of fuel flows through each HP pump to lubricate and cool its internal parts. This fuel then drains through the drain header back to the fuel tank.

#### **Screen 18:**

##### **Detection Strategies:**

Unlike protection strategies used with the split cooling water system and the lubricating oil system, abnormal operating condition detection strategies for the fuel system do not protect the diesel engine from damage. Instead, they detect an abnormal condition and report the incident. No restriction is placed on the locomotive or the diesel engine.

#### **Screen 19:**

##### **Low Fuel Supply Temperature Detection:**

If the fuel supply temperature measured by the EFT sensor is below 60°F for 30 seconds, and the engine water inlet temperature measured by the EWIT sensor has been above 140°F for 60 minutes, an Engine Fuel Temperature Low Incident is logged. This incident clears if the fuel temperature is above 65°F for 30 seconds.

#### **Screen 20:**

##### **Low Fuel Supply Pressure Detection:**

If the fuel supply pressure measured by the EFP sensor is below 30 psi for 30 seconds with the engine running, an Engine Fuel Pressure Low Incident is logged. This incident clears if the fuel pressure is above 50 psig for 30 seconds with the engine running.

**Screen 21:****Operational Details:**

Let's now look at the operational data for the fuel system.

**Screen 22:****System Capacities:**

The fuel tank can hold 5300 gallons of fuel. Of this, 4826 gallons is considered usable capacity. 90 to 95 gallons is sectioned off for waste fluid retention, and the remaining space is for any fuel expansion due to temperature changes.

**Screen 23:****Monitored Parameters:**

To aid maintenance personnel in monitoring the fuel system, monitored parameters are available on a Smart Display in Level 3 access.

**Screen 24:****Self-Tests:**

Self-Test 300, initiated by means of a Smart Display, can be used to test and activate the fuel transfer pump.

**Screen 25:****Normal Operating Temperatures and Pressures:**

The table displays normal expected operating temperatures and pressures for the low-pressure fuel flowing to the engine.

**Screen 26:****Running Maintenance Schedule:**

Engineering recommends that you inspect the fuel system daily to ensure trouble-free operation. During daily maintenance of the system, with the engine at idle, make a visual inspection of the fuel tank, engine, fuel transfer pump, fuel manifold, fuel filter tanks, regulating valve, high-pressure equipment, including HP pumps, HP fuel lines, and injectors, and all system piping for fuel leaks. Make corrections as necessary. Replace the fuel filter elements every 184 days.

**Screen 27:****System Pressure Checks:**

A normal fuel supply pressure reading is between 88 and 92 psi when the engine is running in low idle (i.e., at 335 RPM) and the fuel filters are new. The pressure reading decreases as the engine load increases or as the filters become dirty or clogged. Check the pressure of the low-pressure fuel supply to the high-pressure pumps in two ways.

**Screen 28:****Pressure Gauge:**

Read the pressure by attaching a pressure gauge of 0 to 200 psi range to the quick-disconnect fitting that is located next to the fuel regulating valve.

**Screen 29:****Smart Display:**

Read the pressure by viewing the Locomotive Monitor Screen on a Smart Display.

**Screen 30:****System Pressure Adjustments:**

Typical steps to adjust the pressure of the low-pressure fuel supply are as follows: Ensure that new fuel filter elements have been installed in the fuel filter canisters. Make sure that the fuel system is primed and free of air. Let the engine run until it drops to Low Idle speed (335 RPM).

1. Attach a pressure gauge of 0 to 200 psi range to the quick-disconnect fitting that is located next to the fuel regulating valve.
2. With the engine operating at Low Idle, loosen the adjusting locknut on the regulating valve, then turn the adjusting screw in to increase pressure or out to decrease pressure until 88 to 92 psi is displayed on the gauge.
3. Tighten the adjusting locknut on the regulating valve, then recheck the reading on the gauge.

**Note:** If the reading is incorrect, repeat steps 2 and 3. If the reading is correct, remove the gauge from the quick-disconnect fitting.

**Screen 31:****Fuel Filter Element Removal:**

The fuel filter assembly removes contaminants larger than 5 microns from the fuel. This protects the engine's high-pressure fuel equipment. The fuel filter assembly is made up of two tanks, or canisters, and each tank contains a 45-inch, three-piece filter element. The two parallel fuel filter tanks are located in the radiator cab adjacent and below the combustion air filter or baggy filter compartment. Access is from the Helper's side of the locomotive. Typical steps to remove the fuel filter elements are as follows:

1. Shut down the engine and open the fuel pump circuit breaker.

**Warning:** To prevent personal injury and potential equipment damage, ensure that the engine cannot be started. Open the Locomotive Battery Switch. Also, open the Fuel Pump Circuit Breaker, and apply a warning tag to the Engine Control Switch.

2. Open the fuel filter drain valve, then open the vent valve, which is located above the top fuel filter canister.

**Note:** Allow sufficient time for the fuel filters to drain.

3. Loosen the nuts holding the fuel filter doors in place, swing the fasteners outward, and remove the fuel filter doors.
4. Remove the old filter elements.

#### **Screen 32:**

##### **Fuel Filter Element Installation:**

Typical steps to install new filter elements are as follows:

**Note:** Wipe a small amount of clean lubricating oil on the O-rings on all new GE fuel filter sections to prevent O-ring damage during assembly.

