## Contents 2

This wooden mock-up made by BMW shows in three dimensions the problems of disposing the valves and sparking plugs in an in-line radial valve engine

# BMW'S APFELBECK ENGINE

## FORMULA 2, 1,600 c.c. 4 VALVES PER CYLINDER 4-CYLINDER

RADIAL valve engines are not new. The Rudge-Whitworth motor cycle company of Coventry built a series of T.T.-winning 4-valve motor cycle engines in the late '20s and early '30s, among which were parallel stem units, semi-radials and full radials. The latter are engines in which the projected axes of the valves would meet near the virtual centre of a hemispherical head. It was the performance, and the shortcomings of one of these very engines which set an Austrian motor cycle engineer, Ludwig Apfelbeck, who owned a Rudge radial, to thinking of possible improvements.

The difficulty with 4-valve engines is that overheating causes cracks in the cylinder head between the exhaust valve seats. Besides motor cycles, Bugattis and 3-litre Sunbeams were notorious for this. Apfelbeck had the bright idea of eliminating the problem by putting the cool inlet valves between the hot exhaust valves; that is, the inlet valves and the exhaust valves opposite each other in a hemispherical head.

Not until two years ago, when BMW saw possibilities in the 1,600 c.c. formula 2, did Apfelbeck, now a development engineer with the company, again bring out the idea. BMW decided to build a wooden gas-flow radial head and a reference head with the conventional paired inlet and exhaust valves, with parallel stems working in a pent-roof head. The improvement was impressive, the Apfelbeck head showing relative flow figures in the ratio of 38 to 67. While flow rig figures can be downright misleading, a single-cylinder test engine confirmed the findings, and gave justification for going ahead with a 4-cylinder unit based on a standard block, as the formula demanded.

It had been easy to build a single-cylinder engine, because Rudge provided a ready-made example of how to operate the valve gear, although there were carburettors and exhaust pipes everywhere. The mechanical problems with a 4-cylinder unit were not so simple. Complications were the compound angle of the valves, because of the necessity to locate them so that they did not interfere with the valves on the adjoining cylinders.

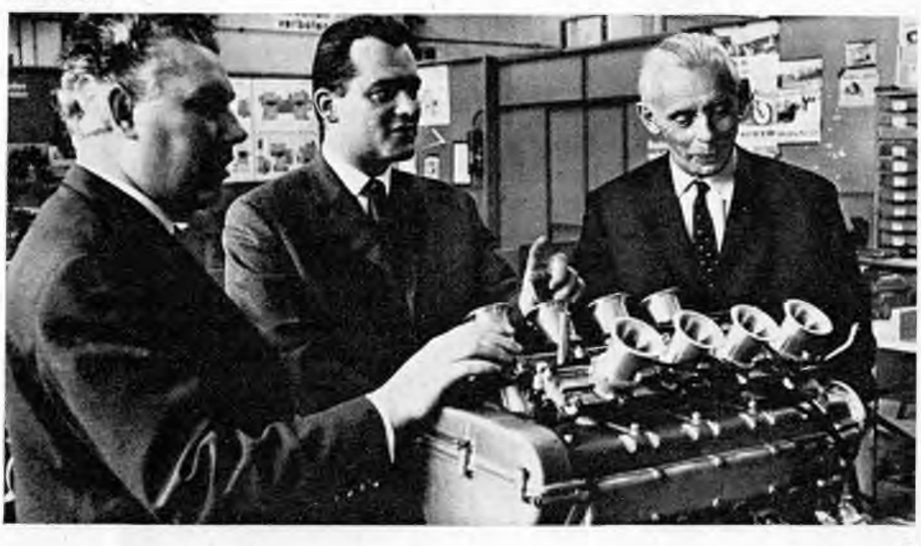
The disposition of the porting is shown in the accompanying diagrams. Visualizing the tops of the heads as four clock faces in a row, the inlet ports are at eight o'clock and two o'clock, while the exhaust valves are at five o'clock and 11 o'clock. This arrangement, with the inlet valves as near as possible to the centreline of the engine, brings the hot exhaust ports and the valve seats into the full flow of cooling water and they are as near as possible to the port faces on the sides of the head. The inlet ports are vertical, with a slight 'kick" above the valves to induce swirl and a single 12mm plug is located in the middle of each valve cluster.

Apart from the novel valve arrangement, BMW's approach to the breathing of the engine is old-fashioned in the sense that the largest possible ports and valves, working in a hemispherical head, are employed with the object of getting optimum cylinder filling at maximum revs. The ram effect obtained by using smaller diameter ports, which gives power in the medium to high speed range, where even a racing engine spends a good deal of time, has been ignored. The section of the inlet ports is roughly egg-shaped, and the gas speed through them is approximately 183ft/sec at 9,500 r.p.m., little better than half that of the current Cosworth engines. Inlet and exhaust valve sizes are 42 and 34mm dia., with 7mm lift, the respective throat diameters being 39 and 31mm.

Gas flow figures achieved experimentally may have led the BMW team to assume that cylinder filling will be better than that of their rivals at medium speeds, even without resorting to ram charging. There is no provision for squish in the design of the piston or head, but the "kick" at the bottom of the inlet ports is intended to impart a degree of swirl, although its existence is not yet proven. The figures quoted by ▶

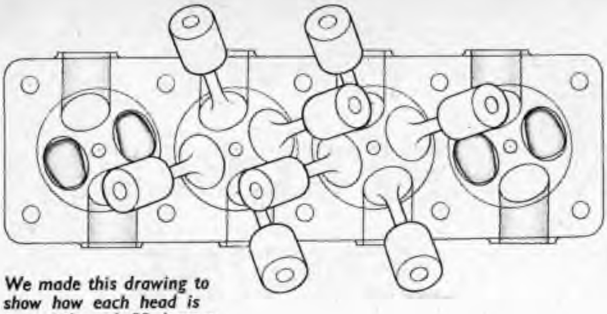
### SPECIFICATION

| | |
|---|---|
| Configuration .. | Four in line, 2 OHC, 4 valves per cylinder |
| Bore and stroke | 89 x 62·4 in. (3·5in. x 2·45in.) |
| Capacity .. | 1553 c.c. |
| Power .. .. | 220 b.h.p. net at 9,500 r.p.m. |
| Max. Torque .. | 139 lb. ft at 8,500 r.p.m. |
| Max bmep .. | 220 p.s.i. |
| Piston Area .. | 9·6 sq. in x 4 |
| Max. mean piston speed.. .. | 3,885 ft./min. |
| Weight (dry) .. | 286 lb. (130kg.) |
| Piston Acceleration .. .. | 125,000ft./sec.² |
| Fuel injection .. | Lucas |
| Ignition.. .. | Bosch transistorised |

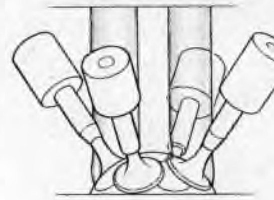


In charge of development of the BMW radial engine, Ing. Otto Stulle, Konstr. Paul Rosche and race chief Alex von Falkenhausen

# BMW'S APFELBECK ENGINE . . .



*We made this drawing to show how each head is turned through 30 degrees so that the inlet valves miss each other but are almost in line to simplify manifolding*



BMW are impressive; maximum power is 220 b.h.p. net at 9,500 r.p.m. with 139lb.ft of torque at 8,500 r.p.m. The maximum equivalent b.m.e.p. is 220 p.s.i. At the moment there is a dip in the power curve in the 7,000 to 8,500 r.p.m. range which is proving difficult to eliminate.

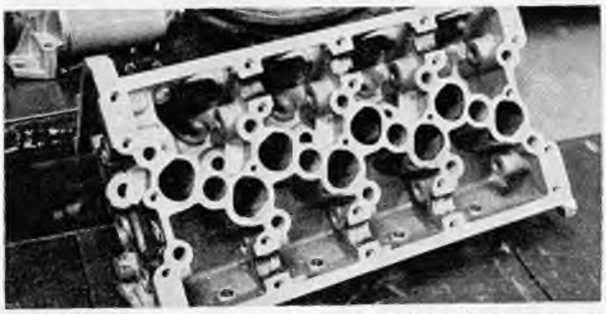
Lucas port injection equipment provides the mixture a single 4-cylinder metering unit driven off the right-hand camshaft feeding two sets of four nozzles, located above the guillotine pattern throttles in the latest engines. Fuel injection reduces the height of the engine by 5·5in. compared with carburettors. Although the inlet ports are vertical, inlet manifolds are splayed out to provide room to insert the sparking plugs. The manifolds and the plug wells are cast in one with the single-piece valve cover, a composition joint being used at the mating face to make an airtight and oiltight seal.

A double roller chain driven off a sprocket on the half-time gear drives the camshafts; it is tensioned by a jockey pulley on the drive run. The crankshaft nose carries a toothed pulley for the water pump drive, this unit being located on the right-hand side of the engine. It pumps water into the front of the head, where it is formed into two streams over the exhaust parts and is extracted from the back. The water in the block does not circulate.

BMW are naturally reticent about their valve gear, but from photographs of the head castings it is possible to deduce the main working principles. The camshafts are set very high relative to the heads proper. Below them, and in towards the centreline, are two series of drilled bosses in the cam box partitions, for rocker shafts which are located parallel to the camshafts. In line with each inlet valve and on a plane normal to the stem a small platform is machined to carry the bracket for a valve finger which is in contact with the valve stem. A bellcrank-shaped rocker operated by the camshaft and bearing on the back of this finger opens the valve.

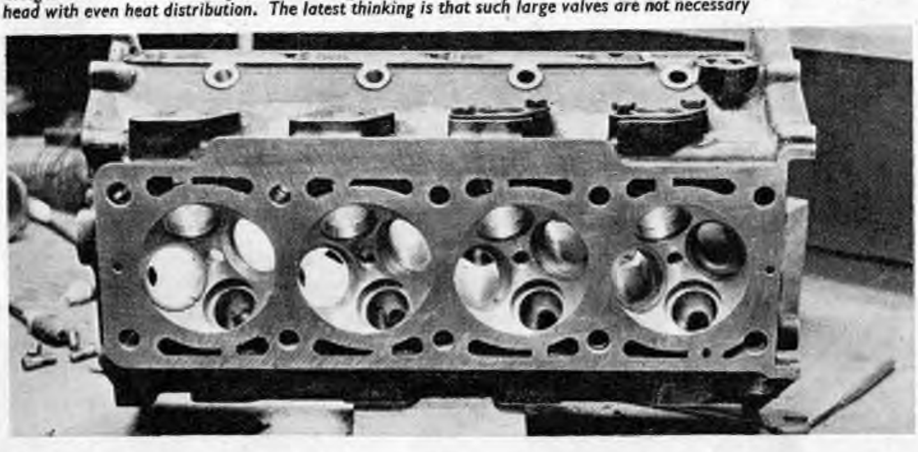
As the exhaust valves are almost square to the cam and rocker shafts, the leverages are different in that the bellcrank is operated by the underside of the cams; it bears on the middle of the valve fingers, which lie fore and aft in the cam box and swing on shouldered pins bolted to the walls of the cam box. The journal portion of each pin is eccentric to the screwed portion, to provide a means of adjustment. With each layout there is still one single point contact, but it would seem likely this is taken care of in the case of the inlet

*A special crankshaft giving a stroke of 62·4 mm has been designed for the engine. Bearing sizes are the same as those of the standard BMW 2000*

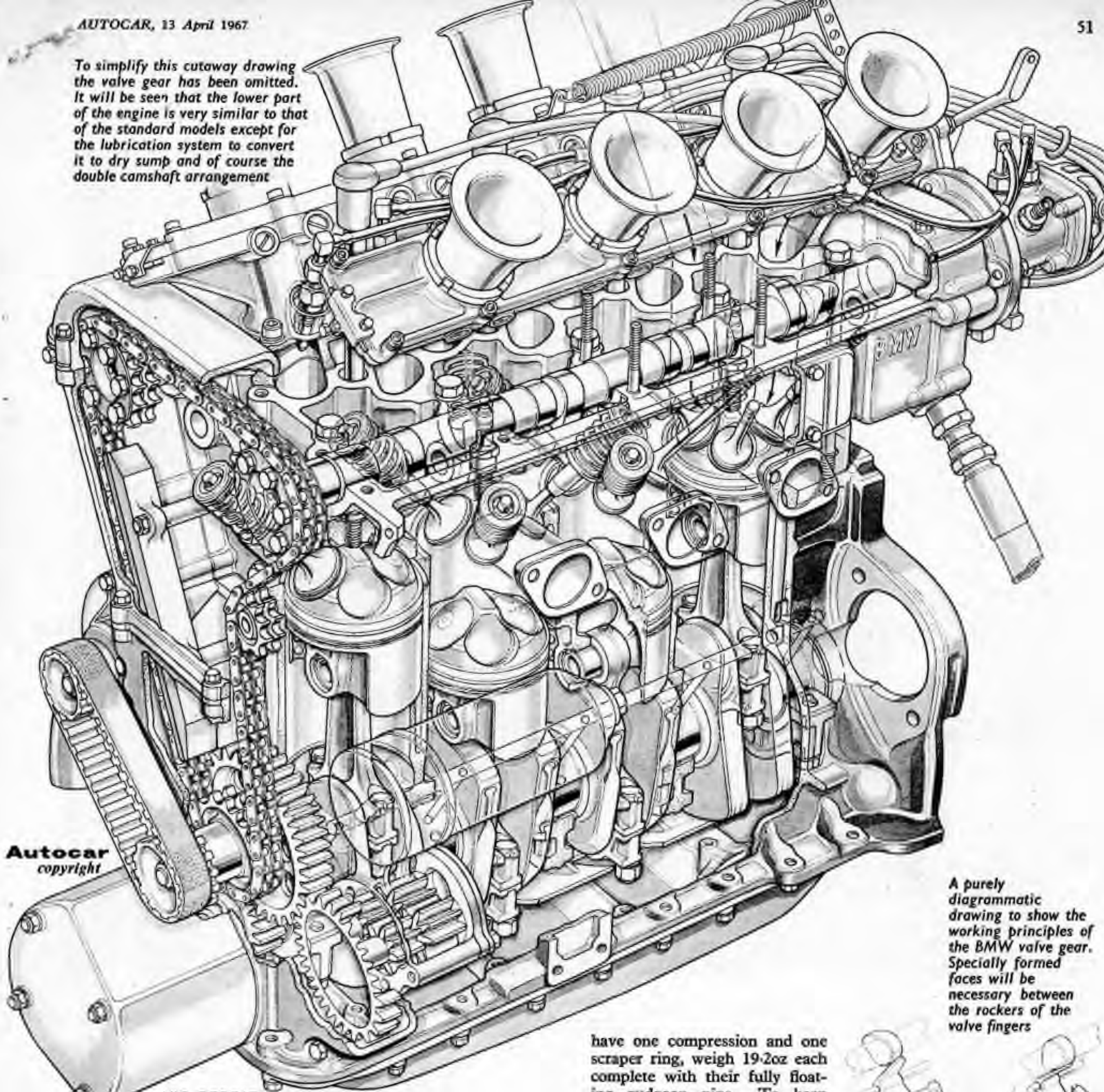


*Left: Looking down at a cam box one sees the vertical large diameter ports on the jointing face for the inlet manifolds. Right: Krupp forge the titanium. It is machined by BMW*

*Above: Camshaft and valves of the BMW radial. Wear marks on the cams show that the rocker faces are of normal design. Below: The main object of the design seems to be to get the largest possible valves into a hemispherical head with even heat distribution. The latest thinking is that such large valves are not necessary*



*To simplify this cutaway drawing the valve gear has been omitted. It will be seen that the lower part of the engine is very similar to that of the standard models except for the lubrication system to convert it to dry sump and of course the double camshaft arrangement*

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valves, by fitting a roller on the end of the rocker. One must not forget that this is a racing engine with a short life between overhauls and involved mechanical expedients can be tolerated in exchange for lightness and simplicity. After all, the 1930 T.T.-winning Rudge had exposed valve gear and four single point contacts between six rockers.

