Refreshing the formula

A new Formula One season means new teams, such as the BMW-owned Sauber F1.06 (shown) piloted by Jacques Villeneuve, and new rules, primarily the new 2.4-L V8 powerplants mandated for 2006.

F1 reins in power with a new generation of smaller V8 engines.

*by **Dan Carney***

Since the fatal crash of three-time world champion Ayrton Senna in 1994, **Formula One** (F1) organizers have sought to restrain speeds through various engine, suspension, tire, and aerodynamic restrictions.

Renault's RS26 V8 has been the class of the field in the early races, winning amid a flood of sometimes spectacular engine failures by most of the teams, especially during the second race of each engine's two-race life span.

The racing series is also struggling to restrain spending, with budgets at top-level teams approaching a half-billion dollars a year—a level sustainable by only a few teams, which makes it impossible for some teams with less in the way of resources to compete.

Addressing both of those concerns, new rules for 2006 severely restrict engine design to a 90° 2.4-L V8 configuration. A decade ago, F1 was home to a variety of engine types: V8, V10, and V12. Eventually, under the previous 3.0-L limit, the V10 engine was widely agreed upon to represent the best compromise between power and packaging, and this agreement was later codified to prevent costly development of more powerful V12s.

But even saddled with a two-race-weekend durability requirement for 2005, the 3.0-L V10s approached 1000 hp (746 kW), a level that worried organizers. And engine makers continued to tinker with parameters such as the engine's V-angle in pursuit of packaging gains and lower center of gravity.

To limit costly experimentation and reduce power while retaining the knowledge gained from 3.0-L V10 design, Formula One for 2006 has moved to a 2.4-L V8 configuration—a design that maintains the same displacement per cylinder as the previous engines. Power

Vibrations from the V8s, which worsen in the heart of the power band, require not only reinforced engine parts, but also strengthened accessory mounts, brackets, and other attachments on the car so they can withstand the punishment over the course of a race. Shown is the new BMW P86 F1 engine during dyno testing.

Extensive wind tunnel testing of 60% scale models helped teams such as BMW Sauber F1 minimize drag by testing the benefits of the smaller radiators permitted by the V8 engine's reduced cooling requirements.

loss is described by teams variously as "approximately 20%" and as "roughly 200 hp," confirming previous power at nearly 1000 hp (746 kW) and 2006-spec V8 cars at around 800 hp (597 kW).

The engines make up some for the loss of displacement with additional revs, screaming to 20,000 rpm while continuing to adhere to the two-race durability requirement.

Additionally, use of exotic materials has been banned, both through the specific prohibition of some likely suspects, and through a mandatory 95-kg (210-lb) minimum mass for the engine. Banned materials include magnesium alloys, metal matrix composites, intermetallic materials, and alloys containing more than 5% beryllium, iridium, or rhenium.

Because teams used these materials to differing degrees, the impact of their prohibition varies, according to Simon Corbyn, Head of Formula One Race Engineering for **Cosworth Engineering**, engine supplier to the **WilliamsF1** team. "Exhaust valve material was the biggest one for us," he said. "But the others have had a bigger impact on the other teams, which is probably an advantage for us."

Engine blocks, heads, and pistons must now be aluminum alloy, and crankshafts and camshafts must be iron. Maximum cylinder bore diameter is 98 mm (3.86 in). Variable-length intake velocity stacks, a tool used previously to shore up mid-range torque, are no longer permitted, creating an even greater impression of reduced torque for drivers.

New engine development

The basics of the new engines were pioneered with single-cylinder test engines that validated the dimensions before teams committed to building a V8 block, said Corbyn. "The single-cylinder engine can give you direction on bore size and the valve-area-to-combustion-chamber ratio," he said. Using computer simulations and the single-cylinder engine saved a lot of costly trial-and-error, he added. "A lot of effort went into analysis work to understand the problems and design them out, rather than building lots of [prototypes] and testing them."

A key concern among engine designers was vibration, something that could be assessed only with complete engines. The areas of concern were the cam drive system, piston durability, and the torsional behavior of the engine, said Corbyn.

