Table of Contents

Brake Systems

Initial Print Date: 10/11 Revision Date: 11/13

Subject	Page

Brake Systems

Model: All

Production: All

OBJECTIVES

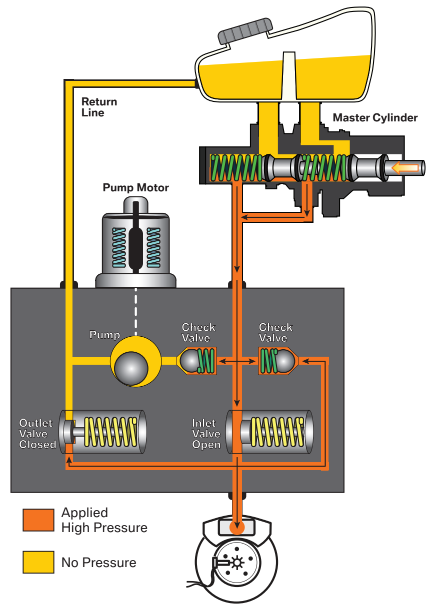
After completion of this module you will be able to:

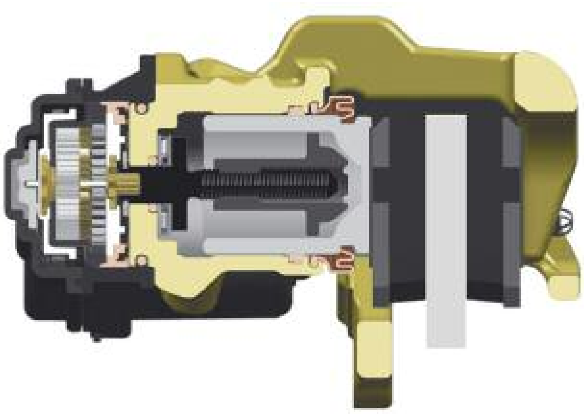
- Understand shop safety pertaining to brake systems.
- Acquire a fundamental knowledge of hydraulics and all aspects of vehicle braking systems.
- Able to diagnose, inspect, service and repair BMW braking systems.
- Diagnose, service and repair BMW antilock brake systems.

Introduction

The ability of a braking system to provide safe, repeatable stopping, is a key to safe motoring. A clear understanding of the brake system is essential for anyone involved in servicing automobiles.

Many aspects of slowing and stopping a car are controlled by simple physics. These are the natural laws, dealing with deceleration of a body in motion, which cannot be violated. An understanding of these basic principles will aid greatly in thoroughly understanding brakes and the limitations placed on them by the laws of physics.





Shop Safety

Asbestos

Probably the biggest health concern associated with brakes is working with asbestos. Studies have shown that breathing asbestos dust is a cause of lung cancer. Even though asbestos is being eliminated in friction material, it is simply not healthy to breathe any type of brake dust. **Using compressed air is not an acceptable practice when it comes to cleaning brakes**. Asbestos fibers can remain airborne for hours, and remain in shops for weeks.

Please adhere to the following recommendations:

- Avoid breathing brake dust.
- Do not use compressed air to blow out brake dust.
- Spray water or other dust suppressant on floors before sweeping dust.
- Wash hands and other exposed skin thoroughly after working around brake dust.
- Use OSHA approved aqueous solution brake washer to clean brakes.
- Change out of work cloths before going home.

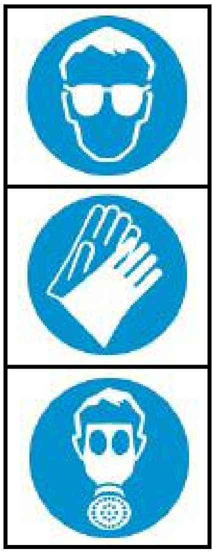
OSHA

The Occupational Health & Safety Administration is the federal agency charged with setting work place standards for automotive Brake Service. Though these standards were originally designed for working with asbestos, it is good practice to apply them to working with any type of friction material. The long term effect of working around non-asbestos lining material is still not certain.

The cleaning method approved by OSHA is the low pressure/wet cleaning method when dealing with brake dust. This is a portable parts washer that uses water containing an organic solvent as a wetting agent. As the wheel brake is washed down the residue is collected in a basin. A special filtering system removes the dirt and dust from the fluid as it is recycled through the machine. This wet cleaning method is preferred since it is good at keeping airborne dust to a minimum.

Basic Safety Procedures

As working technicians, you are familiar with basic shop practices. However, there are some basic items that will be emphasized for this class.



Eye Safety
The single most important safety practice is wearing safety glasses in the shop. Eye protection is essential not only for keeping dirt and dust out of your eyes, but also when removing and installing brake hardware or when working with machining tools such as a lathe.

Clothing
Avoid wearing loose clothing that may get caught on rotating components or power tools.

Respiratory
Avoid breathing brake dust.

Fundamentals of Braking

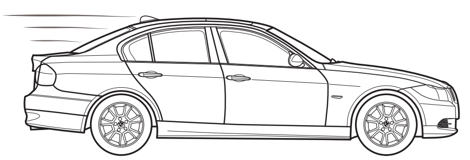
Heat / Kinetic Energy

Motivating and stopping a vehicle is a cycle of heat energy. The engine uses hydrocarbons and oxygen to generate heat energy. Energy can not be created or destroyed, it can only be converted into another form of energy. In the case of an automobile, heat energy is converted into kinetic energy when the vehicle is put in motion. The amount of energy of a moving object such as a car can be calculated by using the formula.

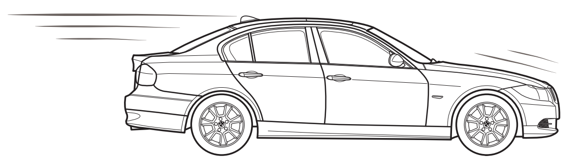
$$\frac{\textbf{Weight} \times \textbf{Speed}^2}{\textbf{29.9}} = \textbf{Kinetic energy (ft-lb)}$$

Unless you're an engineer you will have very little use for this formula. What this formula clearly explains is that if you double the weight of a car you double the kinetic energy, but if you double the speed of the vehicle you will quadruple the kinetic energy.

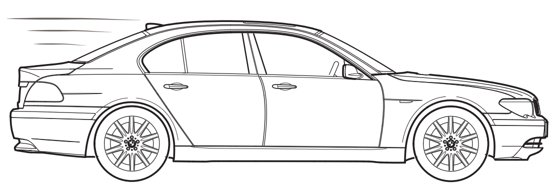
The job of a vehicle's brake system is to convert the kinetic energy of the moving vehicle into heat energy using friction as a medium; hence it becomes a cycle of heat energy.



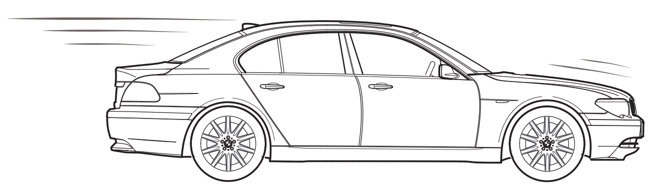
$$\frac{\text{3,000 lbs} \times 30^2\text{mph}}{29.9} = \text{90,301 ft-lbs}$$



$$\frac{\text{3,000 lbs} \times 60^2\text{mph}}{29.9} = \text{361,204 ft-lbs}$$



$$\frac{\text{6,000 lbs} \times 30^2\text{mph}}{29.9} = \text{180,602 ft-lbs}$$



$$\frac{\text{6,000 lbs} \times 60^2\text{mph}}{29.9} = \text{722,408 ft-lbs}$$

Vehicle Kinetic Energy Comparison

The following table compares the total kinetic energy of six unique vehicles at four different speeds. Due to the nature of energy calculations, the units are given in foot-pounds. Since torque also is expressed in units of foot-pounds this can be a little confusing, but regardless of the units used, note the extreme differences in kinetic energy between the various conditions.

Kinetic Energy (in ft-lb)

Vehicle	35 mph	75 mph	150 mph	225 mph
200-lb soap box derby car	8,194	37,625	150,502	338,629
400-lb race cart	16,388	75,251	301,003	677,258
600-lb sport bike	24,582	112,876	451,505	1,015,886
1,900-lb formula car	77,843	357,441	1,429,766	3,216,973
3,000-lb passenger car	122,910	564,381	2,257,525	5,079,431
80,000-lb tractor trailer	3,277,592	15,050,167	60,200,669	135,451,505

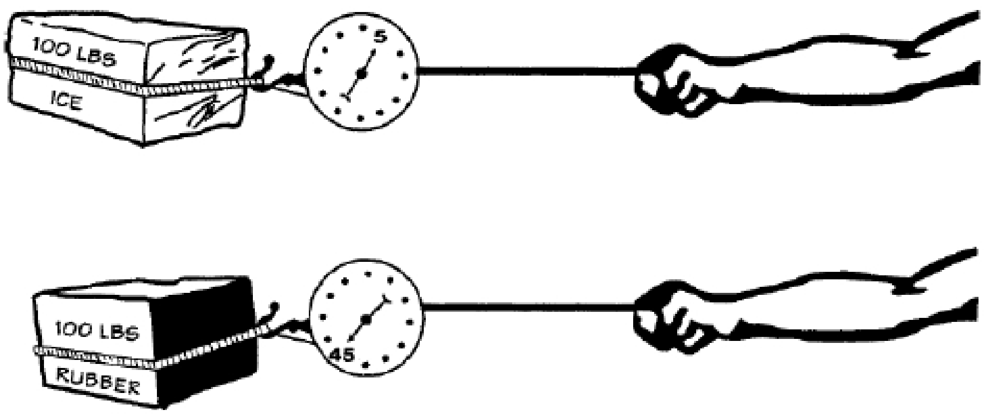
Not all of these vehicles are capable of reaching the speeds listed, the data allows for some interesting comparisons. For example, a 600 lb sport bike at 150 mph has less kinetic energy than a 1,900 lb formula car traveling at half that speed, while an 80,000 lb tractor trailer traveling at just 35 mph has the same amount of kinetic energy as a 1,900 lb formula car traveling at over 225 mph!

Friction

Friction is the resistance of movement between two objects in contact with each other. Friction produces heat. The brake lining, also known as friction material, is designed to produce heat from friction as it rubs against the brake disc or drum. The amount of heat produced is determined by the coefficient of friction between the lining and the disc, the amount of pressure pushing them together, and the relative speed of each.

Coefficient of Friction

The coefficient of friction is calculated by dividing the amount of drag needed to move the object by the amount of force pushing them together.



The above example illustrates how the type of friction surface and the material can influence the coefficient of friction (COF).

Example:

100 pounds of ice pulled across a concrete floor might require 5 pounds of force to move.

5 lbs force / 100 lbs = 0.05

COF = 0.05

However 100 pounds of rubber pulled across a concrete floor might require 45 pounds of force to move.

45 lbs force / 100 lbs = 0.45

COF = 0.45

This example also applies to the brake system. The coefficient of friction varies on the type of brake lining used and the condition of the drum or rotor surface.

Surface Effects on Maximum Deceleration

A vehicles maximum deceleration is always limited by the maximum coefficient of friction available at the contact patch. While the values shown below are approximate, they are quite representative of what you can expect to encounter in the real world with typical performance tires.

Condition	Mu peak (unitless)	Maximum deceleration (g)
Glare ice	0.1-0.2	0.1-0.2
Wet grass	0.2-0.4	0.2-0.4
Packed snow	0.3-0.6	0.3-0.6
Loose gravel	0.4-0.7	0.4-0.7
Wet pavement	0.6-0.8	0.6-0.8
Dry pavement	0.8-1.0	0.8-1.0
Dry pavement with race tires	1.3-1.6	1.3-1.6

Tire selection and condition is critical for proper brake performance.

Brake Pad Edge Codes

The average coefficient of friction for brake linings is 0.3. The coefficient of friction can easily be determined by the edge code on the edge of the lining or on the backing plate.

Official D.O.T. Edge Code	Coefficient of Friction (C.F.) @ 250° F and @ 600°F	Comments
EE	0.25 to 0.35 both temps	0-25% fade at 600°F possible
FE	0.25 to 0.35 @ 250°F 0.35 to 0.45 @ 600°F	2% to 44% fade at 600°F possible
FF	0.35 to 0.45 both temps	0-22% fade at 600°F possible
GG	0.45 to 0.55	Very Rare
HH	0.55 to 0.65	Carbon/Carbon only. O.K. up to 3000° F where it glows

The edge code is composed of three groups of numbers and letters.

The first group identifies the manufacturer of the lining.

The second group of digits identifies the composition of the lining.

The third group is two letters that identify the coefficient of friction when the material is cold and hot.

FF pads are usually considered the minimum for a high-performance pad.

1st Group	2nd Group	3rd Group
JURID	187	FF

Brake pad edge code

Swept Area

Swept Area (SA) is an engineering term that is directly related to the amount of friction that can be generated and the amount of heat that can be dissipated. This is the area of the rotors or drums that is swept or rubbed by the brake pads or shoes. To calculate the swept area for a rotor the following formula can be used.

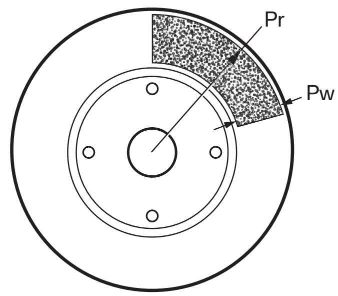
Disc Brake

SA = Pr2 x π - [(**Pr** - **Pw**)2 x π]

Where: **SA** = swept area

Pr = pad radius to outer edge

Pw = pad width



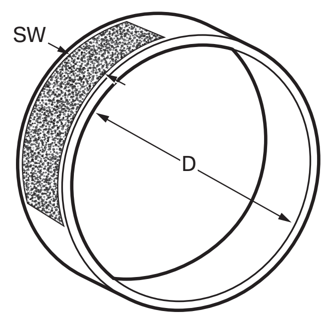
Drum Brake

SA = D x π x Sw

Where: **SA** = swept area

D = drum diameter

SW = shoe width



Most passenger cars use a swept area of about 200 square inches of lining for every 2,000 lbs of vehicle wait. Road racing vehicles that place a severe load on their brakes will use double the swept area or about 400 square inches of lining for every 2,000 lbs of vehicle weight.

Weight Transfer & Weight Bias

Another factor that affects the braking performance of any vehicle is weight transfer and bias. Newton's first law of motion dictates that a moving vehicle will remain in motion unless acted upon by an outside force. The vehicle brakes provide that outside force, but when the brakes are applied at the wheel only the wheels and tires slow immediately. So technically all of the vehicle weight that is supported by the suspension, attempts to remain in motion, the result if the vehicle is traveling forward is that the front springs compress and the rear springs extend and weight is transferred to the front of the car. The total weight of the vehicle is not changed only the amount supported by each axle.

With regard to the brakes this means that the front brakes must satisfy a much higher braking requirement than the rear brakes. To help offset this physical characteristic; BMW's are engineered with a weight bias that is at, or very close to, 50% on each axle when the vehicle is not in motion. This not only benefits the vehicles cornering capability but its braking performance as well.

Brake Fade

The fact that brake components are forced to absorb the heat of braking, there may come a time when the brakes are forced to absorb more heat than they can dissipate to the surrounding air. A brake rotors temperature will rise more than 100 F (55 C) in a matter of seconds during a hard stop, but it can take a minute or more for a rotor to cool to its temperature before the stop took place. If repeated hard stops are necessary then the brake system can overheat and lose effectiveness. This loss of braking power is called Brake Fade.

The point at which a brakes fade is determine by a number of factors including brake design, its cooling ability and the type of friction material used.

There are four primary types of brake fade, three of which are caused by heat:

- Mechanical Fade (drum brakes)
- Lining Fade
- Gas Fade
- Water Fade (not cause by heat)

Mechanical Fade
Brake fade caused by heat expansion of the brake drum away from the linings. The drum expands to the point where the clearance between the shoes and the drum cause the pedal travel to increase. This type of fade is exclusive to drum brakes and not disc brakes.

Lining Fade
This type of fade occurs from overheating of the friction material to the point where the coefficient of friction drops off. This type of fade can occur on both disc and drum brake systems.

Gas Fade
Brake fade caused by a thin layer of hot gases and dust generated by the friction material that reduces the friction between the linings and the rotor or the drum.

Water Fade
Water fade is when a hydro-dynamic layer of water accumulates between the linings and the friction material, decreasing the coefficient of friction. This is much less of a problem on disc brakes when compared to drum brakes, however our own engineering studies do show a slight decrease in disc brake performance when the brake discs are wet. This is the reason for development of “Brake Dry” on many newer BMW DSC systems.

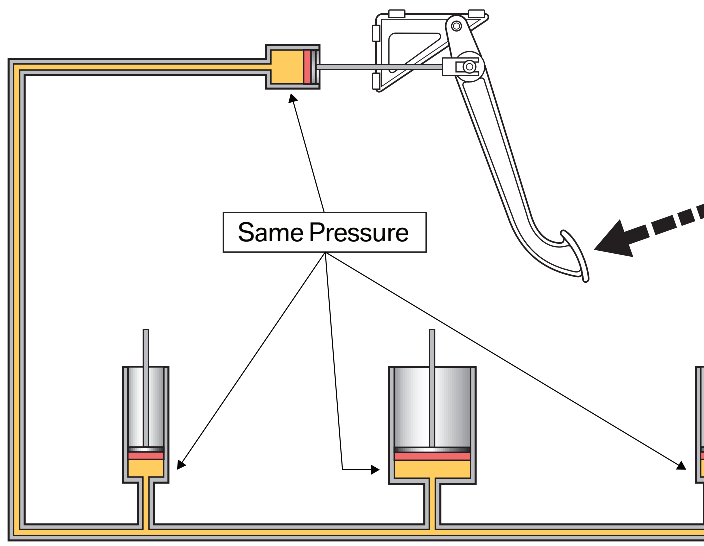
Brake System Hydraulics

Hydraulic Principles

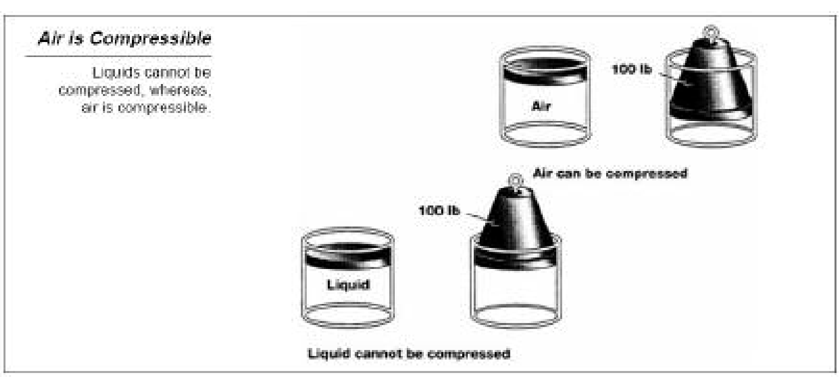
Simply defined, hydraulics is the science and technology of the behavior of fluids. Modern automotive brake systems operate according to the basic laws of hydraulics.

