1992 - 1996 Corvette: Technical Article: LT1 Reverse Flow Cooling System

LT1 Reverse Flow Cooling System
By Scott Mueller.

One of the greatest features of the ’92 and up Chevrolet LT1 engine is the reverse flow cooling system. In fact it is reverse flow cooling that is truly the key to the incredible performance of the modern LT1. Reverse flow cooling is vastly superior to the conventional cooling systems used on virtually all other engines. This is because it cools the cylinder heads first, preventing detonation and allowing for a much higher compression ratio and more spark advance on a given grade of gasoline. A fringe benefit is that cylinder bore temperatures are higher and more uniform, which reduces piston ring friction. Because of this new cooling system, the LT1 can easily meet ever increasing emissions standards with significant gains in power, durability, and reliability.

Conventional Coolant Flow:

In a conventional engine design, coolant enters the front of the block and circulates through the block’s water jacket. The coolant is first heated by the cylinder barrels, and then hot coolant is subsequently routed through the cylinder heads and intake manifold before returning through the thermostat to the radiator.

Because the coolant from the radiator is first directed to the cylinder bores, they run at below optimum temperatures which increases piston ring friction. The heads subsequently get coolant that has already been heated by the cylinder block, which causes the heads to run well above optimum temperatures. The hotter cylinder heads promote detonation (spark knock) and head gasket failures. To combat the increased tendency to detonate, compression ratios has to be lowered and spark advance reduced, which significantly reduces engine power output and efficiency.

Besides promoting detonation, causing gasket failures, forcing reduced compression, spark advance, and significantly reduced power output, a conventional cooling system causes several other problems. Since the thermostat is on the exit side of the system, it does not have direct control over the cold coolant entering from the radiator. This is especially true when the thermostat first opens after reaching operating temperature. As the thermostat first opens allowing hot coolant to exit the engine, a rush of very cold coolant enters the block all at once, shocking the engine and causing sudden dimensional changes in the metal components. The extreme thermal shock experienced by the engine causes head gaskets and other soft parts to fail much more quickly.

Conventional cooling system design also allows isolated engine hot spots to occur, which lead to the generation of steam pockets and coolant foaming. Coolant which is full of air and foam reduces cooling system performance and can even lead to engine overheating.

LT1 Coolant Flow:

The LT1 is completely different since it uses reverse flow cooling. The incoming coolant first encounters the thermostat, which now acts both on the inlet and outlet sides of the system. Depending on the engine coolant temperature, cold coolant from the radiator is carefully metered into the engine. This allows a more controlled amount of cold coolant to enter, which immediately mixes with the bypass coolant already flowing. This virtually eliminates the thermal shock present in the old system.

After entering through one side of the 2-way thermostat (at the appropriate temperature), the cold coolant is routed directly to the cylinder heads first, where the combustion chambers, spark plugs and exhaust ports are cooled. Then the heated coolant returns to the engine block and circulates around the cylinder barrels. The hot coolant from the block re-enters the water pump, and hits the other side of the 2-way thermostat, where it is either re-circulated back through the engine or directed to the radiator, depending on temperature.

The main concept behind reverse flow cooling is to cool the heads first, which greatly reduces the tendency for detonation, and is the primary reason that the LT1 can run 10.5 to 1 compression and fairly significant ignition advance on modern lead-free gasoline. Reverse flow cooling is THE KEY to the Generation II LT1s increased power, durability, and reliability over the first generation smallblock engine.

Thermostats:

All LT1 engines utilize a special 2-way acting full bypass thermostat. This means that the thermostat regulates coolant flow both in to as well as out of the engine, while the bypass portion of the thermostat circuit supplies the water pump with a full flow of liquid coolant at all times. This is unlike a conventional engine thermostat, which only regulates coolant flow at the engine outlet, and which does not allow full flow through the water pump when the engine is cold and the thermostat is in bypass mode.