A standard 89mm bore BMW 2000 block forms the lower part of the engine, in accordance with the regulations. To reduce the capacity to 1,600 c.c., special nitrided steel crankshafts with 62·4mm throws have been forged. The five main bearings are 55mm in diameter, with 48mm big-end journals giving a good journal overlap. An interesting small point is that the leading edges of the crank webs are faired off to reduce oil drag. Titanium connecting rods and bolts help to keep reciprocating weight to a minimum. These are forgings by Krupp machined by BMW. In view of the poor and sometimes disastrous results experienced by other engine manufacturers with this material, it is interesting that BMW do not polish the rods, in order to retain the forging skin which contributes a good deal to the strength of the rods. The split is at right angles to the centre-line and the bolts are waisted to act as dowels at the joint. The bolt heads are recessed into spotfaces in the shoulders of the rods and are restrained from rotating by small ears on the bolts.

Each connecting rod weighs 15·7oz and the pistons, which have one compression and one scraper ring, weigh 19·2oz each complete with their fully floating gudgeon pins. To keep engine height to a minimum, the flywheel disc has been reduced to 9·25in. diameter, necessitating a step-down gear in the starter drive.

If formula 2 becomes a long-standing fixture, it will have a good effect on passenger car design, because manufacturers will lay down engines with the possibility of racing in view. Both the current contenders, Ford and BMW, are good engines by any standards, especially so far as their cylinder head holding down arrangements are concerned. Both have evenly spaced cylinder head studs with adequate provision in the casting to feed loads directly to the main bearing caps and thus hold the engine's hat on when it is developing full pressure.

Back-to-back gear-type pressure and scavenge pumps lubricate the engine and return oil from the dry sump to the oil tank. They are driven off the camshaft drive half-time wheel and rotate at two-thirds engine speed. To keep the amount of oil in the crankcase to a minimum and to reduce crankcase pressure, the scavenge to pressure ratio of 30 to 18 is used. Oil is pumped from the tank through a full-flow filter to the main distribution gallery in the block whence it is fed to the crankshaft and valve gear. An outside gravity drain is provided from the cam box to the sump.

**Edward Eves** ■

*A purely diagrammatic drawing to show the working principles of the BMW valve gear. Specially formed faces will be necessary between the rockers of the valve fingers*

# THE RANGE

DATA ON PAGE 75

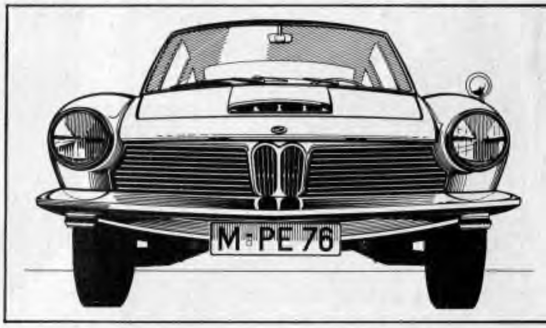
**ALL BMWs have independent suspension all round, disc front brakes and a four cylinder single overhead camshaft engine. For the 1969 season there have been some changes in rationalisation and the 1800 now has the bore of the 2000 and the stroke of the 1600 (instead of vice-versa).**

**For the three engine capacities—1,573, 1,766 and 1,990 c.c.—there are only two bores (84 and 89mm) and two strokes (71 and 80mm). Originally there was an 1800 TI, but now the only tuned versions are based on the 1600 and 2000 units. TI tune means a pair of twin-choke Solex carburettors instead of a single downdraught Solex; in the case of the 2000 it means an extra 20 bhp (see data table on page 75).**

**With two wheelbases (8ft 2.5in. two-door, 8ft 4.4in. four-door and two-door coupé) there is a choice of three distinctive body styles.**

*Right: Most basic model is the 1600 two-door saloon. It can be distinguished by its anodised aluminium grille and plain wheels*

*Below left: The 2002 uses the single-carburettor 2000 engine in the 1600 body. Most of the styling details are the same as those of the 1600 TI which is not imported here*


*Classic European engineering, which many have copied: single-overhead-cam front engine, trailing arm independent suspension, four-door unitary body—BMW 1800*

*Above: Last year BMW absorbed Glas and the first result is the BMW 1600 GT. It uses the old Glas 1300 GT body with BMW engine and suspension*

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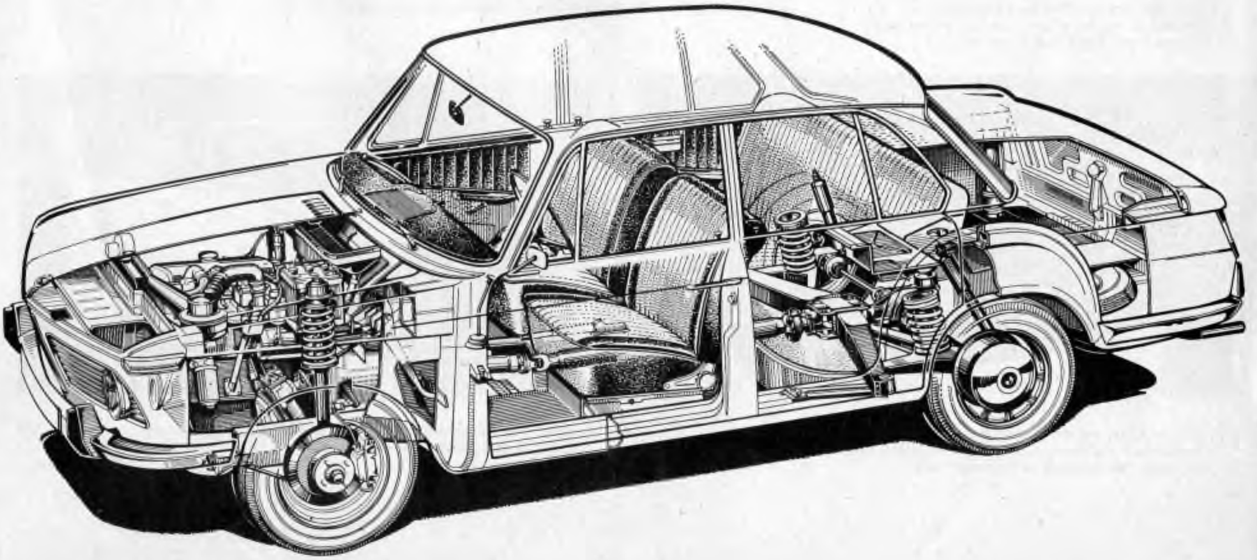


# THE RANGE . . .


*Right: With its new bore/stroke ratio the 1800 has a new matt black grille to identify the 1969 model*


*Above: Externally the 2000 has not changed, although cars imported here have four headlamps instead of this rectangular type, which identifies the 2000 Tilux in the UK*

*Above: There is a new interior for the 2000 Tilux for 1969. Facia capping is shaped differently and the instruments are in a hooded sub-panel. Heater controls are new*

*Above: At the Frankfurt show last year a new 1600 convertible was introduced. It uses the ordinary, non-TI engine and the back seat room is reduced. This model is not imported here*

*Above: Top model in the range is this 2000 CS coupé (see test on pages 64-66). Here it pauses briefly in Barnstaple bay*

# DATA FOR BMW RANGE 1969

SEE PAGES 57-8

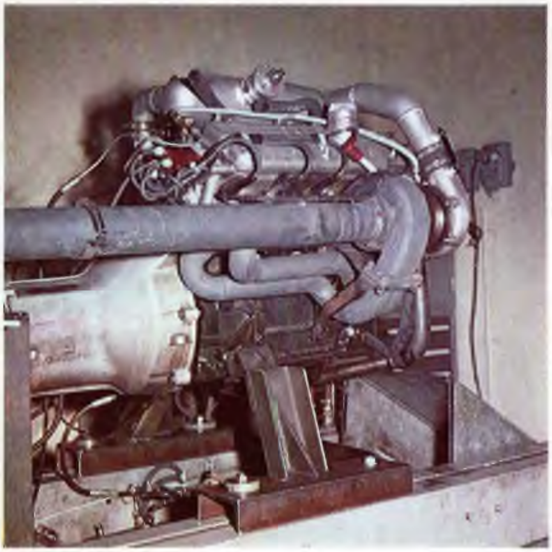
| | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **1600** | 1600 CABRIOLET | 1600 TI | 1600 GT | **2002** | **1800** | **1800 Automatic** | **2000 [redacted]** | **2000 Automatic** | 2000 TI | **FRAZER NASH 2000 TI** | **Tilux 2000** | 2000 C | **2000C Automatic** | **2000 CS** |
| Bore × stroke (mm) | **84×71** | 84×71 | 84×71 | 84×71 | **89×80** | **89×71** | **89×71** | **89×80** | **89×80** | 89×80 | **89×80** | **89×80** | 89×80 | **89×80** | **89×80** |
| Capacity (c.c.) | **1573** | 1573 | 1573 | 1573 | **1990** | **1776** | **1776** | **1990** | **1990** | 1990 | **1990** | **1990** | 1990 | **1990** | **1990** |
| Carburettor/s | **1 Solex** | 1 Solex | 2 Solex | 2 Solex | **1 Solex** | **1 Solex** | **1 Solex** | **1 Solex** | **1 Solex** | 2 Solex | **2 Solex** | **2 Solex** | 1 Solex | **1 Solex** | **2 Solex** |
| Compression ratio | **8·6 : 1** | 8·6 : 1 | 9·5 : 1 | 9·5 : 1 | **8·5 : 1** | **8·6 : 1** | **8·6 : 1** | **8·5 : 1** | **8·5 : 1** | 9·3 | **9·3 : 1** | **9·3 : 1** | 8·5 : 1 | **8·5 : 1** | **9·3 : 1** |
| Max. net bhp | **85 @ 5,700** | 85 @ 5,700 | 105@6,000 | 105@6,000 | **100@5,500** | **90 @ 5,250** | **90 @ 5,250** | **100@5,500** | **100@5,500** | 120@5,500 | **120@5,500** | **120@5,500** | 100@5,500 | **100@5,500** | **120 @ 5,500** |
| Max. net torque (lb.ft.) | **91 @ 3,000** | 91 @ 3,000 | 97 @ 4,500 | 97 @ 4,500 | **116@3,000** | **106@3,000** | **106@3,000** | **116@3,000** | **116@3,000** | 123@3,500 | **123@3,500** | **123@3,500** | 116@3,000 | **116@3,000** | **123 @ 3,500** |
| Overall gear ratios—Top | **4·11 : 1** | 4·11 : 1 | 3·9 : 1 | 3·64 : 1 | **3·64 : 1** | **4·11 : 1** | **4·11 : 1** | **4·11 : 1** | **4·11 : 1** | 3·9 : 1 | **3·9 : 1** | **3·9 : 1** | 4·11 : 1 | **4·11 : 1** | **3·9 : 1** |
| —3rd | **5·53 : 1** | 5·53 : 1 | 5·23 : 1 | 4·89 : 1 | **4·89 : 1** | **5·53 : 1** | — | **5·53 : 1** | — | 5·23 : 1 | **5·23 : 1** | **5·23 : 1** | 5·53 : 1 | — | **5·23 : 1** |
| —2nd | **8·44 : 1** | 8·44 : 1 | 8·0 : 1 | 7·47 : 1 | **7·47 : 1** | **8·44 : 1** | **6·25 : 1** | **8·44 : 1** | **6·25 : 1** | 8·0 : 1 | **8·0 : 1** | **8·0 : 1** | 8·44 : 1 | **6·25 : 1** | **8·0 : 1** |
| —1st | **15·76 : 1** | 15·76 : 1 | 14·91 : 1 | 13·96 : 1 | **13·96 : 1** | **15·76 : 1** | **10·52 : 1** | **15·76 : 1** | **10·52 : 1** | 14·91 : 1 | **14·91 : 1** | **14·91 : 1** | 15·76 : 1 | **10·52 : 1** | **14·91 : 1** |
| Torque convertor stall ratio | — | — | — | — | — | — | **2·3 : 1** | — | **2·1 : 1** | — | — | — | — | **2·1 : 1** | — |
| Top gear mph per 1,000 rpm | **16·3** | 16·3 | 17·0 | 18·8 | **18·5** | **17·1** | **17·1** | **17·1** | **17·1** | 18·3 | **18·3** | **18·3** | 17·4 | **17·4** | **18·3** |
| Disc (front dia. (in.) | **9·5** | 9·5 | 9·5 | 10·5 | **9·5** | **10·5** | **10·5** | **10·75** | **10·75** | 10·75 | **10·75** | **10·75** | 10·75 | **10·75** | **10·75** |
| Drum (rear) dia. (in.) | **7·9** | 7·9 | 7·9 | 7·9 | **7·9** | **9·75** | **9·75** | **9·75** | **9·75** | 9·75 | **9·75** | **9·75** | 9·75 | **9·75** | **9·75** |
| Wheelbase | **8ft 2·5in.** | 8ft 2·5in. | 8ft 2·5in. | 7ft 7·3in. | **8ft 2·5in.** | **8ft 4·4in.** | **8ft 4·4in.** | **8ft 4·4in.** | **8ft 4·4in.** | 8ft 4·4in. | **8ft 4·4in.** | **8ft 4·4in.** | 8ft 4·4in. | **8ft 4·4in.** | **8ft 4·4in.** |
| Track—front | **4ft 4in.** | 4ft 4in. | 4ft 4in. | 4ft 2in. | **4ft 4in.** | **4ft 4in.** | **4ft 4in.** | **4ft 4in.** | **4ft 4in.** | 4ft 4in. | **4ft 4in.** | **4ft 4in.** | 4ft 4in. | **4ft 4in.** | **4ft 4in.** |
| —rear | **4ft 4in.** | 4ft 4in. | 4ft 4in. | 4ft 2in. | **4ft 4in.** | **4ft 6in.** | **4ft 6in.** | **4ft 6in.** | **4ft 6in.** | 4ft 6in. | **4ft 6in.** | **4ft 6in.** | 4ft 6in. | **4ft 6in.** | **4ft 6in.** |
| Overall length | **14ft 1·5in.** | 14ft 1·5in. | 14ft 1·5in. | 13ft 3·5in. | **14ft 1·5in.** | **14ft 9in.** | **14ft 9in.** | **14ft 9in.** | **14ft 9in.** | 14ft 9in. | **14ft 9in.** | **14ft 9in.** | 14ft 10·25in. | **14ft 10·25in.** | **14ft 10·25in.** |
| Overall width | **5ft 4in.** | 5ft 4in. | 5ft 4in. | 5ft 1in. | **5ft 4in.** | **5ft 7in.** | **5ft 7in.** | **5ft 7in.** | **5ft 7in.** | 5ft 7in. | **5ft 7in.** | **5ft 7in.** | 5ft 6in. | **5ft 6in.** | **5ft 6in.** |
| Overall height | **4ft 7·5in.** | 4ft 7·5in. | 4ft 7·5in. | 4ft 2·5in. | **4ft 7·5in.** | **4ft 9in.** | **4ft 9in.** | **4ft 9in.** | **4ft 9in.** | 4ft 9in. | **4ft 9in.** | **4ft 9in.** | 4ft 5·5in. | **4ft 5·5in.** | **4ft 5·5in.** |
| Ground clearance | **6·5in.** | 6·5in. | 6·5in. | 6·5in. | **6·5in.** | **6·0in.** | **6·0in.** | **6·0in.** | **6·0in.** | 6·0in. | **6·0in.** | **6·0in.** | 6·0in. | **6·0in.** | **6·0in.** |
| Turning circle | **31ft 5in.** | 31ft 5in. | 31ft 5in. | 31ft 5in. | **31ft 5in.** | **31ft 5in.** | **31ft 5in.** | **31ft 5in.** | **31ft 5in.** | 31ft 5in. | **31ft 5in.** | **31ft 5in.** | 31ft 5in. | **31ft 5in.** | **31ft 5in.** |
| Weight (approx.) | **2,150 lb** | 2,260 lb | 2,183 lb | 2,238 lb | **2,194 lb** | **2,359 lb** | **2,359 lb** | **2,535 lb** | **2,535 lb** | 2,557 lb | **2,557 lb** | **2,557 lb** | 2,645 lb | **2,645 lb** | **2,645 lb** |
| Fuel tank | **10 gal** | 10 gal | 10 gal | 12 gal | **10 gal** | **12 gal** | **12 gal** | **12 gal** | **12 gal** | 12 gal | **12 gal** | **12 gal** | 12 gal | **12 gal** | **12 gal** |
| Tyres | **6.00—13** | 6·00—13 | 165—13 | 155—14 | **165—13** | **6·00—14** | **6·00—14** | **6·45—14** | **6·45—14** | 175—14 | **175—14** | **175—14** | 175—14 | **175—14** | **175—14** |
| Battery | **12volt 36Ah** | 12volt 36Ah | 12volt 36Ah | 12volt 36Ah | **12volt 36Ah** | **12volt 44Ah** | **12volt 44Ah** | **12volt 44Ah** | **12volt 44Ah** | 12volt 44Ah | **12volt 44Ah** | **12volt 44Ah** | 12volt 44Ah | **12volt 44Ah** | **12volt 44Ah** |
| Performance—max. speed | **102 mph** | — | — | — | **107 mph** | **100 mph** | — | **104 mph** | **100 mph** | — | **110 mph** | — | — | — | **110 mph** |
| —0-60 mph | **12·5 sec** | — | — | — | **10·6 sec** | **13·7 sec** | — | **11·7 sec** | **13·1 sec** | — | **10·8 sec** | — | — | — | **10·4 sec** |
| —standing ¼-mile | **18·5 sec** | — | — | — | **17·4 sec** | **19·0 sec** | — | **17·7 sec** | **19·3 sec** | — | **17·7 sec** | — | — | — | **17·9 sec** |
| —overall mpg | **26·3 mpg** | — | — | — | **25·5 mpg** | **27·2 mpg** | — | **23·3 mpg** | **24·1 mpg** | — | **21·1 mpg** | — | — | — | — |
| Total price in UK | **£1,375** | — | — | — | **£1,597** | **£1,597** | **£1,749** | **£1,848** | **£1,999** | — | **£1,899** | **£1,999** | — | **£3,365** | **£3,365** |

