The Ford Power Stroke is the bestselling diesel engine in North America. According to Mahle, 6.7 liter Power Stroke production for 2011 was 362,000 units. By comparison, there were 116,000 Cummins ISB 6.7 and 64,000 GM Duramax engines built during the same time period. In other words, the Ford Power Stroke outsells the Cummins 6.7 liter by 3 to 1, and the Duramax by 6 to 1. For technicians who are considering branching into diesel engine repair, a good place to start would be to get familiar with the Ford Power Stroke. Certainly, there are enough of them, and they need frequent enough service that your efforts could turn into a good revenue stream.

The Power Stroke has seen much change over its 18-year history. There have been four different Power Stroke engines introduced during this span, the first three built by International Truck and Engine, and the most recent one by Ford. The cooling systems have become more complex with each new model, which can create diagnostic and service challenges for the automotive technician. However, the optimist would say that these challenges are actually opportunities in disguise. There is no shortage of work for technicians who aren’t afraid of a Power Stroke diesel.

The latest version of the Power Stroke, the 6.7 liter, was introduced in early 2010 (Figure 1). This engine sports numerous innovative features, including:

- Reverse airflow, where the intake air enters on the outboard side of the cylinder heads and the exhaust exits in the engine valley (a direct path to the turbocharger)
- A turbocharger that incorporates two compressor wheels on a common shaft (used in pickup versions)
- An engine block made from compacted graphite iron (CGI) that increases strength while reducing weight
- Two separate cooling systems, each with its own belt-driven water pump, thermostats, radiator, and degas bottle.

The 6.7 liter Power Stroke diesel is also one of the first Ford engines to use the newest version of Motorcraft Specialty Orange coolant, which has an organic acid technology (OAT) corrosion inhibitor package similar to DEX-COOL.

It sounds intimidating at first glance, but if we take it one piece at a time, we can figure it out. Stay with the tour, folks, as we embark on an overview of the 6.7 liter Power Stroke cooling system.

### Primary Cooling System

The primary cooling system is also known as the high temperature cooling system. With a coolant capacity of 27.8 liters (29.4 quarts), this side of the system is used to cool the engine block and cylinder heads, as well as the engine oil cooler, turbocharger, and the first section of the EGR cooler.

As mentioned earlier, the primary cooling system has its own radiator, water pump, degas bottle (Ford’s term for...
for surge tank) and a pair of thermostats (Figure 2). It also supplies coolant to the vehicle’s heater core for warming the passenger compartment.

The primary radiator is a crossflow (left to right) design, and is the largest of a series of heat exchangers located at the front of the engine compartment. Starting from the front of the vehicle, air flows through a small power steering cooler, then through the A/C condenser, the powertrain secondary (low temperature) radiator, and finally the primary radiator.

The primary cooling system has its own belt-driven water pump on the left front of the engine. This pump draws coolant from the bottom right of the primary radiator and sends it through passages in the engine front cover to each side of the engine block. Coolant then flows from the block to the cylinder heads, turbocharger, engine oil cooler, and the heater core (Figure 3).

Figure 2: Major components in the primary cooling system include the degas bottle (1), water pump (5), engine oil cooler (8), and primary radiator (13).

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Figure 3: Coolant flow in the primary cooling system. Major components include the EGR cooler assembly (2), dual thermostat assembly (6), coolant crossover tube (7), turbocharger (9), and water pump (15).
A dual thermostat assembly is located in the coolant crossover at the front of the engine. The thermostats open at different temperatures; the rearward one opens first at 90° C (194° F), and the front one at 94° C (201° F). The first thermostat will allow limited coolant flow to the radiator when the engine is near operating temperature. If the coolant temperature continues to rise, the second thermostat opens to maximize flow to the radiator. This design allows for more precise engine coolant temperature control.

When the thermostats are closed, coolant returns to the water pump inlet via a bypass passage in the left cylinder head and engine block. The PCM monitors the temperature of the primary cooling system using an engine coolant temperature (ECT) sensor located in the coolant crossover above the water pump (adjacent to the thermostat housing).

The turbocharger assembly is also cooled by the primary cooling system. Coolant enters the base of the turbocharger from a passage in the engine block, then flows out a tube on the left side, and is returned to the crossover at the front of the engine.

