



POWER PACK

Powerful, 'clean' and immensely flexible, Audi's Sport quattro-derived, 20-valve, 220bhp turbo engine had to be tailored to fit the new Coupé S2. Geoff Howard analyses its design with Axel Werner, the engineer responsible. Photos: Andrew Yeadon

Axel Werner is the kind of man who makes Audi what it is today. Unassuming and modest to a fault, at the age of 47 he already has 18 years' company service behind him and has lived with five-cylinder engines since the day Dr Ferdinand Piech first persuaded the Audi board to take the unconventional route to more power and refinement.

But didn't he ever have doubts in those early days that this innovative concept was more trouble than it was worth? "Definitely not!", he replies with positive vigour. "We never allowed ourselves even to contemplate such thoughts, or the possibility of failure. If we had problems, we looked for ways to solve them."

Coming from a family of lawyers, Dipl Ing Werner considers himself something of a genetic black sheep. During studies for his mechanical engineering degree at Darmstadt Technical High School, he quickly found he wanted to work in the field of engines and took his first job after graduation with Audi at Ingolstadt, developing the power unit for the original 1975 Porsche 924, an Audi research project which changed identity before its launch and was then produced for Porsche by Audi in Neckarsulm.

At about the same time, the roots of a new generation of five-cylinder engines were becoming firmly entrenched in future Audi product plans as the need for more powerful saloon car engines grew stronger and the results of the mid-1970s fuel crisis put pressure on vehicle designers to reduce aerodynamic drag. With all its engines mounted ahead of the front wheels, Audi had no room for an in-line six under the 100's clean, sloping nose and no inclination to develop a totally new V6 for a large car market which was then in serious decline.

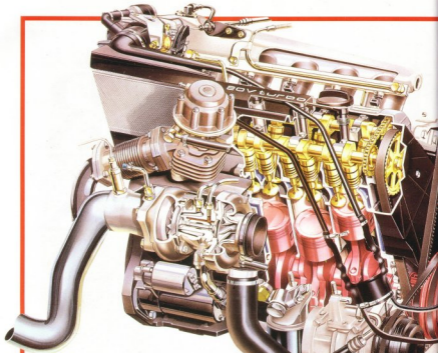
To provide an advanced technical solution to this conflicting set of requirements, Axel Werner's team took the obvious, but

more challenging, route of adding an extra cylinder to Audi's existing 1600 four-cylinder engine. Initial high speed noise problems were quickly traced to bending forces in the engine/transmission assembly, and completely fixed by stiffening the overall structure. Compared with a conventional six, the resulting design then proved smoother – because, being shorter, there were less torsional vibrations – and more efficient – because the frictional losses of one cylinder and its valve gear were eliminated.

The natural progression after increasing the engine from four to five cylinders was to add a turbocharger, boosting power from 136 to 170bhp from the same engine

When writers asked in '88 if turbo engine would fit new Coupé, answer was an honest "No." Axel Werner, left, shows he finally found a suitable shoehorn. Werner designed Sport quattro engine and led development of Audi's first five-cylinder unit. S2's four-valve head and turbo unit, right





*Catway of Coupé
S2's Werner-
developed engine
shows KKK turbo,
compact intercooler
and how left cam is
chain driven from
belt-driven right*

size. When a high performance engine was needed for the first quattro coupé in 1979, the same basic Audi 200T engine was further developed to produce 200bhp in standard production trim and 310-330bhp in the rally cars which followed. In 1984, Audi quattros won ten of the 12 qualifying rounds of the World Rally Championship, with the best engines by then developing in excess of 340bhp.

As the competition in Group B from Lancia and Peugeot began to hot up, Audi engineers turned their attention to a new competition quattro design. To make the car more nimble on loose rally stages they literally cut 12.6in from the middle of the car and designed a new motorsport engine with a crossflow head layout for the first time, four-valves per cylinder and an alu-

minium cylinder block. It developed up to 450bhp in rally tune and 306bhp in the road-going version, of which 200 were built to support Group B homologation.

It was for this car – the limited-production road version of the Sport quattro S1 – that Axel Werner developed his first 20-valve twin-cam intercooled turbo engine. "That design," he explains, "drove its second camshaft off the first by gears, giving us a very compact lightweight head with only 26 degrees between the inlet and exhaust valve stems."