**MODELS AVAILABLE IN U.K. IN BOLD TYPE**

# The power of turbocharging

*BMW were by no means the first, but they are achieving some spectacular results.*

**by Charles Bulmer**



IN SPITE of that hackneyed old maxim about racing improving the breed, many competition departments are disappointing to visit—even the most successful ones. More often than not you find them applying standardised tuning procedures while any original development work is directed towards the touring cars and goes on quietly in an obscure part of the research department. This is a comment you can't apply to BMW; the company has always had a reputation for innovation and this is particularly true in competition engine design.

Just over three months ago (*Motor*, May 24) Paul Frère described their recent experiments with the Apfelbeck radial valve engine and its successor the current twin o.h.c., 16 valve, 12 plug F2 engine. The former gave breathing characteristics in 2 litre form which have not since been matched but it wasn't so successful as a short stroke 1600 F2 engine because the complex valve gear didn't allow the necessary increase in maximum r.p.m. The twin cam engine, which has one exhaust and one inlet on each side of its pent roof four-valve head and three 10 mm. plugs along the roof ridge, is now giving 235 b.h.p. and, installed in the new Dornier-built monocoque chassis, it should liven up F2 racing.

But the most interesting and possibly significant development of all is to be found in their latest Group 5 saloons—the turbocharged versions of the production 2002 TI models. Turbocharging isn't new, of course; it is used in many commercial vehicle engines, it was available on the most powerful version of the Chevrolet Corvair and it was exploited by Harry Weslake in developing the Sea Unicorn for power boat racing. But Alex von Falkenhausen, who is responsible for BMW engines, seems to have overcome most of the problems which have made supercharged engines so often thirsty and unreliable. Last year, in unsupercharged form, the Group 5 engine was getting near the limit of development imposed by its standard components and it still wasn't fast enough to beat the Porsche 911 which was also homologated as a touring saloon. Although supercharging involves a 40% capacity handicap in this Group, BMW felt that it would be more than worth this penalty.

## The Turbocharger

In a well-designed modern engine about 35% of the total heat energy supplied in the fuel is recovered as useful power output; a similar amount is lost in the hot exhaust gases and the remainder in the cooling system and in general heat losses. So about 65% of the fuel is wasted and there isn't a great deal that can be done to recover it in most practical circumstances although in exceptionally cold winter weather at moderate speeds, virtually all the heat rejected to the cooling system may be used in the car heater.

However, one thing you can do with the car exhaust is to use it to drive a turbine which will in turn drive a centrifugal supercharger. In fact, this is the working principle of the gas turbine engine except that it dispenses with the piston engine altogether and concentrates on extracting all the useful work from the exhaust gases. The main advantage of turbo-supercharging then is that the considerable amount of power necessary to drive a supercharger of any kind (typically 30% of the power *increase* it produces) comes not from the engine but from waste heat. A secondary but important advantage is that since you don't pay an appreciable power penalty for manufacturing the compressed air, you can afford to be extravagant or even wasteful with it—we will return to this point again because it is important in two ways.

Basically, the turbocharged unit is an ordinary 2-litre 2002 TI production engine—it has a standard bottom end, including the crankshaft and a standard head with normal sized valves. The four exhaust pipes are looped (see photograph) so that they all have the same length and they come together at the inlet of the exhaust turbine which is of radially inward flow type—the gases enter tangentially at the periphery and emerge axially through a single large pipe at the centre. The turbine drives a centrifugal supercharger (the two housings are bolted together) in which, of course, this gas flow arrangement is exactly reversed and the compressed air is led across the engine to the inlet manifold.

The whole turbocharger is a standard unit used on certain German truck engines and is rather larger than it need be. It runs safely up to 100,000 r.p.m. but at the moment it produces all the air that is needed at 80,000 r.p.m. Like any other turbine, this one works by expanding the exhaust gases from a high pressure down to atmospheric pressure and in this case the high pressure (i.e. the back pressure in the exhaust system) runs up to about 21 lb./sq.in. above atmosphere and the supercharge pressure to 14 lb./sq.in. at which it is limited by a blow-off valve in the intake system. In fact this blow-off pressure is reached at an engine speed of 4,500 r.p.m.

*Hot and cold: BMW's turbocharged engine (below left) on the test bed. An asbestos heat shield protects the sparking plugs from the intense heat of the glowing exhaust.*

*BMWs have become formidable opposition in European saloon car racing. A 2002 TI shares the front rank with a brace of 911S Porsches (below) and another (right) gets a little crossed up on the Nurburgring.*

BMW's post-war revival, road tests of the new 2500 and 2800, classic (and infamous) BMWs . . .

and in this way it is possible to avoid the well-known hollow power curve usually associated with centrifugally-blown engines where the boost pressure rises rapidly with rising speed.

In its present form the engine is giving 280 b.h.p. at 6,000 r.p.m. with a useful racing torque range which extends from 4,000 to 7,000 r.p.m. (the normal rev. limit) as shown in the power curves. For comparison, the most highly developed unsupercharged engine gives 205 b.h.p. with useful torque from 5,000 to 7,000 r.p.m. It is quite easy to raise the power much higher still by screwing down the relief valve and allowing the boost pressure to rise; at 17 lb./sq.in. pressure a power output of 330 b.h.p. was seen on the bench at 7,500 r.p.m. but the cylinder head was then beginning to rise and pressure was leaking past the gasket. Even 280 b.h.p. is enough to give a maximum speed in the region of 155 m.p.h. and at the Spa 24-hour race Hahne's car was lapping in practice at over 123 m.p.h.

At this stage certain obvious questions have to be answered—how can an engine designed for less than half this output stand the mechanical and thermal stresses involved, particularly when working against an exhaust back pressure of over 20 lb./sq.in.? As far as mechanical loadings are concerned, they are in fact reduced. During the second half of the compression stroke and the first half of the firing stroke, the inertia load on the big end bearings, due to the reciprocating mass of the piston and connecting rod, is upwards and is opposed by the downward gas pressure load on the piston crown. Of the two, however, the inertia load is the greater above about 4,000–5,000 r.p.m. (depending on whether the engine is blown or not) and it follows that the higher combustion pressure merely helps to achieve better cancellation of acceleration forces in the highly stressed top end of the speed range.

Heat flow, however, is enormously increased by the virtual doubling of the mixture charge in the cylinder and it is here that the ability to use air extravagantly comes in useful for the second time (the first being the blow-off valve). The ordinary racing camshaft which is used which has a valve overlap period of 120° and at high supercharge pressures a considerable amount of cold air passes straight through the engine immediately after the exhaust stroke, not only scavenging the combustion chambers properly but also cooling the exhaust valves. In fact, this is not quite as wasteful as it sounds because it increases the volume of gas available to drive the turbine. The exhaust manifold, incidentally, runs extremely hot as you can see in the coloured photograph but the energy extraction in the turbine leaves the gas both unusually cool and also quiet.

One point, however, which we haven't mentioned yet is that you can only afford to use air liberally if it is pure air rather than fuel/air mixture and it is therefore essential that fuel injection be used and that the injection pulses should be timed so that they start only after combustion chamber blowby has finished. The throttle is located at the entrance to the final inlet manifold (to avoid a time lag due to the large inlet gas volume) and so is the Kugelfischer injection system which is controlled by two parameters only—throttle opening and inlet manifold pressure.

Specific fuel consumption is about 0.57 lb./b.h.p. hr. which would be a normal figure for an unsupercharged racing engine of this kind running as it does at a compression ratio of 8:1.

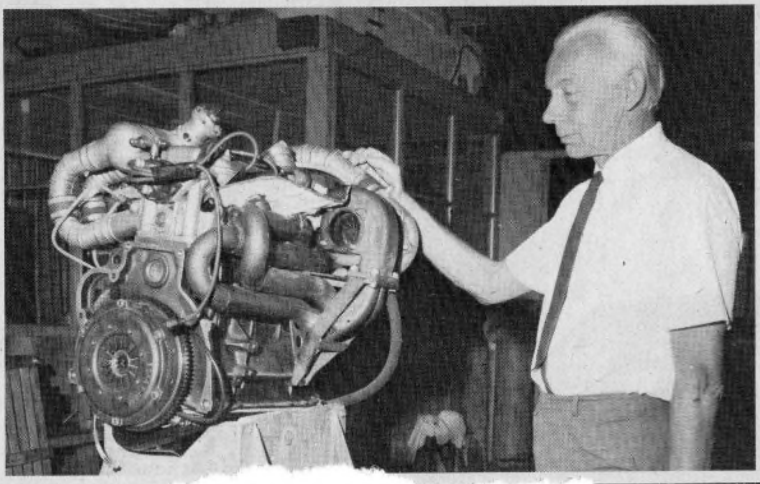
Reverting to the question of heat flow, it is of course necessary to use a bigger radiator because of the greater power but no oil cooler is necessary—oil temperature is almost entirely a function of r.p.m. and for a racing machine 7,000 r.p.m. is quite low. The most difficult problem was to find sparking plugs which would stand the extraordinary heat range and eventually this was solved by adopting the special surface discharge plugs made by Bosch and Champion for use in the Ro80 Wankel engine.

As tuning methods go, the use of a turbocharger seems to be extravagant neither in cost nor weight. This truck unit costs about £30 and weighs 33 lb. or, with its associated manifolding about 45 lb., bringing the total weight of the 280 b.h.p. engine to 350 lb. There doesn't seem to be any insuperable reason why the system shouldn't be adopted to production cars giving a unit which could rival the Wankel engine in power/weight and power/volume ratio while still retaining good low speed torque.

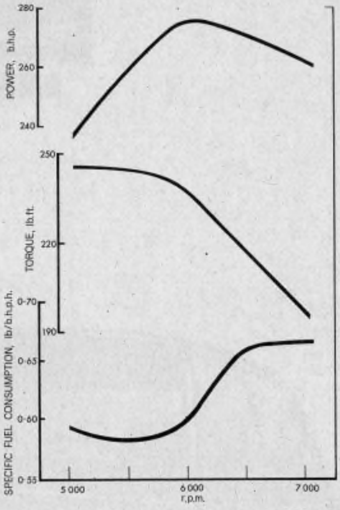
The very not exhaust system, although it would raise problems of underbonnet temperature, might well lend itself to exhaust pollution control on afterburner lines. It would, however, be very resistant to the amateur tuner; at present it is only necessary to screw down the relief valve to achieve quite spectacular and totally unsafe increases in top end power.

However, it must be assumed that methods will be found to prevent owners tampering with the designed blower pressure and, with this proviso, turbocharging could offer a method of drastically up-rating performance without apparently increasing overall engine size and without the investment costs of designing and building a completely new power unit. Certainly there are people in Germany (there are others working in the same field) who regard it as a way of competing with the Wankel engine for compactness.

*Alex von Falkenhausen who is in charge of BMW competition-engine department.*



*Power, torque and specific fuel consumption curves for the engine in its most useful racing range. The fall-off at the top-end is due to the operation of the pressure relief valve in the intake system. For comparison, maximum torque of this 2-litre engine falls midway between the corresponding figures for the Rover 3500 and Jaguar 4.2-litre engines.*



# Continental diary

**Paul Frère describes BMW's long struggle to succeed in Formula Two racing with a short-stroke version of their 2-litre engine**

In 1966 and 1967, BMW became a formidable challenger to Porsche's supremacy in hillclimbs and even though he never actually managed to beat them Dieter Quester came home a very close 2nd several times. The BMW certainly had the power of the Porsches, but its chassis was probably not quite so good and the Bavarians were apparently always one short step behind in their fight against weight.

The engine, which developed 278 DIN bhp in its ultimate form, used the standard 2-litre BMW cylinder block in conjunction with the ingenious but very complicated radial valve Apfelbeck head. In this the valves were not only disposed radially around the more or less hemispherical combustion chamber, but they were set cross-wise, i.e. the two inlet and the two exhaust valves were diametrically opposed. 140 bhp/litre from an 89mm bore, four-cylinder engine is not bad by any standard (and this was four years ago) so the BMW management was persuaded to try its luck at F2 racing. It was here that the trouble really started. Not only did they find out how good the Cosworth engine really was, but they discovered the limitations of the Apfelbeck design. With the stroke shortened to reduce the engine's capacity to 1600cc, the complicated valvegear used to operate the radially disposed valves showed a very unwelcome tendency to flex if the revving ability of the short stroke engine was exploited, upsetting the timing and reducing the valve lift by as much as 8 per cent at 9500 rpm, while the considerable included valve angle necessary to accommodate the many rockers and tappets led to the use of sharply domed pistons and a resultant unfavourable combustion chamber form. Nevertheless, 225 bhp was obtained at 9500 rpm—probably as much as for the contemporary Cosworth —but the torque characteristics were bad. Another fault was that the cylinder head was quite tall, raising the centre of gravity of the Lola shell in which the engine was mounted more than was desirable. So the car never made the grade.

Paul G. Hahnemann, BMW's managing director, is not the man who will put up with a failure, so once he had decided to participate in F2 racing, he was determined that the cars should be developed to win. It took his team four years to achieve this goal. The "Trophée de France" won by Jo Siffert in Rouen last July and counting toward the European F2 Championship will long be remembered in Munich, for it was BMW's first ever single-seater victory in a major race. It was also the first time for nearly two years that the Ford-Cosworth engined cars were beaten and later races proved it was no mere flash in the pan.

Though he was convinced of the unsuitability of the Apfelbeck head, experimental and racing chief Alex von Falkenhausen was first to accept that it had some advantages, one of which was that if you put the two inlet valves across the combustion chamber, that is next to a (smaller) exhaust valve, you could make them bigger. Also flow tests had shown that the "cross valve" configuration produced a better gas flow, diameters being equal. As a consequence, the radial valve head was replaced by an entirely new design with twin camshafts operating four valves per cylinder by means of cylindrical tappets in a fully conventional way. But instead of having all inlet valves on one side and all exhaust valves on the other, each camshaft operates one set of inlet and one set of exhaust valves. The valves are set in a pent roof head, the pistons being nearly flat, and there are no less than three plugs per cylinder, set in line along the top of the head, so as to ensure quick combustion and reduce the necessary ignition advance. The three plugs don't increase the power spectacularly, they say, but they improve the torque curve and the smaller advance necessary saves the bearings. From the start, a Kugelfischer injection system has been used, the pump and metering unit being practically standard except for the removal of the revolution sensitive control: the quantity of fuel injected per stroke is dependent upon the position of the accelerator pedal only by means of a mechanical linkage from the throttle slide. In order to save weight, however, the pump body is made of aluminium by BMW to the same design as the original cast iron body.