The engine oil cooler is mounted on the left side of the engine oil pan. Coolant from the primary cooling system leaves the lower rear of the engine block and flows through the plate-style cooler before being returned to the water pump inlet. All oil from the engine oil pump passes through the oil cooler, and then is sent on to the oil filter.

The primary cooling system is also used to cool the first half of the EGR (exhaust gas recirculation) cooler. Coolant is sent to the EGR cooler from the right valve cover, which is also the mounting location for the cooler assembly. Most of this coolant is then returned to the right valve cover, except a small amount that is bled off to the degas bottle. Heat from the EGR cooler represents a major increase in cooling system load, so dividing the heat between the primary and powertrain secondary systems shares the work.

**Powertrain Secondary Cooling System**

This is where things start to get interesting. The 6.7 liter Power Stroke has a second, completely separate cooling system that operates at lower temperatures than the primary cooling system. Known as the powertrain secondary cooling system, it can also be divided into high and low temperature circuits. Like the primary cooling system, it has its own belt-driven water pump, thermostats, degas bottle, and radiator. This system has a coolant capacity of 11.1 liters (11.7 quarts) and is responsible for cooling the following components:

- The second half of the EGR cooler – high temperature circuit
- Transmission oil cooler – high temperature circuit
- Charge air cooler (CAC) - low temperature circuit
- Fuel cooler - low temperature circuit

The degas bottle is the starting point for all coolant flow in the system. In turn, all four of the system’s heat exchangers return coolant back to the degas bottle. A large hose attaches the bottom of the degas bottle to the inlet of the water pump, which is located on the right front of the engine. The outlet of the water pump is connected to the LH tank of the radiator through the coolant crossover hose assembly, which passes in front of the A/C condenser (Figure 4).

The radiator for the secondary cooling system is also a cross-flow design, and is divided horizontally into two sections. The upper section comprises approximately 2/3 of the radiator, with the coolant from the water pump entering on the left side and flowing to the right. The lower section/remaining 1/3 of the radiator flows coolant from right to left. The radiator’s LH tank is

![Figure 4: The powertrain secondary cooling system. Major components include the charge air cooler (3), fuel cooler (6), EGR cooler assembly (7), low temperature thermostat (8), water pump (9), transmission oil cooler (12), secondary radiator (14), high temperature thermostat (15), coolant crossover hose assembly (16), and degas bottle (21).](image-url)
divided, and separates the upper section of the radiator from the lower section. The RH tank, however, connects the two sections of the radiator and allows coolant to make a “U-turn” as it flows from the upper section to the lower section.

**High-Temperature Circuit**

The radiator RH tank houses the high-temperature thermostat, which controls the temperature of the coolant flowing to the transmission oil cooler and the EGR cooler. The high-temperature circuit of the powertrain secondary cooling system uses ONLY the upper section of the radiator for dissipating heat.

The degas bottle supplies coolant to the inlet of the water pump, which sends the coolant through the coolant crossover hose assembly to the inlet on the LH radiator tank. The high-temperature thermostat housing is connected to this coolant circuit at the RH tank of the radiator.

When the system is cold, the high-temperature thermostat is closed and diverts some of the coolant flow from the water pump and sends it directly to the transmission oil cooler and EGR cooler (Figure 5).

When coolant in this circuit reaches 45° C (113° F), the high-temperature thermostat starts to open. The thermostat redirects coolant through the upper section of the radiator and then on to the transmission oil cooler and the EGR cooler (Figure 6).

All of the EGR gas comes from the RH exhaust manifold. This makes the plumbing much simpler and also eliminates airflow balance problems that occur when EGR is pulled from both cylinder banks. EGR flow is controlled by a valve located on the upstream (hot) side of the cooler assembly. This keeps the EGR valve running hotter, but also cleaner, with less particulate matter collecting on the valve. This is in sharp contrast to earlier Power Strokes (6.0 liter is one example) that had the EGR valve downstream from the cooler. These designs were prone to valve “coking” and required frequent service, especially if the engine was allowed to idle extensively.

A bypass valve is also integrated into the EGR cooler assembly. When this vacuum-operated valve is closed, EGR gas is routed past the cooler and directly into the air intake system. Cold starts are one example of when the EGR cooler would be bypassed, because the hot exhaust gas could then be used to help warm up the cylinders faster and reduce emissions.

