Abrasive Friction
In braking, intermolecular bonds of rotor and pad are broken for the conversion of Kinetic to Thermal energy. The term Abrasive friction is reference to one of two types of friction mechanisms in braking. The other type being Adherent friction (see Adherent Friction). Abrasive friction is a friction mechanism where abrasive particles in the pad are in a crystalline sense harder than the materials in the rotor. The dust observed from brakes made from grey iron, no matter the color, is primarily from this rotor wear. The small amount that is from the pad is due to the abrasive particles in the pad, as they wear down and become dull, being dislodged due to the force acting on them. Abrasive friction is also sometimes described as mechanical plowing. An abrasive friction mechanism best describes the function seen on many OEM vehicles from Europe.

ABS
Acronym for Anti-lock Braking System. Anti-lock braking systems during a braking cycle sense vehicle speed, rate of vehicle deceleration, the rate of velocity change of each of wheel independently and, through a microprocessor control system, act to prevent lock up of any wheel under braking force by controlling the line pressure to the wheel that is approaching lock up. While ABS controllers are constantly being developed with other design strategies, historically ABS feels like it is cycling due to the system programming and design that is controlling pressure at the wheel cylinder by first isolating the driver then cyclically lowering then raising pressure to correspond to what is required. The pulsation the driver feels in the pedal is due to the design paradigm that uses the driver's pedal effort at any given instant to set the maximum pressure the system will yield. Most current passenger cars and trucks are fitted with ABS due to national and international laws, while even more elaborate system to control vehicle yaw or spin under extreme maneuvers is becoming a requirement. See "Active Handling."

Active Handling
Active Handling is an upcoming requirement for most new vehicles sold where the ABS systems basic components and programming are upgraded to act independent of driver brake system input. The ABS system has added sensors and programming to control the vehicle tendency to lose traction, spin (yaw), act unfavorably or even anticipate actions required like increasing brake force output beyond that being directed by the driver to improve the handling of the vehicle in complex dynamic situations. For example, one manufacturer's version applies the vehicle brakes when the vehicle is stopped or moving slowly and the automatic transmission is not in park but the driver's door is opened, anticipating that the driver has forgotten to set the parking brake if also not putting the transmission into park.

Adherent Friction
Adherent friction is reference to one of two types of friction mechanisms in braking. The other type being Abrasive friction (see Abrasive Friction). Adherent friction is a friction mechanism where a thin layer of brake pad material bonds (adheres) to the rotor face. This transfer layer of brake pad material, once evenly established on the rotor, is what rubs on the brake pad. Intermolecular bonds that are broken, for the conversion of Kinetic to Thermal energy, are formed instantaneously before being broken again. Wear of the rotor is almost non-existent and pad wear comes from material being dissociated from pad and rotor during the braking cycle. Uneven pad material transfer on the rotor surface can lead to brake judder. Brake judder due to an uneven transfer layer is often mistakenly diagnosed as a warped rotor. See also "Transfer Layer," "Brake Judder" and "Warped Rotors." Adherent friction is also called adhesive friction and sometimes described as mechanical attraction. This is a friction mechanism that best describes mostly a Semi-metallic (semi-met) and some non-asbestos organic (NAO) type formulas as seen on North American and Japanese cars. The distinction comes from the ferrous based formulas in the semi-mets and the copper and other non-ferrous based metal formulas in the NAOs.

Aluminum Beryllium
An engineered alloy of Aluminum of exceptional stiffness to weight ratio used for Formula One calipers (and Ilmor/Mercedes engine blocks) in the late 1990s. Now outlawed on health grounds.

AK Master Test
This is a basic automotive brake dynamometer test protocol used to characterize a brake pad material friction couple with a given rotor material or substrate as in a special case of Carbon Ceramic rotors. This test includes a "green" or as installed friction testing, burnishing, post-burnishing friction couple testing, testing to determine fade resistance and then post fade friction testing. Centric runs AK Master testing on our brake dynamometers as requested or required, but we have also developed our own more comprehensive test protocols to better qualify friction. See "Friction Couple and "Fade Resistance."

Aluminum Lithium
An engineered alloy of Aluminum of high strength and stiffness to weight ratio currently being used for Formula One calipers.

Anti-lock Braking System
Anti-lock braking systems during a braking cycle sense vehicle speed, rate of vehicle deceleration, the rate of velocity change of each of wheel independently and, through a microprocessor control system, act to prevent lock up of any wheel under braking force by controlling the line pressure to the wheel that is approaching lock up. See ABS definition.

Anti-squeal Plate
Very thin stiff metallic or composite plate, sometimes coated and or layered with a high temperature rubber or plastic, inserted between brake pad backing plates and caliper pistons on passenger cars to reduce or eliminate brake squeal. Can also be called pad shims, noise shims.

Asbestos
Impure magnesium silicate with very low thermal conductivity - once used as an insulating material and as one of the components in brake friction materials. Starting in the mid-1980s, attempts were made to ban its use in brake friction materials. In fact, in 1989, the EPA did ban asbestos in brakes but it was challenged in court and defeated. In 1993, the EPA again tried to reach agreement with at least one half of all the OEMs to ban its use but the voluntary plan was never implemented and there has been no subsequent successful effort to ban its use. Based on product liability concerns alone, its use has been steadily declining. While responsible manufacturers and distributors of brake friction material have eliminated its use in their product. There is no asbestos in any product sold by CWD group of companies or in any of our brands: Centric, Qualis or StopTech.

Backing Plate
The steel portion of a disc brake pad which contacts caliper piston(s) and to which the brake friction material is bonded. Backing plate provides the necessary stiffness and mechanical strength to a brake pad. Its dimensions, flatness and surface finish must be closely controlled. The longer or the larger the area of a pad, the thicker the backing plate must be. Backing plates of less than about 3 mm should be viewed with suspicion unless the pad is very short.

Bedding In
Also called “breaking in” or “break-in.” There are two types of “bedding in” with regard to brakes:
1. Bedding of brake friction material: All brake friction materials contain volatile elements used as binders. In initial thermal cycling of the new pad these volatiles boil off, forming a gaseous layer between the friction material and the rotor which can result in a severely diminished brake torque. A bedded pad will exhibit a layer of discolored material from 1.5 to 3 mm thick. Alternately, some brake friction materials are manufactured “scorched” or “pre-scorched” to eliminate the need to perform this step. See “Scorched.” Pads that have been scorched only require a few brake applications to feel ready to use. As is the case below the brakes will feel better with continued use.

2. Bedding of brake rotor: Before using a new rotor, all machining and preservative oils must be completely removed following the rotor manufacturer’s recommendations. Usually it involves washing with soap and water or using one of the proprietary “brake clean” compounds. The rotor should then be mounted and checked for run out. It should be bedded in with a number of moderate stops allowing for a steady build up of temperature to the pad manufactures recommend limit followed by complete cool off. Generally brake system bed-in will improve by performing a second cycle and cool off. When completed, the entire surface of the rotor will be evenly discolored. This method will prevent thermal shock, distortion and the formation of “hot spots” (regional deposition of pad material which results in a permanent transformation of the cast iron underneath the deposit) and ensure maximum rotor life.

BEEP
BEEP is an acronym for Brake Effectiveness Evaluation Procedure. It is an automotive brake dynamometer test protocol and certification process developed by the Brake Manufacturers Council (BMC) for friction materials.

BEEP is administered by the Society of Automotive Engineers (SAE). See “SAE” and “Brake Manufacturers Council.”
The BEEP program uses the SAE J2784 brake dynamometer standard and the BMC’s vehicle specific dynamometer test data model. See “J Standards or Recommended Practices, SAE.” Formally released in 2011, the BEEP program is the only certification program in the brake friction industry that follows the National Highway Traffic Safety Administration (NHTSA) directive to use voluntary industry standards that are developed by standards development organizations like SAE.

The BEEP program monitors the sample product’s performance relative to its braking torque ability during normal and high temperature operation including moderate and high speed stops and considering curb and gross vehicle weight, failed system and brake recovery as required in FMVSS 105 and 135.

Bell See “Hat”

Bias Bar
A system allowing rapid adjustment of the front to rear braking force on a car. Universal in racing, the bias bar connects pushrods of dual master cylinders with an adjustable fulcrum allowing crew or driver adjustment of the braking ratio.

Bite
The speed at which the friction material reaches its maximum coefficient of friction when braking is initiated. The amount of bite is a compromise. Too much bite makes initial modulation difficult. Too little causes a delay in braking. In racing, different drivers prefer pads with different degrees of bite.

Blades See “vanes”

Bleeding
A process of removing air bubbles from a newly filled system or existing brake fluid from a hydraulic brake system while simultaneously replacing it with fresh fluid. In the latter case this is typically done to remove overheated fluid and/or air bubbles from a hydraulic circuit(s) shortly following hard use, but should be performed on a regular basis as well due to the natural tendency of brake fluid to absorb water over time.

