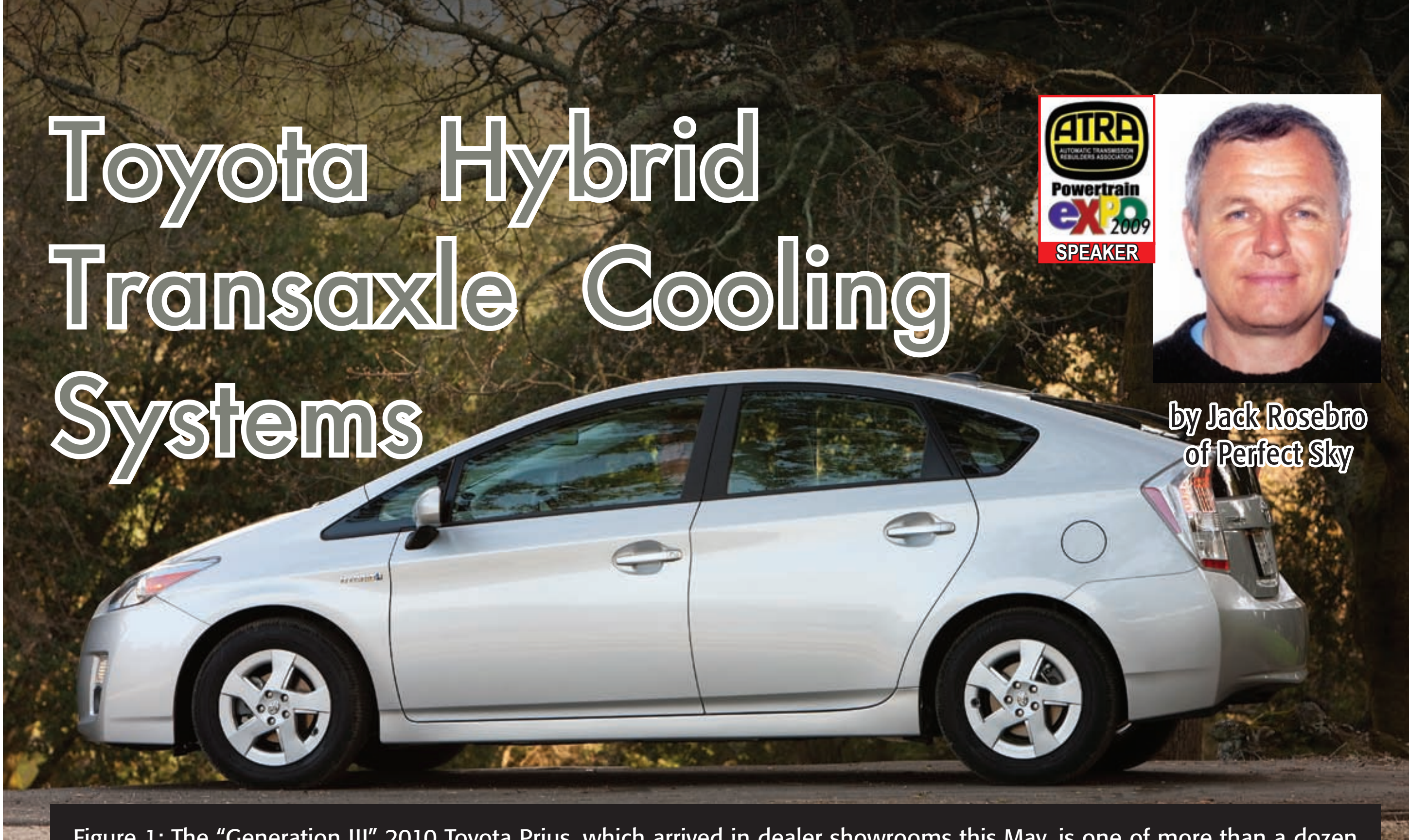
Toyota Hybrid Transaxle Cooling Systems



by Jack Rosebro
of Perfect Sky

Figure 1: The "Generation III" 2010 Toyota Prius, which arrived in dealer showrooms this May, is one of more than a dozen Toyota and Lexus hybrids which each use two liquid powertrain cooling systems. Photo courtesy Toyota Motor Corporation