Pascal's Law
This law states that liquid in a confined area applies pressure equally in all directions. This statement, based on the fact that liquid cannot be compressed, has two principles hidden in it. Pressure is equal in all areas of a container holding pressurized fluid and pressure can be transferred from one area to another

Pascal's Law
Pressure applied anywhere to an enclosed body of fluid is transmitted equally to all pans of the fluid.

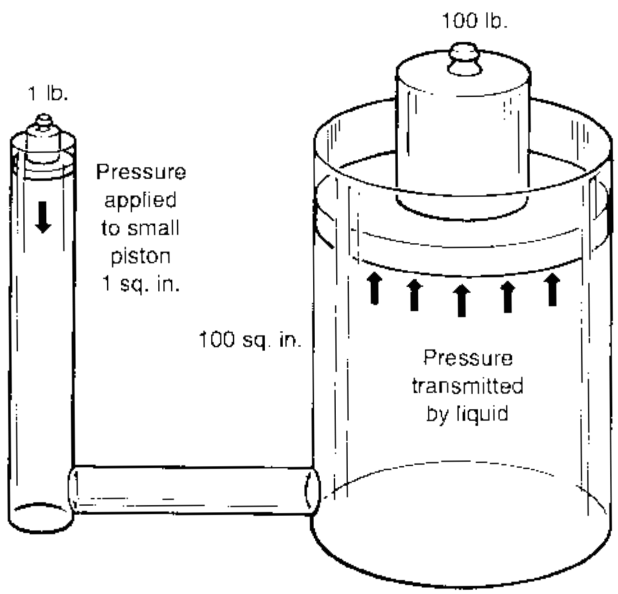


Compressibility
For all practical purposes, liquids do not compress when placed under pressure. For Pascal's Law to be applicable there must not be any air or gas present in the system. It would seem obvious that any trapped air will compress under pressure and reduce the output of the system. Bleeding the brake system has always been a necessary procedure after opening the hydraulic circuits because of this. Later in this course you will learn that there are many bleeding techniques but because of the intricacies of BMW's brake systems there is a way to do it with the highest efficiency.



Hydraulic Pressure vs. Working Force

Though pressure is equal in all parts of a hydraulic system, the working/output force can vary. As you can see by the diagram the working force will vary even though the pressure applied to all of the pistons is the same.

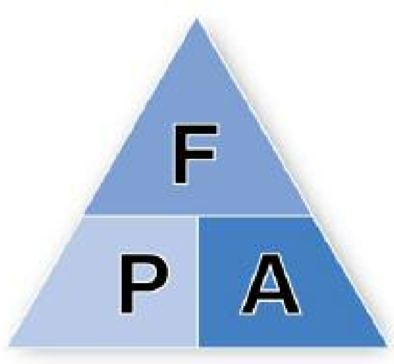


The formula that describes this principle is similar to the Ohm's law triangle.

Pressure x Area = Force

Force ÷ Pressure = Area

Force ÷ Area = Pressure



F = Force

P = Pressure

A = Area

Hydraulic Transfer of Motion

Another important property of a hydraulic system is the transfer of motion from one part of the system to the other.

Illustration "A"

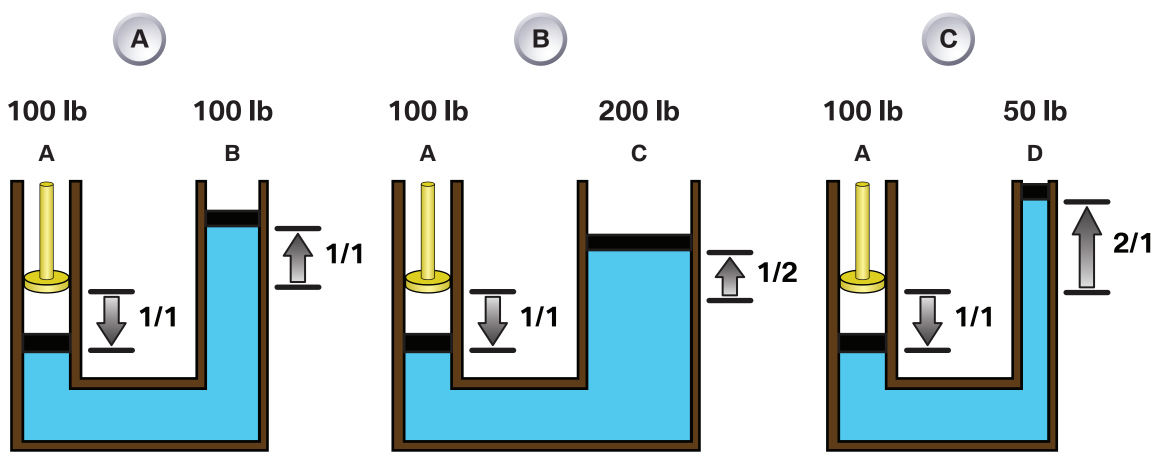
Show's that if the input piston 'A" is equal to the output piston "B" the distance travelled is equal as well as the input and output forces.

Illustration "B"

When the area of the output piston "B" is double that of the input piston "A", the output force is doubled but the output piston only moves half the distance.

Illustration "C"

If the output piston "B" is reduced to half the input piston "A", the effect is to reduce the working force in half but double the distance travelled by the piston.



Pressure = force ÷ area

Force = pressure x area

A = 1 sq. in.
B = 1 sq. in.
C = 2 sq. in.
D = 1/2 sq. in.

NOTES PAGE

Brake Fluid

This is a specially formulated hydraulic fluid that is designed to comply with the standards set by automotive engineering and safety organizations, such as SAE and DOT.

Some of the standards brake fluid must meet are:

- It must have a stable viscosity and be free flowing at all operating temperatures.
- High boiling points are required so that the fluid remains a liquid at the high operating temperatures that the fluid in the hydraulic system is exposed to.
- Low freezing points are required so the fluid does not freeze at extremely low temperatures.
- The brake fluid must be non-corrosive to the metal, rubber and composite materials used in the brake system. It should also prevent corrosion or rust formation in the system.
- Brake fluid must have lubricating properties to inhibit wear to seals and other moving parts.
- Brake fluids must have very low compressibility.

BMW introduced a lower viscosity brake fluid in 2001. It is designated DOT 4 ESL and was engineered to have better cold temperature properties. This started with E53 4.6is and is due to of the elimination of the DSC pre-charge pumps. It is OK to “top up” earlier vehicle with the ESL type fluid, however conventional DOT 4 must not be used on any BMW vehicles from 2001on.

Reference SIB# 34 09 01 for more information

Brake fluids in use today can be separated into two general categories: glycol-based and silicon based. The key point to understand with these two types of fluid is that they are chemically different, will not blend but by law are chemically compatible.

What this means is that no damaging reaction takes place when the two types of fluids are combined. Although the fluid may not blend together in a single solution, it does not affect the properties of liquid under pressure. These differences mean that the fluid behaves differently with regard to their boiling points, compressibility and their ability to absorb moisture and air.

Glycol-based fluids have a lower boiling point than silicone-based fluids. Also glycol-based fluids are hygroscopic. This means that they have the ability to absorb moisture, which in turn will reduce its boiling point. Glycol-based brake fluids will damage painted surfaces so contact with these surfaces should be avoided.

Silicon fluids are not hygroscopic and therefore have virtually no rust or corrosion problems. It has a higher boiling point and can be used in higher heat applications. It will not harm paint when it comes in contact with it. It will have up to three times as much dissolved air versus glycol fluids.

This characteristic can make it very difficult to bleed the hydraulic system of trapped air. The other issue that arises with this higher amount of trapped air is that silicone fluid will “off gas” at altitudes greater than 5,000 feet (1,500m). This changes the fluids compressibility characteristics, which has a dramatic effect on the feel and travel of the pedal.

Silicone-based fluid is not recommended for any vehicles with ABS because the fluid will have a tendency to foam when exposed to the rapidly changing pressures and forced through small openings, which is typical of ABS systems. Another major drawback of silicone fluid is that it is considerably more expensive.

Silicon based brake fluid is not approved by BMW and should never be mixed with any other type of fluid. The entire system must be completely flushed if the fluids are mixed.

Brake Fluid Boiling Points

Heat is one of the brake systems biggest enemies. Excessive heat wears out mechanical parts and can cause brake fluid to boil, causing the system to vapor lock. Obviously if the fluid in a brake system turns into a vapor it becomes compressible and the brake pedal will become spongy and ineffective.

A major factor that lowers the boiling point of brake fluid is the presence of moisture in the system. Moisture can penetrate through flexible hoses, seals and reservoir. BMW engineering studies show the boiling point of brake fluid will drop by 100ºC (212ºF) with 3% water absorption.

The DOT specifies two boiling points for each brake fluid grade; The DRY boiling point which is for fresh, uncontaminated fluid with no water absorption. The wet boiling point, which is more critical, is the point at which brake fluid will boil with a specific amount of water absorption. The technical term for this standard is the Equilibrium Reflux Boiling Point (ERBP).

Brake Fluid Grades

DOT 3

This is a glycol-based fluid that is the most commonly recommended by vehicle manufactures (Not BMW). Its dry boiling point is 401ºF (205ºC). It's wet boiling point is 284ºF (140ºC). It is hygroscopic, meaning it will absorb moisture. The DOT specifies this fluid should be colorless to amber.

DOT 4

This is also a glycol-based hydraulic fluid. It is a heavy duty brake fluid that has a higher boiling point than DOT 3. Its dry boiling point is 446ºF (230ºC) and its wet boiling point is 311ºF (155ºC). DOT specifies this fluid be colorless to amber.

DOT4 ESL

This is a glycol-based fluid with wet and dry boiling points that are similar to standard DOT 4 fluid, however the viscosity is slightly lower to accommodate today's modern brake systems. **This is presently the fluid required in all BMW's from the 2001 model year to present.** DOT 4 ESL can be used in all BMW brake system's that use DOT 4 brake fluid. Refer to SI B 34 09 01.

DOT 5

This is a silicone based brake fluid which has higher boiling points than glycol-based fluids and is widely used in extreme applications such as racing vehicles. Silicone based fluids are not hygroscopic. The dry boiling point of DOT 5 is 500ºF (260ºC) and its wet boiling point is 356ºF (180ºC). DOT 5 does not blend with glycol-based fluids and should never be mixed. The DOT specifies that DOT 5 be blue or purple in color.

DOT 5.1

This is a glycol-based hydraulic fluid. It is a heavy duty brake fluid used in racing applications that has a higher boiling point than DOT 5. Its dry boiling point is 518ºF (270ºC) and its wet boiling point is 374ºF (190ºC).

Hydraulic Brake Operation

Tandem Hydraulic Brake Systems

Federal law has required all motor vehicles since 1967 to have a dual or tandem master cylinder. This means there are two separate hydraulic circuits, so that in the event that one of the circuits develops a major leak the other system will operate with the ability to stop the vehicle. All BMW vehicles utilize a front/rear split, this means that the front brakes will still operate if a brake hose in the rear ruptures.

The typical brake system consists of disk brakes in front and either disk or drum brakes in the rear connected by a system of tubes and hoses that link the brake at each wheel to the master cylinder. Other systems that are connected with the brake system include the parking brakes, power brake booster and the anti-lock system.

When you step on the brake pedal, you are actually pushing against a plunger in the master cylinder, which forces hydraulic oil (brake fluid) through a series of tubes and hoses to the braking unit at each wheel. Since hydraulic fluid (or any fluid for that matter) cannot be compressed, pushing fluid through a pipe is just like pushing a steel bar through a pipe.

Unlike a steel bar, however, fluid can be directed through many twists and turns on its way to its destination, arriving with the exact same motion and pressure that it started with. It is very important that the fluid is pure liquid and that there are no air bubbles in it.

Air can compress, which causes a sponginess to the pedal and severely reduced braking efficiency. If air is suspected, then the system must be bled to remove the air. There are "bleeder screws" at each wheel cylinder and caliper for this purpose.

On a disk brake, the fluid from the master cylinder is forced into a caliper where it presses against a piston. The piston, in-turn, squeezes two brake pads against the disk (rotor), which is attached to the wheel, forcing it to slow down or stop.

Brake Proportioning

Early braking systems use a valve that limits braking force to the front or rear wheels, usually as a function of pedal effort or line pressure, loading of the car or front-rear weight transfer, to prevent wheel locking and provide the most effective braking.

Electronic Brake Proportioning (EBV)

The Electronic Distribution of the braking force (EBV). Will adjust the braking force to the rear wheels based on the vehicle's loading to maximize the braking force at all wheels.

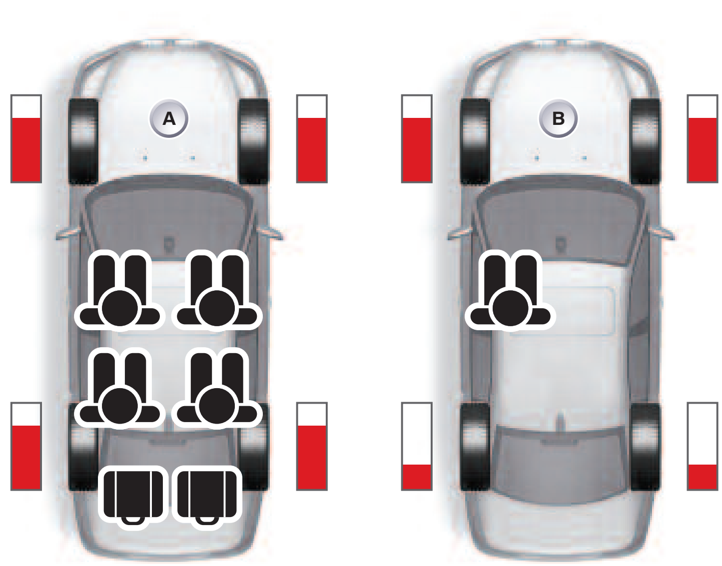
The control module monitors the wheel speed sensor inputs, when the brakes are applied, to determine vehicle loading. The control module compares the rate at which the front and rear axles are slowing down.

If the rear axle is slowing at a rate similar to the front it indicates that the vehicle is loaded and more braking force can be applied to the rear calipers to stop the vehicle.

If the decel rate of the rear wheels is far less than the front, it indicates a lightly loaded vehicle. At this point, if the same braking force were applied to the front and rear axles, the vehicle would become unstable.

If this difference exceeds the threshold values programmed in the control module, EBV is activated. The control module will cycle the inlet valves to the rear brakes to regulate the braking force.

The red bars in the graphic below symbolize the braking pressure controlled by the EBV function at the wheel brakes for two different vehicle load situations.



Index	Explanation	Index	Explanation
A	Rear of vehicle fully loaded	B	Vehicle with driver only

Brake Components

Power Brake Booster

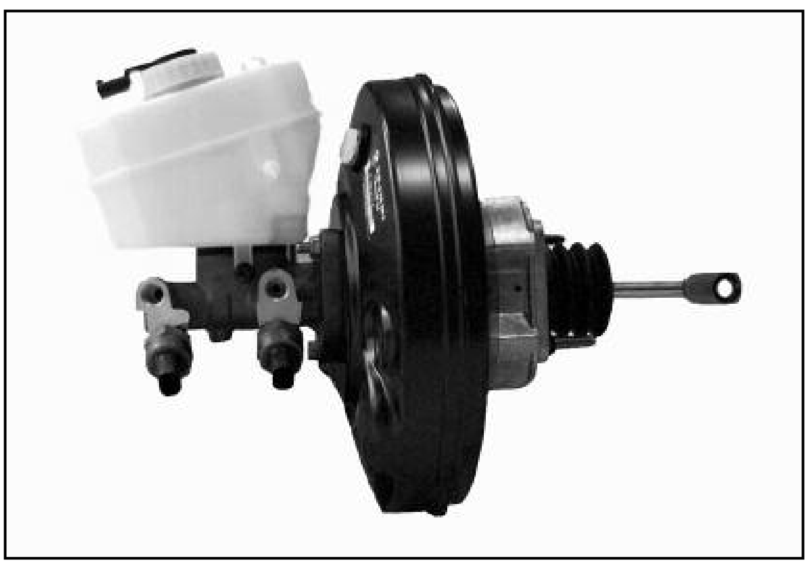
The power brake booster is mounted on the bulkhead directly behind the master cylinder and is directly connected with the brake pedal. Its purpose is to amplify the available foot pressure applied to the brake pedal so that the amount of foot pressure required to stop even the largest vehicle is minimal.

Power for the booster comes from engine vacuum. The automobile engine produces vacuum as a by-product of normal operation and is freely available for use in powering accessories such as the power brake booster. Vacuum enters the booster through a check valve on the booster. The check valve is connected to the engine with a rubber hose and acts as a one-way valve that allows vacuum to enter the booster but does not let it escape.

The booster is an empty shell that is divided into two chambers by a rubber diaphragm. There is a valve in the diaphragm that remains open while your foot is off the brake pedal so that vacuum is allowed to fill both chambers. When you step on the brake pedal, the valve in the diaphragm closes, separating the two chambers and another valve opens to allow air into the chamber on the brake pedal side. This is what provides the power assist.

Power boosters are very reliable and cause few problems of their own, however, other things can contribute to a loss of power assist. In order to have power assist, the engine must be running. If the engine stalls or shuts off while you are driving, you will have a small reserve of power assist for two or three pedal applications but, after that, the brakes will be extremely hard to apply and you must put as much pressure as you can to bring the vehicle to a stop.