While the V10 engines also had vibration issues, they occurred in a less critical area of the rev range, said Mario Theissen, **BMW** Motorsport Director. "The V10 entered a critical area between 12,000 rpm and 14,000 rpm," he said. "This was not an issue because the engine did not spend much time in this rev band."

But the new V8 engine's vibrations fall in a more critical range—right where driver's need engine power. "Its vibration level enters critical territory at higher speeds compared to the V10—at approximately 16,000 rpm—and continues to climb from there," Theissen said. Before, it was possible to avoid the problem, but now it must be addressed directly. "In order to get on top of this problem, the calculation and analysis of each individual engine component has to be totally reliable," he said.

That means that the cranktrain layout, masses, and forces must be evaluated to optimize designs before going into detail

Increasingly, minimizing drag and maximizing downforce means managing airflow not just around the body, but away from the tires and toward the wings, as illustrated by these appendages on the Renault R26.

To make F1 cars less sensitive to the disruption of airflow by the car ahead, rules makers have raised the front wings to lessen their effectiveness. Teams such as Renault have responded with biplane wing elements designed to recover some of the downforce lost when the main element was raised away from the road.

design. In critical areas, trial-and-error is still the best approach, with multiple solutions built and tested. "The results lead to design changes and refinements before the first engine is assembled and tested," Theissen said.

The smaller displacement means that the new engines will work harder than the old ones, spending a higher percentage of each lap at full throttle. Further, the average engine speed over a lap will be 400 to 500 rpm higher than before, according to the **Renault F1** team.

An added complication to the technical challenge was the compressed timetable dictated by the relatively late decision by Formula One authorities to mandate the V8 engine for the 2006 season. "In an ideal world, you would have 18 months to develop an F1 engine," said Theissen. "As it only became clear at a relatively late stage that V8 engines would be stipulated in 2006, we have had to make do with 15 months up to the first race."

Chassis implications

The changing engine rules also presented teams some significant challenges and opportunities in chassis design. Because the engines are smaller, designers can taper the car's rear bodywork for less drag. Because of the smaller displacement, the engines produce less heat, so radiators and the side pods that hold them can be smaller, too.

"The engine is shorter, lighter, and develops less power than the V10," said Tim Densham, Chief Designer of the Renault R26. One important factor is the engine's vibration, which not only affects the durability of internal engine parts, but of parts of the car, too. "We have paid particular attention in the detail design phase to mount accessories in such a way that they can function correctly in this environment," he said.

An added challenge for Renault was packaging the wider 90° engine into the space where its 72° V10 resided. Renault was the only team that used the 72° angle engine in 2005, and the team's winning the constructor and driver championships suggests that the engine's higher center of gravity was never the handicap other teams believed it was.

Both the Renault F1 team and **Panasonic Toyota Racing** chose to roll out undeveloped cars as early as possible for maximum testing, with last-second aerodynamic upgrades installed just prior to the opening race. "In this way, we have been able to run the mechanical base of the TF106 since the end of November to gain extremely valuable data from the car and the **Bridgestone** tires as we concurrently work on honing the most advanced aerodynamic package possible," said Toyota Technical Director Mike Gascoyne.

"We have looked at every single component to produce what I believe is our most competitive aero package to date," he said. "We have a new front wing and rear wing, more sculpted side pods, modified diffuser, and restyled engine cover and floor."

The other significant change for 2006 is a return to tire changes during races. In 2005, teams had to qualify and race on just one set of tires. Of the two competing tire suppliers, **Michelin** and Bridgestone, Michelin had an evident advantage in this format, winning all the races its teams entered after several consecutive championships won by Bridgestone.

However, at the U.S. Grand Prix at Indianapolis, Michelin's tires failed during practice and qualifying, leading the teams using its tires to withdraw from the event. For 2006, Formula One organizers eliminated the one-set tire limit, citing safety concerns as a result of that event. Of course, the change should also help Bridgestone teams, such as **Ferrari**, to be competitive this season, a fact bitterly criticized by Michelin. The company issued a statement blasting Formula One's "incoherent decision-making and lack of transparency."

The series plans to settle on a single tire supplier for 2007, and Michelin has already announced its withdrawal from the sport at the end of the season, apparently leaving Bridgestone as the spec tire supplier for next year. ***aei***