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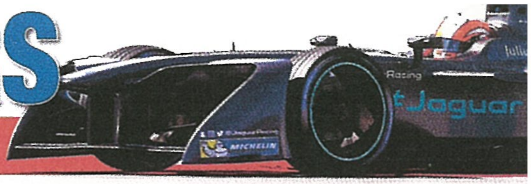

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OCTOBER 2016 No. 191 UK £5.95 USA $11.99 www.racetechmag.com

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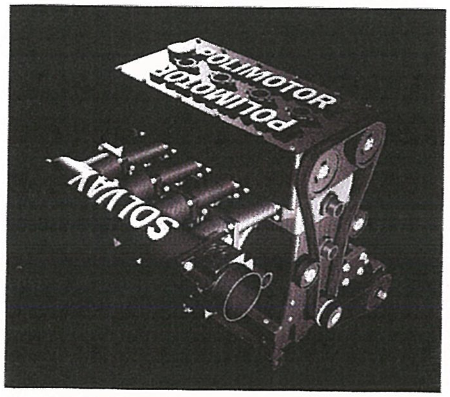


IT'S BACK AND THIS TIME IT'S PERSONAL!

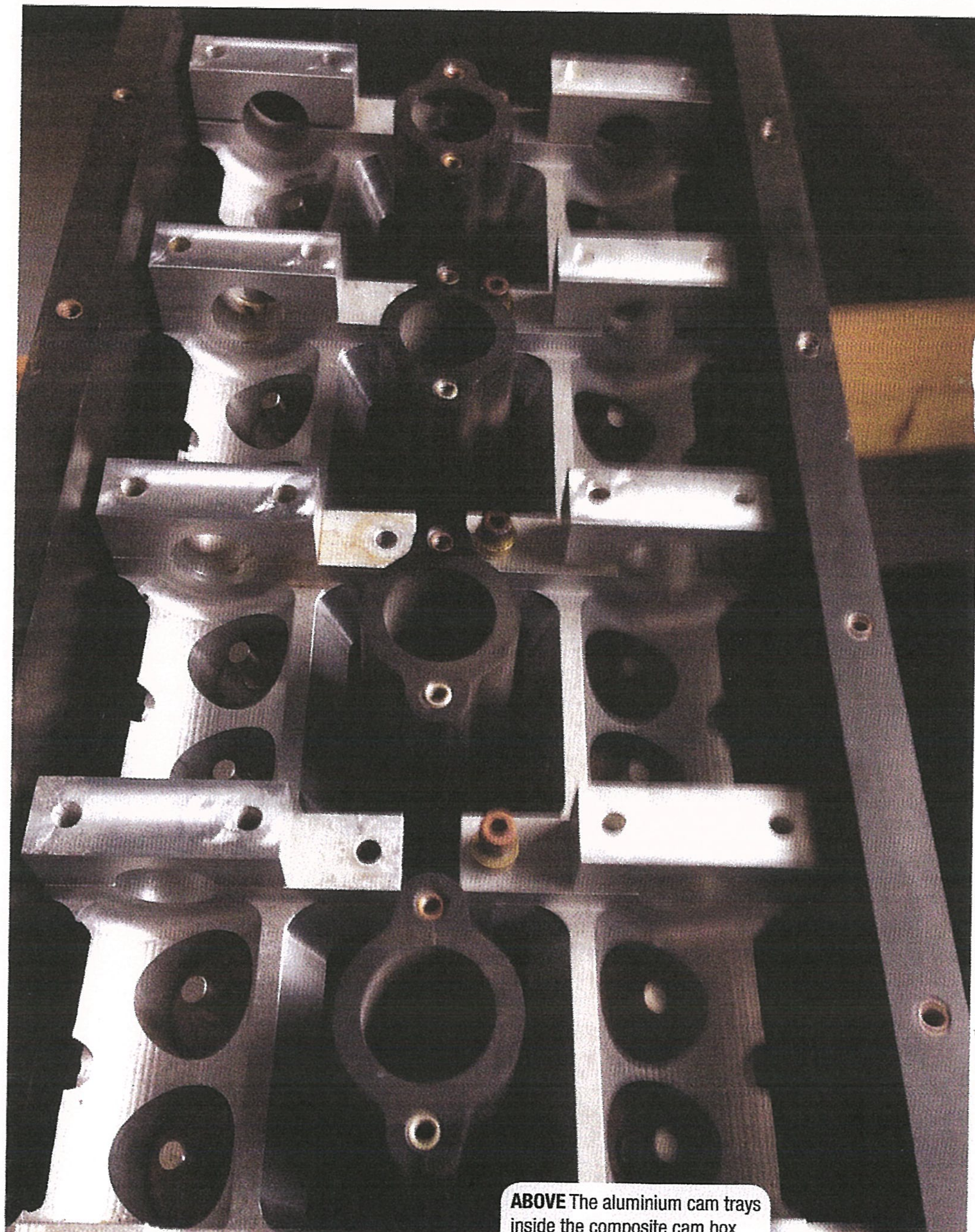
Chris Pickering reports on the advances in technology that promise to make dreams of a composite engine, first trialled three decades ago, a reality

