Figure 21-1  Typical combustion and exhaust temperatures.

TECH TIP: Overheating Can Be Expensive

A faulty cooling system seems to be a major cause of engine failure. Engine rebuilders often have nightmares about seeing their rebuilt engine placed back in service in a vehicle with a clogged radiator. Most engine technicians routinely replace the water pump and all hoses after an engine overhaul or repair. The radiator should also be checked for leaks and proper flow whenever the engine is repaired or replaced. Overheating is one of the most common causes of engine failure.
Figure 21-2: Coolant circulates through the water jackets in the engine block and cylinder head.

Figure 21-3: Coolant flow through a typical engine cooling system.

Figure 21-4: A cross section of a typical wax-actuated thermostat showing the position of the wax, pellet, and spring.
When the engine is cold, the coolant flows through the bypass.

When the thermostat opens, the coolant can flow to the radiator.

The temperature of the coolant depends on the rating of the thermostat.

<table>
<thead>
<tr>
<th>THERMOSTAT TEMPERATURE RATING</th>
<th>STARTS TO OPEN</th>
<th>FULLY OPEN</th>
</tr>
</thead>
<tbody>
<tr>
<td>180°F</td>
<td>180°F</td>
<td>200°F</td>
</tr>
<tr>
<td>195°F</td>
<td>195°F</td>
<td>215°F</td>
</tr>
</tbody>
</table>

**Chart 21-1**
A thermostat stuck in the open position caused the engine to operate too cold. If a thermostat is stuck closed, this can cause the engine to overheat.

The internal bypass passage in the thermostat housing directs cold coolant to the water pump.

A cutaway of a small block Chevrolet V-8 showing the passage from the cylinder head through the front of the intake manifold to the thermostat.
Do Not Take out the Thermostat!

Some vehicle owners and technicians remove the thermostat in the cooling system to “cure” an overheating problem. In some cases, removing the thermostat can cause overheating rather than stop it. This is true for three reasons:

1. Without a thermostat, the coolant can flow more quickly through the radiator. The thermostat adds some restriction to the coolant flow, which keeps the coolant in the radiator longer. This also gives the engine more time to cool down. A thermostat with the engine coolant temperature just below the operating temperature allows for a greater reduction in the coolant temperature before it returns to the engine.

2. Heat transfer is greater with a greater difference between the coolant temperature and air temperature. Therefore, when coolant flow rate is increased (no thermostat), the temperature difference is reduced.

3. Without the restriction of the thermostat, much of the coolant flow often bypasses the radiator entirely and returns directly to the engine. If overheating is a problem, removing the thermostat will usually not solve the problem. Remember, the thermostat controls the temperature of the engine coolant by opening at a certain temperature and closing when the temperature falls below the minimum rated temperature of the thermostat.

**Figure 21-9** Checking the opening temperature of a thermostat.
Figure 21-11 The tubes and fins of the radiator core.

Figure 21-12 (a) A radiator may be either a down-flow or a crossflow type.

Figure 21-12 (b) A radiator may be either a down-flow or a crossflow type.
Many vehicles equipped with an automatic transmission use a transmission fluid cooler installed in one of the radiator tanks.

**TECH TIP: Working Better Under Pressure**

A problem that sometimes occurs with a high-pressure cooling system involves the water pump. For the pump to function, the inlet side of the pump must have a lower pressure than its outlet side. If inlet pressure is lowered too much, the coolant at the pump inlet can boil, producing vapor. The pump will then spin the coolant vapors and not pump coolant. This condition is called pump cavitation. Therefore, a radiator cap could be the cause of an overheating problem. A pump will not pump enough coolant if not kept under the proper pressure for preventing vaporization of the coolant.

The pressure valve maintains the system pressure and allows excess pressure to vent. The vacuum valve allows coolant to return to the system from the recovery tank.
Chart 21-2  Comparison showing the metric pressure as shown on the top of the cap to pounds per square inch (PSI).