Toyota hybrids such as the popular Prius—now entering its tenth year and third generation on the North American market (figure 1)—employ series-parallel transaxles and transmissions that house the powertrain's two primary electric motors. Such motors are more properly called "motor-generators", referring to their ability to generate torque (such as, during acceleration, engine-off propulsion, or to start the vehicle's engine) or alternating current (for example, during charging as well as regenerative braking). Motor-generator stator windings can rapidly produce a significant amount of heat, particularly when they are suddenly subjected to high torque demands. While some cooling is achieved by the circulation of air within the transaxle or transmission as well as contact with the transmission fluid that lubricates the unit's bearings, gears, and/or chain, additional cooling is required.

To help carry heat away from the stator windings, Toyota's hybrid transaxles and transmissions share a unique coolant loop with the vehicle's inverter assembly. This coolant loop is completely separate from the vehicle's engine cooling system, and carries heat away from the inverter's power electronics, which in turn control the vehicle's motor-generators. Proper maintenance of this cooling system is vital to the integrity of the vehicle's inverter as well as its transaxle or transmission.

System Description

A 12V brushless electric pump transports coolant from a front-mounted radiator to the inverter's coolant passages (figure 2). This radiator may or may not be integrated with the engine cooling system radiator into a

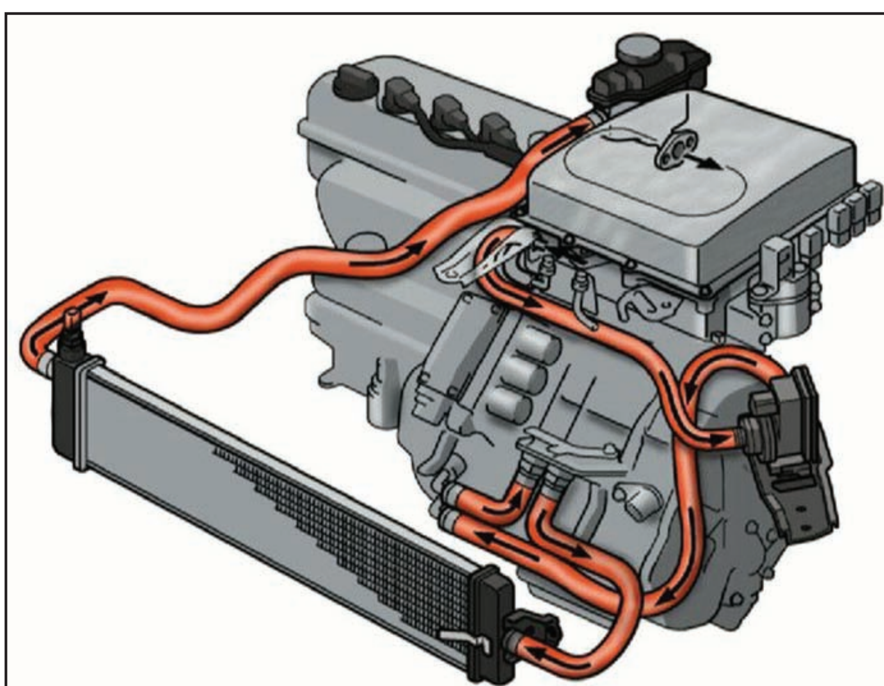


Figure 2: 2001-2003 Toyota Prius inverter/transaxle cooling system. Graphic courtesy Toyota Motor Corporation

single assembly. However, coolant does not pass between the powertrain's two coolant loops: as previously mentioned, they are physically separate.

After entering the inverter's coolant passages, the coolant indirectly absorbs heat radiated from the inverter's power electronics before flowing through hoses to coolant passages in the transaxle or transmission. Having absorbed additional heat from the vehicle's primary motor-generators, the coolant is then returned to the radiator to transfer heat to the air passing through it.