Both sides of the 2-way thermostat used in the LT1 are linked together, and a single wax pellet actuator operates the spring loaded mechanism at a pre-set temperature. When the designated temperature is reached, the wax pellet expands, opening the dual acting valve. All current LT1s come from the factory with a relatively low 180 degree temperature thermostat. Most conventional engines today use 195 degree thermostats in order to meet emissions specifications at the expense of power, durability, and reliability.

It is important to note that the 2-way thermostat is unique to the Generation II LT1 and is not interchangeable with older Chevrolet smallblock engines. This is particularly important if you decide to change to a colder 160 degree thermostat, make sure it is the proper dual acting type required by the modern LT1.

Additional LT1 Cooling System Improvements:

In addition to reverse coolant flow, there are several other improvements in the LT1 cooling system over conventional engines.

Dry Intake Manifold:

The LT1 has absolutely NO water running through the intake manifold! Conventional cooling systems have passages in the intake manifold which allow coolant to crossover from one side of the engine to the other. In the LT1, coolant crossover occurs in the water pump, which is also where the thermostat is located. Since there are no coolant passages in the intake manifold, a major source of leaks has been eliminated. Overall engine reliability is improved since an intake manifold leak allows coolant to enter the top of the engine which can quickly wipe out the camshaft, lifters, and other major engine components. Designing a dry intake manifold without either coolant passages or a thermostat housing also allows a much lower profile. The LT1 engine is 87mm (nearly 3.5 inches) lower than the previous L98 Corvette engine.

Gear Driven Water Pump:

One big problem with conventional cooling systems is the water pump, which simply cannot last a targeted minimum 100,000 mile reliability figure without experiencing leaking gaskets or seal failures. This has traditionally been caused by the excessive side loads placed on the bearings and seals of a conventional water pump through the belt drive mechanism. In the LT1 this problem is solved by driving the water pump directly via a spur gear driven by the camshaft sprocket. This results in a dramatically more reliable water pump that should easily last 100,000 miles or more.

Since the water pump is no longer belt driven, the vehicle will still be driveable even if the serpentine belt fails. This is a major safety factor as it allows one to drive the partially disabled vehicle to the nearest service center.

Steam Vents:

The LT1 has strategically placed steam vents at the back of both cylinder heads. Since the heads are the hottest part of the engine, pockets of steam can be more easily generated there. The steam vents are connected together by a crossover vent tube at the back of the heads, which directs any steam and a small flow of coolant to the front of the engine where it flows through the throttle body, warming it for improved cold weather performance. After passing through the throttle body, most of the steam is condensed back into liquid coolant and returned to the system.

In LT1 B/D-cars, coolant exiting the throttle body is passed directly into a pressurized coolant reservoir where any air remaining in the coolant is completely scavenged. In LT1 F-cars, coolant from the throttle body connects to the heater outlet via a vented "tee" connector, where any trapped air in the system can be bled off manually. Eliminating steam pockets and foam in the coolant allows for more uniform cooling system performance, preventing hot spots and potential overheating.

Reverse Flow Radiator:

Unlike a conventional cooling system, the thermostat coolant outlet is connected to the bottom of the radiator. This forces the coolant entering the radiator to push up through the radiator core and eventually emerge through the top radiator coolant outlet. This helps to eliminate air pockets in the radiator, and provides a more even distribution of cooling through the core and improving radiator efficiency.

Precision Machined Thermostat Housing:

The thermostat housing is a precision machined component that fits directly onto the top of the water pump without a gasket. Instead, an O-ring is used to seal the thermostat inside the housing. This precision design reduces the tendency for leaks, plus it makes thermostat replacement a very simple job since there is no old gasket material to scrape off. Servicing is further simplified because the thermostat housing is situated directly on top of the water pump, and access is unobstructed. I dare say that the LT1 thermostat is the easiest to change I have ever experienced. Finally, an air bleeder valve is located on the top of the thermostat housing, which allows one to quickly and easily bleed out any trapped air after cooling system maintenance has been performed.