Bluing
Discoloring of cast iron rotor due to heat. Although bluing is evidence of thermal stress and will lead to reduced rotor life, it is normal under repeated hard braking and is not a cause for concern.

BMC
BMC is an acronym for Brake Manufacturers Council. See “Brake Manufacturers Council.”

Brake Bias
A term used to indicate the ratio between the amount of brake torque exerted by the front brakes compared with the rear. Brake bias is normally expressed as a percentage of brake torque at one end of the car to the total brake torque, as in “60% front.”

Brake Booster
A vacuum or hydraulic assist device that amplifies pedal force. In some cases, this assist is accompanied by small increases in pedal travel and reductions in pedal firmness. However, due to its compact design and efficiency, a vacuum boosted version is virtually universal on passenger cars up through 2000. At around that time hydraulic power boosted systems began to be used in some luxury and armored cars.

Brake Judder
Brake judder is a term used by brake manufacturers to describe the physical effects of non-uniform brake friction material deposits from an Adherent friction material type on a rotor. The physical observation of shaking in the brake pedal and steering comes from the oscillating hydraulic pulsation and high and low torque created by the pad interacting respectively with a slightly varying rotor thickness and friction coefficient due to uneven pad material deposits. See also “Adherent Friction,” “Transfer Layer,” “Warped Rotors.”

Brake Line Pressure
The hydraulic pressure at any instance within the brake lines. Brake line pressure in inch-pound-second (IPS) units of measure are reported in pounds per square inch (psi) is the force applied to the brake pedal in pounds multiplied by the mechanical pedal ratio (plus any booster assist where applicable) divided by the area of the master cylinder piston in square inches. For the same amount of pedal force, the smaller the area of master cylinder and/or the greater the mechanical pedal ratio and/or booster contribution, the greater the brake line pressure and the longer the pedal travel.

Brake Manufacturers Council
Brake Manufacturers Council is industry association and since 2010 is part of Automotive Aftermarket Suppliers Association (AASA).

Braking Efficiency
The ratio of actual deceleration achieved on a given surface compared with the theoretical maximum.

Braking Torque
Braking torque in pounds-feet, in the inch-pound- second (IPS) units, on a single wheel is the effective rotor radius in inches times clamping force in pounds times the coefficient of friction of the pad against the rotor (a unit-less value) all divided by 12. Braking torque is the force resisting rotation that actually decelerates the wheel and tire. To increase braking torque it is necessary to increase brake line pressure, piston area (clamping force), coefficient of friction, or effective rotor radius. Increasing the pad area will not increase braking torque.

Burnishing
Burnishing is an industry term for additional conditioning of brake pads after primary manufacturing. It is also often referred to as a step before testing. In this latter context, the term is most often used to say that a pad is fully matured by performing a number of burnishing cycles on a vehicle or a brake dynamometer. Again in this context, the number of brake applies can be the equivalent of as much as 500 to 1000 miles (800 to 1500 km) on a vehicle.

Scorching the surface of the brake pad is one method of performing enough of a burnishing prior to packaging and distribution so that a pad can be used without delay. See “Scorching.”
On a vehicle or a brake dynamometer, another type of a burnishing cycle (also known as bed-in) is performed during a series of controlled stops. See “Bedding-In.” This accomplishes two functions:

1. It completes preparation of the brake pad material closest to the rotor to do its most effective work. A function also realized by Scorching.

2. In the case of a brake pad material that works by adherent friction, it creates a controlled, uniform transfer layer of pad material on the surface of the brake rotor to promote what is termed an “adherent” friction mechanism. See “Adherent Friction.”

Caliper
The “hydraulic clamp” portion of a disc brake system. Manufactured from either ferrous or non-ferrous material and attached to the suspension upright (or “knuckle”) the caliper typically holds the pads in place and, through the action of hydraulic pistons actuated by the master cylinder, forces them against the surface of the rotating rotor when pressure is applied to the brake pedal.

1. Fixed caliper: A brake caliper in which one or more pistons are arranged on both sides of a rigid body with the rotor in the center. Due to its inherent stiffness a fixed caliper is the only design suitable for racing categories where it is allowed and is the preferred design for high performance cars. However, its commensurate increased size, cost, and weight depending on the materials used prevent its widespread use on passenger vehicles.

2. Floating caliper: A design in which a single or dual piston is located inboard of the rotor and the outer body of the caliper slides on suitable surfaces in reaction to piston pressure. The caliper piston forces the inboard pad against the outer rotor surface while the sliding outer body clamps the outboard pad against outer rotor surface. The inherent lack of rigidity in this design, compared to fixed caliper design, combined with friction inherent in the sliding outer body makes this design less suitable for racing and high performance use. This design is well suited for use with front wheel drive as the absence of any outboard pistons allows greater negative (inward) wheel offset. In all applications, this caliper type is simpler to manufacture and affords more packaging flexibility for zero or even negative scrub radius front suspension designs. It is sometimes used in the rear brake on an application that has a fixed design in the front.

3. Open caliper: The design of fixed caliper in which the “window” through which the brake pads are inserted is structurally open. This design, while less expensive to manufacture, significantly reduces caliper rigidity or stiffness.

4. Closed caliper: The design of fixed caliper in which the “window” through which the brake pads are inserted is structurally reinforced by a bridge.

5. Caliper bridge: The structural reinforcement across the open face of a fixed caliper. If removable, in order to be effective the bridge must be bolted or pinned in place with the correct fasteners.

Caliper Pistons

Hydraulic cups that transmit brake line pressure to clamp the pads against the rotating rotor. Manufactured from Aluminum, steel, stainless steel, Titanium or Phenolic and sealed in caliper bores, mechanical design of caliper piston is critical. Some movement of the pad can cause the piston to “cock” in its bore so the piston to bore clearance, thermal coefficients of expansion between piston and caliper as well as seal design and location are crucial. Care should be taken in using pistons or seals from a supplier other than an OEM. In all cases that a StopTech part is listed as a direct replacement for the OE part, it will work as well as the OE part.

Carbon/Carbon Brake

A braking system in which both rotor and pads are manufactured from carbon composite material. Utilized in every form of racing where they are not outlawed, carbon/carbon brakes offer significant reduction in rotating mass and inertia along with increased thermal storage capacity and dimensional stability in use. The disadvantages include cost, a certain amount of lag time while heat builds up (especially in the wet), slow heat transfer into and out of the core vs other material like gray iron and some difficulty in modulation. Contrary to popular belief, its coefficient of friction is no better than that of state of the art carbon metallic pads and cast iron discs. Its friction mechanism is characterized as adherent. A major advantage on super speedways is a reduction of gyroscopic precession on corner entry.

Cast Iron

Metallic iron containing more than 2% dissolved carbon within its matrix (as opposed to steel which contains less than 2%) and less than 4.5%. Because of its cost, relative ease of manufacture and thermal stability cast iron (sometimes referred to as “gray cast iron” because of its characteristic color, but is actually a more specialized material for brake applications) is the material of choice for almost all automotive brake discs. To work correctly, parts must be produced at a foundry with tightly monitored chemistry and cooling cycles to control the shape, distribution and form of the precipitation of the excess carbon. This is done to minimize distortion in machining, provide good wear characteristics, dampen vibration and resist cracking in subsequent use.

Center Split Core Molding (Symmetric)

Brake rotors are formed by sand casting where molten iron is poured into a cavity in a sand mold and allowed to cool. In the case of a solid brake rotor, the cavity formed exists between indentations in the sand mold on each side of the parting line. To create a center ventilated core in the finished part, a separate sand core must be made and placed in between the two halves of the sand mold. When forming the sand core, a slight amount of taper or draft angle must be included so that the core can be removed cleanly from the core box that it was formed in.

In a center split core design, the sand core for the cooling vane cavity is typically formed as two symmetric halves. This results in the cast cooling vane with the same thickness at the points where it connects to the inner and outer friction plates. This thickness symmetry promotes the uniform transfer of heat from both friction plates into the cooling vanes.

An alternate and less complicated method is a side split core design. In this case the core is formed from one mold and a flat plate instead of two halves and yields a draft angle that tapers clear across the vane, ending up significantly thinner on one side than the other. This inhibits the transfer of heat from friction plate connected to the thinner side of the vane, causing that friction plate to tend to operate at a higher temperature than the other plate.

Ceramic Buttons

Insulating buttons inserted in the face of caliper pistons to reduce conduction of heat to brake fluid. Not currently used in racing except in so called “Spec Series” as Titanium and Stainless Steel buttons have proved more effective. Also referred to as Ceramic piston noses.

Ceramic coatings

Some racing calipers feature a ceramic coating sprayed onto the interior surfaces as a radiation barrier to reduce heat transfer from rotor and pads to the caliper and fluid.

