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Combustion Chamber Heat Dissipation and Engine Cooling

One of the biggest ‘killers’ of any engine is varying thermal gradients in the cylinder block and head. Obviously, they must exist for cooling to take place throughout the engine, but increased distortion and accelerated wear occur when there are contrasting thermal gradients in the same region, over a short distance. The two major cooling mediums in a water-cooled engine are water/coolant and engine oil. The heat in an engine is generated in the combustion chamber and dissipates by several routes:

- Warming the incoming air
- In the exhaust gases exiting the engine
- Through the cylinder head
- Through the valves to the valve seats and stems and into the cylinder head
- Through the cylinder walls
- Through the piston crown

This heat is then dissipated by exhaust gases exiting the engine; the water/coolant passing through the cylinder head and block and out to the radiator; by the engine oil passing through the oil galleries, through the bearings, sprayed up under or into the piston crowns, sprayed up the bores etc. and through the engine oil cooler; and finally by heat radiation from the engine being cooled by air passing through the engine bay. Ideally, the engine oil and coolant passing through an engine should be similar temperatures. If you have a water passage at 80°C and an oil gallery at 120°C passing nearby, the 40°C differential is less than ideal. If either of these rapidly peaks higher or lower, the surrounding metals distort, wears and can even fracture.

In a low power output diesel piston with splash lubrication, approximately 70% of the heat absorbed by the piston crown during the combustion process is dissipated through the rings to the cylinder walls. Of that 70%, about 45 - 55% through the top ring, 20 - 30% through the second ring and 5 - 15% through the oil ring. The remaining 30% goes out the piston skirts to the cylinder walls and into gudgeon pin to the conrod. Most diesel engines have under crown jet oil spray cooling – either directly on the underside of the crown or into oil galleries inside the crown of the piston. For direct jet spray cooling, 56 – 64% of the absorbed piston heat goes out through the rings and piston skirts, and 36 – 44% through the oil spray and gudgeon pin. For oil gallery cooled pistons, 30 – 33% of the absorbed piston heat goes out through the rings and piston skirts, 16 – 22% through oil spray and the gudgeon pin, and 48 – 51% is carried away by the oil passing through the crown oil gallery.

This large cooling effect of oil gallery cooling explains why almost every new diesel engine has oil gallery cooled piston crowns. It is how engine manufacturers can achieve such high-power outputs while still using aluminium pistons. However, this extra heat in the engine oil means it can contribute less to the cooling of the engine and requires increased and significantly more efficient oil cooling. When a diesel engine is modified to produce more power, the combustion chamber temperatures increase, and that heat must be dissipated through the available modes listed above. The most vulnerable components are the aluminium pistons, but many of the steel and iron components are also operating at near maximum temperatures and they will also fail if the cooling system is not adequate. It is important to remember the cooling system was designed to cater for the rated horsepower of the engine with an added safety factor. It is not surprising that many performance diesel engines suffer engine overheating problems when the power output is increased 100%, 200% and even more.

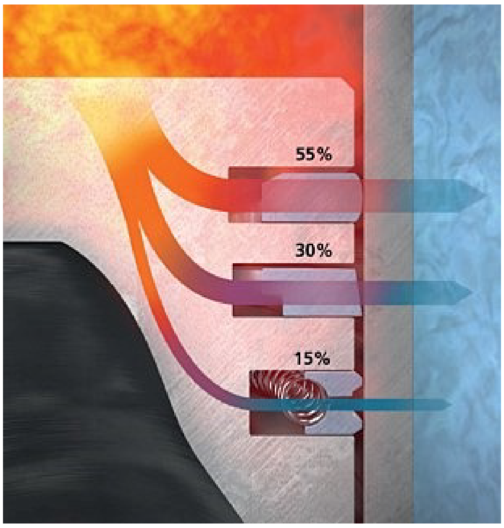

Diagram from ‘Piston Rings for Combustion Engines’ by Kolbenschmidt.

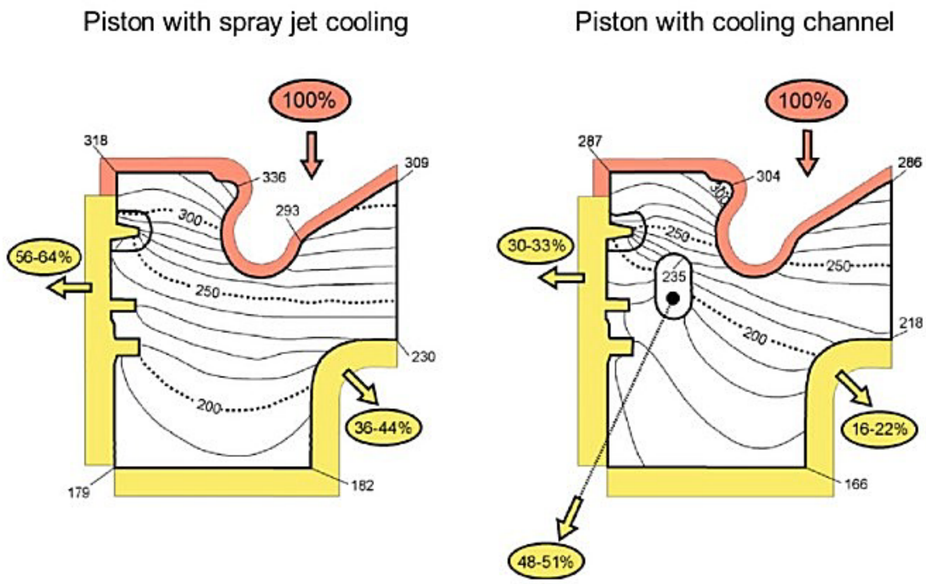

Diagram from
‘Pistons and Engine Testing’
by Mahle GmbH.

Before modifying the cooling system, it is important to measure the temperature of the engine coolant going into and out of the radiator, and the engine oil temperature going into and out of the oil cooler. It is not uncommon to see engine oil temperature in excess of 120°C in a modified diesel engine with oil gallery cooled pistons. It is a good idea to fit an external oil to air (with a fan) or oil to water cooler with an oil thermostat to the engine to reduce the oil temperature. This will help keep the engine cooler and the engine oil to last longer, which in turn will help preserve the engine. An oil to air oil cooler can drop the oil temperature by up to 25°C and an oil to water oil cooler up to 35°C.

If the engine still has cooling issues, then it is time to look at the cooling system. The radiator should drop the water temperature between 6°C and 10°C. The water temperature exiting the radiator is ideally 80°C - 85°C. The thermostat should not be removed from an engine unless it is running an electric water pump with temperature-controlled pumping rates. Pushing increased horsepower from an engine without having the engine coolant and oil cooling systems operating correctly and efficiently not only robs horsepower, but will ultimately lead to premature engine wear, unreliability and failure. Getting these right means you can feel more confident in the reliability of your engine, even when pushing it harder than usual.