Low Operating Pressure:

The entire cooling system on the LT1 is designed to operate at lower pressures than conventional cooling systems. The maximum operating pressure in the LT1 cooling system is 15 psi for B/D-cars and 18 psi for F-cars, limited by a pressure cap. These limits are similar to other cars, but in the LT1, these maximum pressures are rarely reached. Running at a lower pressure drastically decreases the number of leaks and significantly improves overall reliability and durability.

Coolant Reservoir:

Corvette and B/D-car LT1 applications use a pressurized coolant recovery reservoir instead of a non-pressurized overflow tank used with conventional cooling systems. All of the coolant flows continuously through the pressurized reservoir, which is an integral part of the cooling system. The pressurized reservoir in the LT1 B/D-cars is connected to the cooling system in three places. One inlet hose connects to the top of the RH radiator tank, a second inlet hose is attached through a "tee" connection on the heater inlet hose, and a third outlet hose is connected to a "tee" connection in the throttle body heater outlet.

The pressurized reservoir is mounted at the highest point in the system, and provides a place where all air can be continuously scavenged from the coolant. Any steam and bubbles are allowed to rise to the surface, eliminating foam and providing pure liquid coolant back to the engine. Pure liquid coolant is returned to the system via the heater outlet hose connection. The pressure relief/vent cap in these systems is rated at 15 psi and is located on the reservoir rather than the radiator.

LT1 F-cars use a conventional coolant recovery system which consists of a non-pressurized coolant overflow tank connected to the radiator by a single hose. These cars use an 18 psi rated pressure relief/vent cap on the radiator like most conventional systems. Since these cars cannot scavenge air from the coolant as well as the B/D-car or Corvette systems, they have two air bleeder valves for manually bleeding trapped air from the system. One is in the thermostat housing, which is the same as all other LT1 engine vehicles, and the second one is located in a "tee" where the coolant from the throttle body connects to the heater return hose.

B/D-car LT1 (Caprice/Impala/Roadmaster/Fleetwood) Cooling Systems:

Standard equipment for all LT1 equipped B/D-cars is a dual electric fan setup with a 150-watt primary (RH) fan and a 100-watt secondary (LH) fan. The electric engine coolant fans are independently operated by the PCM (Powertrain Control Module) based on the inputs from the Engine Coolant Temperature (ECT) sensor, A/C Pressure Sensor, Vehicle Speed Sensor (VSS), and various other inputs.

The B/D-car coolant fans operate under PCM control at the following engine temperatures and A/C system pressures:

Fan Mode
Temperature A/C Pressure
Primary (RH) Fan ON 107 C 225 F 189 psi
Primary (RH) Fan OFF 103 C 217 F 150 psi
Secondary (LH) Fan ON 111 C 232 F 240 psi
Secondary (LH) Fan OFF 107 C 225 F 210 psi

Additionally, the PCM will turn off the fans at higher vehicle speeds (above 48 MPH I believe) since running fans can actually impede airflow through the radiator at high
speed. Each fan also has a minimum running time. Once activated, the primary fan will run for a minimum of 50 seconds, and the secondary fan for a minimum of 26
seconds. Finally, certain Diagnostic Trouble Codes (DTCs) may cause the PCM to turn on one or both fans.
All LT1 B/D-cars have two transmission oil coolers and an engine oil cooler as standard equipment. The transmission coolers include a primary oil to water type inside the RH radiator tank, and a secondary external oil to air cooler (KD1) mounted in front of the radiator on the RH side. The external KD1 cooler is an aluminum stacked plate type cooler painted black with metal tube lines linking it in series with the other cooler in the radiator tank. LT1 B/D-cars also include an engine oil to water cooler (KC4) mounted in the LH radiator tank.