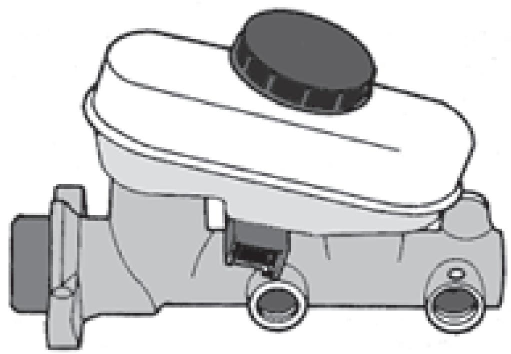
Brake booster, master cylinder and fluid reservoir



Master Cylinder

The heart of the hydraulic brake system is the master cylinder. The master cylinder converts the mechanical force exerted by the driver through the brake pedal into the hydraulic pressure that operates the wheel brakes.

Master cylinder



Brake Lines & Hoses

Solid Brake Lines

Hydraulic lines and hoses transmit the fluid pressure generated in the master cylinder to the wheel brakes. Brake lines and hoses are designed to withstand the high pressures in a hydraulic system, which can reach over 140 bar (2,030 psi).

The SAE standards require that a brake line must be able to hold 551 bar (8,000 psi) and have high requirements with regard to rust and anti-corrosion characteristics. To meet these requirements double wall steel lines are used with either a double or ISO flare.

Flexible Brake Hoses

Flexible brake hoses are required when the wheels turn or articulate with suspension movement. They are made from rubber and synthetic compounds and are internally reinforced for strength.

Flexible hoses must conform to standards set by the National Highway Traffic Safety Administration, as they are considered a safety item. By law flexible hoses must be labeled with the inside diameter, manufacturer and a code to designate whether it is a regular expansion (HR) or low expansion (HL) hose

Brake Calipers

BMW uses a variety of different types brake calipers.

These include:

- Single piston
- Double piston
- Six piston (E82/E88 135 only)
- Floating calipers
- Fixed calipers

The most common caliper design uses a single hydraulically actuated piston within a cylinder. BMW's use different types of calipers to actuate the brakes on each set of wheels as a safety measure. The hydraulic design also helps multiply braking force.

Floating Caliper

A floating caliper (also called a "sliding caliper") moves with respect to the disc, along a line parallel to the axis of rotation of the disc; a piston on one side of the disc pushes the inner brake pad until it makes contact with the braking surface, then pulls the caliper body with the outer brake pad so pressure is applied to both sides of the disc.

Fixed Caliper

A fixed caliper does not move relative to the disc and is, thus, less tolerant of disc imperfections. It uses one or more single or pairs of opposing pistons to clamp from each side of the disc, and is more complex and expensive than a floating caliper.

BMW Performance 6 piston fixed caliper

Brake Discs (Rotors)

BMW uses a number of different types of brake discs. Brake discs are primarily made of cast iron. Some discs are constructed in two pieces, with the hub portion of the disc made of aluminum and the disc portion made of cast iron. Ventilated and cross drilled discs can also be directional. This means that discs must be installed on the left or right side of the vehicle.

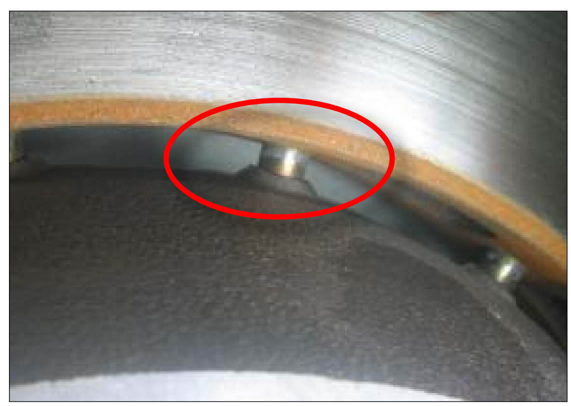
Here are the different types of discs used:

- Solid
- Ventilated
- Floating
- Cross Drilled

Solid Disc
Solid brake discs are the mostly used in the rear and are one of the most commonly used type of disc.

Ventilated Disc
Ventilated discs are primarily used on the front, but now are used in the rear as well. The "ventilated" disc design helps to dissipate the generated heat and is currently used on all BMW models.

Floating Disc
The floating type ensures optimized heat dissipation, improved response, as well as reduction of unsprung masses. The rotor has an aluminum center section (hub) with pins embedded in a radial pattern that are “connected” to the rotor surface utilizing a free moving or floating configuration. This allows the rotor surface to contract and expand with the changes in temperature.



Cross Drilled Disc
High performance applications use this type of rotor, this design allows for better heat dissipation and also allows gasses to be vented away from the contact area between the rotor and pads.This type of disc can not be machined.

Some brake discs may be directional, please pay special attention when ordering and installing discs on vehicle.

Brake Pad Wear Sensors

Dual Stage

The outer side of the brake pad on the left front and right rear brake is equipped with a two-stage brake pad wear sensor. The housing is inserted in the brake pad. It is therefore worn down in the same way as the brake pad by the friction together with the brake disc. Consequently, the two conductor loops are also worn down one after the other.

Index	Explanation	Index	Explanation
1	Housing	4	Conductor loop, wear stage 1
2	Connector	5	Conductor loop, wear stage 2
3	Brake disc	6	Electrical resistor

As a result, the electrical resistance at the connections of the sensor changes with the degree of wear:

- < 5 Ohms for new brake pads
- 470 Ohms on reaching wear stage 1
- >100 k Ohms on reaching wear stage 2

The resistance is measured by the relevant control unit and communicated to the corresponding driving dynamics system via the bus system. Here the wear stage is evaluated for the purpose of activating warning indicators and for the "condition based service" function.

Single Stage

The single stage brake pad wear sensor is also installed on the left front and right rear brake. It is mounted the same as the two stage sensor. The major difference is that the single stage contains a single conductor loop instead of two. Once the loop is broken the control module recognizes an open circuit and turns on the brake pad warning light.

Wear sensors should always be replaced when the brake pads are replaced along with resetting the CBS data for pad replacement.

Fundamentals of Anti-Lock Brakes

Anti-Lock Brake System Theory

The ability to slow or stop a vehicle depends upon the braking forces applied to the wheels and the frictional contact that exists between the tires and the road surface. Very low frictional forces exist when the tire is locked (or skidding). A locked tire also causes a loss of the lateral locating forces that effect directional control of the vehicle. The result of a locked tire (or tires) is the loss of steering control and stability.

The major forces that affect how easy a tire will lock include:

- The braking force applied from the vehicles braking system.
- Environmental factors - rain - ice - snow - etc.
- Type and condition of the road surface.
- Condition of the tires (tread and design).

The anti-lock braking system is designed to allow the maximum amount of braking force to be applied to the wheels without allowing the wheels to lock or skid.

The advantages that ABS provides includes:

- Driving stability - by maintaining the lateral locating forces between the tires and the road surface.
- Steerability - allowing the driver to continue to steer the vehicle while stopping (even during panic stops) or accident avoidance maneuvers.
- Provides optimum braking distances - the rolling wheels transfer higher frictional forces to slow the vehicle.

Brake Regulation

In order to prevent the wheels from locking during braking, yet provide the optimum braking force for maximum braking efficiency.

The ABS braking system must:

- Have the ability to monitor the wheel rotation rates
- Be able to regulate the braking forces applied to the wheels.

The ABS system carries out these functions with an electronic control system.

The components of the ABS system include:

- The electronic control module
- The wheel speed sensors
- The brake hydraulic unit
- The brake master cylinder

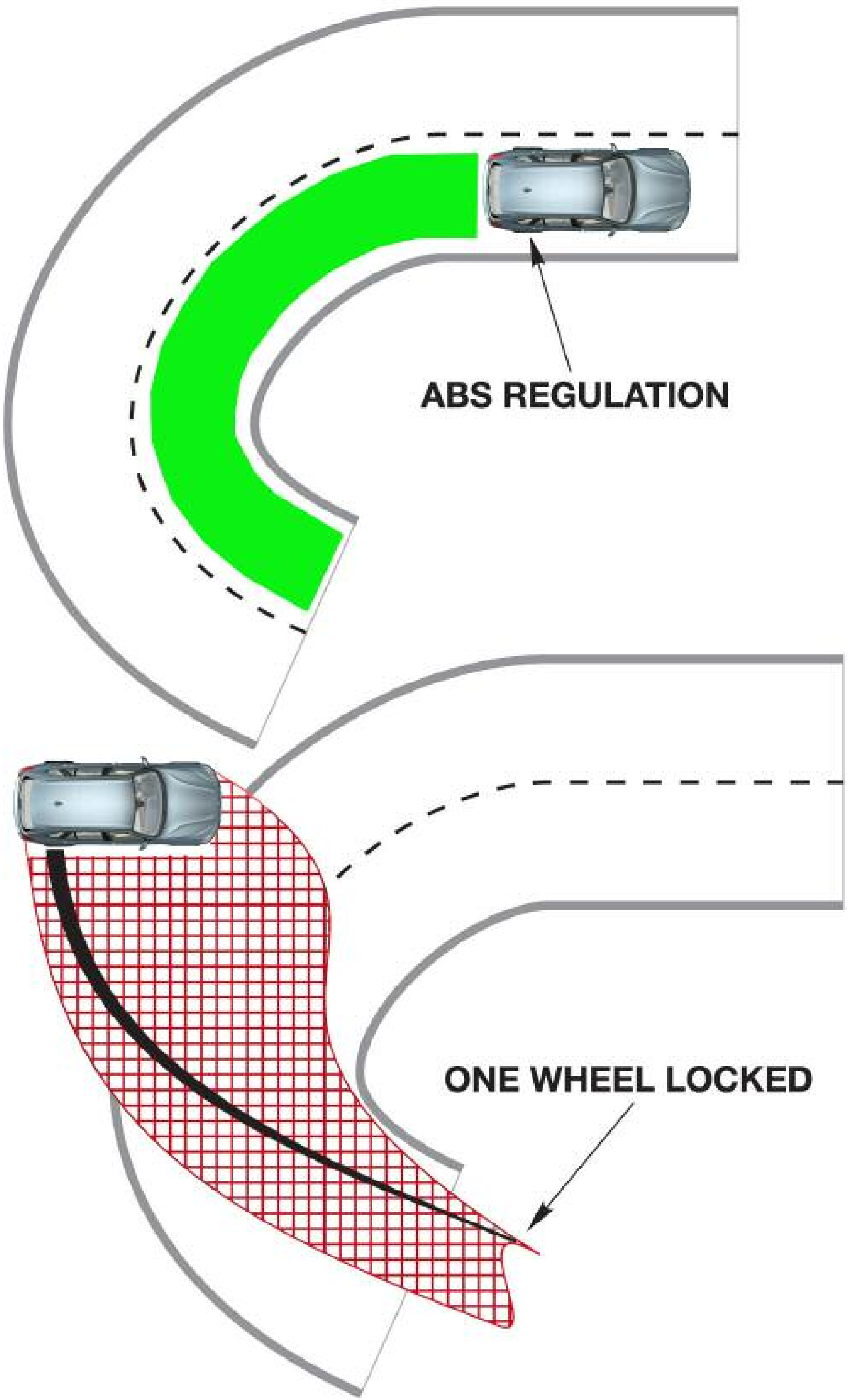
The four wheel speed sensors are used as inputs to the control module. The module uses these signals to determine wheel speed, wheel acceleration and deceleration. ABS controlled braking starts when the module detects that one or more wheels are about to lock.

Once activated, the ABS control module pulses the brakes on the affected wheel rapidly (2-15 times a second). This allows the vehicle to be slowed down while still maintaining steerability and directional stability.

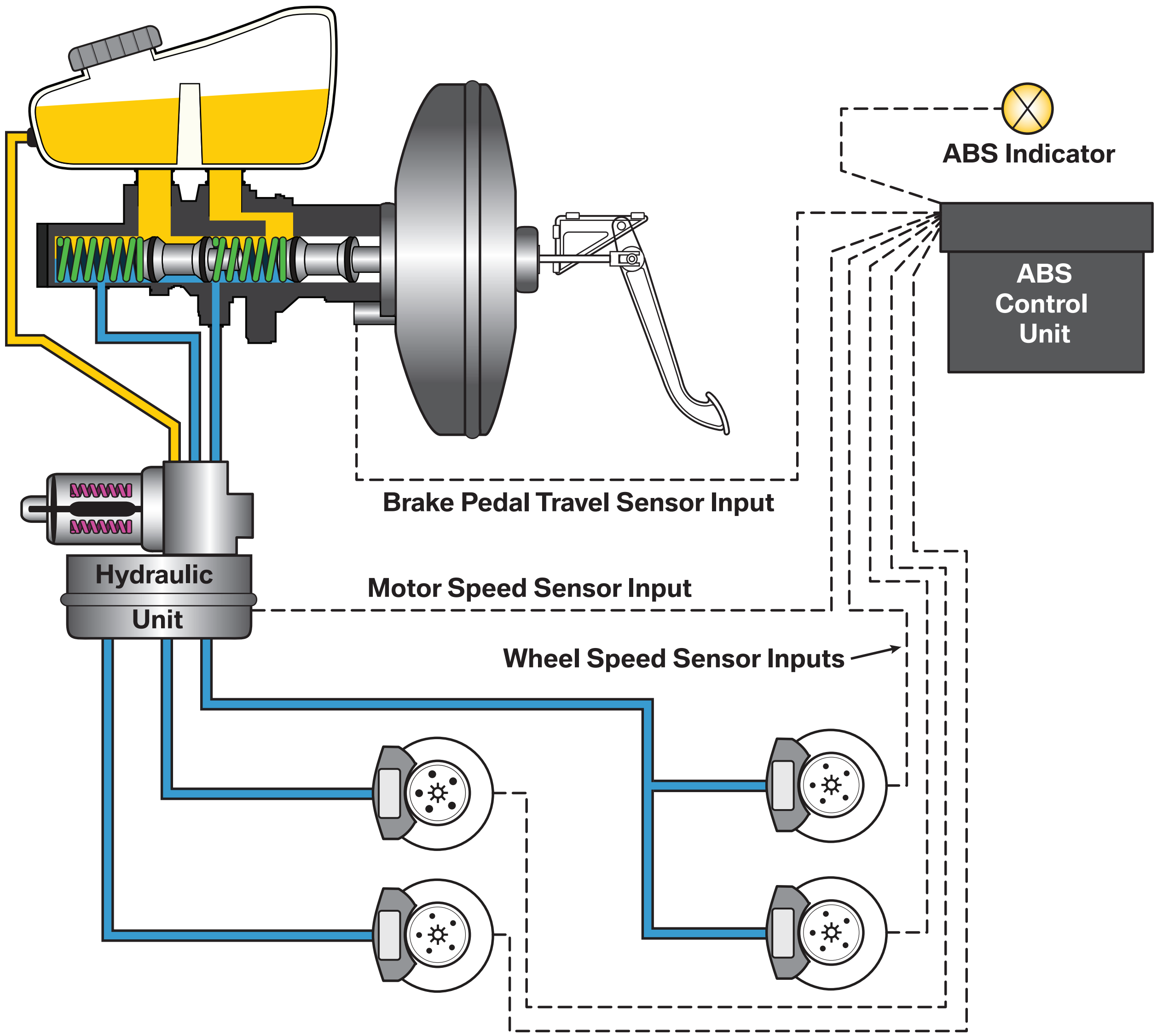
The ABS pulses the brakes through solenoids mounted in the hydraulic unit. The solenoids regulate the pressure to the affected wheel through three phases of control:

- Pressure Hold
- Pressure Drop
- Pressure Build

Braking in a turn with and without ABS



Bosch ABS Overview (early design with sererate ABS control unit)

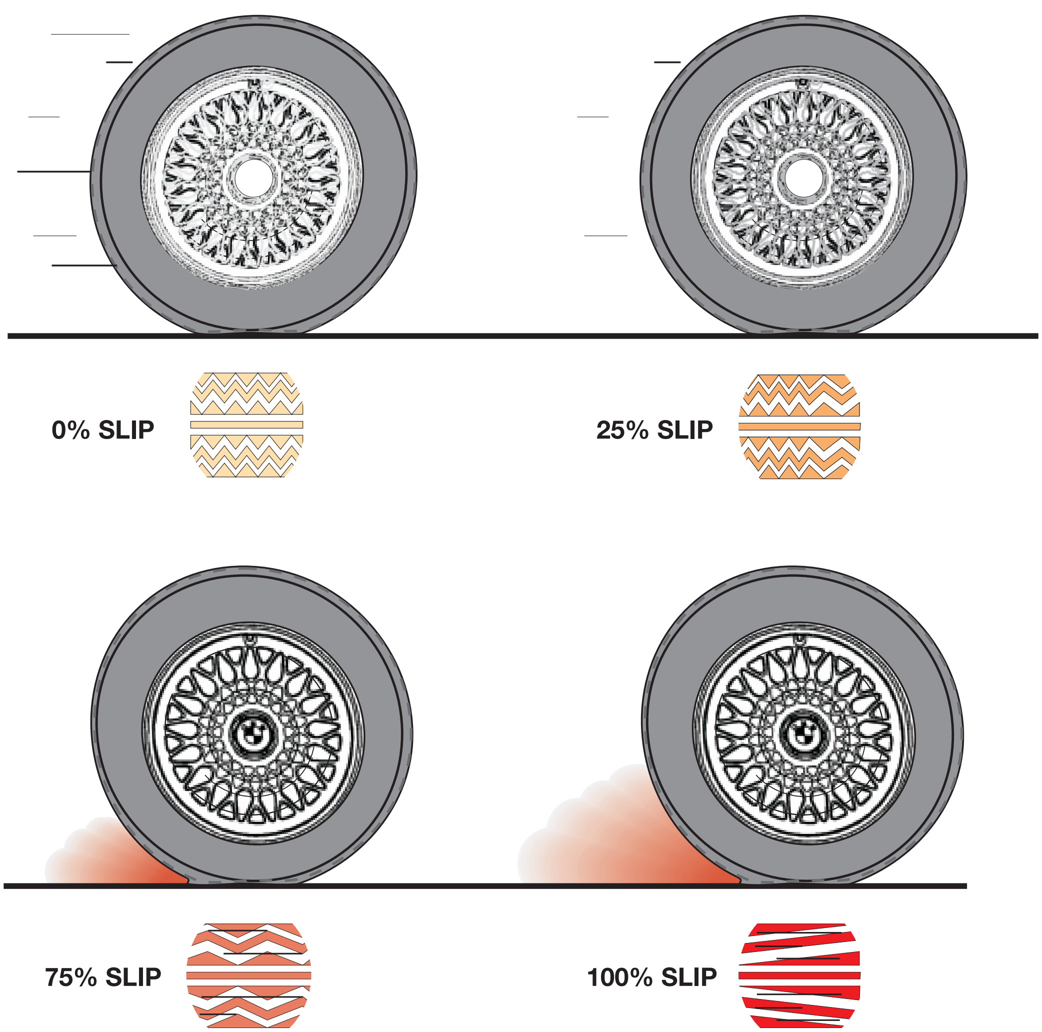


Braking Forces

When the brakes are applied, brake force counters the inertia of the moving vehicle. This force is created by the brake pads acting on the rotors and through the wheel and tire to the roadway. Even in the best of conditions, some wheel slip occurs. Up to a point this wheel slip is acceptable and in most cases it can even be helpful.

