

Binder Bender

HOW TO BUILD AND TROUBLESHOOT A SAFER BRAKING SYSTEM

HIGH-PERFORMANCE DRIVING HAS its share of ironies, especially when you consider how best to put a leash on the action.

There's always intense focus on speed and power without much thought to how to tame it when the excitement is over. All the power in the world is dangerous if you can't manage it safely. We've seen this time and time again. The 600-hp, rubber-burning road hugger with four-wheel, non-power, drum brakes on the ground—the proverbial cart before the horse—a suicide machine.

If we did this priority thing the right way, we'd have a remarkable brake and suspension system before installing the 600-horse mill. However, that's not how any of us want to do it. There's no real excitement in brakes and suspension, because brakes and suspension are like having mom tell you to get out of the pool before you get in—there's no fun in that. But because we want to wisely manage power and arrive alive, it's a good idea to not only match brakes to power, but to have brakes that work effectively.

Your brakes are simple physics. You want sufficient friction to stop your vehicle along with a firm pedal that activates brakes at the top of pedal travel. You're also going to want the right friction material for driving conditions. And then there is the mechanics of braking: master cylinder bore size, pedal-to-booster or master cylinder geometry, brake size and type, brake fluid type and condition, and even tire/wheel sizing.

BRAKE FUNDAMENTALS

Brake function begins with hydraulic pressure, which comes from the linear motion of the brake pedal into the master cylinder piston and bore. Fluid under pressure via the piston's



movement in a cylinder bore moves brake friction surfaces into rotors or drums to stop vehicle motion. This technology dates back to 1914 and a racer and car builder by the name of Fred Duesenberg who used it on his race cars. Duesenberg understood the power of hydraulics and its necessity to automobile safety, applying this technology to passenger automobiles in 1921. His forward thinking caught on, and hydraulic brakes are still with us nearly a century later.

DOT 3 brake fluid, the most common type, is mineral-based ethylene glycol. It's been an effective hydraulic medium for braking since the dawn of hydraulic brakes. The problem with ethylene glycol is its hygroscopic characteristic, which means it likes to absorb moisture. Moisture absorption has an adverse effect on hydraulics because moisture in brake fluid reduces its effectiveness. Ethylene glycol brake fluid absorbs moisture and other contaminants through steel brake lines and reinforced hoses. That's how much it likes moisture. What's more, it has a very limited shelf life once the container is opened.

When brake fluid becomes contaminated with moisture, it becomes dangerous. Slam on the brakes and the associated pressure creates heat, causing moisture to boil and create air pockets. The result is a spongy brake pedal and poor brake performance. This is why your brake hydraulic system must be flushed and serviced every two years.

MASTER CYLINDER RIGHT SIZING

To achieve proper braking system function, you must also have a master cylinder sized to your brake sizing and pedal geometry. Pedal geometry means the distance from the pedal pivot and master cylinder and your foot. The longer the pedal arm, the greater the mechanical advantage and brake sensitivity. Another issue is master cylinder bore size and compatibility with pedal geometry and brakes.

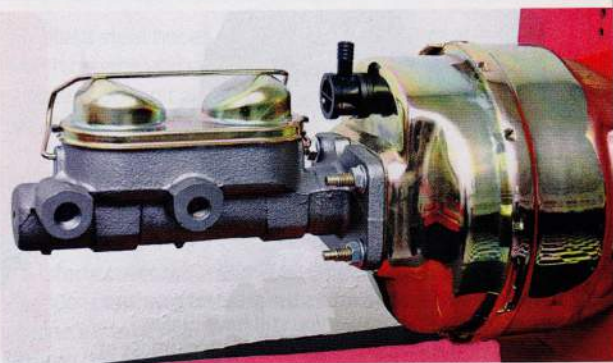
If you're like most of us with truck-building projects, chances

are good you'll be fabricating a braking system from scratch using off-the-shelf components. This means you will need to know proper brake sizing and selection for your specific mission, plus master cylinder size and brake pedal ratio, because no one wants to make an expensive mistake. *Street Trucks* consulted with Mark Williams Enterprises (MWE), which offers an easy formula for proper brake master cylinder selection.