This engine was first raced at the end of 1968 when it developed 235 bhp at 10,200 rpm but it took the winter to make it acceptably reliable. The most consistent trouble was timing gear breakage which was overcome by using a rubber cushioned gear on the camshafts. There was also an

epidemic of valve spring breakages to which a complete solution has yet to be found, but which was considerably attenuated by fitting an ignition cut-out coming into operation at 10,800 rpm.

An interesting feature of the engine is that the crankshaft main bearings are standard production parts. The crankpins are the same diameter as standard, but are 1 mm wider and the connecting rods are of titanium, not so much in an effort to save weight as to make them stronger than steel rods of the same weight. The complete piston and rod assembly weighs nearly 1 Kg (2.2 lb.), and to overcome the poor friction characteristics of the titanium, the big end sides are sprayed with Teflon, which has proved very successful. This looks like a better solution than using shouldered bearings, as it makes it possible fully to utilise the crankpin width to support the bearing. Attention to details has now raised the output of the engine to a maximum of 250 bhp at 10,800 rpm for the best examples.

In addition to valve spring troubles and various minor mishaps due to insufficient preparation (last year, touring car racing was handled by the same team as handled F2 racing), the 1969 season was marred by ignition troubles. It was first thought that the thyristors of the condenser discharge ignition system were getting too hot and the "black box" was moved to a cooler position, but to no avail. It was not until last winter that Bosch found a satisfactory solution to the problem and the BMW engineers themselves seem not to know exactly what the trouble was.

How sensitive and temperamental modern racing engines can be was shown by a recent episode which probably cost BMW a victory last July on the Paul Ricard Circuit of Le Castellet. Up to that time, the bottom end had proved entirely reliable when, all of a sudden, an engine that was being bench tested ran its big ends. Investigation revealed nothing abnormal, so another engine was put on the bench and promptly ran its bearings. Finally the oil was suspected and after some discussion the supplier send another sample on which the engines ran perfectly. But the drums sent to Le Castellet apparently were the wrong brand again, for two engines went in practice and the other two in the race, all with bearing trouble again. No further trouble was experienced after BMW took strong action.

**Left, success at last, as Jo Siffert's BMW shows the others the way round Thruxton. Below, three views of the latest version of the F2 machine.**

When the engine was first tried at the end of 1968, running in a race at Hockenheim, it was immediately clear that it had the right sort of power, but that the Lola chassis, now nearly two years old, was out of date. So Len Terry was commissioned to design a new monocoque of which the construction was entrusted to Dornier, the aircraft specialists. Being a closed monocoque, it is notably stiffer than the Lola and its suspension has less camber change to suit the wider modern tyres. Only very minor alterations have been made to it since its debut and its frontal area is larger than for some more modern rivals, but apparently the aerodynamic shape is quite good. For comparison purposes the factory recently bought a March 702 into which they fitted one of their engines and it turned out to be some 500 rpm (equivalent to about 7-8 mph) slower than the original BMW. Dieter Basche, who is responsible for the preparation of the cars and acts as test driver, also told me that the front fairings used on high speed circuits are worth some 400 rpm, equivalent to about 6-7 mph.

In view of the results achieved with the "cross valve" engine, it is surprising that a BMW fitted with a more conventional cylinder head having all the intake valves on one side and the exhaust valves on the other should have made its victorious debut a few weeks ago in the Austrian F2 Grand Prix in Salzburg, driven by Jacky Ickx. The general layout of the new head is identical with the "cross valve" design, except, of course, that all inlet ports are on one side and all exhaust ports on the other, and for reasons of space, the inlet valve diameter is reduced from 38 to 36 mm. In the development stage, camshafts giving 324° valve opening were used, as on the "cross valve" engine, but better results were obtained with a slightly lesser overlap and 316° valve opening. One advantage of the "parallel valve" head is that, for reasons of space, its exhaust ports have a better shape. It provides a slightly lower maximum power output, but better torque characteristics, giving higher power in the medium speed ranges, the two power curves crossing each other at about 9500 rpm. The poorer torque characteristics of the "cross valve" engine are probably due to higher scavenging losses between the adjacent inlet and exhaust valves. Two incidental advantages of the "parallel valve" head is that there is only one throttle slide, reducing the pressure required on the accelerator, and that, there being only one intake and one exhaust system, the engine is some 18 lb lighter.

As the "cross valve" engine has a higher output and should have a slight advantage on very fast circuits, while the "parallel valve" engine is better suited to circuits on which flexibility is a major asset, it is intended that both engines should be further developed in view of the 1971 season. After that BMW's F2 activities will come to an end, as the factory has no production engine that could make a suitable basis for an F2 engine under the new rules. From then on, the main emphasis will probably turn back to saloon car racing. ■

# Continental diary

Paul Frère track tests some of BMW's successful racing saloons at Hockenheim, including the Alpina 1600 below. On page 42 Motoring Plus road tests an Alpina BMW 2002 from Crayford


Perhaps BMW's main object in inviting some 40 journalists to try various racing saloons at Hockenheim was to emphasise that they have no intention of retiring from competition. This was made quite clear by Dipl.-Ing. Helmuth Boensch of BMW who recalled that after several years' unsuccessful efforts, their F2 cars had finally emerged at the top. In developing their F2 engine, BMW found simplicity could be a better key to success than a theoretically optimal, but much more complicated, design. Herr Boensch recalled that the radial valve Apfelbeck cylinder head had shown a 30 per cent improvement in volumetric efficiency on the flow meter compared with a normal twin-cam, two-valve head, and a 20 per cent improvement over a four-valve head—though it is not known whether this was due only to the longer valves that could be accommodated which, in practice, are not necessarily an advantage.

The unreliable Apfelbeck head was finally abandoned in favour of a more conventional 4-valve arrangement, keeping the crosswise arrangement of one inlet and one exhaust valve on each side of the chamber. Finally the crosswise scheme was also dropped and the latest and most successful engine was the simplest and most conventional. Power output varied between 246 and 250 bhp for the crossvalve engine which scored BMW's first of three victories of the season. The parallel-valve engine which accounted for the rest gave 243-246 bhp, making up for its slightly inferior power with notably better torque. As the main reason for BMW's demise in F2 Herr Boensch mentioned the fact that some 45 per cent of the factory's engineering staff are involved in meeting the forthcoming demands of the safety and exhaust emission laws and that the best brains involved in racing were now urgently required for the development of future production models.

This is why BMW will return to touring car racing and rallying on a larger scale than in the past two or three years, but relying on outside specialists to deal with the preparation and organization. Some of the better tuning establishments have done extremely well during the past season, and while the BMW experimental department will continue development work with an eye on racing, a good part of the work will be entrusted to some of the tuners.

The greatest part will be assigned to Alpina who will officially represent BMW in the 2- and 3-litre classes of the European touring car championship. Koepchen will also have cars running in the 2-litre class of the European championship and in the German touring car championship. Schnitzer will mainly contend the German hillclimb championship and prepare engines for F3. One such engine was on show, fitted with a four-piston Kugelfischer injection pump, four nozzles and a common intake pipe featuring the regulation restrictor of 20 mm diameter. It has the standard bore and stroke of the 1600, not the 2-litre bore and shorter stroke, as used for the F2 engine. Apart from racing, BMW will also have works, or semi-works, cars in all the major rallies counting towards the European, French and German rally championship.

Before getting into the driver's seat, a note on how the various cars had been prepared. The output of the 2002 TI has not progressed very much over the past two years. The factory were extracting some 205-207 hp with Kugelfischer fuel injection two years ago and this is what most tuners are now getting on carburettors. Schnitzer, though, is alone in using injection (Kugelfischer) and claims something between 210 and 215 bhp. This advantage was not really borne out by driving impressions, or by racing results. Schnitzer maintains however that he has another bagful of power up his sleeve for next year.

All these engines use the racing camshaft developed by the factory, providing a 324° valve opening period, and all use the factory developed 39 mm exhaust and 46 mm inlet valves. The main differences lie in the preparation of the cylinder head, pistons and intake and exhaust systems. Schnitzer uses Kugelfischer injection, Koepchen sticks to Solex carburettors (though they are 45 mm instead of the standard 2002 TI's 40 mm); all the others fit 45 mm Webers.

On the chassis side, there are obvious differences in rim width, ranging from 8.5 to 10 inches at the rear, but in all cases the basic BMW suspension is retained, including the pivot points for the (standard) rear trailing arms and the front MacPherson layout, though the struts themselves are non-standard units with a stub axle providing up to three degrees negative camber. These are specially made by Boge, Koni and Bilstein.

In all cases ventilated front discs, a 5-speed gearbox and a limited-slip differential are fitted. The differential is modified to provide much more (approx. 75 per cent) slip restraint than the factory optional equipment.

As the racing equipment, including roll bars and large tanks, adds some weight, about 40 Kg can be taken off the car without getting under the homologated limit of 890 Kg; this is achieved by fitting a plastic bonnet; a plastic boot lid; a plastic rear window; and plastic side windows, a total of 37.7 Kg. Schnitzer cars also have plastic doors, so with the removal of the mats, bumpers

Above: the BMW 2800CS Coupe that won the Spa 24 hour race. Right: Schnitzer use Kugelfischer fuel injection on the 2800, Alpina, bottom right, use three twin-choke Webers

and so forth, there is little else you can lighten and still remain within the rules.

I drove the Schnitzer car and the GS-tuning version. The most obvious difference between them was the carburation—Kugelfischer injection by Schnitzer, Webers by GS—and rim sizes which represented the two extremes: 7.5 and 8.5 inches in Schnitzer's case, 9 and 10 inches on the GS. On a wet track, of which only the short circuit was used, the two cars felt much alike though the GS was correctly geared for the occasion and probably had the edge here. The rev limit on all these tuned 2-litres is 7500 rpm, some 500 rpm above peak.

Even with a specific output of well over 100 bhp per litre, the flexibility is quite remarkable; there is immediate and willing response from as low as 4000 rpm though normally the revs are kept over 6000. This flexibility, which brought back memories of the D-type Jaguar, was not the only thing that made the BMWs easy to drive. Their handling is also without problems, as it was on the 1600s I drove. Basically, they understeer slightly in sharp curves, as do all good racing cars, and they become pretty neutral in faster bends. On the wet track, applying too much power would, of course, bring the tail out, but this is done in a beautifully smooth and controllable way, helping the driver rather than urging him into panicky manoeuvres.

One thing that struck me when changing over from a 1600 to a 2-litre was the obvious difference in performance. The 1600 Alpina which develops 170 hp and can be wound up to 8500 rpm, actually felt notably slower than my own road-going Alpina 2002 TI which has the advantage of much better middle-range torque. But strangely the 35 bhp difference between the 1600 and the 2002 racing models is much less obvious in lap times. Herr Bovensiepen, the Alpina chief, told me that thanks to improved tyres and handling, Soler Roig was actually one second faster around the Jarama course with the 1600 this year. Our German contemporary *Auto, Motor & Sport* took some figures (with two up) on both the 1600 and 2002 Alpina racing saloons; unfortunately it was done in pouring rain. The high rolling resistance of the wet track is also reflected in the relatively low maximum speeds reached:

| | 1600 | 2002 |
|---|---|---|
| 0-60 mph | 7.3 sec | 6.8 sec |
| 0-100 mph | 20.1 | 16.4 |
| ss ¼-mile | 15.0 | 14.5 |
| ss Kilometre | 27.9 | 26.9 |
| Max speed | 127 mph | 128 mph |

The highlight of my day however, was the race-prepared 2800 CS Coupe. Two were present—the Alpina car which won the Spa 24 Hours race, and the Schnitzer car with which Furtmayr won the large touring class in the German hillclimb championship. There are considerable differences in the preparation of the two; Schnitzer has Kugelfischer fuel injection; the Alpina three twin-choke 45 DCOE Webers, though fuel injection will be fitted next year. In both cases, the capacity has been brought up to the 3-litre limit by boring the cylinders; a 324° camshaft is fitted together with the same larger valves as on the 2-litre; and an output of well over 300 bhp is obtained. Both cars also have the optional 5-speed gearbox.

Alpina and Schnitzer have very different methods of chassis tuning, though. Schnitzer throws away most of the rubber and replaces it with solid bushes; Alpina just substitutes harder rubber. Then Alpina matches single Bilstein dampers to the slightly harder than standard springs, Schnitzer duplicates the dampers all round, even adding a normal Koni damper to each of the MacPherson struts at the front. In both cases the front struts are special, giving appreciable negative camber; and the rim width is 9.5 in. at the front and 11 in. at the rear. But whereas Alpina went down from the standard 14 in. diameter to 13 in. to lower the car and make room for wider tyres, Schnitzer went up to 15 in. This allows him to fit larger brakes, which have ventilated discs all round. As with the Alpina, the standard rear drums are discarded.

Schnitzer also believes in leaving the suspension settings well alone once they have been


optimized, especially as his car runs mainly in hillclimbs and replicas are sold to customers. So he fits non-adjustable anti-roll bars (they are adjustable front and rear in the Alpina). Finally Schnitzer has kept the standard power steering—he thinks the car would be undriveable without it.

A trouble Alpina ran into was overheating of the rear axle oil. This was solved by adding a belt-driven gear pump circulating the oil through long pipes and a separate element included in the water radiator.

The biggest handicap of the BMW Coupe is that it was homologated at the incredibly honest weight of 1230 Kg. So it is quicker than the 2002 only on fast circuits where its much higher maximum speed can be used. On slow and short circuits, like the small Hockenheim course, it is less agile and does not quite achieve the lap times of the smaller car. On the other hand it is certainly the most comfortable racing saloon I have ever driven, with all the original trim in place, including the floor mats; in several races cars were even run with the standard electric lifters for the rear windows.

Unfortunately Schnitzer only did a few demonstration laps with his coupe and then put it aside, fearing the worst under the prevailing conditions, so I could not compare the two very differently prepared cars.

Once under way, the Alpina's steering did not strike me as being particularly heavy, though the wet road surely helped a lot and I can well imagine that on a dry course with many sharp corners, power steering could be well worth having. The loud bark of the six-cylinder engine seemed a bit out of place in this luxuriously appointed car, but the flexibility is still there to a remarkable extent. In the wet it was quite a boon to be able to nurse the car around some of the sharper corners in a controlled drift in third at some 4500 rpm, and still have enough power to accelerate out of the bend with the wheels on the point of spinning. To start with I had some difficulties with the gearbox, due to insufficient spring loading protecting first gear, but this was soon forgotten and I just sat down to listen to the roar of the beautifully smooth engine. So smooth, in fact, that you really have to watch the rev counter. When necessary, the revs may be pushed up to 7500, but I was asked to keep to 6700. Gunther Huber, who came second in last year's European touring car championship, acted as a telltale in the passenger seat.

As to handling, I found the heavy Coupe rather less forgiving than a 2002 under the appalling conditions. Basically, it behaves much like a 2002, but once the tail slides out, it certainly requires more instant checking. Otherwise sheer mass will carry it out too far. However, the drivers say that on really fast bends, it is a more stable car than the 2-litre.