Optional B/D-car LT1 Cooling Systems:

There are two optional cooling system upgrades for LT1 B/D-cars, called V03 (Extra Capacity Cooling), and V08 (Heavy Duty Cooling). Performance models such as the WX3 (Impala SS) and 9C1 (Police) cars automatically get the upgraded V03 (Extra Capacity Cooling) system. V03 includes a larger radiator, an increased capacity A/C condenser, and an upgraded secondary electric fan. V03 is also optional on most B/D-car models.

Note that the ’94 V03 (Extra Capacity Cooling) option uses a 150-watt primary (RH) fan, and an upgraded 240-watt secondary (LH) fan. In ’95-’96 the V03 package was revised and no longer included an upgraded 240-watt secondary fan. Instead the standard 100-watt secondary fan was used, which is the same as the base cooling system.

B/D-cars other than the Impala SS or Police package Caprice also have an optional V08 (Heavy Duty Cooling) package which is part of the V92 (Trailer Towing) package. V08 includes the larger radiator, increased capacity A/C condenser, and upgraded secondary fan as in the V03 system, however it differs in the primary cooling fan. With V08 the 150-watt electric primary fan is replaced by a mechanical belt driven thermostatic clutch fan. To drive the mechanical fan, the V08 system includes a crank pulley, belt tensioner and bracket, and a large radiator shroud in addition to the mechanical fan itself. This package is not available on the WX3 (Impala SS) or 9C1 (Police) cars since the mechanical fan is driven by an additional pulley and belt on the engine crankshaft, which draws engine power thus reducing performance.

The mechanical fan used with the V08 cooling system contains a built-in thermostatic clutch which senses the temperature of air that has been drawn through the radiator. When the temperature of this air is below 66 degrees C (151 degrees F), the clutch freewheels and limits the fan speed to 800-1,400 rpm. When the temperature rises above 66 degrees C (151 degrees F), the clutch begins to engage, and the fan speed increases to about 2,200 rpm. The RH radiator hose in V08 equipped vehicles has a steel tube section near the fan designed to prevent damage in case of fan contact.

There are several SEO (Special Equipment Option) B-car cooling options which are included as standard only with 9C1 (Police) package Caprices. These include the following:

In addition to the standard inclusion of the V03 (Extra Capacity Cooling) package, all LT1 Caprice 9C1 (Police) cars also include SEO 1T1 (Silicone Radiator and Heater Hoses). SEO 1T1 consists of special green radiator and heater hoses made out of pure silicone rubber. These hoses are designed to last the life of the vehicle and never need replacement unlike the standard black rubber hoses. SEO 1T1 also includes heavy duty stainless steel worm gear hose clamps which replace the standard squeeze type hose clamps. The clamps have a solid full perimeter band, which prevents the hose from extruding between the slotted area where the screw fits. This also prevents the hose from being cut or damaged by the clamp, and allows a more even sealing force around the entire clamp perimeter.

The 9C1 Police package also includes SEO 7P8 (External Engine Oil to Air Cooler). This is an unpainted aluminum stacked plate type cooler which is mounted in front of the radiator on the LH side opposite the external transmission cooler. This heavy duty engine oil cooler replaces the standard engine oil to water cooler found in the LH radiator tank of other LT1 B-cars.

Also included with the Police package is SEO 7L9 (Power Steering Fluid Cooler). This consists of a loop of metal tubing installed between the radiator lower support and the front stabilizer bar. This cooler prevents the power steering fluid from overheating in rigorous driving situations such as high speed persuit.

F-car LT1 (Camaro/Firebird) Cooling Systems:

Standard equipment for all LT1 F-cars with A/C is a dual electric fan setup with primary (LH) and secondary (RH) fans. There are two different wiring schemes used for these fans, an early design that was used in ’93-’94 and a late design that has been used from mid-’94 up. Note that non-A/C F-cars have a single primary fan which operates at a fixed high speed.

