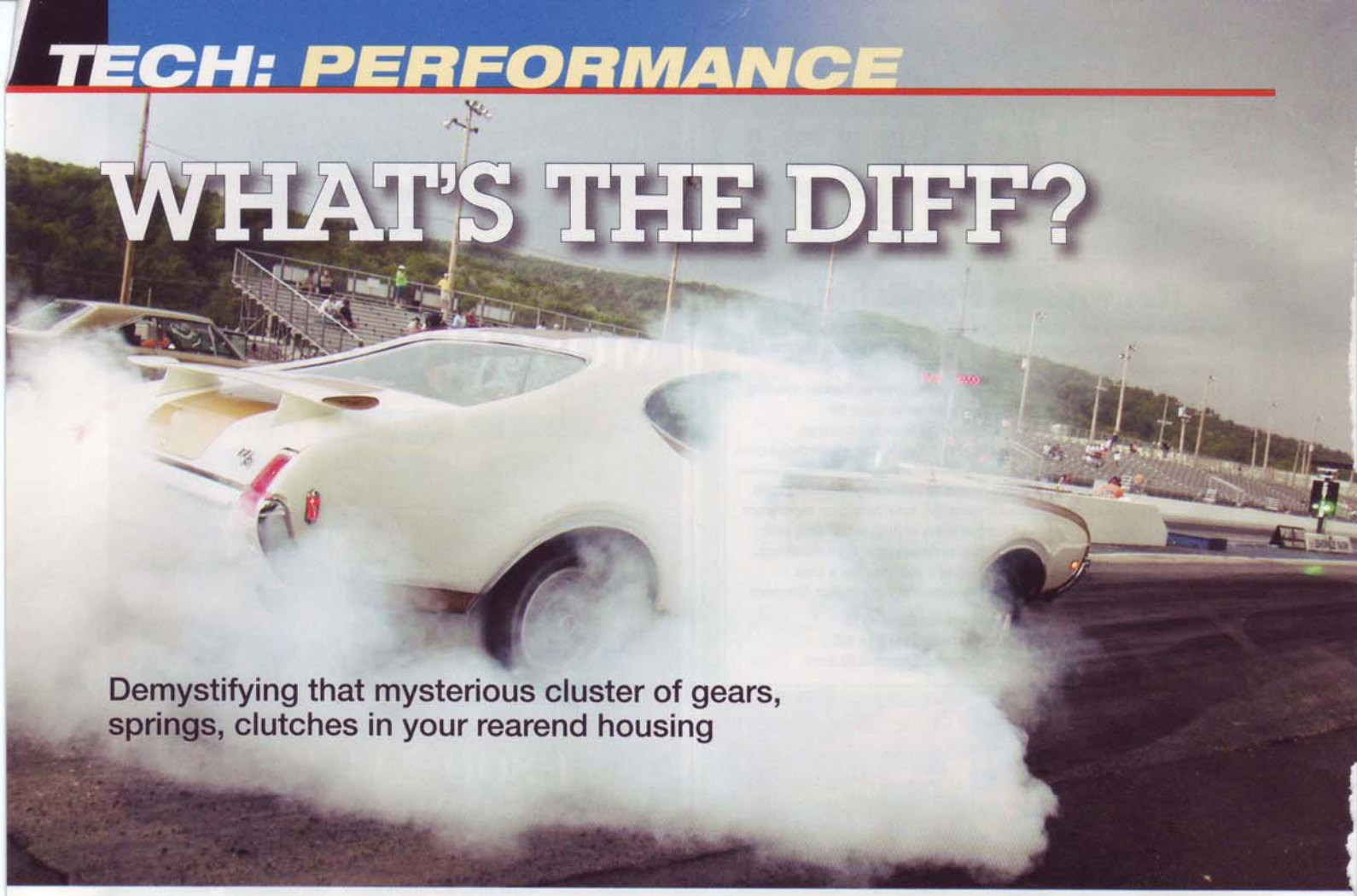
WHAT'S THE DIFF?



Demystifying that mysterious cluster of gears, springs, clutches in your rearend housing

By Mike McNessor
Photography by Mike McNessor and Eaton Corporation

You stomp on the far right pedal and your muscle car lunges forward like a magazine editor pouncing on a free beer. Perfect. But were there two smoldering black stripes left behind (your car, that is, not the editor) or only one? You undoubtedly know the answer, but do you know why or how your car spins one tire or two?