It's important to understand master cylinder feel and pedal travel. Your brake pedal should become hard at one-third pedal travel from the top. To achieve the one-third travel and a firm pedal, Mark Williams tells *Street Trucks* you should have firewall and pedal support construction to be such that you can deliver 1,200 psi from your master cylinder to the brakes under extreme braking conditions. Minimum allowable pressure is 1,000 psi, according to MWE. You want the pedal range to be in your comfort zone where you aren't contorted or too stretched out using the brakes.

Brake hydraulic systems by nature yield a certain amount of pedal travel or "sponge" as brakes are applied and the master cylinder acts on fluid. The master cylinder piston has to travel some distance before it applies pressure to the fluid, which in turn applies pressure to calipers and/or wheel cylinders. Movement comes from servo piston travel in either disc brake calipers or drum brake wheel cylinders. MWE tells us it's a popular misconception that if you go with a larger master cylinder you will get more pressure, however, this isn't true. You will get volume but not pressure. In fact, you will get a harder pedal because it takes more effort to create the same amount of pressure. If you convert from a ¾-inch bore to a 1-inch bore, you will need to apply 77.7% more foot pressure.

What you want from a master cylinder is a balanced approach where pedal pressure, system pressure and pedal travel must all be considered and applied. Here's



Your truck project should be fitted with a contemporary vacuum or hydroboost power-assisted, dual-braking system. Power brakes make light work of braking. Old school single four-brake systems have never been safe; so don't use them. Your system should be divided fore and aft, which gives you some braking in an emergency.

what you want to consider when shopping for a master cylinder.

- A brake pedal lever/piston that moves the entire length of your master cylinder bore.
- The lever must also move freely throughout its movement.
- Uses a reasonable amount of pedal pressure to reach desired system pressure.
- Sports the alignment necessary to minimize pedal travel.

MWE CALIPER COMBINATIONS	PISTON AREA (IN SQUARE INCHES)	SUGGESTED MASTER CYLINDER BORE SIZE	MASTER CYLINDER DISPLACEMENT USING A 1.25-INCH STROKE
Two 83100 two-piston calipers	4.8	¾ inch	0.55 ci
Two 81100/82100 four-piston calipers	9.6	¾ inch	0.75 ci
Four 81100/82100 four-piston calipers	19.2	1 ½ inch	1.24 ci
Two 81000/82100 four-piston calipers and two 83100 two-piston	14.4	1 inch	0.98 ci
Two 81100/82100 four-piston calipers and two 73002 two-piston billet calipers	13.7	1 inch	0.98 ci

The simple calculator pictured above, courtesy of MWE, will help you select the right master cylinder and pedal linkage.

These are typical caliper sizes, which will vary to some degree from company to company, but you get the idea. This table enables you to calculate master cylinder bore sizing and stroke while choosing disc brake assemblies.

Wilwood suggests choosing a master cylinder based on how you intend to drive and whether or not you will have a power booster. You want a firm, responsive brake pedal while also getting sufficient pressure to stop safely. What's more, you want a dual reservoir system that ensures brake function should one system fail.

MASTER CYLINDER BLEEDING

There are a lot of theories about the best way to bleed a master cylinder, on the vehicle or on the bench. Bench bleeding a master cylinder gets all of



A dual brake system offers the greatest measure of brake safety because you still have brakes should the front or rear system fail. Regardless of whether you're building a stocker or a resto-mod, you must have a dual braking system with a proportioning valve for optimum pressure distribution and brake control.

the air out before installation. However, you still have an entire system to flush and bleed. Every brake system overhaul must include a complete flush, so have plenty of brake fluid available. How you bleed a brake system is a matter of personal preference. You can bleed them with a helper on the brake pedal beginning with the brake furthest away from the master cylinder. There are also manual and pneumatic pressure bleeders, which do a better job than your right foot. They don't cost much and are available from The Eastwood Company and Harbor Freight.

The type of brake fluid you use depends on what you want your brakes to do. There are five types of brake fluid classified by the U.S. Department of Transportation (DOT). Which type you use depends on where you live and what you want brake fluid to do. You must consider compressibility, viscosity, corrosion issues and boiling point.

As a rule, no one uses DOT 2 brake fluid though it is included in the table below and has similar characteristics to DOT 3. DOT 3,

which is ethylene glycol based, is the most common type of brake fluid there is. As we said earlier, it's hygroscopic, which means it will absorb moisture and needs to be flushed every two years. DOT 3 offers a high boiling point, which makes it suitable for just about any kind of driving.

