

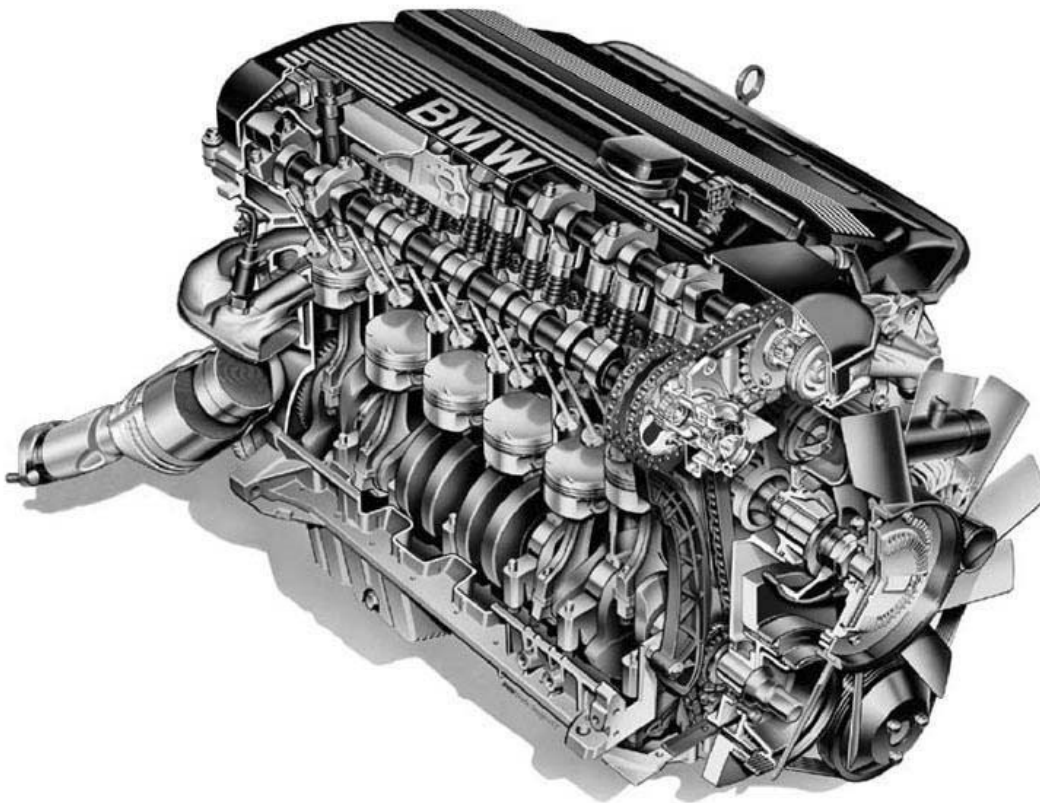
GENERAL INFORMATION

Basic Engine Measuring Techniques - Overview

BASIC MEASURING TECHNIQUES

BASIC ENGINE MEASUREMENTS

During the course of engine repairs some basic engine measurements are required to verify engine diagnosis as well as to complete proper repairs. These measurements are made by precision measuring tools such as micrometers, Vernier calipers, cylinder bore gauges and dial indicators.



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Fig. 1: Sectional View Of Engine
Courtesy of BMW OF NORTH AMERICA, INC.

Also, a working knowledge of the metric system is also a vital skill that is needed by the technician. All BMW engine measurements consist of metric specifications. Some of the routine engine measurements performed include:

- Valve Guide Wear (Tilt Angle K)

- Cylinder Bore Measurements (Taper and Out-of-Round)
- Cylinder Head Warpage and Thickness
- Axial and Radial Endplay Measurements (Crankshaft/Camshaft etc).

Among all of the skills possessed by a modern technician, basic measuring techniques are perhaps the most overlooked and least used. This is why it is important to review these skills from time to time as a refresher.

Also, it is necessary to access technical data to obtain the proper specifications for these measurements. This course is designed to review measuring techniques to assist in engine diagnosis.

Vernier Measurement

The Vernier scale is used on various measuring tools such as the Vernier caliper and the Depth Gauge. The Vernier scale can be used with Fractional (US) and Metric systems. For the purposes of this training module we will always refer to the Metric Vernier scale.

The Vernier scale consists of a fixed scale and a sliding scale. The fixed scale is divided with graduations in 1 millimeter increments. The sliding scale has 10 graduations in increments of .5.

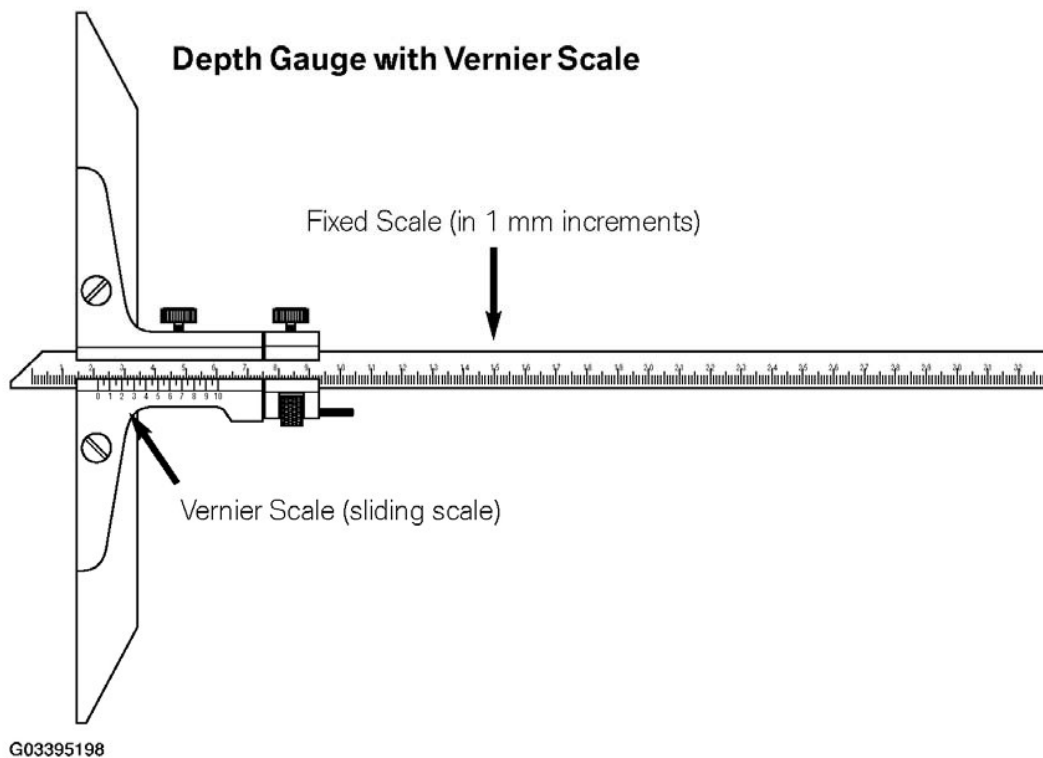


Fig. 2: Identifying Depth Gauge
 Courtesy of BMW OF NORTH AMERICA, INC.

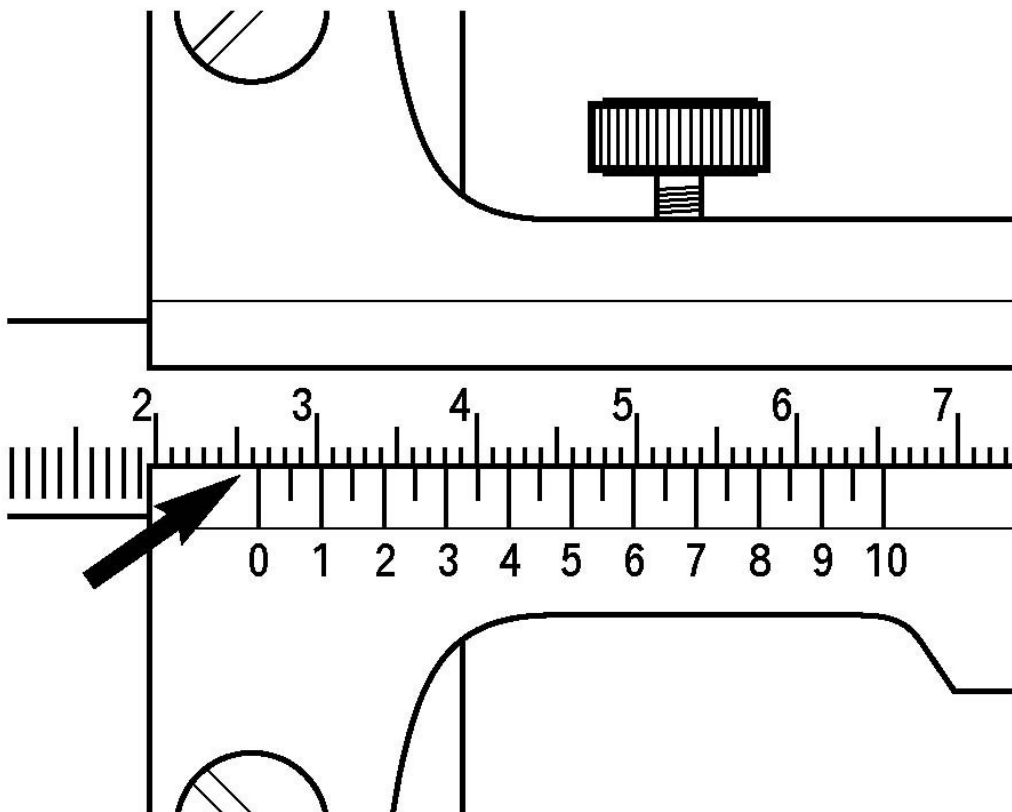
In order to read a measurement, use the zero mark on the left end of the vernier scale to use as a guide to read a measurement on the fixed scale.

In the example shown at the right, the zero mark is resting between 26 and 27 mm. Therefore the base measurement is 26 mm.

Next, the decimal measurement must be taken. For this, find a line on the Vernier that most closely matches any line on the fixed scale.

Using the example drawing, the "4" on the Vernier scale is lining up directly with a line on the fixed scale.

Combining the previous reading with this reading, the result would be 26.4 mm.



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Fig. 3: Locating Vernier Scale Reading
Courtesy of BMW OF NORTH AMERICA, INC.

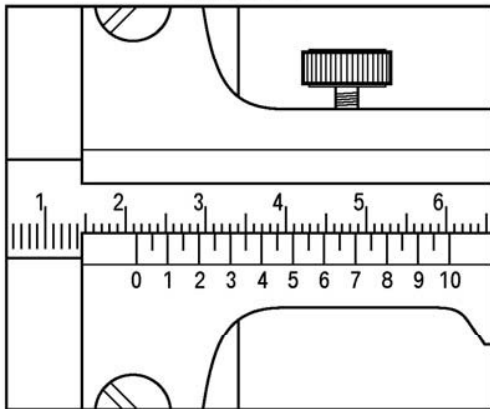
The designations on the Vernier scale are in increments of .5. For example, if a reading on the Vernier scale falls on the .5 (i.e. 2.5, 3.5 etc) designation this would indicate 5/100th's of a millimeter.



Classroom Exercise - Vernier Readings

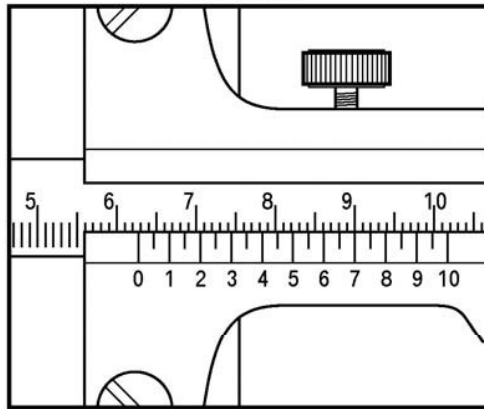
Fill in the correct Vernier scale readings in the spaces provided below.

Vernier 1



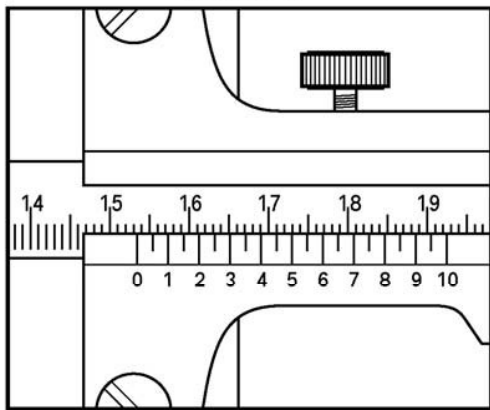
Vernier Reading 1:

Vernier 2



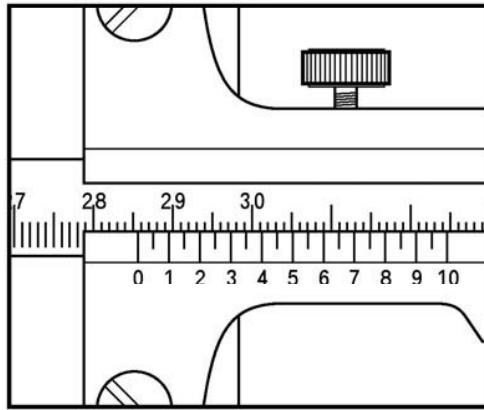
Vernier Reading 2:

Vernier 3



Vernier Reading 3:

Vernier 4



Vernier Reading 4:

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Fig. 4: Identifying Vernier Scale Reading
Courtesy of BMW OF NORTH AMERICA, INC.

Micrometer Measurements

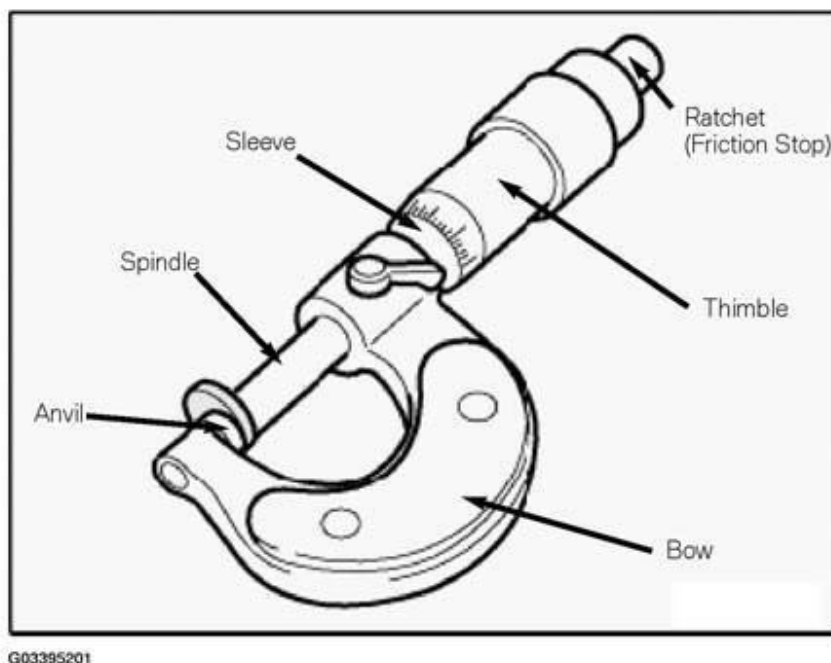
Another valuable measuring tool is the micrometer, which can be used for measurements such as bearing journal diameter, cylinder head thickness, valve shim thickness and brake rotor thickness etc. Micrometers also come in configurations for inside measurements as well.

The micrometer scale comes in both fractional and metric varieties. We will cover only the metric micrometer scale in this course.

First you must familiarize yourself with the construction of the micrometer in order to understand how measurements are made.

Metric Micrometer Construction

The micrometer is constructed of a few basic parts. The actual item to be measured is placed between the anvil and the spindle. The micrometer can be adjusted to the approximate size using the thimble. The thimble should only be used for the coarse adjustment. In order to make the actual measurement, the micrometer should only be turned using the ratchet (a.k.a. the friction stop). Do not attempt to make a measurement using the thimble. This will give an inaccurate measurement and ultimately damage the micrometer.



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Fig. 5: Identifying Micrometer
Courtesy of BMW OF NORTH AMERICA, INC.

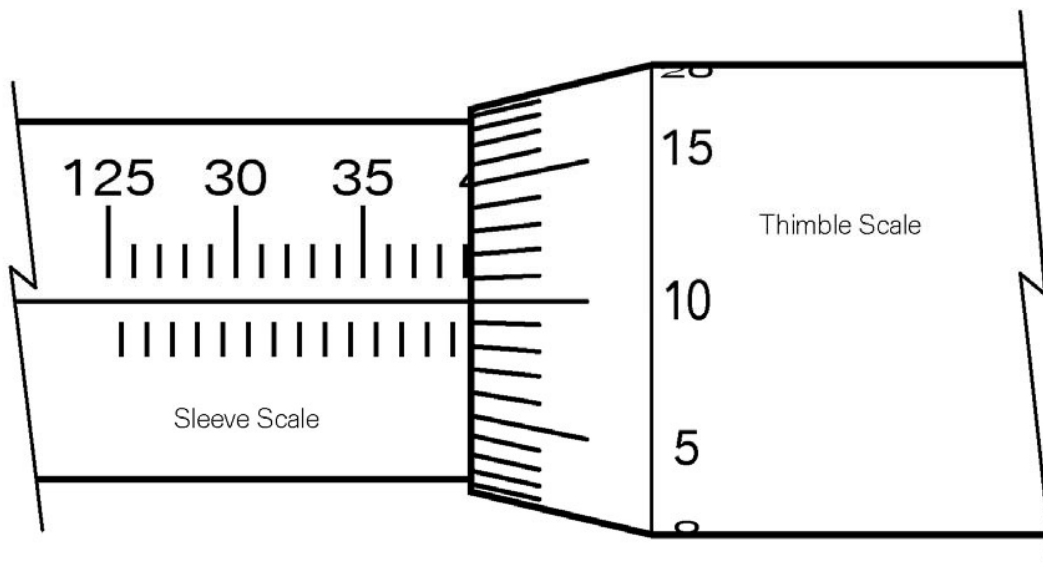
Micrometers are available in various sizes for outside as well as inside measurements. The more common variation is the outside micrometer. They are usually available in 25 millimeter increments such as 0-25 mm, 25-50 mm, 50-75 mm etc..

The metric micrometer can measure in increments of one hundredth of a millimeter (.01mm). One hundredth of a millimeter is equal to 0.0003937 inch which is less than one thousandth of an inch.

The measurement area of the micrometer consists of the sleeve scale and the thimble scale. The sleeve scale is used to read whole and half millimeters. The thimble scale (which rotates) reads in hundredths (.01) of a

millimeter from zero to fifty. Two complete revolutions of the thimble equals one millimeter.

On the sleeve scale, each scale mark above the center line indicates whole millimeters. Below the center line, half of a millimeter (or .5mm) increments are indicated.



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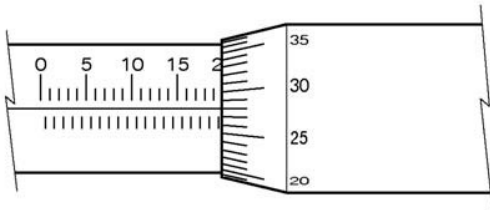
Fig. 6: Identifying Micrometer Reading
Courtesy of BMW OF NORTH AMERICA, INC.

Using the example shown above, the micrometer is a 125-150mm micrometer. To read this micrometer, first take the basic reading from the sleeve scale. The thimble is past the 139 mm mark. Therefore the reading is a least 139 mm. Next, look at the thimble scale and note the reading on the centerline. The "10" on the thimble scale is lined up with the centerline. This indicates a reading of .10 mm. If you add the two readings; $139 + .10 = 139.10$ mm.

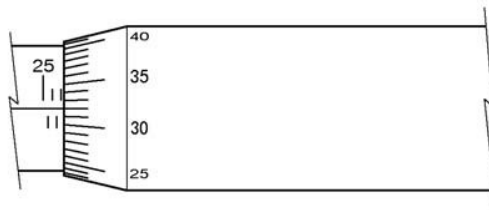


Classroom Exercises - Micrometer Measurements

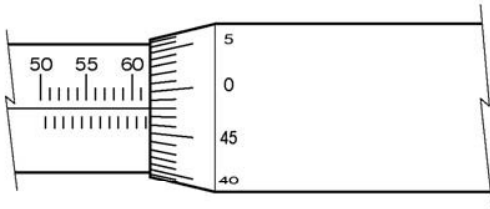
Fill in the correct micrometer readings in the spaces provided below.