Snuggled in the womb-like confines of your axle housing, there might be an open differential, a limited-slip differential, a locker or, if you're really serious about traction, a spool. It pays to understand the differences between these axle connectors, because they influence your car's performance on the street, drag strip or road course.

If your car's drive axle was a solid piece connecting the two rear wheels, it would plant the power to the pavement nicely on takeoff, but it wouldn't negotiate turns very well. To overcome this, most cars uses two axle shafts connected by a differential—a device that allows the wheels to rotate at different speeds.

The drive axle in a rear-drive car has a pinion gear that is connected to and turns in the same direction as the driveshaft. The pinion drives the ring gear, which converts lateral rotational forces to longitudinal rotational forces, in line with the rotation of the wheels.

The differential's most important job is to allow the wheels to turn at different speeds. When you go around any turn, the inside wheel needs to turn at a slower rate than the outside wheel.

An open differential (this is the car doing the one-wheel burnout at the drags) consists of six gears: the driveshaft pinion gear, the ring gear, two pinion gears mounted on spindles in a cage connected to the ring gear, and side gears at the differential end of each axle. During a turn, the pinions mounted in the cage start to spin, allowing the wheels to turn at different rates. The axle mounted to the inside wheel turns slower than the cage, and the axle mounted to the outside wheel turns faster. In the extreme, the inside wheel could conceivably be stationary, or even turn backwards to allow the outside wheel to complete its turn.

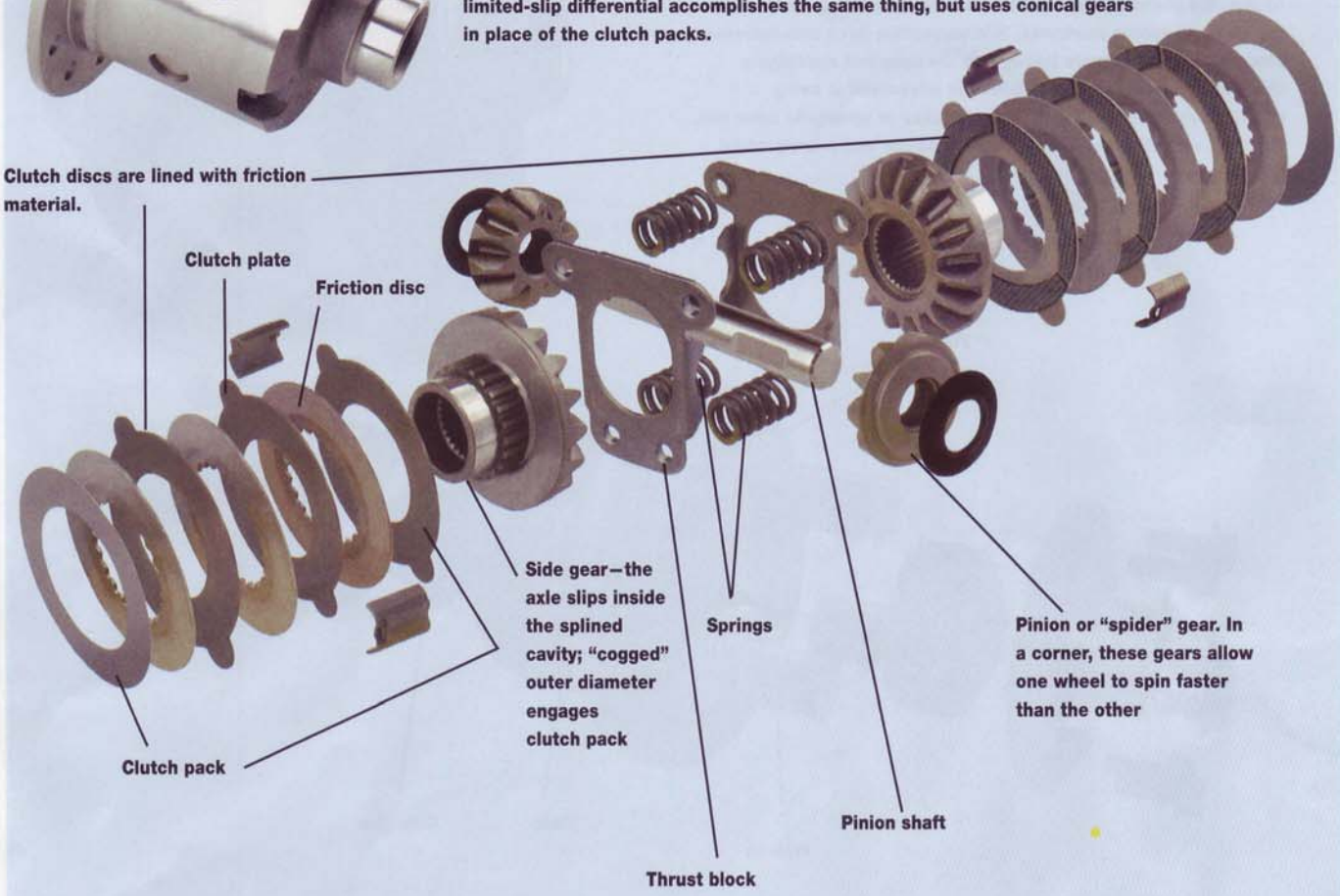
There's good and bad in this configuration: The good is that no matter how tight the turn, the driven wheels can turn independently, with no stress on the axle components. The bad is that if one wheel begins to slip, there's no way to get torque to the wheel that isn't slipping.