WHEN carbon fibre chassis construction came to Formula 1 it was nothing short of a revelation. Just months after the technology debuted on McLaren's MP4-1 it had spread to half the grid. Composite technology had become a must-have and it's remained that way ever since, with everything from steering wheels to suspension arms sporting the familiar black weave. There is one very significant area of the car that's largely resisted this trend, though. The occasional cam cover or plenum chamber aside, you simply don't see any major composite engine parts. But what if you could make an engine out of composite materials?

As a matter of fact it's been done. Around the same time that John Barnard and his colleagues were developing the MP4-1, an American engineer by the name of Matti Holtzberg developed the world's first composite engine. The so-called Polimotor raced with a degree of success in the IMSA Camel Lights series before the project was put on hold. Now, however, Holtzberg has returned. Working in partnership with Belgian chemicals giant Solvay, he's using state of the art techniques to revive the Polimotor concept. And he plans to take it racing.

"A few years ago *The New York Times* ran a story on the composite engine that we'd developed in the 1980s," he recalls. "With all the current interest in lightweighting it sparked a new wave of interest and we were approached by a number of OEMs who were keen to investigate its potential for weight reduction."

Holtzberg claims that his thermoset plastic parts are comparable in strength to T6061-T6 billet aluminium and



ABOVE The aluminium cam trays inside the composite cam box approximately twice as strong as cast aluminium. They're also said to be lighter, cheaper when produced in quantity and easier to recycle.

ARCHITECTURE

The new engine – dubbed the Polimotor 2 – is a 2-litre naturally aspirated inline four with port injection. By Holtzberg's own admission it's a relatively traditional design in terms of airflow and combustion, which is largely intended as a proof of concept for the various materials involved. Holtzberg's company POLIMOTOR LLC provides the thermoset material for major structural components, such as the block and cylinder head, while Solvay provides a range of thermoplastics for the ancillaries.

"We look at this as a great way to highlight innovation," comments Brian Baleno, global automotive business development manager for Solvay Speciality Polymers. "A lot has changed in the thermoplastics since the original Polimotor and this gives us a chance to showcase materials that didn't even exist at the time of the previous project."

The first Polimotor was based around the Ford Pinto engine that eventually went on to form the basis of the Cosworth YB. Over time, however, it evolved into something rather different.

"Back then we didn't have many four-cylinder engines in the States, certainly not for racing," Holtzberg recalls. "I was doing a lot of work with Ford in those days, so the Pinto just seemed like a logical candidate."

The initial study stuck quite faithfully to the original single overhead cam Pinto design, but Holtzberg was good friends with Ford's head of global motorsport, Michael Kranefuss, who encouraged him to develop a twin cam head for the engine. This was inspired by the work of German tuning firm Zakspeed – owned by Kranefuss's brother-in-law, Erich Zakowski – that was developing a twin cam engine for the ill-fated Ford Probe GTP at the time (this, incidentally, is well worth a Google, being a front-engined GTP car!)

The first engine used a Pinto crankshaft, but the new head demanded a more compact bore spacing, so the Polimotor began to diverge from its original inspiration. In 2-litre Camel Lights spec it weighed 76 kg (168 lb) and produced 290 bhp at 8,500 rpm. The target for the new engine is just 63 kg (138 lb, minus starter, flywheel and exhaust) although the power output has actually been relaxed somewhat to meet the SCCA P1 regulations.

"We're not trying to come up with a novel port or combustion chamber design to increase the horsepower," comments Holtzberg. "If you're in the 250 to 280 bhp range with a 2-litre engine, that's pretty much all anyone will let you have in the sort of racing we're looking at."

