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ZF Life²

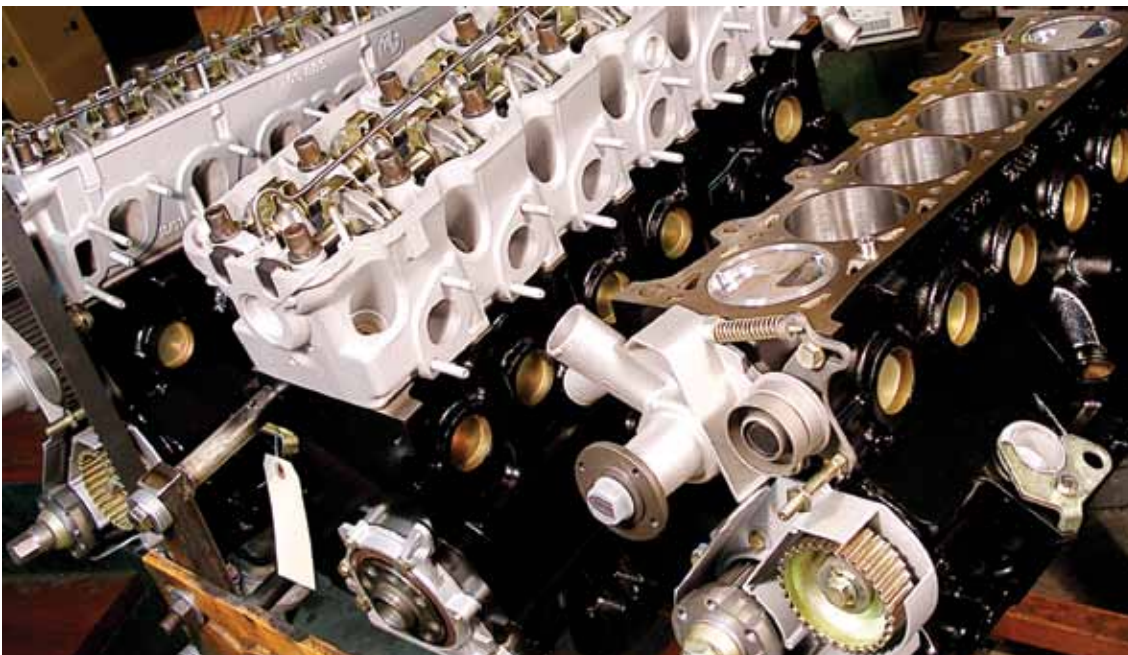
S6-37 & S5-31 ZF Transmissions
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ZF Parts on the S5-31

**M20 Engine
Series**

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History, Methods and Reasoning in MM M20 Engines

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*From left to right: Metric Mechanic M20 3200 Rally Engine, 240 HP - Metric Mechanic M20 3000 Engine, 225 HP
Metric Mechanic M20 2900 Sport (bottom end) 205 HP*

M20 Sport & Rally Engines

Revival of the Fittest! Improving the M20 Engine.

Metric Mechanic "Baby Six" M20 Engine Series - Revival of the Fittest!

Introduction

Originating in Europe, the M20 Engine made its way into the E21, 320/6 and the 323i. In 1982, the US market received this engine in the 528e and in 1984, the 325e. Most of the M20 engines we rebuild are installed in '87 and later 325i E30s - a favorite well built model that is fairly light at around 2750 lbs. Our current HiPerformance "Baby Six" M20 engines range from a 2900 HiFlo Sport at 205 HP up to a 3200 HiFlo ST Rally at 240 HP. See graph page 3.

Power gains from bolt-ons are usually moderate. Large power gains come from within the engine itself. It's done by increasing displacement, compression, head flow and camming. Lighter reciprocating and rotating parts also enhance acceleration.

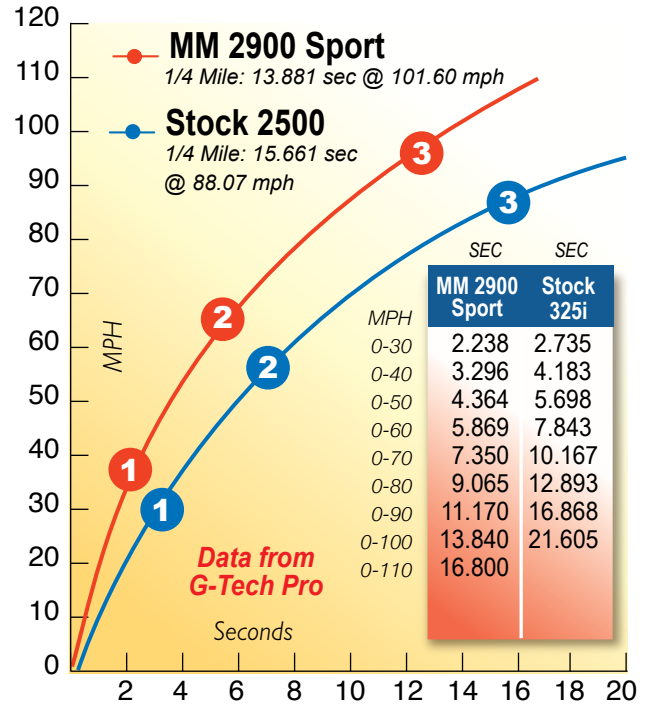
One of our 2900 Sport Engines will advance the 2750 lb. 325i to the performance level of a E36 M3. Install a 3200 Rally Engine and that 325i is comparable to an E46 M3. See Chart 2 immediately right.

Because the E30 is fairly light, it can be revamped to take corners faster than many other heavier BMWs, making it an excellent track car. The drivetrain is identical to the Big Six's of that era, so it has no trouble coping with the added displacement and horsepower. We offer several Ultimate Transmission rebuilds and Variable Limited Slip Differential options to further maximize the acceleration of your BMW.