Has it got a posi, dude?

It seems like everyone has adapted "posi" as the de facto term for a limited-slip differential, but that's actually a nickname for Chevrolet's Positraction (manufactured by Eaton). More recently, Eaton has trademarked the name "Posi" and uses it as the brand for its line of clutch-type limited-slip differentials. Here's what other American manufacturers called their optional limited-slip differentials:

American Motors.... Twin-Grip
Buick ..... Positive Traction
Ford ..... Equa-Lock and Traction-Lok
Mopar ..... Sure Grip
Oldsmobile..... Anti-Spin
Pontiac ..... Safe-T-Track
Chevrolet ..... Positraction

Eaton's Posi differential (pictured left and in the exploded view below) is an excellent choice for a street machine and occasional drag racer. This is a disc-type limited-slip differential; the springs in the center force the side gears against the clutch discs and plates, limiting the rotation of the side gears. The springs are not strong enough to prevent one wheel from rotating faster than the other in a turn, but when one wheel is slipping, additional load from the driveline pushes the side gears against the clutches, reducing the amount of slip and forcing power to the wheel with traction. A cone-type limited-slip differential accomplishes the same thing, but uses conical gears in place of the clutch packs.



To compensate for this situation, torque needs to be transmitted to the driven wheels equally; at the same time, the wheels need to turn independently. The solution is a limited-slip differential, of which there are several types commonly used by the muscle car set: the clutch type, the cone type, locking, and torque sensing.

A spool isn't a differential, but rather a positive connection tying the two axles together permanently. In the old days, racers would weld the "spider gears" (the gears mounted inside an open differential that allow the wheels to turn independently in a corner) to their shafts, thus creating a grassroots spool.

If the only surface you were ever going to drive on was slippery mud or snow, a locked differential would work just fine. Both wheels would turn at the same rate all the time, regardless of whether you were turning or traveling in a straight line. The slippery surface you were driving on would allow the inside wheel to slip during a turn, effectively mimicking the action of an open differential.

