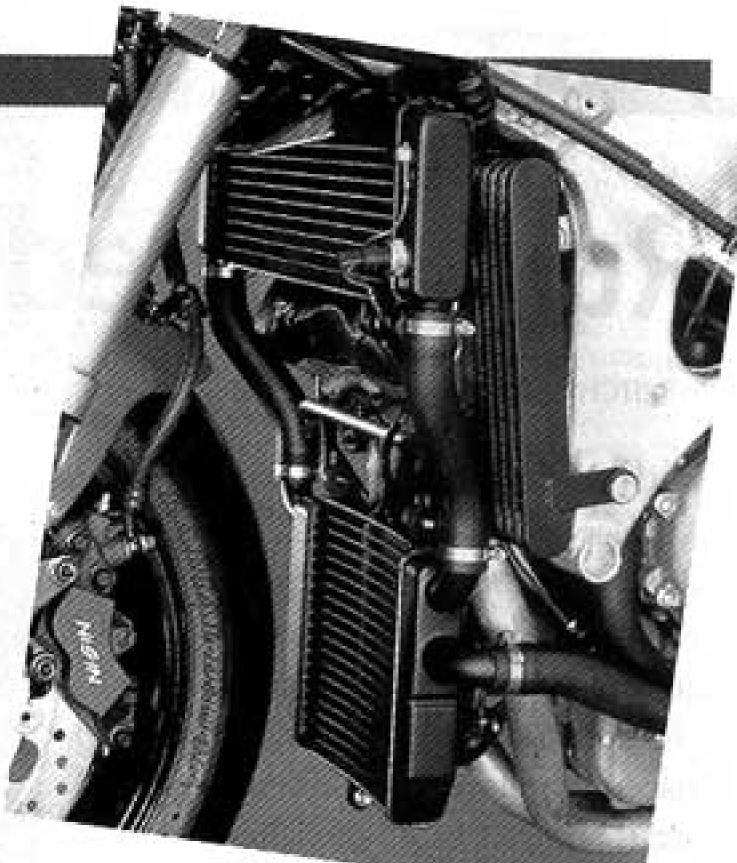
Keeping Your Cool

BY GORDON JENNINGS



Honda's RC45 uses dual radiators *and* an oil cooler.

Internal combustion engines' cooling systems are regrettable necessities, as they are machines that convert heat to horsepower, and heat removed is power lost. But maximum full-throttle combustion gas temperatures are in the order of 4000 degrees Fahrenheit. The aluminum in pistons and cylinder heads melts at around 1200 degrees, while iron goes at 2800. Some means of drawing heat away from combustion's container is needed to prevent this.

Pistons are especially melt-prone, having crowns exposed to combustion gases but limited direct cooling. Two-stroke engines' pistons lose heat via radiation and convection to air passing through their crankcases, which is bad for power but helps prevent meltdown. Oil splashing inside four-stroke engines' pistons carries away heat, a process aided in many high-output engines by upward aimed oil spit holes drilled in their connecting rods' big ends.

Some of the large amount of heat entering a piston's crown is transferred to the cylinder wall from the land above the compression ring—little reaches the skirt. Most of the heat travels from piston to cylinder via the top ring, and this has been the cause of problems in the distant past. High ring temperatures cooked oil in the ring groove, leading to ring-sticking. Effective detergents in oil cured this, though it still occurs in supercharged engines.

Detonation melts pistons because it creates a violent shock wave. This wave scours away the film of cooled gases that provide a measure of insulation between the 4000-degree fire and 1200-degree melting point of aluminum. The metal is then melted and blasted loose by the shock wave. This process produces the tiny balls of aluminum you sometimes find decorating spark plugs' center electrodes.

Heat in cylinder and combustion chamber walls can be transferred to the surrounding atmosphere either directly or indirectly. Direct air cooling requires fins on the cylinder and head. These cool by increasing the area of surfaces transferring heat to air. On ancient engines, fins usually had the same length all over the cylinder and head. Modern engines have deep finning above and shallower fins below, reflecting the distribution of the heat load.

All but very short fins should have a tapered cross section, thicker at the root than the tip. This shape makes the fin stronger (less likely to be broken off), and it provides a heat path for the fin's full length if the fin is dimensioned to suit the thermal conductivity of the metal from which it is made.

Cast-iron cooling fins generally are short because length is wasted. Iron's thermal conductivity is only 37 percent that of aluminum, so the outer part of a long cast-iron fin does nothing. Some Italian motorcycle makers have in years past employed useless fin length to lend puny cylinders a big-displacement appearance. Gilera was notable for this kind of deception, though certainly not alone in practicing it.

Direct air cooling once was almost universal in motorcycling, and it still has the look many riders prefer. But water cooling offers so many advantages in high-performance engines, it is sure to come into broader use despite the system's unsightly (to some) pump, radiator and hoses.

Liquid cooling has been seen on a few motorcycles for a very long time, but none of the ancients had mechanical water pumps. The water in their cooling systems was circulated by the same thermosiphon process relied upon in ancient Ford cars.

Thermosiphon systems are characterized by high-mounted radiators and large-diameter hoses. They work because water heated in the engine rises and flows through the top hose to the radiator's top tank. As the water cools in the radiator, its increasing density makes it sink to the bottom tank, and from there it flows through the return hose back to the engine. Improbable though it may seem, the thermosiphon effect circulates cooling water fairly effectively.

Crank-driven pumps have replaced thermosiphon systems for two reasons: First, pumped water moves much faster, which means the cooling job can be done with less liquid and a smaller radiator. Second, a fast flow of coolant directed at hot spots (like exhaust port walls) scrubs away the steam bubbles that form there and keeps them from becoming an insulating blanket.

Steam formation basically is a great aid to cooling. The liquid-to-vapor change absorbs huge amounts of heat, a fact of physics that has been used in steam-cooled aircraft engines.

Today's water-cooling systems gain efficiency by using high temperatures. The systems are lightly pressurized, which helps suppress boiling at water temperatures above 212 degrees, and more of the same is provided by "antifreeze," which further raises the coolant's boiling point. The engine itself sees little difference between coolant at, say, 190 degrees and 220, but heat transfer from the radiator into the atmosphere is greatly increased.

One especially useful enhancement is incorporating an oil heat exchanger in the engine's cooling system radiator. This feature heats the oil in the period immediately after start-up, then removes heat from the oil when its temperature rises above that of the coolant. Isn't good engineering wonderful? MC

I invite readers' comments, suggestions and even criticisms. My e-mail address is gj@wheelbase.com; call me at (805) 239-2192, 9:00 to 5:00 PDT, or fax (805) 239-0855.