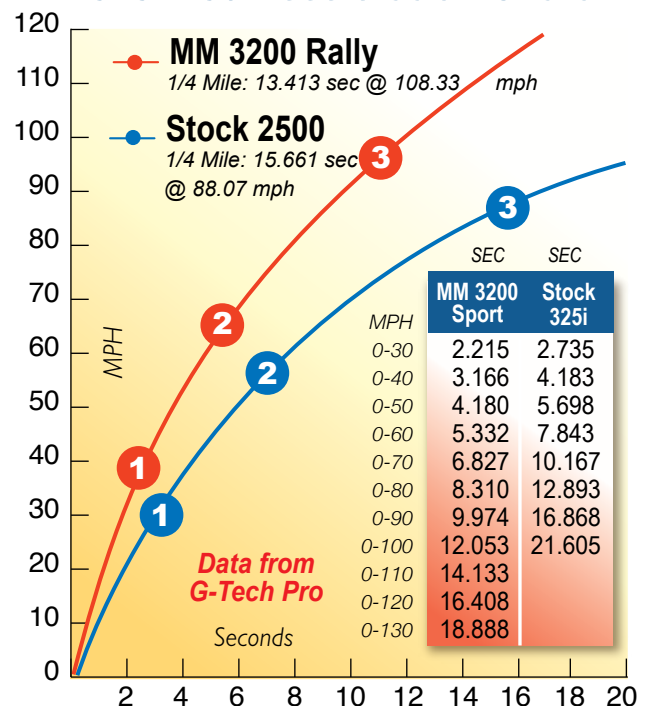
Who are these Engines For?

All the MM Sport and Rally Engines described in these pages are designed for daily driving as well as track use. They run on pump gas, deliver close to stock gas mileage, pass emissions, no loss in driveability, have a minimal noise increase, idle smoothly and require only minor tuning in order to run right! The average BMW enthusiast will experience only slight behavioral differences between a stock engine and the MM engines, except acceleration. Ours are FAST!

MM 2900 Sport Engine 325i E30 Acceleration Chart 1



MM 3200 Rally Engine 325i E30 Acceleration Chart 2



M20 Sport & Rally Engines

Building in Reliability - then Boosting Performance

Reliability Before Performance

Solving Problem Areas

Our goal when it comes to creating an MM High Performance engine is to address problem areas first and then build in more performance. We corrected **5** such areas in the M20 engine as follows;

Problem #1

Cambelt failure that can cause catastrophic engine failure.

At a minimum, hitting the pistons causes the valves to bend. In extreme cases, the entire engine is destroyed. A broken belt tensioner can lead to the same results.

MM Solution

In designing the M20 Piston, we decided to incorporate deep valve pockets so that in case of cam belt failure, the valve head would travel, under full cam lift, down into the valve pocket and not hit the piston. To add more performance, we use a strong lightweight forged Alusil Piston with 10:0:1 CR.



Left: MM 3200 Sport Piston & Right: MM 2900 Sport Piston
Both with deep valve pockets.

Problem #2

Head Cracking at the top edge of the Cam Valley between the #4 & #5 Cylinders.

This type of crack allows oil into the coolant and consequently into the cooling system which can quickly result in rod bearing failures.

MM Solution

With a head gasket modification, we are able to force more water flow circulation through the head, thereby keeping it cooler to prevent cracking.

Problem #3

Head Bolts breaking off.

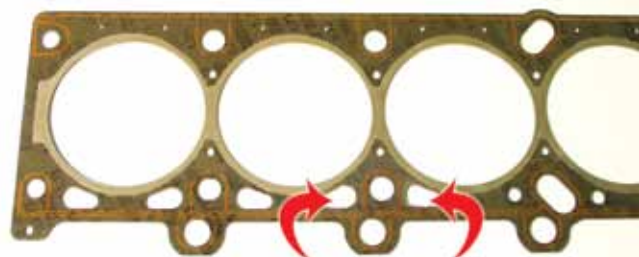
When failures first started appearing in the “e” engines, BMW went to a torx head bolt on the “i” engines. This was done to fix the weakness. I often think it made it worse.

MM Solution

We use a 10 mm Socket Head that we torque to 55#. These bolts have a cut-down shank which permits the bolt to stretch or “give” and maintain even torque on the head. To date, we have NEVER had a head bolt failure. As a bonus, these bolts are reusable!



Bottom Left: ETA Stock 17mm Hex Head Bolt, 10mm Shank
Bottom Middle: i Torx Head Bolt, 9mm Shank
Bottom Right: MM 10mm Socket Head Bolt, 9mm Shank



MM modified Head Gasket. Note: Water Feed holes between the fourth and fifth cylinder have been enlarged to prevent head cracking.

M20 Sport & Rally Engines

Building in Reliability then Boosting Performance

Reliability - continued

Problem #4

Wear on the inside of the Rocker Arm Pad & Cam nose

MM Solution

We use a modern progressively wound "Bee Hive" valve spring with small lightweight retainers - similar to those used in the new M5/V10 engines. The spring and retainer are 26.5 grams lighter than the stock dual spring and retainer. This lightens the valve train mass by 310 grams (2/3 lb.) giving the engine a few more ponies. Even though our cam has 11.75 mm lift (stock is 10.25) these "Bee Hive" valve springs (at 165 lbs.) add no more nose pressure than does a stock spring on a stock cam. Good valve train integrity is maintained by using stock spring pressure on the nose combined with a lighter spring and retainer. Valve float occurs at higher rpms when the valve bounces on the seat during closing. This is controlled by the seat pressure. That's why we increase seat pressure by 10% with our Bee Hive springs to help prevent valve float.

Perfect Pressure is a Priority

Correct valve spring pressure is essential. A deviation in extra pressure as minute as 10% can seriously shorten the life of the rocker arm and increase wear to its inside foot as well as the nose of the cam lobes. If spring nose pressure at full cam lift goes over 185 lbs., valve train and rocker arm life will be short lived (20,000 to 50,000 miles) under hard driving. Over 200 lbs., it can be just a matter of hours before rocker arm failure - 20 to 40 hours under racing conditions.

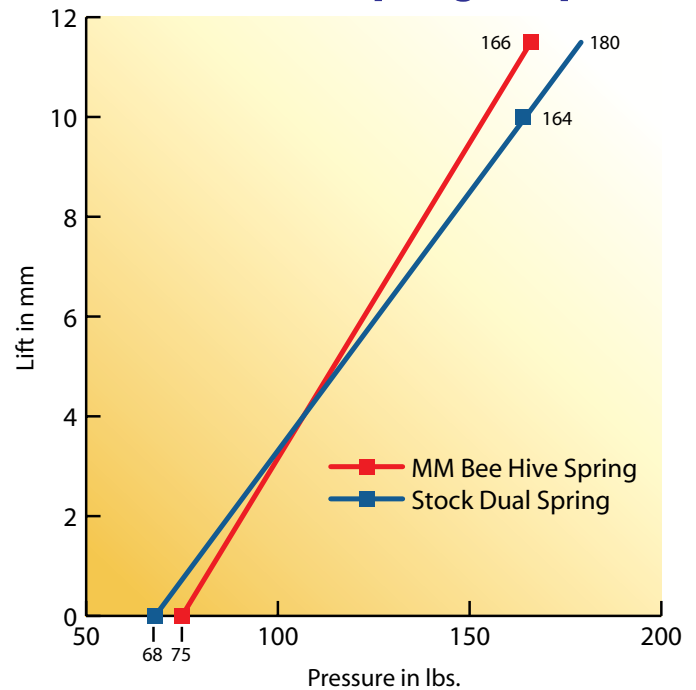
Problem #5

Sometimes Stock M20 Engine Rocker Arms Break

MM Solution

Due to the high rpm nature of a performance engine, the rocker arm is going to be more likely to fatigue out and break over time. We hold rocker arm breakage to minimum by using our "Bee Hive" valve springs and highest quality rocker arms, inspected for porosity (air bubbles in the casting).