*Auto, Motor & Sport* test figures taken last summer confirm that on winding courses the big car would have no advantage over the smaller one. In this case, the figures were obtained on a dry road, but a rather weak clutch prevented proper racing starts (reflected by the slow 0-60 time):

| | |
|---|---|
| 0-60 mph | 8.2 sec |
| 0-100 mph | 17.5 sec |
| ss kilometre | 27.0 sec |
| max speed | approx 152 mph |

With 150 kg less (which is easy to achieve) the BMW Coupe could be quite a formidable contender in next year's touring car racing, but it is up to BMW to produce a lightweight version in sufficient numbers to be homologated. Quite recently, they got a jolt that really did make them wake up. There's a race on the short Hockenheim course for non-professional drivers, in cars put at their disposal by the industry. Many of the drivers are industry heads themselves, others are motoring journalists. Any sort of car is accepted as long as it has a series production body shape with at least two seats.

The race was easily won by Klaus Steinmetz, the official Opel tuner, who drove one of his 3-litre Commodore GSs fitted with the new cross-flow head to be used next year. The car was so fast it even beat the Larrousse Porsche 911 which weighs only 785 Kg and produces 245 bhp from its 2.4-litre engine; it was driven by Manfred Jantke, *Auto, Motor & Sport's* chief tester who is a very competent driver. Neither the big nor the small BMW could hold a candle to it. So if touring car racing is going to be BMW's showroom on next year's sporting scene, they must make the necessary steps to have the right cars in it. And that's what they'll do. ■

# MOTORING PLUS

*BY JIM TOSEN*

## BMW 2002 ALPINA

One of the advantages of having a roving Continental editor like Paul Frère is that he has the opportunity to drive and examine cars which are often out of bounds for practical or economic reasons to home-based scribes. It can also be tantalizing as most of the creations recorded in Continental Diaries are just not obtainable in Britain. This used to apply to the Alpina-modified BMWs, an example of which so impressed Frère that he bought for himself a highly modified 2002TI with 163 bhp engine, five speed gearbox, lowered suspension and limited slip diff. This car recorded a top speed of 126.4 mph, good enough for a Belgian National record incidentally, and last August had proved to be completely reliable over nearly 12,000 miles. But then virtually the same bottom end has withstood 280 bhp in the turbocharged factory Group 5 cars!

Having read and listened to Paul's description of this fabulous car we were immediately interested when Crayford Engineering announced that they were to import Alpina equipment. Director David MacMullan offered us his own 2002 which had just been kitted out with some of the latest goodies. He pointed out that they were still getting established on the Alpina front, that the car was getting on a bit and not a particularly good example and that we should forget any ideas about matching the Frère car's top speed or acceleration times of from rest to 60 mph in 6.8sec. and 100 mph in 18.7sec. But it made an already potent and excellent road car even better and in effect makes up for the lack of a TI version of the 2002 in the British BMW range, not that the standard car is exactly sluggardly. And our test car, from which the comparison figures are taken, seems to have been a particularly swift example.

The Frère car incidentally (described in detail on August 22, 1970) started life as a TI with the 9.3 to 1 compression pistons of that car which the Alpina mods raised to 11.5:1. The Alpina head raises the cr of the standard engine to 10.2:1.

The cylinder head comes with special valve springs, modified guides, combustion chambers reworked and balanced and both inlet and exhaust ports opened up and flowed in position. This costs £250 complete with the second wildest camshaft giving 300° valve opening, or if you really want the ultimate at the top end at the expense of flexibility and a really depressing fuel consumption, there is the full race 324° profile. The standard Solex carburetter is replaced by a pair of Webers with specially opened up chokes to match the head costing £67 for the pair.

Other Alpina modifications not carried out on the MacMullan car include what is called the sports chassis. This consists of reinforcing the rear suspension by boxing in the semi-trailing arms, uprated rear

**Alpina Price List**

| | |
|---|---|
| Cylinder head complete with modified cam, valve springs, guides, flowed ports and chambers. Compression raised to 10.2 to 1 | £250 |
| Cam separately 300 degree type | £38 |
| 324 degree racing cam | £40 |
| Gaskets etc to suit | £10 |
| Twin Weber carburetters modified to suit head | £67 (pair) |

**Crayford 2002 with Alpina modified cylinder head and 300° camshaft. The neat filter box for the Weber carburetters was added after tests were completed.**

dampers, stronger front hubs and bearings and ventilated front discs, all for £139. Tyres up to 175 section can be fitted to the 2002 provided the front wheel arches are slightly flared. The test car was shod with Goodyear G800s on alloy wheels. Crayford hope to bring in a few of the Alpina full race engines with forged pistons and an output of 180 bhp which cost £850 on an exchange basis, provided the customer's engine has covered less than 5000 miles, and for the ultimate there is a Kugelfischer fuel injection kit which costs £600.

Apart from an air scoop let into the bonnet, the big GT wheels and Alpina flashes on the back, the MacMullan car looks like any other 2002 and retains most of that car's good manners and freedom from temperament. It started easily after a night out in the cold, warmed up smartly and though the figures show there is some loss in top gear acceleration up to 60 mph the engine gives the impression of having an exceptionally wide power band with no flat spots. Sometimes it showed a tendency to fluff after a long spell in dense traffic, but a short squirt on the open road soon cleared this.

The power really comes in around 2700 rpm which with the standard 3.64 to 1 final drive is equivalent to 50 mph in top. The last modified BMW we tested had the lower 4.1 axle which it seems would be better suited to this car since the engine spins freely and safely to an easy 7000 rpm and must develop peak power rather higher than the standard unit's 5500 rpm. On this gearing at our maximum speed, around 112 mph, the engine is still barely pulling 6000 rpm. A lower final drive would of course also benefit acceleration; not that 0 to 60 mph in 8.4sec. and 0 to 100 mph in 27.3sec. is exactly slow, but the former is less than a second quicker than our standard figure and viewed quite clinically hardly seems a fair return for an investment of around £300.

With the lower axle we have got a tuned 2002 up to 60 mph in under 8sec. Another deterrent to tyre-smoking starts is shudder in the transmission which seems to apply to all 2002s to some extent. It would appear that the body mounted differential transmits tramp disturbances up the drive line to the engine, through the mounts into the front suspension cross member and up the steering column where the effect on the driver can be quite alarming. The more wear in the rubbers at the various attachment points the worse it gets, and as I have said this one was a fairly well used car. It was even noticeable accelerating hard out of a sharp corner when the steering sometimes developed a mind of its own. This completely kills its response and self-centring effect, never one of the best points on a BMW. Otherwise, within the limits of the 2002's tendency to lift the inside wheel when cornering hard, the car's roadholding and traction on the big Goodyears were very good. Paul Frère found that with the full conversion the optional BMW differential with 25 per cent locking factor was not sufficient to prevent the inside wheel spinning under power on sharp corners and opted for a diff with 75 per cent factor. Another favourite gripe of ours, directed at all older BMWs, is the uncomfortable pedal layout which makes heel and toe gear-changes almost impossible. Apparently the makers have at last paid some attention to this in the latest cars.

Though the car was obviously more raucous than standard, nobody who drove it objected to the noise. There is some harshness in the middle of the range and a lot of intake roar from the gaping throats of the Webers under power. The air cleaners shown in the illustrations were not fitted at the time of our test so we cannot comment on their effectiveness, but they must make some difference.

Steady speed fuel consumption figures show that the inlet tracts are rather too wide for economy at low speeds and the car is actually slightly more economical at constant 70 mph than it is at 30 mph. With much of our test conducted on icy or congested roads this is reflected in the rather heavy overall consumption of just under 18 mpg, though the touring figure, based on a steady speed of 71 mph, is not so far behind the standard figure and we had no difficuty in exceeding 20 mpg on a long run out of town.

Obviously when assessing the value of this Alpina kit it must be borne in mind that it is always much more difficult to make a significant improvement on a very good engine like the 2 litre BMW than a more ordinary mill, and as Crayford have found even BMWs, originating from a country with very strict trade description regulations, do show some considerable variation in standard power output. Alpina have done enough to convince me that they know their way around the BMW engine and a determined effort to promote their wares in this country is good news for BMW enthusiasts.

### Performance

| | BMW Alpina 2002 | Standard BMW 2002 |
|---|---|---|
| **Maximum speed** | | |
| Mean | 111.2 mph | 107.4 mph |
| Best ¼ mile | 112.5 | 111.1 |
| Maximile | 110.4 | 105.4 |
| **Acceleration** | | |
| 0–30 mph | 2.7 sec | 3.1 sec |
| 0–40 | 4.5 | 4.8 |
| 0–50 | 6.3 | 6.8 |
| 0–60 | 8.4 | 9.2 |
| 0–70 | 11.6 | 13.3 |
| 0–80 | 15.4 | 17.6 |
| 0–90 | 19.1 | 24.7 |
| 0–100 | 27.3 | 37.4 |
| Standing ¼ mile in top | 16.4 | 17.3 |
| 20–40 mph | 9.6 | 7.6 |
| 30–50 | 8.9 | 7.4 |
| 40–60 | 8.9 | 7.7 |
| 50–70 | 9.3 | 8.8 |
| 60–80 | 9.8 | 9.8 |
| 70–90 | 10.8 | 12.5 |
| 80–100 | 13.2 | 20.3 |
| In third | | |
| 10–30 mph | 6.3 | 5.7 |
| 20–40 | 5.6 | 5.3 |
| 30–50 | 5.8 | 5.3 |
| 40–60 | 6.0 | 5.6 |
| 50–70 | 6.1 | 6.5 |
| 60–80 | 7.6 | 7.9 |
| **Fuel consumption** | | |
| Constant 30 mph | 25.1 mpg | 43.8 mpg |
| 40 | 26.1 | 41.0 |
| 50 | 27.9 | 38.5 |
| 60 | 27.9 | 32.3 |
| 70 | 25.6 | 28.5 |
| 80 | 22.0 | 24.3 |
| 90 | 18.5 | 20.6 |
| 100 | 15.2 | 16.8 |
| Overall | 17.9 | 24.0 |
| Touring | 24.1 | 27.5 |

**BMW's Touring has 1600 and 2000 engine options and is due in the UK in August or September**


# New BMW estate at Brussels show

**by Hamish Cardno**
**photographs by Maurice Rowe**

The economy is out of balance, the populace is terrified by the rising cost of living, and the motor industry feels it is being used unfairly as an economic regulator. No, not Britain, but Brussels, capital city of Belgium and administrative centre of the Common Market.

In a vast exhibition site near the Atomium, on a hill on the city's outskirts, they've parked the 50th Brussels Motor Show, which should be an occasion for rejoicing, but isn't.

Since January 1 something called "TVA" has been introduced in Belgium, and those three initials have caused a bigger general depression than if they were "FLU". The initials are an abbreviation for value added tax, an all-embracing economic sanction which operates on a sliding scale from 6 to 25 per cent and has really put the jitters into Belgium's businessmen.

In a city where the cost of living is already among the highest in Western Europe, TVA is certain to raise it still higher. The only uncertain thing is by how much.

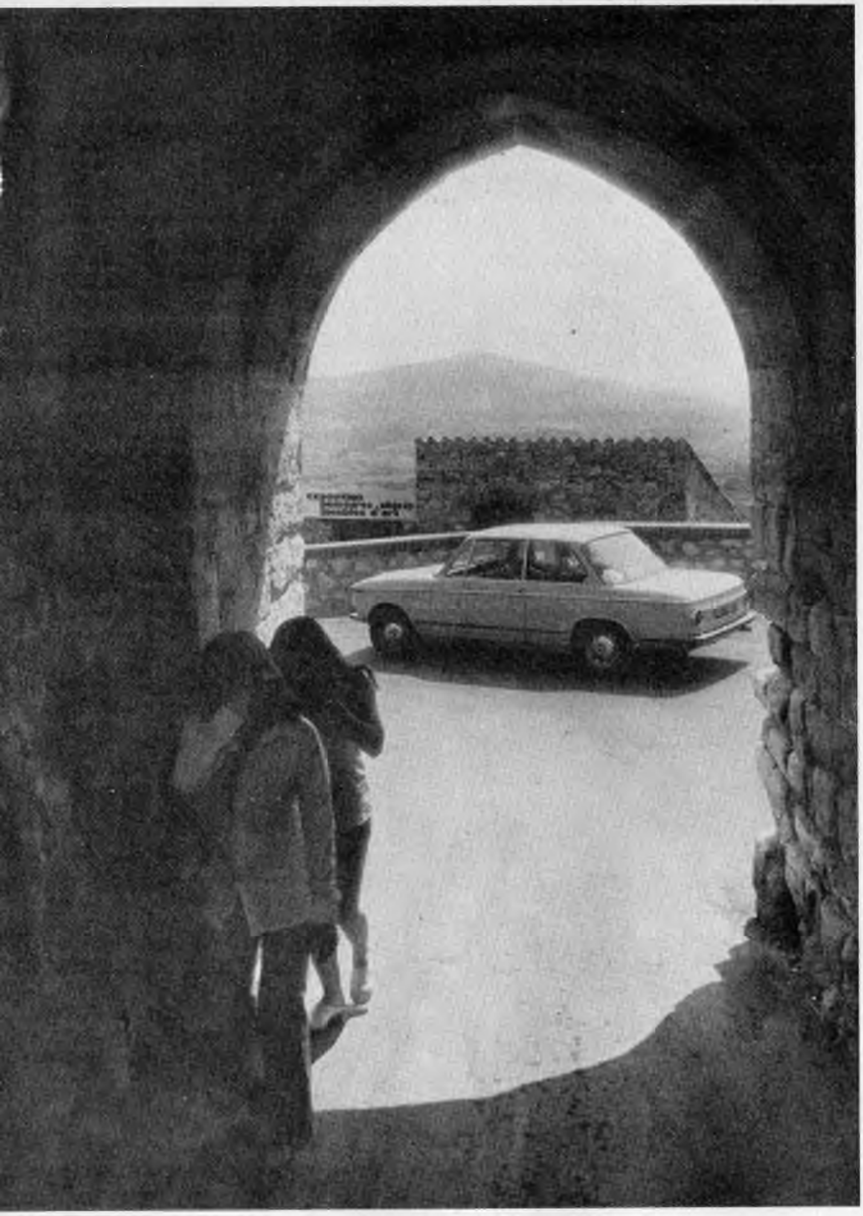
Shrewdly, the Government put the lowest TVA rate on food. The 7 per cent purchase tax (like purchase tax on other goods) disappeared, and 6 per cent TVA took its place. But on cars the tax is at the highest rate—25 per cent—and spare parts, commercial vehicles, and labour in garages are all subject to an 18 per cent surcharge. The effect has been to increase car prices by 4 or 5 per cent, a nightmare for the motor trade which last year saw a substantial drop in car sales as hire purchase repayment periods went from three years to 30 months, and then to two years.

However, the salesmen smiled bravely in the vast halls behind the Atomium on the hill, and prepared to sell very desirable motor cars to the people.

Of these, probably the most interesting newcomer is the BMW Touring—an estate car based on the small body, and available with either a 1600 or 2000 engine, the latter with carburettors or Kugelfischer fuel injection. The body is the same as that of the saloon from front bumper to a few inches behind the doors, then the roofline drops at a similar angle to the sloping rear window of a Renault 16 to a squat, squared-off tail. The lines of the car are practical rather than elegant, and with individual rear seats which fold forward to double the carrying capacity it should be a fast and useful estate car. BMW say it will be introduced in the UK in August or September, and the basic price is likely to be about £150 more than the equivalent saloon.

On the next stand, General Motors were proudly showing off the GM Ranger, a medium-sized car based on an Oldsmobile-engined model originally made by GM in South Africa. The car was subsequently sold in Switzerland and has now been introduced to the Benelux countries where it is being sold through the Vauxhall dealer network. With engine sizes of 1.7, 1.9 and 2.5 litres, it fills gaps between the models in the Vauxhall range, and whichever body style you choose—two- or four-door saloon or two-door coupé—it looks like a cross between an Opel Rekord and a Vauxhall Victor.