The secondary cooling system temperature sensor (ECT2) is located on the EGR cooler near the coolant inlet hose. The PCM uses this sensor to determine the temperature of the coolant in the powertrain secondary cooling system.

**Low Temperature Circuit**

The low-temperature thermostat is located in the LH tank of the radiator, and controls the temperature of the coolant flowing to the charge air cooler (CAC) and the fuel cooler. The low-temperature thermostat effectively acts as the “gatekeeper” between the upper and lower sections of the radiator, and uses both sections of the radiator for dissipating heat.

Coolant from the degas bottle is pumped through the coolant crossover hose assembly to the LH tank of the radiator. When the low-temperature thermostat is closed, it allows coolant to bypass the radiator entirely and be sent directly to the CAC and the fuel cooler (Figure 7).

When the coolant in this circuit reaches 20° C (68° F), the low-temperature thermostat starts to open (blocking bypass flow) and causes the coolant to flow through the upper and lower sections of the radiator before being sent to the CAC and the fuel
cooler (Figure 8). The temperature of the coolant in the lower section of the radiator is maintained at approximately 45° C (113° F).

The charge air cooler (CAC) is used to decrease the temperature of the intake air after it leaves the turbocharger. When turbocharger boost pressure rises, the temperature of the intake air increases as well. In order to increase air density and improve engine efficiency, a charge air cooler (also known as an intercooler or aftercooler) is used to cool the intake air downstream of the turbocharger. Lower intake air temperatures also help decrease NOx formation by contributing to lower combustion temperatures. Charge air cooling is a win-win emission control device, because it increases engine output while also helping to limit emissions.

While the 6.4 liter Power Stroke used an air-to-air heat exchanger for charge air cooling, Ford uses air-to-liquid cooling in the 6.7 liter. This design was adopted due to the smaller size of the components involved, so higher cooling capacity could be achieved while using less engine compartment space.

The fuel cooler is located on the left frame rail ahead of the diesel fuel conditioning module (DFCM). The DFCM incorporates the following components:

- Low-pressure fuel pump
- Primary fuel filter (10 micron filtration)
- Thermal recirculation valve
- Water-fuel separator (200 ml capacity)
- Water-in-fuel (WIF) sensor
- Manually-operated water drain valve

Fuel that is returned from the high-pressure common rail (HPCR) injection system is sent through the fuel cooler and then on to the DFCM. If the fuel is below 80° F, the thermal recirculation valve in the DFCM sends all of the fuel to the inlet of the low-pressure fuel pump. This aids greatly in cold weather operation, as the warm return fuel is recirculated to help prevent gelling and fuel flow problems. As fuel temperature rises above 80° F, progressively more return fuel is bled to the tank. At 100° F and above, the thermal recirculation valve is fully closed and all of the return fuel is sent to the tank. Sending return fuel to the tank assists in dissipating heat and maintaining fuel viscosity in high ambient temperature conditions.

### Cooling Fan Operation

The cooling fan in the 6.7 liter Power Stroke utilizes a PCM-controlled viscous drive. The fan assembly has a reservoir filled with viscous fluid. When the actuator valve is opened, the fluid flows from the reservoir into the working chamber where a "shearing" effect causes the fan to rotate (Figure 9).

An integrated hall-effect sensor (FSS – Fan Speed Sensor) is used to monitor fan speed. The PCM sends a pulse width modulated (PWM) signal to operate the actuator valve, thus controlling the amount of fluid in the fan assembly’s working chamber. The PCM adjusts fan speed based on a number of parameters, including (but not limited to) engine coolant temperature, engine oil temperature, intake air temperature, or air conditioning requirements.

The cooling fan can be tested using the Key On Engine Running (KOER) On-Demand test. This test can be performed using the Ford Integrated Diagnostic System (IDS), or with many...
aftermarket scan tools. When the test is activated, the PCM will command a 100% duty cycle to the actuator valve, and then look at voltage on the valve control circuit and fan speed. If either one of these is not in the expected range, a diagnostic trouble code (DTC) is set.

**Service Tips and Tricks**

Cooling system service is evolving rapidly as diesel engines become more technologically advanced. We require much higher levels of performance from our diesels these days – they must weigh less, put out more horsepower and torque, get better fuel economy, and produce lower emissions. These demands cause diesel engines to generate increased heat loads, putting a great deal more stress on their cooling systems.