M20 Valve Spring Graph



MM Bee Hive Spring Using MM Rally Cam

| | |
|--------------------------------|----------------------------------|
| Spring Installation Height | 1.495" at 75 lbs. seat pressure |
| Compressed Height | 1.040" at 166 lbs. nose pressure |
| Valve Spring & Retainer Weight | 49.50 grams |

325i Stock Dual Springs

| | |
|--------------------------------|----------------------------------|
| Spring Installation Height | 1.465" at 68 lbs. seat pressure |
| Compressed Height | 1.040" at 164 lbs. nose pressure |
| Valve Spring & Retainer Weight | 76 grams |



M20 Sport & Rally Engines

Building in Reliability - then Demanding Performance

Problem #5 ... continued Sometimes Stock M20 Engine Rocker Arms Break

Rocker Arm Breakage Test

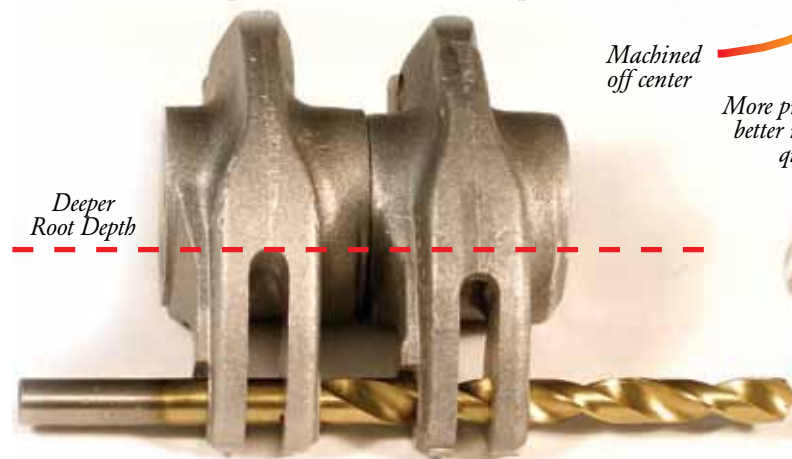
We've tested rocker arms from three different manufacturers to determine their breaking points. Using a fabricated jig fixture, we load the rocker arm eccentric into a hydraulic press and measure the breaking point on a 1000 lb. liquid filled gauge. Results are in the Chart on this page. We also load tested our valve retainers to insure that they will not break or pull through at the keepers.



Left Brand B - the eccentric hole is machined off center to the casting. Right Brand A - is of a higher casting and machining quality.

Machined off center

More proportional, better machining quality



Deeper Root Depth

Left Rocker Arm: Brand B - the root depth of the rocker arm fork is 1.25 mm (.050") deeper than Brand A to the Right. A deeper fork makes for a weaker rocker arm.

Brand B Rocker Arm with high porosity. As shown, the key area to check for casting porosity is in the inside of the eccentric bolt hole and the root of the rocker arm fork.

Rocker Arm Strength Chart

| Rocker Arm | Breaking Point in lbs. per square inch | Comments |
|-------------------------|---|--|
| Brand A | 410 - 425 lbs. | The rocker arms had little to no porosity and the fork is not machined as deep as the other brands. |
| Brand B | 380 - 395 lbs. | With this brand, about half the rocker arms in a box of 20 had low porosity levels and the others were high. |
| Brand B (high porosity) | 310 - 355 lbs. | High porosity equals greatly reduced strength. |
| Brand C | 300 - 325 lbs. | The fork area of this brand was skinny and weak. |

M20 Sport & Rally Engines

Knowing How the Wear Out - Knowing How to Extend Life

How Does an Engine Come to the End of it's Life?

Introduction

A stock M20 engine deteriorates quite differently from a High Performance or Race engine. Stock engines basically just wear out. Performance engines get hammered out and Race engines fatigue or break.

Stock Engines Wear Out

A high mileage stock engine starts to go into high oil consumption near the end. This occurs because the top rings become worn and loose their ability to seal against the cylinder wall and the bottom of the top ring groove. Due to the compromised seal, combustion blows by the rings entering the crank case. This stirs up oil vapors which are blown out the valve cover vent tube into the intake manifold. Once in the manifold, these vapors are sucked into the engine and bingo - the engine is burning oil! This sequence of events is called Engine Blow-By. Naturally, when Blow-By sets in, oil consumption escalates and engine life is short lived.

Performance Engines Hammer Out

In the more powerful Performance Engine, the explosion in the combustion chamber is far greater and happening with more frequency, i.e. higher rpms. This puts an added load on the upper compression ring. In time, the upper compression ring hammers out the bottom of the top ring groove and compression leaks by the rings. Once this happens, blow-by sets in and the engine goes into high oil consumption.

Race Engines Fatigue Out

During hard cornering when racing, the oil in the oil pan will draw away from the oil pump pickup. This is not good because the pickup must stay submerged for the bearings to receive oil. Once a rod bearing is starved, it will knock out in a matter of seconds. Even if the oil pump pickup does stay submerged, the life of a race engine is still very short, about 60-90 hours because race engine moving parts become fatigued and left unattended, they break.

Getting off and on the throttle hard at high rpms twists the crank back and forth. This loading occurs towards the back of the crankshaft and after 60-90 hours running, the crank will crack and eventually break if it isn't replaced ahead of time. Stock rods last about the same amount of time when used with a heavy stock piston. During overlap, the piston is at TDC (top dead center) and there is no explosion to counteract the force of the piston when it comes to a stop. This hard stopping force generated by the piston mass fatigues the rod until it eventually breaks in half about 20mm under the pin bore. The piston's upper compression ring also hammers out. Due to high rpms, more radical camming and stiffer valve springs, the rocker arms fatigue as well and break. Seriously, in a race engine, most of the engine is fatiguing out.

How Does MM Greatly Extend Engine Life?