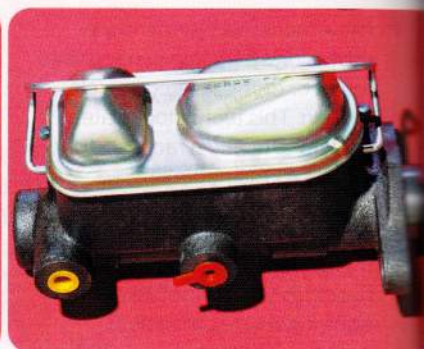
You want to be concerned with boiling point because brake temperatures can get very high, especially in racing. When ethylene-glycol-based brake fluid boils, it vaporizes, putting air into the braking system. This will adversely affect braking performance. When we speak of "wet" and "dry" brake fluid boiling points we're talking the moisture content of the brake fluid. If there's moisture in your brake fluid, the boiling point becomes lower, known as the wet boiling point. Right out of the can and in a sealed environment is known as the dry boiling point. When moisture content goes over 3.7% water by volume, it becomes known as wet. Brake fluid viscosity is the density of the fluid much like viscosity is with engine oil or gear lube. This becomes critical in extremely cold weather with traction control and anti-lock braking systems.

DOT 4 isn't much different from DOT 3 except that it delivers a higher boiling point of 311°F wet and 446°F dry. DOT 5.1 yields similar qualities and chemical properties to DOT 3 and 4, yet with the same high boiling point as DOT 5 silicone, 356°F wet and 500°F dry. If you want the high boiling point of silicone DOT 5 without the spongy pedal, DOT 5.1 is your best choice.

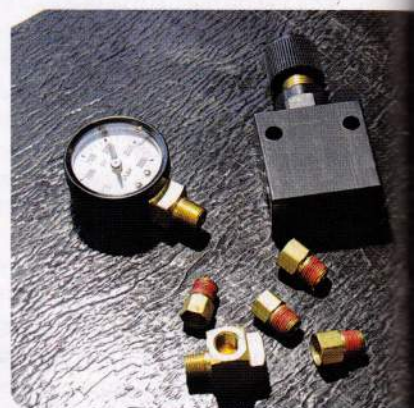
DOT 5 silicone brake fluid won't damage paint or absorb moisture, which makes it perfect for race cars,



Prior to the 1967 model year, U.S. vehicles had single hydraulic braking systems with one master cylinder (above) tied to all four brakes. Dual braking systems (front and rear) became federally mandated beginning with the 1967 model year, and this is the only braking system to have even if you're building a stocker.



Master cylinder bench bleeding fully prepares the master cylinder for installation. However, it's suggested that you completely flush the brake system any time you do a brake job or replace any hydraulic component. Because air tends to accumulate in small pockets throughout the system, expect to bleed the system several times before all air is expelled. Begin system bleeding at the furthest point away from the master cylinder: right rear and left rear, then right front and left front. Be prepared to do it again and again until you have a rock hard pedal.



This is an adjustable brake proportioning valve, which controls brake pressure to rear drum or disc brakes when you have front disc brakes. Front brakes should always apply first. This takes a lot of practice with multiple applications before it becomes safe and comfortable. Premature rear brake application will cause loss of vehicle control.

BRAKE FLUID TYPES & CHARACTERISTICS

DOT TYPE	WET BOILING POINT	DRY BOILING POINT	MATERIALS
DOT 2	284°F	374°F	Castor oil
DOT 3	284°F	401°F	Ethylene glycol/ester based
DOT 4	311°F	446°F	Ethylene glycol/ester based
DOT 5	356°F	500°F	Silicone based
DOT 5.1	356°F	500°F	Ethylene Glycol/ester based

show cars and rarely driven vehicles. What's more, silicone DOT 5 brake fluid can be used indefinitely without the need for flushing every two years. The downside to silicone is compressibility; it tends to yield a spongy brake pedal no matter how aggressively you bleed the brakes.

LINES AND HOSES

Brake lines are something you can fabricate yourself or buy pre-made/custom made from Classic Tube. If you're seeking professionally bent and flared tubing, Classic Tube can take your sample template and custom fabricate ready-to-install brake lines for your project. There is also a large product line of pre-made kits available depending upon your application.