> ***"There are a couple of tricks we use to keep more heat in the combustion chamber"***

At first glance, the Polimotor 2's engine block looks much like a conventional aluminium unit. It uses an open-deck layout with steel top hat liners. The ports and the combustion chambers are formed by a 2.5-inch thick aluminium casting surrounded by the water jacket. Internally, their geometry is said to be quite conventional. Each cylinder has a four-valve pent-roof combustion chamber that displaces 36 cc. This one-piece casting now forms the majority of the cylinder head, whereas the original engine used four distinct combustion bowls set into a composite box.

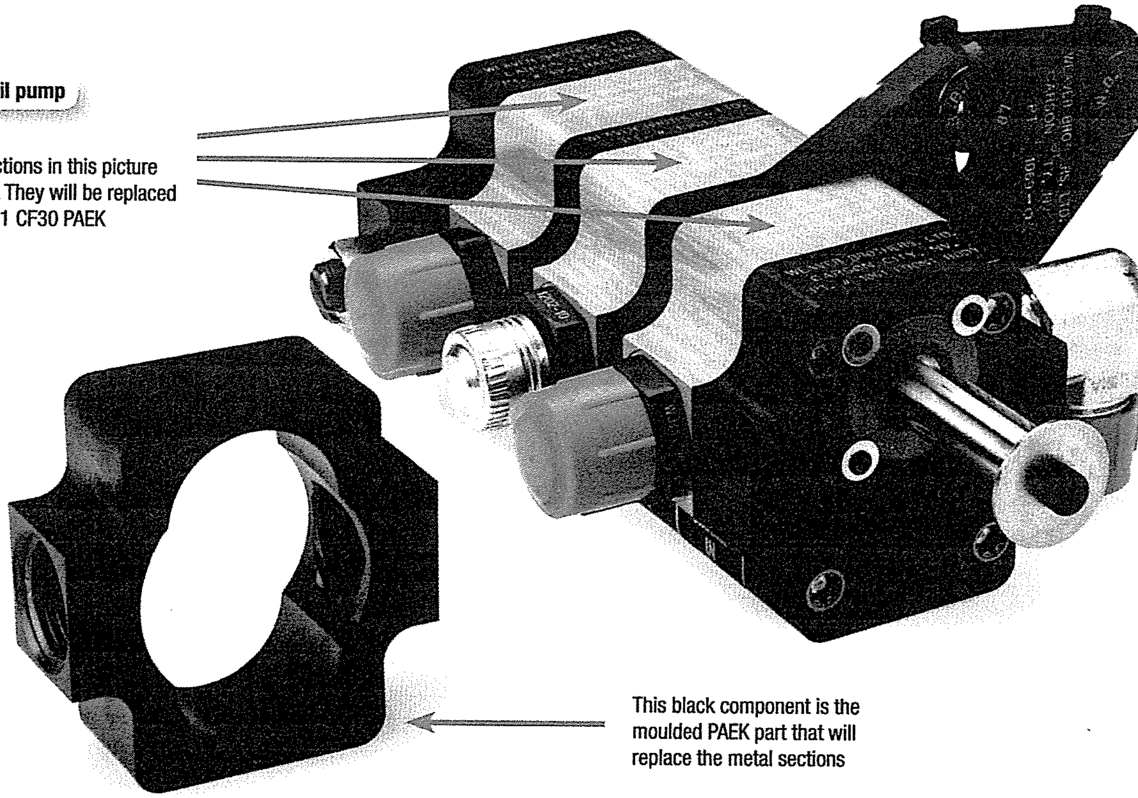
Above the aluminium casting sits a composite cam tray, similar to the arrangement used in the Cosworth BDA. This is made in the same thermoset material as the block – as is the sump, which is a structural design with integrated main caps to boost the rigidity of the bottom end. Inside there's a Moldex steel crankshaft and a set of Carillo rods. The pistons, bearings and rings all come from Mahle, while the valve springs, retainers and locks are from Ferrea.

BELOW Never disclosed publicly before, this is what the materials look like when the fibres and resin are mixed together, just prior to going into the mould. The unbroken fibres are critical to the overall high strength of the moulding compound

MATERIALS

As a rule of thumb, Holtzberg says, he limits the glass fibre-reinforced polymer to areas that see no more than around 140 deg C during use. That may sound quite limiting for a high performance combustion engine, but in reality it allows most of the structural parts to be constructed from the lightweight glass fibre-reinforced polymer material.