A high quality properly designed forged piston, more than other engine component, can greatly increase the life of the HiPerformance or Race Engine.

Engine life, as stated earlier is curtailed by the upper compression ring hammering out the ring groove and parts fatigue caused by heavy reciprocating mass. A forged piston is 40% stronger and can be made 15% - 20% lighter

than a cast piston - when designed properly. Although a forged piston is the perfect solution, average (not ours) forged pistons do have disadvantages. Their expansion rate is 35% - 50% more than a cast piston and requires .0040" clearance or more. This much clearance creates high oil consumption (250-500 miles/quart) and causes the piston to rattle on

A Metric Mechanic Forged Alusil Piston (13% Silicon content) will last about 3 times as long, be 15% to 20% lighter, 40% stronger and expand only 5% more than the cast stock piston in an M20 Engine

M20 Sport & Rally Engines

Knowing How the Wear Out & Knowing How to Extend Life

How Does MM Greatly Extend Engine Life? ... continued

Consider this in light of the fact that high revving heats up the piston, requiring more cylinder wall clearance to accommodate the expansion. When we began development of our HiPerformance Engines in 1984, we quickly understood the benefits of switching to the Forged Alusil Piston. These early pistons were graphite coated to reduce cylinder wall scuffing. During the engine break-in period, the coating effectively wore off. Many such engines, under hard use, are still performing with over 200,000 miles on them. Despite this success, we felt certain that there must be an even better way to achieve tighter piston to cylinder wall clearance.

Metric Mechanic Slitted Pistons

Then around 1990, we completed development of our "Slitted Piston" technique by machining a horizontal slit in the piston just under the oil ring groove. This slit keeps piston crown heat from trans-



Left: 3200 Sport Piston. Right: 2900 Sport Piston. Notice the horizontal slits just below the oil ring groove. Slits prevent piston crown heat from directly transferring to the skirt, consequently reducing piston expansion to only 5% over that of a stock cast piston. Also allows oil feed into the top of the skirt which prevents scuffing.

ferring directly to the skirt by conducting it initially to the quite massive pin boss which acts like a heat sink. This interruption along with the longer traveled path, helps the heat dissipate allowing for cooler skirts that expand less. This slit reduces the expansion rate of our Forged Alusil Piston from 35% to only 5% over that of a stock piston and is the principle reason for our tight clearances. Generally, we run .0020" - .0025" clearance on our Sport Engines and .0023" -.0028" on the Rally Engine. This keeps oil consumption low and piston rattling to a minimum on cold start-ups.

2900 & 3200 Sport and 3200 Rally Pistons

Deep pockets in our 2900 and 3200 Sport Pistons protect against cam belt failure. ❶ For our shallow pocket 3200 Rally Pistons, ❷ we recommend cam belt and tensioner maintenance at 60,000 mile intervals using a Continental Belt & Tension Kit. Our Rally piston has shallow pockets for two reasons.

1.) To accommodate the longest possible rod (138mm "H" beam). This moves the pin and rings up higher. On this piston, the back of the upper compression ring groove runs into the valve pocket if it's deep. 2.) Cutting back on the valve pocket helps reduce the flame travel distance and improve combustion. Notice our patented Surface Turbulence "stair-step" grooves machined into the piston head. This reduces detonation and lowers fuel consumption by atomizing the fuel mixture more efficiently. Because our high density pistons are 15% lighter and 40% stronger, they transfer heat more quickly than a heavy porous cast piston and this allows for a compression increase of 5% - 8% over a cast piston at the same pre-detonation level.



Far top left is our 2900 Sport Piston with our 3200 Sport Piston shown top right. Both have deep valve pockets to protect them from the valves in the event of a cam belt failure. Front and center is our 3200 Rally Piston with shallow valve pockets.

M20 Sport Engines

MM 2900 HiFlo ST Sport Engine - Displacement: 2822 cc



Our MM 2900 HiFlo ST Sport Engine makes a great fast daily driver that is economically priced and very reliable. Using the cast crankshaft from the "e" keeps the build cost down. The deep valve pockets protect the pistons from valve damage in case of a cam belt failure. Several lighter rod choices (600-540 grams or less as listed above) may be used for a more "track worthy" engine. No slouch when it comes to performance, this engine will put an E30 325i nose to nose with a stock E36 M3.

- 1 Crankshaft** - 81mm Stroke Cast Iron "e", Weight - 23 kg / 50.5 lbs.
- 2 Piston** - MM 2900 Sport 86mm Forged Alusil with deep valve pockets, Compression Ratio 10:1, Weight -330 g
- 3 Pin** - 22mm tapered wall, Weight 89 g
- Rods** - left to right - 135mm long
- 4** Stock 325i (87-91), 640 g
- 5** Stock 325i (91-92), 600 g
- 6** Stock 328i & 330i (97>), 575 g
- 7** M3 Rod (95-99), 540 g

MM 3000 HiFlo ST Sport/Rally Engine - Displacement: 2926 cc



The MM 3000 HiFlo ST Sport/Rally Engine is designed with hard street driving in mind. By using the 3200 Sport Piston and 138mm "H" Beam Rally Rod, the reciprocating components are very light and strong. Engine damage caused by cam belt failure is eliminated with our non-valve interference piston design. Expect just over 100 mph in a 1/4 mile at 14 seconds.

- 1 Crankshaft** - 84mm Stroke Forged Steel, Weight - 24.5 Kg/54 lbs.
- Crank Adaption Parts**
- 4** Modified Auxiliary Shaft
- 5** Seal Sleeve Spacer
- 6** Stepped Washer & Bolt (*bolt not shown*)
- 2 Piston** - MM 3200 Sport 86mm Forged Alusil with deep valve pockets, Compression Ratio 10:1, Weight -310 g
- 3 Pin** - 22mm tapered wall, Weight 89 g
- 7 Rods** - H Beam, 138mm long, 510 g

MM 3200 HiFlo ST Sport Engine - Displacement: 3121 cc



Being the largest M20 engine we sell, our MM 3200 HiFlo ST Sport Engine provides a strong wide power band. The 3200 Sport Piston has deep valve pockets which prevent the valves from hitting the piston in case of a cam belt failure. Fairly lightweight production rods from the E36 M3 or 328i are used. This engine pulls like a big six in your 325i - without the weight penalty - and easily spans an E36 M3