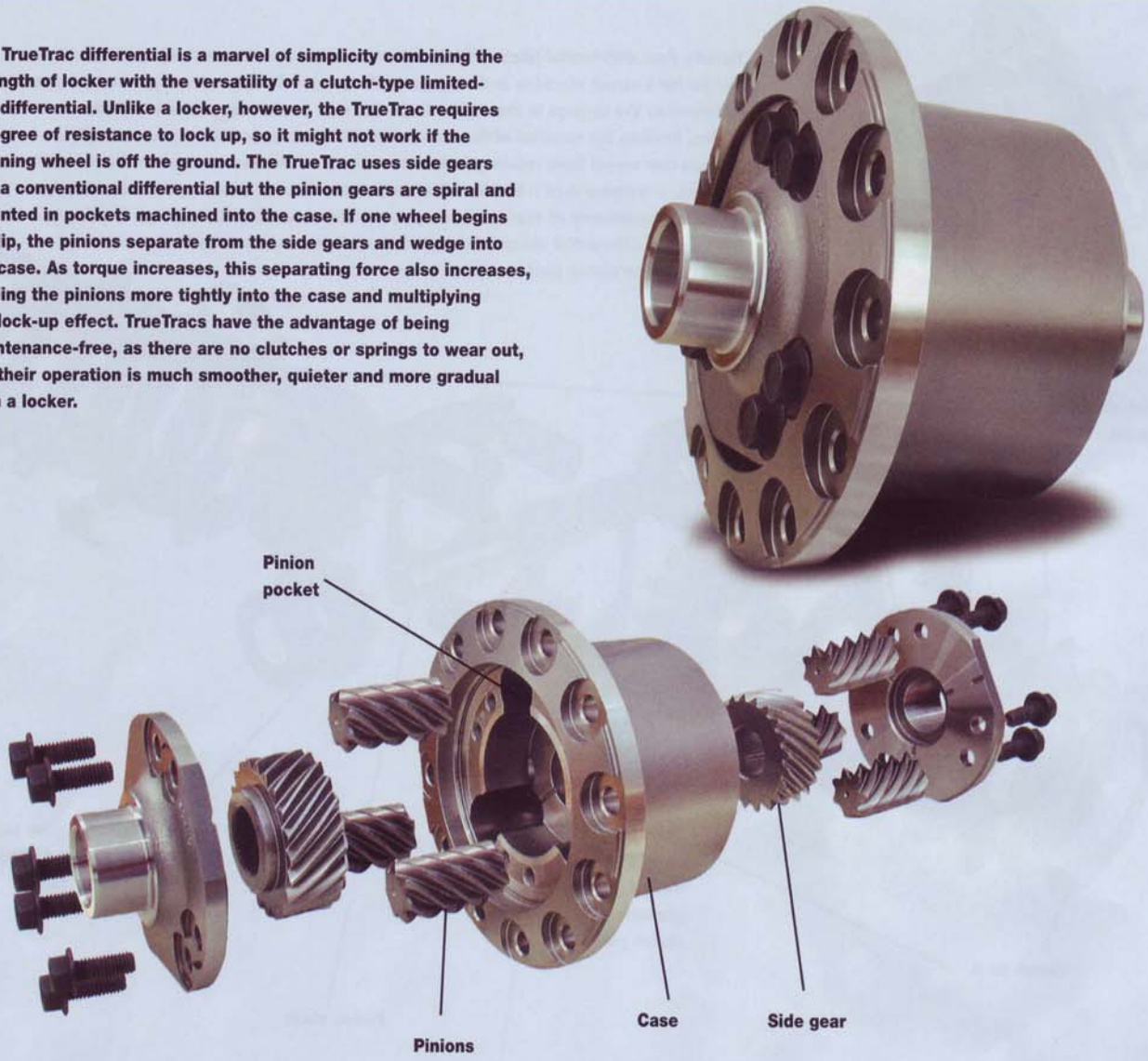
But since most of us drive on grippy, paved surfaces, a limited-slip differential offers the best of both worlds: Power to both wheels when the tires are having trouble maintaining traction, and enough give to allow the wheels to rotate at different rates during a turn.

Limited-slip differentials use various mechanisms to allow normal differential action when going around turns. But when a wheel slips, they allow more torque to be transferred to the non-slipping wheel.

A clutch-type limited differential has all the same components as an open differential, but adds a spring pack and a set of clutch plates. The spring pack forces the side gears (those connected to the axles) against the plates. The clutch plates aren't needed when both wheels are spinning at the same rate, but come into play when the vehicle is executing a turn—then the clutch fights against the wheels' desire to spin at different rates.

If one wheel tries to spin faster than the other, it has to overpower the clutch. As more power is applied, more outward force is placed on the side gears, increasing the load on the clutch plates and reducing the amount of slip. In this way, the clutch-type LSD can increase the amount of torque sent to the wheel that has traction in situations where one wheel is slipping excessively.