When braking, the transmitted brake force concentrates at the tire "foot print", where the rubber meets the road. This causes a distortion which, when excessive, promotes wheel slip.

When controlled, the distortion can actually enhance the transmission of brake force. Therefore, the ABS logic allows wheel slip up to 20-25%. Beyond that the ABS system limits the application of additional brake force. This allows the transmission of maximum brake force while reducing the stopping distance.



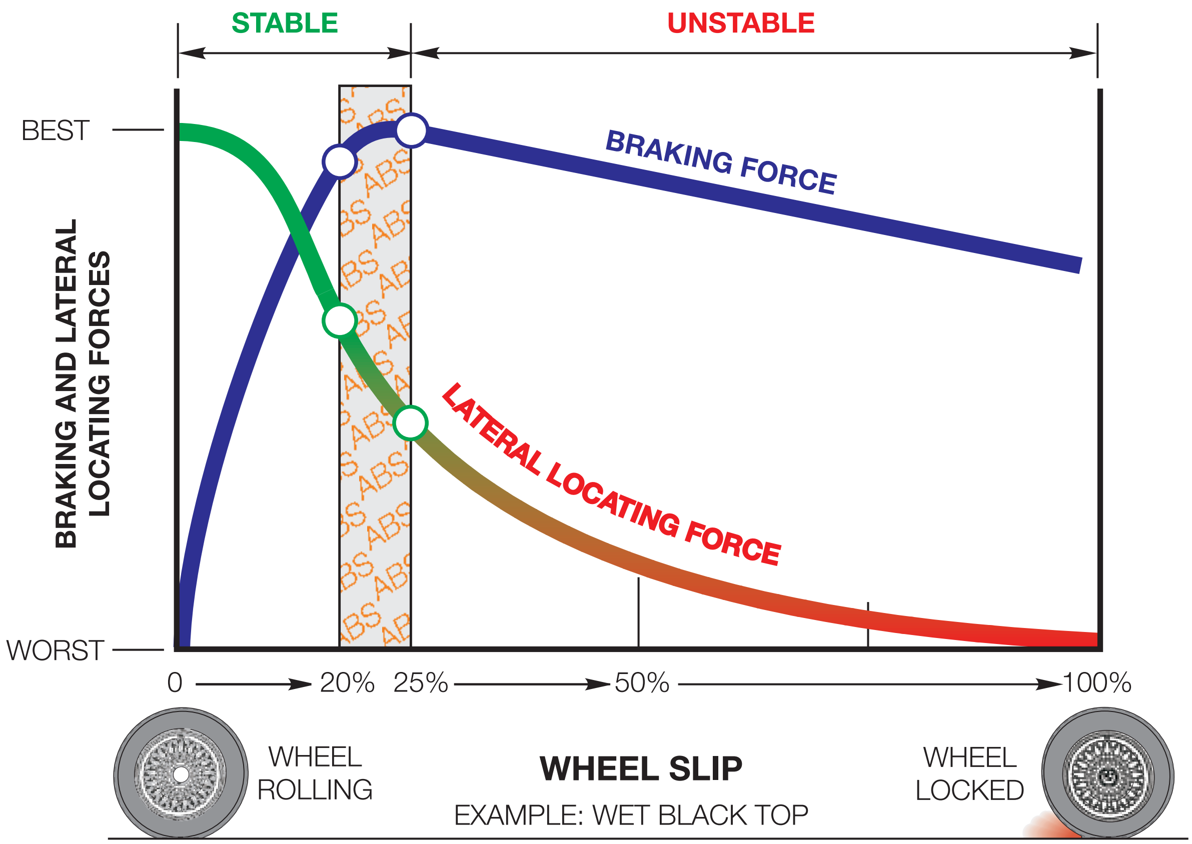
The transmission of braking forces and the retention of Lateral Locating Forces are inverse. That is to say as braking forces increase the locating forces decrease.

As indicated in the chart, the rolling wheel has a wheel slip value of 0% which provides the best Lateral Locating Forces.

As the applied brake force increases the locating force decreases. Depending on the prevailing road surface friction, the optimum transmission of brake force is at the end of the “stable range” with a wheel slip value of 20-25%.

Additional brake force at this point is clearly counter-productive as the additional brake force only increases wheel slip and reduces Lateral Locating Forces.

Therefore the ABS system limits wheel slip by regulating the application of brake force while providing the shortest possible stopping distance.



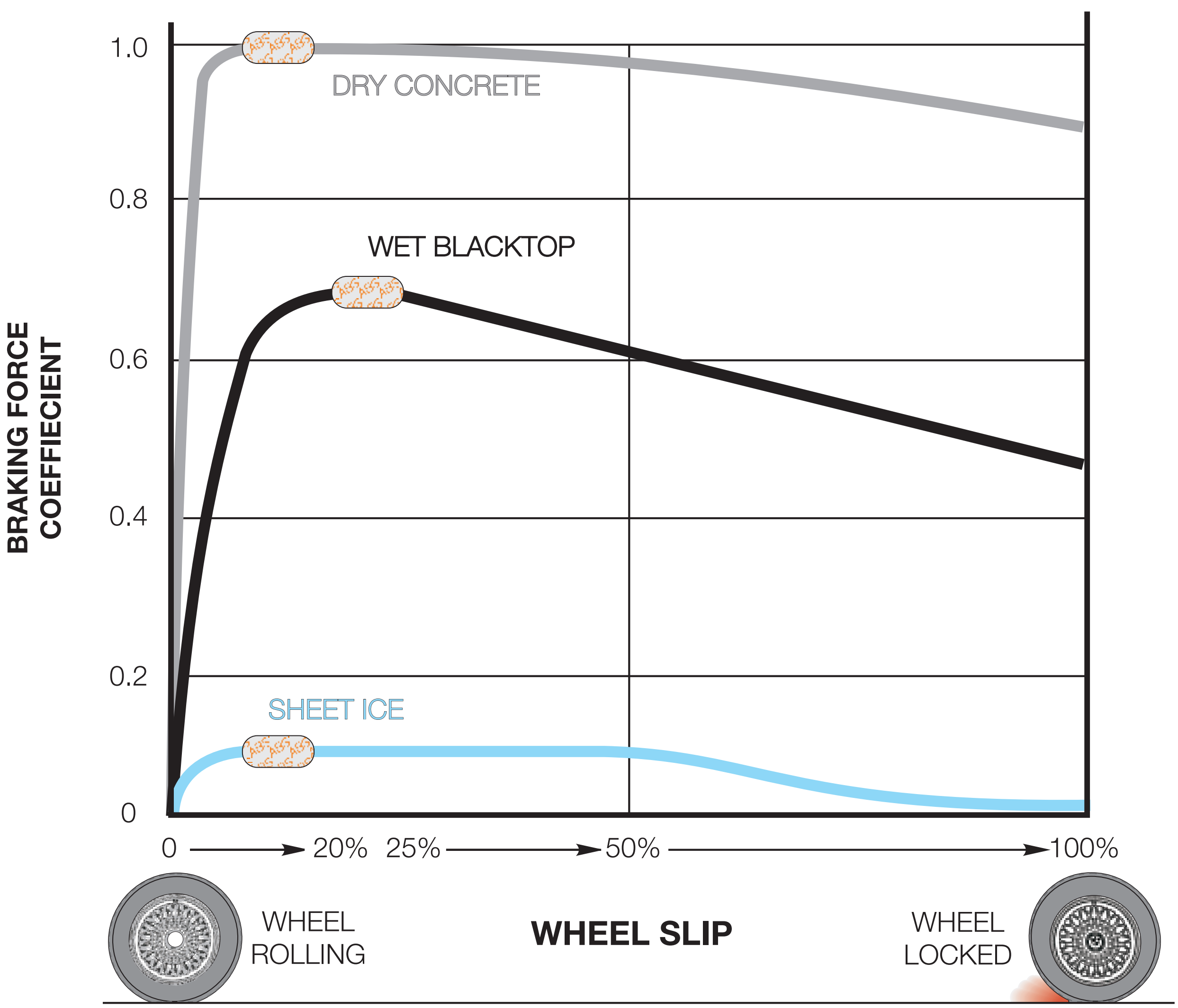
Road Surface

Clearly the condition of the roadway and weather conditions are significant influences regarding wheel slip and the retention of Lateral Locating Forces.

As road surfaces vary and weather conditions impact the tire's ability to maintain good rolling contact, the function of the ABS remains unchanged. Only the stopping distances increase due to the regulated transmission of braking force.

Whatever the road surface or weather, the wheel slip will still be limited to 20-25%.

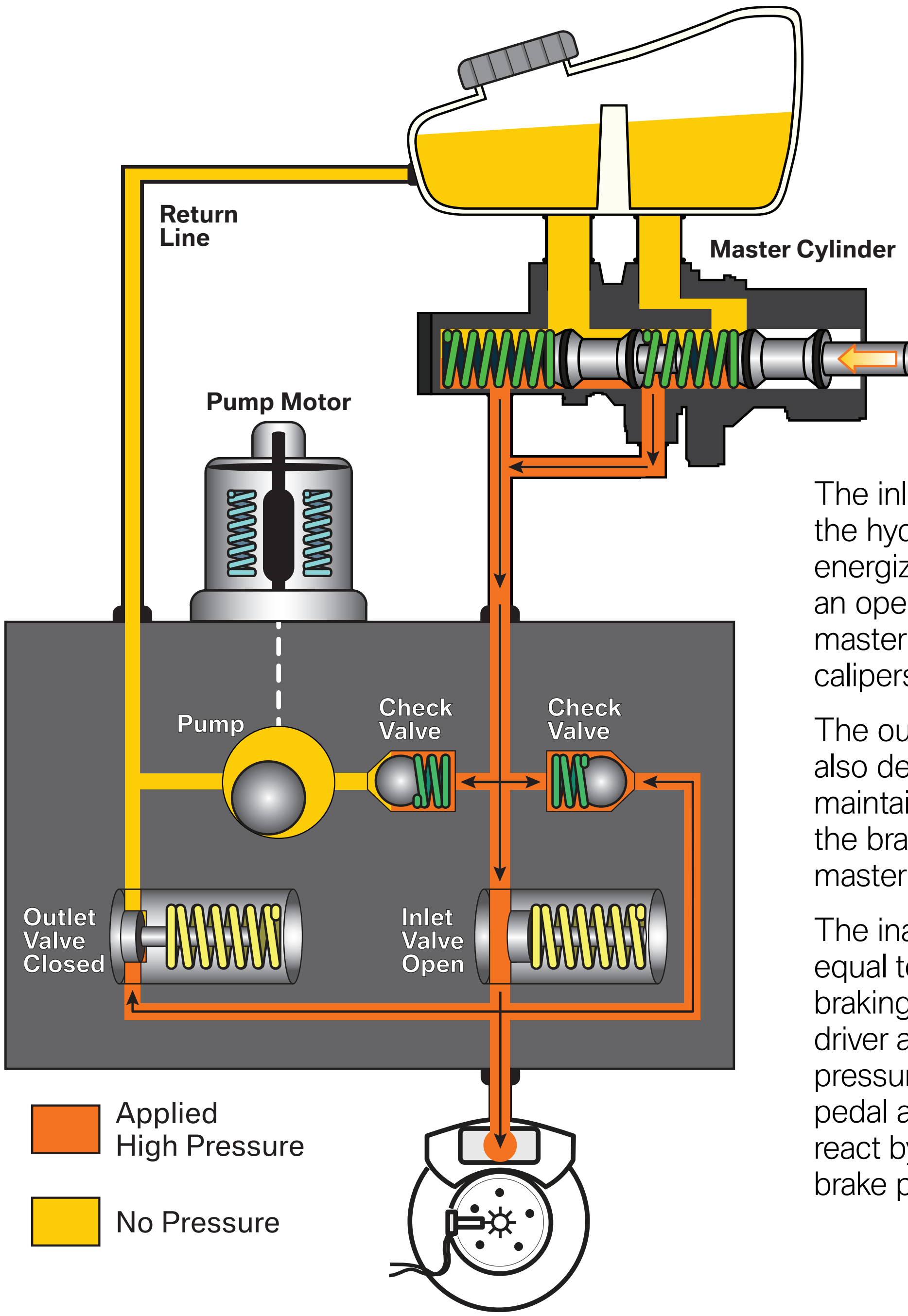
Regardless of the ABS system, good judgement and common sense are still required.



ABS Operation

Normal Braking

The ABS control module constantly monitors and compares the wheel speed sensor signals. When all four signals are at the same frequency within a small window of tolerance, the ABS system is not active and normal braking takes place.



The inlet solenoid valves of the hydraulic unit are de-energized. This maintains an open passage from the master cylinder to the brake calipers.

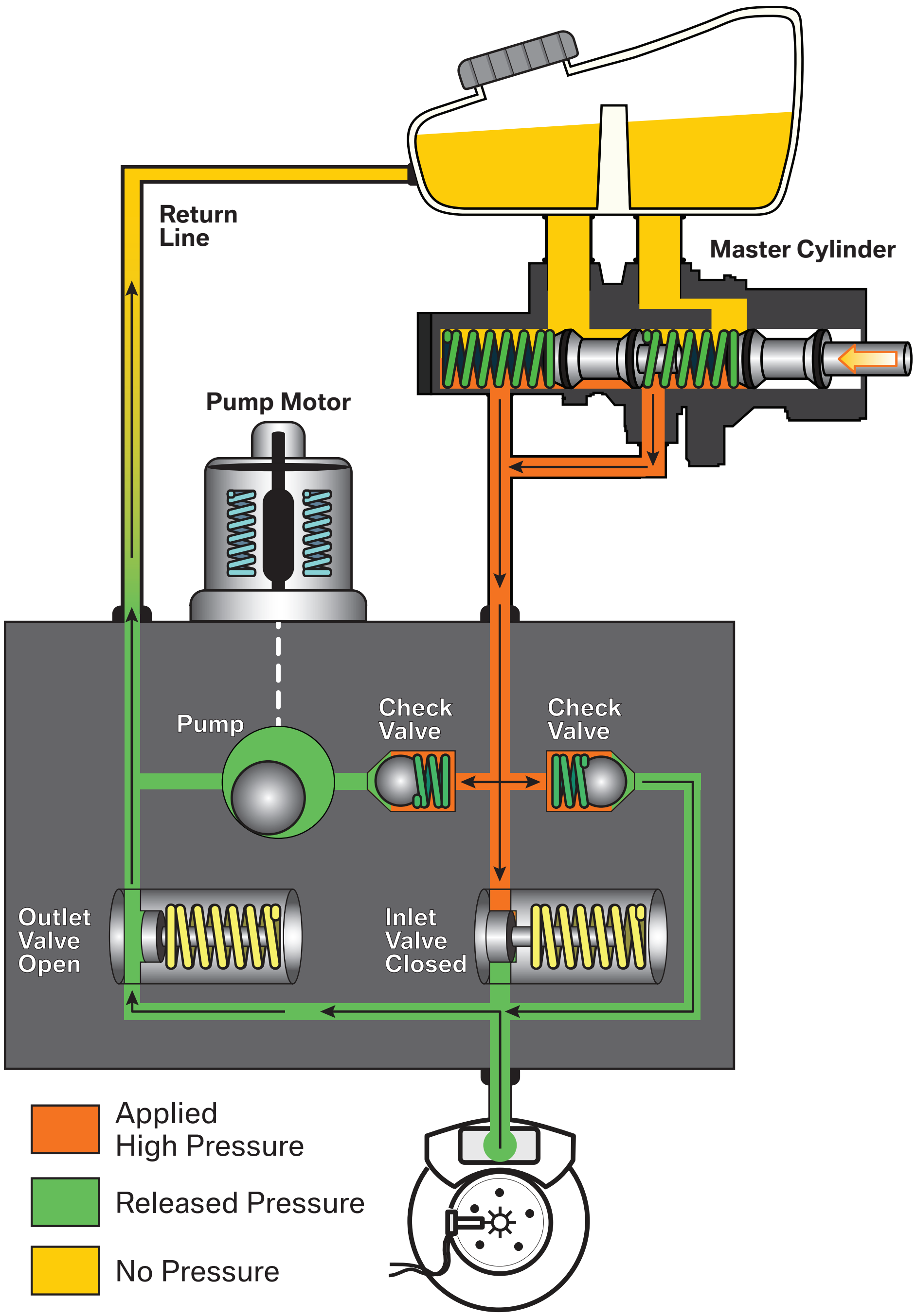
The outlet solenoids are also de-energized. This maintains a closed outlet of the brake circuit back to the master cylinder reservoir.

The inactive scenario is equal to a conventional braking system where the driver applies hydraulic pressure from the brake pedal and the brake calipers react by compressing the brake pads on the rotor.

Pressure Hold

If the control module detects a decrease in the frequency (rate of deceleration) of one or more of the individual signals it perceives this as possible wheel lock.