- 1 Crankshaft** - 89.6mm Stroke Forged Steel, Weight - 23 Kg/51 lbs.
- Crank Adaption Parts**
- 4** Modified Auxiliary Shaft
- 5** Seal Sleeve Spacer
- 6** Stepped Washer & Bolt (*bolt not shown*)
- 2 Piston** - MM 3200 Sport, 86mm Forged Alusil, Compression Ratio 10:1, Weight -310 g
- 3 Pin** - 22mm tapered wall, Weight 89 g
- 7 Rods** - Stock 328i & 330i (97>), 575 g
- 8** M3 Rod (95-99), 540 g

M20 Rally Engines

MM 3000 HiFlo ST Rally Engine - Displacement: 2926 cc



- 1 Crankshaft** - 84mm Stroke Forged Steel, Weight - 24.5 Kg/54 lbs.
- Crank Adaption Parts**
- 4** Modified Auxiliary Shaft
- 5** Seal Sleeve Spacer
- 6** Stepped Washer & Bolt (*bolt not shown*)
- 2 Piston** - MM 3200 Rally, 86mm Forged Alusil, Compression Ratio 10.5:1, Weight -260 g
- 3 Pin** - 21mm, Weight 80 g
- 7 Rods** - H Beam, 140.5mm long, 535 g

The MM 3000 HiFlo ST Rally Engine is our spirited "Drivers School" engine. Using longer 140.5 mm "H" Beam Rods and an 84mm stroke crank, makes this unit a virtuous high revving engine. Minus the deep valve pockets, these pistons have better flame travel so compression can be increased and they are 50 grams lighter than the sport piston. For those planning to track this engine, MM sump modifications should be considered to prevent oil starvation at the oil pump pickup under hard cornering. Again, if tracking is the name of the game, this MM 3 liter is a great choice.

MM 3000 Full HiFlo ST Rally Engine - Displacement: 2996 cc



- 1 Crankshaft** - 86mm Stroke Forged Steel, Weight - 23.4 Kg/51.5 lbs.
- Crank Adaption Parts**
- 4** Modified Auxiliary Shaft
- 5** Seal Sleeve Spacer
- 6** Stepped Washer & Bolt (*bolt not shown*)
- 2 Piston** - MM 3200 Rally, 86mm Forged Alusil, Compression Ratio 11:1, Weight -260 g
- 3 Pin** - 21mm, Weight 80 g
- 7 Rods** - H Beam, 139.75mm long, 510 g

This MM Full 3000 HiFlo ST Rally Engine using 139.75mm "H" Beam Rods and an 86mm stroke crank, makes this unit a full 3 Liter Rally Engine. Minus the deep valve pockets, these pistons have better flame travel so compression can be increased and they are 50 grams lighter than the sport piston. For serious track addicts, MM sump modifications should be considered to prevent oil starvation at the oil pump pickup under hard cornering.

MM 3200 HiFlo ST Rally Engine - Displacement: 3121 cc



- 1 Crankshaft** - 89.6mm Stroke Forged Steel, Weight - 23 Kg/51 lbs.
- Crank Adaption Parts**
- 4** Modified Auxiliary Shaft
- 5** Seal Sleeve Spacer
- 6** Stepped Washer & Bolt (*bolt not shown*)
- 2 Piston** - MM 3200 Rally, 86mm Forged Alusil, Compression Ratio 11:1, Weight -260 g
- 3 Pin** - 21mm, Weight 80 g
- 7 Rods** - H Beam, 138mm long, 510 g

The MM 3200 HiFlo ST Rally Engine - using a very lightweight but extremely strong piston & rod assembly, the reciprocating mass is just 870 grams versus 1170 gram in a stock 325i. Eliminating 4 lbs of reciprocating mass allows the engine to rev quickly and reliably to its 7000 rpm redline. Properly set up, this engine can accelerate a 325i through the 1/4 mile in 13.7 seconds at 105 mph. This is our biggest, fastest, most powerful M20 engine - Period!

MM Stroker M20 Engines

Metric Mechanic Department History of the M20 Engine

Evolution of our MM Stroker M20 Engines

MM Introduces the 2900 Engine

In the early 90's, we were selling 2.8 Liter (85mm x 81mm "Baby Six" engines. Later, the bore was increased 1mm which led to our current 2900 Sport Engine. To build this larger engine, we replaced the stock 75mm "i" crank with an 81mm

stroke "e" crankshaft as used in the ETA engine. These readily available cranks have proven to be very tough and durable and rarely show signs of wear. Also, they bolt read-

ily into either the "e" or "i" block without creating clearancing issues with the rods. For the "do-it yourselfer", this is welcome news!

The 524 TD Crank vs. the ETA Crank - Debunking the Myth 81mm Stroke Crankshafts

Over the years we've heard a rumor that the cast iron ETA crankshaft was somehow inferior to the Forged Steel 524 Turbo Diesel Crank. BMW used cast iron cranks in the following engines.

| | |
|--------------|---------------|
| 320/6 | - 71mm stroke |
| 323i | - 76mm stroke |
| 325e | - 81mm stroke |
| 325i/E30 | - 75mm stroke |
| 325i/E36/E46 | - 75mm stroke |

In our experience, the cast iron cranks used in Baby Six Engines are very reliable punctuated by the fact that we have never seen one break.

However, we have seen 4 Diesel cranks break. Two that we found in salvage yard engines, were broken in the middle. The other two were fatigued from hard racing

- 275 HP engines revving to 7500 rpms. After 65-75 hours running vigorously, they cracked at the back of the 6th rod throw. Diesels rattle and vibrate throughout their lives and the crankshafts take a beating. Naturally, before we install a 524 Turbo Diesel crank in an engine, we would check it for cracks. This can be done by lifting the crank off the ground and striking each one of the 12 counter weights with a large wrench (19 mm or larger). It should ring like a bell. If it doesn't - check the rod journal nearest the dead counter weight and look for a crack. A dead ring indicates a junk crankshaft.

Although we do use the Diesel Crank, it is rare. Out of every 100 2900 engines we build, 99 have "e" cast cranks and 1 a Diesel Crank, typically per the customer's request. Nice advantages are that the "e" cast crank is readily available, far more economical, and it is 3.5 lbs. lighter - 50.5 lbs "e" vs. 54 lbs. for the Diesel.

By using our lightweight pistons and limiting the engine output to 225 HP and 6750 rpm, I see no reason why anyone would see an "e" crank break.

Breaking the 3.0 Liter Barrier

By 2000, we had developed the 3200 Sport Engine using the 89.6mm stock crankshaft. Several times in the past, we had stuffed our "Big Six" engines into the 320i and WOW! these 3200 engines felt like a Big Six in the 325i, without the nose heavy weight penalty. We were so impressed, that over the next 4 years, we developed an entirely new engine line

of larger displacement M20 engines. Using later cranks from E36, E39 and E46 BMW models, we've been able to adapt these cranks to the M20 blocks by making modifications to the crank and clearancing the block. The 84mm, 86mm and 89.6mm stroke crankshafts are forged steel and are used in our 3.0 to 3.2 liter Sport or Rally Engines.