You have a choice of galvanized steel, e-coated or stainless steel brake lines when you're planning a braking system. Galvanized and e-coated steel lines are easier to work with and you can double flare them. Stainless steel brake lines provide great aesthetics, but because stainless is very hard, it's challenging to bend and flare. Stainless steel brake lines get a single flare because a double flare is virtually impossible to achieve without splitting the line. Stainless calls for the use of a collar and special flaring tool, which may or may not be something you will want to get into.

Flexible brake hoses are available in three basic types: standard OEM-style black reinforced rubber, braided stainless and braided coated stainless. The beauty of braided

stainless steel hoses is aesthetics and brute strength, which means you get a firmer pedal because braided stainless doesn't give the way reinforced rubber does. Braided stainless will last the life of the vehicle.

POWER BRAKES

Power brakes are little more than vacuum, hydraulic or electric-assist to reduce pedal effort. Vacuum-assisted power brakes consist of a spring-loaded vacuum diaphragm that gets its power from the engine's intake manifold vacuum. A large spring returns the brake pedal to rest when foot pressure is suspended. As brakes are applied, manifold vacuum draws the diaphragm toward the master cylinder piston aiding brake pedal application and brake application. Power brake boosters fail when the return spring breaks or the diaphragm ruptures, causing a vacuum leak and higher pedal effort.

Hydroboosted power brakes work on the same principle as power steering. When you step on the brake pedal, hydraulic pressure is applied to a servo and master cylinder piston to aid in brake application. Rarely does a hydraulic brake booster fail. When they do, it's normally a control valve or servo issue.



Brake lines are of double wall construction for the extreme pressures associated with hydraulic brakes. Galvanized steel lines get a double flare for unequalled sealing strength at each union. Stainless steel lines get a single flare via a stainless-specific flaring tool and collar.



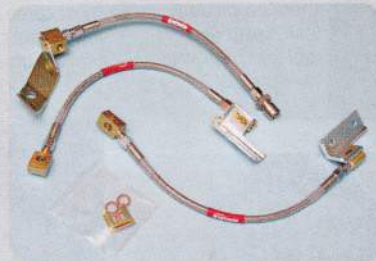
There are three basic types of brake lines: galvanized steel, coated steel and stainless steel. Galvanized and coated steel lines are easiest to work with. The Eastwood Company has a huge variety of self-help home garage tools that enable you to fabricate your own brake lines. You can buy rolls of galvanized and stainless brake lines and, using Eastwood tube bending and flaring tools, custom make lines for your truck project.



Classic Tube's pre-bent brake lines for rear axles have this anti-chafe coil to protect lines from road debris. You can specify the use of anti-chafe when you're ordering custom pre-bent lines.



This is one type of flaring tool for the home garage fanatic. The Mastercool universal hydraulic flaring tool (P/N 71475) from Eastwood yields a precision fit and a perfect flare because it keeps the line centered on the flaring head. The Eastwood Company has a variety of brake line flaring tools hinged to your budget. Remember, you get what you pay for. Opt for higher ground and get better results.



Classic Tube's Stop Flex braided and coated stainless brake hoses are literally the last brake hose you will ever have to buy for your truck project. They are made to fit perfectly and will outlast any OEM hose on the market.



There is always some debate on what material to use at brake hose unions, but copper has always been the industry standard with aluminum as an acceptable alternative. Copper washers yield good crush qualities as do aluminum, which provides excellent sealing quality. It's suggested you only use them once and always install new versions during reassembly.



Invest in a good set of tubing wrenches in the most popular sizes if you want to protect fittings. Standard open-end wrenches can damage fittings, rendering them useless.

Electric power brakes are becoming more common as time goes on because they make brake systems more powerful and safer than anything we've seen to date. What makes electric power brakes a better idea is consistent braking pressure under all conditions. You have a pump and an accumulator, which maintain braking pressure. An electric power brake-specific master cylinder with a large $1\frac{3}{16}$ -inch bore provides plenty of fluid volume to get the job done. You can mount the pump just about anywhere as long as it's below the master cylinder reservoir. The accumulator can go anywhere. Like hydroboosted power brakes, rarely does anything go haywire with electric power brakes. Should a problem arise it's easily remedied.

DRUM BRAKES

Although drum brakes are considered old school they can also be a nice complement to front disc brakes because they provide

adequate braking without getting into the expense of rear disc brakes. What's more, there is more friction surface area in a drum brake than we find with disc brakes. The downside to drum brakes is wear issues and severe brake fade when they get wet or hard braking occurs.