Engine coolants have also evolved to meet the new demands. Of course, the Ford Power Stroke is no exception, as it has used three different types of coolant since its introduction in 1994. As we’ve seen, Power Stroke cooling systems themselves have become much more complex, and this requires greater attention to detail on the part of the service technician.

**Don’t Forget the Basics**

We need to be fussy about virtually every aspect of cooling system service – whether it’s the water we use to mix our coolant, or the manufacturer’s recommended service intervals. Let’s begin our service tips section with a review of the basics, things that we all know, but sometimes don’t take as seriously as we should.

- ALWAYS use the manufacturer’s recommended coolant when filling or topping off a cooling system. In the case of the 6.7 liter Power Stroke, use Motorcraft Specialty Orange engine coolant or an equivalent meeting Ford WSS-M97B44-D specifications (Figure 10). If a non-specified coolant is used, the system will need to be chemically flushed and fresh coolant installed. There is a total of 10 gallons of coolant in a 6.7 liter Power Stroke, so using the wrong one could be an expensive mistake from a materials perspective alone.
- Only use distilled water when mixing engine coolant. Even if you have really good drinking water in your area, it is not worth it to use anything but distilled water for mixing your coolant. Consider the costs; the coolant is going to run you 15 to 20 dollars per gallon anyway, so what’s an extra buck-fifty per gallon for the water? You might save yourself some hassle by using a pre-diluted coolant if the right type is available.
- Engine coolant should be mixed at a 50/50 concentration. Remember that you are counting on your coolant for freeze protection, boil-over protection, corrosion protection, and cooling efficiency. The coolant can’t do its job unless it is mixed with distilled water at the correct concentration. A 50/50 mix will provide freeze protection down to -37°C (-34°F). However, Ford does allow for concentration levels between 40% and 60% to adjust for unusual conditions.
- Always fill the cooling system to the correct level. On the 6.7 liter Power Stroke, the degas bottles should be filled to within the COLD FILL range with the engine cold. Overfilling the cooling system can result in damage to the pressure cap due to coolant expansion. This, in turn, could cause the engine to overheat.

One other item in the “basics” category – there is no such thing as “too clean” when dealing with engine coolant. This

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**Can DEX-COOL Be Used as a Substitute for Motorcraft Specialty Orange Coolant?**

According to the Ford workshop manual, Motorcraft Specialty Orange is the only coolant to be used in the 6.7 liter Power Stroke diesel. However, Ford has also published “Ford 6.7L Power Stroke Diesel Operating, Maintenance & Care Tips,” in which latitude is given to use any coolant that meets Ford specification number WSS-M97B44-D. This specification is listed prominently on the Motorcraft Specialty Orange engine coolant label. However, the label on AC Delco branded DEX-COOL does not list it as meeting WSS-M97B44-D.

On the other hand, both Prestone and Zerex offer coolants whose labels list them as meeting the WSS-M97B44-D specification. Presumably, either of these coolants would be acceptable substitutes for Motorcraft Specialty Orange coolant. Ford has also stated in a parts sales video that Motorcraft Specialty Orange can act as a replacement for DEX-COOL, despite the fact that their label does not show the GM 6277M (DEX-COOL) specification!
starts with the bucket you’re draining the coolant into. If you’re planning on putting the used coolant back into the engine, be certain that the drain pan starts out clean and stays clean during the service process. In the end, it may not even be worth it to reuse the coolant if it’s been in service for some time.

Coolant Inhibitors

Engine coolant is made up of antifreeze (most often ethylene glycol) and a corrosion inhibitor package. Besides corrosion protection, inhibitors play an important role in preventing cavitation in diesel engine cooling systems. When engine loads are high and combustion pressures rise, the engine cylinders tend to deflect towards the cooling system on their major thrust side. The major thrust area is the side of the cylinder that the piston skirt pushes against when it is being forced downwards by combustion gases.

When combustion pressure decreases, the cylinder rebounds and causes low pressure areas to form where the coolant contacts the outside of the cylinder. If the coolant inhibitor concentration is depleted, these low pressure areas form tiny vapor bubbles, which then suddenly collapse and act like jack hammers as they erode the metal on the outside of the cylinder. Left unchecked, cavitation damage can eventually pierce the cylinder and cause combustion and/or coolant leakage. With that in mind, coolant condition is of utmost importance, especially in diesel engines.