These 3200 engines feel like one of our Big Six's in a 325i, without the nose heavy weight penalty.

MM Stroker M20 Engines Continued ...

Metric Mechanic M20 Stroker Engines



M20 Stroker Crankshafts - information on pages ? to ?

Crankshafts used in Metric Mechanic M20 Engines from Left to Right

81mm Stroke 2900 Sport --- 84mm Stroke 3000 Sport/Rally & 3000 Rally ---
86mm Stroke Full 3000 Rally --- 89.6mm Stroke 3200 Sport & 3200 Rally

Crankshaft Use Chart

| Stroke | MM Engines | Weight | Counterweight Radius ¹ |
|--------------------------|--------------------------|---------------------|-----------------------------------|
| 81mm Cast | 2900 Sport | 23 kg / 50.5 lbs. | 67.50 mm |
| 84 Forged | 3000 Sport/Rally | 24 kg / 54 lbs. | 72.75 mm |
| 86 Forged | 3000 Full Rally | 23.4 kg / 51.5 lbs. | 67.75 mm |
| 89.6 Forged ² | 3200 Sport 3200 Rally | 23 kg / 51 lbs. | 70.50 mm |

¹ Counterweight Radius is an indication of block clearance problems. The larger the radius, the greater the clearance issue with the block.

² On a 3200 Sport Engine with an 89.6 stroke, the M3 or 328i rod shoulder can sometimes hit the bottom of the cylinder and might require block clearancing.

MM Stroker M20 Engines Continued ... Rods

Metric Mechanic Development History of the M20 Engine



1 The MM “H” Beam Rally Rod is forged out of 4340 Chrome Moly Steel. It’s length, measured from the center of the small end to the center of the large end, is 138mm. Weight is 510 grams. The small end is set up for a 21mm wrist pin that weighs 80 grams.

2 The Stock M3 or 328i Rod at 135mm long is used in a 3200 Sport Engine. These rods weigh 540 grams to 575 grams.

3 The Stock 325i M20 Rod is 135mm long and is commonly used in our MM 2900 Sport Engine. Weight is 640 grams.

The MM Rally Engine: A New Level of High Performance

Wanting to take these engine to a higher level yet, we introduced the M20 Rally Engine Series focusing on reducing the weight of the reciprocating mass (piston, pin, rod) while adding strength. Key to achieving this goal is the “H” Beam Rod which is not only light at 510 grams but also fortified by nature of it’s “H” design and it’s material - 4340 chrome moly (molybdenum) steel. Given the height constraints of the block, we installed the longest rod we could.

4 The MM “H” Beam Rods can handle twice the horsepower of a factory “I” Beam Rod. The principle load bearing beam member in the middle has an elongated hour glass profile. This shape helps focus the pin load and the rod bearing load into the central beam.



A New Level of High Performance Continued ...

Our “H” beam rods are 138mm long with an 89.6mm crank, 139.75mm long with an 86 crank and 140.5mm long with an 84mm crank. There are several advantages to using longer lightweight “H” Beam Rods in a high RPM engine.

- 1) It can’t be over-emphasized, engine reliability is greatly extended with strong lightweight reciprocating parts.
- 2) Light rods and pistons allow an engine to rev up more quickly resulting in faster acceleration.
- 3) A shorter lighter piston can be used with a lengthened rod. The piston in our Rally Engine is 50 grams lighter than a Sport piston (260 g Rally vs. 310 g Sport). Installing a lighter piston enables us to use a smaller 21mm piston pin (Sport pins are 22mm), over 10% lighter (80 g Rally vs. 89.9 g Sport).
- 4) By using a longer rod, the piston dwells longer in the top dead center area during combustion. This allows the flame front to more effectively push against the top of the piston at high RPMs. A short rod will pull the piston away from the top faster than the flame front can grow, causing a high RPM power loss.
- 5) A long rod will reduce the thrust angle of the reciprocating mass into the cylinder wall. This puts less load on the piston skirt. Also, our “I” beam is 150 grams lighter than the stock 325i rod, further reducing piston skirt loading to aid in the prevention of piston collapse.
- 6) When using a longer stroke crank, the bottom portion of the piston skirt will travel out the bottom of the cylinder. Since this causes a slight rocking of the piston, it can be perceived as piston slap. By using a longer rod, the piston moves up in the cylinder and becomes more stable.

In summary, Rally engines are all about hi-tech lightweight extremely strong reciprocating components that increase longevity and aid acceleration.

M20 Oil Pan Modifications

A Perfect Compliment to the M20 Engine

Oil Pan Modifications for Hard Cornering and Track use

Introduction

Under hard cornering (.9 g's or greater) oil in the oil pan will migrate away from the oil pick-up. If the pick-up does not stay submerged in oil, it's only a matter of seconds before the oil film between the rod bearings and the rod journal wipes away, the bearing goes out and the engine needs rebuilding. Hard long left corners are the most common culprit. During this kind of turn, oil in the pan is climbing up the right side of the block which is laying 20° from vertical. Meanwhile, at high rpms, the camshaft sprayer bar is over loading the head with oil - further robbing the pick-up. The longer the duration of a long left sweeper, the more oil drifts away from the pick-up. Once the oil pressure drops off seriously to 20 or 25 lbs., the rod bearings are already in trouble. By the time the oil light comes on at 7.5 lbs., its usually too late and a rod bearing is already gone.

Quick Fix

A cheap fix to this problem is to over fill the engine with 1/2 to 1 quart of extra oil. But there is a downside of course. The extra oil slinging around the crank case causes added drag on the crankshaft consuming HP and makes the engine burn an excessive amount of oil.

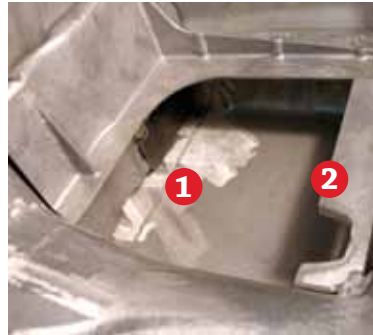
Metric Mechanic Oil Pan Modifications

A better way to inhibit this oil starvation is to properly modify the oil pan so that is physically keeps the oil pick-up submerged. We do the following:

- 1.) A Horizontal Baffle on the right side of the oil pan which prevents oil from climbing the side of block under hard left cornering.
- 2.) A Trap Door on the left side of the oil pan allows oil in the level indicator reservoir, to transfer to the oil pick-up.
- 3.) A Windage Tray with scrapers to pull oil off the crankshaft and isolate the crankshaft from

the oil pan. A Windage Tray can also add 2-3 HP to an engine by reducing oil drag on the crankshaft.

