Compression Ratio

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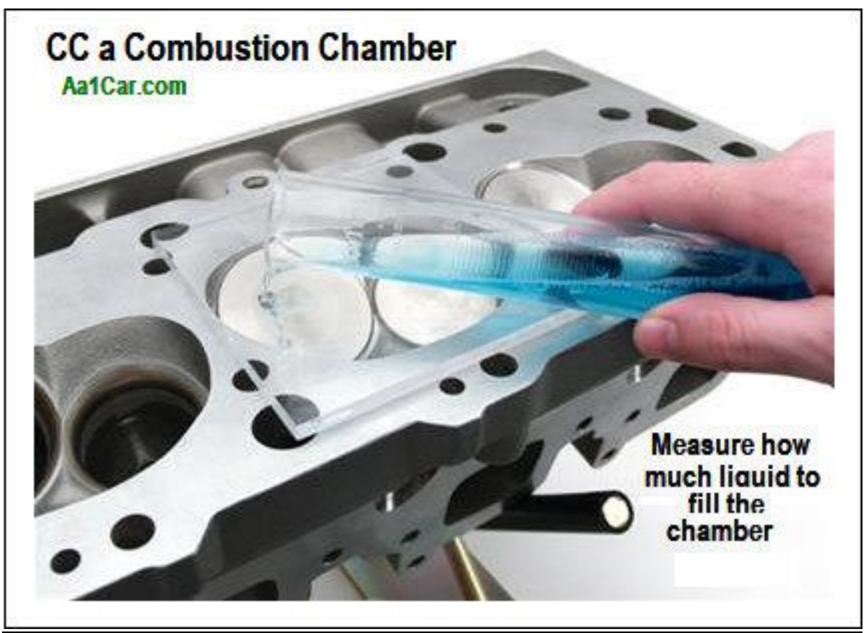
An engine's compression ratio is a measure of how much it squeezes the air/fuel mixture prior to combustion.

Compression Ratio = Cylinder Volume divided by Chamber Volume

Cylinder volume can be determined by measuring the bore and stroke of the engine, then doing the match to calculate the volume of the cylinder. It can be measured in cubic inches or cubic centimeters.

Cylinder Volume = 3.14 x ((bore diameter/2) x (bore diameter/2)) x stroke



Combustion Chamber Volume is difficult to measure directly because of the complex shape of most combustion chambers. So chamber volume has to be measured by filling the chamber with liquid (water or a light oil) and measuring how many CC's (cubic centimeters) of liquid it takes to fill the chamber. A plastic plate is used to cover the chamber and the liquid is poured in through a small vent hole. NOTE: The valves and spark plug must be installed to contain the liquid.

1 Cubic Centimeter = 0.0610237 Cubic Inches

Just remember when calculating a compression ratio, you have to use the same units of measure (cubic inches or cubic centimeters for both numbers).

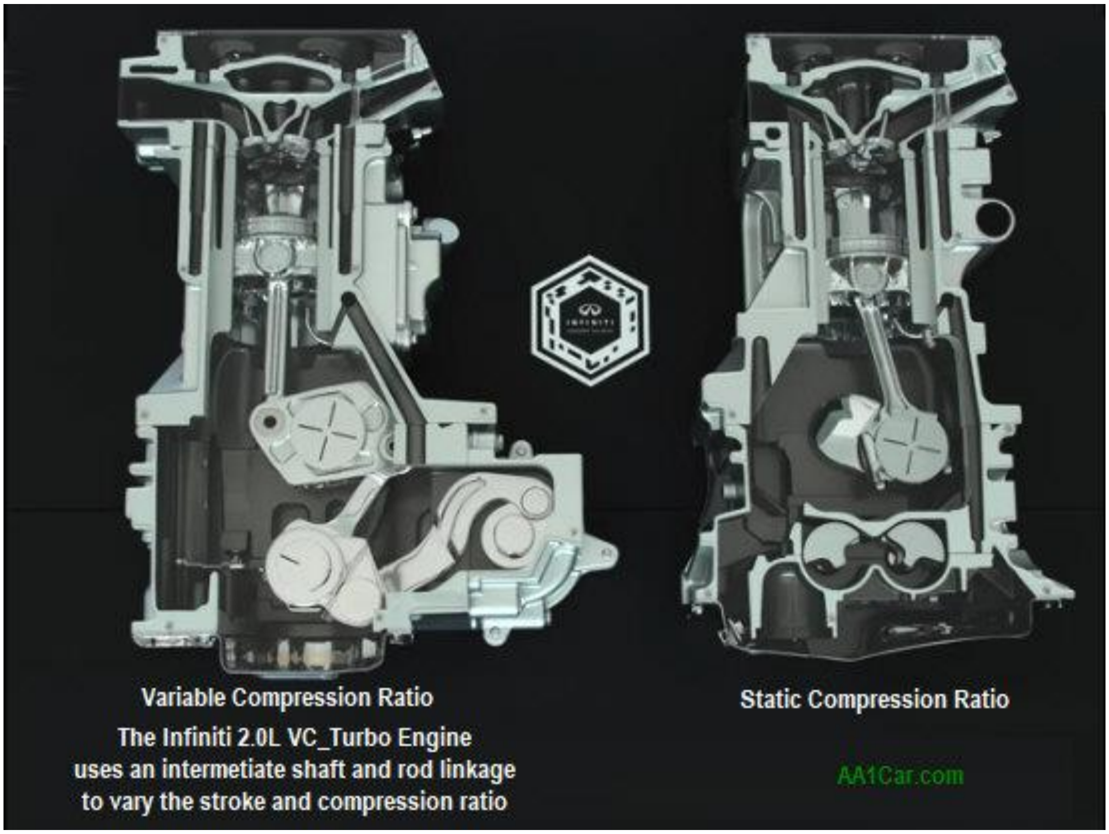
What Compression Does to the Air/Fuel Mixture