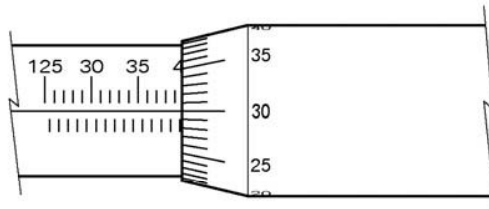
Micrometer Reading 1:



Micrometer Reading 2:



Micrometer Reading 3:



Micrometer Reading 4:

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Fig. 7: Identifying Correct Micrometer Reading
Courtesy of BMW OF NORTH AMERICA, INC.

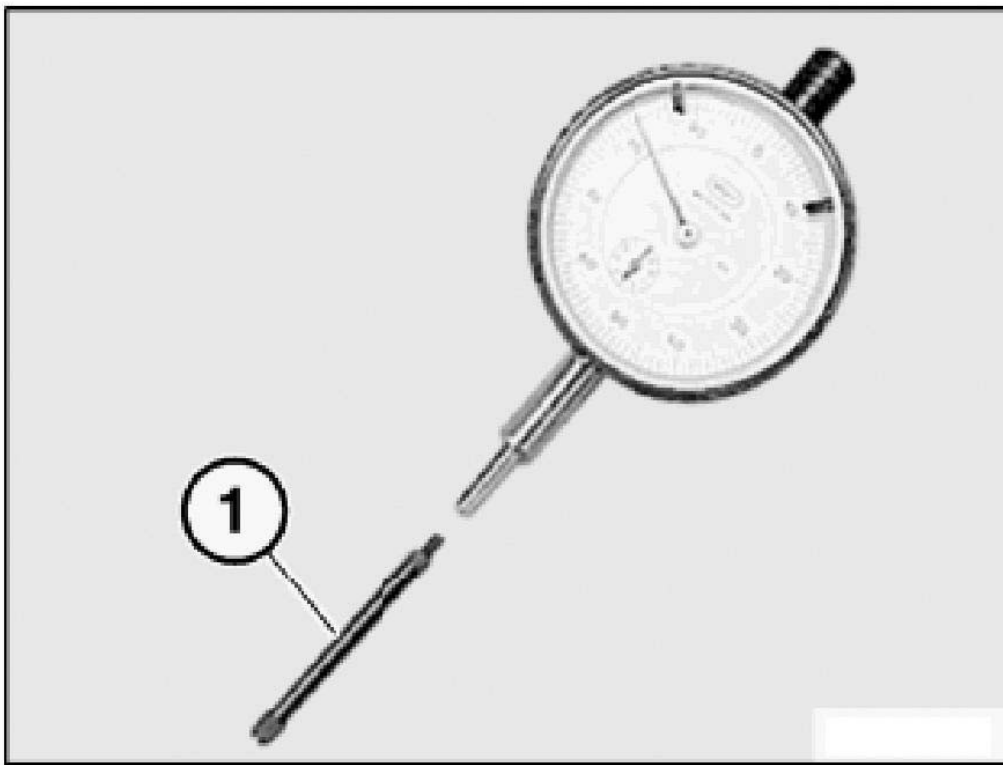
Dial Indicator Measurements

The dial indicator is used to measure the travel or movement of a specific item. It can also be used to measure axial and radial runout. In engine measurement applications, the dial indicator can be used to measure valve guide wear, axial movement of the crankshaft (thrust), and runout of flywheels and harmonic balancers.

First, it is important to familiarize yourself with Dial Indicator construction. The face of the dial indicator consists of a moveable bezel which is also attached to the large measuring scale. This allows the tool to be brought to the "zero point" when needed.

The main measuring device is the contact point. The contact point (1) is placed against the object to be measured. Usually, the contact point is rounded or has a ball bearing. This allows for a more accurate measurement.

The measuring face of the dial indicator consists of 2 scales. The smaller scale is for the "coarse" measurement which is in graduations of 1 millimeter. One revolution of the small scale is 10 millimeters.



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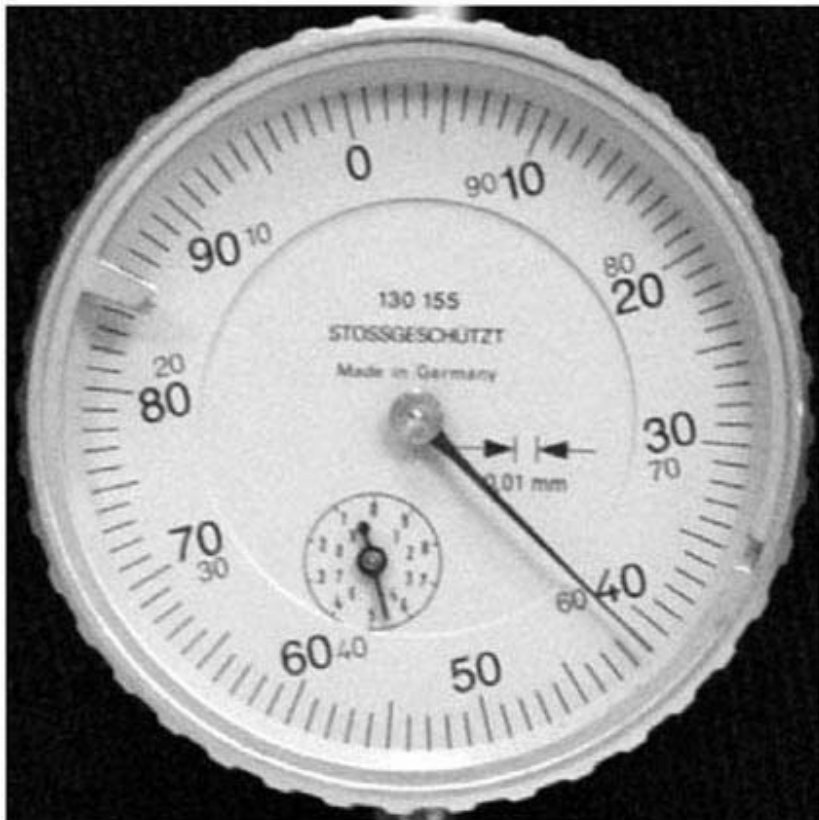
Fig. 8: Identifying Dial Indicator
Courtesy of BMW OF NORTH AMERICA, INC.

The large scale is in graduations of .01 millimeter and the scale goes from zero to one hundred. Therefore, one revolution of the large scale is one millimeter.

The dial indicator also needs to be held in place when taking a measurement. This requires a stand or base. Depending upon the application, these stands can be a clamp type, magnetic or a threaded base.

When taking a measurement, place the contact point on the object to be measured. The dial indicator must be pre-loaded slightly to prevent the measurement from bottoming out.

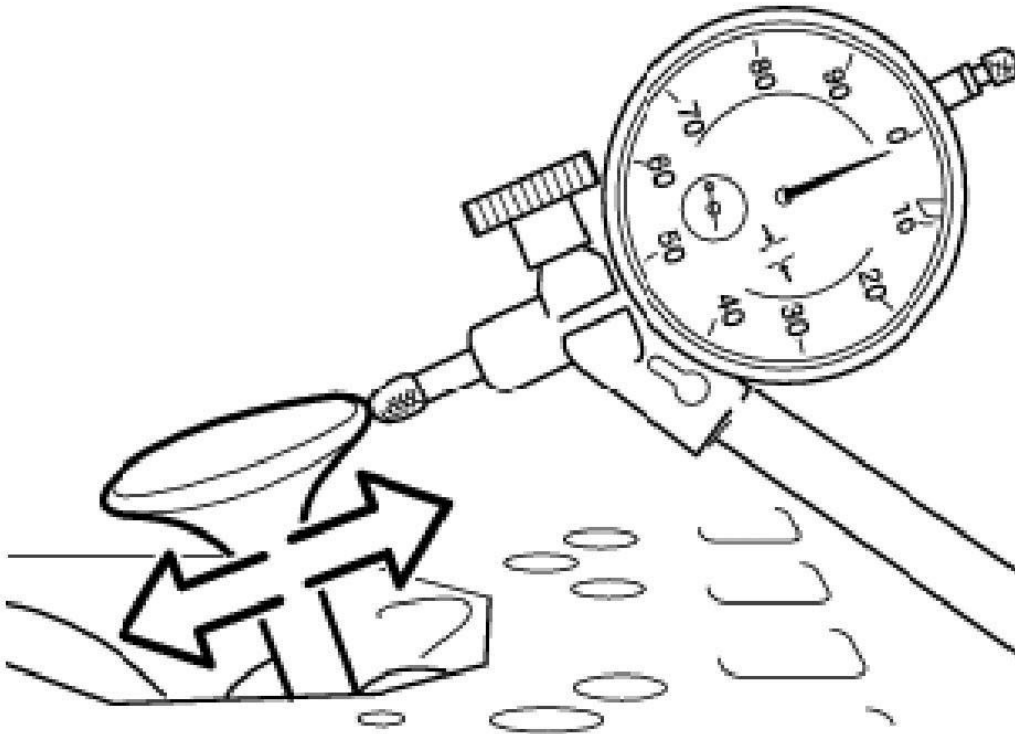
When reading the scale, be sure to "zero" the dial indicator first. If the readings to be taken are less than 1 millimeter, you do not need to use the small scale. If the readings are larger than 1 millimeter, be sure to factor the small scale into your measurement.



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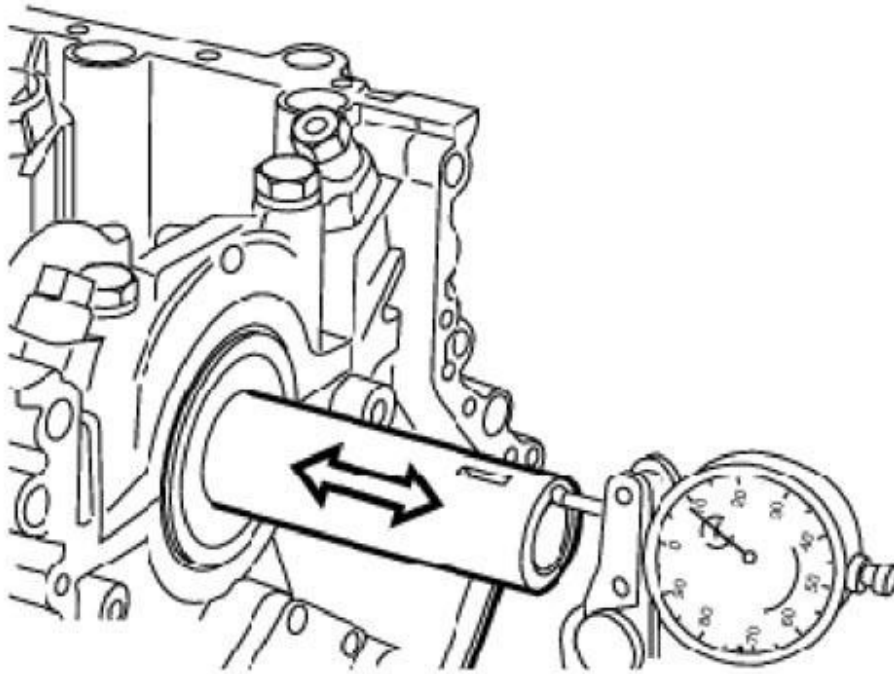
Fig. 9: Identifying Dial Indicator Reading
Courtesy of BMW OF NORTH AMERICA, INC.

Examples Of Dial Indicator Measurements



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Fig. 10: Measuring Valve Guide Wear - Tilt Angle "K" Using Dial Indicator
Courtesy of BMW OF NORTH AMERICA, INC.



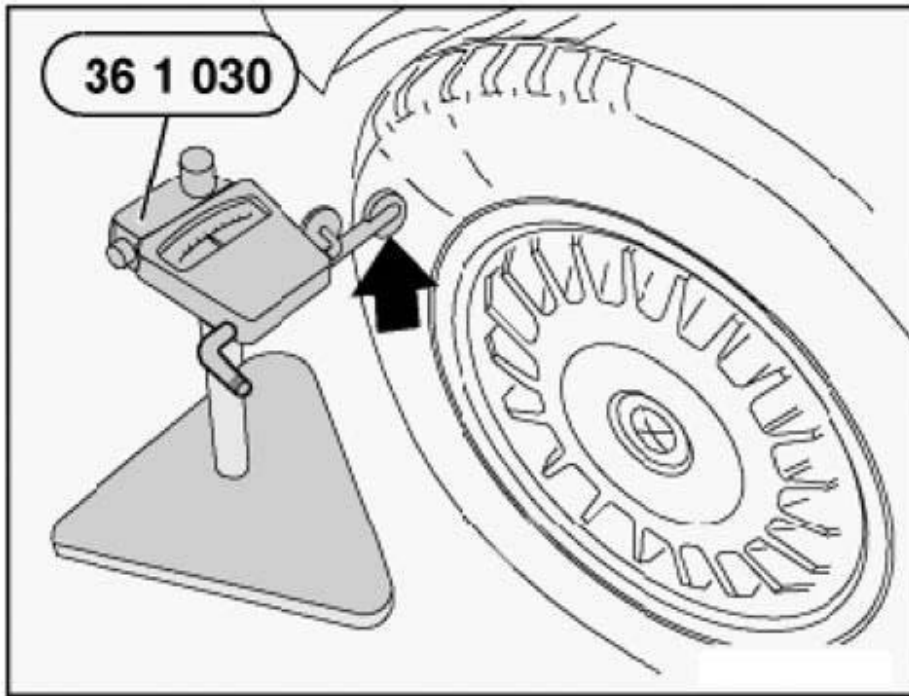
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Fig. 11: Measuring Crankshaft Endplay - Axial Using Dial Indicator
Courtesy of BMW OF NORTH AMERICA, INC.



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Fig. 12: Measuring S62 Engine - Basic Throttle Setting Using Dial Indicator
Courtesy of BMW OF NORTH AMERICA, INC.



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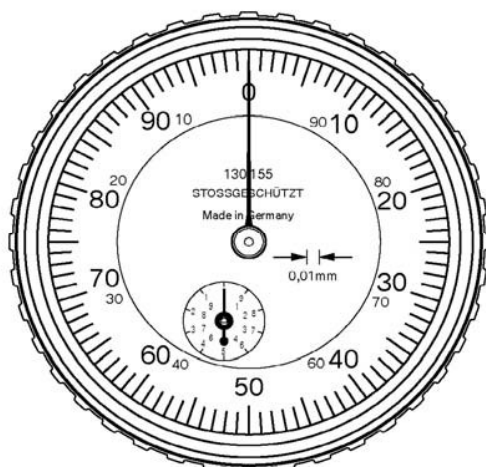
Fig. 13: Measuring Wheel Runout - Axial Using Special Tool
Courtesy of BMW OF NORTH AMERICA, INC.



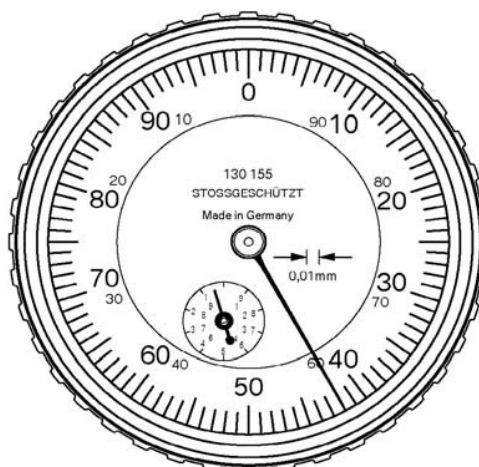
Classroom Exercise - Dial Indicator Measurements

Compare the dial indicator readings, and determine the total travel. Record your results below in the spaces provided.

Dial indicator A

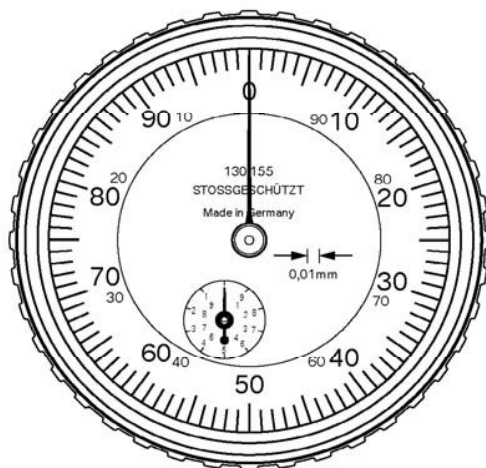


Dial indicator B

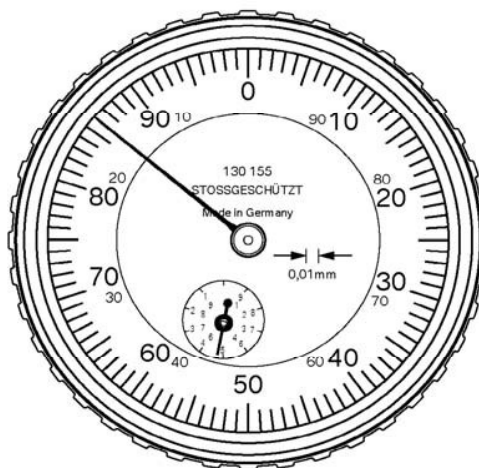


What is the difference (total travel) between dial indicator A and dial indicator B?

Dial indicator C



Dial indicator D



What is the difference (total travel) between dial indicator C and dial indicator D?

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Fig. 14: Identifying Correct Dial Indicator Reading
Courtesy of BMW OF NORTH AMERICA, INC.

ADDITIONAL ENGINE MEASUREMENTS

During engine repair procedures it is sometimes necessary to assess engine wear to make determinations on

parts replacement. Also, some engine measurements are needed to verify a previous diagnosis.

For example, a cylinder leakdown test could indicate a cylinder sealing concern. Once the engine is disassembled, it would be necessary to verify this condition by checking the piston and piston ring condition. If OK, the next step would be to determine the condition of the cylinder bore. At this point, the cylinders should be checked for taper (conicity) and for out-of-round. The correct measurements could mean the difference between just replacing the rings and/or pistons or replacing the engine block. This is why it is necessary to make accurate measurements when needed.

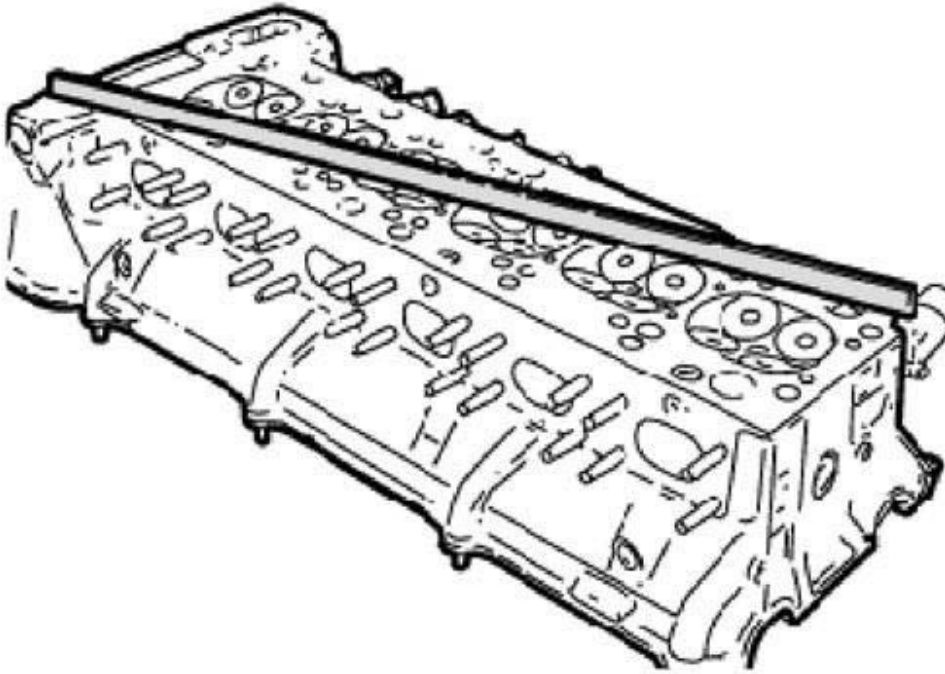
Some of the other routine engine measurements include:

- Cylinder head warpage
- Cylinder head thickness (on some applications)
- Piston rings - end gap and axial clearance
- Cylinder bore - including out-of-round and taper

Cylinder Head Measurement

If a repair requires removal of the cylinder head, a few basic measurements can be performed to save time and unnecessary machine shop costs. If an engine has been overheated or has an internal or external fluid leakage (coolant/oil), it is a good idea to check the cylinder head for warpage.