Carbon fibre has tumbled in price since the original Polimotor, but Holtzberg prefers to stick with S-glass reinforcement. This is partly ▶

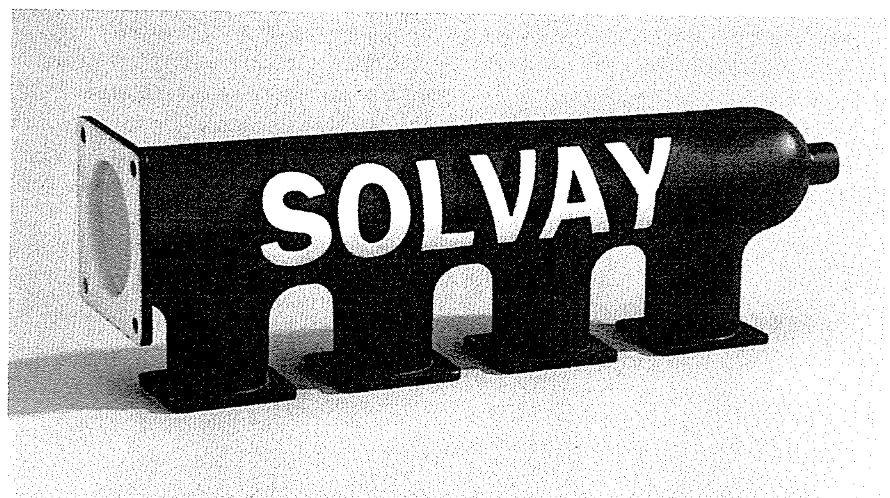


because he believes it would be a more cost-effective option for large scale production (which, ultimately, is what the racing project is intended to inspire) but also because of its mechanical properties.

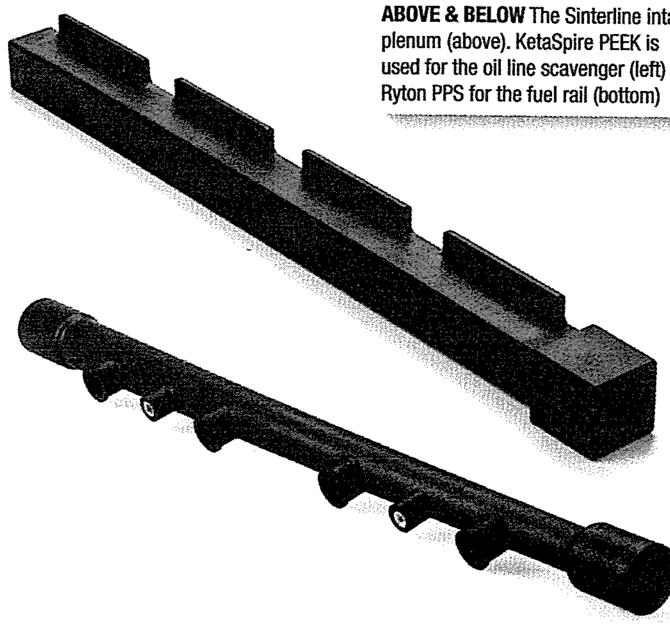
While glass fibre is clearly not as light as carbon, it brings some other useful properties. For a start, it's a great thermal insulator, Holtzberg points out: "The key is to keep the composite materials as cool as possible, at which point they're stronger than aluminium. At full chat at 9,000 rpm the headers can be cherry red, but the external skin of the block is at about 75 deg C. There are a couple of tricks that we use to keep more heat in the combustion chamber that I can't elaborate on. Everybody says, 'You must need a bigger water pump, you must need a bigger radiator' but actually the water temperature is quite cool."

Holtzberg is keeping quiet on the exact details of the material. The resin is one of only a handful of commercially-available high-temperature compounds, but there are a lot of other variables involved, such as the size of the fibres, the specific type of fibre and the pre-treatment that's used.

