OPEL'S ENGINE MAN

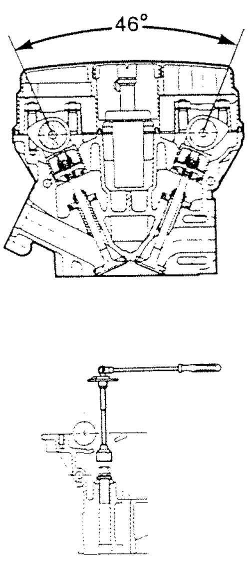
We interview Dr Fritz Indra, the man behind Opel's four-valve and turbocharger technology

Dr Fritz Indra, Opel's engine wizard

Whenever a major company begins to excel in a particular area there's usually a person behind the achievement and the man behind Opel's current range of outstanding engines is Dr Fritz Indra. In particular, he is the man responsible for this German company's four-cylinder 2-litre 16-valve engine which is generally acknowledged in the motor industry as a standard-setter in its combination of power and efficiency.

Dr Indra (no relation to the creator of the Indra car) was born in Vienna in 1940 and after studying at the Technical University of that city worked for various companies including Alpina and Audi, where he was involved in the development of four-valve heads, before joining Opel in 1985. There he was in charge of advanced engine development until 1989 when he became Chief Engineer, Advanced Project Studies. He is the author of a book on engine design, a keen motorsport enthusiast and, following Germany's excellent tradition of building links between industry and academia, is a visiting Professor, regularly lecturing to university students. He is also a down-to-earth person with forthright views. Theory has been refined and modified by years of deeply-ingrained experience, so that opinions are expressed with force and conviction.

He is, for example, rather dismissive of the groundwork done by Cosworth in designing a four-valve version of the existing 2-litre Opel/Vauxhall engine, at first for rallying, but later for road cars. Developing a four-valve engine for high-volume production, he feels, is quite a different ballgame from the creation of competition engines, or from building four-valve conversions in low numbers, which is the strength of small companies like Cosworth.



1. The dohc valvegear and cylinderhead assembly of the 2-litre 16v engine, showing the access to the cylinderhead bolts made possible by the 46deg valve included angle.
However, other similar designs do achieve smaller angles in mass production. For example, the new Ford RS 2000 and Zeta engines have 40° included angles and, of course, the use of rockers or finger followers allows totally different camshaft spacing (e.g. Honda single cam or twin-cam VTEC)

Take, for instance, the vital question of include valve angle which Brian Lovell has analysed wit great skill and insight in the last two issues o *Car Design & Technology*. You can forget, Dr Indra says, all that business about the angle being small fo optimum compactness in the combustion chambers: i the cylinderhead with its valve gear has to be preassembled - as is essential to cut production cost - then the minimum included valve angle which ca be achieved is limited (**1**) by the need to inser cylinderhead bolts inside the twin camshafts. Th closer together these bolts are, then the smaller th valve angle possible. For most practical engines buil in this way for high volume production, though, th minimum included valve angle is generally aroun 45deg - it's 46deg for the Opel unit.

But in any case Dr Indra strongly believes tha there's much more to a successful four-valve engin than the optimum included valve angle. Designs buil in large numbers are often spoiled by insufficien attention to detail, he says - a four-valve head i wasted unless every other part of the engine i carefully optimised to exploit its breathing potenti and combustion efficiency. "You must have the be induction system, the best injection system, the be exhaust system, the best ignition system and prope knock control." In some rival four-valve engines, h says, the potential for free breathing is thrown awa by the use of an intake air cleaner of the same size a for the two-valve variant.

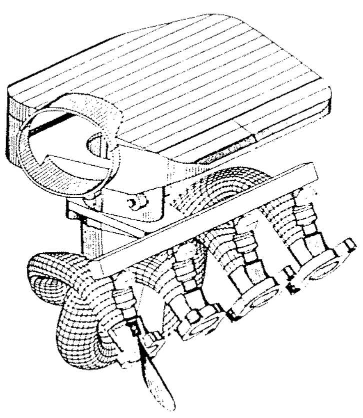
So the air drawn into the Opel 16v engine fir meets the high-efficiency hot wire mass flow sens of the Bosch fuel injection system before entering plenum chamber and inlet manifold which has bee carefully optimised (2) with the help of computer-aided design techniques. It then passes through machined ports into combustion chambers which have also been fully machined - to equalise their volumes so that the very high (10.5:1) compression ratio does not have to be reduced to allow for cylinder to cylinder variations. Fuel is injected sequentially, on each induction stroke, and is ignited by a high-efficiency ignition system, the products of combustion passing to a freeflow two-stage two-into-one exhaust system.

All these refinements cost money, of course, but Dr Indra says it is vital "not to look at every Deutschmark" and claims that he had no difficulty in persuading his management of the need to pay a little more. And, as is so often the case when such judgements are made, the payoff in enhanced prestige, improved customer satisfaction and increased sales almost certainly offsets the increased costs. Certainly Dr Indra has every reason to be proud of the result, for in addition to producing a healthy 150bhp at 6,000rpm, his four-valve engine has an outstandingly low optimum specific fuel consumption of 232g/kWh which is equivalent to a maximum efficiency of 37 per cent - "better than many diesels."

When pressed on the subject of the ideal four-valve combustion chamber, freed of production constraints, he points out that the plug is *not* at the centre of a conventional pentroof chamber - only in a bowl-in-piston design, but this creates heat dissipation problems in the piston and leads to a short conrod which is bad for second-order vibrations. He therefore feels that a good compromise is a pentroof design with an included valve angle of around 30deg, a long sparking plug, protruding deep into the chamber, and a shallow bowl in the piston having approximately one third of the total combustion chamber volume.