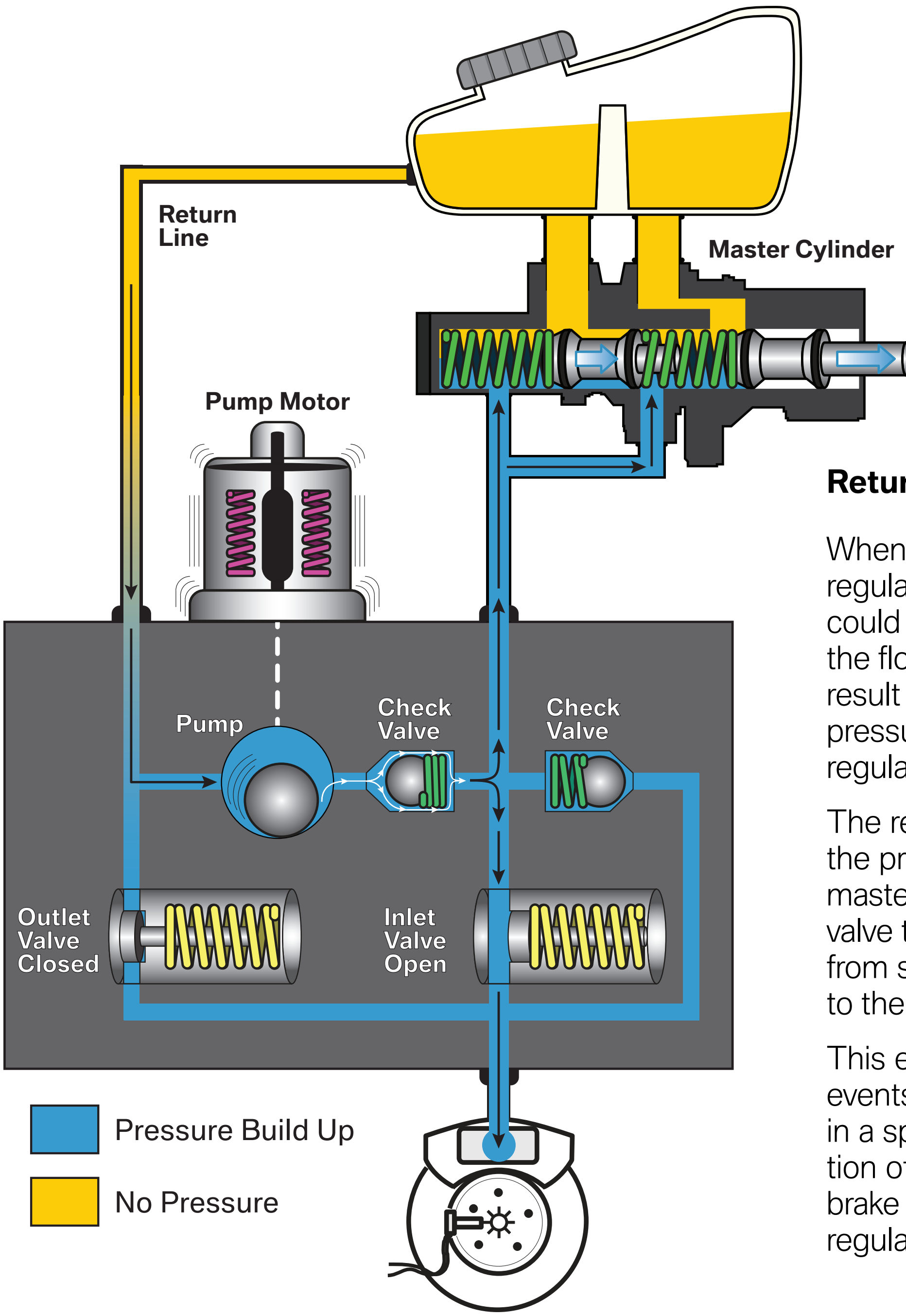
The control module energizes the inlet valve for that specific brake circuit. This closes the inlet port and prevents any additional hydraulic pressure from being exerted on the brake caliper by the driver.



Pressure Build

The control module de-energizes the inlet and outlet valves. This returns the brake circuit back to normal braking and the hydraulic pressure is once again determined by the driver's pedal force.

This sequence continues rapidly until the wheel speed signals are once again acceptable and the contact of the road and the tire surfaces are restored.



Return Pump Activation

When the system is in regulation, the brake pedal could progressively sink to the floor. This would be the result of bleeding hydraulic pressure during ABS regulation.

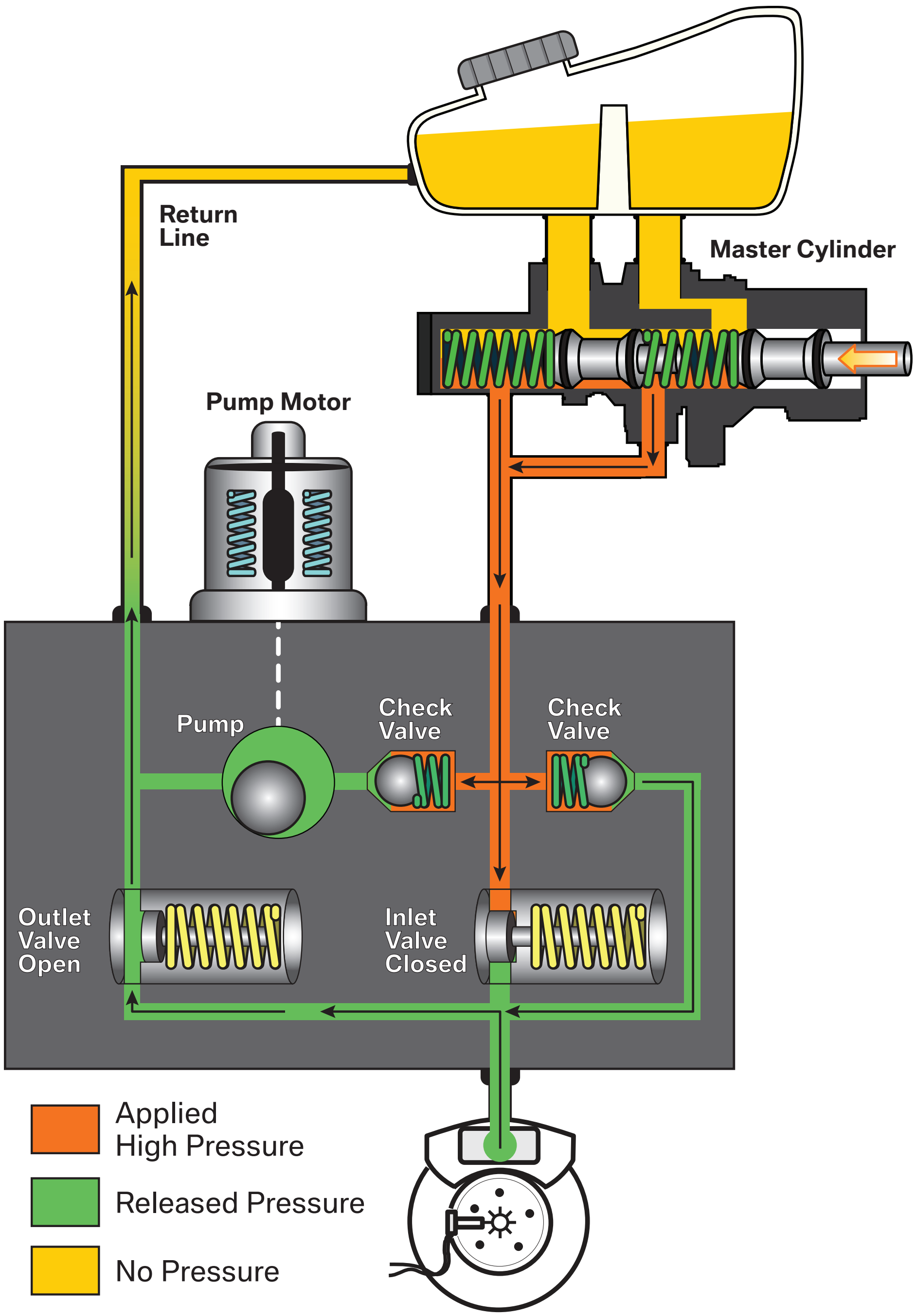
The return pump maintains the pressure between the master cylinder and the inlet valve to prevent the pedal from sinking completely to the floor.

This entire sequence of events happens repeatedly in a split second. The function of the pump is felt in the brake pedal during ABS regulation.

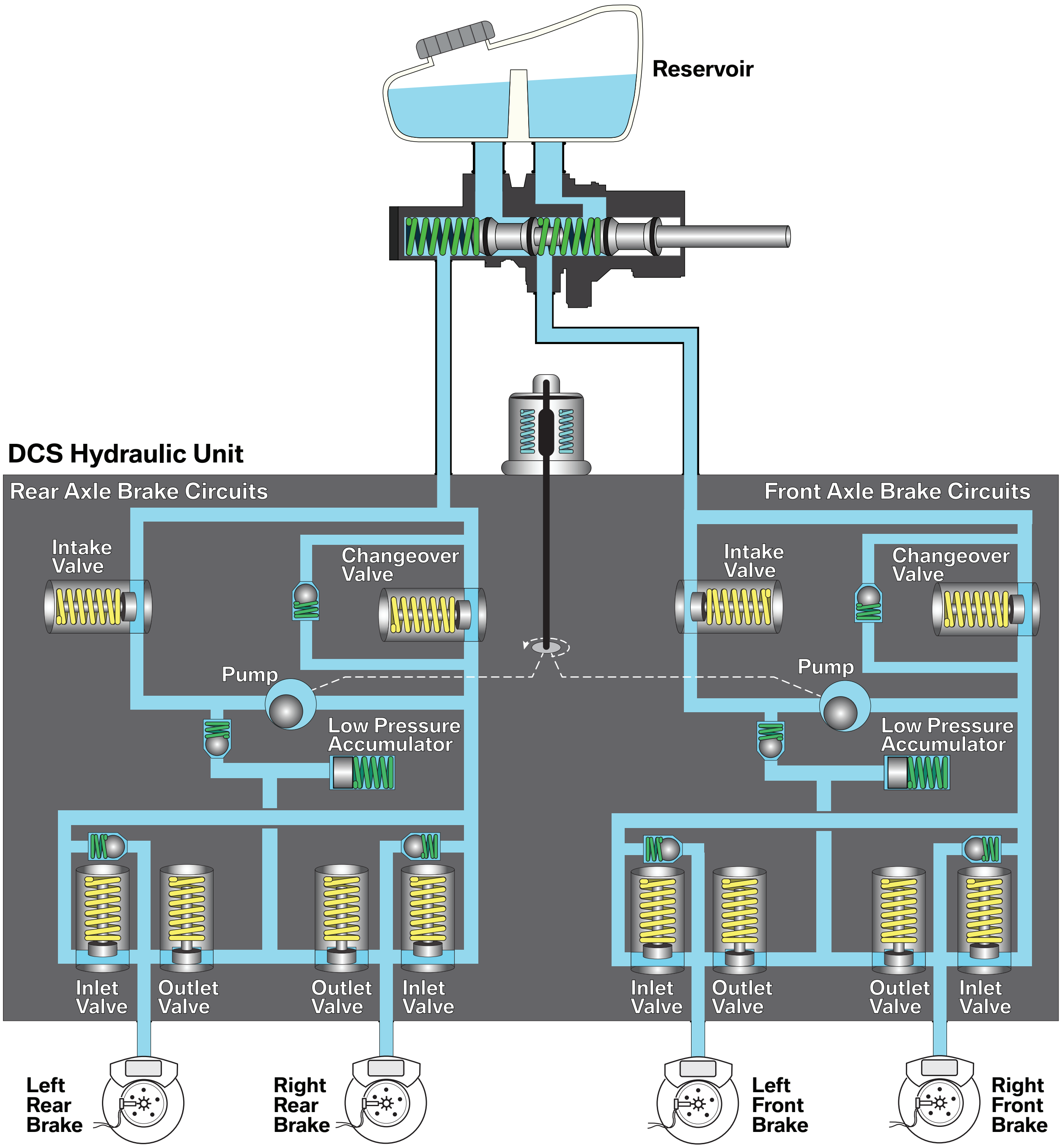
Pressure Drop

With the inlet valve closed the pressure on the caliper is stabilized and isolated. The control module energizes the outlet valve which opens the outlet port and drops the pressure in the isolated portion of the circuit.

The brake fluid flows back to the master cylinder reservoir.



Typical ABS/DSC Hydraulic Schematic

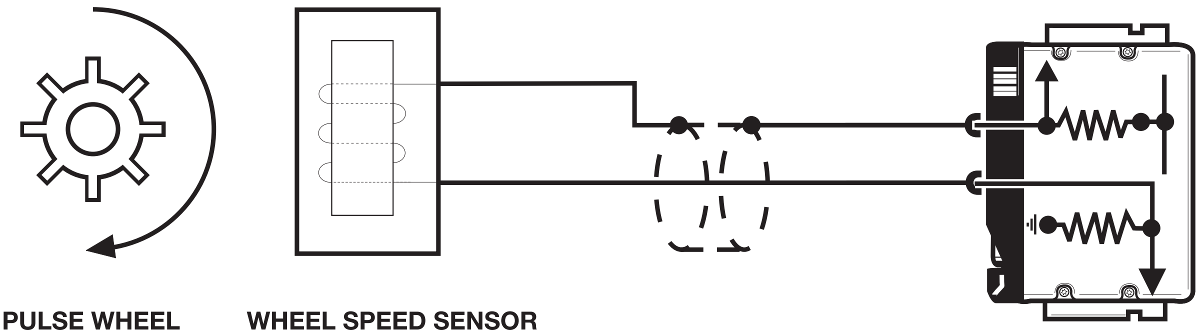


Wheel Speed Sensors

The wheel speed sensor is used to determine the individual speed of each wheel. BMW uses a number of different types of speed sensors

Inductive Type Sensor

Earlier wheel speed sensors are the inductive type which generate a AC voltage signal. The accuracy of this sensor is questionable at speeds lower than 3 kph/2 mph and generally use a virtual speed calculation when coming to a stop.



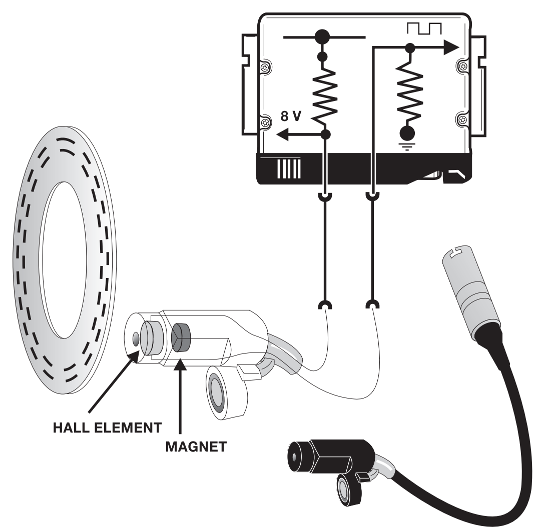
Hall Type Sensor (Two Wire)

The hall effect type sensors replaced the inductive and generate a digital square wave signal to the ABS/DSC control unit. Unique to this sensor is the two wire versus three wire configuration as on most hall effect circuits.

The three wire sensor receives power from the control unit on one wire along with a separate ground and signal wire.

The two wire hall effect wheel speed sensors receive a stabilized 8 volt power supply from the control module through one wire. The ground path for the sensor is through the second wire back to the control module.

The signal is generated by a pulse wheel affecting the voltage flow through the hall element in the sensor. The pulse wheel is integrated into the wheel bearing assembly, behind the seal. This protects the trigger wheel from foreign substances which may affect the wheel speed signal.



This creates a DC square wave signal with a low of .75 volts and a high of 2.5 volts.

Magneto Resistive Sensor

Active wheel speed sensors that operate on the principle of magnetoresistive effect are also used on BMW vehicles. The sensor element and evaluation module are two separate components within the sensor housing.

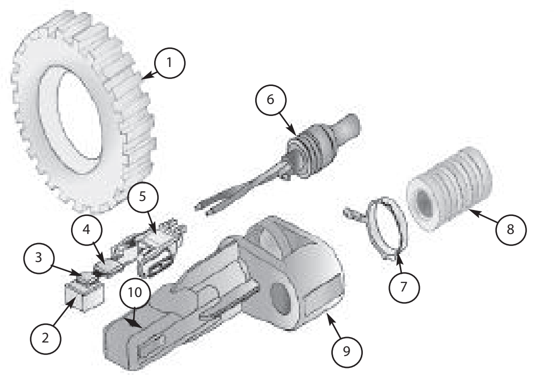
The active sensing of the magnetoresistive sensor is particularly suitable for advanced stability control applications in which sensing at zero or near zero speed is required.

An additional advantage of using this type of sensor is that they can detect a difference in the direction of wheel rotation.

A permanent magnet in the sensor produces a magnetic field with the magnetic field stream at a right angle to the sensing element.

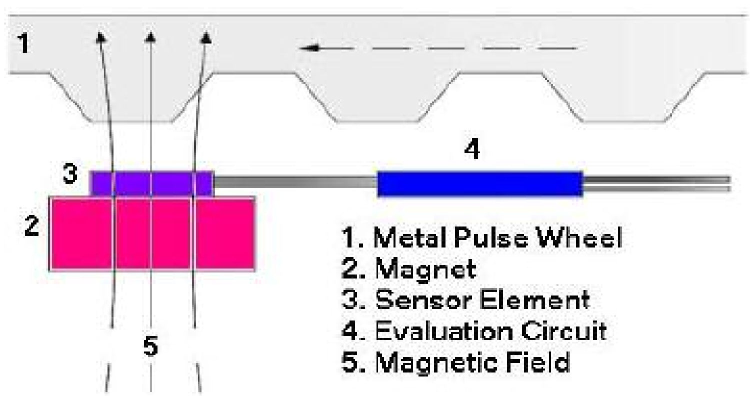
The sensor element is a ferromagnetic alloy (Permalloy) that changes its resistance based on the influence of magnetic fields.

1. Metal pulse wheel
2. Magnet
3. Sensor element
4. Evaluation module
5. Support for sensor element
6. Sensor wiring with weather boot
7. Ground contact ring
8. Fastening element
9. Sensor housing
10. Pick-up surface

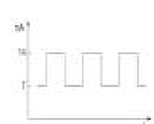


As the high portion of the pulse wheel approaches the sensing element a deflection of the magnetic field stream is created. This creates a resistance change in the thin film ferromagnetic layer of the sensor element.

The sensor element is affected by the direction of the magnetic field, not the field strength. The field strength is not important as long as it is above a certain level. This allows the sensor to tolerate variations in the field strength caused by age, temperature or mechanical tolerances.