The largest fanfares were reserved for Ford's introduction of the GT70, their idea of how to stop Porsche and Alpine-Renault winning rallies. The silver, mid-engined two seater, completed after some non-stop work for 72 hours by the competitions staff, looks elegant and very practical. No decision has yet been made on whether it will go into production. At the moment Ford are planning to build seven cars and it is likely that the first event in which any will compete will be the Tour de France in September. For homologation reasons 500 must be built before the car will be eligible for events such as the Monte Carlo Rally, but it seems that making even this number



# BOWLER'S BURN-UP

**Michael Bowler drives the new 3 litre coupe, an improved 2500, and the 2002 Tii**

I have always been a bit of an addict for the blue and white whirling prop that makes up the BMW insignia and the chance of a good run in three of the latest models was very welcome. I took the 2002 Tii down to the French GP and then joined in with a BMW party at Le Havre. I drove a new 2500 most of the way down to a hotel some 100 miles south of Paris. Then to get a decent test on a 3.0CS, I went for an hour's fast run at 6.30 am the following morning and then reverted to the Tii for the 260-mile run back to Boulogne.

Of the three mentioned only the 2500 is familiar. It is more or less the same as before but has a heated rear screen as standard, modified seats, different make of gearbox, better wiper control and slightly modified front suspension. It's a nice smooth comfortable six-cylinder car.

The 3.0CS is the latest bigger engined version of the 2800 CS with the bore upped to the 89mm of the 2-litre four cylinder cars; the engine now gives 180 (DIN) bhp at 6000 rpm and 189 lb.ft. of torque at 3700 rpm against 170 and 174 respectively on the 2.8 litre. New ventilated discs -replace the previous solid ones and twin servos are used for the twin brake circuits. The same Getrag gearbox is used in the 3.0-litre cars as in the 2500. There are minor changes in the suspension settings and the self-levelling option is no longer available. The maximum speed of the coupe now passes the magic 130 mph which demands 195/70 VR-14 tyres.

The 2002 Tii was announced at Brussels in an Estate body, but in fact this hot engine also goes into the 2002 coupe and we won't see the Estate version until later this year. Foreign markets have had the 2002 Ti for some time, but the UK has been deprived because right hand drive steering columns get caught up with the exhaust manifold. Now, however, with the Tii the UK can have the fast one. The Ti gave 120 bhp with twin Solex carburetters and the Tii with Kugelfischer injection gives 130 bhp at 5800 rpm with 131 lb. ft. of torque at 4500 rpm. Other changes include a stiffer body shell, firmer suspension settings, more powerful brakes and HR instead of SR 165-13 tyres on 5J rims, ½-inch wider than before. The final drive ratio has been raised from 3.64 to 3.45:1, a 5½ per cent change.

I drove the 2500 saloon first with normal, non-assisted, steering; it had its usual very willing smooth engine quite happy to rev effortlessly to 6000 rpm with a useful punch—0-60 mph in about 9½ sec. I went from Dreux to the Auberge des Templiers (friars to you) on the N7 south of Montargis at Les Bezards, via Chartres (where due homage was paid to the magnificent cathedral) and on all sorts of minor bumpy roads as well as the high speed carriageways. I was much more impressed with the stability on bumpy roads of this 2500 than on another that I drove with power assisted steering, both cars carrying four people and luggage. The ride was comfortable with four up without getting too floaty, which means that with one up you still get the sports car handling that impressed us so much when these cars first arrived. The non-assisted steering wasn't too heavy for parking and gave a nice feel at speed.

The weather was particularly hot at that time and comfort was vital—ventilation with all the grilles open was good out of town but you needed the fan on full speed when pottering in town. With this class of car (£3,000 minus £1) the back seat space is important, and the 2500 gives plenty of room for two adults without any compromise from those in front; and the boot is plenty large enough for the luggage of four people too. It isn't really a very different car from its predecessor, but the fact that improvements have been incorporated and that the price has remained unchanged surely suggests good value.

The 3.0CS is rather different; it's a handsome, striking beast but you have to pay a lot more for it—£5345 with another £119 for the excellent ZF power steering. The extra cost is partially justified by the fact that it is built at the Karmann coachworks and isn't just part of the normal

BMW production line; the right hand drive is now installed in Germany rather than being converted in the UK.

As I said before I hadn't driven the coupe on the first day of our trip and the only way seemed to be to get up early and have a go. The coffee stage of dinner the night before hadn't arrived at 1.30 am when I went to bed, so I wasn't exactly at my most alert five hours later, but it was one of those idyllic hot summer mornings with the mist still playing over the local canal—I must have crossed this at least six times. In short, car and countryside justified the personal effort. I warmed it up gently on the local main road and found that 100 mph plus was a very natural cruising gait which came up astonishingly quickly; then off to the D roads with an ideal mixture of long fast bumpy straights and short twisty hill sections. Gradually it shrunk from being the big car that I had got into, to the neat and compact 2002 size in which I had just done 1600 miles. The ride was good and really soaked up the bumps in a smooth rattle-free fashion, despite 10 per cent less suspension travel than the 2500 saloon. Roadholding on the big fat tyres was equally impressive and losing adhesion seemed virtually impossible. If you deliberately threw it at a corner it was just possible to get the tail out enough to straighten up prematurely for the exit—remarkable handling for a large car. The power steering actually encouraged such treatment. Seats were comfortable, controls well placed and the right weight and it just inspired confidence generally.

Towards the end of my hour blind I came to one of those really long straight stretches with wide flat borders to the road that excluded any irresponsible emergents from the *droit* arriving unseen to exercise their *priorite*. I put my foot flat and in very little time it was indicating an impressive 130 at 6300 rpm; brakes hauled it down steadily to safer speeds as the open verges became forest and I became a town potterer again wuffling along at a gentle 20 mph in top. That hour included 68 exhilarating miles of every conceivable type of motoring excluding motorways, and I returned impressed that whatever the car cost it was still a good 'un.

Back to the hotel, a quick dip in the 75° pool after which I contemplated breakfast but rejected the idea in favour of avoirdupois and sun worship. Then off at 9.30 to catch the 3.15 pm boat at Boulogne in the Tii.

We will be publishing a full road test on the Tii soon, with full road test figures. It is cast exactly in the 2002 mould of sporting four-seater coupe but with an extra 30 bhp to play with and some stiffening of the suspension to make the handling more taut. On my run down to the south of France completing the latter stage of running in, 90 mph and 5000 rpm, it returned 26 mpg which suggests that the fuel injection system is capable of providing both power and economy; it is a smooth powerful unit which seemed quieter than in the normal 2002. Our car had occasional difficulty with hot starting and seemed reluctant to pull its full whack of revs but we hope that further adjustment will sort this out before the full test. Despite this, though, it was obviously faster than the standard 2002 and 95-100 mph was an easy motorway lope.


**The new coupe above is outwardly virtually unchanged apart from side indicator repeaters but inside the extra cc make a useful difference. Bigger changes have taken place with the 2002 Tii, seen here in the old village of Le Castellet; the bodyshell is tougher and now has a rubber kickstrip all round. If you are observant you can spot the extra 'i' for injection at the rear**


The suspension strikes a nice balance of ride and handling; it can be a bit choppy at low speed but at high speed it is very good on all surfaces, solid and sure-footed. The car steers well with good road feel and is really remarkably compact for such spacious internal dimensions. My major criticism is a lack of fresh air ventilation which really should have been overcome in a car costing £2295; you can set the heater to cold but the throughput isn't great enough to keep you cool. For those prepared to tolerate the noise the swivelling quarter lights will pivot round to act as scoops.

However, despite this I enjoyed my long solo run being quite happy to stay in the seat for the 250 or so miles that I managed per tankful on the non-motorway run down. It really is a driver's car that anyone can drive.

So ended 10 days of BMW motoring—10 days of enjoyable comfortable driving round the highways and byways of France at its best time of the year. ■

# Top power from BMW

## *How the new 16-valve 2-litre BMW racing engine was developed*

By Olaf Fersen

AFTER trying hard for the better part of eight years, BMW at last have a really competitive power unit in formula 2 as well as in the 2-litre sports car category.

The original 1.5-litre 4-cylinder BMW unit of the early 1960s was designed as a "sports" engine, capable of being developed to produce a lot more power than it was offering in standard form. Over the years, the unit was stretched to 1.6, 1.8 and ultimately to 2 litres, the range was supplemented by Ti and Tii versions fed by two Solex twin-choke carburettors or fitted with Kugelfischer port-type fuel injection.

The Munich factory proudly cherished their pre-war racing traditions and although they had some extremely lean financial years, they always planned a return to racing. The first real attempt to get back into big-time competition started in 1965/66 when Ludwig Apfelbeck of KTM motorcycle-fame joined Alex von Falkenhausen's design staff and produced an intriguing cylinder head with four radially positioned valves per cylinder. This "M 10" unit was built in 1.6-litre and 2-litre sizes — the former for the then valid formula 2, the latter for a sports car.

**The smaller unit gave 220 bhp (DIN),** the larger one some 260-265. Although the power output seemed remarkably good, reliability left much to be desired. Chief trouble with the engine was its complicated valve gear that displayed a certain "softness" in operation at high revs. One British competitor nicknamed the Apfelback the "H & H" engine — meaning high and heavy and this indeed it was.

The next step came in 1967 when a new cylinder head with the valves in parallel pairs was introduced. This stage was the "Diametral" engine, so called because the head was not of the more usual cross-flow **type, but the valve-pairings put an inlet and an exhaust valve adjacent at each side** of the longitudinal centreline. Several versions of the Diametral-engine were built. M 12/1 (that won a race at Hockenheim and another at Albi), M 12/4 (also a 1.6 litre) and the 2-litre M 12/3.

When development had reached a point **where there was sufficient power available** and reliability seemed within reach, management clamped down on the activities of the competition department and stopped further investments in such exotic machinery.

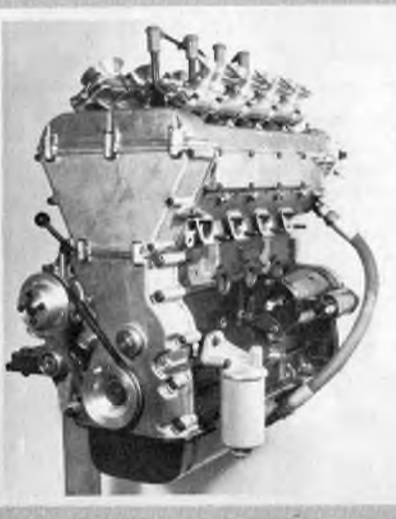
During these dark days a small group of enthusiasts led by Falkenhausen carried on their development work clandestinely in their spare time, jokingly calling themselves "BMW Underground Racing Team". They were developing a new unit, the M 12/6. This had a capacity of 2 litres and a 16-valve cross-flow cylinder head. When, after a change in management, the green light was switched on officially again, this engine was fairly well advanced. It was decided to build at least 100 units by the end of 1972 to have it homologated. At the same time a contract was negotiated with March Engineering in England by which the British constructor was granted exclusive rights to fit the BMW 12/6 racing engine into their formula 2 and sports cars.

### Straightforward design

The BMW 12/6 racing unit is built around the standard production cylinder block. It has a bore of 89 and a stroke of 80 mm and a cubic capacity of between 1,991 and 1,999.7 c.c. The light-alloy cylinder head is fitted with two overhead camshafts driven off the crankshaft front end by spur gears. The camshafts run in five plain bearings that are cast into a narrow casing, the bottom of which houses the bucket-tappets. The top of the camshaft case is closed by a neatly ribbed lid. Between the two camshaft housings the plugs are placed centrally. The head-casting provides for three plugs per cylinder but usually only the central recess is drilled and tapped to take one plug per cylinder only. Slightly more power is generated at peak revs by using three plugs per cylinder, but apparently some nasty things happen to the pistons if a central plug fails.

Valve diameters are 36.5 mm inlet and 31.5 mm exhaust with 7 mm stems for both. It is interesting to note how the included valve angle has been reduced over the years. The Apfelbeck engines started with 70 deg, the latest M 12/6 is down to 40 deg symmetrically split both sides of the vertical centreline.

A few years ago 70 deg was common with double ohc-designs and only lately angles have gone narrower. The Ford BDA uses 40 deg as well and the Lotus 2-litre has gone to 38 deg. I asked Alex von Falkenhausen about this and his opinion seemed to be that somewhere betwen 30 and 40 deg was the optimum angle, but there are other considerations



*Far left: The 1600 c.c. "Apfelbeck" racing engine with radially placed valves. It had the same number of inlet trumpets and exhaust ports as valves — eight each*

*Left: Next in line of development came the "Diametral" engine — again with sixteen ports — but one inlet and one exhaust valve on each "side" of every cylinder. It gave very good results except at very high revs when apparently gas flow inside the combustion space got "mixed up" and power tailed off rapidly. Fuel-injection here is by Lucas* like space and plug positions.

Inlet and exhaust port-pairs are Siamesed inside the head casting, their entries and exits being horizontal. A massive light-alloy induction manifold includes a common throttle-slide and its "lid" supports the inclined inlet-trumpets with the nozzles of the Kugelfischer injection, facing downstream.

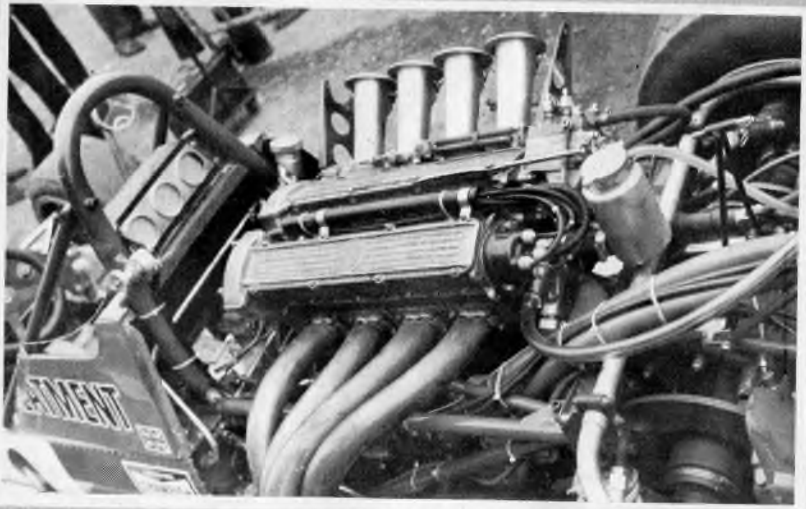
The lower part of the engine follows normal lines, but the massive connecting rods are made of titanium. BMW had some trouble with them at an earlier development phase, but after the supplier had been changed all seemed well. The forged pistons have recesses in their crowns for valve clearance and there are two compression and one scraper ring each. The method of securing the gudgeon pin, however, is unusual, as the end pads are screwed into the boss and staked by dents made in the outer edge of the plug that engage with little cavities in the skirt.

Lubrication is by a dry sump system of course. There are one feed and two scavenge pumps, all driven by gears plus a full-flow filter. Normaly the oil tank holds 11 litres and at 7,000 rpm and an oil temperature around 120 deg C, pressure should be 112 psi. The use of Castrol R30/B353 is recommended. Ignition is by condenser with individual impulse-charge.

In current form the M 12/6 is developing some 265-275 bhp (DIN) between 8,500 and 9,000 rpm on a compression ratio of 11 to 1. Safe rev-limit is rather near this at 9,100 rpm.