This can be done by using a commercially available machinists straight edge and a feeler gauge. by sliding the feeler gauge under the straight edge in various locations, it can determine if there are any low spots or warpage. Usually, the specification is about .05 mm.



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Fig. 15: Identifying Cylinder Head

Courtesy of BMW OF NORTH AMERICA, INC.

Also, check to see if the cylinder head has a specification for machining limit. If so, it may be possible to have the cylinder head re-surfaced. Depending on the amount of material removed during the machining process, it may be necessary to install a thicker head gasket. There are some "service" head gaskets available through the parts department.

The cylinder head can be checked for minimum thickness. This is done using a micrometer or a vernier caliper. This is not possible on all engines, the example shown is a 6-cylinder (M52TU/M54).

If the minimum thickness is not met, the head will need to be replaced.

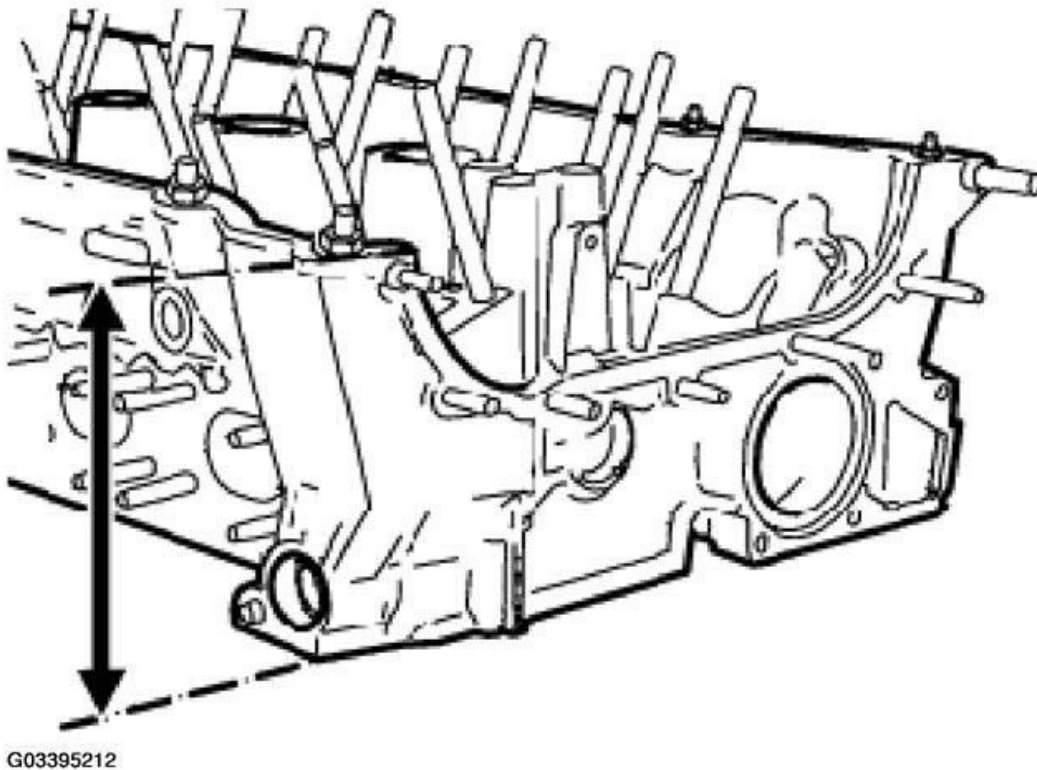
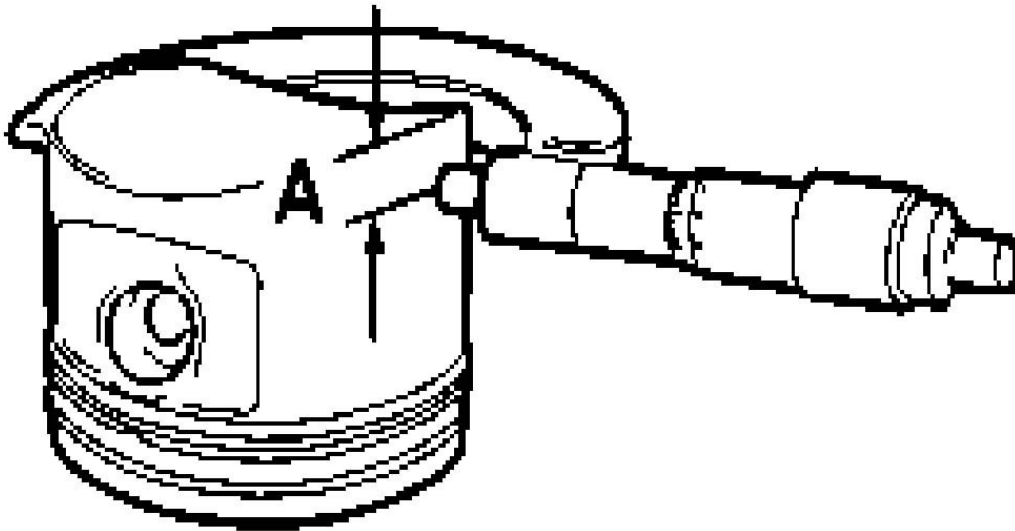


Fig. 16: Measuring Thickness Of Cylinder Head
Courtesy of BMW OF NORTH AMERICA, INC.

Piston Measurements

When replacing pistons and/or piston rings, there are some basic measurements that need to be made. When fitting a piston to a cylinder bore, the piston diameter should be checked to ensure a proper fit.

The piston diameter is measured using a micrometer. The measurement is taken at a specified point (A) which is 90 degrees from the piston pin axis. Each engine has a specific location to measure piston diameter. For example, the illustration below shows measuring Point A. The specification for this engine (N62) is 18 mm. So the piston diameter is measured 18 mm from the bottom of the piston skirt.



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Fig. 17: Measuring Piston Diameter Using Micrometer
Courtesy of BMW OF NORTH AMERICA, INC.

The piston diameter, when subtracted from the cylinder bore equals the cylinder wall to piston clearance. If the clearance measurement obtained is not correct, re-check your readings.

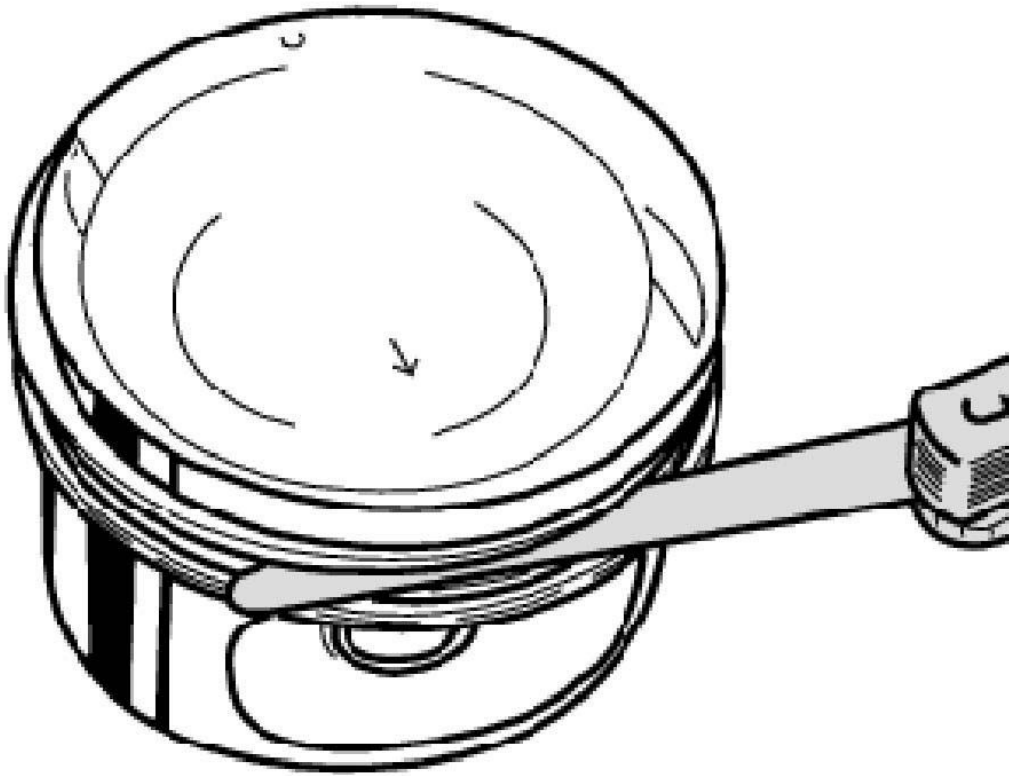
Piston Ring Measurements

There are some important specifications to check when installing piston rings. One of the measurements is axial clearance. Axial clearance is the distance between the piston ring and ring land. This prevents the rings from binding in the ring land at operating temperature. Axial clearance is measured using a feeler gauge.

Also the piston ring end gap has to be checked. This measurement is checked using a feeler gauge.

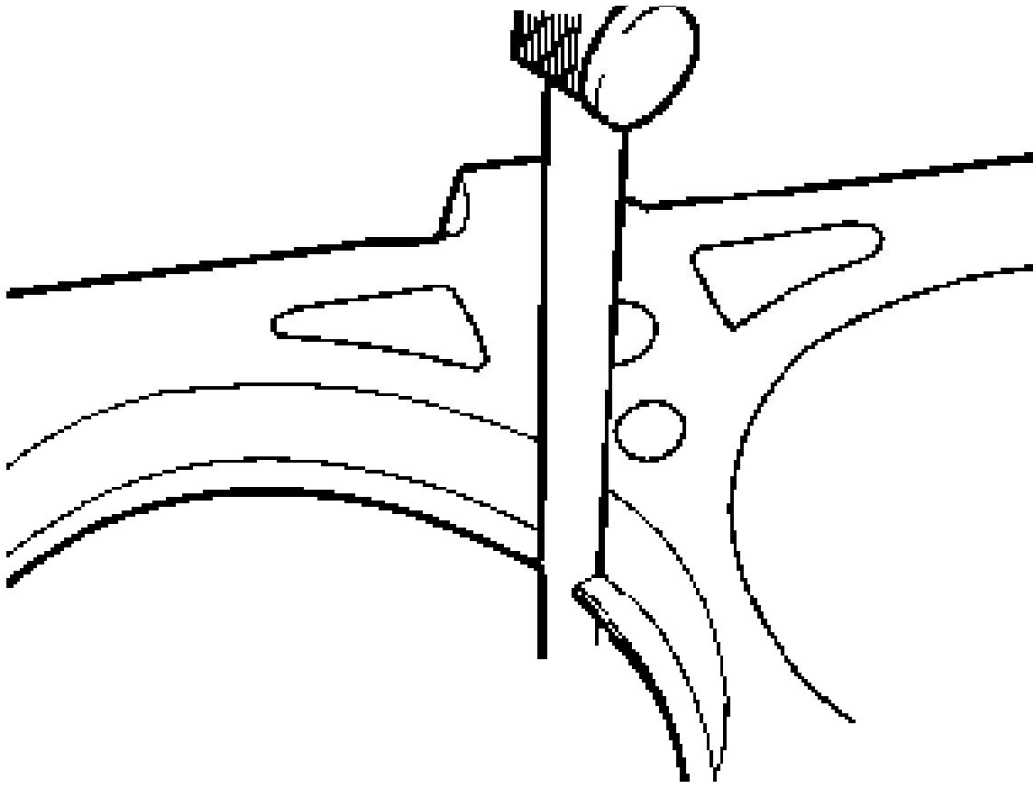
This clearance is critical in order to prevent the end gaps from contacting each other when the engine is at operating temp.

When installing the piston rings, always stagger the end gaps as per the repair instructions.



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Fig. 18: Measuring Piston Ring Gap Using Feeler Gauge
Courtesy of BMW OF NORTH AMERICA, INC.



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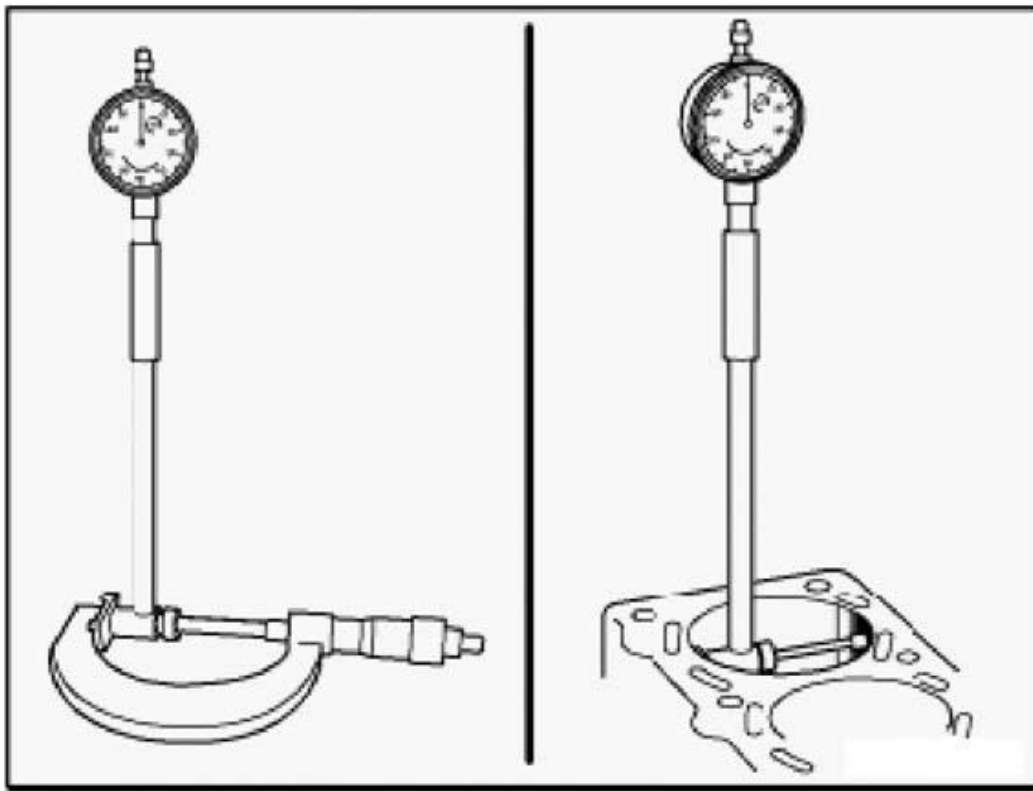
Fig. 19: Measuring Piston Ring End Gap Using Feeler Gauge
Courtesy of BMW OF NORTH AMERICA, INC.

Cylinder Bore

In order for the cylinder bore to be considered acceptable, it must not be excessively tapered or out-of-round. Once the cylinder has been checked for obvious damage and the surface finish is OK, the integrity of the bores must be verified. If cylinder wear is suspected, it must be checked using the proper cylinder bore gauge.

Each cylinder must be checked at three position in the bore - top, middle and bottom. Also there must be two opposing dimensions that should be checked. The difference between the top and bottom measurements will indicate the taper of the bore. The opposing dimensions will indicate the out-of-round specification.

If these measurements are out of specification, the cylinder bore must be re-finished or overbored. New pistons and rings must be fitted as well.



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Fig. 20: Checking Cylinder Bore Using Cylinder Bore Gauge
Courtesy of BMW OF NORTH AMERICA, INC.

METRIC SYSTEM

The unit of length, and the basis for all other metric units of measurement is the meter. The meter (1 meter), as a point of reference, is slightly longer than a yard (39.37 inches).

The divisions of a meter are hundredths and thousandths. One hundredth of a meter is called a centimeter, and is equal to .3937 inch or about half the diameter of a nickel.

One thousandth of a meter is called a millimeter. The small marks between the centimeter increments are each one millimeter, or one tenth of a centimeter. And as a point of reference, a standard paper clip is about one millimeter thick.

Metric System Denominations

Throughout the metric system, common to all units of measurement, are prefixes which designate multiples or fractions of the unit.

For automotive applications, the most common prefixes are centi; designating one-hundredth; milli; for one thousandth and kilo- for one thousand.

There are letters uniformly used throughout the system to label the divisions or multiples of each unit of measurement. The letter "m" represents milli, "c" is for centi and "k" is for kilo. These are then combined with the letter representing the unit of measurement.

For example, mm is millimeter, cm is centimeter and km is kilometer. The same applies to liter which is the unit of volume and gram which is the unit of weight.

One kilogram is equal to one thousand grams which is equal to 2.2 pounds. All metric measurements are directly related. For example, one thousand cubic centimeters, or 10cm x 10cm x 10cm of water weighs one kilogram. The volume of those one thousand cc's is one liter.

Metric Reference Chart

METRIC REFERENCE CHART

Weight			
1 kilogram	= 1 kg	= 1000 grams	= 1000 g
1 hectogram	= 1 hg	= 100 grams	= 100 g
1 dekagram	= 1 dag	= 10 grams	= 10 g
1 gram	= 1 g		
1 decigram	= 1 dg	= .1 gram	= 0.1 g
1 centigram	= 1 cg	= 0.01 gram	= 0.01 g
1 milligram	= 1 mg	= 0.001 gram	= 0.001 g
Length			
1 kilometer	= 1 km	= 1000 meters	= 1000 m
1 hectometer	= 1 hm	= 100 meters	= 100 m
1 dekameter	= 1 dam	= 10 meters	= 10 m
1 meter	= 1 m		
1 decimeter	= 1 dm	= .1 meter	= .1 m
1 centimeter	= 1 cm	= 0.01 meter	= 0.01 m
1 millimeter	= 1 mm	= 0.001 meter	= 0.001 m
Volume			
1 kiloliter	= 1 kl	= 1000 liters	= 1000 l
1 hectoliter	= 1 hl	= 100 liters	= 100 l
1 dekaliter	= 1 dal	= 10 liters	= 10 l
1 liter	= 1 l		
1 deciliter	= 1 dl	= .1 liter	= .1 l
1 centiliter	= 1 cl	= 0.01 liter	= 0.01 l
1 milliliter	= 1 ml	= 0.001 liter	= 0.001 l

Metric System Conversion Charts

METRIC SYSTEM CONVERSION CHARTS

Linear Measure to Metric	Linear Measure (Metric) to English
1 inch = 2.54 cm	1 mm = 0.03937 inch
12 inches = 1 foot = 30.48 cm	1 cm = 0.39 inch
3 feet = 1 yard = 0.91 m	1 m = 39.37 inch
5.5 yards = 1 rod = 5.03 m	1 km = 0.62 miles
5280 feet = 1 mile = 1.61 km	-
Square Measure to Metric	Square Measure (Metric) to English
1 in ² = 6.45 cm ²	1 mm ² = 0.002 in ²
144 in ² = 1 ft ² = 0.09 m ²	1 cm ² = 0.16 in ²
9 ft ² = 1 yd ² = 0.84 m ²	1 m ² = 1549 in ²
640 acres = 1mi ² = 2.59 km ²	1 km ² = 0.39 mi ² = 247.10 acres
Cubic Measure to Metric	Cubic Measure (Metric) to English
1 in ³ = 16.39 cm ³	1 mm ³ = 0.000061 in ³
1728 in ³ = 1 yd ³ = 0.76 m ³	1 cm ³ = 0.061 in ³
27ft ³ = 1 yd ³ = 0.76 m ³	1 m ³ = 35.32 ft ³
	1 km ³ = 0.24 mi ³
Liquid Measure to Metric	Liquid Measure (Metric) to English
1.81 in ³ = 1 fluid oz. = 30 ml	1 ml = 0.03 fluid oz = 0.061 in ³
1 pint = 0.47	1 1000 cm ³ = 1 l = 61.02 in ³ = 1.06 qt
57.75 in ³ = 1 quart = 0.95 l	1 ft ³ water = 62.5 lb
231 in ³ = 1 gal = 3.79 l = 0.0038 m ³	
1 ft ³ = 7.48 gal = 28.35 l	
Weights to Metric	Weight (Metric) to English
1 Oz = 28.35 g	1 g = 0.035 oz
1 lb = 453.59 g	1 kg = 2.20 lb
1 lb = 0.45 kg	1 metric ton = 1000 kg = 1.102 tons = 2205 lb
1 ton = .91 metric ton	
Temperature to Metric	Temperature to Fahrenheit
F = 9/5C +32	C = 5/9 (F-32)

Pressure Conversion Chart

PRESSURE CONVERSION CHART

Bar	kPa	psi	in.Hg.
6.0	600	87.0	
5.9	590	85.5	
5.8	580	84.0	
5.7	570	82.5	

5.6	560	81.0	
5.5	550	79.0	
5.4	540	78.5	
5.3	530	77.0	
5.2	520	75.5	
5.1	510	73.5	
5.0	500	72.5	
4.9	490	71.0	
4.8	480	69.5	
4.7	470	68.0	
4.6	460	66.5	
4.5	450	65.5	
4.4	440	64.0	
4.3	430	62.5	
4.2	420	61.0	
4.1	410	59.5	
4.0	400	58.0	
3.9	390	56.5	
3.8	380	55.0	
3.7	370	53.5	
3.6	360	52.0	
3.5	350	51.0	
3.4	340	49.5	
3.3	330	48.0	
3.2	320	46.5	
3.1	310	45.0	
3.0	300	43.5	
2.9	290	42.0	
2.8	280	40.5	
2.7	270	39.0	
2.6	260	37.5	
2.5	250	36.5	
2.4	240	35.0	
2.3	230	33.5	
2.2	220	32.0	
2.1	210	30.5	
2.0	200	29.0	
1.9	190	27.5	
1.8	180	26.0	
1.7	170	24.5	
1.6	160	23.0	
1.5			

	150	22.0	
1.4	140	20.5	
1.3	130	19.0	
1.2	120	17.5	35.90
1.1	110	16.0	32.91
1.0	100	14.5	29.92
0.9	90	13.0	26.93
0.8	80	11.5	23.94
0.7	70	10.0	20.94
0.6	60	9.0	17.95
0.5	50	7.5	14.96
0.4	40	6.0	11.97
0.3	30	4.5	8.98
0.2	20	3.0	5.98
0.1	10	1.5	2.99
0.0	0	0.0	0.0

Introduction - Z4

INTRODUCTION

The new Z4, successor to the E85 Z4 Roadster and E86 Z4 Coupe, is the first BMW Roadster to have a retractable hardtop. With its long engine compartment lid, large wheel apertures, long wheelbase and squat overhang it features all typical elements of a BMW Roadster. The vehicle's manufacturing has been moved from Spartanburg, South Carolina to the Regensburg, Germany plant.