Chase Test

The Chase test is a relatively simple friction testing method used to assign friction edge codes. See “Edge Code.” The Chase test measures the coefficient of friction range to determine “normal and hot friction” when a 1” square piece of friction material is subjected to varying conditions of temperature on test machine, also known as chase machine. See “J Standards, Procedures and Recommended Practices, SAE, J661.”

Clamping Force

The clamping force of a caliper in pounds, in inch-pound- second (IPS) units, is the brake line pressure, in psi (pounds per square inch),multiplied by the piston area, in square inches, of one half of fixed caliper or total piston area in a floating design. To increase clamping force it is necessary to either increase the brake line pressure or the piston area. Increasing the pad area or the coefficient of friction will not increase clamping force.

Coefficient of Friction

A dimensionless indication of the friction qualities of one material vs. another. See “Friction Coefficient.”

Compressibility

All materials are compressible. Under enough pressure the rock of Gibraltar will compress to some extent. It is important that brake friction material not compress significantly under expected clamping force. If it does, pad wear will be uneven and braking efficiency will be compromised. Compressibility is seldom mentioned in advertising. It should be. Compressibility of a given material and wear rates are the two primary factors that are considered in determining the size of a pad for a given application.

Conduction

One of only three heat transfer mechanisms. Convection and radiation are the other two. Conduction is a transfer of heat by physical contact. For example, some of the heat generated by the automobile braking system is transferred to the caliper pistons and thence to the brake fluid by conduction. Some of it is also transferred to the hub, upright (knuckle) bearings, and wheels in the same way. Two-piece or floating rotors reduce conduction to the hub, and other parts because of the intervening hat. Conduction is also a strategy used in ventilated rotor designs to move heat from brake pad interface to the vanes. The sacrifices made if this is the primary strategy used for heat transfer are weight and inertial penalty in a rotating part.

Convection

One of only three heat transfer mechanisms. Conduction and radiation are the other two. Convection is a transfer of heat by fluid flow. Air can be considered to be a fluid in a thermal model of a brake system when it is moving and is contact with heated surfaces of the rotor or drum. In the case of a solid rotor, air moving over the surface of the rotor functions to provide some cooling. In the case of a ventilated rotor, by pressure of a forced air duct or by induced flow that is a result of the centrifugal acceleration of air already in the vents of a rotating rotor, air flows through the vents. The air absorbs thermal energy along the vent path. In this way, the heat generated by the braking system of an automobile is transferred to the moving air stream and away from the brake rotor.

Cracking

Cracking is primarily due to heat cycling that weakens cast iron rotors. The exact mechanism of this failure is disputed. Cast iron rotors are formed with the excess carbon being precipitated in the form of carbon plates or flakes dispersed throughout the ferrite (iron) matrix. What is believed to happen is that when rotors are operated above about 900º F, the carbon becomes more flexible or “fluid” in its shape partly due to the thermal expansion of the enclosing ferrite matrix. Then, as the rotor cools relatively rapidly back below about 900º F the carbon is trapped in a changed, more random shape then when it was first cast. This creates internal stress on the part and continuously transforms the rotor by relieving stress through cracking.

The cracks begin by appearing between carbon flakes. Nodular or ductile iron would resist this cracking due to the excess carbon being precipitated in a spheroidal form, but it, like other alternative materials do not have the mechanical properties needed to function ideally in a brake disc application. In rotor that are cast to resist cracking through chemistry and controlled cooling at a foundry, cracking will still occur, but more slowly and take the form of heat checks on the surface. In some cases cracks will begin at the periphery of a rotor and propagate inwards. In this situation, propagation can be delayed by drilling small holes at the end of the cracks (stop drilling). We do not recommend this however, because if the cracks continue to propagate unnoticed, catastrophic mechanical failure will result. Replace a rotor at the first sign of cracks at the outer edge of any size. A historic note, one of the first benefits recognized of a curved or angled vane rotor design was to prevent cracks from propagating by imposing a solid vane in the path of the crack. An improvement in cooling function was secondary.

Cryogenic Tempering
Cryogenic tempering is a one-time process that involves first extreme cold treatment followed by heat treatment of a metal part. When a brake rotor is cast and the molten iron cools to a solid form, the resulting structure of the iron at a microscopic level is often less than optimal and stress patterns are present that are unequally distributed throughout the part. Cryogenic tempering changes the material characteristics and reduces the internal stresses left from the casting process thereby permanently improving performance and service life of the metal.

Cryogenic Treatment
A thermal process in which metallic components are slowly cooled to near Kelvin temperature and then equally slowly returned to room temperature. Proponents claim that stresses are relieved and that a transformation of the iron to a more uniform and favorable microstructure occurs. See also “Cryogenic Tempering.”

D3EA®
D3EA® is an acronym for Dual Dynamometer Differential Effects Analysis referring to a proprietary friction testing standard. It is a brake dynamometer protocol that measures a vehicle’s front and rear brake component performance during the same test, hence the name Dual Dynamometer. This test is claimed to show how closely replacement friction materials match applicable FMVSS standards and the original OEM performance. Since this test is not a Federal or International standard and since it is only available from one source, has not been peered reviewed or gained wide acceptance, certification to the D3EA standard is no different than any other proprietary claim. Alternately there is a BEEP process used by some friction suppliers not subscribing to the D3EA certification. The BEEP process is a standard developed by an industry association and is administered by the SAE. See “FMVSS,” ”BEEP” and “SAE.”

Differential Bores
The leading edge of a brake pad wears faster than its trailing edge. This is due to the leading edge of the brake pad being drawn down into the rotor surface by the friction couple when the brakes are applied while the back edge is lifted. As well there is a migration of particles of incandescent friction material carried from the leading to trailing edge of the brake pad. In effect the trailing portion of the brake pad is riding on this layer of incandescent material. By providing an optimally designed larger caliper piston at the trailing edge of the pad, wear can be evened along the length of the pad.

Disc
The rotating portion of a disc brake system. Mechanically attached to the axle, and therefore rotating with the wheel and tire the disc provides the moving friction surface of the brake system while the pads provide the stationary friction surfaces. Except for racing, rotors are normally manufactured from one of several grades of cast iron. Some European front drive passenger cars, where the rear brakes do very little work, are using aluminum metal matrix rear discs to save weight. Some forms of professional race cars use carbon/carbon discs.

1. One-piece disc: A disc cast in one piece with its hat or bell. This is an inexpensive way to manufacture a disc and is perfectly adequate for normal use. There are some tricks to the design to reduce distortion.

2. Floating disc: A norm in racing, floating or two-piece disc consists of a friction disc mechanically attached to a hat either through dogs or through drive pins. Properly designed this system allows disc to dilate (grow radially) without distortion and to float axially, greatly reducing drag.

3. Solid disc: A disc cast as a solid piece suitable for light cars not subjected to extreme braking.

4. Ventilated disc: A disc cast with internal cooling passages. A norm in racing, high performance and heavy vehicles.

Drive Cycle
Drive cycle is a term for brake dynamometer tests designed to simulate real world user profiles. For example in the context of testing friction material or components for use by Police Departments a drive cycle would be developed using on-vehicle data acquisition system like our Link 3801 or Racelogic V-Box to gather the entire velocity, handling and braking profile of a typical shift. This data can be converted to simulate that particular profile on a brake dynamometer and run for as many times as required to equal a daily or monthly use or the measured service interval of the vehicle types. Other examples are used for race cars where additional sensors are added to measure rotor and / or pad temperature and circuit pressure which is used to more accurately develop that particular drive cycle test. Another drive cycle test is as simple as developing a series of repetitive stops initiated by temperature or distance and a preset deceleration rate for thousands of stop cycles or miles,

Drilled or Cross-drilled Rotor
Rotors that have been drilled through with a non-intersecting pattern of radial holes. The objects are to provide a number of paths to get rid of the boundary layer of out gassed volatiles and incandescent particles of friction material and to increase “bite” through the provision of many leading edges. The latter is the primary reason that all carbon–ceramic rotors have drilled holes – they are present to improve friction couple when wet. Typically in original equipment road car applications these holes can be cast then finished machined to provide the best possible conditions by which to resist cracking in use. But they will crack eventu-

ally under the circumstances described in another section (see Cracking). Properly designed, drilled rotors tend to operate cooler than non-drilled ventilated rotors of the same design due higher air flow rates through the vents from the supplemental inlets and increased surface area in the hole. That's right, inlets. Flow is into the hole and out through the vent to the OD of the rotor. If rotors are to be drilled, external edges of the holes must be chamfered (or, better yet, radiused) and should also be peened.

Drum in Hat

A rotor design in which the internal surface of the hat serves as a brake drum. Often used as a parking brake.

DTV

Disc Thickness Variation, or DTV, is an industry term to describe a condition of the brake rotor where the surfaces of the friction plates (the flat surfaces that the pads rub against) are closer or further apart at different points in the rotation of the rotor. This variation in thickness of the rotor, if due to how the rotor was manufactured or later “turned” by a shop during a brake job, usually occurs at one point where the distance between the planes of the two friction plate surfaces is greatest.