<table>
<thead>
<tr>
<th>BAR OR ATMOSPHERES</th>
<th>POUNDS PER SQUARE INCH (PSI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>16</td>
</tr>
<tr>
<td>1.0</td>
<td>15</td>
</tr>
<tr>
<td>0.9</td>
<td>13</td>
</tr>
<tr>
<td>0.8</td>
<td>12</td>
</tr>
<tr>
<td>0.7</td>
<td>10</td>
</tr>
<tr>
<td>0.6</td>
<td>9</td>
</tr>
<tr>
<td>0.5</td>
<td>7</td>
</tr>
</tbody>
</table>

Figure 21-15  The level in the coolant recovery system raises and lowers with engine temperature.

Figure 21-16  Some vehicles use a surge tank, which is located at the highest level of the cooling system, with a radiator cap.
REAL WORLD FIX

The Collapsed Radiator Hose Story
An automotive student asked the automotive instructor what brand of radiator hose is the best. Not knowing exactly what to say, the instructor asked if there was a problem with the brand hose used. The student had tried three brands and all of them collapsed when the engine cooled. The instructor then explained that the vehicle needed a new pressure cap and not a new upper radiator hose. The student thought that because the lower hose did not collapse that the problem had to be a fault with the hose. The instructor then explained that the lower radiator hose has a spring inside to keep the lower hose from collapsing due to the lower pressure created at the inlet to the water pump. The radiator cap was replaced and the upper radiator hose did not collapse when the engine cooled.
FREQUENTLY ASKED QUESTION

How Much Coolant Can a Water Pump Move?
A typical water pump can move a maximum of about 7,500 gallons (28,000 liters) of coolant per hour, or recirculate the coolant in the engine over 20 times per minute. This means that a water pump could be used to empty a typical private swimming pool in an hour! The slower the engine speed, the less power is consumed by the water pump. However, even at 35 mph (56 km/h), the typical water pump still moves about 2,000 gallons (7,500 liters) per hour or 0.5 gallon (2 liters) per second! See Figure 21–18.

Figure 21–19  This severely corroded water pump could not circulate enough coolant to keep the engine cool. As a result, the engine overheated and blew a head gasket.

Figure 21–20  The bleed weep hole in the water pump allows coolant to leak out of the pump and not be forced into the bearing. If the bearing failed, more serious damage could result.
A cutaway of a typical water pump showing the long bearing assembly and the seal. The weep hole is located between the seal and the bearing. If the seal fails, then coolant flows out of the weep hole to prevent the coolant from damaging the bearing.

TECH TIP: Release the Belt Tension Before Checking a Water Pump

The technician should release water pump belt tension before checking for water pump bearing looseness. To test a water pump bearing, it is normal to check the fan for movement; however, if the drive belt is tight, any looseness in the bearing will not be felt.

A Chevrolet V-8 block that shows the large coolant holes and the smaller gas vent or bleed holes that must match the head gasket when the engine is assembled.
WARNING:
Some electric cooling fans can come on after the engine is off without warning. Always keep hands and fingers away from the cooling fan blades unless the electrical connector has been disconnected to prevent the fan from coming on. Always follow all warnings and cautions.
TECH TIP: Be Sure to Always Use a Fan Shroud

A fan shroud forces the fan to draw air through the radiator. If a fan shroud is not used, then air is drawn from around the fan and will reduce the airflow through the radiator. Many overheating problems are a result of not replacing the factory shroud after engine work or body repair work to the front of the vehicle.

Figure 21-25 A typical heater core installed in a heating, ventilation, and air-conditioning (HVAC) housing assembly.

Figure 21-26 A heavily corroded radiator from a vehicle that was overheating. A visual inspection discovered that the corrosion had eaten away many of the cooling fins, yet did not leak. This radiator was replaced and it solved the overheating problem.
Figure 21-27 Pressure testing the cooling system. A typical hand-operated pressure tester applies pressure equal to the radiator cap pressure. The pressure should hold; if it drops, this indicates a leak somewhere in the cooling system. An adapter is used to attach the pump to the cap to determine if the radiator can hold pressure and release it when pressure rises above its maximum rated pressure setting.