The TrueTrac differential is a marvel of simplicity combining the strength of locker with the versatility of a clutch-type limited-slip differential. Unlike a locker, however, the TrueTrac requires a degree of resistance to lock up, so it might not work if the spinning wheel is off the ground. The TrueTrac uses side gears like a conventional differential but the pinion gears are spiral and mounted in pockets machined into the case. If one wheel begins to slip, the pinions separate from the side gears and wedge into the case. As torque increases, this separating force also increases, binding the pinions more tightly into the case and multiplying the lock-up effect. TrueTracs have the advantage of being maintenance-free, as there are no clutches or springs to wear out, but their operation is much smoother, quieter and more gradual than a locker.



Eaton is best known for this type of differential, having introduced it on the 1961 Chevrolet under the name, "Positraction." It was available on numerous GM cars and light trucks for decades, and today, the Eaton Corporation offers a similar unit through its aftermarket division, branded the Eaton Posi.

Cone-type limited-slip differentials accomplish a similar feat with a pair of cone-shaped clutches that progressively seat against the differential case as torque is applied, gradually locking the wheels together. Auburn Gear produces cone-type limited-slip differentials, offering several variations suited for different applications, including drag racing and road racing.

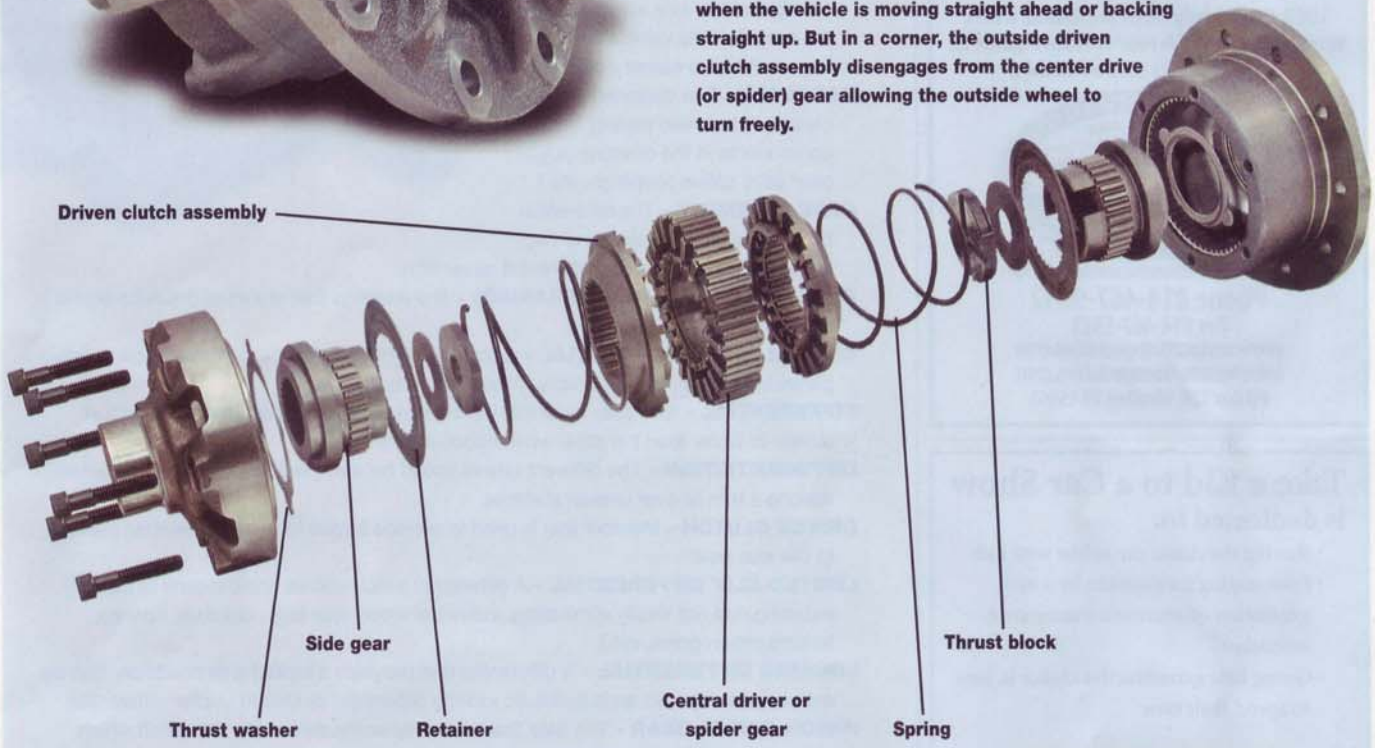
In a situation where one wheel is on a slick surface and one is on asphalt (which would render a car with an open differential motionless), the wheel on the slick surface will still spin. But the wheel on the asphalt is also receiving torque, equal to the torque required to overpower the spring and clutches in the differential. The car will still move, but not with 100 percent of the power it would if both wheels were on asphalt.