A lot of it also comes down to the production process. The thermoset parts for the Polimotor 2 prototype were cast by hand using Holtzberg's COMPCAST process. Here, a specially developed system is used for mixing the fibres, resin and hardener into ▶



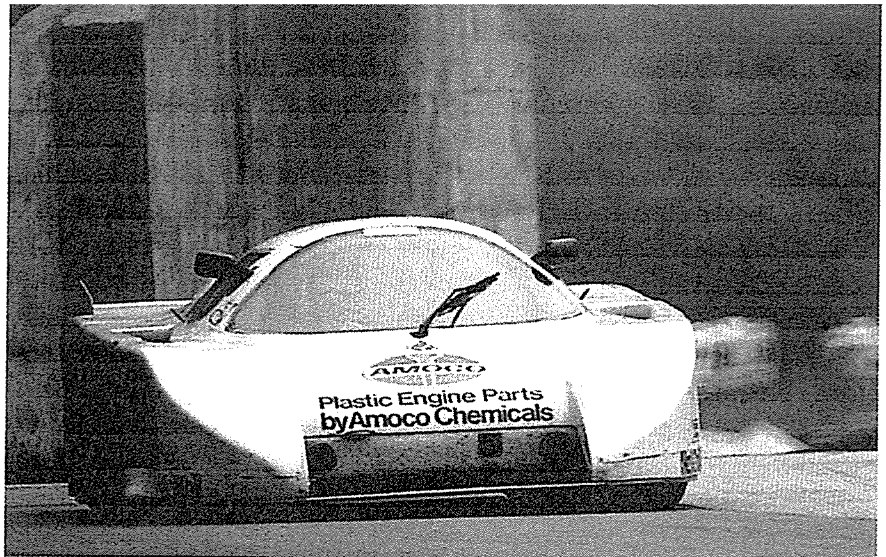
ABOVE & BELOW The Sinterline intake plenum (above). KetaSpire PEEK is used for the oil line scavenger (left) and Ryton PPS for the fuel rail (bottom)

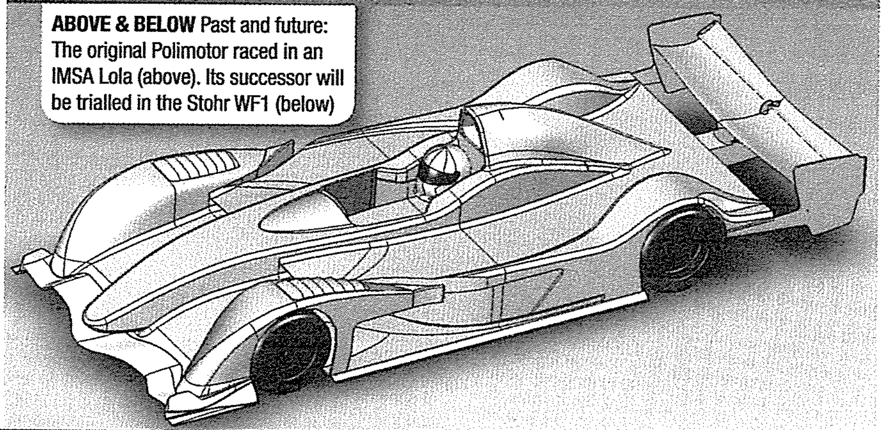


a gloopy substance he likens to porridge. This is then placed into the mould where it's squeezed – relatively gently – for a few minutes to remove any air. Afterwards, it cures at room temperature for around four hours before being placed into an oven to complete the thermal cycle.