- 4.) The MM Restrictor Sprayer Bar keeps the head from overloading with oil at high rpms without cutting off oil flow to the cam bearings or rocker arms.



- 1) Trap door mounted to the wall of the oil level indicator reservoir.
- 2) Right Side Horizontal Baffle

These oil pan modifications add 10% to the cost of an engine but this is a small price to pay to prevent oil starvation at the pick-up and consequent catastrophic engine failure.



Bottom: Stock Sprayer Bar has a .110" oil feed hole into the bar.
Top: MM Sprayer Bar with a .062" oil feed hole to prevent oil build-up in the head at higher rpms and under track use.



MM Windage Tray with Scrapers - used to remove oil spray from the crank.

M20 Super ETA Performance

There's Only One Way to Make it Hot

Super ETA Choices, Routine Performance to HiPerformance

Pitfalls in building a 2.7 performance Super ETA Engine

On the surface, this engine has a lot of appeal to the budget minded person. The formula for building a standard performance 2.7 liter M20 engine using mostly stock parts goes like this:

- 1.) Using an "e" or "i" block, install an 81mm strike diesel or ETA crankshaft.
- 2.) Usually a super ETA piston out of a 1988 super ETA engine is selected and combined with an ETA rod. Another choice is the 11.0 Euro ETA piston, again with the 130mm ETA rod. Another option is to machine 2mm off the top of an "i" piston, recut the valve pockets and run a longer 135mm "i" rod. The valve pocket ends up dangerously close to the upper compression ring groove and the compression gets too high. Lastly, folks use an "i" piston with an "e" rod. This puts the piston 2mm from the top and lowers the compression ratio down to about 7.5:1

***Note:** Of all these choices, the only one that makes half decent sense to us is the super ETA piston with the "e" Rod. An "I" head or super ETA head (same thing) is combined with an "I" cam and valve springs or a 272° cam of some sort. This engine combination will make about 180 HP and have a life expectancy of about 65,000 to 100,000 miles when driven hard.*



2900 Sport Piston

MM's Piston Upgrades the Super ETA to a 2.9 HiPerformance Engine

Personally, I would rate the 2.7 Super ETA engine as a "Fair" performance engine when compared to one of our 2900 HiFlo ST Sport Engines. With just one major change, this engine could be hugely improved - our 86mm 10.0:1 Forged Alusil Pistons as used in our 2900 HiFlo ST Sport Engine. This piston has the following advantages over a Super ETA Piston.

- 1.) **Larger 2.9 liter displacement:** Over boring an engine is one of the most economical ways to increase displacement.
- 2.) **High compression 10.0:1 MM pistons are forged and are much denser than a cast piston:** The denser a piston, the faster it transfers heat and the cooler it runs. Because of this, our forged piston at 10.0:1 will have about the same detonation level as a cast piston at 9.3:1.
- 3.) **Lighter reciprocating mass makes for faster acceleration:** The piston and rod weigh about 1200 grams in a Super ETA engine. Using our 330 gram Forged Alusil Piston and 89 tapered wall pin coupled to an "i" rod, the reciprocating mass drops from 150 grams to 1050 grams. Because our piston is so much lighter, every part beneath it can also be made lighter. M3 or 328i rods from the E36 models at 70-90 grams lighter can be used. Also, the light ETA crankshaft at 50.5 lbs. works in place of the 54 lb. diesel crank. All this weight reduction makes for a faster more reliable engine.
- 4.) **Improved rod ratio:** The rod ratio on a Super ETA engine using an "e" rod is 1.605. Substituting an "i", the rod ratio on a Super ETA engine is 1.605 (rod length 130mm ÷ 81mm stroke). Substituting a longer 135mm "i" rod improves this to a 1.666 rod ratio. Longer rods make for better revving engines.
- 5.) **Longevity:** Given equal driving styles and power levels, our forged pistons have about 2-3 times the life of a cast piston.
- 6.) **Safety margin:** Using the stock ETA or any other stock piston, if the cam belt or tensioner fails, the valves will hit the pistons and bend. Our pistons have a deep valve pockets to keep this from happening.

In the end, you'll have a good 2.9 liter engine that will have a wider power band, rev quicker and be far more reliable than a 2.7 liter super ETA Performance engine. Expect about 190-195 HP range and 150,000 to 200,000 mile life.

Honestly, I feel the real answer to an M20 performance engine is to buy or build one of our "Excellent" 205 HP 2900 HiFlo ST Sport Engines. Using our HiFlo ST Sport Head will bring out the best performance.

Reciprocating Mass & Acceleration

Weight Reduction to Achieve Power and Longevity

MM "Baby Six" Engines All Muscle, no Fat!

The stock 325i piston and rod assembly is about 1150 grams. Think about this. We have increased the displacement of our 3200 engines by 25% over the stock 2.5 liter engine. Yet, we managed to drop the weight of the reciprocating mass by 17% in a 3200 Sport Engine and 32% in a Rally Engine. This is truly an incredible feat!

Benefits of Reducing the Reciprocating Mass

Reducing the weight of the reciprocating mass (piston and rod assembly) has a far greater effect on acceleration than reducing the rotational mass. Lightening the rotational mass, such as a flywheel, only comes into play under acceleration but the reciprocating mass (piston & rod) are always accelerating and decelerating in the engine. For example, in our 3200 Rally Engine, the piston and rod assembly at 4200 rpm are accelerating from 0 mph to 60 mph and back to 0 mph in a distance wide as your hand or about 3.5".

At a redline of 7000 rpm, it's going from 0 mph to 100 mph and back to 0 mph 14,000 times in one minute since the piston changes direction twice at the top and bottom in one revolution. The jerking motion against the piston goes to 1500 G-Force. At 1500 G-Force, the stock 325 piston and rod (weighing 1150 grams) starts to look like 3795 lbs. (1725 kilograms). Our very light but strong 3200 Rally Piston and Road Assembly at 840 grams looks like 2770 lbs. (1260 kg). In reducing the reciprocating mass by 32%, I

MM Sport & Rally 3200 Engine Reciprocating Mass Comparisons

| | 3200 Sport | 3200 Rally | Stock |
|--------------|--------------|--------------|---------------|
| Piston | 310 g | 260 g | 385 g |
| Rings | 20 g | 20 g | 20 g |
| Wrist Pin | 89 g | 80 g | 105 g |
| Rod | 565 g | 510 g | 640 g |
| TOTAL | 984 g | 870 g | 1150 g |



Horizontal: MM 3200 Sport Piston with M3 Rod.