When brakes are applied, the hydraulic system moves and then holds the brake pistons so they press the brake pads against the friction plates. Subsequently, when the position is reached in the rotation of the brake rotor where the thickness of the rotor between the pads increases to its maximum, it causes an increase in clamping force and therefore torque on that wheel/tire assembly and hydraulic circuit pressure. Then as the rotor turns past this point, the torque and pressure fall. Each rotation of the rotor causes this rise and fall in torque and pressure sending a pulsating input to both the steering wheel and the brake pedal. In a case that the condition described exists on both brake rotors on a front axle, the oscillating torque can cause a large side to side steering shake. This DTV that was originally due to an error in manufacturing, if slight and not noticed initially eventually develops into a noticeable problem when pad material is deposited on the thick position due to the rotor running much hotter there.

A similar result can be seen when a car that has been driven hard is stopped when the pad and rotor have not been broken in completely. In this case, a pad that is very hot stops on the friction surface and some of the pad material transfers onto the friction plate in one location. This very slight build up of material then functions as described above when the rotor was made with a slight variation in thickness to promote the deposit of additional pad material in that spot of greatest thickness. This condition is often called a warped rotor due to its characteristic oscillation with rotation of a rotor. This type of DTV due to pad transfer can occur in multiple locations on a rotor.

Brake lathe turning of a rotor to correct DTV or uneven pad transfer works to remove manufacturing error and excess pad deposit only if done soon after problem is noticed and only if done correctly to improve parallel condition of two friction plates. It is almost impossible to correct DTV by turning with a single point tool on a shop brake lathe. The industry uses a term called “straddle cutting” to describe a two point cutting tool method that will most likely yield a satisfactory result. In many cases, metallurgical changes will occur under the pad deposits that resist cutting by the lathe tool so a slight thickness difference will still exist after lathe turning and the problem will eventually return.

Dust Boots

Rubber shields that fit over the exposed portion of the caliper pistons to prevent the ingress of dust and road grime. As no known rubber compound will withstand the temperatures generated by racing brakes, dust boots are not used in racing and should be removed before truly hard driving for extended periods. New materials with silicone added have been developed to increase the temperature range where dust boots can be used.

EBD

Acronym for Electronic Brake Distribution. See “Electronic Brake Distribution.”

Edge Code

Edge code is a term used in context with vehicle brakes that refers to a letter designation that is printed on the edge of the brake pad or backing plate that describes the friction characteristics of that material. The first letter describes the normal coefficient of friction. The second letter describes the hot coefficient of friction or friction fade resistance. See “Coefficient of Friction” and “Fade Resistance.” It is meant to aid installers in making sure that the edge code of the friction material being installed matches the original specified for a vehicle. The importance placed on the edge code by an installer will differ and most often is based on the installer's experience with a particular product. As it was originally intended to be used, especially on the front axle of a vehicle, the installation of a pad friction with a lower designation in either letter position would not be recommended for brake balance and safety reasons. The application of Edge codes was originally outlined in SAE J866a. SAE J866a was based on the test procedure SAE J661. The J866a document is no longer an active SAE Recommend Practice, but it has been openly adopted by other countries. The British Standard BS AU-142 is an example. Subsequently there has been much debate about the determination of Edge codes including an SAE published paper refuting the use of the SAE J866a Recommended Practices and it was due to be withdrawn pending approval starting in 1995 of a new standard J1652, which itself was cancelled in May of 2002.
In each position of the Edge code then, the letter corresponds to a result that fits the range on the table below.

Code Letter	Coefficient of Friction
C	Not over 0.15
D	Over 0.15 but not over 0.25
E	Over 0.25 but not over 0.35
F	Over 0.35 but not over 0.45
G	Over 0.45 but not over 0.55
H	Over 0.55
Z	Unclassified

Effective Temperature Range
The range of operating temperatures within which a brake pad remains effective or consistent. As with coefficient of friction, this should be used for comparative purposes only as measurement procedures very between manufacturers and pad temperatures are strongly affected by disc mass and rate of cooling. A similar term for Maximum Operating Temperature (MOT) is used to denote the upper limit of the temperature range.

Electronic Brake Distribution
Electronic Brake Distribution systems differentially control the brake line pressure applied to the front and rear axle brakes under conditions that are similar to those where a pressure limiting valve or proportioning valve would function. EBD systems typically use software that is calibrated to perform the function of a brake line proportioning valve in combination with ABS system hardware to eliminate the need for a stand-alone valve. In most cases, disabling a vehicle's ABS will also disable the EBD function. Check with the vehicle manufacturer's documentation on the status of this important function if you plan to disable an ABS system. See "Proportioning Valve."

Ether Based Brake Fluid
"Normal" brake fluids are based on Alkyl Polyglycol Ether Esters. Also, sometimes referred to as Glycol Ether Borate Ester fluids. DOT 3 and DOT4 fluids are suitable for high performance passenger car use.

Fade
Loss of braking efficiency from excessive thermal stress. There are three separate and distinct types of brake fade:

1. Pad fade: When the temperature at the interface between the pad and the rotor exceeds the thermal capacity of a pad, the pad loses friction capability due partially to out-gassing of binding agents in the pad compound. The brake pedal remains firm and solid but the car won't stop. The first indication is a distinctive and unpleasant smell, which should serve as a warning to reduce the thermal input to the brakes like by shifting to a lower gear to use more engine braking or slowing down, as when on a track, or both.

2. Fluid boiling: When the brake fluid boils in the calipers, gas bubbles are formed. Since gasses are compressible, brake pedal becomes soft and "mushy" and pedal travel increases. You can probably still stop the car by pumping the brake pedal but efficient modulation is gone. This is a gradual process with lots of warning.

3. Green fade: When a pad is first placed in service the first few heat cycles will cause volatile elements of the material to out gas. The process is continuous throughout the service life of the pad, but it is most pronounced in the bedding in process when the out gassed materials form a slippery layer between the pad and the rotor reducing the coefficient of friction to near zero. Once the pads are bedded in out-gassing is so slow as to not be a problem unless the effective temperature range of the pad is exceeded.

Fade Resistance
A term most often used in reference to a pad materials hot coefficient of friction performance. See "Fade, Pad Fade."

Fine Casting Sand
Brake rotors are formed by sand casting. Molten iron is poured into a sand mold and allowed to cool. Fine casting sand refers to the size of each grain of sand. Sand is divided into 5 categories: very fine, fine, medium, coarse and very coarse. Fine sand ranges in diameter from 0.125mm to 0.250mm. The use of fine sand allows a foundry to achieve good as-cast surface details. Conversely, the use of coarse sand would result in a pebbly or rough surface texture.

Fireband
The name given to a boundary layer of out gassed volatiles and incandescent particles of brake friction material that rotates with the rotor.

FMSI
FMSI is an acronym for Friction Material Standards Institute. See "Friction Material Standards Institute."

FMVSS
FMVSS is an acronym for Federal Motor Vehicle Safety Standard. It is a set U.S. Federal Standards governing vehicle and component minimum performance criteria. The most commonly referred to standards in context with passenger cars and light

trucks are:

1. FMVSS 105: Prior to 2000 all new vehicles had to comply with this standard which specified maximum stopping distances according to vehicle weight, loading, pedal effort with and without power assistance and varying brake friction condition of as new, as burnished and fading.

2. FMVSS 106: This standard governs hydraulic hose material, assembly, marking and testing.

3. FMVSS 135: Since 2000, it is a tougher version of FMVSS 105 to address changes in vehicle technologies like ABS. Again this is a standard applicable to new vehicle only. See “ABS.”

Friction Coefficient

Friction Coefficient is a measure of the resistance to movement or sliding of a material over a surface. One model for defining Friction Coefficient is, in a gravitational field, when a block of a certain weight is standing still on a surface and is also tied on its side to a string parallel to the surface and the string passes over a pulley of negligible resistance to another block of variable weight hanging over the side of the surface, the weight of the second block that will yield the start of movement of the first block. The Friction Coefficient is the weight of the second (pulling) block divided by the weight of the first (starting stationary) block. In the context of a fully bedded vehicle friction and rotor combination this number is typically below 1 and is usually in the 0.3 to 0.6 range. This is often referred to in context with a certain set of conditions including temperature or if the pad set is “new” vs. broken in. The higher the coefficient, the greater the friction. Typical passenger car pad coefficients are in the neighborhood of 0.3 to 0.4. Racing pads are in the 0.5 to 0.6 range. The optimum is to select a pad with a virtually constant but decreasing coefficient over the expected operating range of temperatures. As a result, the driver does not have to wait for the pad to heat up before it bites, and the pad fade will not be a factor so that modulation will be easy (see “Plot Shape”).

Friction Consistency

The variation in coefficient of friction over a range of repeated stops. Minimum variance allows efficient brake modulation and happy race car drivers.