The sensor element converts the changes in resistance into voltages. The small amount of voltage coming from the sensor element (1 to 100mV) is monitored by the evaluation module. The evaluation module generates current pulses with a distinct low and high level:

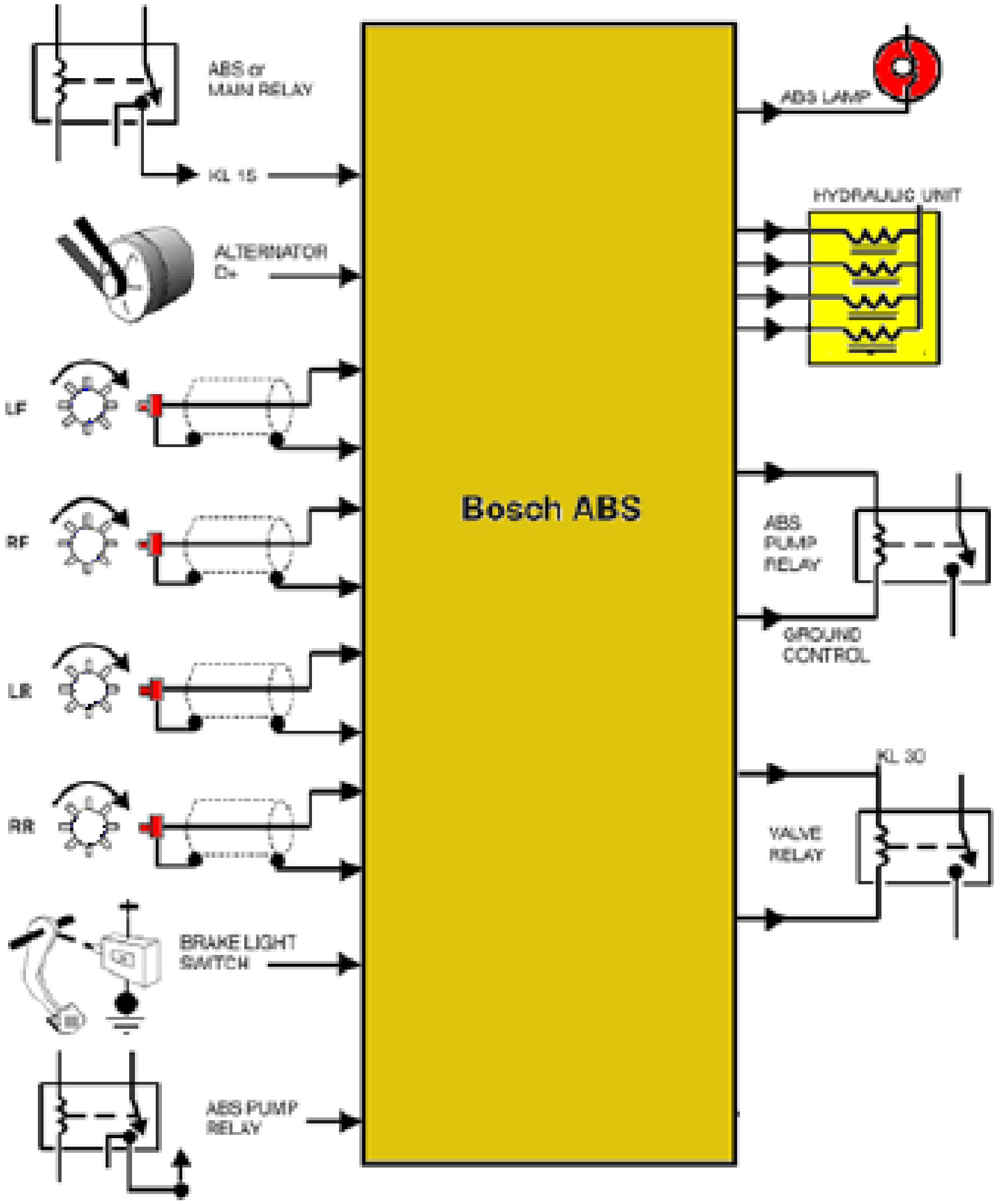


• Signal Low-7mA

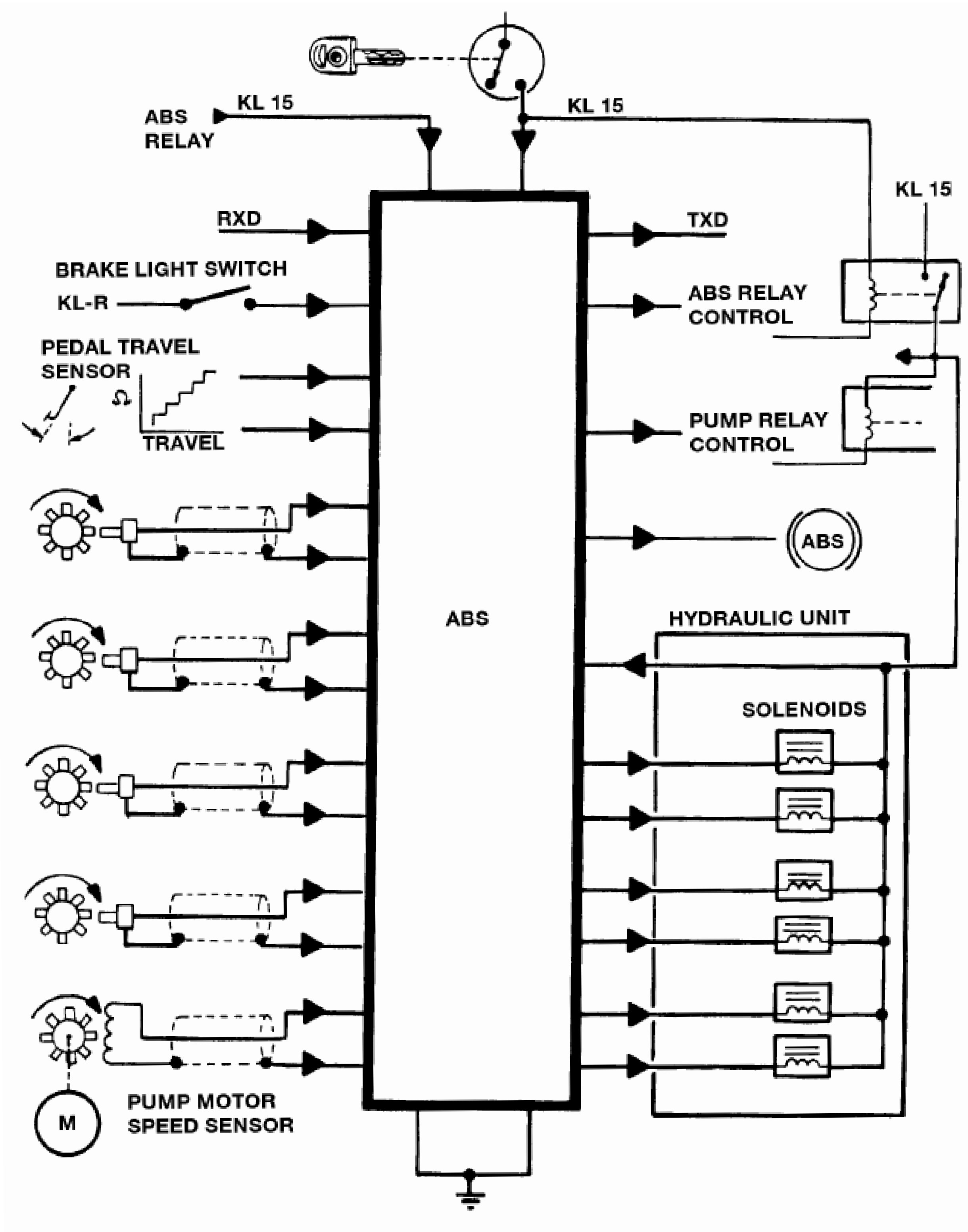
• Signal High-14mA

The sensor is supplied 12V by the DSC control unit. Output voltage from the sensor is a steady 10V. The control unit counts the high and low current pulses to create the wheel speed signal.

Early Bosch ABS (Typical)



Teves ABS



ABS RELAY
KL 15
KL 15
KL 15
RXD
TXD
BRAKE LIGHT SWITCH
KL-R
ABS RELAY CONTROL
PEDAL TRAVEL SENSOR
Ω
TRAVEL
PUMP RELAY CONTROL
ABS
ABS
HYDRAULIC UNIT
SOLENOIDS
M
PUMP MOTOR SPEED SENSOR

Braking Features

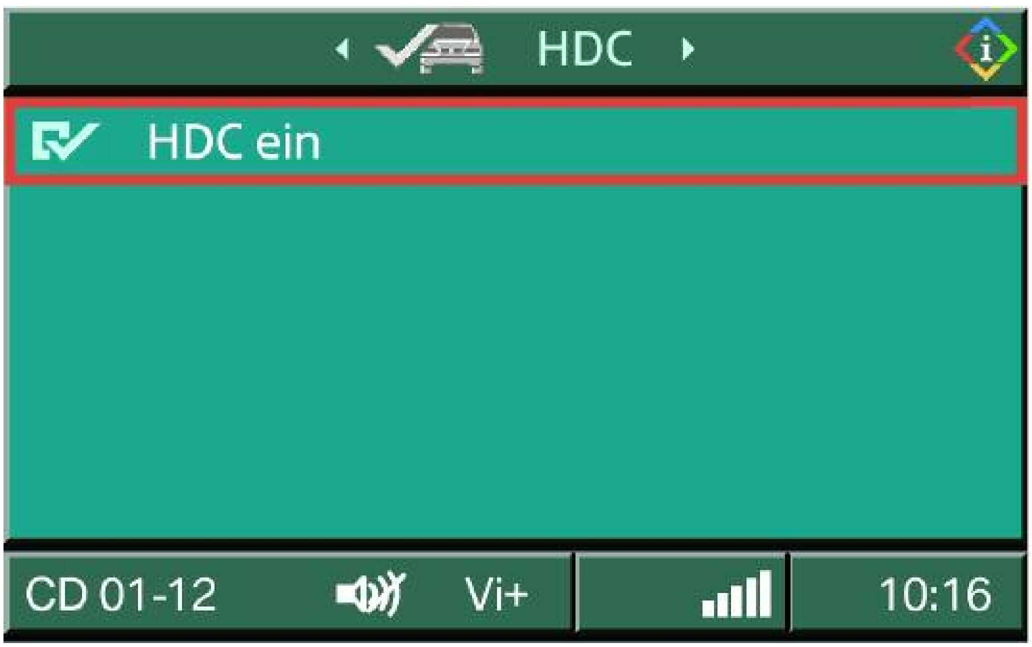
Hill Decent Control (HDC)

All xDrive vehicles in the BMW line, feature hill descent control facility for safe vehicle operation on steep downhill inclines. The HDC stabilizes the vehicle and prevents the wheels locking. The DSC module controls the build-up of braking pressure at all four wheels so that the vehicle drives downhill at a speed of approx. 7.5 mph (12 km/h).

The HDC function is activated in the central information display via the menu:

- Settings => Vehicle settings => HDC
- Or by a push button switch on the center console if no CID is installed.

The HDC ON function can be activated by setting a tick in the menu and deactivated by removing the tick.



Menu HDC ON / Active

Dry Braking

The water spray produced in wet conditions coats the brake discs with a water film, causing delayed response of the brakes. In connection with previous systems it was therefore recommended to operate the brakes from time to time.

The dry braking function is dependent on the position of the wiper switch and therefore on the signal of the rain/lights sensor. The brake discs are kept dry by lightly applying the brake pads cyclically as required, this achieving improved braking response in wet conditions.

While doing so, the pressure in the brake system is increased by approx. 1 bar and the brake pads are applied for approx. 1.5 seconds.

Dry braking takes place under following conditions:

- Driving speed > 70 km/h
- Continuous wipe operation in stage 1 or 2

The repeat interval depends on the wiper stage:

- Continuous wipe stage 1 - 200 s
- Continuous wipe stage 2 - 120 s
- Generally 90 s as from 09/2005

This applies only when the driver himself does not apply the brake during this time.

The driver notices no deceleration or noise.

Left disc with water film before dry braking **Right brake disc after dry braking**

Brake Standby

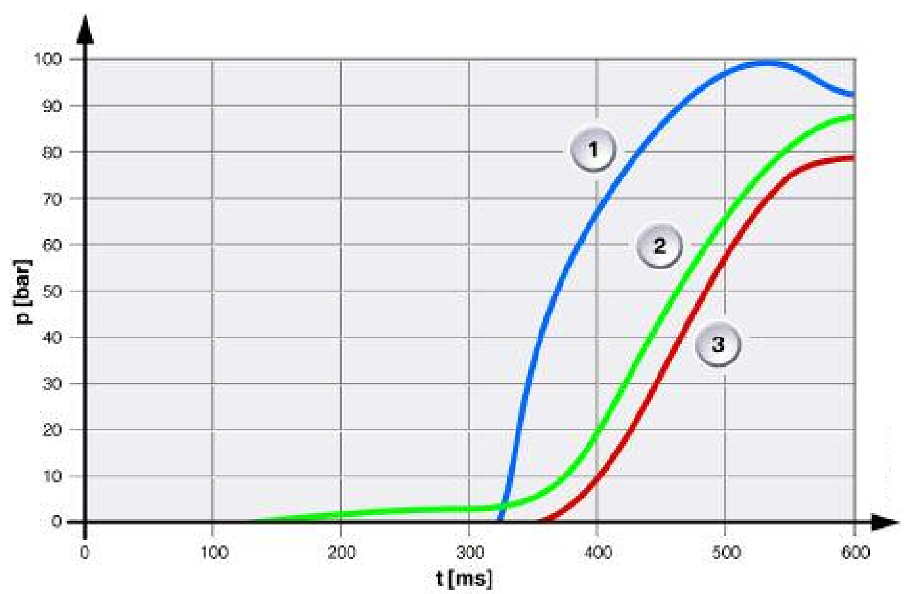
Quick release of the accelerator pedal causes the brake pads to be applied against the brake disc thus reducing the stopping distance (by approx. 30 cm/100 km/h) during emergency braking. The DSC module builds up slight brake pressure (approx. 2.5 bar) temporarily (approx. 0.5 seconds) in order to eliminate the clearance between the brake pad and brake disc by applying the brake pads.

The brake standby function is activated under following conditions:

- Driving speed > 70 km/h
- Minimum time between brake application 8 s
- The brake standby function is not activated in connection with sudden acceleration (sports driving style).

The DME/DDE control unit makes available the signal indicating quick release of the accelerator pedal via the PT-CAN.

The sensitive driver may perceive a slightly harder brake pedal. No delay or noise is discernible for the driver.

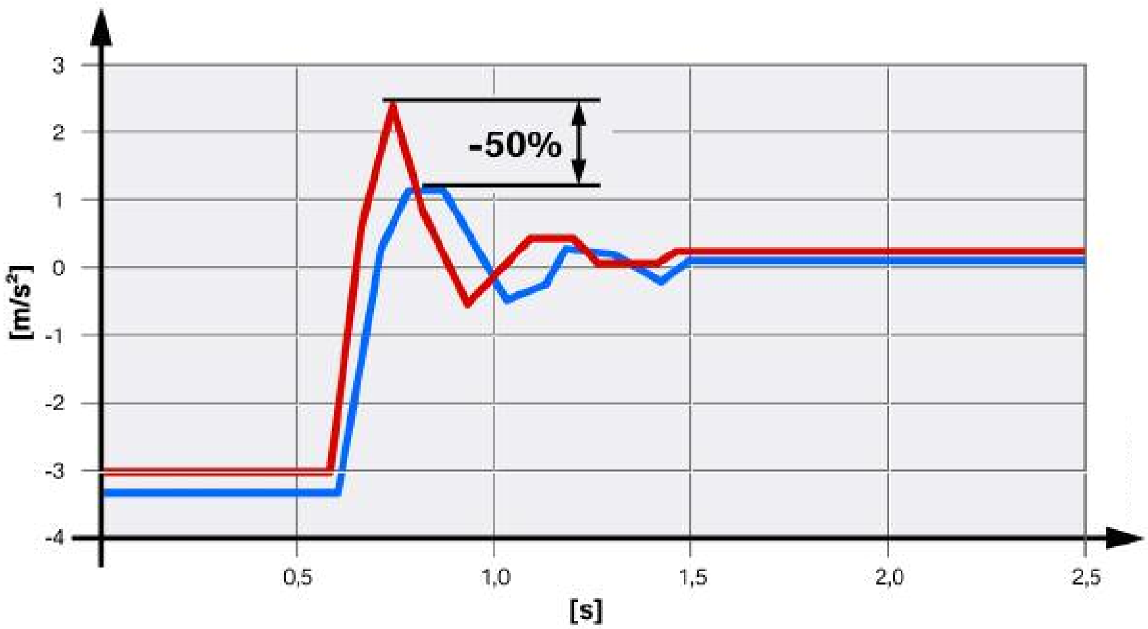


Index	Explanation
P	Braking pressure in Bar
T	Time in milliseconds
1	Pilot pressure applied by driver
2	Braking pressure progression with brake standby
3	Braking pressure progression without brake standby

Automatic Soft Stop

Due to the transition from sliding friction to static friction on the brake disc, a stopping jolt occurs when braking to a standstill where the occupants perceive an increased feeling of deceleration.

When braking lightly (< 25 bar) at constant pressure to bring the vehicle to a halt, the soft stop function automatically reduces the braking pressure at the rear axle just before the vehicle comes to a stop. This consequently reduces the positive acceleration peak perceived by the occupants by approx. 50% while extending the action time.



Index	Explanation
m/s^2	Deceleration
s	Time in seconds
Red	Deceleration without soft stop
Blue	Deceleration with soft stop
-50%	Reduction of occupant deceleration

The speed and standstill status are recognized by way of the wheel speed sensors.

This function is inactive at medium to high deceleration or in the event of ABS control in order not to lengthen the stopping distance.

Fading Compensation

High temperatures (> 550°C) can occur at the brake discs when driving downhill over long periods or as the result of extreme multiple braking operations (> 80 bar). These high temperatures cause a change in the coefficient of friction of the brake pads resulting in the braking effect diminishing (fading).

For this purpose, the temperature of the brake disc is calculated by means of a temperature model contained in the DXC8+ software. The braking pressure applied by the driver is measured by the delivery pressure sensor and compared with the current vehicle deceleration (target/actual value).

When the braking effect diminishes, the fading compensation provides assistance for the driver in that pressure is additionally built up by the DSC module.

Brake Disc with Fading

Drive-off Assistant

When negotiating uphill gradients, the drive-off assistant holds the vehicle for a short time (approx. 1.5 s) after releasing the brake so that the vehicle drives off comfortably without the need to use the handbrake. The braking pressure required by the driver to hold the vehicle is maintained automatically in the system.

When driving off, the braking pressure is not reduced before the torque is sufficient for the vehicle to drive off. The holding pressure in the brake system (10 to max. 70 bar) is dependent on the uphill gradient.

