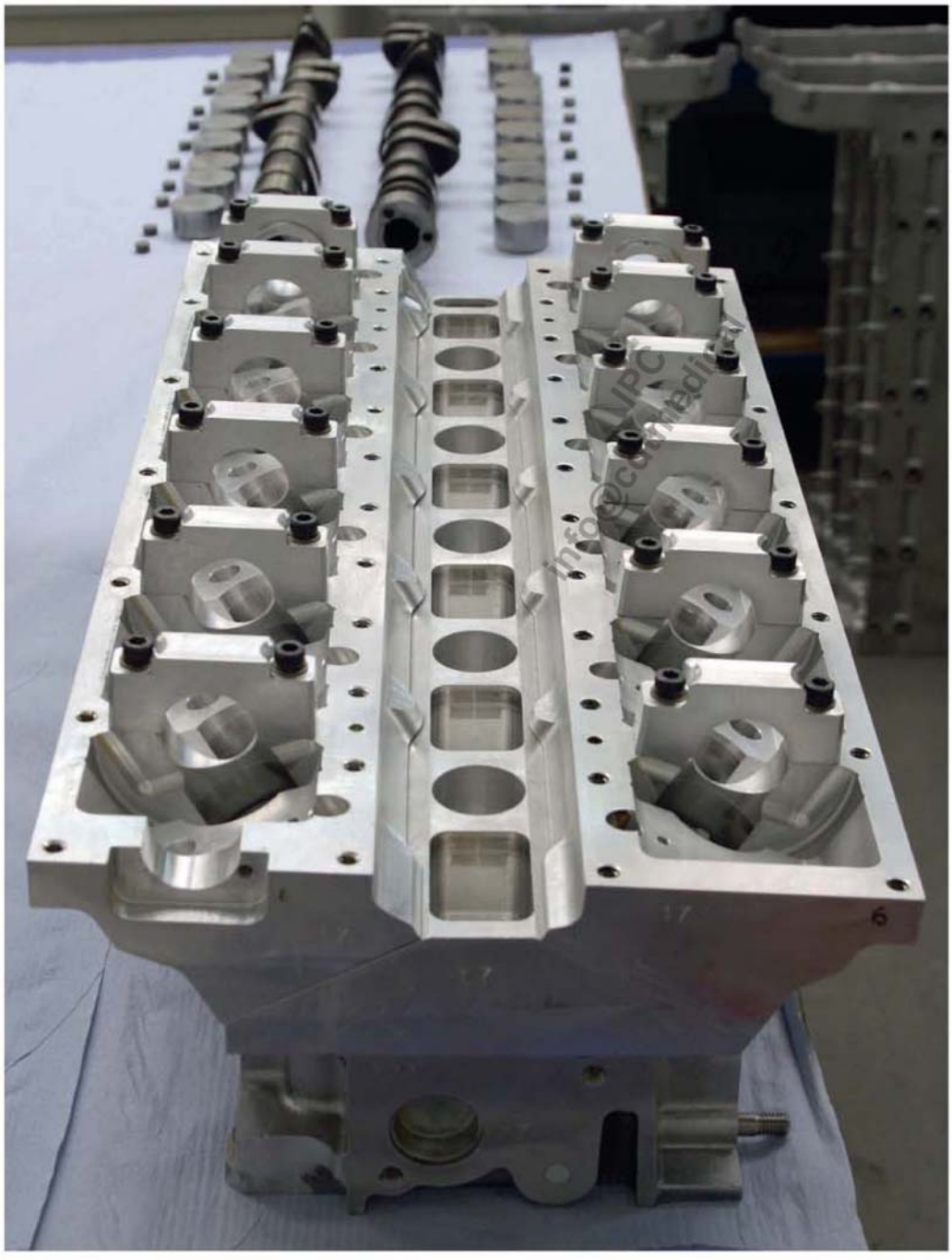
EXCLUSIVE

Mind games

We investigate the challenge of framing motorsport regulations with a look at the Volvo Touring Car cylinder head of the 1990s

BY GRAHAM JONES



The Volvo Touring Car programme was a classic example of ingenious engineers thinking their way around what initially appeared to be tightly framed regulations, and cylinder head development was at the heart of its success

It was an unlikely basis for a racecar. Despite that, the Volvo 850 estates fielded by Tom Walkinshaw Racing on behalf of the Swedish manufacturer during the 1990s remain among the most memorable vehicles to have graced modern Touring Car grids. They may not have been regular winners on track, but the racing estate cars were outright victors in the publicity stakes, as well as firm favourites with race crowds up and down the UK.

Beating out a distinctively uneven five-cylinder thrum from beneath its bonnet was a TWR-developed engine that, later in the decade (1998) and fitted to the smaller S40 saloon, would bring Volvo the Touring Car glory it had been seeking. That engine was in many ways like the original 850 estate car it powered – not an obvious choice for the track, but one which, with careful reading of the regulations and some clever thinking, was turned into a winner.