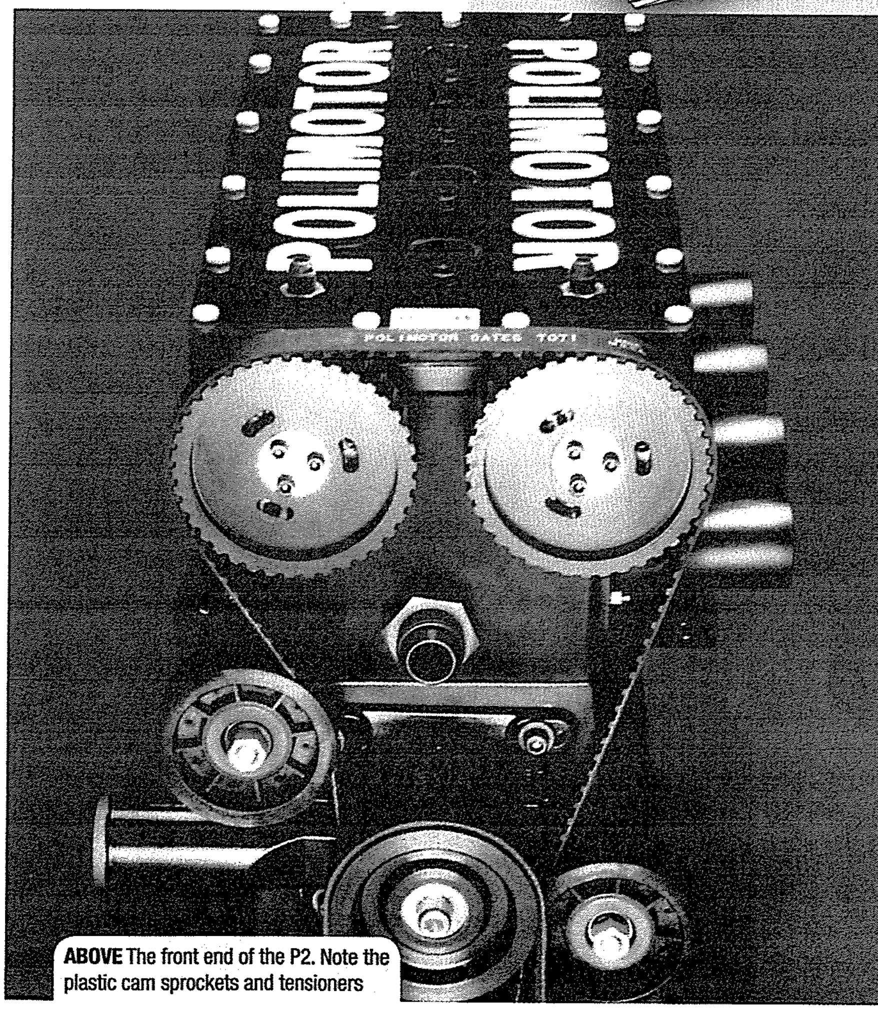
"I refer to it as non-compression moulding, because we don't use a lot of pressure – maybe 40 or 50 psi (2.8 to 3.4 bar)," comments Holtzberg. "That's just enough to fill the mould. In contrast, the original Polimotor used a traditional high-pressure compression moulding process with a dry fibrous compound, where you might use 10,000 to 15,000 psi (689 to 1034 bar)."

Reducing the temperature and pressure required for the moulding process is one of the key benefits, he explains: "Traditional compression moulding requires very expensive steel moulds and a lot of pressure. The tool could be hundreds of thousands of dollars, which is hard to justify for a prototype. With my process, the heat and the pressure is much lower so the tooling can be relatively inexpensive. We actually managed to 3D print some of the tooling, which accelerated the whole process."





ABOVE & BELOW Past and future: The original Polimotor raced in an IMSA Lola (above). Its successor will be trialled in the Stohr WF1 (below)



ABOVE The front end of the P2. Note the plastic cam sprockets and tensioners

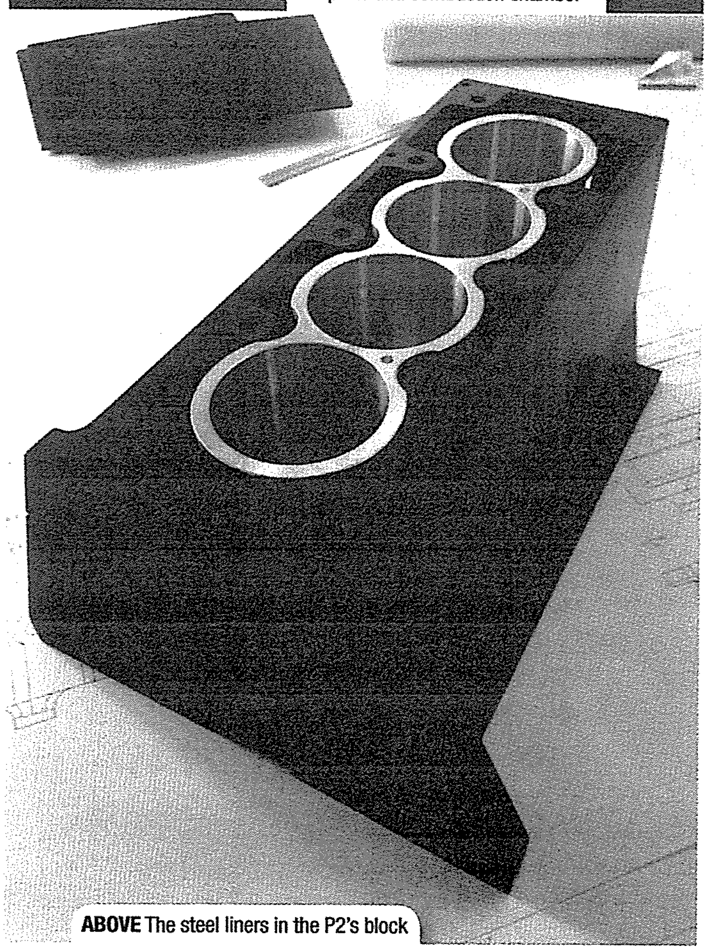
The thermoset material requires a degree of machining. It comes out of the mould to a dimensional accuracy of approximately 2 mm in prototype form, although Holtzberg reckons this could be brought down to 0.5 mm in a productionised process. From there we're told it can be machined much like aluminium with similar processing times. In fact, POLIMOTOR has recently begun producing billets of the material for parts to be machined from solid.