Parallel to the BMW developments, the Schnitzer brothers, one of the better-known tuning enterprises specializing in BMW power units, designed a 16-valve cylinder-head for the 2-litre unit, of which 100 were made by the end of last year to have the conversion homologated. The Schnitzer conversion fits production engines and relies on the chain-drive for the twin overhead camshafts. Unlike the factory's 12/6 engine, the Schnitzer conversion or Schnitzer-converted power units with their 16-valve head, are readily available to all racing teams. □


*Above: Unlike the works 16-valve engine, Schnitzer's can be installed at an angle in the 2002 saloon. Note the provision for drilling further sparking plug holes for three-plugs-per-cylinder version*



*Above: The latest 12/6 racing unit installed in the March 732 formula 2 car. Fuel-injection and distributor are driven by the camshafts*

*Right: Gudgeon-pins are located by threaded-in rings*

*Practical applications of the 16-valve engine. Above: Dieter Quester drove this Dornier-built BMW formula 2 car at an Austrian hill-climb in 1969. It uses one of the versions of the Diametral engine. An exclusive tie-up with March Engineering for formula 2 racing this season has proved most successful. Right: Frenchman Jean-Pierre Jarier leads the European F2 Championship in the works car*


*Not the latest Batmobile, but the 3.0CSI in 1974 guise! There is no front bumper, whilst that at the rear is simply a plastic moulding. Most of the aerodynamic appendages are glass-fibre mouldings, but soft rubber is used at critical safety points*

# BMW 1974

**Next week's Frankfurt Motor Show will see the unveiling of three new BMW models. Most important of them is the 525 — essentially a 520 powered by the compact and lively 2500 six.**

**Despite the 525's undoubted appeal, much of the limelight will be stolen by the Turbo 2002. A limited-production "special", this is based on the 2002 Tii. Because of the space limitations imposed by the use of a turbocharger, this exciting newcomer will be made only in left-hand-drive form.**

**In complete contrast, there is the new 3.3L — a long-wheelbase saloon equipped and trimmed to very high standards. This luxurious model is powered by a 3.3-litre engine — the largest BMW six to date.**

**Even more eye-catching than the Turbo is the latest version of the 3.0 CSI lightweight coupé. Export models feature the elaborate arrangement of spoilers, guides, fins and wings developed for use in Group 2 racing. Additionally, power and torque have been boosted by stroking the engine to 3.15 litres.**

**It is likely that the 525 will become available to UK buyers early in January, but no price has been fixed. In contrast, the 3.3L will not appear over here until the spring. We are told that at least 100 of the new 3.0CSI coupés are to be imported by the British concessionaires, but that deliveries will not commence until early in the New Year.**

**Because of the limitations of left-hand-drive, no decision has been made regarding the sale of Turbo 2002s in Britain. BMW plan to build just 2,000 units, although there is a slim possibility of a further batch at a later date. Alex von Falkenhausen, BMW's Technical Director, indicated that the model should be homologated for use in Group 2 events as from the beginning of next year.**

**Of the remaining BMWs sold in Britain, the 2002 variants and the established six-cylinder saloons benefit from various trim and styling changes. These revised models are already in production and should be appearing over here in the very near future.**

*525, Turbo 2002 and 3.3L models added to the range. Bigger engine and extra stabilizers for the 3.0CSI. Detail improvements to six-cylinder saloons and smaller fours*

## The 525

It is no surprise to learn that the handsome 520 bodyshell was planned from the outset to accommodate the 2500's six-cylinder engine. Although the latter is a snug fit, the installation calls for no significant sheet-metal changes other than the provision of a shallow blister along the bonnet top.

Efficient cooling is assured by the use of a radiator of the type employed in other BMW sixes. Unlike the five-bladed fan fitted to 520 and 520i models, that on the 525 incorporates a thermostatically-controlled magnetic clutch.

Engine specification closely follows that of the 2500, but different carburettors are employed (INAT 32/V6 on the 525, INAT 32/40 on the 2500 — both matched pairs of Zenith-Solex instruments). This may well explain why slightly lower peak outputs are claimed for the 525 installation (to the tune of 5 bhp and 2 lb. ft., the actual figures being 145 bhp (DIN) at 6,000 rpm and 153 lb. ft. (DIN) at 4,000 rpm respectively).

Externally similar to that used on the 520 and 520i, the four-speed gearbox features the more widely-spaced ratios found in other BMW sixes. There is no five-speed option, but ZF automatic transmission is included in the list of extras. Incidentally, BMW have found Britain to be a good market for automatic cars, around 50 per cent of the sixes currently sold here being so equipped.

As in the case of the 520 and 520i, a two-piece propeller shaft is employed. This utilizes a flexible coupling at its front end and Hooke-type joints at its centre and rear. Apart from having a ratio of 3.65-to-1, the final-drive unit is the same as those used in the equivalent fours. A limited-slip differential, designed to provide a 25 per cent locking effect, is listed as an extra-cost option. All four half-shaft joints are of constant-velocity design.

Spring rates, damper settings and anti-roll bar diameters have been tailored to suit the greater weight, but there have been no other suspension changes. In contrast, the ratio of the ZF-Gemmer worm-and-roller steering gear has been raised from 16.4-to-1 to 19.1-to-1 (equivalent overall ratios are 19.1-to-1 for the 520/520i and 22.5-to-1 for the 525). Unlike the fours, power-assisted steering is available as an extra-cost option.

Whereas the four-cylinder models have a disc front/drum rear braking system, that on the 525 is of all-disc design. Front units are the same as on 520/520i models, the four-piston callipers actuating 10.7 in. discs. Rear disc diameter is 10.7in. also (as in the case of the 2500), the callipers in this instance being of the two-piston variety. In line with normal BMW practice, the naves of the rear discs serve as drums for the shoe-type parking mechanisms. A 9in. direct-acting servo actuates the two hydraulic systems, both of which include the front callipers. A load-sensitive pressure regulating valve safeguards against premature locking of the rears.

Wheel and tyre equipment is the same as that used on the 520i, rim width being 5.5in. (as distinct from 6.0in. used on the 2500) and tyre size 175 HR14. In conjunction with the 3.65-to-1 axle ratio, gearing works out to 19.7 mph per 1,000 rpm in top (again, the same as that of the 2500).

Fuel tank capacity is 15.4 gallons — some 3 gallons more than that of the 520 and 520i, but close to 2 gallons down on the 2500. In the interests of safety, the tank is located beneath the boot floor, away from the car's interior.

A quick-action telescopic mechanism allows the steering wheel to be adjusted for reach. Another good feature is the provision of a height-cum-tilt adjustment for the driver's seat — this is in addition to the usual adjustments for reach and backrest rake. Both these features are available on 520 and 520i models as an extra-cost option (listed as a single package).

In all other aspects, the layout of the 525 closely follows that of its four-cylinder counterparts. It shares the same first-class heating/ventilating system and has the same excellent control and instrument layout. Careful attention has been paid to passenger safety, crushable front and rear body zones providing a large measure of protection for the rigid centre section. The latter features a robust, integral roll-over cage, whilst the wide doors have their own stiffening members to minimize risk of injury from side impact.

A full description of the very similar 520, complete with cutaway drawing, is to be found in our 14 September 1972 issue.

### Driving Impressions

During a recent visit to BMW's Ascheim proving ground, we were given the opportunity of driving a pilot-built 525. In typical BMW fashion, the new car feels "right" from the moment one slides behind the wheel. Playing a part in this are the new column and seat-height adjustments, which enable the driving position to be set exactly according to one's taste. Adding to the feeling of well-being is the logical control layout and first-class visibility.

When planning the 520, BMW engineers were anxious that the increase in size should not involve penalties in terms of response and general feel — requirements which were met in a very convincing manner. Now, with a six-cylinder engine, the car has lost very little of its former *elan*. Lower-geared steering (without power assistance in this particular case) did little to discourage us from hurling the car around the tortuous handling circuit — a procedure which called for surprisingly little physical effort

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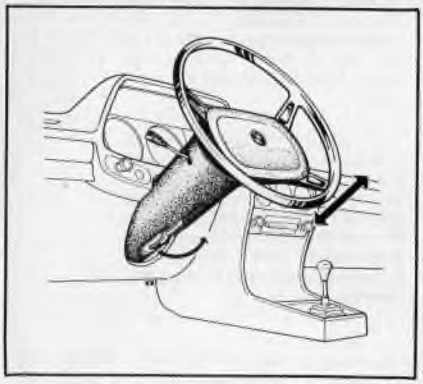

*Above, left: Bonnet bulge and 525 motif are identification points for new six*
*Above, right: Turbo 2002 cockpit. Other 2002 variants share new instruments, but have different steering wheel and no boost gauge*
*Left: New telescopic column adjustment is standard on all sixes and optional extra on 520 and 520i*
*Right: Turbo engine installation is neat and compact. Note air-delivery pipe behind radiator*

and inspired the utmost confidence. The only point worthy of criticism concerns the readiness with which the inside rear wheel will spin on tight corners. It may well be that exuberant drivers will find the optional limited-slip differential a worthwhile investment.

Bearing in mind the model's similarity to the 2500 in terms of power output, gearing and weight (just 22lb lighter according to BMW's figures), it is no surprise that one can detect no difference in performance. In actual fact, the makers claim a top speed of 120 mph (some 2 mph up on that claimed for the 2500) and a 0-60 mph time of 9.8sec (around 0.3sec quicker than the larger-bodied car). Past experience of BMWs suggests that the model will achieve better than this in actual practice. Certainly, on the proving ground's impressive high-speed straightways, readings of 209 kph (129 mph) and 6,300 rpm (equivalent to 122 mph) were achieved with considerable ease.

We gained the impression that the 525 is a quiet car, but due allowance must be made for the fact that we stepped into it immediately after a drive in the Turbo 2002 — more of this anon! Nevertheless, we were impressed by the absence of wind- and fan-noise, and by the silky smoothness of the magnificent 2500 six. Likewise, the ride and road-noise insulation matched the high standards set by the 520 and 520i.

Summing up, we rate the 525 as being the most desirable medium-range saloon in production today, and await news of its price with considerable interest. Currently, there is a £300 differential between the 520 and the 520i and a similar amount between the 520i and the 2500. Just where the 525 will fit into the range and what is to be the future of the 2500 remain to be seen.

## The Turbo 2002

BMW are no strangers to the art of turbocharging. Quite apart from the company's extensive aero engine experience, the 1969 racing season saw them campaigning turbocharged 2002s to such good effect that they ended up by winning the European Touring Car Challenge. Runners up were no less worthy adversaries than the neighbouring Bavarian firm of Porsche.

With the introduction of the Turbo, the lessons gained are to be passed on to those fortunate beings who will acquire one of the 2,000 examples it is planned to produce. Basis of the car is the 2002 Tii, itself a notably potent performer. Apart from the addition of a turbocharger, the engine remains surprisingly standard. Compression ratio is lowered from the usual 9.5-to-1 to a modest 6.9-to-1. A larger radiator is used and an oil cooler provided for good measure. Camshaft profile remains the same, there being no danger of an excess of fuel being discharged through the exhaust during the overlap period. The reason for this is the use of timed port-injection — in this case a Schafer mechanical system.

The turbocharger is a KKK, made by a subsidiary of Bosch. It is situated at the right-hand lower corner of the engine — a position which brings the turbine into convenient proximity to the exhaust-manifold outlet. So far as we can ascertain, careful matching of turbine and engine has rendered the use of a waste gate or other control device unnecessary.

The compressor portion of the unit draws air from a large filter situated at the right-hand front corner of the engine bay. From the compressor, the air passes into the intake manifold via a steel pipe with rubber-hose couplings. Maximum manifold pressure is said to be 1.55 atm, equivalent to a peak boost of around 8psi.

With maximum rotor speeds approaching 100,000 rpm, bearing lubrication is of vital importance. This is looked after by piping a supply directly from the engine's main pressure gallery; a large-bore pipe drains excess oil back into the sump at the front of the engine. Despite the high rotational speeds and elevated temperatures (around 1,000 deg C at the turbine inlet), turbocharger durability is not a problem. BMW claim that its life should at least equal that of the engine.

Apart from the tremendous increases in power and torque, BMW claim that the more even distribution and better charge-preparation resulting from the use of a turbocharger pays useful dividends in terms of improved emission characteristics and higher thermal efficiency. An incidental advantage is a reduction in exhaust noise (compared with normally aspirated engines of similar size and performance). However, they stress that turbocharging can lead to considerable inefficiency in carburettor-equipped engines.

A glance at the Turbo's power and torque curves provides ample testimony to the turbocharger's effectiveness. Peak values are a staggering 170 bhp (DIN) at 5,800 rpm and 177 lb. ft. (DIN) at 4,000 rpm — all from a 1,990 c.c. nominal displacement! On the debit side, the unit is at a slight disadvantage in comparison with the 2002 Tii at lowish speeds (below 1,800 rpm); furthermore, the car moves into a higher capacity class for competition purposes.

Impressive though these figures are, we would mention that the racing unit developed a reliable 270 bhp; revs and boost are not known! These figures augur well for the reliability of the road-going unit.

Concerning the remainder of the power train, a beefed-up clutch transmits the drive to a strengthened four-speed gearbox. The latter has appreciably closer ratios than those used in the 2002 Tii. Listed as an extra-cost option is a five-speed gearbox with direct-drive fifth.

The final-drive unit has a ratio of 3.36-to-1 and features a limited-slip differential as standard

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*Top, left: Beard-type spoiler and wheel-arch extensions give Turbo 2002 a distinctive appearance. All are glass-fibre mouldings*

*Above: Frontal appearance of 2002 range has been improved by subtle changes to the grille. Also different are wheels, seats and use of padded steering wheel*

*Left: Turbo sports a glass-fibre spoiler on edge of bootlid. New rear-lamp cluster is shared by other 2002 variants*

# BMW 1974

equipment. The latter provides for a 40 per cent locking action.

Brakes have received a great deal of attention. In addition to being of slightly larger diameter (now 10.1in.), the front discs are internally ventilated. Rear drum diameter has been upped from 9.0in. to 9.8in. and a pressure-regulating valve introduced into the rear line.

To cater for the increased torque, stronger half-shafts are used. Likewise, bearings with a higher load capacity are employed in the hubs and final-drive unit.

Spring rates are higher and the dampers stiffer than those of the 2002 Tii. Diameter of the front anti-roll bar is up from 15 to 20mm, but that of the rear remains at 16mm.

The ZF-Gemmer steering mechanism is precisely the same as that used in the 2002 Tii, but a "quicker" alternative is listed as an extra-cost option (12.8-to-1 ratio instead of the standard 15.5-to-1). The model's sports-type steering wheel is slightly smaller in diameter than the padded variety now used in other 2002 variants (15.0in., as distinct from 15.8in.).

Pressed-steel wheels with 5.5in. rims are fitted as standard. Listed as extras are 6.0in.-wide alloy components. Currently, only Michelin 185/70 VR 13 tubed tyres have received BMW's official approval, but we understand that Pirelli equivalents are shortly to follow suit. Overall gearing works out at 20.1 mph per 1,000 rpm.

To cope with the model's increased fuel consumption, the petrol tank's capacity has been increased from the standard 11.0 gallons to 15.4 gallons.

The Turbo's appearance is just as distinctive as its mechanical specification. Beneath the front, it sports a large, beard-type spoiler which bears the insignia "turbo 2002" in mirror image. This spoiler is contoured to mate with flared, plastic extensions which are riveted to the edges of the front wheel apertures; similar extensions are used at the rear. Adding to the model's way-out appearance is a spoiler across the back of the bootlid. Standard body colours are Chamonix (white) and Polaris (silver), each complemented by decorative side-stripes in BMW's racing colours.

Inside, the Turbo features the revised instrumentation now standardized on other 2002 derivatives. Differences on this particular version include a speedometer calibrated to 240 kph (150 mph) and the provision of a supplementary gauge to indicate manifold pressure. Seats are special, with built-in headrests. Automatic safety belts are standard.

Like its less potent stablemates, the Turbo features two 7in. headlamp units. These incorporate double-filament halogen bulbs (H4 pattern).

### Driving Impressions

Driving the Turbo provides a totally new experience. Despite its tremendous potential, it displays none of the temperament associated with normally-aspirated engines of equivalent power and size. At low speeds (below 2,000 rpm), it is extraordinarily docile. This, of course, results from the use of a low compression ratio. Under these conditions, the turbocharger has little or no effect — a fact confirmed by a manifold pressure reading of 1 atm under full-throttle conditions.

Observation of manifold pressure during full-throttle acceleration indicates that the turbocharger begins to have effect around 2,000 rpm. A distinct whistle becomes evident at a little above this speed, its pitch increasing as the revs continue to rise. At 3,000 rpm, the gauge shows 1.2-1.3 atm and one can be in no doubt concerning the system's effectiveness. By the time the tachometer indicates 4,000 rpm, pressure has risen to 1.5 atm and things are really happening. As mentioned earlier, peak pressure supposedly is 1.55 atm, but we saw a good 1.6 atm indicated on the test car.