In ’93 and early ’94 models with A/C, the two cooling fans are independently operated by the PCM (Powertrain Control Module) at a high fixed speed by using a single relay for each fan. Late ’94 and newer F-car models operate both fans simultaneously in either a low or a high speed mode by using 3 relays. In low speed mode, the fans are powered in series. In high speed mode, the relays operate to power both fans in parallel, resulting in a higher speed of operation.

One way to tell which setup you have is by looking at the alternator. If an F-car is equipped with the 124 amp alternator (KG7), then the vehicle has the early design setup and the fans are operated independently. If the vehicle has the 140 amp alternator (KG9), then it also has the newer design configuration which operates the fans simultaneously in low or high speed modes.

The PCM operates the coolant fans based on input from the Engine Coolant Temperature (ECT) sensor, A/C Pressure Sensor, Vehicle Speed Sensor (VSS), and various other inputs. The F-car coolant fans operate at the following temperatures and pressures:

Fan Mode
Temperature A/C Pressure
Primary (LH) or Dual Low-speed Fan(s) ON: 108 C 226 F 248 psi*
Primary (LH) or Dual Low-speed Fan(s) OFF: 105 C 221 F 208 psi*
Secondary (RH) or Dual High-speed Fan(s) ON 113 C 235 F 248 psi
Secondary (RH) or Dual High-speed Fan(s) OFF: 110 C 230 F 208 ps

*Note - this information is probably incorrect, although it is quoted from the service manual.

Additionally, the PCM will turn off the fans at higher vehicle speeds (above 70 MPH I believe) since running fans can actually impede airflow through the radiator at high speed. Each fan or fan mode has a minimum running time. Once activated, the primary fan or dual low-speed fans will run for a minimum of 50 seconds, and the secondary or dual high-speed fans for a minimum of 30 seconds. Finally, certain Diagnostic Trouble Codes (DTCs) may cause the PCM to turn on one or both fans.

All LT1 F-cars with automatic transmissions also have a transmission oil cooler as standard equipment. The transmission cooler is an oil to water type mounted inside the RH radiator tank.

Optional F-car LT1 Cooling Systems:

There is only one option in an LT1 F-car with respect to cooling, and that is an engine oil cooler (KC4). The engine oil cooler is an oil to water design that is mounted in the LH radiator tank. The KC4 oil cooler is included with various other combinations of options on the F-cars.

Operating Characteristics and Observations:

I have an accurate digital temperature gauge installed in the RH cylinder head water jacket on my ’94 Impala SS. I installed a brass "T" fitting in the RH cylinder head, in the tapped hole where the factory temperature gauge sender was originally installed. This allowed me to install both the original analog gauge sender as well as the sender for the new digital gauge. With the stock 180 degree thermostat, cruising at 80 mph on a cool night I would routinely measure coolant temperatures in the head as low as 167 degrees! If I slowed down, the temperature would climb up into the 170-180 degree range depending on ambient temperatures and cruising speed. The temperature would run in the 180s-190s cruising more slowly on a hot summer day. In heavy stop and go traffic, the temperature would quickly climb up into the 220-230 degree area, which is where the primary fan starts to come on.

Many have noticed as I have that the engine will actually run cooler in traffic with the A/C on. This is because turning on the A/C will also cause the PCM to activate at least the primary fan, and possibly the secondary fan (depending on A/C system pressure) as well.

The radiator and A/C condenser in B/D-cars equipped with the RPO (Regular Production Option) V08 (Heavy Duty Cooling) or V03 (Extra Capacity Cooling) systems are extremely large, perhaps the largest of any passenger car on the market today. The cooling and A/C system performance on these cars are outstanding, in fact the best I have seen on any vehicle.