These features are further enhanced by the flat front section, the pronounced shoulder line and rear end. In addition, the engine compartment lid that extends over the wheel arches, the large BMW radiator grill, the side gills, the black A-pillar, the contoured roof and rear lights with innovative light technology further cement the characteristic accents.

The two-piece, electrohydraulically operated retractable hardtop made of lightweight aluminum panels takes approximately 20 seconds to open or close fully automatically. The compact stowage of the roof elements in the luggage compartment allows for a flat, Roadster-characteristic rear design and a luggage compartment volume between 180 and 310 liters (6.3 and 10.9 cubic feet). Large window areas together with the heated glass rear window provide an optimum all-round field of view.

All models are equipped with Efficient Dynamics measures and thus no compromise has been made in terms of acceleration, performance and fuel economy. At launch in May 2009, the E89 is offered as two model variants.

Z4 sDrive35i - N54B30O0 (300 hp/300 lb-ft)

Z4 sDrive30i - N52B30O1 (255 hp/220 lb-ft)

Both model variants come standard with a manual 6 speed transmission but if the automatic transmission option is desired, two transmissions are available. For the Z4 sDrive30i, there is the familiar GA6HP19Z (TU) transmission. For the Z4 sDrive35i, the sports automatic with double clutch (DCT) GS7D36SG transmission that was first utilized in the fourth generation M3 is available.

The new BMW Z4 is equipped with a three level dynamic driving control as standard. This allows the driver to change the accelerator pedal characteristics, gearshift program and shift speed of the optional automatic gearbox, DSC response and the optional adaptive M running gear with the touch of a button.

Head and elbow clearance as well as ease of entry have been greatly improved compared to the predecessor model. The low seat position near the rear axle creates the typical ride experience of a BMW Roadster.



Fig. 1: Identifying Complete Vehicle (BMW E89 Model)
Courtesy of BMW OF NORTH AMERICA, INC.



Fig. 2: Identifying Interior Of E85
Courtesy of BMW OF NORTH AMERICA, INC.

Changes when compared to the E85:

- Improved interior and comfort
- Retractable hardtop
- Bi-xenon as standard (fog lights discontinued)
- Through-loading facility
- Wheelbase increased by +146 mm (5.75")

- Standard "wheels optional 19" wheels
- Optional adaptive M running gear
- Optional sports automatic transmission with double clutch (only on Z4 sDrive35i)
- Cruise control with brake intervention
- Dynamic driving control
- CIC (with navigation)

BODY

The following are some important design objectives in the development of the E89 body:

- Harmonious overall impression with extended proportions, coupe-inspired roof line and flat rear end
- Remote controlled, fully automatic retractable hardtop with load help function
- Through-loading capability for carrying skis or a golf bag regardless of top position
- More and easier-to-use storage compartments in the vehicle interior as well as a rear storage area behind the seats
- Greatly improved all-round vision (rear side windows) and a larger rear window
- Compelling impression (driver-orientated), top-quality appearance and functionality of the interior
- Distinctly reduced noise level at higher speeds

Comparison of Body Components

The new Z4 has been designed with very few components actually used from the previous model. The illustration below identifies the components used in both generation Z4.



Fig. 3: Comparison Of E85/E89 Body Components
 Courtesy of BMW OF NORTH AMERICA, INC.

INDEX EXPLANATION REFERENCE CHART

Index	Explanation
1	New components (newly developed)
2	Common parts
3	Modified components (developed with minimum expenditure)

Dimensions

The E89 has grown compared to the E85. The width is now 1790 mm (+9 mm).

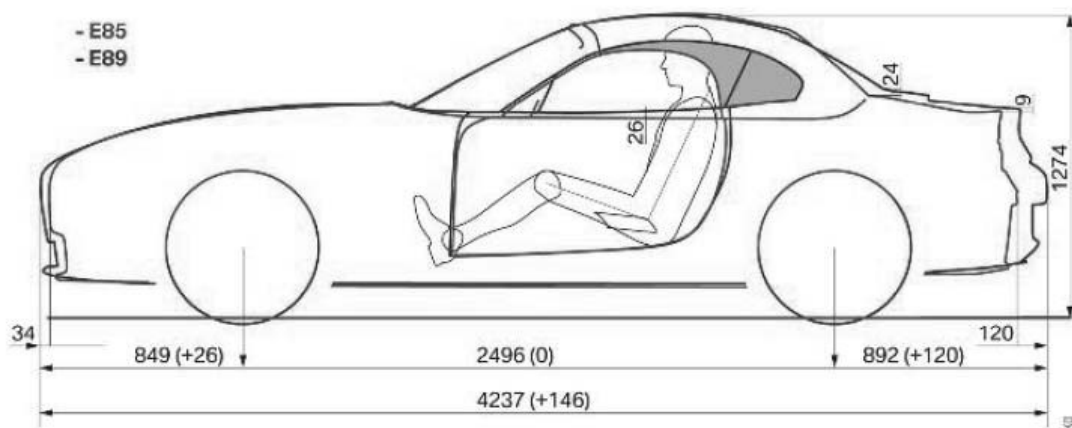


Fig. 4: Identifying Garage Dimensions E85/E89
Courtesy of BMW OF NORTH AMERICA, INC.

GENERAL INFORMATION

New Engine Technology - Overview

BASIC MEASURING TECHNIQUES

Model: All

BASIC ENGINE MEASUREMENTS

During the course of engine repairs some basic engine measurements are required to verify engine diagnosis as well as to complete proper repairs. These measurements are made by precision measuring tools such as micrometers, Vernier calipers, cylinder bore gauges and dial indicators.

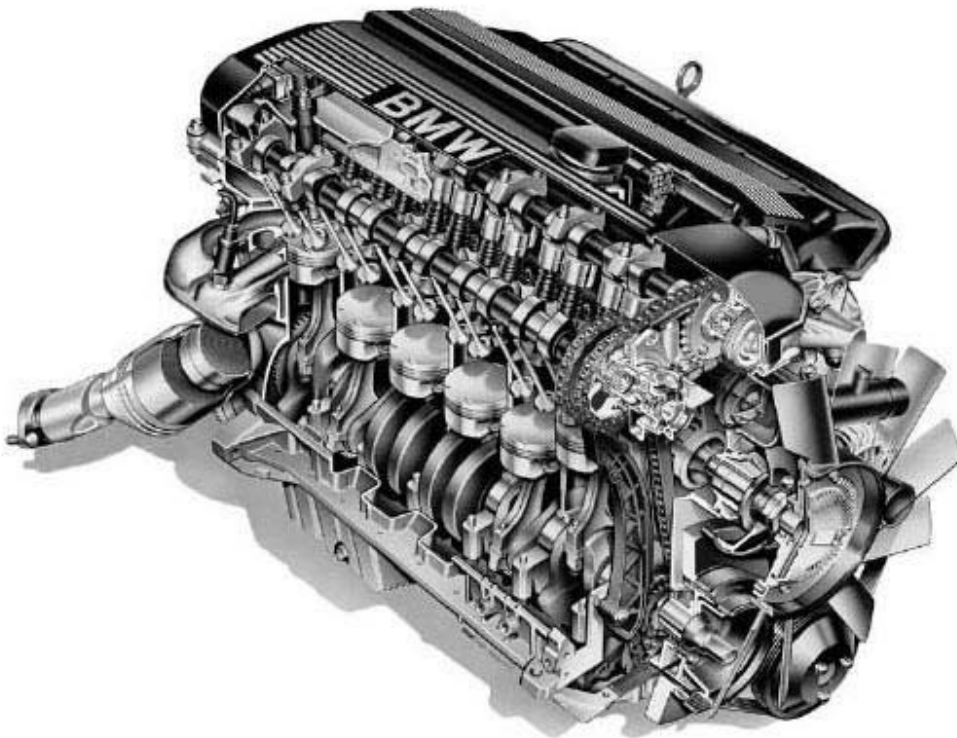


Fig. 1: Identifying Basic Engine Measurements
Courtesy of BMW OF NORTH AMERICA, INC.

Also, a working knowledge of the metric system is also a vital skill that is needed by the technician. All BMW engine measurements consist of metric specifications. Some of the routine engine measurements performed include:

- Valve Guide Wear (Tilt Angle K)
- Cylinder Bore Measurements (Taper and Out-of-Round)
- Cylinder Head Warpage and Thickness

- Axial and Radial Endplay Measurements (Crankshaft/Camshaft etc).

Among all of the skills possessed by a modern technician, basic measuring techniques are perhaps the most overlooked and least used. This is why it is important to review these skills from time to time as a refresher.

Also, it is necessary to access technical data to obtain the proper specifications for these measurements. This course is designed to review measuring techniques to assist in engine diagnosis.

Vernier Measurement

The Vernier scale is used on various measuring tools such as the Vernier caliper and the Depth Gauge. The Vernier scale can be used with Fractional (US) and Metric systems. For the purposes of this training module we will always refer to the Metric Vernier scale.

The Vernier scale consists of a fixed scale and a sliding scale. The fixed scale is divided with graduations in 1 millimeter increments. The sliding scale has 10 graduations in increments of .5.

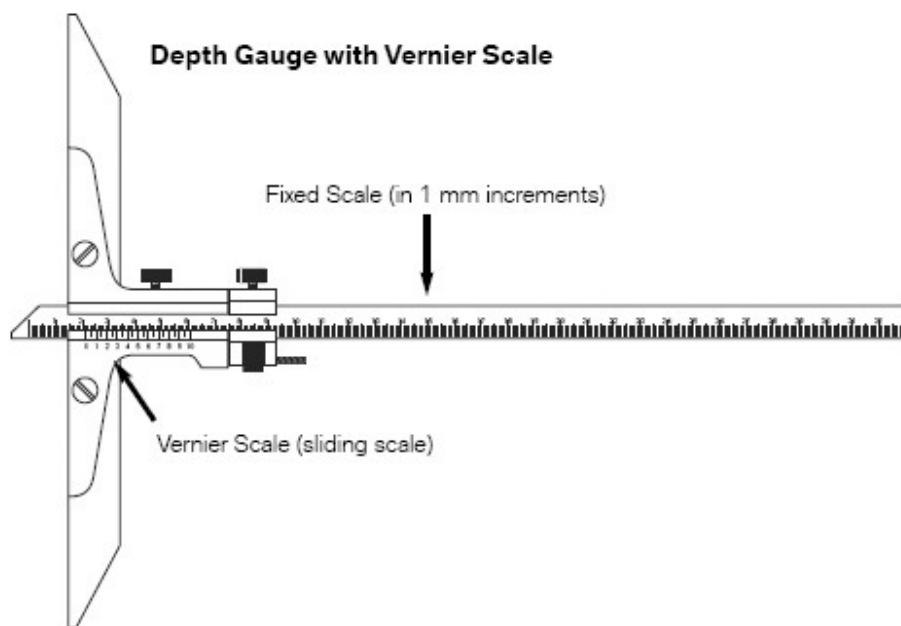


Fig. 2: Identifying Depth Gauge With Vernier Scale
 Courtesy of BMW OF NORTH AMERICA, INC.

In order to read a measurement, use the zero mark on the left end of the vernier scale to use as a guide to read a measurement on the fixed scale.

In the example shown at the right, the zero mark is resting between 26 and 27 mm. Therefore the base measurement is 26 mm.

Next, the decimal measurement must be taken. For this, find a line on the Vernier that most closely matches any line on the fixed scale.

Using the example drawing, the "4" on the Vernier scale is lining up directly with a line on the fixed scale.

Combining the previous reading with this reading, the result would be 26.4 mm.

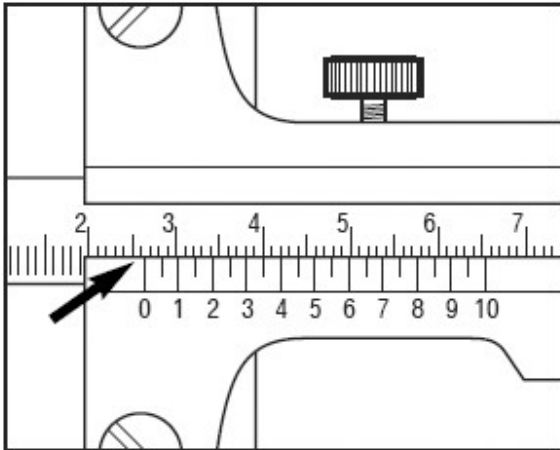


Fig. 3: Identifying Read Measurement, Zero Mark On Left End Of Vernier Scales
Courtesy of BMW OF NORTH AMERICA, INC.

The designations on the Vernier scale are in increments of .5. For example, if a reading on the Vernier scale falls on the .5 (i.e. 2.5, 3.5 etc) designation this would indicate 5/100th's of a millimeter.

Micrometer Measurements

Another valuable measuring tool is the micrometer, which can be used for measurements such as bearing journal diameter, cylinder head thickness, valve shim thickness and brake rotor thickness etc. Micrometers also come in configurations for inside measurements as well.

The micrometer scale comes in both fractional and metric varieties. We will cover only the metric micrometer scale in this course.

First you must familiarize yourself with the construction of the micrometer in order to understand how measurements are made.

Metric Micrometer Construction

The micrometer is constructed of a few basic parts. The actual item to be measured is placed between the anvil and the spindle. The micrometer can be adjusted to the approximate size using the thimble. The thimble should only be used for the coarse adjustment. In order to make the actual measurement, the micrometer should only be turned using the ratchet (a.k.a. the friction stop). Do not attempt to make a measurement using the thimble. This will give an inaccurate measurement and ultimately damage the micrometer.

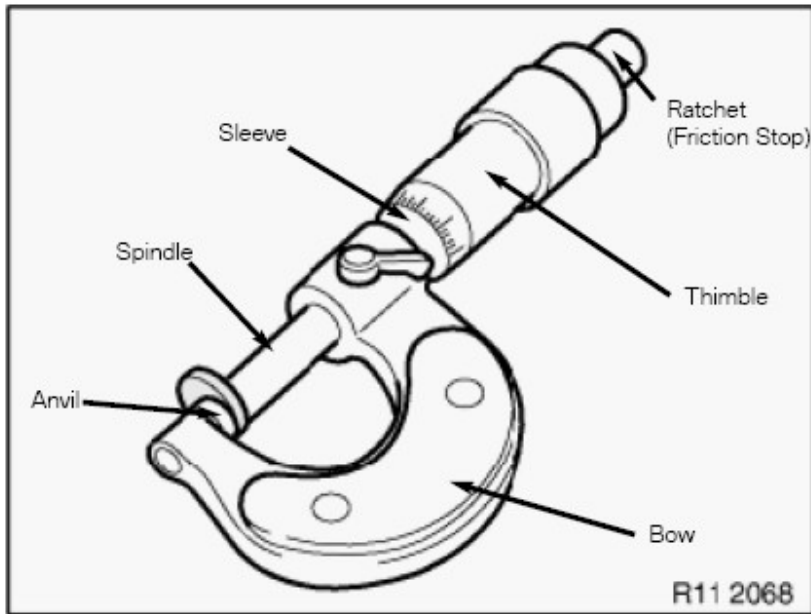


Fig. 4: Identifying Metric Micrometer Construction And Spindle
Courtesy of BMW OF NORTH AMERICA, INC.

Micrometers are available in various sizes for outside as well as inside measurements. The more common variation is the outside micrometer. They are usually available in 25 millimeter increments such as 0-25 mm, 25-50 mm, 50-75 mm etc.

The metric micrometer can measure in increments of one hundredth of a millimeter (.01mm). One hundredth of a millimeter is equal to 0.0003937 inch which is less than one thousandth of an inch.

The measurement area of the micrometer consists of the sleeve scale and the thimble scale. The sleeve scale is used to read whole and half millimeters. The thimble scale (which rotates) reads in hundredths (.01) of a millimeter from zero to fifty. Two complete revolutions of the thimble equals one millimeter.

On the sleeve scale, each scale mark above the center line indicates whole millimeters. Below the center line, half of a millimeter (or .5mm) increments are indicated.

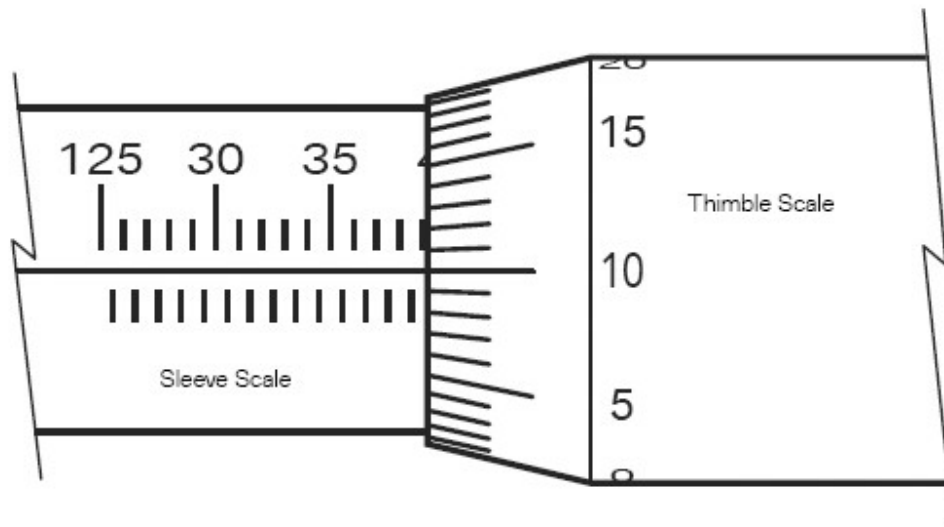


Fig. 5: Identifying Sleeve Scale
Courtesy of BMW OF NORTH AMERICA, INC.