This last feature (introduced to cut the compression ratio to 9:1) is a characteristic of the latest version of the 2-litre 4-valve unit: its turbocharged variant destined for the Calibra. As informed readers will already know, this is unique for its turbocharger installation which embodies two basic tenets of Indra's design philosophy. The first is that it's not difficult to size a conventional turbocharger so that it is large enough for adequate maximum power but small enough for very rapid response. For this reason he does not believe that variable geometry turbochargers justify their expense and complexity for petrol engines - though he concedes that they might be of some value for diesels. And he also says that the manufacturing techniques used to make ceramic turbine wheels lead to coarsely-shaped vanes with a relatively low aerodynamic efficiency which negates any advantage conferred by lightness.

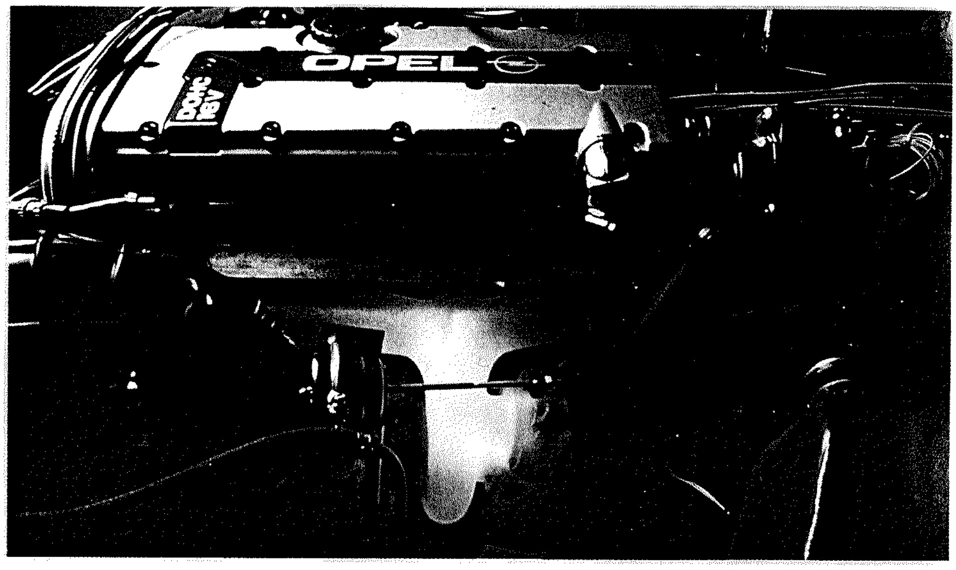
The second is a belief derived from observation of turbochargers in F1 racing a few years ago. As experience with these was gained, so they were moved closer and closer to the exhaust valves to reduce the volume of the intervening gas and thus cut turbo lag. It is this proximity principle which is the unique feature of the new Calibra engine. For in it the turbo is not contained in the conventional separate bolt-on casing but (3) in a housing which has been cast into the exhaust manifold and closely integrated with it. The result is an installation which is not only physically very compact but one which reduces the volume of gas between turbine and exhaust valve to an absolute minimum. As a result, Indra insists, there is virtually no turbo lag at all. And another advantage of the arrangement is that the catalytic converter is also brought closer to the engine, enabling light-up temperatures to be reached more quickly.



2. A computer-generated drawing of the plenum chamber and inlet manifold which includes the predicted spray pattern from the injector

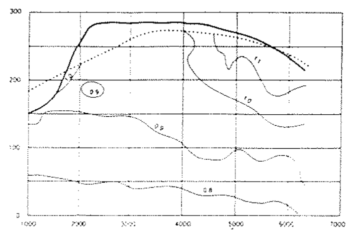
It has been argued, though, that without the temperature drop through a turbine, catalyst temperatures would be higher still. Had, therefore, Opel considered the use of superchargers as an alternative means of boosting power for high-performance models?

Dr Indra replied that he and his team had indeed spent a good deal of time and money doing just that. But after investigating ten different types of supercharger his conclusion was that apart from offering better engine response at low speeds they were "terribly bad in all other things, especially size: they're much too big." When an engine was fitted with a supercharger of the VW G-Lader, type, for instance, it was difficult if not impossible to fit air conditioning. Manufacturing difficulties and long-term durability problems were other worries.



3. Red hot design: the photograph show more clearly than any drawing the neat compactness of the turbocharger installation and its close proximity to the exhaust valve

These findings made him more than ever convinced that a turbocharger was the best route to increased power once conventional measures had reached their limits. It is further his view that a turbocharged engine should be more efficient than a naturally aspirated engine of the same output. To illustrate the point he makes an interesting comparison between the specific fuel consumption of the new 200bhp Calibra turbo engine and Opel's 3-litre six-cylinder 24-valve engine which develops exactly the same power. From a theoretical point of view this creates a finely-balanced contrast: there will be more friction in the six-cylinder engine than in the four, but the higher compression ratio (or, more important, expansion ratio) of the bigger naturally aspirated unit should perhaps confer an overall advantage in efficiency. But it can be seen (4) that the specific fuel consumption of the 2-litre engine is superior to that of the 3-litre unit at all regimes save those near maximum torque or maximum power and particularly so at low load factors where friction and pumping losses absorbs a larger proportion of cylinder power. On the road, says Dr Indra, this translates into a definite overall fuel consumption advantage for a turbo car.



4. This graph shows the ratio of the specific fuel consumption values achieved by the 2-litre four-cylinder 16v turbo engine to those of the 3-litre six-cylinder 24v naturally-aspirated engine. A ratio of 1.0 indicates parity; of less than 1.0 a lower consumption for the turbo engine than for the big six. It can be seen that the turbo's specific fuel consumption is better than the big six's except at high levels of torque or power