As mentioned earlier, three different types of coolant have been used in the Ford Power Stroke over its lifespan. Most 7.3 liter Power Strokes used green coolant, which utilizes silicates and nitrites as corrosion inhibitors. Ford recommends that these engines have Diesel Cooling System Additive (Motorcraft part# VC-8) added to their coolant every 15,000 miles to maintain corrosion protection. No coolant testing is required; just add the specified amount (typically 4 ounces per gallon of cooling system capacity) based on the vehicle odometer reading (Figure 11).

Late model 7.3 liter, 6.0 liter, and 6.4 liter Power Strokes used Motorcraft Premium Gold coolant, which is also known as G-05. Premium Gold is a hybrid organic acid technology (HOAT) coolant, which uses nitrites as its primary corrosion inhibitor. Ford recommends that this coolant be tested periodically using Rotunda test kit #328-00001. For normal service, the coolant check is optional at 15,000 to 20,000 miles. However, if the engine is subjected to severe service (heavy towing, extended idle times, etc.), the check is required at these same intervals. If necessary, Ford specifies the addition of Motorcraft VC-8 to maintain corrosion protection. However, you need to be careful to not add too much VC-8 or you could cause system damage (Note: Rotunda products can be ordered online at https://rotunda.spx.com.)

Motorcraft Specialty Orange Coolant (and others meeting Ford WSS-M97B44-D specifications) are organic acid technology (OAT) coolants. OAT coolants use carboxylates to prevent corrosion. In turn, there aren’t any silicates, phosphates, or nitrites used in OAT coolants. Like other corrosion inhibitors, carboxylates deplete over time and must be recharged periodically using an additive. Ford takes coolant condition very seriously with the 6.7 liter Power Stroke. So seriously, in fact, that vehicles with optional message centers are programmed to display CHECK COOLANT ADDITIVE every 15,000 miles as a reminder to have the coolant tested (Figure 12).

Coolant Testing

You will need both the Rotunda #328-00001 (Figure 13) and #328-00008 (Figure 14) kits to accurately test 6.7 liter Power Stroke coolant. The 328-00001 kit is used first to determine coolant freeze point (must be within 40-60% concentration for further test results to be accurate), and nitrite contamination.

When performing this test, make sure that the coolant is as close to room temperature as possible, and take the sample from the radiator drain cock (not the degas bottle). Pay attention to cleanliness throughout this procedure, as test results could easily be skewed by careless handling of the coolant samples.

To be clear, there should be ZERO nitrites in 6.7 liter Power Stroke coolant. If some show up in the test, it may be because the wrong coolant was used, or VC-8 additive was put into the system. Regardless, if nitrites are found in 6.7 liter Power Stroke
coolant, the system must be chemically flushed using Motorcraft VC-9 Diesel Cooling System Iron Cleaner and fresh coolant installed.

If the coolant is at the correct concentration and has passed the nitrite test, kit #328-00008 is used to determine the coolant’s reserve alkalinity (RA) and contamination level. The kit includes a syringe for taking a sample from the degas bottle. Place the sample in the container with the white lid and dip a reserve alkalinity strip into the coolant sample for two seconds. Shake the strip once and wait 30 seconds. Compare the dip strip color to the RA chart included with the kit. If RA is low, the last (contamination) test should be performed using an orange-capped test vial. If RA is high, use a clear-capped test vial.

To perform the contamination test, fill the syringe with exactly 5 ml of coolant from the degas bottle, and transfer it to the appropriate vial. Place the cap on the vial and shake the sample for 15 seconds. Dip the contamination strip into the sample for two seconds, then shake it once and wait 60 seconds. Match the test strip color to the contamination chart. If the results indicate a pass, the system does not show excessive contamination. If the results show a fail, the system will have to be chemically flushed and fresh coolant installed (Figure 15).

If the coolant RA is low and the system does not have excessive contamination, add one bottle of VC-12 Motorcraft Specialty Orange Engine Coolant Revitalizer to the coolant. The coolant can be recharged a total of two times; if further recharging is necessary, the system must be flushed and fresh coolant installed. ■