Recommendations for Cooling System improvements:

If you have a B/D-car, there are several easy improvements you can make by simply adding the cooling related SEOs (Special Equipment Options) from the 9C1 Caprice Police package. For example, I have installed all of the Police package cooling upgrades in my ’94 Impala SS. This includes the 1T1 silicone hoses, 7L9 power steering fluid cooler, and 7P8 external engine oil cooler. Combined with the already powerful V03 cooling system, these factory upgrades combine to form the most extreme duty factory cooling system present on any automobile I have seen.

If you have an F-car which was not factory equipped with the optional KC4 engine oil cooler, then I would highly recommend installing it as an upgrade. The KC4 option consists of a different radiator with the engine oil cooler located inside the LH tank. An adapter installs on the oil filter pad between the filter and the engine, and lines run to the cooler in the radiator tank.

There are two other cooling system improvements that can be applied to any vehicles with the LT1 engine, including the Corvette and F-cars (Camaro/Firebird). These are to change to a colder 160 degree thermostat (180 is standard), and to alter the electric cooling fans to come on at a lower temperature. This latter function can be accomplished by adding an external thermostatic switch to the fan circuit, or by re-programming the PCM fan operation settings.

As mentioned earlier in this article, the stock fans do not come on until at least 225 degrees, which I feel is too hot. To prevent the engine from heating up this high in traffic or while moving slowly, I installed a 203 degree GM thermostatic switch (p/n 3053190) in a pre-existing tapped hole in the LH cylinder head water jacket, and wired it to both the primary and secondary fan relay via a 3-position toggle switch.

When the coolant temperature reaches 203 degrees, the primary or secondary fan (depending on the setting of the toggle switch) will run. This prevents the engine from running hotter than about 200 degrees or so. I have tested this modification in 100 degree ambient temperatures, while trapped in stop and go traffic, and never saw coolant temperatures higher than 205 degrees. I wired the toggle switch to operate either the primary or secondary fan, as well as to disconnect the thermostatic switch from the circuit, thus disabling this function. No matter what the toggle switch setting, the PCM still has control over the fan relays, and will continue to operate the fans oblivious to the additional thermostatic switch function.

I have more recently purchased the Hypertech Power Programmer, which re-programs the PCM to turn the primary fan on at 176 degrees (instead of 225), and the secondary fan on at 191 (instead of 232). At first I installed the Hypertech program without the recommended 160 degree thermostat in order to observe the operation of the fans. I found that the primary fan would run continuously once the engine had warmed up, and even the secondary fan would be on most of the time. This is due to the overlap between the high thermostat setting and the lower fan activation temperatures programmed in by Hypertech. The new settings were turning the primary fan on at a setting lower than the thermostat itself would open.

After installing the recommended 160 degree thermostat, the fans worked normally, and would only begin to run after the car was not moving which allowed the temperature to rise. In actual operation I saw temperatures while moving about 10 degrees lower than what I observed with the 180 degree thermostat. While moving very slowly or sitting stationery, the engine would never climb above the low 190 range, no matter how high the ambient temperatures was or how slow I was moving. After observing this operation, I would wholeheartedly recommend the 160 degree thermostat and the Hypertech Power Programmer. If you use the Power Programmer, then the 160 degree thermostat MUST be installed or the fans will run continuously, which is not good for either the fans, alternator, or battery.

If you do not want to purchase the (fairly expensive) Power Programmer, then I highly recommend installing the 203 degree thermostatic fan switch I listed, which will prevent the excessive temperatures encountered in traffic that are allowed by the stock PCM program settings. The fan switch will work well with either the stock 180 degree thermostat or a 160 degree unit, and will limit the maximum coolant temperatures to 205 degrees or less.

GM Vehicles Featuring the Generation II LT1:

Chassis Models Years
Y-car Corvette ’92-’96
F-car Camaro/Firebird ’93-’96
B-car Caprice/Impala/Roadmaster 94-’96
D-car Fleetwood ’94-’96

Note that the D-cars are really a slightly stretched version of the B-car and are virtually identical except for the wheelbase.

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