Friction Couple

Often means the same as friction coefficient. It is used in reference to the friction coefficient over a range of conditions.

Friction Level See “Friction Coefficient”

Friction Material Standards Institute

Friction Material Standards Institute is an association of friction producers and distributors like U.S. manufacturers of brake linings and/or clutch facings; foreign manufacturers and U.S. manufacturers of brake shoes or materials or tools for friction materials assembly. It functions to maintain an industry-wide numbering and cataloging system for brake linings so that replacement linings can be correctly manufactured and supplied. Centric is a major member contributor to FMSI.

Friction Mechanisms

For a pad and disc to function as a brake there has to be the conversion of kinetic energy to heat. There are two primary models of the mechanism of this conversion; both involve breaking of bonds to convert energy. In the case of the abrasion model the bonds broken are the ones already existing in a material, please see Abrasive Friction. The bonds are broken due to the chafing or abrasion of a harder material or particle in direct contact with it. The second model is the adhesion-breakage model where temperature and pressure at the interface between the pad and rotor surface cause a fusion of one material to the other or a diffusion of one material into the other. In this case, the instantaneous bonds formed in the process are broken converting energy. Please see “Adherent Friction”. Abrasive friction mechanism predominates at lower temperatures but is also necessary to control build-up of low melting point pad materials at elevated temperatures where the adhesion-breakage mechanism is thought to predominate. The adhesion-breakage model requires a transfer layer of pad material to be established on the rotor surface to function. The abrasive friction model is the primary mechanism with many high dusting European automotive designs where the rotor wears observably as the pad wears. The iron in these discs is also typically a “softer” more dampened form of cast iron.

G3000 and G4000

G3000 and G4000 are two different grades of automotive gray iron casting material defined by the SAE J431 standard. Commonly used materials range from grade G1800 up to G4000. The percentage content of the minor constituents of the metal like carbon, iron, manganese, phosphorous, silicon and sulfur, plus the Brinnel hardness and tensile strength distinguish one grade from the next.

The higher material grades are characterized by lower carbon content and higher tensile strength and hardness. However, the SAE J431 standard is not a scale of quality. Each material grade in the range has an ideal or best use. For example, lower grade G1800 iron is well suited for casting brake drums while higher grades G3000, G3500 and G4000 are commonly used for replacement brake discs. Lower tensile strength typically yields a reduced tendency to make noise. What are sometimes referred to as noise dampened irons are often in the G1800 grade of iron. This grade can be used for brake rotors if the design and use profile takes the material strength into consideration.

Glycol Brake Fluid See "Ether Based Brake Fluid"

Grooves See "Slotted"

Grooving
A wear pattern of concentric grooves on the rotor surface. This can be caused by inclusions within a pad material, inappropriate pad material for the operating conditions, poor initial machining of the rotor, and/or improper bedding in procedure. Not a major cause for concern on passenger cars. Often seen on drilled rotors in line with the drilled holes due to the area of the pad that is at the same radial height and running cooler to the point where the abrasive friction mechanism is more dominant. The area that is solid and running slightly hotter is where an adherent mechanism is more dominant. The resulting alternating abrasive and adherent mechanism appear as concentric grooves corresponding to the drilled holes radial locations. See also "Abrasive Friction" and "Adherent Friction"

Heat Checking
The precursor to cracking. Heat checks are actually surface cracks caused by thermal stress. By themselves heat checks are not a cause for concern on a street driven car but they are a warning sign that the disc is not receiving adequate cooling air and cracks are sure to follow. On a race car they are to be expected and should be monitored. See also the section "Cracking."

Hydraulic Ratio
The ratio of fluid displacement by the master cylinder to fluid displaced in the caliper pistons. Hydraulic ratio is an important factor in the brake pedal effort equation, the higher the ratio, the less pedal effort is required but the longer the pedal travel to achieve a given clamping force. The stiffer the caliper design and the stiffer the pad, the higher the hydraulic ratio that can be employed.

Hydroscopic
A term often mistakenly used to describe a characteristic of most brake fluids to absorb water. The correct term to use is hygroscopic. See "Hygroscopic."

Hygroscopic
The property of readily absorbing water. All non-silicon based brake fluids are hygroscopic in nature. Adsorption of a minute amount of water will dramatically lower the boiling point of brake fluid. For this reason brake fluid should be completely replaced annually or more frequently in conditions of severe use. In professional racing, the fluid is replaced at least daily.

"J Standards, Procedures or Recommended Practices, SAE."
J Standards, Procedures or Recommended Practices are a series of formal opinion papers on various topics deemed to need documentation and input to the public, industry and governmental agencies by the Society of Automotive Engineers (SAE). They cover a broad range of topics but we will only outline the topics most relevant to vehicle brakes and brake testing here but more will be added as identified. The following statements of scope are copied from the actual SAE document descriptions:

J431: "Automotive Grey Iron Castings," This SAE Standard covers the hardness, tensile strength, and microstructure and special requirements of gray iron sand molded castings used in the automotive and allied industries.

J866a was withdrawn pending approval starting in 1995 of SAE J1652. See J1652 below.

J661: "Brake Lining Quality Control Test Procedure," The purpose of this SAE Recommended Practice is to establish a uniform laboratory procedure for securing and reporting the friction and wear characteristics of brake linings. The performance data obtained can be used for in-plant quality control by brake lining manufacturers and for the quality assessment of incoming shipments by the purchasers of brake linings.

J1652: "Dynamometer Effectiveness Characterization Test for Passenger Car and Light Truck Caliper Disc Brake Friction Materials" was cancelled May 2002. It was intended to address passenger car and light truck disc brake effectiveness. A formula was specified for calculating both normal and hot friction levels using an average recorded for 9 stops at 212°F and line pressures varying from 10 psi to 50 psi, followed by another 9 similar stops at 600°F.

J2430: "Recommended Practice and its Application for Characterizing Aftermarket Brake Friction Material Effectiveness," the purpose of this paper is to describe the background and uses of the SAE J2430 Recommended practice for Dynamometer Effectiveness Test and the use of the BMC guidelines to characterize aftermarket friction material products as an advancement over the regular SAE J661 test, support the BMC resolution that aftermarket brake friction materials should not deteriorate vehicle performance below the applicable Federal Motor Vehicle Safety Standard.

J2521: "Disc and Drum Brake Dynamometer Squeal Noise Matrix," This procedure is applicable to high frequency squeal type noise occurrences for passenger car and light truck type vehicles that are used under conventional operating conditions. The procedure does not encompass the consequences associated with changes in environment relate to temperature and humidity variations. This recommended test practice is intended to establish a common universally recognized method for performing a series of screening test sequences that identify the propensity of a brake assembly to generate squeal noise under a variety of test conditions.

J2522: "Dynamometer Global Brake Effectiveness," This SAE Recommended Practice defines an Inertia Dynamometer Test procedure that assesses the effectiveness behavior of a friction material with regard to pressure, temperature and speed for motor vehicles fitted with hydraulic brake actuation. The main purpose of SAE J2522 is to compare friction materials under the most equal conditions possible. To account for the cooling behavior of different test stands, the fade sections are temperature-controlled.

J2707: "Wear Test Procedure on Inertia Dynamometer for Brake Friction Materials," This SAE Recommended Practice specifies a dynamometer test procedure to be used for the measurement of automotive service brake linings and disc brake pads wear. Special motor vehicles and motorcycles are excluded from the application. Trailers with nominal Gross Combination Weight Rating exceeding 40 tons are also excluded from this Recommended Practice.

J2784: "FMVSS Inertia Dynamometer Test Procedure for Vehicles Below 4540 kg GVWR," This Recommended Practice is derived from the Federal Motor Vehicle Safety Standard 135 vehicle test protocol as a single-ended inertia-dynamometer test procedure. It measures brake output, friction material effectiveness, and corner performance in a controlled and repeatable environment. The test procedure also includes optional sections for parking brake output performance for rear brakes. It is applicable to brake corners from vehicles covered by the FMVSS 135 when using the appropriate brake hardware and test parameters. This procedure is applicable to all passenger cars and light trucks up to the GVWR weight limits named.

J2928: "Brake Rotor Thermal Cracking Procedure for Vehicles Below 4,540 kg GVWR" SAE J2928 test procedures subjects a rotor to 150 heat cycles. A heat cycle is when a rotor is cold and brought to a high temperature then allowed to cool. During a heat cycle, a rotor will expand and contract. This can create fatigue in a rotor that can cause cracking and structural failure. During the 150 heat cycles, the rotor is inspected; this includes dimensions and an inspection for damage. The objective of the test is to thermally and mechanically stress the rotor any deficiencies in the metallurgy or structure are exposed. J2928 also covers how to document and classify cracks.

Knockback Springs
Small coil springs fitted inside the caliper pistons of some brakes to prevent the pads from excessive knock back due to flexing of the suspension system or run out in the rotors. If the rotor run out is within specification and the upright/axle assembly is sufficiently rigid, there should be no need for knockback springs. However, when operating conditions are severe with regard to either generated side force or bumps, they may be required on the best of designs.