Using the example shown above, the micrometer is a 125-150mm micrometer. To read this micrometer, first take the basic reading from the sleeve scale. The thimble is past the 139 mm mark. Therefore the reading is a least 139 mm. Next, look at the thimble scale and note the reading on the centerline. The "10" on the thimble scale is lined up with the centerline. This indicates a reading of .10 mm. If you add the two readings; $139 + .10 = 139.10$ mm.

Dial Indicator Measurements

The dial indicator is used to measure the travel or movement of a specific item. It can also be used to measure axial and radial runout. In engine measurement applications, the dial indicator can be used to measure valve guide wear, axial movement of the crankshaft (thrust), and runout of flywheels and harmonic balancers.

First, it is important to familiarize yourself with Dial Indicator construction. The face of the dial indicator consists of a moveable bezel which is also attached to the large measuring scale. This allows the tool be brought to the "zero point" when needed.

The main measuring device is the contact point. The contact point (1) is placed against the object to be measured. Usually, the contact point is rounded or has a ball bearing. This allows for a more accurate measurement.

The measuring face of the dial indicator consists of 2 scales. The smaller scale is for the "coarse" measurement which is in graduations of 1 millimeter. One revolution of the small scale is 10 millimeters.

The large scale is in graduations of .01 millimeter and the scale goes from zero to one hundred. Therefore, one revolution of the large scale is one millimeter.

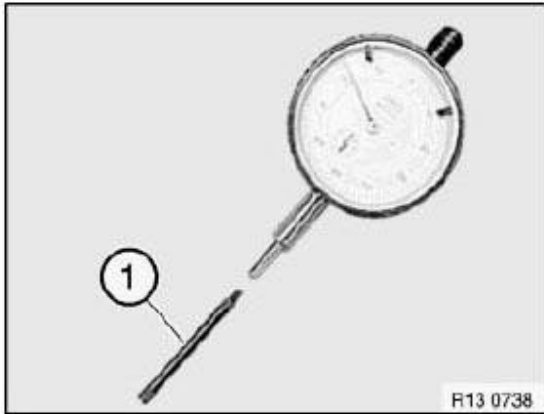


Fig. 6: Identifying Device Is Contact Point
Courtesy of BMW OF NORTH AMERICA, INC.

The dial indicator also needs to be held in place when taking a measurement. This requires a stand or base. Depending upon the application, these stands can be a clamp type, magnetic or a threaded base.

When taking a measurement, place the contact point on the object to be measured. The dial indicator must be pre-loaded slightly to prevent the measurement from bottoming out.

When reading the scale, be sure to "zero" the dial indicator first. If the readings to be taken are less than 1 millimeter, you do not need to use the small scale. If the readings are larger than 1 millimeter, be sure to factor the small scale into your measurement.

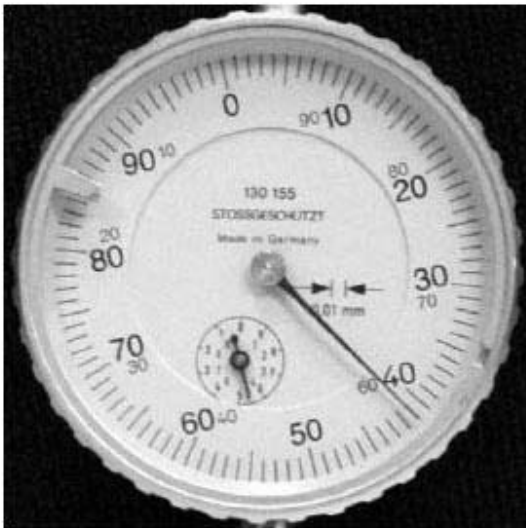


Fig. 7: Identifying Dial Indicator
Courtesy of BMW OF NORTH AMERICA, INC.

Examples of Dial Indicator Measurements

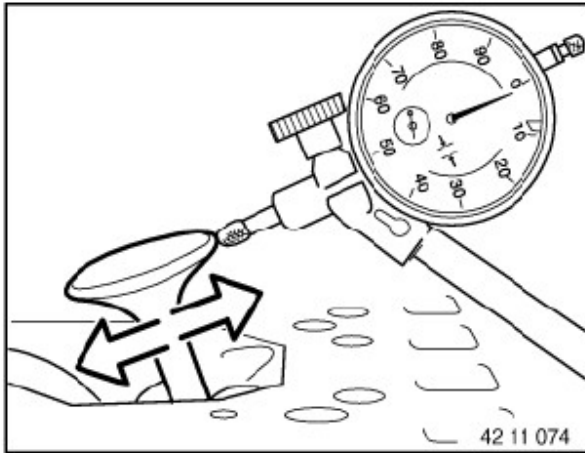


Fig. 8: Identifying Valve Guide Wear - Tilt Angle (K)
 Courtesy of BMW OF NORTH AMERICA, INC.

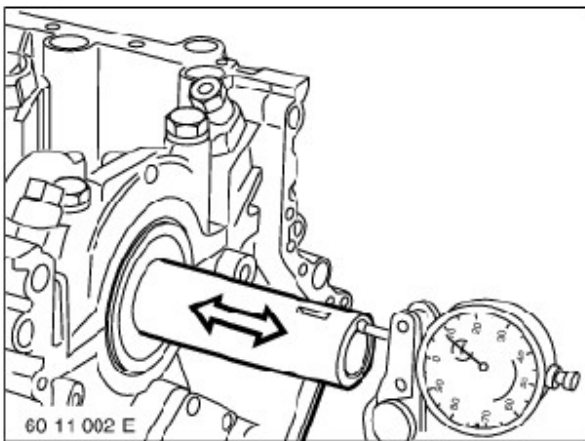


Fig. 9: Identifying Crankshaft Endplay - Axial
 Courtesy of BMW OF NORTH AMERICA, INC.

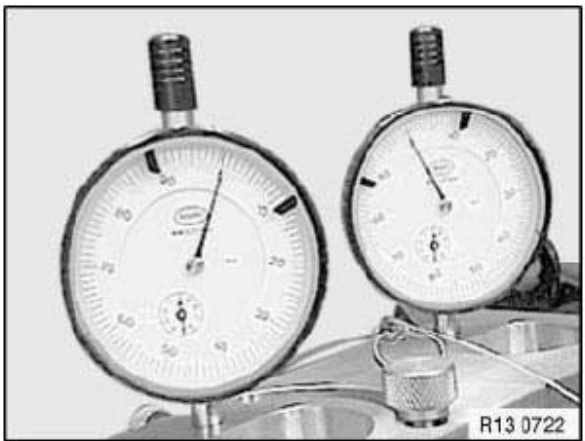


Fig. 10: Identifying S62 Engine - Basic Throttle Setting
Courtesy of BMW OF NORTH AMERICA, INC.

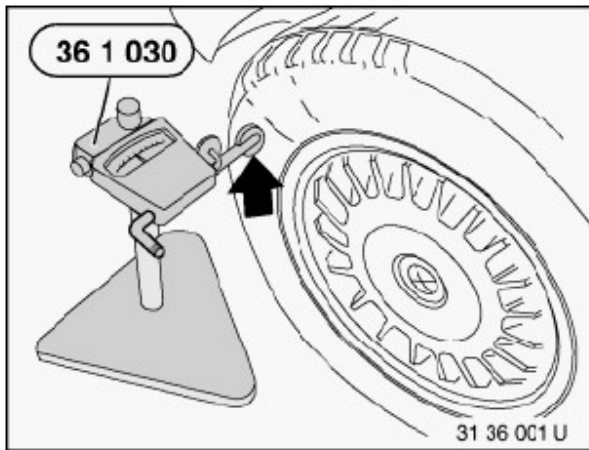


Fig. 11: Identifying Wheel Runout - Axial
Courtesy of BMW OF NORTH AMERICA, INC.

ADDITIONAL ENGINE MEASUREMENTS

During engine repair procedures it is sometimes necessary to assess engine wear to make determinations on parts replacement. Also, some engine measurements are needed to verify a previous diagnosis.

For example, a cylinder leakdown test could indicate a cylinder sealing concern. Once the engine is disassembled, it would be necessary to verify this condition by checking the piston and piston ring condition. If OK, the next step would be to determine the condition of the cylinder bore. At this point, the cylinders should be checked for taper (conicity) and for out-of-round. The correct measurements could mean the difference between just replacing the rings and/or pistons or replacing the engine block. This is why it is necessary to make accurate measurements when needed.

Some of the other routine engine measurements include:

- Cylinder head warpage
- Cylinder head thickness (on some applications)
- Piston rings - end gap and axial clearance

* Cylinder bore - including out-of-round and taper

Cylinder Head Measurement

If a repair requires removal of the cylinder head, a few basic measurements can be performed to save time and unnecessary machine shop costs. If an engine has been overheated or has an internal or external fluid leakage (coolant/oil), it is a good idea to check the cylinder head for warpage.

This can be done by using a commercially available machinists straight edge and a feeler gauge. by sliding the

feeler gauge under the straight edge in various locations, it can determine if there are any low spots or warpage. The specifications for warpage are found in WebTIS under Technical Data. Usually, the specification is about .05 mm.

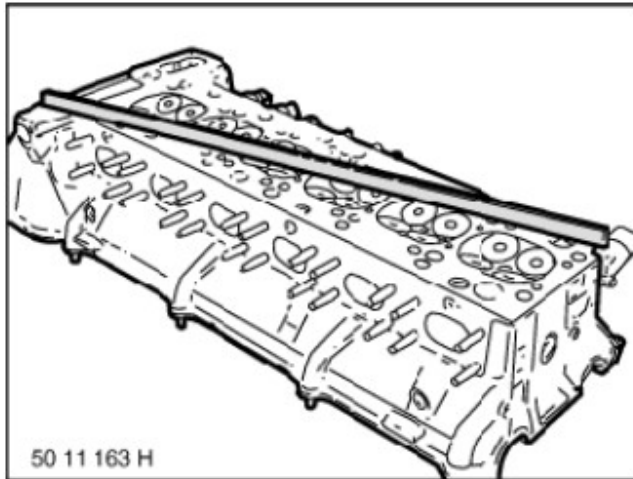
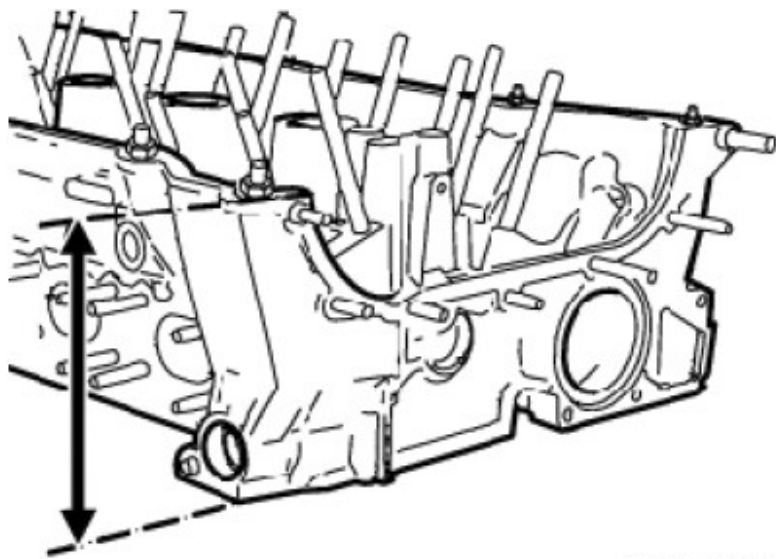


Fig. 12: Checking Cylinder Head Warpage
Courtesy of BMW OF NORTH AMERICA, INC.

Also, check to see if the cylinder head has a specification for machining limit. If so, it may be possible to have the cylinder head re-surfaced. Depending on the amount of material removed during the machining process, it may be necessary to install a thicker head gasket. There are some "service" head gaskets available through the parts department.

The cylinder head can be checked for minimum thickness. This is done using a micrometer or a vernier caliper. This is not possible on all engines, the example shown below is a 6-cylinder (M52TU/M54).

If the minimum thickness is not met, the head will need to be replaced.



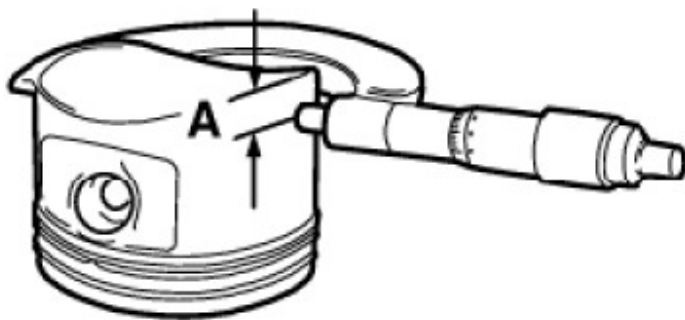
50 11 104 H

Fig. 13: Identifying Cylinder Head Minimum Thickness
 Courtesy of BMW OF NORTH AMERICA, INC.

Piston Measurements

When replacing pistons and/or piston rings, there are some basic measurements that need to be made. When fitting a piston to a cylinder bore, the piston diameter should be checked to ensure a proper fit.

The piston diameter is measured using a micrometer. The measurement is taken at a specified point (A) which is 90 degrees from the piston pin axis. Each engine has a specific location to measure piston diameter. For example, the illustration below shows measuring Point A. The specification for this engine (N62) is 18 mm. So the piston diameter is measured 18 mm from the bottom of the piston skirt.



88 11 051 U

Fig. 14: Checking Piston Diameter Is Measured Using Micrometer
 Courtesy of BMW OF NORTH AMERICA, INC.

The piston diameter, when subtracted from the cylinder bore equals the cylinder wall to piston clearance. If the clearance measurement obtained is not correct, re-check your readings.

Piston Ring Measurements

There are some important specifications to check when installing piston rings. One of the measurements is axial clearance. Axial clearance is the distance between the piston ring and ring land. This prevents the rings from binding in the ring land at operating temperature. Axial clearance is measured using a feeler gauge.

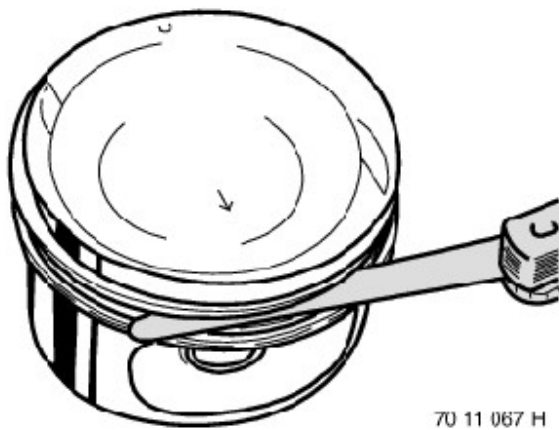


Fig. 15: Checking Piston Ring Of Feeler Gauge
Courtesy of BMW OF NORTH AMERICA, INC.

Also the piston ring end gap has to be checked. This measurement is checked using a feeler gauge.

This clearance is critical in order to prevent the end gaps from contacting each other when the engine is at operating temp.

When installing the piston rings, always stagger the end gaps as per the repair instructions.

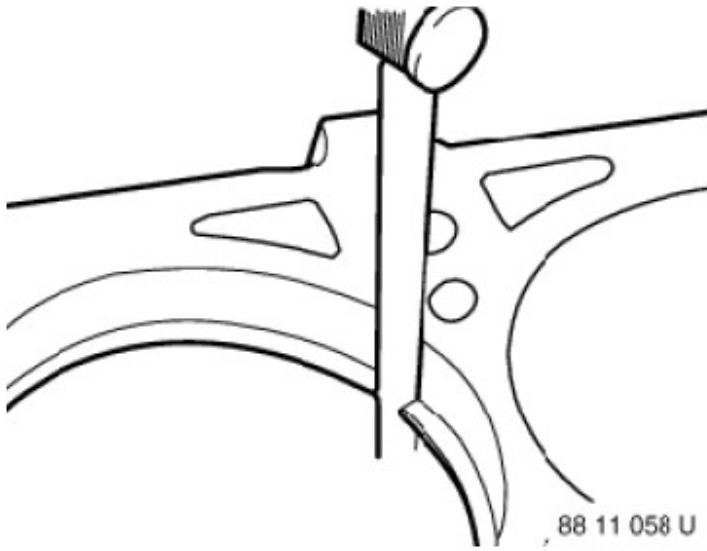


Fig. 16: Identifying Piston Ring End Gap
Courtesy of BMW OF NORTH AMERICA, INC.

Cylinder Bore

In order for the cylinder bore to be considered acceptable, it must not be excessively tapered or out-of-round. Once the cylinder has been checked for obvious damage and the surface finish is OK, the integrity of the bores must be verified. If cylinder wear is suspected, it must be checked using the proper cylinder bore gauge.

Each cylinder must be checked at three position in the bore - top, middle and bottom. Also there must be two opposing dimensions that should be checked. The difference between the top and bottom measurements will indicate the taper of the bore. The opposing dimensions will indicate the out-of-round specification.

If these measurements are out of specification, the cylinder bore must be re-finished or overbored. New pistons and rings must be fitted as well.

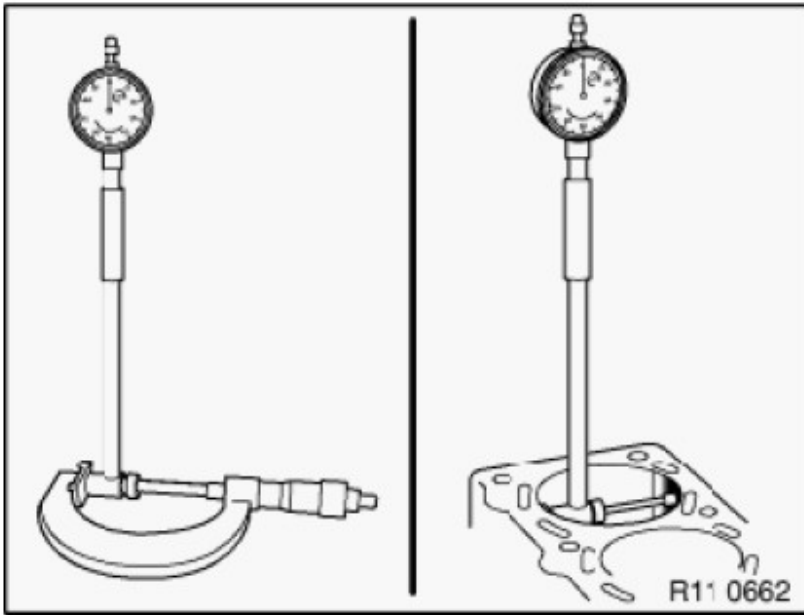


Fig. 17: Measuring Proper Cylinder Bore Gauge
Courtesy of BMW OF NORTH AMERICA, INC.

METRIC SYSTEM

All BMW specifications are metric. Therefore, a thorough knowledge of those areas on the metric system which apply to BMW vehicles is vital to a BMW Service Technician.

The unit of length, and the basis for all other metric units of measurement is the meter. The meter (1 meter), as a point of reference, is slightly longer than a yard (39.37 inches).

The divisions of a meter are hundredths and thousandths. One hundredth of a meter is called a centimeter, and is equal to .3937 inch or about half the diameter of a nickel.

One thousandth of a meter is called a millimeter. The small marks between the centimeter increments are each one millimeter, or one tenth of a centimeter. And as a point of reference, a standard paper clip is about one millimeter thick.

Metric System Denominations

Throughout the metric system, common to all units of measurement, are prefixes which designate multiples or fractions of the unit.

For automotive applications, the most common prefixes are centi; designating one-hundredth; milli; for one thousandth and kilo-for one thousand.

There are letters uniformly used throughout the system to label the divisions or multiples of each unit of measurement. The letter "m" represents milli, "c" is for centi and "k" is for kilo. These are then combined with the letter representing the unit of measurement.

For example, mm is millimeter, cm is centimeter and km is kilometer. The same applies to liter which is the unit of volume and gram which is the unit of weight.

One kilogram is equal to one thousand grams which is equal to 2.2 pounds.

All metric measurements are directly related. For example, one thousand cubic centimeters, or 10cm x 10cm x 10cm of water weighs one kilogram. The volume of those one thousand cc's is one liter.