The key to keeping drum brakes effective is regular preventative maintenance and adjustment. Although self-adjusting brakes are billed as "self-adjusting" they rarely do that even under the best of circumstances. To do so, self-adjusting brakes have to be applied when you're backing up, which is the only time they live up to their name. Otherwise, brake drum and lining wear continues and pedal travel increases. Drum brakes need to be adjusted every 10,000 miles on average. While spinning the wheel and drum assembly, adjust the star wheel adjuster until you hear shoe drag. Apply and release the brakes

several times and spin the wheel again. Adjust until you hear shoe drag and check again.

When you perform a drum brake overhaul, it's suggested you replace drums rather than turn them unless you're on a really tight budget. This causes excessive pedal travel and reduces drum integrity. When you turn brake drums, you're reducing the amount of material you have there. This makes drums



Rear drum brakes can be excellent performers given good preventative maintenance. With each and every brake job must come all new parts including drums, linings, hardware and wheel cylinders for optimum performance. When you turn brake drums and reuse them, you increase shoe and pedal travel, which is why it's suggested that you install new drums.



Vacuum-assist power brakes are old technology but still quite effective. When power boosters fail, you can expect high pedal effort or a pedal that won't return to rest. If the pedal won't return, you have a failed return spring. If there's high pedal effort, the diaphragm is damaged and there's a vacuum leak. In either case replace the power booster.



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Master cylinder and power booster linkages should be adjustable in order to control pedal height. Pedal height should be such that you have plenty of travel room, yet don't have to be a contortionist. When you consider entire pedal travel from top stop to bottom out, the pedal should become firm at one-third pedal travel.



One area we don't check often enough is the pedal support. Because the pedal support can also be a clutch pedal support, there's a lot of stress, wear and tear going on there. The aftermarket offers all kinds of brake and clutch pedal support repair and replacement systems. This is but one example from Scott Drake Reproductions with needle bearings and a hard tool steel shaft.



The age old debate addressing riveted versus bonded brake shoes continues to resonate, but in the end it boils down to what you want your brakes to do. Riveted linings carry heat away better than bonded; whereas, bonded linings provide more friction surface area.

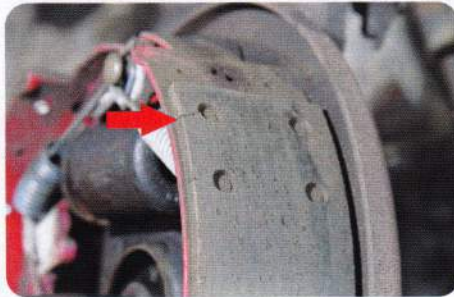


When you reline, check the lining-to-drum relationship and ascertain fitment. In the good old days, repair shops used to arc brake shoes for solid drum fitment. Those days are gone, but it's up to you to examine shoe-to-drum contact prior to assembly.



New brake backing plates and complete hardware kits are available from Summit Racing Equipment. You may also recondition existing back plates by welding in a rise at shoe contact points and grinding them flush to improve the shoe's relationship with the backing plate. Use white grease at these contact points to reduce wear. Don't overdo the grease.

more prone to irregularities and pedal pulsation. When you install new brake drums, don't forget to seat the linings and heat cycle the drum for improved integrity. Heat cycling the drums is getting vehicle speed up to 50-60 mph and slamming on the brakes to get them hot. Do this at least three times to seat the linings and heat cycle the drums. Then, perform another adjustment. While you're performing a drum brake overhaul, opt for a new hardware kit with new springs and hold-downs. It's a good idea to replace wheel cylinders and flush the system every time you perform a brake job.



Brake linings crack from excessive heat and even high water, which thermal-shocks the linings, causing them to crack from a sudden change in temperature. When linings crack they must be replaced.



Brake drums are turned and machined all of the time. Machining limits are always cast into the drum. It's strongly suggested you replace the drums rather than turn them to keep pedal travel conservative.

DISC BRAKES

Disc brakes became common on American cars in the '60s and have only improved with time. It used to be that you had to cop a set of disc brakes from a late-model car or truck and retrofit them to your classic truck; not anymore. Innovative companies like Baer, Classic Performance Products, Stainless Steel Brakes Corporation, Wilwood and a host of others have stepped up with the greatest disc brakes in automotive history.