LACT
An Acronym for LA City Test. See "LA City Test."

LA City Test
The LA City Test is an on-vehicle test. It was started in an era when different areas of the country were chosen to represent a typical user profile based on conditions like terrain, road conditions, traffic, temperature and humidity. There have been other similar test developed and in fact there is a new one for a drive between major cities in mainland China. The test can be simulated on the latest dynamometers to a degree, but nothing substitutes easily for the actual road conditions and traffic so test agencies including Link Engineering ®, Ford ®, and others offer the service of outfitting a car with multiple sensors and recording devices and hiring a driver to run the established route in LA city traffic. Primary output from the test is pad and rotor wear and Noise Vibration and Harshness (NVH).

Leading Edge (of pad)
With respect to disc rotation the leading edge is that edge of pad that first comes into contact with the rotor when brake pedal pressure is applied. Unless differential piston diameters are used the leading edge wears faster than the trailing edge. See "Differential Pistons" and "Taper Wear."

Line Pressure See "Brake Line Pressure"

Low-metallic
Brake friction materials characterized as containing abrasive elements and low amounts of metallic compounds resulting in an abrasive friction mechanism. Results in 'dusting' due to the grinding down of the friction plates during normal brake use. Sometimes referred to as "Low-met." See also "Abrasive Friction."

Master Cylinder
The hydraulic cylinder that converts the driver's pedal effort into hydraulic fluid pressure for subsequent transmission to the operating end of a braking system (calipers).

Material Transfer
Please see "Friction Mechanisms," where beneficial material transfer is discussed in context with the adhesion-breakage model. Otherwise, when the operating temperature of the pad (particularly organic pads) is exceeded, friction material may be depos-

ited onto the surface of the rotor in a non-uniform manner while degrading the braking capacity and causing noticeable roughness. The only cure is to either upgrade the pad material or increase the cooling (or both). “Pick up” should never be removed with ordinary sandpaper, which uses aluminum oxide as the abrasive. The same is true of sand blasting - don’t do it. The correct way to remove pick up is by grinding (not turning) the rotor. When that is not practical, the major portion can be removed by scraping and the remains sanded off with garnet paper.

Mechanical Pedal Ratio

The brake pedal is designed to multiply driver’s effort. The mechanical pedal ratio is the distance from the pedal pivot point to the effective center of the footpad divided by the distance from the pivot point to the master cylinder push rod. Typical ratios range from 4:1 to 9:1.The larger the ratio, the greater the force multiplication (and the longer the pedal travel)

Metal Matrix (MMC)

Term applied to a family of composite materials consisting of metallic cores infused with “whiskers” or “grains” of very stiff non-metallic elements resulting in a light and strong material. The most popular of the metal matrix composites is Aluminum Ceramic metal matrix, the ceramic typically but not exclusively being composed of Silicon Carbide, Aluminum Oxides and Boron Carbides, which are well suited for use in racing calipers. Also, lightweight rotor have been made for Original Equipment and aftermarket applications using Silicon Carbide and Aluminum Oxides, but with only limited success due to two factors, the first being a low maximum operating temperature of the materials mentioned of around 900° to 1000° F. Second the much greater expansion rate of the typically aluminum based MMC material results in thermal distortion or cracking. One OE application actually has small slots and stop drill holes positioned radially around the rotor periphery. In all cases of MMC rotors, the primary friction mechanism is the adhesion-breakage model. Please refer to the section, “Friction Mechanisms.”

Modulation

The term given by the process by which a skilled driver controls the braking torque to maintain maximum retardation without locking wheels. Because the human being modulates most efficiently by force rather than displacement, effective brake modulation requires minimum pedal travel and maximum pedal firmness.

Monobloc Caliper

A caliper machined from a single piece of billet, cast or forged material.

Mu

The name for the Greek letter “m” written as “μ” and pronounced “mew.” This symbol is used in mathematical formulas to replace friction coefficient. See “Friction Coefficient”

Multi Pad Systems

Caliper systems utilizing multiple pistons (either four, six or eight) with separate pads and abutment systems for each pad. The design, almost universal in professional racing, provides multiple leading edges for better “bite.” Unfortunately a short pad with any amount of pad thickness wants to tip in so much at the leading edge and lift at the trailing edge that longitudinal taper occurs if the piston is positioned symmetrically in the pad cavity. Only by placing the piston on the trailing side of the pad cavity can it manage this tendency just like differential bores in modern racing calipers do.

NAO Friction

This is an abbreviation for Non-Asbestos Organic friction. The use of the term was stimulated by the trend to discontinue the use of Asbestos in the U.S. due to concerns over health risks. NAO friction material formulas were developed to replace asbestos with other kinds of fiber including Kevlar ®. See “Asbestos.” See also “Adherent Friction.”

OE

This is an abbreviation for Original Equipment. Please see section “Original Equipment.” Sometimes it is used as an abbreviation to refer to the Original Equipment Manufacturer (but more correctly referred to as the OEM).

OEM

This is an abbreviation for Original Equipment Manufacturer.

Off Brake Drag

A condition in which caliper pistons do not fully retract when brake line pressure is released. Off brake drag increases temperature and wear while decreasing acceleration, top speed and fuel mileage. It is caused by either non-optimum seal design, seals that have been hardened by thermal stress or excessive disc run out.

Original Equipment

This is an industry standard term for that equipment that was installed on the model(s), being referred to in context, at the time of manufacture.

Organic (Pad Material)

A family of friction materials, often containing asbestos, used for both drum linings and disc pads through the 1980s. Now largely supplanted by semi-metallic materials with better temperature characteristics, but new non-asbestos organic (NAO) compounds can be found as well.

Out-gassing

The boiling off of volatile elements in friction materials. Out-gassing, while it is continuous over the useful life of a pad, is only noticeable during the bedding in process or when the temperature capability of the pad has been exceeded. Under those conditions volatiles form a layer between the friction materials and the rotor surface, smelling bad and causing “green fade.”

Pad

The stationary element of a disc brake system. Brake pads, consisting of friction material bonded to steel backing plates are held in place by a brake caliper and forced against the rotor by caliper pistons when pedal pressure is applied.

Pad Abutments (or Pad Abutment Plates)

Mechanical elements that locate brake pads in the brake caliper and provide a hard surface for the pads to slide against. Non-ferrous (Aluminum or MMC) calipers, which do not provide a hard and smooth surface to locate the ends of the pads and provide an efficient sliding surface, should be viewed with great suspicion.

Pad Retraction

To prevent drag and premature pad wear a properly designed seal systems retract the caliper pistons a few thousandths of an inch when the brake pedal pressure is released. This allows what little rotor run out there is to “knock” the pads back from contact with the disc. When everything works right the amount of retraction is so slight that the free play is not noticeable when pedal pressure is applied.

Performance Balanced Brake System

During a single stopping event, if braking force is continuously increased, the vehicle’s tires must eventually break traction. If the front wheels reach their traction limit first, we say that the car is “front biased,” as the front tires are the limiting factor for deceleration. If the rear tires are the first to reach their traction limit, we say that the car is “rear biased.” In either case, the tires at one end of the vehicle have reached their limit before the tires at the other end are able to make their full contribution to the braking event, limiting the ultimate deceleration capability of the vehicle.

Pioneered by StopTech, the Performance Balanced Brake System is created by matching brake component dimensions such as number of caliper pistons, piston sizes, and rotor diameter to a vehicle’s dynamic weight transfer that occurs under braking. The ultimate goal of a Performance Balanced Brake System is to distribute the braking forces so that all four tires are simultaneously generating their maximum deceleration, thereby minimizing stopping distances.

Pick Up See “Material Transfer”

Plot Shape

The shape of the friction plot during a long brake application. It is easier and more efficient for a driver to add pedal pressure than to remove it. Therefore the easiest pad to modulate exhibits a high initial bite followed by a gradual decrease in coefficient throughout a stop. If the level of friction rises throughout a stop, brake modulation will be very difficult.

Positive Molding

Positive molding uses extreme pressure to compress the friction material and bond it to backing plate. This process assures consistent friction material density throughout a pad, resulting in even wear and performance characteristics throughout the life of a brake pad.

Post Curing

After the friction material has been formed and bonded to the backing plate (as in the case of integrally molded brake pads), the brake pad always undergoes a curing operation known as Post Curing. Additional subsequent Post Curing (heat treating) is sometimes used to help remove more uncured resin, but is not a substitute for a process called scorching. See “Scorching.”

Pressure Bleeder

A tool allowing rapid bleeding of a brake system and replenishment of the brake fluid. Pressure bleeders should never be used on racing or high performance cars as rapid forcing of brake fluid through small passages may cause cavitation and the formation of air bubbles rather than their removal. At no time should a pressure bleeder be used which does not contain a physical separation (either through a flexible diaphragm or otherwise) between the brake fluid and the pressurizing agent (air).