When a 20-valve turbo engine was required for the latest Audi 200 and original-shape quattro coupé, the alloy multi-valve head of the Sport quattro unit was used as the starting point, mounted on a normal cast-iron cylinder block. "But we

changed the camshaft gears for a chain-drive to reduce noise and substituted hydraulic tappets for solid valve lifters, to eliminate the need for routine adjustment."

It was at this point that Axel Werner set himself an extraordinary personal objective. "On the Sport quattro we had to use a very large turbo to get high power – up to 600bhp at the peak of development. For the latest 20-valve turbo we changed to a much smaller turbo – from a K.27 to K.24 unit – to get high torque at low rpm. I wanted the peak of the torque curve to be below 2000 rpm, to make it flexible and easy to drive in traffic."

The resulting peak of 309 Nm at 1950 rpm is a remarkable achievement which



"We wanted a very high basic torque – the torque you get when you start to accelerate," recalls Axel Werner, "because this provides a bigger flow of exhaust gases to accelerate the turbo rotor up to speed quickly. So, as well as all the other changes, we positioned the turbo as close as possible to the cylinder head face."

To operate at such a high compression ratio, equivalent to about 16:1 on a non-turbo engine, the 20-valve turbo engine uses two independent knock sensors to prevent detonation on 95-octane unleaded fuel. Before the rate of combustion pressure rise detected by the sensors can reach the point of detonation the ignition is retarded, step by step, up to a preset limit. "The problem with this control, however, is that it raises the combustion temperature," said Axel Werner. "So, if knock characteristics are still detected the engine management computer increases the mixture strength to cool the combustion gases and reduce the knock sensitivity further. For the final preventive control of knock, the boost pressure is lowered."

To keep engine torque below the Coupé S2's gearbox limit of 310Nm, the 20-valve turbo engine in this application runs at only 0.75 bar boost, compared with 0.85 in the Audi 200 and quattro coupé (and 1.03 in the original Sport quattro road car). To achieve 220bhp within the limits set by the S2's installation, 98-octane super unleaded fuel is specified, although the Motronic engine management system automatically adjusts with a small power loss if lower 95 or 91-octane grades are used instead. For a clean exhaust at high speed, as well as within the stringent '85 US emission test cycle, the Coupé S2 has two catalysis in parallel, reducing back pressure in the process.

In developing the 20-valve turbo installation for the tightly-packaged Coupé body, Audi took the unusual step of cooperating with racing car constructors Konrad Schmidt of Cadolzburg. "They worked out how to make it fit, while we concentrated on performance, economy and emission calibrations and making durability targets," says Axel Werner.

A small supplementary radiator is added on the right-hand side of the front grille, with main radiator further back on the left, the turbo intercooler below the bumper and the oil cooler in the right-hand wheelarch. A total of five pre-production prototypes ran 140,000 test miles each, while two Coupé S2 engines each passed 1200-hour tests on dynamometers, including 400 hours under maximum speed, full load conditions, equivalent to nearly 62,000 miles at 154mph.

An advanced diagnostic system is a basic part of the Coupé S2's engine management system, which includes a fully-



'I wanted the peak of the torque curve to be below 2000 rpm, to make it flexible and easy to drive in traffic'

has won acclaim in every press road test of cars with this engine. It allows the new Coupé S2 to pull like a train from below 1200 in fifth gear and be manoeuvred in first and reverse without any throttle at all. By 1500 rpm it is already developing more torque than the maximum – at 4500 – produced by the non-turbo 20-valve engine and sustains over 90 per cent of its peak output from only 1700 right through to 5600 rpm.

But it took more than a smaller turbo to achieve this impressive effect. New intake and exhaust manifolds were developed, the camshaft timing was revised but retained the same Sport quattro cam profiles, the compression ratio was raised from 8.0 to 9.5:1 and the intercooling characteristics optimised.

mapped boost control to improve fuel consumption as well as separate maps for ignition and fuel metering. The all-electronic module automatically updates and adapts its settings to give optimum performance throughout the car's life. If any malfunction is detected during regular self-checking operations results are stored in the system's memory, which can be interrogated by a servicing module so that corrections can be made. If anything goes seriously wrong with the engine controls a warning light illuminates and the calibrations revert to an average level to protect the engine but allow the driver to carry on almost as normal. "We have to make sure the driver notices a fault, but is not handicapped too much by the consequences," explains Axel Werner.