When you overhaul an existing disc brake system, it's advisable to replace the rotors instead of turning them for the same reasons it's suggested that you replace drums. When you turn brake rotors on a brake lathe,



Self-adjusting brakes rarely self-adjust, which means drum brakes need to be adjusted periodically. Inspect and adjust drum brakes every 10,000 miles. This is a star wheel self-adjuster. If it works properly, it will advance the star wheel adjuster and shoes every time you back up and pump the brakes. This is why new hardware is vital whenever you perform a brake overhaul. Star wheel adjusters wear out with time and use.



Stainless Steel Brakes Corporation offers a wide variety of disc brake packages from one- and two-piston iron caliper budget kits to high-end, large-disc jumbo jet binders. You can get into a budget front disc brake conversion kit for around \$1,000 and achieve excellent stopping power. Remember, anything beats four-wheel, non-power drum brakes. It's an investment in your own safety.

you're removing material from the rotor, which to some degree adversely affects rotor integrity. When you do a disc brake job and install new pads and rotors, it's important to bed the pads and heat cycle rotors with 60-to-zero-mp/h hard stops with a cool down period in between hard stops. Heat-cycling brake rotors is the same as heat-treating any metal, it contributes to increased strength.

One huge unknown with new brake rotors is

molecular composition, better known as a flawed casting. You can have a new rotor and perform proper break-in (heat-cycling) and wind up with scrap iron due to flaws in the rotor you can't see and no manufacturer could see in the casting process. Irregular brake rotor castings are sometimes born into the manufacturing process. Sometimes warped rotors happen because we don't break them in properly or abuse them with poor driving technique (slamming

on the brakes excessively, riding the brakes, high water). Frustrated, we take warped rotors to a brake shop and have them turned to get rid of the pulsing pedal. Those first few miles are flawless. Gradually, the pulsing pedal returns and we have scrap iron. Chronic brake rotor warping isn't always brake abuse, but a flawed rotor casting that cannot be corrected with a lathe. When that happens, your only choice is rotor replacement.

SOURCES

- **Baer Brakes**
602.233.1411
Baer.com
- **Classic Performance Products**
800.522.5004
Classicperform.com
- **Harbor Freight**
800.423.2567
Harborfreight.com
- **Mark Williams Enterprises**
303.665.6901
Markwilliams.com
- **Stainless Steel Brakes Corporation**
800.448.7722
Ssbrakes.com
- **Summit Racing Equipment**
800.230.3030
Summitracing.com
- **The Eastwood Company**
800.343.9353
Eastwood.com
- **Total Cost Involved (TCI)**
800.984.6259
Totalcostinvolved.com
- **Wilwood**
805.388.1188
Wilwood.com



Baer Brakes offers the broadest selection of disc brake conversion kits and parts in the industry. If your plan includes canyon cutting, road racing or any other type of speed driving, Baer offers great tech support designed to help you make the right decision. Drilled and slotted brake rotors are engineered to dissipate heat and vent friction material gassing when you're on the binders at speed. Aluminum calipers act as heat sinks for excessive heat, which keeps friction at a productive temperature. Finned rotors provide heat sink capability under extreme conditions.



Brake pads should get noise reduction grease between the pad and caliper, which quiets brake operation and eliminates binding. Make sure rotors and friction surfaces are hospital clean before pads are installed. Clean rotors with a high-evap' solvent, like brake cleaner or lacquer thinner, and allow them to dry before pad installation.



Absolutely never do this. Grease doesn't belong between the bearing and axle because the bearing race must remain stationary and secured to the axle spindle. We see this all of the time with the logic being corrosion prevention or lubrication; however, the bearing race/hub is not supposed to rotate.



Always use a high-temperature wheel bearing grease even if you're building drum brakes. Use a good bearing packer or heavy massage work in the palm of your hand. Keep working the bearing in your palm until it's completely saturated with grease. Bearing failure happens when we fail to thoroughly pack the bearings or properly seat bearings on spindles.



There are two basic types of axle seals: with a garter spring and without. Seals fitted with garter springs have to be handled carefully. Pack the spring cavity with wheel bearing grease, which keeps the spring secure while you're driving the seal in. Otherwise, the spring pops off and you will have leakage. Lubricate the seal lip generously to ensure a happy marriage with the spindle or axle shaft.



There are two ways to properly seal a castle nut, yet there are many ways to screw it up, including using a nail instead of a cotter pin. Follow these two images and you can't go wrong. Always select a cotter pin sized for the job. Make sure cotter pin legs clear the bearing cap.