Vertical: MM 3200 Rally Piston and 138mm "H" Beam Rod.

Strong lightweight parts are key ingredients to a fast reliable engine.

think it's fairly obvious that the lighter reciprocating mass will accelerate faster and twist the crankshaft up quicker. Put another way, if you had a 2700# 325i and a 3700# 540i with the same engine powering both which one would be faster? That's right!

Running a lightweight reciprocating assembly will not only make an engine spool up quicker but it will greatly increase its reliability.

MM HiFlo ST Sport/Rally Heads

Weight Reduction Achieve Power and Longevity

Head Flo Dictates Horsepower Output

Introduction

Two major units combine to create an engine: head and block. The torque output of an engine is determined by two primary block functions: displacement and compression. The engine's horsepower output is determined by two primary head functions: flow rate and camming. Engine displacement, compression, head flow rate and camming all need to be balanced and tuned to work in harmony for maximum power output.

Head Porting

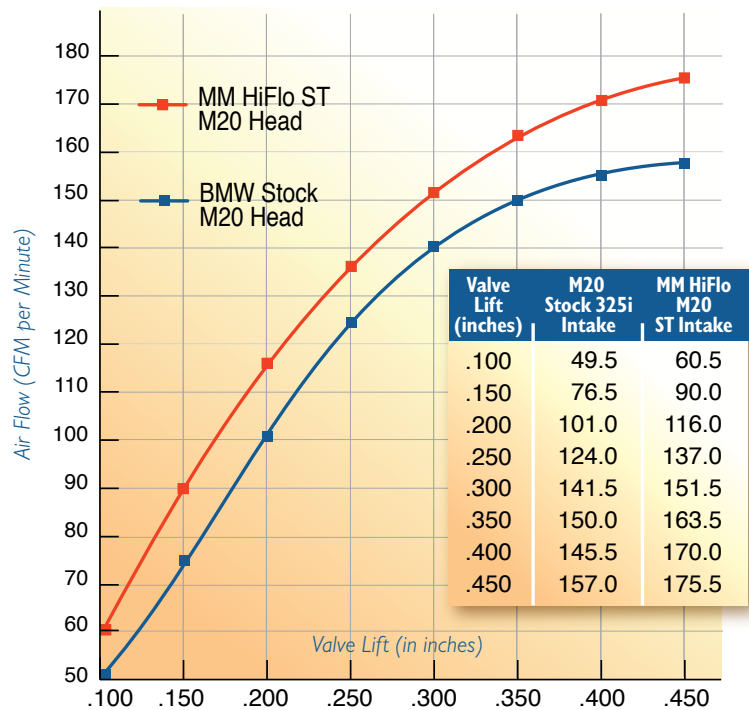
The stock 325i head is enhanced with quite a bit of factory porting. For example the short side radius (which is usually left in a cast in state) is rolled over and radiused with an automated milling machine. The 325i head has 16% improvement over the early 323i and 325e ETA head. In fact, when we port a 323i or 325e head, we can achieve flow results equal to a 325i head on a smaller port. And when we port a 325i head, we reach a 12% flow increase over a stock 325i head.

Porting Exhaust

- 1 Seat angles.
- 2 Move seat angles to outer edge of the valve face.
- 3 Short side radius
- 4 Surface Turbulence the valve.

Metric Mechanic Intake Port Flow Data Sport/Rally HiFlo ST M20 Head

Versus the stock BMW 325i Head



Measured on a SuperFlow 600 Flow Bench at 25" Vacuum / S.F. 600

Porting Intake

- 1 Roof Cut - 2 distinct airflow paths are machined into the roofing of the port to reshape it and remove the valve guide boss area.
- 2 Seat Angles
- 3 Move seat angle to outer edge of the valve face.
- 4 Bullet shaping the valve guide (show picture)
- 5 Short side radius.
- 6 Unshrouding the intake valve at the combustion chamber
- 7 Back-cut on the intake valve (show ST valve)
- 8 Surface Turbulence Valves

MM Rally Cam 286° / 272°

Lift Off the Seat during Overlap .038"

Valve Adjustment .008 Intake .008 Exhaust

| Lift | Intake Lobe | Exhaust Lobe |
|-------|-------------|--------------|
| .011" | 286° | 272° |
| .015" | 274° | 260° |
| .020" | 264° | 250° |
| .050" | 238° | 226° |
| .100" | 208° | 202° |
| .200" | 170° | 166° |
| .300" | 132° | 126° |
| .400" | 84° | 80° |
| Lift | 11.75 mm | 11.75 mm |

MM Sport Cam 286°/260°

Lift Off the Seat during Overlap .038"

Valve Adjustment .008 Intake .010 Exhaust

| Lift | Intake Lobe | Exhaust Lobe |
|-------|-------------|--------------|
| .011" | 286° | 280° |
| .015" | 274° | 260° |
| .020" | 264° | 248° |
| .050" | 238° | 220° |
| .100" | 208° | 194° |
| .200" | 170° | 156° |
| .300" | 132° | 114° |
| .400" | 84° | 60° |
| Lift | 11.75 mm | 11.20 mm |

Shrick Cam 284° / 272°

Lift Off the Seat during Overlap .069"

Valve Adjustment .008 Intake .010 Exhaust

| Lift | Intake Lobe | Exhaust Lobe |
|-------|-------------|--------------|
| .011" | 284° | 296° |
| .015" | 269° | 272° |
| .020" | 257° | 256° |
| .050" | 230° | 227° |
| .100" | 206° | 202° |
| .200" | 169° | 163° |
| .300" | 128° | 120° |
| .400" | 76° | 57° |
| Lift | 11.5 mm | 11.0 mm |

Stock 325i Cam

Lift Off the Seat during Overlap .050"

Valve Adjustment .010 Intake .010 Exhaust

| Lift | Intake Lobe | Exhaust Lobe |
|-------|-------------|--------------|
| .011" | 276° | 276° |
| .015" | 260° | 260° |
| .020" | 245° | 245° |
| .050" | 212° | 212° |
| .100" | 188° | 188° |
| .200" | 150° | 150° |
| .300" | 106° | 106° |
| .400" | 34° | 34° |
| Lift | 10.44 mm | 10.44 mm |