Metric Reference Chart

METRIC REFERENCE CHART

Weight			
1 kilogram	= 1 kg	= 1000 grams	= 1000 g
1 hectogram	= 1 hg	= 100 grams	= 100 g
1 dekagram	= 1 dag	= 10 grams	= 10 g
1 gram	= 1 g		
1 decigram	= 1 dg	= .1 gram	= 0.1 g
1 centigram	= 1 cg	= 0.01 gram	= 0.01 g
1 milligram	= 1 mg	= 0.001 gram	= 0.001 g
Length			
1 kilometer	= 1 km	= 1000 meters	= 1000 m
1 hectometer	= 1 hm	= 100 meters	= 100 m
1 dekameter	= 1 dam	= 10 meters	= 10 m
1 meter	= 1 m		
1 decimeter	= 1 dm	= .1 meter	= .1 m
1 centimeter	= 1 cm	= 0.01 meter	= 0.01 m
1 millimeter	= 1 mm	= 0.001 meter	= 0.001 m
Volume			
1 kiloliter	= 1 kl	= 1000 liters	= 1000 l
1 hectoliter	= 1 hl	= 100 liters	= 100 l
1 dekaliter	= 1 dal	= 10 liters	= 10 l
1 liter	= 1 l		
1 deciliter	= 1 dl	= .1 liter	= .1 l
1 centiliter	= 1 cl	= 0.01 liter	= 0.01 l
1 milliliter	= 1 ml	= 0.001 liter	= 0.001 l

Metric System Conversion Charts

METRIC SYSTEM CONVERSION CHARTS

Linear Measure to Metric	Linear Measure (Metric) to English
1 inch = 2.54 cm	1 mm = 0.03937 inch
12 inches = 1 foot = 30.48 cm	1 cm = 0.39 inch
3 feet = 1 yard = 0.91 m	1 m = 39.37 inch

5.5 yards = 1 rod = 5.03 m	1 km = 0.62 miles
5280 feet = 1 mile = 1.61 km	
Square Measure to Metric	Square Measure (Metric) to English
1 in ² = 6.45 cm ²	1 mm ² = 0.002 in ²
144 in ² = 1 ft ² = 0.09 m ²	1 cm ² = 0.16 in ²
9 ft ² = 1 yd ² = 0.84 m ²	1 m ² = 1549 in ²
640 acres = 1mi ² = 2.59 km ²	1 km ² = 0.39 mi ² = 247.10 acres
Cubic Measure to Metric	Cubic Measure (Metric) to English
1 in ³ = 16.39 cm ³	1 mm ³ = 0.000061 in ³
1728 in ³ = 1 yd ³ = 0.76 m ³	1 cm ³ = 0.061 in ³
27ft ³ = 1 yd ³ = 0.76 m ³	1 m ³ = 35.32 ft ³
	1 km ³ = 0.24 mi ³
Liquid Measure to Metric	Liquid Measure (Metric) to English
1.81 in ³ = 1 fluid oz. = 30 ml	1 ml = 0.03 fluid oz = 0.061 in ³
1 pint = 0.47 l	1000 cm ³ = 1 l = 61.02 in ³ = 1.06 qt
57.75 in ³ = 1 quart = 0.95 l	1 ft ³ water = 62.5 lb
231 in ³ = 1 gal = 3.79 l = 0.0038 m ³	
1 ft ³ = 7.48 gal = 28.35 l	
Weights to Metric	Weight (Metric) to English
1 Oz = 28.35 g	1 g = 0.035 oz
1 lb = 453.59 g	1 kg = 2.20 lb
1 lb = 0.45 kg	1 metric ton = 1000 kg = 1.102 tons = 2205 lb
1 ton = .91 metric ton	
Temperature to Metric	Temperature to Fahrenheit
F = 9/5C +32	C = 5/9 (F-32)

Pressure Conversion Chart

PRESSURE CONVERSION CHART

Bar	kPa	psi	in.Hg.
6.0	600	87.0	
5.9	590	85.5	
5.8	580	84.0	
5.7	570	82.5	
5.6	560	81.0	
5.5	550	79.0	
5.4	540	78.5	
5.3	530	77.0	
5.2	520	75.5	

5.1	510	73.5	
5.0	500	72.5	
4.9	490	71.0	
4.8	480	69.5	
4.7	470	68.0	
4.6	460	66.5	
4.5	450	65.5	
4.4	440	64.0	
4.3	430	62.5	
4.2	420	61.0	
4.1	410	59.5	
4.0	400	58.0	
3.9	390	56.5	
3.8	380	55.0	
3.7	370	53.5	
3.6	360	52.0	
3.5	350	51.0	
3.4	340	49.5	
3.3	330	48.0	
3.2	320	46.5	
3.1	310	45.0	
3.0	300	43.5	
2.9	290	42.0	
2.8	280	40.5	
2.7	270	39.0	
2.6	260	37.5	
2.5	250	36.5	
2.4	240	35.0	
2.3	230	33.5	
2.2	220	32.0	
2.1	210	30.5	
2.0	200	29.0	
1.9	190	27.5	
1.8	180	26.0	
1.7	170	24.5	
1.6	160	23.0	
1.5	150	22.0	
1.4	140	20.5	
1.3	130	19.0	
1.2	120	17.5	35.90
1.1	110	16.0	32.91
1.0			

	100	14.5	29.92
0.9	90	13.0	26.93
0.8	80	11.5	23.94
0.7	70	10.0	20.94
0.6	60	9.0	17.95
0.5	50	7.5	14.96
0.4	40	6.0	11.97
0.3	30	4.5	8.98
0.2	20	3.0	5.98
0.1	10	1.5	2.99
0.0	0	0.0	0.0

GENERAL INFORMATION

Starting Systems - Overview

STARTING SYSTEMS

Model: All

Production Date: All

PURPOSE OF STARTING SYSTEM

The purpose of the starting system is to convert chemical energy stored in the battery into electrical energy, then into mechanical energy in the starter motor. This mechanical energy is then transferred through gears and drives from the starter motor to the engine flywheel.

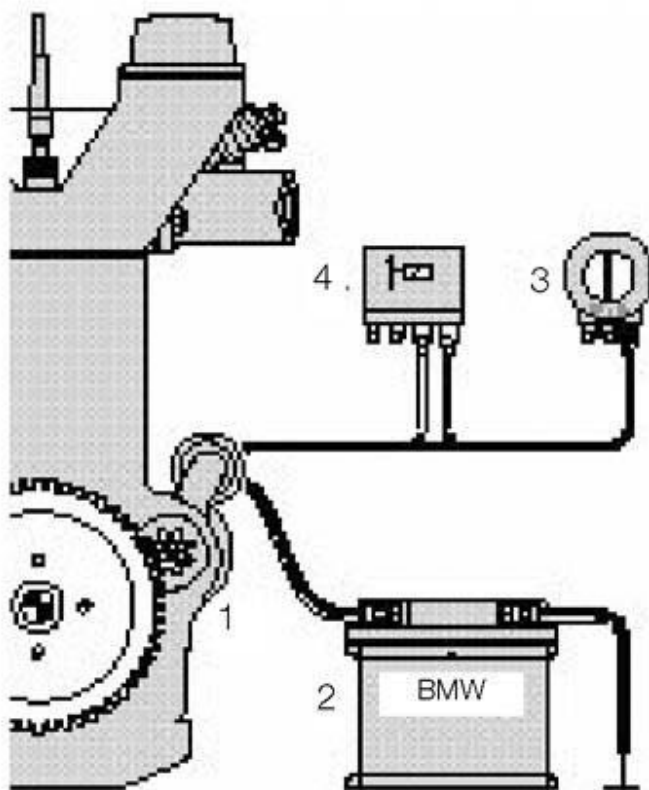
After the transfer and conversion of all this energy the engine flywheel begins to rotate.

The rotation must be of sufficient speed to allow the engine to form the combustible air-fuel mixture required for starting. It must be maintained during initial combustion long enough until the engine can sustain operation.

To accomplish this a starter or cranking motor is used.

The starting system consists of the following components:

- Battery.
- Ignition Switch.
- Starter Motor Assembly.
- EWS (if equipped).
- Starter Safety Switch.
- Cables and Wiring Harness.



- | | |
|-------------|------------|
| 1. Starter | 2. Battery |
| 3. Ignition | 4. Relay |

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Fig. 1: Identifying Starting System

Courtesy of BMW OF NORTH AMERICA, INC.

SYSTEM COMPONENTS

Battery

The Battery is the primary EMF source in the automobile. The automotive battery is an electromechanical device that provides the potential difference (voltage). The battery does not store electrical energy. It stores chemical energy that is converted to electrical energy as it discharges.

All energy for starting the car is drawn from the battery. State-of-charge, and capacity of the battery are important factors in the ability of the engine to start, especially in cold and harsh conditions.

Ignition Switch

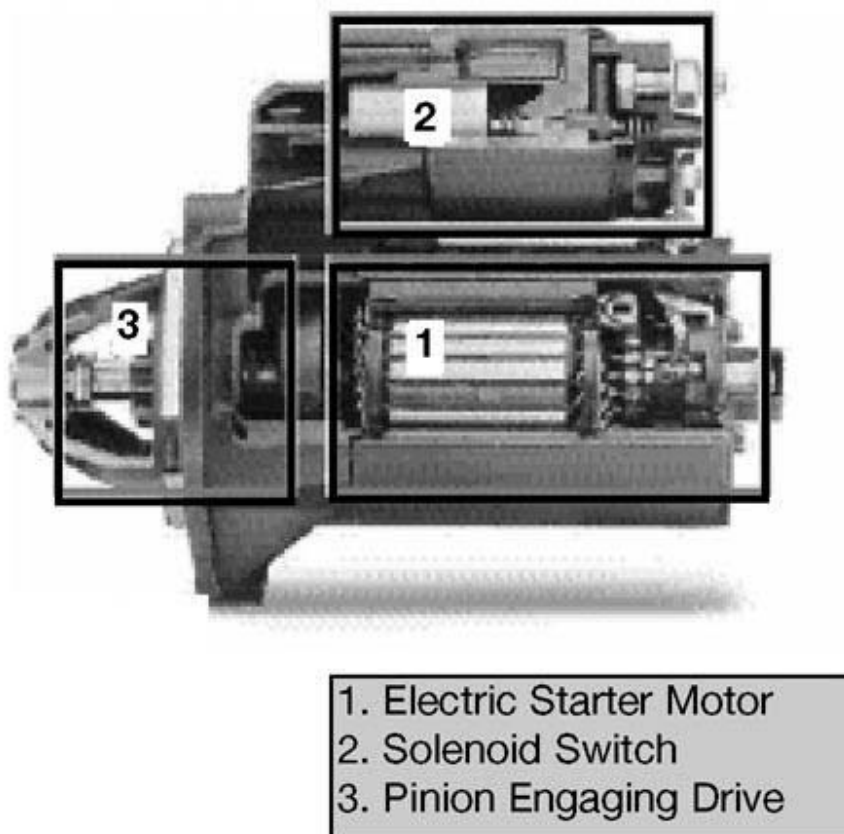
The Ignition Switch provides a request to the starting system to engage the starter motor. This request is handled differently depending on the year of the vehicle and particular systems the vehicle is fitted with.

In non EWS systems the ignition switch provided power directly to the starter solenoid or a starter relay. Beginning with EWS I the start request (KL50) is passed to an Immobilizer control module or an EWS module (EWS II/III).

On vehicles with one touch starting the KL50 signal is passed to the DME.

Starter Motor Assembly

The Starter Motor Assembly is a DC motor which uses the interaction of magnetic fields to convert electrical energy into mechanical energy.



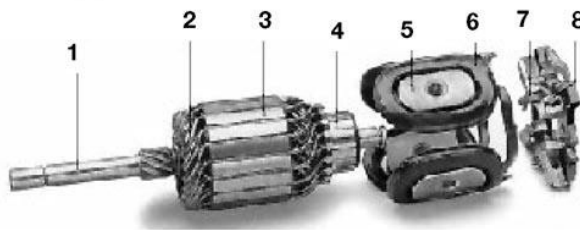
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Fig. 2: Identifying Starter Motor Assembly
Courtesy of BMW OF NORTH AMERICA, INC.

Electric Starter Motor

The Starter Motor provides the mechanical energy to rotate the engine through a direct or a gear reduction drive.

- Armature Shaft (1)
- Armature Winding (2)
- Armature Stack (3)
- Commutator (4)
- Poles Shoes (5)
- Field Coil (6)
- Carbon Brushes (7)
- Brush Holder (8)

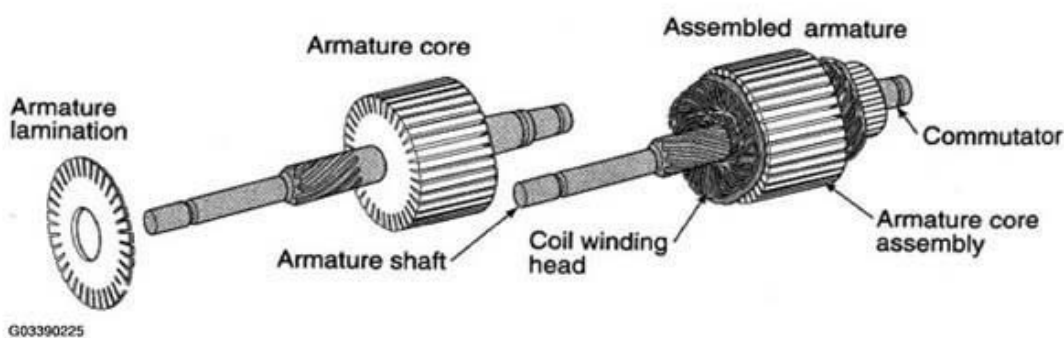


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Fig. 3: Identifying Major Components Of Starter Motor
Courtesy of BMW OF NORTH AMERICA, INC.

Armature

The Armature assembly is comprised of the armature shaft, armature winding, armature stack and commutator. Thin iron stampings are laminated together to form the stack or core. The slots on the outside of the laminations hold the armature windings. The windings loop around the core and are connected to the commutator. Each commutator segment is insulated from the adjacent segments. The commutator may have up to 30 segments. A steel shaft is insert in the center hole of the laminations with the commutator insulated from the shaft.



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Fig. 4: Expanded View Of Armature Assembly
Courtesy of BMW OF NORTH AMERICA, INC.

Field Coils

There are two types of field coils:

- Electromagnetic.
- Permanent magnet.

Electromagnetic

Wire ribbons or coils wrapped around a pole shoe, attached to the inside of the starter housing. The iron pole shoes and the iron starter housing work together to increase and concentrate the strength of the field coils. When current flows through the field coils strong electromagnetic fields with North and South poles are created.

Permanent

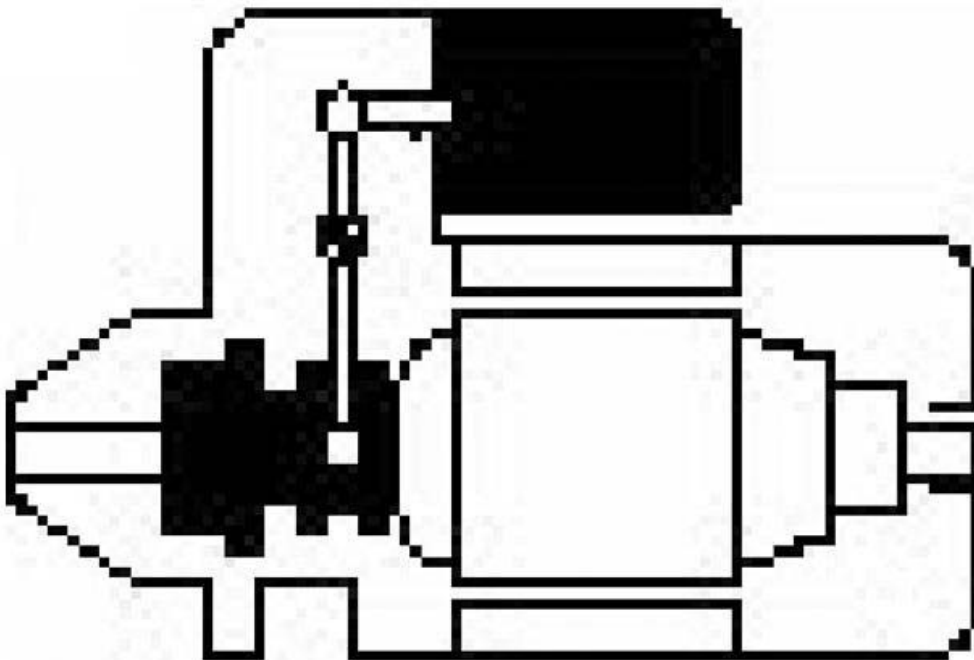
Multiple permanent magnets manufactured from an alloy of boron, neodymium and iron are positioned in the starter housing. Use of permanent magnets allow for the elimination of the field circuit and windings and realize a 50% weight savings.

Brushes

Brushes are electrically conductive sliding contacts, usually made of copper and carbon. The brushes make contact with the commutator and as the starter begins to rotate the brushes reverse the flow of current to the armature. Starter brushes carry the full flow of current through the motor.

Solenoid

The Solenoid assembly is an integral part of the starter and is actually a combined relay and engagement solenoid.



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Fig. 5: Identifying Solenoid Switch And Pinion Engaging Drive
Courtesy of BMW OF NORTH AMERICA, INC.

Solenoid switch and pinion engaging drive.

The solenoid has two functions:

- Pushing the pinion forward so that it engages in the ring gear of the engine.
- Closing the moving contact, providing the main current path for the starter.

The solenoid has two windings.

- Pull-in winding.
- Holding-in winding.

Both windings are used to draw in the plunger and engage the pinon, only the hold-in winding is used to hold the plunger in position.

Pinion Engaging Drive

The starter's end shield assembly contains the Pinion Engaging Drive with pinion, overrunning clutch, engagement lever and spring. The drive mechanism is responsible for coordinating the thrust motion of the solenoid switch and the rotary motion of the electric starter motor and transferring them to the pinion.

The starter engages the ring gear on the flywheel by means of the pinion. A high conversion ratio of pinion teeth to flywheel teeth (between 10:1 and 15:1) make it possible to overcome the high cranking resistance of the engine using a relatively small but high speed starter motor.

As soon as the engine starts and accelerates past cranking speed, the pinion must automatically demesh in order to protect the starter. For this reason, the starter incorporates an overrunning clutch.

STARTER DRIVES

Conventional Drive

In a Conventional Drive starter the pinion gear is located directly on the armature shaft.

The pinion and overrunning clutch form the driver assembly.

The driver assembly rides on a helical spline on the armature shaft so that when the driver is thrust by the solenoid, a combined axial and rotary motion occurs which greatly facilitates the meshing of the pinion.

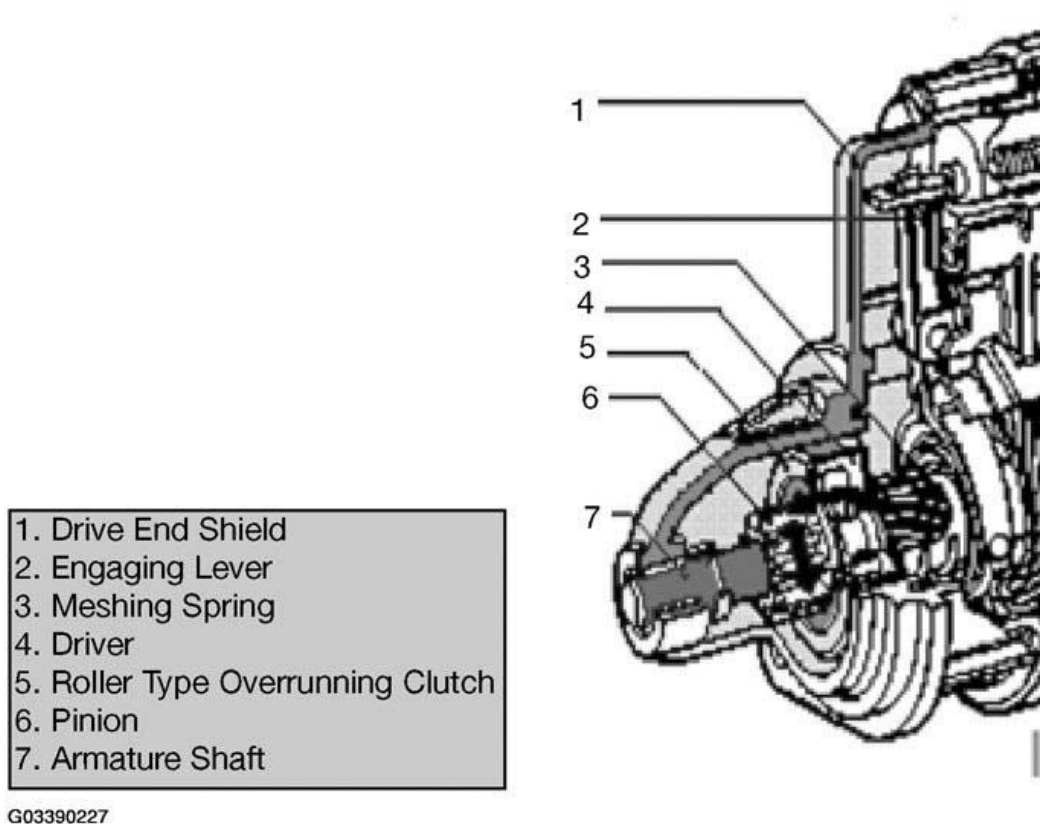


Fig. 6: Identifying Conventional Drive Starter Pinion Gear
 Courtesy of BMW OF NORTH AMERICA, INC.