1. Install new approved filter elements.
2. Check the condition of the O-ring seal on each filter tank door and replace the O-ring, if needed.
3. Close and seal the filter tank doors and ensure that the vent valve is closed.
4. Close the fuel filter drain valve.
5. Place the locomotive in Self-Test 300 and prime the fuel system for five minutes.
6. Start the engine, inspect the entire fuel system for leaks, and make corrections as necessary.

#### **Screen 33:**

##### **High-pressure Fuel Equipment:**

The high-pressure fuel equipment includes the HP pumps, high-pressure lines, and the fuel injectors. The HP pumps take fuel from the low-pressure inlet supply header, greatly increase the pressure, and then send it to the injectors through the high-pressure fuel lines. Each power assembly on the diesel engine has an HP pump, HP fuel line, and a fuel injector. The ECU governs the timing and amount of the fuel delivered by each HP pump by opening and closing a solenoid located on the pump. For removal and installation instructions for the high-pressure equipment, refer to the GEVO Diesel Engine Advanced course.

#### **Screen 44:**

##### **Summary:**

You have reached the end of this module!

In this module, you learned to:

- State the purpose and location of the major components of the fuel system.
  - The primary purpose is to provide fuel for combustion.
  - The secondary purpose is lubricating and cooling high-pressure fuel equipment.
  - The major components of the fuel system are:

- Fuel Tank
  - Fuel Transfer Pump
  - Fuel Filter Assembly
  - High-Pressure Fuel Equipment
  - Fuel Manifold
  - Regulating Valve
  - Engine Fuel Temperature Sensor
  - Engine Fuel Pressure Sensor
- Describe how diesel flows through the fuel system.
    - The four functional sections of fuel system are:
      - Suction
      - Low-Pressure Supply
      - High-Pressure Supply
      - Return/Regulating Valve
    - An electrically driven fuel transfer pump draws fuel from the fuel tank.
    - The pump provides a normal output flow rate of 12.75 GPM.
    - It contains an internal pressure relief valve, which protects the pump if pressure exceeds 130 psi.
    - The low-pressure fuel is then sent to the fuel manifold, which contains a fuel heater and a thermostatic mixing valve.
    - The fuel heater prevents the cold diesel fuel from becoming thick and slushy.
    - The thermostatic valve regulates the outlet fuel temperature.
    - The thermostatic valve is normally open until the main flow temperature reaches 75°F.
    - At this point, the valve starts closing and fully closes when the fuel temperature reaches 85° to 87°F.
    - The fuel then flows to the fuel filter assembly, which consists of two tanks, each containing a three-piece filter element.
    - The filter elements remove contaminants larger than 5 microns from the fuel.
    - From the fuel filter assembly, fuel flows to each of the 12 high-pressure pumps.
    - The circular supply header ensures equal distribution of fuel to each pump.
    - The piston-type high-pressure pumps pressurize the fuel to 23,000 psi, and send it to the injectors.
    - The Engine Control Unit governs the timing and amount of fuel delivered by each HP pump by opening and closing a solenoid on the pump.
    - When HP pump is not pressurizing, the solenoid is open, which allows the fuel to pass to the low-pressure return header.
    - The regulating valve provides back pressure in the low-pressure fuel lines to the HP pumps.
    - Two gravity drain headers are on each side of the engine.
    - After flowing through each HP pump, the fuel drains to the drain header and then back to the fuel tank.



- Describe the abnormal operating condition detection strategies used in the fuel system.
  - The two detection strategies are:
    - Low fuel supply temperature detection - If the fuel supply temperature measured by the EFT sensor is below 60°F for 30 seconds, and the water inlet temperature measured by the EWIT sensor is above 140°F for 60 minutes, an engine fuel temperature low incident is logged. This incident will clear if the fuel temperature is above 65°F for 30 seconds.
    - Low fuel supply pressure detection - If the fuel supply pressure measured by the EFP sensor is below 30 psi for 30 seconds with the engine running, an engine fuel pressure low incident is logged. This incident will clear if the fuel pressure is above 50 psig for 30 seconds with the engine running.
- Describe how to check and adjust the fuel supply pressure.
  - A normal fuel supply pressure reading is between 88 and 92 psi when the engine is running in Low Idle and fuel filters are new.
  - The pressure reading decreases as the load increases or as the filters become dirty.
  - A pressure gauge of 0 to 200 psi range can be connected to the quick-disconnect fitting to measure the pressure.
  - The pressure can also be read by viewing the locomotive monitor screen on a Smart Display.
  - To adjust the fuel supply pressure, loosen the regulating valve and adjust the locknut in or out to increase or decrease the pressure.
  - Tighten the locknut and recheck the reading on the gauge.
- Describe how to remove and install the fuel filter elements.
  - Fuel Filter Element Removal:
    1. Shut down the engine and open the fuel pump circuit breaker.
    2. Open the fuel filter drain valve, then open the vent valve, which is located above the top fuel filter canister.
    3. Loosen the nuts holding the fuel filter doors in place, swing the fasteners outward, and remove the fuel filter doors.
    4. Remove the old filter elements.
  - Fuel Filter Element Installation:
    1. Install new approved filter elements.
    2. Check the condition of the O-ring seal on each filter tank door and replace the O-ring, if needed.
    3. Close and seal the filter tank doors and ensure that the vent valve is closed.
    4. Close the fuel filter drain valve.
    5. Place the locomotive in Self-Test 300 and prime the fuel system for five minutes.
    6. Start the engine, inspect the entire fuel system for leaks, and make corrections as necessary.