When the piston moves up the cylinder during its compression stroke, it squeezes and heats the air/fuel mixture in the cylinder. This helps to atomize the tiny droplets of fuel so it will mix better with the air, and it raises the temperature of the air/fuel mixture so it will more easily ignite.

The reason for increasing the compression ratio is that it increases the thermal efficiency and power of an internal combustion engine. The higher the compression ratio, the more heat energy is retained in the combustion chamber and the more power the engine produces.

Most late model gasoline passenger car and light truck engines have compression ratios between 9:1 and 11:1. Some engines with Gasoline Direct Injection have higher compression ratios of up to 14:1.

Diesel engines usually have compression ratios that are even higher than gasoline engines, ranging from 15:1 up to 23:1.



Some engines even have a Variable Compression Ratio, such as the Infiniti 2.0L VC_Turbo engine. The engine has an intermediate shaft that changes the rod linkage to vary the compression ratio. A higher compression ratio is used to maximize fuel economy. The compression ratio is then decreased when the turbocharger is delivering boost to optimize power.

Compression Ratio and Detonation

Although increasing the compression ratio increases thermal efficiency and power, it also increases the pressure and temperature of the air/fuel mixture inside the combustion chamber. If the compression ratio is too high for the octane rating of the fuel in a gasoline engine, the engine may experience **detonation** (spark knock). Detonation is most likely to occur when the engine is lugging hard under a load.

Detonation is an erratic form of combustion with multiple flame fronts instead of a single expanding flame front. This causes a sharp increase in cylinder pressure that hammers the pistons and produces a rattling or pinging noise from the engine. Detonation is bad because it can break piston rings, damage the pistons and/or the rod bearings.

High compression engines usually require higher octane fuel to reduce the risk of detonation.

Turbocharged and Supercharged engines also require higher octane fuel because the boost pressure from these devices forces more air into the engine's cylinders, increasing its **effective compression ratio**. The **static** or mechanical compression ratio does not change, but boost pressure will increase the volume of air/fuel mixture in the cylinders. For this reason, some turbocharged and supercharged engines actually have a somewhat lower static compression ratio than a similar naturally aspirated engine to reduce the risk of detonation.

Most late model engines also have a **knock sensor** to detect the vibrations caused by detonation.

If the knock sensor detects detonation, the engine computer will momentarily retard ignition timing to reduce or eliminate the detonation. The engine computer may also enrichen the fuel mixture to help cool it and reduce detonation, and if the engine is turbocharged it may open the turbo bypass valve to reduce boost pressure until the detonation goes away.

Changing the Compression Ratio

A variety of things can be changed to increase (or decrease) the compression ratio:

Increasing the bore diameter and installing oversize pistons will increase the compression ratio.

Decreasing the volume of the combustion chambers by using small chamber heads or by milling the surface of the head(s) will increase the compression ratio.

Installing a thinner head gasket will increase the compression ratio.

Installing a thicker head gasket will lower the compression ratio.

Replacing flat top or dished pistons with domed pistons will increase the compression ratio.

Replacing dished pistons with flat top pistons will increase the compression ratio.

Replacing domed pistons with flat top or dished pistons will decrease the compression ratio.

Replacing flat top pistons with dished pistons will lower the compression ratio.

Increasing the compression ratio is beneficial if you are building a performance engine and want to maximize engine power. A higher compression ratio also allows the engine to take advantage of higher octane fuels such as racing gas, and methanol and ethanol alcohol.

If you are building a turbo engine or bolting on a supercharger, and want to use pump gas rather than higher octane racing gas, limiting the static compression ratio to 8:1 or 9:1 is usually recommended to reduce the risk of engine-damaging detonation.

If pistons are replaced, there must be adequate clearance between the top and dome of a high compression piston and the combustion chamber and valves. Clearance will vary depending on the compression ratio and how “tight” the engine is being built. A few thousandths is usually necessary to prevent interference problems at high engine speeds and to compensate for piston growth and rod elongation when the engine is hot.

Piston clearance can be checked by placing a small amount of modeling clay on the piston, installing the head gasket and head, then rotating the crank until the piston reaches top dead center. The piston will squash the clay and reveal how much clearance remains between the piston, valves and chamber.