Uphill gradients are detected by the DSC sensor with the aid of a longitudinal acceleration sensor.

The function is active both when driving forwards (transmission in Drive) and when reversing (transmission in Reverse) on uphill gradients (up to 50 %).

Drive-off Assistant Function

Cornering Brake Control (CBC)

CBC is an extension of ABS. CBC enhances driving stability if the brakes are applied when cornering.

Advantage: If the brakes are applied in a corner, optimum brake force distribution ensures tracking stability.

When cornering, even very light braking can shift the axle-load distribution to the left or right so that driving stability is impaired. If required, CBC generates a stabilizing load moment when the brakes are applied lightly outside the ABS intervention range.

Flushing Brake Fluid

Since glycol-based fluids have an affinity for water, it is important to keep brake fluid in a tightly sealed container. BMW currently recommends flushing the brake fluid every two years to insure maximum braking performance and reliability over the entire life of the vehicle.

Brake Fluid Disposal
Current EPA laws permit used brake fluid to be disposed of with used engine oil.

Checking for Contaminated Brake Fluid
It is hard to spot contaminated brake fluid just by looking at it.

There are some simple tests for spotting brake fluid problems:

- Remove the cover from the master cylinder and inspect the diaphragm. If the diaphragm is swollen or bloated, then the brake fluid has likely been contaminated with a petroleum based product.
- A check for petroleum based contamination is to take a glass of water and place a couple of tablespoons of brake fluid in the water. The brake fluid should dissolve in the water and turn it cloudy. If any petroleum based products are in the fluid they will separate from the brake fluid and float on the top and form circles on the surface of the water. A special note of interest is that if you are using a Styrofoam cup the petroleum factions will dissolve the cup at the water line.
- Non petroleum based contamination can be checked using a DVOM. Measure the voltage across the battery. Next place the positive lead of the meter on the positive battery post. Then place the negative lead in the brake fluid. The voltage should be within three volts of the battery, otherwise fluid contamination is likely.
- There are chemical strips that are commercially available that are designed to check for excessive moisture contamination. These strips are formulated to identify the amount of copper in the system which is related to the amount of moisture in the system. These strips are relatively inexpensive and are a way to verify if a flush is needed.
- There are electronic testers that are available that are able to identify brake fluid contamination as well as the exact boiling point.

Currently BMW does not endorse or recommend any special tools or devices to identify contaminated brake fluid. So any of these methods mentioned are not to be used to mitigate any warranty service on any BMW models.

Brake Bleeding

Brake bleeding is the process of removing any trapped air from the hydraulic system. Air can get into the system whenever the system is opened for service or repair or in the event of a ruptured line.

Bleeding Sequence

With a front/rear hydraulic split system it is customary to start with the wheel furthest from the master cylinder and work toward the closest e.g. RR-LR-RF-LF. However with the implementation of ABS/DSC systems the BMW tester is needed to properly bleed the hydraulic system. When using the tester, the technician should always follow the procedure.

It is always in the service technician's best interest to avoid allowing the hydraulic system to empty when replacing a component in the hydraulic circuit. This will minimize the amount of air introduced into the circuit which in turn will minimize the difficulty of bleeding the hydraulic circuit. So when at all possible cap lines and hoses when removing brake components.

To avoid system drain down without line capping use a pedal jack to move the brake pedal about 1" (25mm), this moves the pistons in the master cylinder past the vent port. By doing this you isolate the hydraulic circuit from atmospheric pressure, which in turn prevents the flow of fluid.

Reference REP # 34 00 050 for more information.

CAUTION!!!

Do not use any type of hose pinching devices on flexible brake hoses to prevent the flow of fluid. These devices can cause internal damage to the hose which could result in premature failure.

Bleeding Methods

- Manual bleeding, this is done with an assistant who will apply the brakes using the pedal while the bleeder is opened slightly. To avoid spillage attach a hose to the bleeder valve and submerge the hose in a clear container partially filled with brake fluid. By keeping the hose submerged in fluid you will see bubbles when air is present. The hose being submerged in fluid will also prevent air from accidentally being drawn in through the bleeder valve.
- Gravity bleeding is a very slow but effective method that will work well in situations where only one wheel circuit was opened and the system did not drain down. This procedure requires no assistance you simply open the bleeder valve and wait until fluid flows from the open valve.
- Vacuum bleeding is a popular method that draws the brake fluid from the bleeder valve and into a container. The advantages to this method are no assistance is needed as well as the fact that big air bubbles are not broken into smaller bubbles, which occurs with the manual bleeding method.
- Reverse Fluid Injection uses a pressurized gun to inject fluid from the bleeder valve back up into the master cylinder. The danger with this method is debris and sediment in the wheel brakes can be back-flushed into the DSC hydraulic control unit and/or the master cylinder.
- Pressure bleeding is another popular method that uses a pressurized bladder or an electric pump and tank to pressurize the master cylinder and replace the fluid as the fluid and air is evacuated via the bleeder valve.

BMW recommends pressure bleeding with the “Power Probe Bleeder”, which utilizes a variable electric pump set at 2 bar (30psi). Proper bleeding of current BMW vehicles will also require the execution of the brake bleeding service function via the tester.

More information on the Power Probe bleeder and the bleeding procedure will be discussed later in this course as well as viewed on 1/11 Service Round Table

Brake Lines and Hoses

Solid Brake Line Repair

BMW Parts offer application specific steel lines that are cut to length with fittings installed and flared. The service technician is required to bend these lines to fit the vehicle. It is important that the technician use the proper tools to bend the line so as not to kink the line or damage any protective coatings.

Important!!!

- **Always refer to the proper repair manual for brake line repair.**
- **Never use compression-type fittings in hydraulic brake circuits or substitute copper, aluminum, composite or single wall steel tubing for use in hydraulic brake systems.**
- **Use old brake lines as a template for bending the new brake lines.**

Flexible Brake Hose Inspection

Flexible Brake hoses tend to take a great deal of abuse. Extreme temperature, constant flexing and ozone in the atmosphere degrade brake hoses.

Always replace hoses that exhibit the following types of wear:

- Hardening and cracking caused by age and exposure to extreme heat.
- External abrasion caused by contact with suspension or chassis parts.
- Bubbles on the exterior. This is a sign that the hose has broken down internally.
- Any signs of fluid leaks where the rubber meets the crimped metal ends.
- Spongy brake pedal with no signs of air in the system. Visually inspect rubber lines while the system is under pressure for signs of ballooning.
- The ribbing on the outside covering is a designed in "tattle tale" so the technician can see if the hose has been twisted excessively.

A customer concern that can be traced to a dragging brake may be caused by a brake hose. This can result when a small tear on the inside of the hose may act as a check valve. This can be identified in many cases by opening the bleeder screw at the wheel and watching to see if fluid squirts out without the brakes being applied.

CAUTION!!! **When working on calipers never allow the caliper to hang by the brake hose. Always support the caliper with a suitable devise. A simple "S" hook can be fabricated from heavy gauge non-flux type welding rod, or metal close hanger.**

Checking Function of Brake Booster

Operation Test

Diagnosing a brake booster is usually straight forward. Always do a complete visual inspection and ask the customer about his braking complaint.

With the engine off operate the brake pedal until it becomes hard to press. This will release any vacuum that has been stored in the booster. With your foot on the brake start the engine, the booster is okay if the pedal drops. This indicates that the vacuum is present at the booster.

Leak Test

Run engine at about 3,500 rpm's and allow to return to idle about 2-3 times. This will allow for sufficient vacuum to build up in the booster. Stop engine and operate brake pedal with normal braking force. The pedal should be spongy at least 1 or 2 times, during this a suction noise should be heard. This will indicate that there is no leak and the system is okay.

Checking Function of Master Cylinder

Symptoms of a faulty Master Cylinder:

- Fluid leakage from the rear of the cylinder. This is visually identified by pulling the master cylinder away from the booster; any sign of fluid loss from this area requires replacement.
- A brake pedal that slowly sinks to the floor when light to moderate pressure is applied. When checking for a faulty master cylinder, do not apply heavy pedal pressure. This is because the cup seals in the master cylinder will hold pressure better when exposed to higher pressures.
- A brake pedal with excessive travel that will generally decrease if the pedal is pumped.

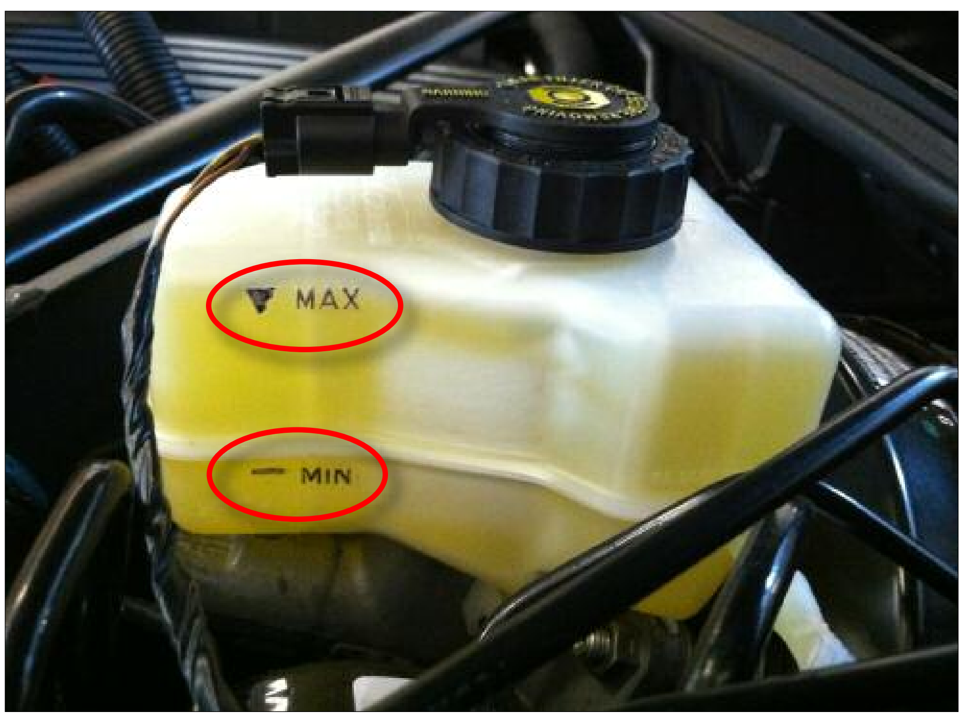
Excessive pedal travel can also be caused by pads being kicked back in the caliper because of faulty wheel bearings. This is why when performing a brake inspection the entire brake and suspension system should be inspected thoroughly.

Checking Brake Fluid Level

Always comply with the following:

- Always wipe the cap for the master cylinder reservoir prior to removal.
- The master cylinder should never be filled higher than the recommended full mark to allow for brake fluid expansion that occurs as the temperature of the fluid increases.
- An overfilled master cylinder may cause the system to self pressurize with rising fluid temperatures, which could result in brakes that drag.
- Prior to retracting caliper pistons for brake pad replacement drain off some fluid from the reservoir to prevent brake fluid from getting on any finished surfaces.

Brake fluid cap



Fluid reservoir

Common Brake Related Complaints

Brake Squeal
Sometimes a loud noise or high pitch squeal occurs when the brakes are applied. Most brake squeal is produced by vibration (resonance instability) of the brake components, especially the pads and discs.

This type of squeal should not negatively affect brake stopping performance. Cold weather combined with high early morning humidity (dew) often makes brake-squeal worse, although the squeal stops when the lining reaches regular operating temperatures. Dust on the brakes may also cause squeal.

Brake Shimmy/Judder
Brake judder is usually perceived by the driver as minor to severe vibrations transferred through the chassis during braking.

The judder can be classified into two distinct subgroups: hot (or thermal), or cold judder.

Hot judder is usually produced as a result of longer, more moderate braking from high speed where the vehicle does not come to a complete stop. It commonly occurs when a motorist decelerates from speeds of around 75 mph to about 37 mph, which results in severe vibrations being transmitted to the driver.

These vibrations are the result of uneven thermal distributions, or hot spots. Hot spots are classified as concentrated thermal regions that alternate between both sides of a disc that distort it around its edges. Once the brake pads comes in contact with the surface during braking, severe vibrations are induced, and can produce hazardous conditions for the person driving the vehicle.

Cold judder, on the other hand, is the result of uneven disc wear patterns or disc thickness variation. These variations in the disc surface are usually the result of extensive vehicle road usage. The variation of the disc thickness is usually attributed to the following causes: waviness of disc surface ,misalignment of axis (runout), wear and friction material transfers.

Brake Dust
When braking force is applied, small amounts of material are gradually ground off the brake pads. This material is known as "brake dust" and a fair amount of it usually deposits itself on the braking system and the surrounding wheel. Brake dust can badly damage the finish of most wheels if not washed off. Airborne brake dust is known to be a health hazard, so most repair manuals recommend the use of a chemical “brake cleaner” instead of compressed air to remove the dust. Different brake pad formulations create different amounts of dust.

General Information

The brake system is one of the most important safety systems on any motor vehicle. It is therefore essential to act with utmost care when working on the brake system and to follow the instructions below.

- Ensure cleanliness and only use rags which do not lose lint.
- Wash away or vacuum up brake dust, do not clear it away using compressed air. This dust is a health hazard.
- Do not under any circumstances allow any oil or grease to get into the brake system. This would result in a complete malfunction of the brake system.
- When cleaning brake components with brake cleaner (refer to BMW Parts Service), do not allow brake cleaner to get into in the brake system.
- Even the most minute traces of brake cleaner must be avoided.

Braking in New Brake Pads and Rotors
After completing work:

- Carry out function check on brake test stand to ensure that the brakes complies with legal requirements.
- Carry out test braking while driving at low speed; the effectiveness of the brakes may be reduced during the initial braking operations.
- Exaggerated drastic and continuous braking operations for faster braking in are not permitted.
- Advise the customer not to perform any willful drastic braking in the first 200 km after brake replacement.
- Attach mirror tag to interior rearview mirror.

Brake Fluid

- Replace brake fluid at least every two years.
- Never reuse drained brake fluid.
- Always dispose of brake fluid in approved receptacles only.
- Dispose of brake fluid in approved appliances only, refer to BMW Service Workshop Equipment Planning documentation.
- Do not allow brake fluid to drain into drain pipes, into the outside environment or into unsuitable facilities.
- Do not allow brake fluid to come into contact with paint work as this will destroy the paint.
- Brake fluid must not be allowed to remain on bare skin too long in order to avoid skin problems. Wash skin coated with brake fluid with water and soap.
- If brake fluid makes contact with eyes, immediately flush with large quantity of clean water and visit eye doctor.

Brake Pads

- Brake pads must be replaced when the warning threshold of the brake pad wear indicator is reached.
- Brake pads must always be replaced on both sides of any axle.
- The friction surfaces of the brake pads must not come into contact with oil or grease. The brake pads must be replaced if they are fouled by such substances.
- In the case of rotation-dependent brake pads, make sure the arrow marking points in the direction of rotation of the brake disc for when the vehicle is moving forward. Brake pads with left/right markings must be fitted on the relevant side of the vehicle.

Brake Discs

- Brake discs must not be scored or cracked. Furthermore, minimum brake disc thickness, disc runout, parallelism and surface roughness of the friction surfaces must not exceed or drop below the permitted values.
- Always strip preservative off new parts before installation. With the rear brake discs, also strip preservative off brake drum on parking brake.
- Never strike friction surface with any type of device such as a hammer.
- Cross drilled discs cannot be machined.

Brake Calipers

- Only approved pastes on the basis of glycol must be used for repairs on brake callipers.
- All moving parts on the brake caliper must move freely: note grease specifications.
- Use only BMW-approved lubricants to grease calliper guides (refer to BMW Service Operating Fluids).
- Newer BMW models utilize a special coatings on the caliper contact points and mechanical cleaning should be avoided.

Brake Lines, Brake Hoses

- Brake lines and brake hoses must be correctly routed and must not contact with body or components in a way which would cause chafing.
- To prevent damage, release and tighten brake line couplings with a special brake line wrench only.
- The system must be bled each time any brake lines have been detached.
- All connection points must be checked for leaks.
- Only tighten down brake hoses on the front axle when wheels are in straight-ahead position.
- Close off open connections of brake lines and individual components to prevent dirt from getting into the brake system.
- When tightening down brake line couplings, observe tightening torque.
- Do not bend or kink brake lines.

Federal Motor Vehicle Safety Standards (FMVSS)

Federal Brake Standards

The statutes pertaining to automotive brake systems are part of the Federal Motor Vehicle Safety Standards (FMVSS) established by the United States Department of Transportation (DOT). These Standards cover many areas of car design, figure 2-1, but the Standards directly affecting brake systems are found in Part 571. Several Standards apply to specific components within the brake system, and these will be covered in the appropriate chapters later in the text. Overall service and parking brake systems are dealt with in Standard 105.

FMVSS 105 was first mandated in 1967, and was substantially revised in 1976 taking into account many advances in brake technology. Since that time several smaller revisions have been made to accommodate lesser technical and procedural changes. In its own words, the scope of FMVSS 105 is to specify "requirements for hydraulic service brake and associated parking brake systems." Its purpose is to "insure safe braking performance under normal and emergency conditions." And it applies "to passenger cars, multipurpose passenger vehicles, trucks, and buses with hydraulic service brake systems."

FMVSS 105 deals with brake system safety by establishing specific brake performance requirements. It does not dictate the design of the system, although some requirements may make older technologies impractical or obsolete. For example, the more stringent performance levels specified in the updated standard of 1976 effectively eliminated drum brakes on the front axles of cars. Only four parts of the brake system are specifically regulated: the fluid reservoir and labeling, dashboard warning lights, a method of automatic adjustment, and a mechanically engaging, friction-type parking brake system.

However, room is allowed for variations in final design. The bulk of FMVSS 105 consists of a comprehensive test procedure designed to reveal any weaknesses in a vehicle's braking system. The test is used by manufacturers to certify the braking performance of new models, and is never performed on a vehicle in service.

Safety Standard Codes

FMVSS	Title
105	Hydraulic Brake Systems
106	Brake Hoses
108	Lamps, Reflective Devices, and Associated Equipment
116	Motor Vehicle Brake Fluids
121	Air Brake Systems
122	Motorcycle Brake Systems
211	Wheel Nuts, Wheel Discs, and Hub Caps

Passenger Car Brake Test Maximum Stopping Distance In Feet

Vehicle Speed (MPH)	1	2	3	4
30	57†	54†	51	114
35	74	70	67	155
40	96	91	87	202
45	121	115	110	257
50	150	142	135	317
55	181	172	163	383
60	216†	204†	194†	456†
80	405*	383*	-	-
95	607*	-	-	-
100	673*	-	-	-

† Values required for specific tests.
* Values required for tests on higher performance vehicles.