Torque-sensing limited-slip differentials work on a completely different principle, using a gear arrangement (rather than clutches) to distribute power to each axle. Under normal conditions, the torque-sensing differential operates like an open unit, but when drive wheel speed varies, more torque can be sent to the wheel with better traction, though the other wheel will continue to receive power as well.

The Detroit TrueTrac is Eaton's entry in this segment, utilizing "parallel-axis helix gears" to handle the splitting of torque. The helix gears take the place of the "spider" gears in a conventional differential, rotating around the side gears under normal conditions. When one wheel begins to lose traction, the helix gears begin to wedge in their individual pockets, creating resistance rather than simply spinning freely as traction diminishes. This allows power to be transferred to the other axle.

Torsen also produces a torque-sensing LSD, though it operates differently. The Torsen uses two or more pairs of satellite gears (called element gears) that mesh with central helical side gears. The pairs of element gears are connected to each other by a spur tooth engagement. The power delivered to the wheel with the best traction is expressed as a "bias ratio." A 3.5:1 bias ratio means that a torque-sensing differential is capable of deliv-

The famed Detroit Locker is the no-compromise-choice differential intended for severe off-road or drag strip use. It's super-strong and provides lockup as positive as a spool, but it's either locked or unlocked—which means its street manners leave much to be desired. When turning corners, you can sometimes hear and feel a Detroit Locker engaging and disengaging. Moreover, because there is some backlash designed into the locker's gears, you might hear and feel a metallic clanking as you back off of and apply the gas. (This has been significantly improved in Eaton's latest design.) Finally, it's easy to spin out in a car equipped with a locker because the quick disengagement in a corner of one wheel will cause the other wheel to spin, which could lead to the locker engaging again. Thus, you will suddenly you find yourself pointing in the direction from which you just came. Bottom line: Lockers need to be driven with respect and are best left to the racers and rock crawlers. The way it works is, the differential is locked when the vehicle is moving straight ahead or backing straight up. But in a corner, the outside driven clutch assembly disengages from the center drive (or spider) gear allowing the outside wheel to turn freely.



ering to the wheel with the best traction, 3.5 times the amount of torque sent to the slipping wheel.

Torque-sensing differentials incorporate few, if any, high-wear components, don't require special lubricants and, in general, work very well for most applications. However, they do require some resistance in order for the wheel-to-wheel power transfer to take place, and if one wheel is off the ground, the differential provides no torque to the opposite wheel. In most situations, applying slight pressure to the brakes will provide enough drive-wheel resistance to cause the torque-sensing differential to send power to the other axle.

Locking differentials are useful in more extreme circumstances, mostly for dedicated drag cars or vehicles used primarily off-road. There are several different types, using either a mechanical, electric, pneumatic or hydraulic mechanism to lock the differential's output pinions together. The most recognized mechanical type and the one most commonly used in drag racing is the Detroit Locker, also produced by Eaton, which keeps both wheels in a constant drive mode under power, but "ratchets" to allow wheel speed differentiation when required.

In a turn, locking differentials free the faster-turning wheel, usually the outside wheel, which definitely affects drivability in street vehicles. Attempts to improve street manners led to the development of switchable lockers, which are usually activated by a dashboard-mounted switch. When the switch is thrown, both axles are positively locked together. This is most commonly seen in Jeeps and 4x4 trucks.

Before choosing a differential, evaluate the intended use of your machine. Open differentials are fine for daily driving. Occasional drag strip duty or harsh weather conditions can be conquered by installing a clutch-type limited-slip differential, or a torque-sensing unit. Extreme drag racing is best served by a locking differential or a spool. See glossary next page.