Now all this may have taken place over a decade ago, but there are some salutary lessons to be derived for cost-conscious motorsport rule makers everywhere, including those who will eventually frame the regulations for the Global Race Engine, should the current deliberations start moving from discussion stage to reality. It is also an example of how the law of unintended consequences can be unleashed from the wording of an apparently clearly written technical document.

One of the more ingenious aspects of the Volvo Super Touring engine was the cylinder head, and to understand how it came about, we spoke with Charlie Bamber, currently managing director of UK-based Menard Competition Technologies (MCT). Bamber is a veteran of TWR's Jaguar Sportscar programme and Nissan's Infiniti programme in North America. He was also chief engineer of the company's race engine department throughout the Volvo programme and responsible for the conception and development of the Touring Car engine.

Bamber's point in discussing the details of this project with *Racecar Engineering* – the first

time this information has ever appeared in the public domain – is, as he says, 'to show how making regulations to drive down cost can actually drive it the other way. What we've got [with the Volvo cylinder head] probably compares very well with the diffuser situation that Formula 1 found itself in this year.'

Understandably enough, a roadgoing engine is just that, so its design parameters and specification are unlikely to be optimised for motorsport.

VALVE ANGLES

In the case of the Volvo cylinder head, one of the most significant compromises involved the included angle of the valves.

'It's set at 58 degrees,' explains Bamber. 'This is not for a good reason in terms of engineering. Rather it involves the equipment used on the Volvo engine production line. A single cutting machine could incorporate two machining heads if the valves were angled further apart, thereby allowing you to cut two sets of valve openings at the same time. If Volvo engineers had gone for a race-style alignment – say, where you had maybe 12 degrees on an inlet and 13 degrees on an exhaust, for a total angle of 25 degrees – then the machine tools would clash. As a result, you couldn't manufacture such a layout as efficiently and [the head] ended up with a very steep spread in the valve angle. It's not for good combustion, it's driven by a desire to manufacture the head more cost effectively.

'This gives you some problems straight away because what it does is put a huge volume in [the combustion chamber] and if, for example, you're competing in a series where the compression ratio is free, then the only way of raising the compression ratio is by pushing the piston into that void. And when you do that, you compromise the gas exchange. Between Ricardo and Volvo, they built a prototype and came up with a 260bhp engine. I think at that time in the BTCC most teams were probably on about 285bhp, or thereabouts.'

In short, it was clear some radical thinking would be required to turn this very competent road engine into a competitive race engine, and that was exactly what TWR brought to the table when it was awarded the contract in late 1993 to build and run the racing Volvos.

> **some salutary lessons for cost-conscious motorsport rule makers**

'One of the first things we chose to do was look very carefully at the regulations,' recounts Bamber. 'They said you must run a standard cylinder head, you must retain the standard included valve angle and you must keep the inlet port in the position it is as standard. You can fettle the port to make it bigger, you can add material (but you're not allowed to weld) and you can fit big valves, but you have to use the standard head. The intention of that quite tightly framed regulation was to drive costs down.'

The fact a certain well-travelled road is paved with good intentions was clearly demonstrated as Bamber and his team started to 'drill into the regulations', as he puts it.

Valve angles and inlet port positions had to remain as standard measured from specific reference points, opening the door wide to interpretation