FMVSS 105 Brake Test

The overall FMVSS 105 brake test consists of 18 steps. Most of the actual performance tests are made with the vehicle loaded to the manufacturer's specified Gross Vehicle Weight Rating (GVWR), although some are made with a light load of 400 pounds that includes the weight of both the test instrumentation and the driver. There are precise instructions for every step of the test, and these must be followed exactly for the test to be valid . The basic procedure for each step is summarized below.

1. Instrumentation test - the test instrumentation is mounted on a vehicle with new brakes and checked for proper operation.

2. First effectiveness test - before the brake linings have any chance to burnish in, the vehicle must make six stops from 30 mph and six stops from 60 mph. At least one stop from each speed must be within the maximum distances shown in column 1 of chart above.

3. Burnish procedure - the brakes are burnished by making 200 stops from 40 mph at a fixed rate of deceleration with a controlled cool-down period after each stop. Afterward, the brakes are adjusted manually according to the vehicle manufacturer's recommendations.

4. Second effectiveness test - the vehicle must again make six stops from both 30 mph and 60 mph. High-performance models must also make four stops from 80 mph. At least one stop from each speed must be within the maximum distances shown in column 2 of the chart above.

5. First reburnish - the brakes are reburnished as in Step 3, except that only 35 stops are required.

6. Parking brake test - the parking brake must hold the vehicle in a stationary position for five minutes in both forward and reverse directions on a 30-percent grade. The force used to apply the brake cannot be more than 125 pounds for a foot-operated system, or 90 pounds for a hand-operated system. This test is performed at both light load and full GVWR.

7. Third effectiveness test - this test is performed only at light load. The vehicle must make six stops from 60 mph. At least one stop must be within the maximum distance shown in column 3 of the chart above.

8. Partial hydraulic failure test - with half of the dual-circuit brake hydraulic system disabled, the vehicle must make four stops from 60 mph. At least one stop must be within the maximum distance shown in column 4 of the chart above. This test is performed at both light load and full GVWR, and is repeated for each half of the system. If the vehicle is equipped with an antilock or variable proportioning subsystem, the test must be performed with each of these systems disabled as well.

9. Inoperative power booster test - with the power booster deactivated and any residual assist capability exhausted, the vehicle must make four stops from 60 mph. At least one stop must be within the maximum distance shown in column 4 of the chart above.

10. First fade and recovery test - this test involves a series of 18 stops from various speeds at different rates of deceleration. To pass the test, the brake system must be able to stop the vehicle in all instances without the required pedal pressure exceeding specified limits.

11. Second reburnish - the brakes are reburnished as in Step 5.

12. Second fade - and recovery test basically the same as Step 10.

13. Third reburnish - the brakes are reburnished as in Step 5.

14. Fourth effectiveness test - this is the final effectiveness test that examines the performance of a fully burnished-in brake system. The vehicle must make six stops from both 30 mph and 60 mph, and passenger cars must also make four stops from 95 or 100 mph, the upper speed limit being determined by the vehicle's acceleration capability. At least one stop from each speed must be within the maximum distances shown in column 1 of the chart above.

15. Water recovery test - after being driven for two minutes at 5 mph in either direction through a 6-inch-deep trough of water, the vehicle must make five consecutive stops from 30 mph at a fixed rate of deceleration without the required pedal pressure exceeding a specified limit.

16. Spike stop test - the vehicle must make 10 stops from 30 mph with the transmission in neutral and a force of 200 pounds applied to the brake pedal. Immediately thereafter, the vehicle must make six stops from 60 mph, one of which must be within the maximum distance specified in column 1 of the chart above.

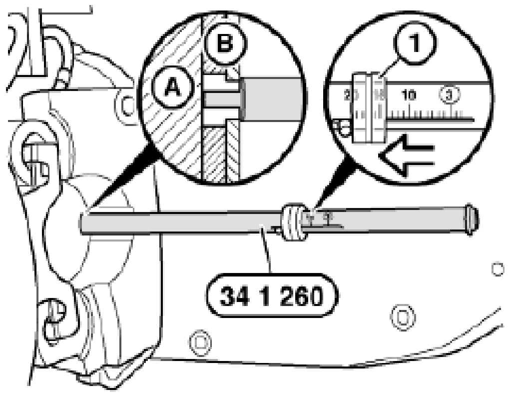
17. Final inspection - following all of these steps, the brake system is inspected for any physical damage or hydraulic fluid leakage; none is permitted. Also, the brake fluid reservoir and the system warning light are checked to ensure that they comply with specific requirements set forth in the FMVSS.

18. Moving barrier (park lock) test - vehicles that use the automatic transmission park lock mechanism when passing the parking brake test (Step 6) must also pass this test. With the transmission in Park and the parking brake not applied, the vehicle is struck by a moving barrier at 2.5 mph, first at the front, then at the rear. The park lock mechanism must survive with no damage for the vehicle to pass the test.

Although these tests may seem extreme, remember that they are only a minimum standard of performance. Any brake repair work performed on a vehicle should leave the brake system capable of meeting FMVSS 105 if the car were taken out of the service bay and put through the battery of tests.

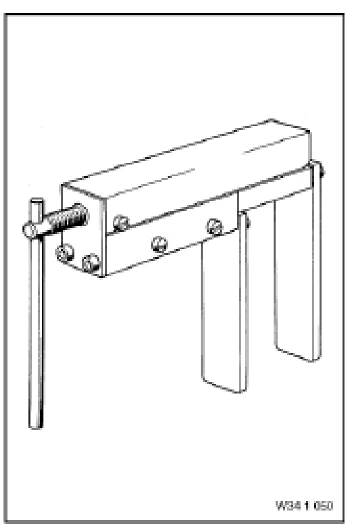
Tools and Equipment

Gauge for checking brake pad thickness 83 30 0 492 467 (34 1 260)

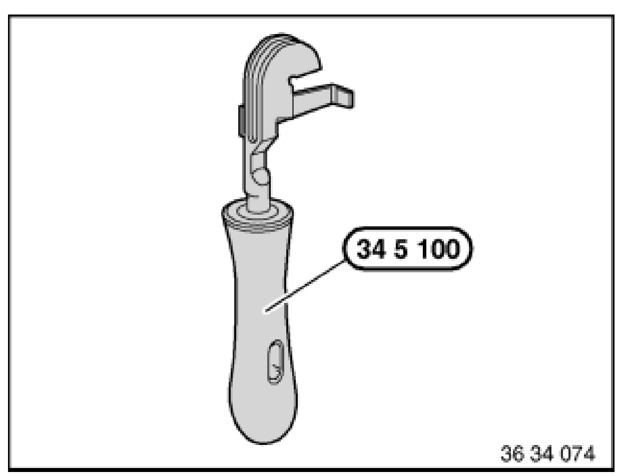


Brake caliper piston compressor 83 30 0 494 057 (34 6 320)

Brake piston retractor (34 1 050)

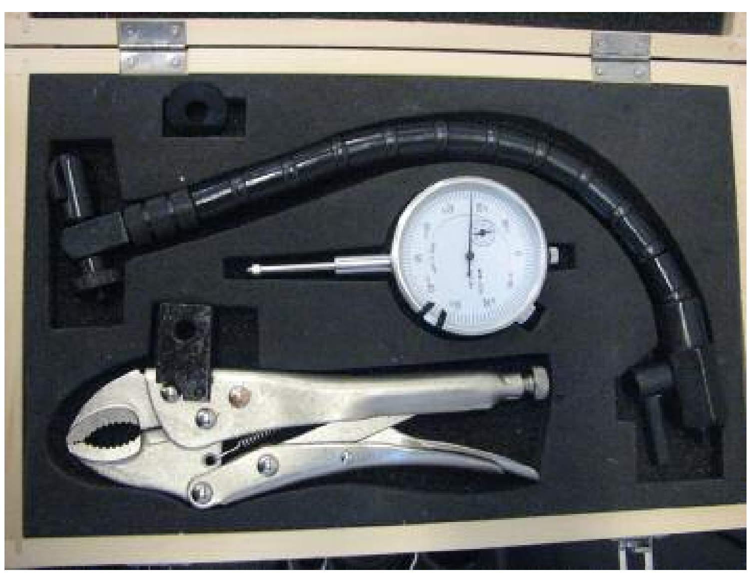


Brake line bending tool (34 5 100)

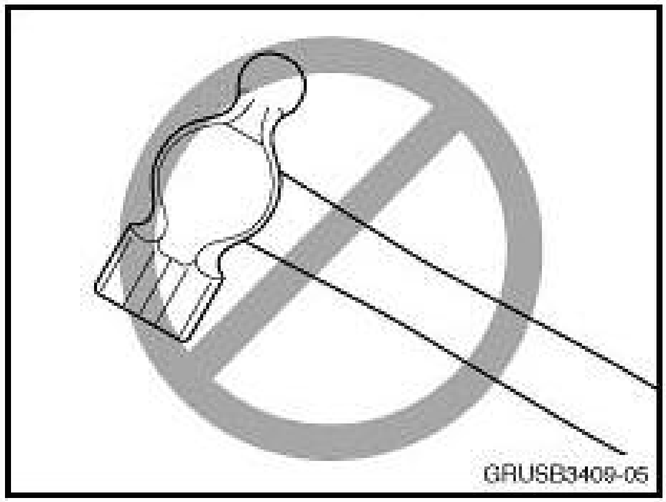


Wheel hub grinder 83 30 0 494 738 (36 1 250)

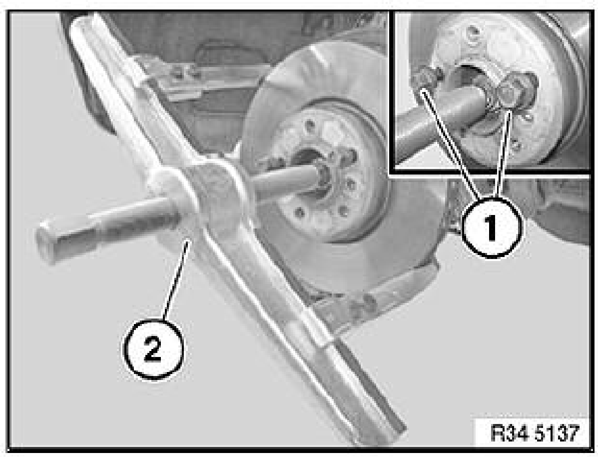
Dial indicator with flex mount (locally available)



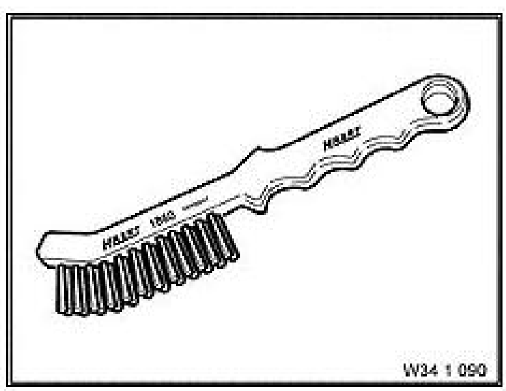
Never use to remove rotors (SI B 34 04 09)



Brake rotor puller P/N 81 64 2 162 483

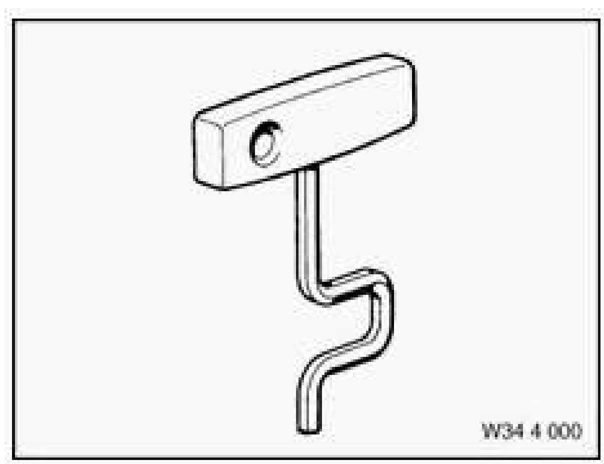


Brake Caliper Brush P/N 90 88 6 341 091 (34 1 091)



Veiner caliper for measuring brake disc 88 88 6 341 280 (34 1 280)

Handbrake shoe release tool 83 30 0 492 488 (34 4 000)



Power Probe Brake Bleeder

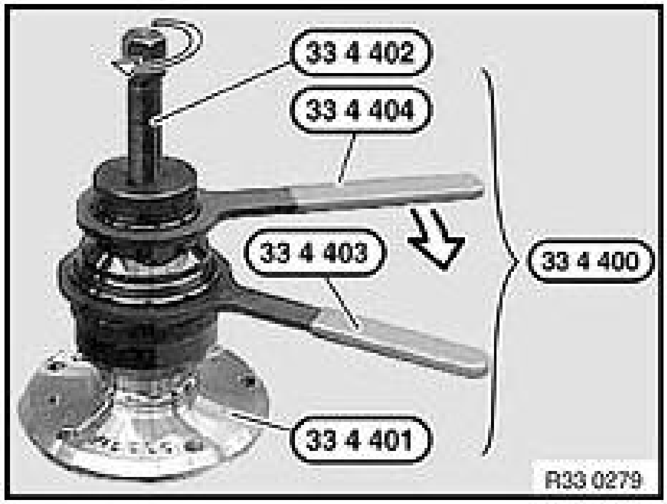
Wheel bearing / output shaft press 81 64 2 160 009 (1 of 3 cases)

Hydraulic Unit

Adapter Set 1

Adapter Set 2

Rear Wheel Bearing Race-Removing Kit 83 30 0 493 416



Operating Fluids

July 2010

Group 34 Brakes

Technical Service

Fluids and sealers that are described in this Operating Fluids manual are BMW approved. Using non approved fluids or sealers can lead to premature failure and will not be covered under Warranty.

1.0 General Information

Brake fluid, (glycol-based) as used in BMW brake systems, must conform with the following requirements:

— High boiling point

— Good low temperature resistance

— Low compressibility

— Corrosion inhibition for all metal parts inside of brake system

— Compatibility with all rubber parts used in brake system

These requirements are fulfilled by reputable brand name DOT 4 brake fluids.

Silicone-based brake fluid has better compressibility, but because it cannot absorb moisture, is subject to vapor lock attemperatures above 212°F/ 100°C. At lower temperatures, it may even ice-up. **Silicone-based brake fluid is not approved by BMW.**

Glycol-based brake fluid absorbs moisture from the atmosphere (hygroscopicity) through the brake fluid reservoir, brake hoses, etc. This absorption of water lowers the original boiling point of brake fluid and active safety of the entire system. If there is extended use of the brakes while driving downhill at high speeds, the thermal loads could cause vapor bubbles in the brake fluid. This situation could lead to reduced braking effectiveness.

The original boiling point of factory-approved brake fluids is approximately 500°F/260°C. Due to the hygroscopic behavior of brake fluid, 2% of water within one year is permissible. The boiling point of brake fluid will drop by 100°C with 3% water absorption. It is essential to conform with brake fluid changing intervals in order to guarantee the safety and maximum effectiveness of a brake system.

It would not be sufficient simply to replace the brake fluid in the reservoir. Experience has shown that vapor bubbles will occur first on areas of the brake caliper. This area is subjected to high thermal loads and also exposed to heat transmission.

When replacing the brake fluid, the brake fluid used as the working fluid in the hydraulic clutch should also be replaced. This is done by draining the clutch operation system or bleeding with the help of the clutch slave cylinder.

The brake fluid should be replaced by filling the brake fluid reservoir. Make sure that each bleeder valve of all wheel cylinders or brake calipers is kept open until the escaping brake fluid is clear and without air bubbles. Never use brake fluid that has been drained from the system.

Storage of brake fluids also deserves your special attention. The aging process begins with the initial contact between the brake fluid and the atmosphere. This means immediately after a new container is opened.

To keep the boiling point of stored brake fluids as high as possible, we recommend conforming with the following points:

— Close all containers tightly.

— Select small size containers, which can be used up quickly.

— Avoid pouring contents of one container into a different container.

2.0 Handling Brake Fluids

Brake fluids could be mixed up accidentally with mineral oil products so it is important to leave them in their original containers and not pour them into a different container.

Caution

If brake fluid accidentally comes into contact with your skin, wash it off with soap and water immediately. Eyes should be thoroughly flushed with cold water if contacted by brake fluid. Vomiting should be induced if brake fluid is internally consumed and a physician should be consulted.

If brake fluid is spilled or drips on a painted surface, wash it off with water immediately to prevent damage to the paint finish. Never rub it off. Brake fluids should not have contact with grease or oil. Wash hands to remove grease and oil before working with brake fluids. Also make sure that grease cannot enter the brake system.

Drained brake fluid must never be discarded in the garbage, oil disposal tanks or water drains.

Read instructions on container label prior to use.

3.0 BMW Tested And Approved Brake Fluids

BMW Tested and Approved **DOT 4 ESL** Brake Fluid is available as follows:

12 fl. oz. bottle	BMW Part No. 81 22 0 142 156
1 gallon container	BMW Part No. 81 22 0 142 155

See S.I. Bulletin B 34 09 01.

4.0 Brake Fluid Change Intervals

All Models Brake fluid change interval every 2 years.

5.0 Other Operating Fluids

Anti-Squeak/Corrosion Paste

Bostik NEVER-SEEZ® to prevent disc brake squeaking. It is applied on cleaned recesses, pressure surfaces of piston crowns, brake pad backplates and possibly transfer plates - but not on friction liners.

To prevent corrosion between the ABS impulse sensor and the hole in the wheel suspension component, apply a thin coat of Bostik NEVER-SEEZ® to cleaned sensor and hole before assembly.

Bostik NEVER-SEEZ® Part No. NSBT-16
See S.I. Bulletins B 34 02 94, B 34 05 98, and B 34 03 00.

Brake Cleaner Spray

Non-CFC spray (former BMW Part No. 81 22 9 407 704) for cleaning brakes, brake pads, brake shoes, drums, disks and other brake components. Also suitable for clutch pressure plates.

3M	Part No. 8895
Loctite	Part No. 82220
CRC	Part No. 08088