Although this coolant is the same formulation as that used in the vehicle's engine cooling system, it typically flows at lower pressures, which can range from about 5 PSI on early systems to 13-15 PSI on the 2010 Prius, depending on the vehicle. As the cooling system is designed to reduce rather than regulate temperature, it does not use a thermostat. The system incorporates one or more bleeder screws, which a technician can use to expel air from the system after the coolant is replaced. Vacuum-fill devices can also be used to service the system.

Maintenance

Figure 3: Toyota SLLC pre-mixed coolant is recommended for both engine and hybrid system coolant loops in many Toyota and Lexus hybrids.

Like any cooling system, a hybrid-related coolant loop is subject to regular maintenance. The 2001-2003 Generation 1 Prius uses Toyota's Long Life Coolant (LLC), which must be mixed with water in a 50-50 dilution. All subsequent Toyota hybrids and all Lexus hybrids use Toyota's Super Long Life Coolant (SLLC), (figure 3) which comes pre-mixed. Service intervals for many US-market Toyota and Lexus hybrids are 100,000 miles for the first coolant replacement, followed by 50,000 mile intervals for subsequent replacements. Check service information for the appropriate coolant replacement interval for each vehicle, as well as for the region or country in which it is being serviced.

Issues

No mechanical system is trouble-free. In addition to coolant leaks, the inverter/transaxle cooling system can be compromised by poor performance or outright failure of the system's electric coolant pump. Assuming that the system is free of air pockets, coolant flow can be confirmed by removing the cap of the expansion tank mounted on or near the inverter and checking for circulation, as well as placing the vehicle in READY mode (system on) and placing a hand on the pump housing. Vibration is normally an indication of pump rotation.

A noisy pump may indicate a lack of coolant and/or a mechanical problem with the pump itself. A pump can also fail intermittently, which complicates diagnosis if the condition cannot be duplicated in the shop. Some vehicles may set a DTC for poor system performance in such a case. Check for relevant TSBs, as some pumps have been redesigned to address performance problems.

Use of non-OEM coolants may require shorter maintenance intervals and/or denial of warranty in case of a system failure. Toyota refers to their engine and inverter/transaxle coolant as a "non-silicate, non-amine, non-borate, ethylene-glycol coolant with a combination of low phosphates and organic acids", and does not recommend any other type of coolant.

Variations On A Theme

Inverter coolant loops can be found in other hybrids, as well. Some mild parallel hybrid systems such as those used by the Chevrolet Malibu, Saturn Aura, and Saturn Vue hybrids incorporate the inverter's cooling circuit into the vehicle's engine coolant loop. This is possible in part because such systems produce less power (and thus less heat) than a series-parallel system. However, the transaxles used in such systems are relatively conventional, and do not require supplemental cooling. Advancements in power electronics, such as the development of silicon-carbide transistors, may enable vehicle manufacturers to employ a single coolant loop for more powerful series-parallel powertrains in future hybrids.

Auxiliary cooling systems are not necessarily limited to inverters or transaxles. The Chevrolet Volt, which is an extended-range series hybrid scheduled for production by the end of next year, is expected to use a large-format 16 kWh (kilowatt-hours) liquid-cooled lithium-ion battery pack. By comparison, today's Prius battery pack is rated at 1.2 kWh. Some battery electric vehicles are also likely to employ liquid-cooled battery systems, which increase vehicle weight and complexity, but can improve battery cooling and safety.

Conclusion

A hybrid vehicle that produces enough motor torque to propel itself using the electric drive alone will usually require a liquid cooling system, which must be serviced according to manufacturers' recommendations, for the vehicle's inverter. As we have seen, series-parallel hybrid powertrains often extend that cooling system to pick up heat from the vehicle's motor-generators. Proper service, diagnosis, and repair of transaxles found in vehicles such as the Toyota Prius, Ford Escape hybrid, and Nissan Altima hybrid, as well as RWD or AWD transmissions in Lexus hybrid sedans, requires a solid understanding of the cooling system that such components share with the inverters that drive them. As more and more hybrids are designed with driver-selectable EV modes, and as plug-in hybrids make their way into the market, we can expect to see more hybrids in our service bays with liquid cooling systems at work on the electric drive side of the powertrain.