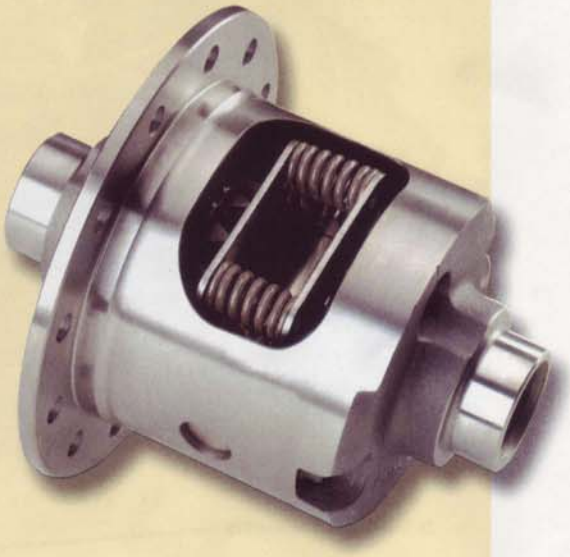
Sources:

Eaton Corporation	Auburn Gear, Inc.	Torsen Traction
216-523-5000	260-925-3200	585-464-5000
www.eaton.com	www.auburngear.com	www.torsen.com

WHAT'S THE DIFF?

A glossary of axle-related terms and lingo

(Information provided by Eaton)



AXLE CARRIER - The differential and ring and pinion gears are mounted on the axle carrier; the "center section" of the axle housing.

AXLE GEAR RATIO - The ratio between the number of teeth on the ring gear and the number of teeth on the pinion gear (e.g., 3.92:1).

AXLE HOUSING - The support member of the axle which sustains the weight of the vehicle and houses the axle carrier assembly.

BACKLASH - The designed clearance between mating components in the driveline (e.g., gear sets, spline couplings, etc.).

CASE ASSEMBLY - The differential housing (usually consisting of two case halves; contains the differential assembly).

CASE BEARING (CARRIER BEARING) - The bearings that mount to the hubs on the differential support case.

CLUTCH PACK DIFFERENTIAL - A limited-slip differential which uses friction clutch plates and/or springs to partially reduce wheel spin.

DIFFERENTIAL - Axle gear assembly which allows one axle shaft and wheel to turn slower or faster than the other when negotiating a turn.

DIFFERENTIATION - The different rate of speed between two wheels of an axle when making a turn or over uneven surfaces.

DRIVEN CLUTCH - Member that is used to provide torque to another member, such as to the side gear.

LIMITED-SLIP DIFFERENTIAL - A differential which utilizes some means of partially reducing, but not totally eliminating, individual wheel spin (e.g., clutches, springs, biasing pinion gears, etc.).

LOCKING DIFFERENTIAL - A differential that provides a locked axle condition. Can be manual or automatic, as in hydraulic locking differential or Detroit Locker differential.

PINION (INPUT) GEAR - The gear that is directly connected to the driveshaft which propels the differential and ring gear and provides power to the axle.

PLANETARY AXLE - Axle having a gearset arrangement in a concentric pattern; consisting of a sun gear surrounded by pinion gears which mesh with an annulus ring gear. This gearset provides torque multiplication in a reduced area on the same center line as the axle shaft usually located on the hub ends of axle.

PRE-LOAD - Differential bearing adjustment achieved by adding or subtracting shims.

RING GEAR - The gear that is attached to the differential case and driven by the pinion gear.

SHIM - "Spacer" used to achieve differential bearing adjustment.

SIDE GEAR - The gear that is mounted in the differential case; has the axle shaft splined to it; driven by the pinion gear.

SPIDER - The "center piece" of a standard, clutch pack or locking differential; having a spider-like shape.

SPIDER CROSS - Two or four armed member used to mount the standard differential pinion gears.

SPIDER GEAR(S) - Bevel pinion gears that are mounted on spider cross that drive the side gears of standard or clutch type differentials.

SPLINES - "Teeth" on axles that mate with "teeth" (splines) on differential side gear.

STANDARD DIFFERENTIAL - Open or conventional differential with no means of traction control.

THRUST WASHER - Used in conventional differential to reduce wear to the support case.