Elsewhere on the engine, many of the parts that were made from metal on the original Polimotor have now been recreated in Solvay's thermoplastic materials.

"When you look at the materials we selected, there's a range of different physical properties and glass transition temperatures. You can really tailor the thermoplastics to the individual components now and that's what we've done," comments Baleno. "The only carryover from Polimotor 1 is the Torlon polyamide-imide that's used for the cam sprockets."

Holtzberg worked extensively with Amoco – Solvay acquired its engineering plastics business in 2000 – on the original engine, using its Torlon material for a variety of parts, including the valve spring retainers ▶

ABOVE The latest Polimotor uses a single-piece aluminium moulding for the ports and combustion chamber



ABOVE The steel liners in the P2's block

and cam followers (the latter, admittedly, with a steel shim). Perhaps more surprisingly he also experimented with the material for valve stems, connecting rods and even piston skirts (using an aluminium crown).

These days KetaSpire PEEK (polyetheretherketone) is used for the oil line scavenger, while the fuel rail is injection moulded from Ryton XK-2340 PPS (polyphenylene sulphide) with seven O-rings fabricated from Tecnoflon VPL 85540 fluoroelastomer (FKM) sealing parts throughout the assembly. The oil pump housing is made from AvaSpire PAEK (polyarylether ketone). Solvay also employed several different techniques. The intake plenum was created from the company's Sinterline Technyl polyamide powder using selective laser sintering. Meanwhile, a fused filament fusion process was used to create the fuel rail in PEEK.

Holtzberg is already contemplating the possibility of a new engine, dubbed P3, using a thermoplastic block. In theory it could be injection moulded out of existing materials, he points out: "The size of press you would need to injection mould a block is no longer a problem. Back in the early days the injection moulding presses required to make a Nylon intake manifold were few and far between. There are so many more benefits to this technology if you can injection mould a block rather than cast it."

The cost benefits of an injection moulded engine would be huge, he says: "A high pressure die to cast aluminium is about a million US dollars and they only make 100,000 blocks before they need to dispose of it. A steel block for injection moulding would probably cost half as much and could maybe make a million parts because of the lower temperatures and pressures required. When you start to save money on tooling that offsets the cost of the material."

That's not to say the material is a direct substitution for aluminium, however. Holtzberg is understandably reluctant to go into details on the design philosophy, but he points out it requires a rather different approach to that of an aluminium casting – particularly if you're using glass reinforcement, where the fibres themselves are not as strong as carbon.

FUTURE PLANS

Next year, the company is looking to compete in the SCCA Majors in the P1 category (similar to Sports 2000 or V de V in Europe). To that end, a Stohr WF 1 – normally powered by a four-cylinder motorcycle engine – has been purchased (the original plan was to use a Norma CN car, but coupes are now prohibited in the rules, Holtzberg notes).

> *"Polimotor's McLaren moment?"*

"We hope to get the engine into the car and testing by the end of the year," he says. "We were hoping to make Road Atlanta for the first race, but it looks like that could be a stretch, so it might be VIR. We want to do four or five events next year, including maybe the 25 Hours of Thunderhill."

The team line-up has yet to be confirmed, although Holtzberg has no shortage of experienced IMSA drivers and engineers in his address book. And while the SCCA Majors may be a relatively low-key return, he has big plans for the future. A certain 24-hour race in northern France is mentioned more than once during our conversation and it would certainly seem a fitting showcase. Who knows, maybe that could be the Polimotor's McLaren moment? RT