Gear Reduction Drive

In their design and function, Gear Reduction Drives are much the same as conventional drive starters. The main difference in the gear reduction drive starter is a planetary gear set added between the field frame and the drive end shield. This design allows for the use of smaller and lighter starters.

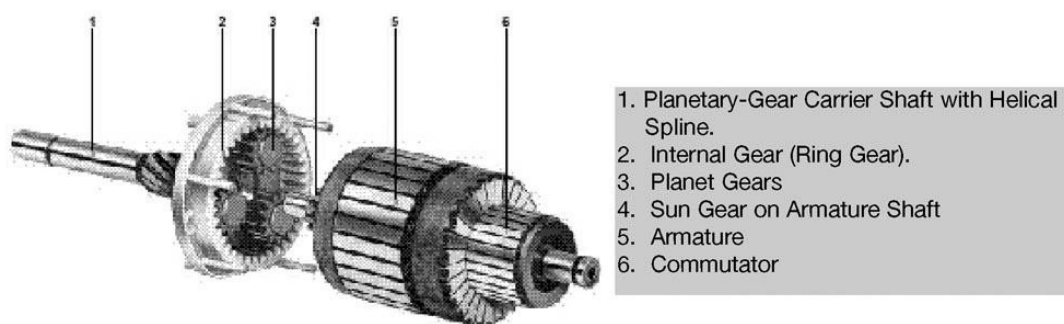
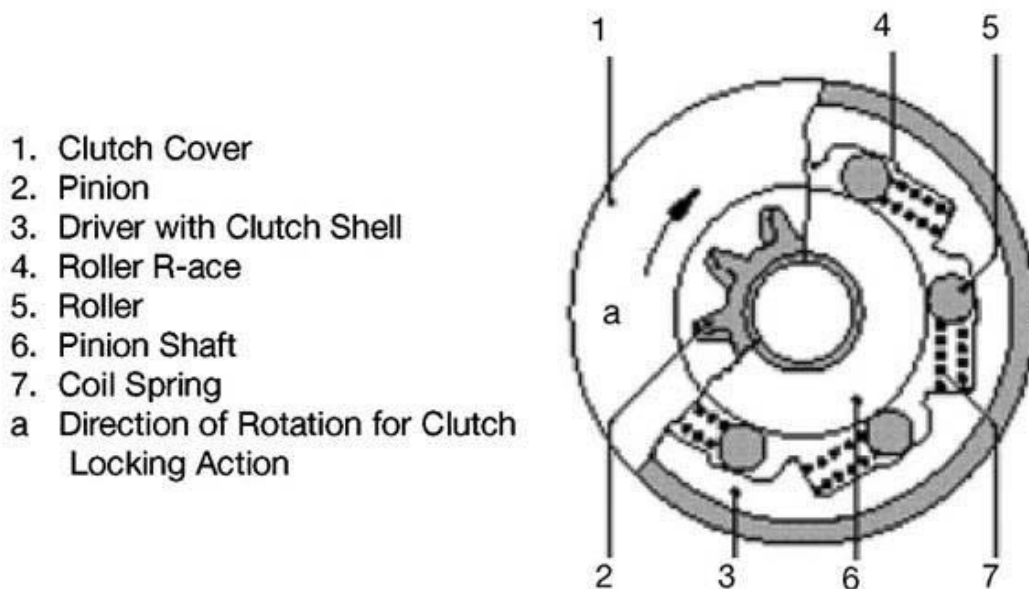


Fig. 7: Identifying Gear Reduction Drive
Courtesy of BMW OF NORTH AMERICA, INC.

OVERRUNNING CLUTCH

In all starter designs the rotary motion is transmitted via an Overrunning Clutch. The overrunning clutch allows the pinion to be driven by the armature shaft (or planetary gear set), however it breaks the connection between the pinion and the armature shaft as soon as the accelerating engine spins the pinion faster than the starter.

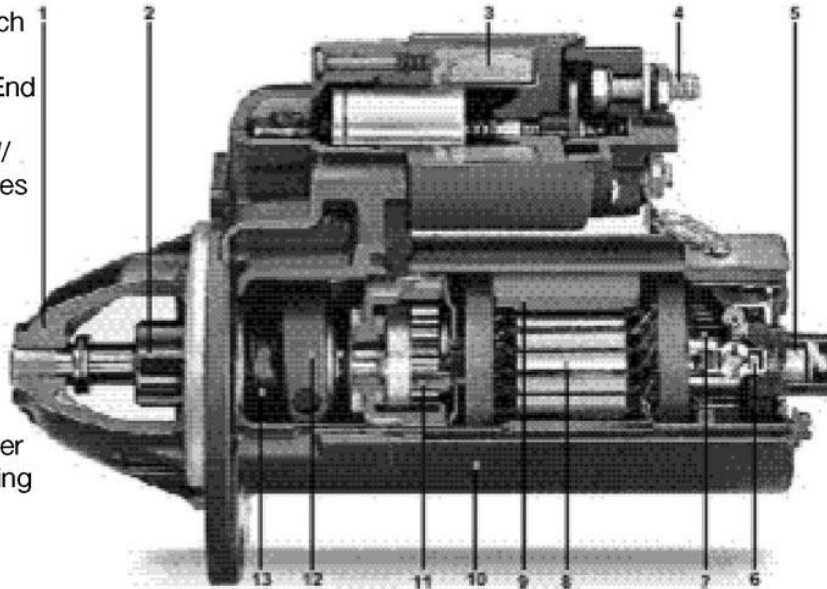
The overrunning clutch is located between the starter motor and the pinion and prevents the starter motor armature from being accelerated to an excessive speed when the engine starts.



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Fig. 8: Identifying Overrunning Clutch Components
Courtesy of BMW OF NORTH AMERICA, INC.

1. Drive End Shield.
2. Pinion
3. Solenoid Switch
4. Terminal
5. Commutator End Shield
6. Brush Plate W/ Carbon Brushes
7. Commutator
8. Armature
9. Permanent Magnet
10. Field Frame
11. Planetary Gear
12. Engaging Lever
13. Pinion Engaging Drive



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Fig. 9: Cross Sectional View Of Starter Motor
Courtesy of BMW OF NORTH AMERICA, INC.

Fully assembled permanent magnet gear reduction starter.

EWS

The EWS system(s) is designed to provide electronic anti-theft protection for the vehicle through the use of coded keys and coded data communication between the EWS and the engine control module. The starter and engine control module are locked out until a properly coded key is recognized and the proper code is established between the EWS and the engine control modules.

Starter Safety Switch

The Starter Safety Switch is part of the transmission range switch on automatic transmission vehicles and a clutch switch on manual transmission vehicles (beginning MY 1997). The purpose of the switch is to prevent engine start-up with the vehicle in gear or the clutch not depressed. On vehicles with EWS, this signal is sent directly to the EWS module for processing.

Cable and Wiring Harness

Cables to the starter from the battery must carry large amounts of current. The wiring harness from the ignition switch and/or EWS carry little current as they are control signals to a relay or starter solenoid. Minimum voltage drop in starter cables is necessary to ensure sufficient starter speed and torque.

PRINCIPLE OF OPERATION

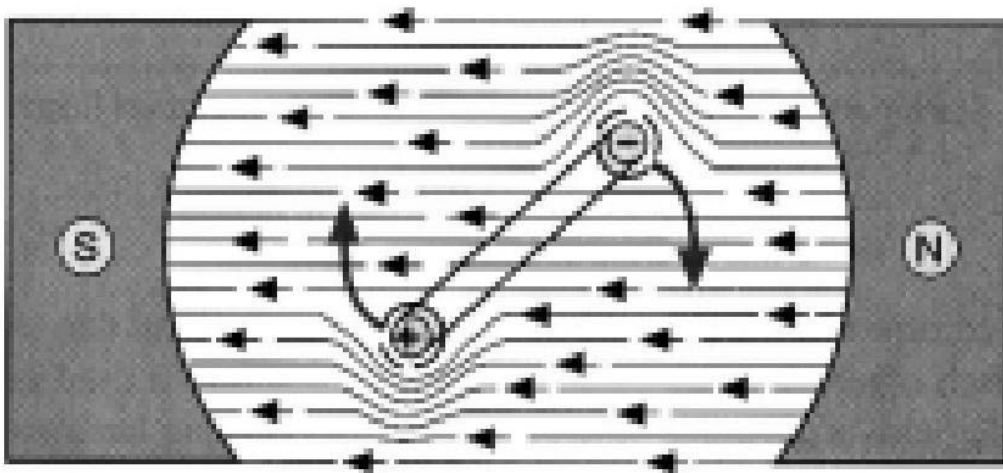
Electric Starter Motor

The Electric Starter Motor converts electrical current into rotary motion. In doing so it converts electrical energy into mechanical energy. The interaction of two magnetic fields produce this rotational force.

The field coils (either electromagnetic or permanent) located in the housing produce magnetic flux lines. Within the stationary field coils is the armature, a loop of wire (a conductor) with one end connected to B+, the other to B-. When current is applied to the armature flux lines circle the loop in one direction on one side and in the opposite direction on the other side. The interaction of the flux lines on the armature and the flux lines from the field coil cause the armature to rotate.

The armature will only rotate to the point where the magnetic force is equal on both sides. (Armature 90° to magnetic flux lines of field) For the armature to continue to rotate, the polarity or direction of current flow must be reversed.

Through the brushes and the commutator, the current flow is reversed as the magnetic forces become equal, causing the armature to continue to rotate.



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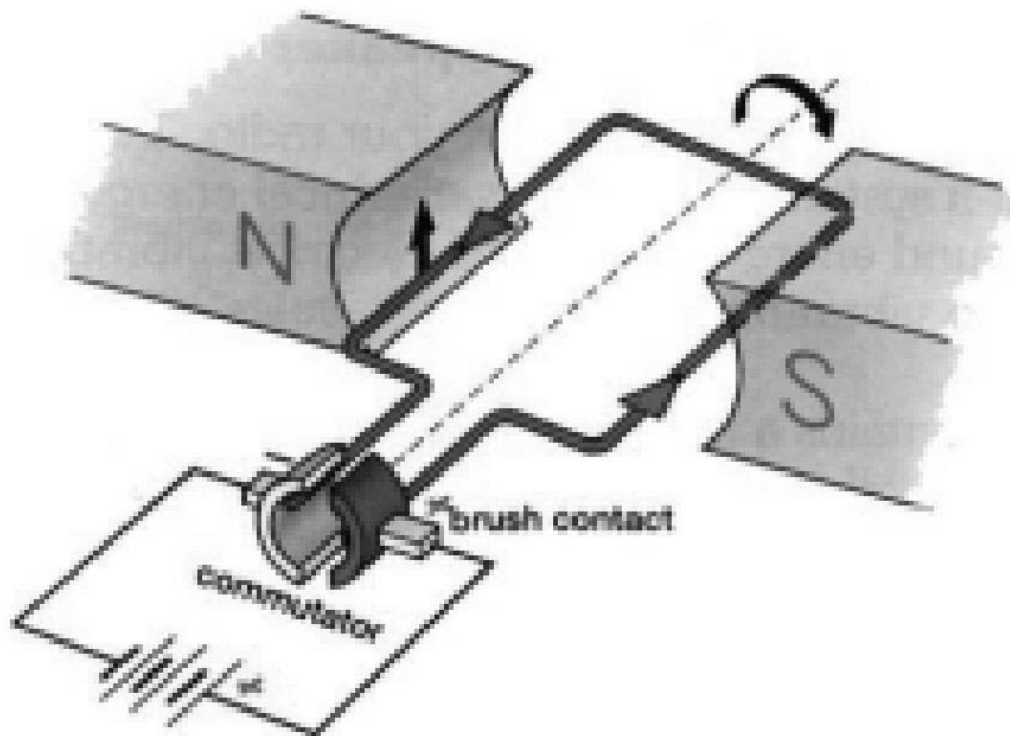
Fig. 10: Identifying Magnetic Flux Lines
Courtesy of BMW OF NORTH AMERICA, INC.

This constant reversal of current flow in the armature provides continual rotation.

Direction of rotation is determined using **Flemings Left Hand Rule**.

- Point your First finger in the direction of the magnetic Field (from N to S).
- Rotate your hand about that finger until your second finger points in the direction of the Current

(conventional current, from + to -).



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Fig. 11: Identifying Magnetic Field
Courtesy of BMW OF NORTH AMERICA, INC.

Loop symbolizes force out of magnetic field.

- Then your thumb points in the direction of the Movement of the wire.

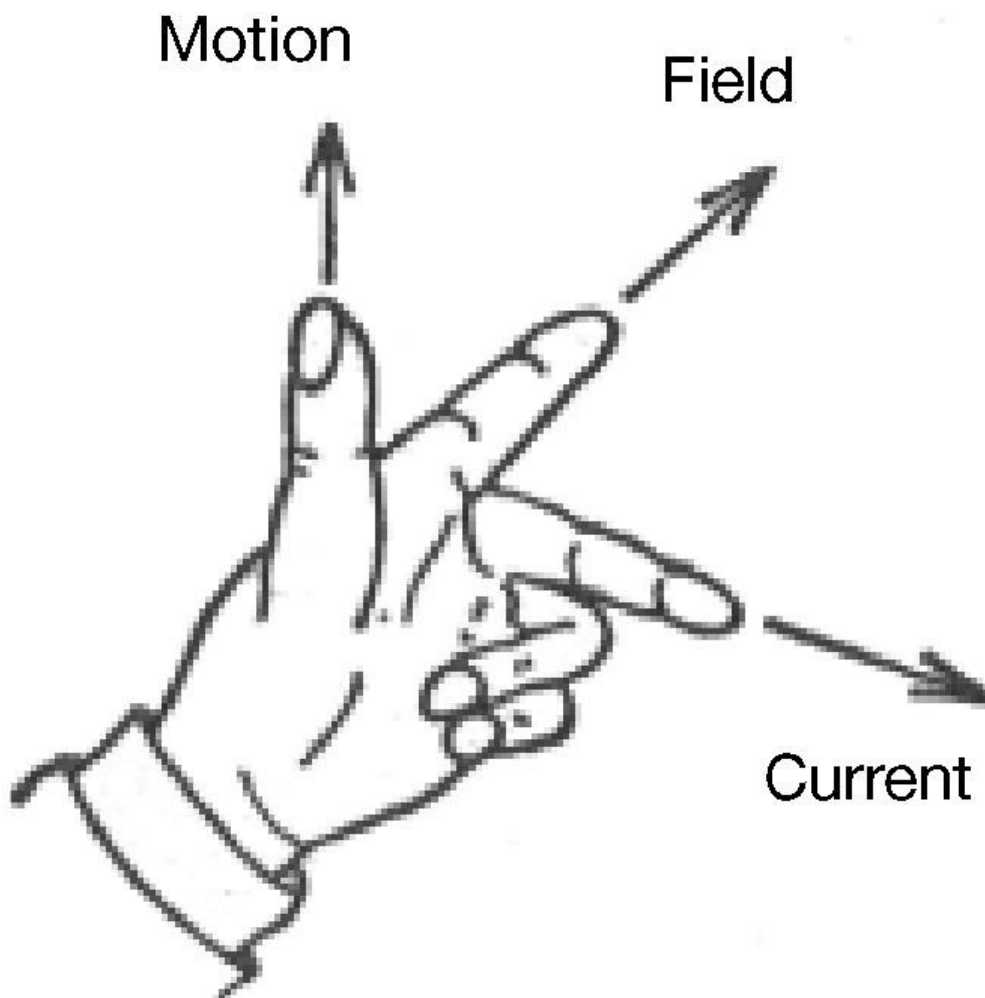
To increase the force on the wire (armature) do one of the following:

- Use a larger current.
- Use a stronger magnetic field.
- Use a greater length of wire in the field.

To increase torque and speed in the starter motor, more windings in the armature are added, and the field has more pairs of magnets (either permanent or electromagnetic).

Flemings left hand rule:

The basic law of motors, the direction of force on a wire that is carrying current when it is in a magnetic field.



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Fig. 12: Illustrating Flemings Left Hand Rule
Courtesy of BMW OF NORTH AMERICA, INC.

MOTOR WINDINGS

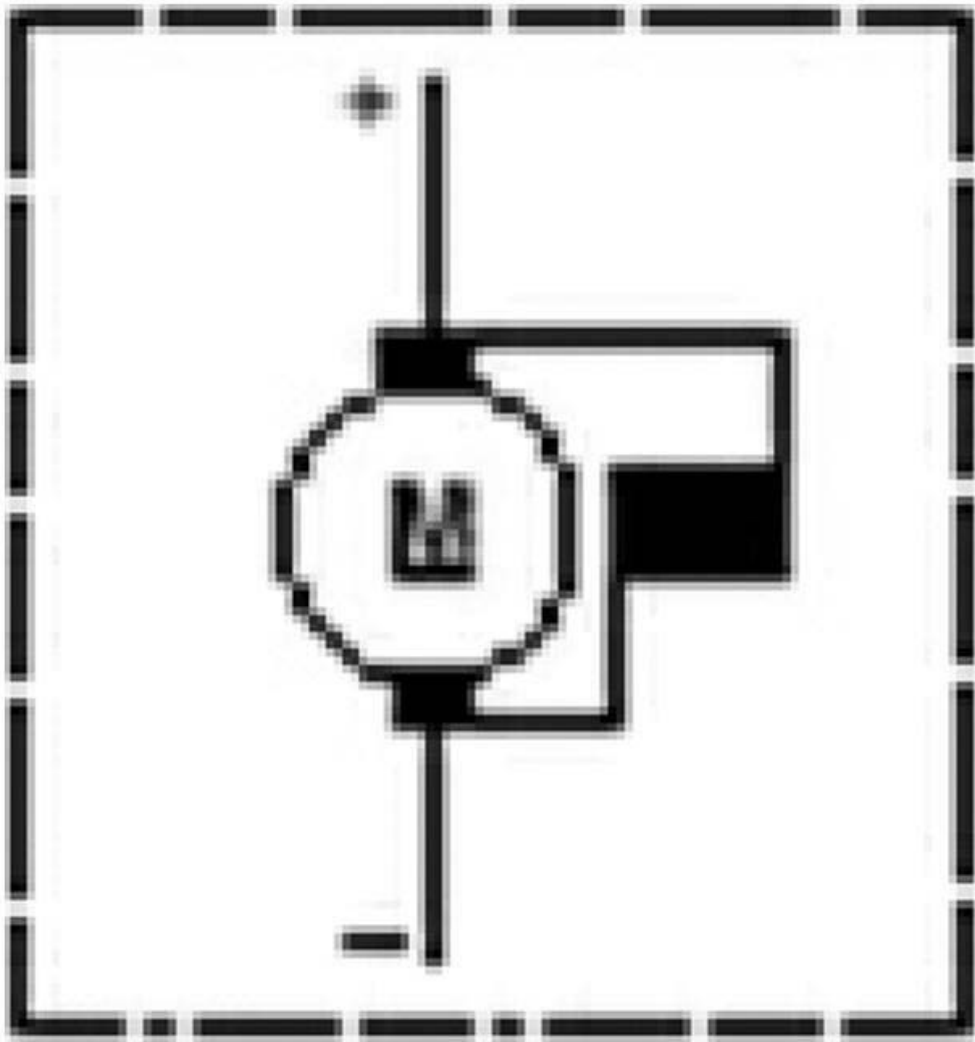
Torque and speed of the starter motor is dependent on the wiring of the field coils (electromagnetic coils).