Figure 21-28 The pressure cap should be checked for proper operation using a pressure tester as part of the cooling system diagnosis.

Figure 21-29 Use dye specifically made for coolant when checking for leaks using a black light.
When an engine overheats, often the coolant overflow container boils.

**REAL WORLD FIX: Highway Overheating**

A vehicle owner complained of an overheating vehicle, but the problem occurred only while driving at highway speeds. The vehicle, equipped with a 4-cylinder engine, would run in a perfectly normal manner in city driving situations.

The technician flushed the cooling system and replaced the radiator cap and the water pump, thinking that restricted coolant flow was the cause of the problem. Further testing revealed coolant sprays out of one cylinder when the engine was turned over by the starter with the spark plugs removed.

A new head gasket solved the problem. Obviously, the head gasket leak was not great enough to cause any problems until the engine speed and load created enough flow and heat to cause the coolant temperature to soar.

The technician also replaced the oxygen (O₂) sensor, because the IAT-type coolant contains phosphates and silicates that often contaminate the sensor. The deteriorated oxygen sensor could have contributed to the problem.
COOLING SYSTEM OPERATION AND DIAGNOSIS

Chart 21-3  The number of ribs determines the tension range of the belt.

<table>
<thead>
<tr>
<th>Number of Ribs Used</th>
<th>Tension Range (lb.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>45 to 60</td>
</tr>
<tr>
<td>4</td>
<td>60 to 80</td>
</tr>
<tr>
<td>5</td>
<td>75 to 100</td>
</tr>
<tr>
<td>6</td>
<td>90 to 125</td>
</tr>
<tr>
<td>7</td>
<td>105 to 145</td>
</tr>
</tbody>
</table>

CHART 21-3

TECH TIP: The Water Spray Trick

Lower-than-normal alternator output could be the result of a loose or slipping drive belt. All belts (V and serpentine multigroove) use an interference angle between the angle of the Vs of the belt and the angle of the Vs on the pulley. A belt wears this interference angle off the edges of the V of the belt. As a result, the belt may start to slip and make a squealing sound even if tensioned properly.

A common trick to determine if the noise is from the belt is to spray water from a squirt bottle at the belt with the engine running. If the noise stops, the belt is the cause of the noise. The water quickly evaporates and therefore, water just finds the problem—it does not provide a short-term fix.

Figure 21-32 (a)  Many vehicle manufacturers recommend that the bleeder valve be opened whenever re-filling the cooling system.
Chrysler recommends that a clear plastic hose (1/4 in. ID) be attached to the bleeder valve and directed into a suitable container to keep from spilling coolant onto the ground and on the engine and to allow the technician to observe the flow of coolant for any remaining oil bubbles.

Using a coolant exchange machine helps eliminate the problem of air getting into the system which can cause overheating or lack of heat due to air pockets getting trapped in the system.

All cooling system hoses should be checked for wear or damage.
**TECH TIP**

Always Replace the Pressure Cap

Replace the old radiator cap with a new cap with the same pressure rating. The cap can be located on the following:
1. Radiator
2. Coolant recovery reservoir
3. Upper radiator hose

**WARNING**

Never remove a pressure cap from a hot engine. When the pressure is removed from the system, the coolant will immediately boil and will expand upward, throwing scalding coolant in all directions. Hot coolant can cause serious burns.

**TECH TIP**

Quick and Easy Cooling System Problem Diagnosis

1. If overheating occurs in slow stop-and-go traffic, the usual cause is low airflow through the radiator. Check for airflow blockages or cooling fan malfunction.
2. If overheating occurs at highway speeds, the cause is usually a radiator or coolant circulation problem. Check for a restricted or clogged radiator.
**TECH TIP**

*Always Use Heater Hoses Designed for Coolant*

Many heater hoses are sizes that can also be used for other purposes such as oil lines. Always check and use hose that states it is designed for heater or cooling system use. **SEE FIGURE 21–35.**

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**Figure 21–35**  
The top 3/8 in. hose is designed for oil and similar liquids, whereas the 3/8 in. hose below is labeled “heater hose” and is designed for coolant.