Proportioning Valve

What is often referred to as a Proportioning Valve is really a Pressure Limiting Valve. Its function is to limit the amount of pressure transmitted to the rear brakes under very heavy braking. Front and rear brake line pressures are the same until some pre-determined “knee” point is reached. After this point, rear line pressure, while it still increases linearly with pedal effort, increases at a lower rate (slope) than front. The purpose is to avoid rear wheel lockup and the attendant unstable condition. It is not a good idea to remove the proportioning valve from an automobile intended to be used on the highway. If you feel that you must do so, the best way is to remove the OEM rear brake line proportioning valve completely and replace it with one of the adjustable units manufactured by Tilton Engineering or Automotive Products. Do not place a second proportioning valve in line with the OEM unit. Note that ABS software in some cases can be calibrated to perform the proportioning function, eliminating the need for a stand-alone valve. This feature if present in an ABS system is sometimes referred to as Electronic Brake Distribution (EBD) because it functions, as the name implies, to differentially control the applied line pressure on the front and rear axle brakes under conditions that are similar to a line proportioning valve. In most cases, disabling ABS systems will also disable EBD function.

Ra

Ra means Roughness Average (Ra). In the context of brake rotors, the many small peaks and valleys that make up the surface finish of a brake rotor can be measured and be expressed in micro-inches or micro-meters. The resulting value can be compared to a range of measurements obtained from other new OEM and aftermarket rotors and provide an indication of how smooth or uniform the surface is. If one rotor has a low Ra value and a second rotor has high Ra value, the rotor with the lower value has a smoother surface condition. Ra value is a two dimensional expression. It is most often recorded by a measuring device called profilometer that drags a scribe in one direction over a surface. Ra value can also be converted to other roughness measurement scales such as RMS. See "Surface Roughness" and "RMS."

Radiation

One of only three heat transfer mechanisms. Conduction and Convection are the other two. Radiation is a transmission of energy by the emission of waves. In the case of braking systems, thermal energy is emitted by both rotor and pads at elevated temperature. In the case of the rotor, as temperature increases, radiation is the predominant heat transfer mechanism. In fact radiation increase by X^4 for every increment of temperature rise. Often the focus in rotor designs is on the vent or the vanes because it is something that can be changed significantly at a reasonable cost. While radiation is a function of the material choices made and rotor friction surface area, keeping in mind the other functional parameters necessary for a given application. A large portion of this radiant energy can be reflected into the air stream by "radiant barriers," such as ceramic coatings on internal surfaces of calipers.

Release Characteristics

The opposite of "bite", release characteristics become important when braking into turns either on track or on road. If braking torque does not decrease linearly with decreasing pedal pressure "trail braking" becomes difficult at best. In the most serious case of slow release, drivers will notice that there is a delay after they lift their foot off of the brake before release is sensed. In a slight case there is force lost to accelerate the car, fuel is wasted or the active handling of the vehicle is interfered with. In general and especially in context with ABS and active handling, release should be fast and residual brake torque should be low or negligible.

Reservoir

The container in which brake fluid is stored to provide a source of fluid for the master cylinder(s). The reservoir must have sufficient volume to allow fluid displacement equivalent to wearing the pads down past the backing plates. It must also be sealed to prevent the absorption of moisture by the highly hygroscopic brake fluid. Typically the reservoir cap is fitted with an elastomeric bellows open to atmosphere but sealed from the fluid.

Residual Pressure Valve

Some passenger cars, particularly those equipped with drum rear brakes, are fitted with a "residual pressure valve" which functions to ensure that the pads are kept in close proximity to the rotors despite run out, knock back, etc. The residual pressure is very small (2-4 psi) so off brake drag is not a problem for street use.

RMS

Root Mean Square is a statistical measurement of the magnitude of a variance, i.e. a math equation. In the context of brake rotors, the many small peaks and valleys that make up the surface finish of a brake rotor can be measured in microinches and input into the RMS equation. The resulting value can be compared to a range of measurements obtained from other new OEM and aftermarket rotors and provide an indication of how smooth or uniform the surface is. If one rotor has a low RMS value and a second rotor has high RMS value, the rotor with the lower value has a smoother surface condition within the measured area. RMS can also be converted to other roughness measurement scales such as Ra. See "Ra."

Rotor See "Disc"

Rotor Balance

A brake rotor is in a state of perfect static balance when its center of mass is on the axis of rotation. Imagine a rotor rotating on a very thin axle. If a rotor's center of mass coincided with a line drawn through the center of the axle, it would be perfectly balanced. Any error in the position of the center of mass relative to the center of rotation leads to an imbalance.

An ounce-inch is the common unit of imbalance. For a rotor, this is calculated by multiplying the error in the location of the center of mass, in this case in inches, by the weight of the rotor, measured in this case in ounces. Correspondingly, a balance correction is calculated by multiplying the radius, or distance from the center of rotation at which correction weight is to be added or removed, by the weight that must be added or removed to achieve perfect balance. There is a common metric based version of the unit of imbalance called gram-cm.

Example: A rotor with 12-in diameter has a mass of 21 lbs., or 336 oz. The center of mass of the rotor after it is cast and machined ends up 0.010 in. (0.25 mm) from the center of the axis of rotation. The resulting imbalance is 0.01 in. x 336 oz. = 3.36 oz-in. The rotor would be brought into perfect balance by machining it so as to remove 3.36 oz-in / 6 in = 0.56 oz. of weight from the outer edge of the part. The "heavy point," or correct location to remove this weight, will be centered on a radius starting at the geometric center of the part and passing through the center of mass.

Roughness See "Surface Roughness"

Run Out
The amount of axial dimensional variation of the surface of a rotor as it rotates. Measured with a dial indicator, normal specification is 0.000 to 0.005" total indicated run out also called "TIR." Excessive run out can result in inefficient braking and perceptible pedal pulsation. Also see "TIR"

SAE
An acronym for Society of Automotive Engineers. Also see "J Standards or Recommended Practices, SAE."

Scorching
This OEM process enhances key friction performance levels beyond what can be done with post curing alone. Scorching raises initial cold effectiveness, stabilizes friction levels right out of the box, and provides improved performance across the entire operating range. During the scorching process, the brake pad face is super-heated on a conveyor by a series of concentrated infrared radiation heat sources to provide complete removal of any uncured bonding agents near the surface. In so doing, it eliminates the need for initial break-in and reduces the chance of noise caused by pad glazing. Scorching also thermally conditions the rest of the pad material like subsequent post curing to yield a more consistent and higher friction level throughout the life of the pad. Sometimes the term post curing or burnishing will be used as equal to scorching. This simply isn't true in process design, equipment used or effect. See "Post Curing" and "Burnishing."

Seals
Caliper pistons are sealed in their bores by elastomeric rings seated in grooves. Seals fulfill a secondary function of slightly retracting pistons when line pressure reduced to zero at the end of braking. This prevents "off brake pad drag," reducing both temperature and wear. Both the compound and the mechanical design of these seals are critical. The cross section of properly designed caliper seals is square, not round. "O" rings cannot be substituted.

Seal Grooves
Caliper seal grooves can be either in the caliper bore or on the piston (or both). The mechanical design of the seal grooves is critical to ensure optimum piston retraction. The cross section of a proper caliper piston seal groove is trapezoidal, not square.

Semi-metallic
Friction materials compounded with significant amounts of metallic elements to increase the operating temperature range. Sometimes referred to as "Semi-met." See also "Adherent Friction."

Shim See "Anti-squeal Plate "

Silicone Brake Fluid
Brake fluid based on silicone. While silicon based fluids are less hygroscopic than ether based fluids, they are subject to "frothing" when subjected to high frequency vibration and when forced through small orifices. This makes them unsuitable for racing or high performance use.

Sliding Caliper See "Caliper, Floating Caliper"

Slotted
1. Rotor: Shallow, sharp edged but radiused bottom grooves milled into cast iron discs to provide leading edges for bite and a path for the fire band of gases and incandescent friction material to be dissipated through. If the slots fill up with pad material, the system is operating at too high a temperature.

2. Pad: Radial grooves molded or cut into the surface of a pad to provide a path for fire band dissipation and to double the number of leading edges and improve bite. Some long pads also have a longitudinal groove.

Squeal
Annoying high-pitched noise associated with some combinations of friction materials at low brake torque values. Reduced by the use of anti-squeal plates. Can be improved by a different pad material, but also made worse if the former and current pad materials are incompatible.

Squeeze Form Casting
A casting process that is a cross between die casting and forging. Liquid aluminum is poured into a die and, just before it begins to solidify, the die is forced closed under very high pressure.

Alternatively a second smaller cylinder other than the primary injection cylinder is filled during the molding. The content of the second cylinder is then compressed at high pressure and added to the molding flow to increase pressure. This process reduces porosity and leaves grain structure more like a forging than a casting - resulting in a stronger part.