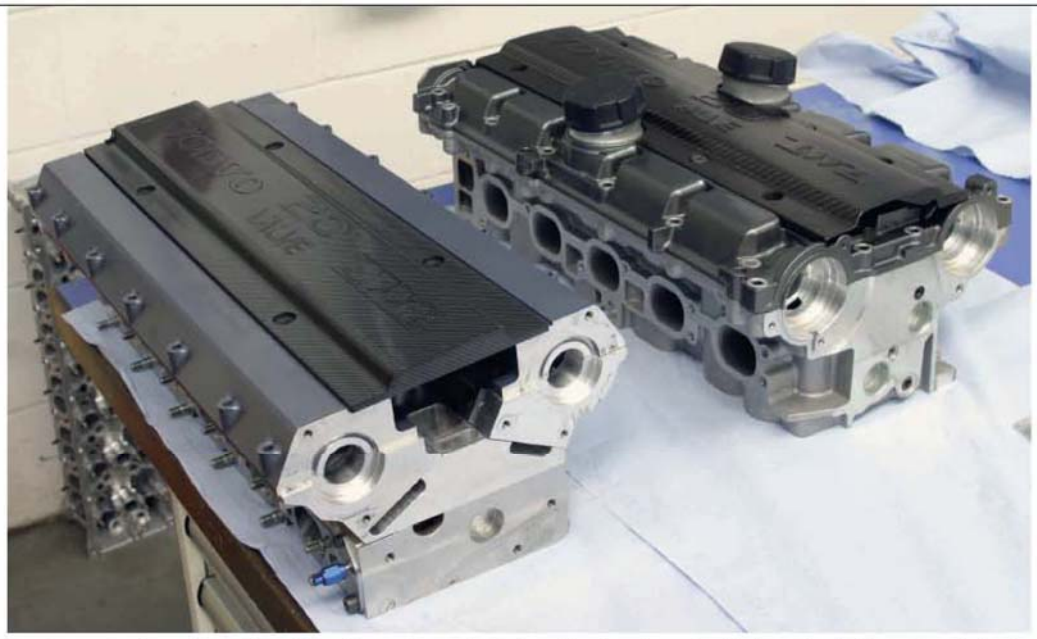
CAMS AND CARRIERS

The first area they looked at was camshafts, and it immediately became obvious that for the sort of profile required to achieve the desired performance, the limiting factor would be the inability of the standard cylinder head to accommodate cams with the necessary base circle diameter. At the same time, the more radical cam profile required tappets larger than the standard engine's 32mm offerings; 36mm was the preferred diameter, as it would allow the team to run cams with sufficient lift for the largest valves that could be fitted to the combustion chambers. A standard production camshaft, for example, would have approximately 300thou of lift, while the ultimate cam TWR was looking to run in the Volvo engine had 825thou of lift. The challenge was to make the chosen cams and tappets fit and still comply with the rulebook.

LAT

After the 850 estate Touring Cars, Volvo switched to the 850 saloons. All cars were run by Tom Walkinshaw Racing

Going back to the regulation that said you could remove as much material as you like from the standard head casting, the decision was taken to cut off the sections where the cams are fitted and fabricate new, purpose-designed carriers that bolt to the central core of the Volvo head, thereby allowing the optimum specification of cam and tappet to be fitted.



The Super Touring rules said nothing about the angle the head had to sit on the block - a loophole TWR exploited to great effect. The standard Volvo head is on the right in this photo, the fully compliant TWR version on the left

PORTS AND VALVES

Having overcome that obstacle, the focus then shifted to optimising the design of the inlet port. As Bamber puts it, 'Why have an 825thou lift cam when the maximum flow of the standard port probably peaks at the 400thou mark? The standard head has a decent-sized opening, but it's limited. If we want a port that flows at a very high lift, then it's actually going to have to be a lot steeper [than standard].'

The homologation papers specify that the distance between the cylinder head face and a centre line through the ports may not be altered from standard. To deal with that requirement, Bamber and his team decided to cut back the vertical head face containing the ports, thereby producing a steep run directly onto the back of the valve. In order to retain the critical measurement between head face and port centre line, material was added to the port openings, which was permissible under the regulations.

With that achieved, they turned to the combustion chamber shape and valve choice. 'Valve size was free,' says Bamber, 'so you work out your smallest possible stem diameter and then rig test it to make sure it survives. In this case, we used a 3.5 to 4.0mm stem. Turning to the combustion chamber, you need to maximise the flow of the new valve. That was achieved by chopping the chamber out, to make sure you have the best possible gas exchange, and putting as much volume back in the chamber as you can. Effectively, what you've done is dropped everything further in and back in the casting.'

THE WEDGE EFFECT

The *pièce de résistance*, however, relates to the fact the Touring Car regulations of the time did not stipulate how the cylinder head was to sit on the engine block. Significantly, the measurement of the included angle for the inlet and exhaust valves related to the production head, which had a uniform height across its width. By machining the head face to a 'wedge' and cutting back the face of the port where the inlet manifold mounts, Bamber and his team were able to achieve a significantly steeper inlet port angle, a more optimum inlet valve angle and a shallower exhaust valve angle, all of which still complied with the homologated dimensions. The final steps involved machining the piston crowns to produce the desired compression ratio (13.5:1) and some additional skimming of metal from what remained of the original head casting.

'You're now left with that section of the original head that says "Volvo" on it,' smiles Bamber, 'so it's a standard head with a standard water jacket, standard valve angle and with the inlet ports at the height specified by the regulations. But you've gone from an engine that was stuck at 260bhp to one that ended up with 325bhp, and the fastest car at the end of the straight on many occasions with a body that had a frontal area greater than the other cars. The regulations were designed to reduce costs, but because of the way engineers read those regulations, you ended up with something very different from what the organisers intended.

COST CONTROL?

'That head, in the 1990s, in the small volumes produced cost in the region of £13,000 to £15,000 per head to make. In short, you've produced a £15,000 version of a £200 head. The argument then has to be, "Why not just let somebody have the head they want?" If the regulations had permitted it, we could have spent £15,000 on tooling and £200 per casting, machined up some heads, topped and tailed them, and we would have had the five-cylinder head we wanted. After the initial investment in tooling, we could probably have been making heads at £450 each. Instead, we had heads coming out at between £13,000 and £15,000 apiece as a result of regulations formulated to keep costs down.'

> "a £15,000 version of a £200 head"

Given the 'free-thinking' approach taken by TWR, it's seems a fair assumption the Volvo head would have been questioned, and Bamber confirms this: 'It was queried at every race, and time and again, proved to be within the regulations. It is a production head - there is no way it was anything else.'

LAT

In 1998, fitted into the smaller S40 saloon, the TWR-developed engine brought Volvo the Touring Car glory it so richly deserved