Performance is truly shattering. BMW claim a top speed of 131 mph and a 0-60 mph time of around 6.8sec. On the proving ground, we saw readings of 219 kph (136 mph) and 6,300 rpm (the latter being equivalent to 126 mph).

Snags are confined to somewhat sluggish throttle response, a trait which is especially noticeable when shutting off. Inevitably, the engine generates a fair amount of noise when working hard, but this is not excessive in relation to the model's sparkling performance. Wind noise and turbocharger whine add to the general hubbub at higher speeds.

It is a sobering thought that the car is derived from the 1600 Coupé, which first appeared as long ago as 1966. In Turbo 2002 form, the chassis (albeit, much modified) is required to handle precisely twice the original horsepower. This it does in exemplary fashion. Aided by its limited-slip differential and wide Michelin tyres, it copes with full-throttle starts easily. The model's balance provides a good compromise between nimble response and good straight line stability. Although firm, the ride is by no means harsh. Altogether, the Turbo is a most exciting and reassuring machine to drive.

## The 3.0 CSI

Despite retaining the same type-designation, the latest lightweight coupé has an actual displacement of 3,153 c.c. It will be remembered that the original version displaced 3,003 c.c. (just 8 c.c. more than the other 3-litre variants). Achieved by means of a small increase in bore diameter (from 89.0 to 89.25mm), this was done for homologation reasons. The latest stretch has been achieved by increasing the stroke from 80 to 84mm, the bore remaining at 89.25mm. Sufficient material exists in the standard block and crankshaft to permit such a measure. Compression

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*Top, right: Hans Stuck jnr's 3.0CSI in a German Championship event. Note use of same aerodynamic appendages as production version*

*Above: Latest 2500 and 3.0S models feature minor grille and wiper-arm changes. Also different are seats, wheel trims, and use padded steering wheel*

*Right: Extra length of 3.3L is difficult to spot. Alloy wheels are just one of model's host of luxury fittings*

ratio, at 9.5-to-1, remains unchanged. Peak power is 206 bhp (DIN) at 5,600 rpm — just 6 bhp up on that of the smaller unit. Similarly, peak torque is up from 200 lb. ft. (DIN) at 4,300 rpm to 211 lb. ft. (DIN) at 4,200 rpm.

Already seen in Group 2 racing, the aerodynamic appendages are bound to attract incredulous looks, if not open disapproval. Indeed, the authorities have banned its sale for use on the road in its native Germany.

The car's frontal aspect is dominated by a deep, beard-type spoiler. A glass-fibre moulding, it incorporates a pair of ducts for the supply of cooling air to the brakes.

Atop each front wing is a longitudinal guide, moulded in rubber. Further back, a glass-fibre deflector spans the area above the top of the rear window. Its function is to prevent a breakup in the airflow pattern in this region.

Large, triangular fins (also glass-fibre mouldings) are disposed longitudinally along the sides of the bootlid. Their upper ends are inclined 1 deg outwards, a measure which is claimed to improve their effectiveness.

Spanning the tops of the two fins is an aerofoil "wing", also in glass-fibre. Although arranged to have a zero angle of incidence, its asymmetric design generates the necessary downward thrust.

Finally, there is a spoiler along the rear edge of the bootlid, between the fins. This, too, is made of glass-fibre.

In the interest of safety, the trailing edges of the fins and wing are made of rubber. It is interesting to note that the assembly forms part of the bootlid, it being necessary to raise the whole of the structure to gain access to luggage. Thanks to its light construction, this is not as difficult as it might seem.

As in the case of the Turbo, white and silver are the only body colours offered. Decorative side stripes in BMW's racing colours are standard wear.

#### Driving Impressions

Mechanically, the car feels much the same as its smaller-engined predecessor. Despite the slightly longer stroke, the delightful overhead-cam engine is as smooth as ever.

Performance is there in plenty. Top speed is claimed to be 137 mph and the 0-60 mph time around 6.9 seconds. During our brief test drive, we saw indicated speeds of 225 kph (140 mph) and a little over 6,000 rpm (equivalent to 132-plus mph).

Of much greater interest is the effect of the aerodynamic members on the model's stability. Whatever one's views concerning their appearance, they certainly work. The model feels rock-steady at all times. Observation of the wing in the rear-view mirror reveals that it deflects considerably at higher speeds. At times, its centre seemed to be a good inch lower than its ends.

No mention was made of any changes to the power-assisted steering, yet we gained the impression that the system affords more feel than in the past. Certainly, the model is a delight to drive whatever the going.

Incidentally, we were pleased to find that the wing and fins do not in any way interfere with visibility.

## The 3.3L

BMW have always striven to make their cars agile and handleable. Smaller and lighter than their immediate rivals, they are essentially a "driver's car". Perhaps for this reason, not until now have the company made a model exclusively for chauffeur-driven use.

The introduction of the 3.3L puts right this omission. In essence, the car is a stretched version of the 3.0S saloon, with lengthened wheelbase and larger engine.

The engine has a displacement of 3,295 c.c., achieved by lengthening the stroke to 88.4mm, the bore remaining at 89mm as in the case of the 3-litre sixes. This change has involved the manufacture of a new block and crankshaft, there being insufficient material on the existing components to permit such a stretch. It is anticipated that the new components, machined as necessary, will be used for all the sixes in due course.

Peak power is said to be 190 bhp (DIN) at 5,500 rpm, maximum torque being a hefty 213 lb. ft. (DIN) at 4,000 rpm. These results are achieved using two Solex carburettors, although the example tried featured Bosch electronic injection.

ZF automatic transmission is standard on the 3.3L. As in the case of the 3-litre models, final drive ratio is 3.45-to-1. The light-alloy wheels have 6in.-wide rims and are shod with 195HR14 tyres.

With an overall length of 480cm (15ft 9in.) and a wheelbase of 279.2cm (9ft 1.9in.), the 3.3L is just 10cm (3.9in.) longer than the 3-litre saloons. All of this extra length has been introduced into the rear compartment and door area. However, the opportunity has been taken to increase the rake of the rear-seat backrest. The net result is an increase of 8cm (3.15in.) in rear compartment legroom.

The car is equipped to very high standards. Among items fitted as standard are air conditioning, power-assisted steering, leather trim, power-operated windows, and an electrically actuated sliding roof.

#### Driving Impressions

Not surprisingly, the test model felt very much like a 3.0Si automatic. Handling seemed just as good and the engine felt just as sweet.

A spell in the rear seat emphasized the considerable feeling of spaciousness which results from a comparatively modest increase in length. Both the ride and the general noise level seemed to have benefited from the extra insulation and extra wheelbase, but this may have been our imagination playing tricks.

There is no lack of performance. BMW claim an 0-60 mph time of only 8.1sec — this is in carburettor form. □

# BMW 1974


**Cars like this 3.0CSL which won the '75 European Touring Car Championship are relying increasingly on the extra magic which only Schnitzer seems able to extract from BMW engines**

# GERMAN GINGERBREAD

## Paul Frère takes a look at the racing plans of two top German tuners and predicts lots of extra power for the 3-Series BMW and a test of a 130 mph 528

I was in Munich to give the BMW 320 a more serious outing than the drive around their proving ground I had had before the car was announced, but where should I go? Why not stay with the "marque," I thought, and see what the three major BMW tuners had in store for this season?

The plan proved to be somewhat ambitious, for GS-Tuning is in Freiburg and finally I spent so much time with the first two I visited that I didn't get round to visiting the Georg Schneider establishment where ex-BMW development engineer Dieter Basche is the technical expert. So my first visit was to the Schnitzer brothers, Josef the technician and Herbert the businessman (they drive each other crazy, but neither would stay in business without the other) whose BMW-based engine propelled Jacques Laffite's Martini to a rousing victory in this year's European Formula 2 Championship, beating the full contingent of factory-BMW engined competitors. Laffite practically won its laurels in the first half of the season and the performance of the Schnitzer engine was somewhat overshadowed by the fact that the champion was far less successful in the second half of the season, to some extent because of lack of engine reliability.

"That was mainly a question of finance," said Josef Schnitzer. "In the second half of the season Laffite and his team had apparently run rather short of money and we had to work on a shoestring budget, and meanwhile the works-BMW engined March entries had been properly sorted out and became really competitive. Laffite had to drive harder to try to beat them and in many cases this was just too much for the 'shoestring' engine. If the championship had not been decided, we would surely have put some money into the engine preparation ourselves, but as Laffite and ourselves had achieved our aim, we gave the French team what they paid for." Fair enough, I would think!

When you see Schnitzer's premises in Freilassing, a mile from the Austrian border, you'd never think it possible that they could be the birthplace of a European Championship winning engine. It is ridiculously small and part of it is dedicated to a normal garage workshop, the Schnitzer brothers earning their bread and butter from their BMW and Fiat dealerships. All together, about 60 people work there, 15 of them exclusively in the ordinary garage, the rest mainly on the racing and tuning side.

The sort of life the people in the racing department lead during the racing season can be imagined from the fact that seven teams used the Schnitzer engine in Formula 2 this year and none of them was ever prepared to take the engine out of the car immediately after the race to send it back to Freilassing. So, depending on where the race took place, the engines came back for overhauling on the Tuesday morning at best and usually had to be sent away to their owners not later than Tuesday or Wednesday the following week, to be dropped into the car in time for the following practice, the races normally taking place on every second weekend. Including the spare engines, that makes up a total of at least 10 engines to be completely stripped and rebuilt, and then tested for six or seven hours on the bench in a maximum of six days — no Sunday work being allowed in Germany. And Schnitzers have only one test bed! No wonder they have decided to reduce their activity in Formula 2 next year!

Most people believe that Schnitzer got the fullest possible help from BMW when they designed their twin ohc cylinder head and that this head is largely an inverted port version of the Formula 2 BMW head with chain, rather than gear-driven camshafts, so as to be a bolt-on fit to the BMW block, but this is far from the case. If it was inspired by any previous design, then more than anything that was the Ford-Cosworth BDA head, says Josef Schnitzer.

Without any development, the first engines produced about 270 bhp and the F2 engines run last year produced 295 to 297 bhp. Each pair of valves is angled at 20 degrees to the cylinder axis and an important feature of the Schnitzer head is that it is fully bridged through the water jackets across the securing bolts, which ensures the maximum stiffness at the weakest point of the cylinder head gasket, namely between the cylinder bores. Extraordinarily light steel connecting rods are used. (Schnitzer says they are lighter than the titanium rods in the works engines). They are of I-section, but instead of having their recessed part at right angles to the gudgeon pin, it is parallel to it, as it once used to be in Matra racing engines.

As if the Formula 2 activity were not enough, Schnitzer also ran a BMW 3.0 CSL Coupe in the German National Touring Car Championship for a young driver called Krebs. The car, to full Group 2 specification, was provided by the BMW Sport GmbH, but run, prepared and maintained by Schnitzer. I would hardly mention this, if it were not for a wonderful story showing what sort of wizard Schnitzer really is. In the last race of the series, which was to take place at Hockenheim, Krebs, who is no particular ace, had to win if he was to take the championship. Hockenheim is a fast track where speed and power really make a difference, so Schnitzer went hunting for power. The first thing he did was to modify the engine mountings to turn the normally slanted engine to vertical. This allowed him to use straight instead of curved intake trumpets and provided more room to fit smoothly curved exhaust "bananas" instead of the rather cramped bunch dictated by the lack of space with the engine in its normal position. He also opened up the ports, but when he had the engine screwed together, he had no means of checking the power, as his test bed cannot cope with over 350 bhp. So he put the engine on his transporter and went to Munich where the highest power they had seen up to then was 436-438 bhp: that's what the works cars had in the IMSA championship this year. Schnitzer's engine was duly put on the factory bench and the people there just couldn't believe their eyes: 474 bhp!

At Hockenheim nobody could hold a candle to Krebs until . . . a rod went through the crankcase. But the factory were so impressed that they asked Schnitzer to build another such engine to use in their own car in Kyalami. I would like to add that I would never have told the story if it hadn't been confirmed by a third party whose interest is certainly not to boost Schnitzer.

For the moment most of Schnitzer's time is devoted to developing and preparing Toyota 2-litre, 16 valve engines on behalf of Toyota's European Competitions Centre in Belgium. With Nippon-Denso fuel injection, these engines develop some 240 bhp in rally form. He is also working on turbocharging BMW engines in both 1.4-litre and 2.1-litre form to run in the 2- and 3-litre classes and work has begun on building a 2002 to the new Group 5 specifications to take those engines. There is certainly no unemployment looming in Freilassing!

Thanks to his full involvement in racing, Schnitzer isn't too concerned about the emission rules and other red tape which make a tuning specialist's job increasingly difficult, but what about Alpina whose main source of income is to make road cars go faster and better? A visit to Buchloe provided the answer to that question. The German authorities have made a concession to the professional tuners: the cars they modify — even if they are modified before registration — must comply to the emission and noise standards required from used cars when they pass the German equivalent to the MoT test, rather than with the stricter new car standards. This makes "Stage I" tuning the easiest thing in the world: you just fit a freer flowing exhaust system and modify the carburetter settings, and you have a few extra horses.


**Jacques Laffite (bottom) in the F2 Martini won last year's European Championship largely thanks to the 295 bhp which Schnitzer managed to extract from its 2-litre BMW engine (left)**

But Alpina aim at more than that and customers don't come to Buchloe just to have another set of jets fitted. One of their most popular conversions today is to modify normal 2002s to run on regular grade fuel . . . *and* to go much faster than standard. This involves lowering the compression ratio and fitting two twin choke Solex carburettors and the "rally" camshaft giving a 300 degree valve opening duration. With those modifications, the 2002 becomes a match for the standard 2002 Tii . . . on low grade fuel. A similar treatment is now given to the 1502, the "austerity" BMW which is a 1602 with a lowered compression ratio to use regular fuel, which then becomes nearly as quick as a 2002, though without the latter's torque.

Alpina's latest is a 130 mph 528. There are two ways of making a 130 mph 528. One is to fit a 3.0 Si engine, a conversion currently carried out by the BMW Sport GmbH and which makes a wonderful car—quiet, fast and with a tremendous torque. But throwing away a perfect 2.8-litre engine to replace it with a 3-litre is a rather expensive way of buying performance. So Alpina keep the 2.8 engine and don't even take it out of the car to carry out the conversion. They merely fit the 300 degree "rally" camshaft and replace the twin carburetters by the new DVG (German Solex) continuous flow injection system. This works on the same principle as the well-known Bosch K-jetronic and meters the fuel feed by measuring the intake air flow. The resultant power is 200 bhp (DIN), the same as for the standard injection 3-litre, though, of course, the torque is 10 per cent less. Cars so modified get special Bilstein front struts with one degree negative camber and both the front and rear springs are slightly shortened, while 7in wide alloy wheels are fitted. I have been promised one of these cars for testing in the near future and will keep you informed.

Because of the introduction of the 3-Series in Munich, Alpina are unlikely to feature prominently in competition next season. With the 2002, the most popular car for conversions, out of production, they have lost one of their main sources of income and are now very busy developing conversions for the 316-318-320 range, the latter being by far the most important model. This involves developing not only the engine (which will use the new DVG continuous flow injection system), but also the entire running gear, fitting higher geared steering, ventilated brake discs which BMW insist *must* be used if 120 bhp is exceeded. They reckon it will take them one full year before all the development work is finished, the car is recognised and the parts become freely available. The development and administrative work will take the best part of their capacity and certainly does not leave time for serious racing. They'll go back to it in 1977.

How did I like the 320? Very much indeed, except for the fact that it becomes rather "boomy" between 93 and 100-102 mph in top, to become much more silent again at higher speeds and up to the maximum of nearly 107 mph. The rear compartment is definitely more roomy than that of a 2002, but the performance is much the same. I liked the precise rack-and-pinion steering, though I would like it even better if it had slightly more castor action. Handling is just as I like it and comfort is better than in a 2002. Styling is a matter of taste, and I am not sure I like the new car better —I certainly preferred the 2002 from a rear view. But when you sit behind the wheel, you don't see that and I am sure 2002 owners will not be disappointed.


**Expect some exciting performance developments from Alpina this year. They're busily converting BMW 3-Series cars**