There are three types of Motor Windings:

- Shunt Wound.
- Series Wound.
- Compound.

Shunt Wound Motors

In Shunt Wound Motors, the field coil is connected in parallel with the armature. The shunt motor does not decrease its torque as speed increases. Shunt motors do not produce high torque.



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Fig. 13: Identifying Shunt Wound Motors

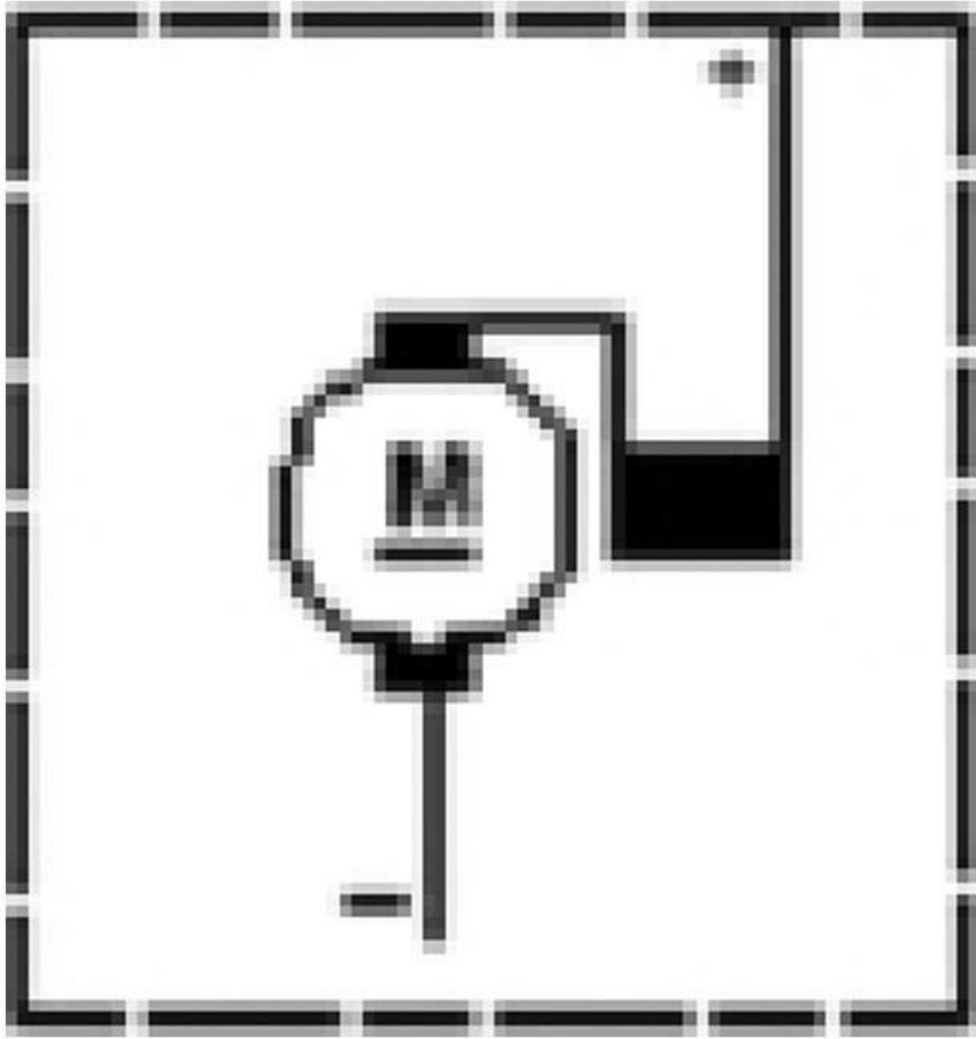
Courtesy of BMW OF NORTH AMERICA, INC.

Series Wound Motors

In Series Wound Motors, the field coil is in series with the armature.

The current flows to the field windings, then to the brushes, commutator, and armature back again to the ground side brush. A series wound motor will develop maximum torque output at the time of initial start, then as motor

speed increases, torque falls off rapidly due to the CEMF.



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Fig. 14: Identifying Series Wound Motors
Courtesy of BMW OF NORTH AMERICA, INC.

Compound Wound Motors

Compound Wound Motors have some of the field coils wired in series to the armature and some in parallel. This configuration allows the compound motor to develop good starting torque and constant operating speed.

CEMF:

Counter Electromotive Force.

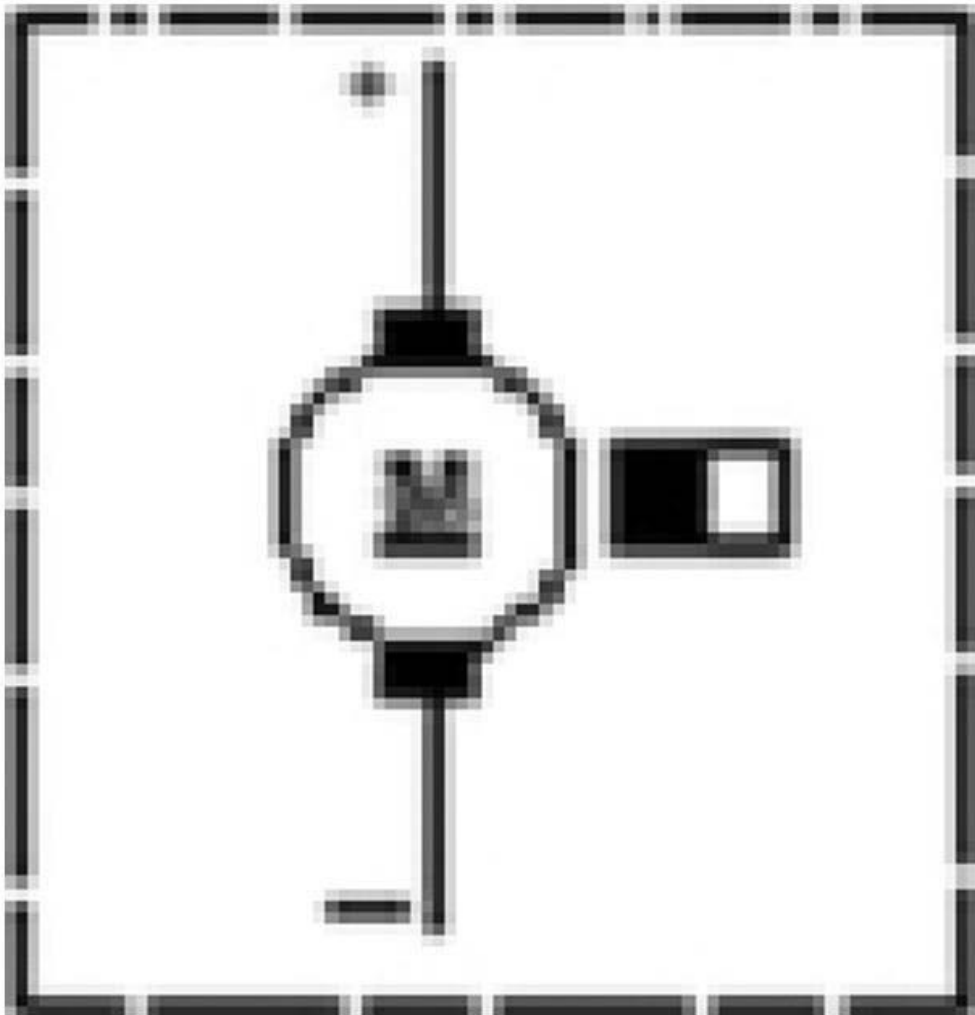
The voltage produced in the starter motor itself through electromagnetic induction.

This voltage acts against the supply voltage from the battery.

Motors must be designed to control the CEMF for optimum operation.

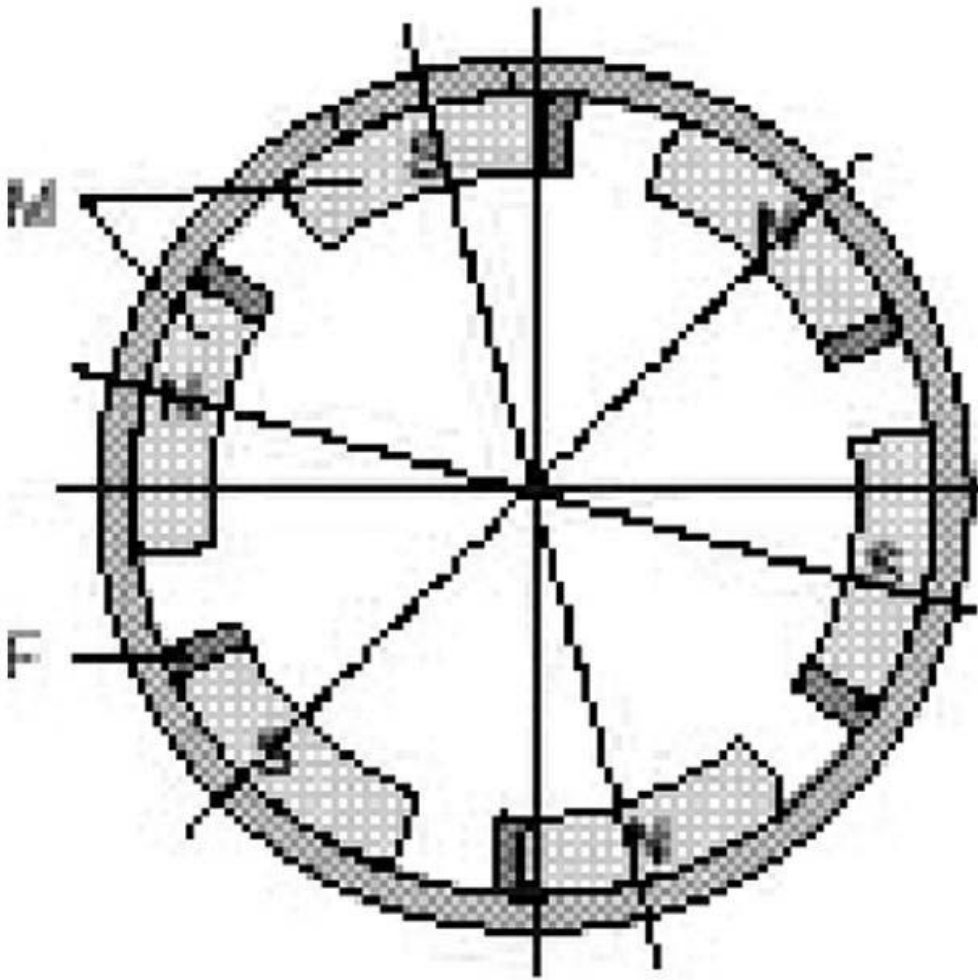
Permanent Magnet Motors

Permanent Magnet Motors eliminate all wiring to the field coils. The magnetic field is generated by the permanent magnet without the need for winding and pole shoes. The magnets use flux-concentrating pieces to direct the magnetic field.



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Fig. 15: Identifying Permanent Magnet Motors
Courtesy of BMW OF NORTH AMERICA, INC.



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Fig. 16: Identifying Permanent Magnets With Flux Concentrating Pieces
Courtesy of BMW OF NORTH AMERICA, INC.

Arrangement of permanent magnets (M) with flux concentrating pieces (F).

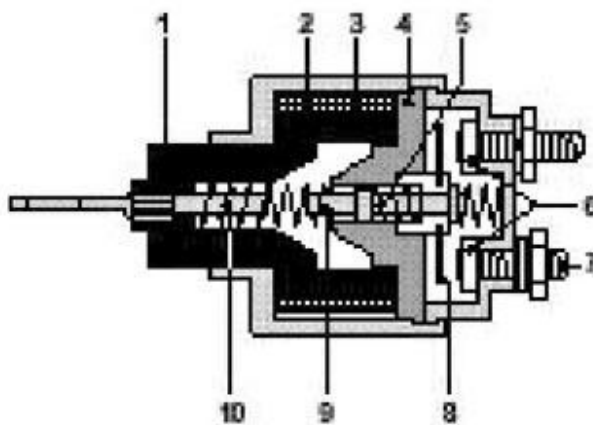
SOLENOID

The Solenoid performs the following functions:

- Pull the pinion to engage the flywheel.

- Hold the pinion engaged with the flywheel during starting rotation.
- Complete the electrical circuit from the battery to the brushes of the starter.
- Cause the pinion to retract from the flywheel.

Two windings are used to pull and hold the pinion engaged to the flywheel.



1. Armature (relay)	2. Pull-in winding
3. Hold-in winding	4. Solenoid armature
5. Contact spring	6. Contacts
7. Terminal	8. Moving contact
9. Switching pin	10. Return spring

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Fig. 17: Identifying Solenoid Components

Courtesy of BMW OF NORTH AMERICA, INC.

Pull-In Winding- The stronger of the two windings, used to pull the pinion into engagement. This winding is released when the starter circuit is completed.

Hold-In Winding- Used to help the pull-in winding move the pinion initially, then holds the pinion engaged to the flywheel.

Signal 50 is received at the solenoid, energizing both windings. The windings cause the armature to be drawn into the coils, pressing on a spring, causing the moving contacts to close. The pull-in winding is released, the starter begins to turn. When signal 50 is released, the power is lost to the hold-in winding, spring pressure forces the armature out of the coil, the moving contacts are opened and the pinion returns to the rest position.

Workshop Hint:

The starter motor does not begin to spin until after the pinion is engaged in the flywheel.

This aids in the meshing of the pinion and flywheel

Workshop Hint:

Battery voltage is critical.

The combination of the pull-in winding and the hold-in winding may have sufficient power to engage the pinion. When the moving contacts are completed and the increased load of the starter motor is added to the system, low voltage will cause the hold-in winding to release the pinion. If signal 50 is still present the pull-in winding will again assist in pulling the pinion into engagement and the cycle starts over again. This gives the "clicking" noise from the starter.

Pinion Drive

The Pinion Drive gear is attached to the roller-type overrunning clutch which is splined via a helical shaft to the starter armature. At rest the spring pressure in the overrunning clutch wedge rollers between the pinion shaft and the clutch hub race. This locks the pinion to the clutch. During start-up the clutch and pinion rotate as one.

As the engine speed exceeds starter speed, the pinion pushes the rollers, against the spring pressure, into a wider area. This movement of the rollers allow the pinion to turn independently of the starter armature, not causing the armature to overspeed.

When the solenoid windings are released the clutch assembly is pulled away from the flywheel through spring pressure.

Phases of Starter Operation

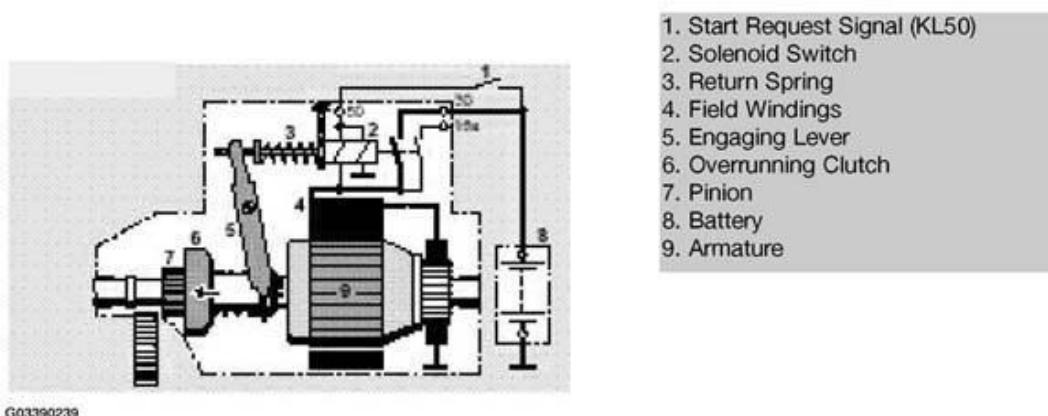


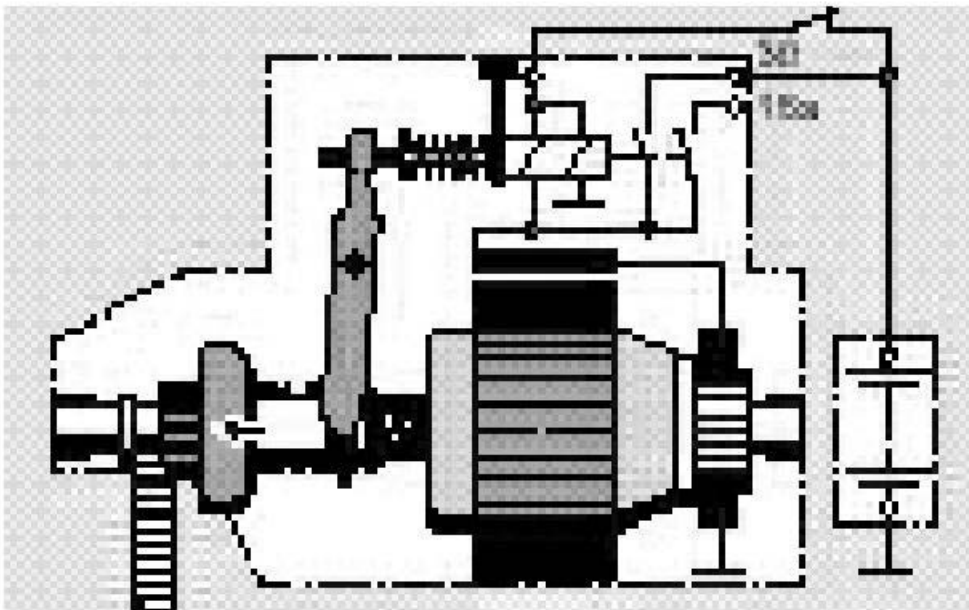
Fig. 18: View Of Starter At Rest

Courtesy of BMW OF NORTH AMERICA, INC.

Starter at rest, no current supplied.

Pull-in and hold-in winding energized.

Pinion tooth meets gap in ring gear and meshes.



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Fig. 19: Identifying First Phase Of Starter Operation
Courtesy of BMW OF NORTH AMERICA, INC.

Starter position just before Main current is switched on.

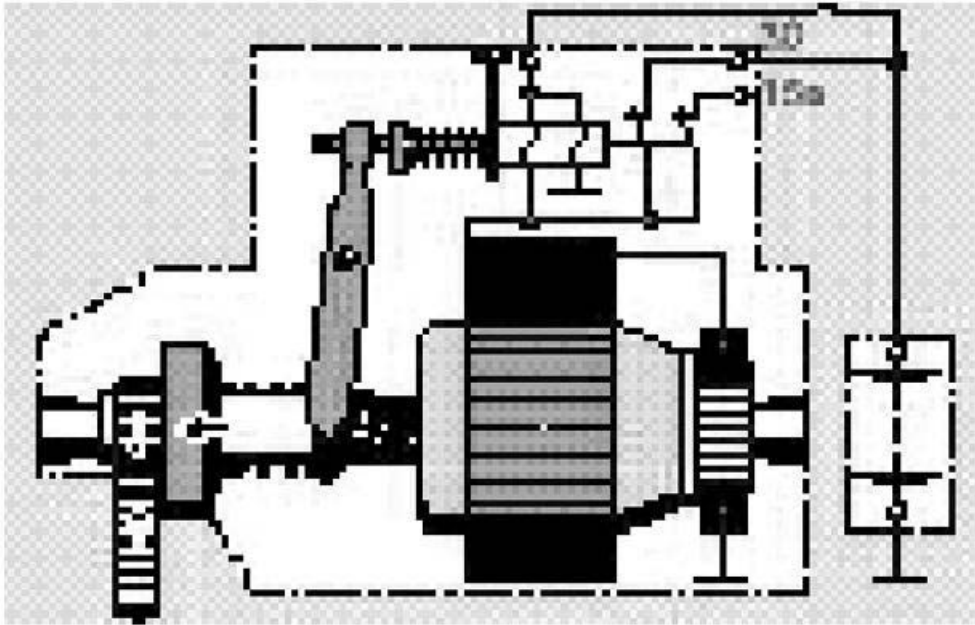
Engaging lever in end position.

Pull-in winding released.

Pinion meshed.

Main current flows.

Engine is rotated.



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Fig. 20: View Of Starter Operation
Courtesy of BMW OF NORTH AMERICA, INC.

Engine is cranked.