Stainless Steel Brake Lines
Flexible brake hoses made of extruded Teflon® protected by a tightly braided cover of stainless steel wire. Because these hoses virtually eliminate line swelling under pressure, and because they offer superior mechanical protection for the brake line itself, they are universally used in racing applications to reduce pedal travel, increase pedal firmness and allow more efficient brake modulation. A few manufacturers offer stainless steel braid protected hoses of extruded Teflon which meet all of the DOT requirements for passenger car use. Several more offer hoses which claim to meet the specification but do not. Let the buyer beware.

Stiffness
Stiffness is the resistance of a material or a structure to deformation. It is not the same as strength. Stiffness of a material is indicated by its “modulus of elasticity” - the measure of the elasticity of the atomic bonds within a material. It is essential that calipers (and caliper mountings) be stiff. Which is why metal matrix composite materials are used for racing calipers.

Strength
Strength is the resistance of a material or structure to rupture. It is defined as stress required to rupture atomic bonds of a material. It is not same as stiffness.

Surface Roughness
Surface Roughness, a phrase sometimes shortened to “roughness,” is a measurement that refers to the texture of any surface. It importance in brake systems is when it is used to control the surfaces on either a rotor(disc) or drum that the friction material will rub against. The condition of that surface will determine how the friction material wears and friction coefficient during break-in or subsequent use. There are many scales in use to describe surface roughness. Some of them are Ra, RMS, Rt, CLA(N) and N. See two often used scales for surface roughness, “Ra” an abbreviation for Roughness average and “RMS” an abbreviation for Root Mean Square.

Taper Wear
Uneven wear of brake pads is caused by geometry, by the difference in temperature between leading and trailing edges and/or by lack of stiffness in a caliper. When pads are taper worn, the first increments of caliper piston travel are used up in forcing the pad flat up against the rotor face, increasing pedal travel. Additionally the piston tends to cock in its bore resulting in bore scoring and wear.

1. Radial taper: Radial taper is apparent when a pad is viewed from either end. The linear speed between pad and rotor is greater at the periphery of the rotor and so the outer band of the face of the pad can wear faster. In addition any tendency for the caliper to “open up” under pressure like a clamshell results in more pressure being placed on the outer portion of the pad, further increasing relative wear. For this reason many pads are trapezoidal in plan view with less surface area toward the inside.

2. Longitudinal taper: Longitudinal taper is apparent when viewed from either the inner or outer surface of a pad. The trailing section of a pad is partially floated in a boundary layer of out gassed volatiles and incandescent particles of friction material torn from the leading section. The leading edge of the pad will therefore always run hotter and wear faster than the trailing edge. This phenomenon is always a factor and can be more pronounced in long pads but is especially apparent in calipers with one piston per pad if the single piston is aligned with the center of a short pad. The theory of more leading edge bite is counterbalanced by pronounced tapered pad wear in multiple small pad caliper designs. (See “Multi Piston Calipers”).

TIR
An Acronym for Total Indicated Run out. See “Run Out.” It is the difference between the highest and lowest reading observed. Actual geometric positional error of an axis of rotation of a part will be one half of TIR.

Thickness Variation (TV)
Variation in the transfer layer, which initiates brake vibration. While the impact of an uneven transfer layer is almost imperceptible at first, as the pad starts riding the high and low spots, more and more TV will be naturally generated until the vibration is much more evident. With prolonged exposure, high spots can become hot spots and can actually change the metallurgy of a rotor in those areas, creating “hard” spots in the rotor face that are virtually impossible to remove. See also “DTV” or Disc Thickness Variation.

Thermal Shock
Materials, particularly cast iron, are degraded not only by the magnitude of temperatures reached, but also by the “delta” temperatures - the speed at which the temperature increases and decreases. In grey iron, cracks are caused by weakening of the bonds between the grains of a metal brought about by rapid change in temperature as well as the increasingly disorganized shape and structure of the carbon in the form of flakes that are precipitated in the iron matrix.

Threshold Braking
Braking at maximum possible retardation in a straight line. In non-ABS controlled scenarios it described a situation where a driver controlled the brake force he applied near or at that limit, hence the name. In ABS controlled systems while a driver applies maximum force, the hardware and its programming cycle the force applied back and forth over the instantaneous limit of friction couple available.

Titanium
A very light, very strong metal with very low thermal conductivity. Almost universally used to make caliper piston noses for racing applications in order to reduce heat transfer to the brake fluid within the caliper. When used as a brake rotor the very low thermal conductivity results in too much of the energy the brakes are converting having to transfer into the pads causing them to overheat. Where are Titanium rotors used? – In Sprint cars where the work the brakes do is much lower than a road race car. A sprint car uses the brakes primarily to cause the car to yaw to help with set up for the corners and scrub speed off.

Trail Braking

The process in which a skilled driver "trails off" the brakes as he enters a corner, thus combining braking and turning-in at the initial phase of a corner and maximizing the total traction available from the tires. The technique, universal used in racing, although not always admitted, also effectively lengthens the straight preceding the corner.

Trailing Edge (of pad)

The portion of a pad located away from the direction of rotation of a disc.

Transfer Layer

An even layer of brake pad material on the rubbing surface of a rotor. Note the emphasis on the word even, as uneven pad deposits on a rotor face are the number one, and almost exclusive cause of brake judder or vibration. See 'Brake Judder' and 'Warped Rotors'.

Two Part (piece) Caliper

A caliper manufactured from two essentially mirror imaged parts rigidly bolted together. To perform as well as a monobloc caliper, the assembly must result in a rigid structure by design, bolt selection and materials.

Vanes

The term given to the central webs which serve to separate the inboard and outboard friction surfaces of ventilated rotors.

1. Straight vanes: Straight vanes are the easiest to manufacture. They extend in straight lines radially outward from the inner surface to the outer surface of a rotor. This design is often used in production automobiles and trucks because the same part can be used on both sides of a vehicle. This design tends to promote non-uniform pad transfer over the vane due to higher stiffness of the rotor surface at its location compared to the area over the vent immediately ahead or behind the vane.

2. Curved vanes: Curved vanes are shaped as curves to act as more efficient pump impellers and increase mass airflow through the central portion of a disc. They also act as barriers to the propagation of cracks caused by thermal stress and, as each vane overlaps the next, they dimensionally stabilize a rotor. These designs will reduce non-uniform pad transfer due to the more uniform stiffness of the friction surface relative to the travel of a pad, unlike the straight vane design. Curved vane rotors are more expensive to produce than straight vanes and must be mounted directionally. They are universally used in racing where carbon/carbon brakes are prohibited.

3. Islands or Pillar: Some designs utilize "islands" to separate the friction surfaces rather than vanes. Properly designed the island system is dimensionally stable and will reduce non-uniform pad transfer but are inefficient from the viewpoint of airflow compared to curve vane and so are not seen in racing. This vane design type is also generally heavier as the design engineer will substitute mass for convective cooling capacity.

4. Differential vanes: Some rotors are designed with alternating vanes of different length. This modern design feature has been dictated by flow studies. It was found that the volume of air that a rotor can flow increases by alternating the length of the inlet without much of a sacrifice in surface area. The more air a vent flows, the more convective cooling can be realized.

Warped Rotors

The term warped rotors is incorrectly used in most situations. The term is used most often to mean vibration and roughness when brakes are applied, but the cause is not a permanent distortion of the rotor because one of the characteristics of gray iron used in almost all rotors including racing is the high stiffness quotient of a material called the Young's Modulus. Instead the roughness that is observed is caused by a previous unsuccessful machining of the rotor by a service provider or the non-uniform transfer of adherent pad friction material. Once the deposit of pad material is present, a re-machining of the rotor surface appears to solve the problem temporarily, seeming to confirm the idea that the rotor was warped. The problem is, if the vibration existed for even a short time, that conversion of the iron below the deposit to cementite an iron-carbide has occurred. Cementite is harder than the base iron matrix so when turned on a brake lathe, the harder deposit area will deflect the nose radius on the cutting tool and the high spot will still be present to a degree and the process of increasing deposit of new pad material over the high spot will re-start. Surface grinding of the rotor will produce a suitable result if both friction surfaces are flat and parallel but there will still be areas of greater hardness. See "Adherent Friction," "Brake Judder" and Transfer Layer."

Wear Sensors

To ensure that pads are replaced before they are worn down to the backing plates, several types of wear sensors are employed. Some cars use an electronic wear sensor in the brake pad. This type of sensor typically is worn through when wear limits are reached, breaking continuity in the sensor circuit. As such, it needs to be replaced if the light has come on. There is another less expensive method used where the pad has a thin but stiff tab riveted to the pad backing plate that rubs on the disc face and squeals when the wear limit is reached. In some modern race cars used in long distance events, calipers are fitted with more complex electronic sensors and circuitry to warn the drivers and, by telemetry, the crew of the pad condition.