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The role of the brake fluid within the braking system is to transfer the force from the master cylinder to the corners of the car...and a vital characteristic of brake fluid that allows it to perform its task properly is its ability to maintain a liquid state and resist compression. In order to keep the fluid in top condition, many enthusiasts have been taught to "bleed their brakes" but many have never stopped to ask the question "why?"

#### **Why Bleed the Brakes?**

The term "bleeding the brakes" refers to the process in which a small valve is opened at the caliper (or wheel cylinder) to allow controlled amounts of brake fluid to escape the system. (When you think about it, "bleeding" may appear to be a somewhat graphic term, but it aptly describes the release a vital fluid.)

We bleed the brakes to release air that sometimes becomes trapped within the lines. Technically, "air" only enters the lines if there is a compromise of the system's sealing (as when flex lines are removed or replaced), because when fluid boils, it will instead create "fluid vapor." Vapor in the brake fluid, like air, will create an efficiency loss in the braking system. However, for the sake of simplicity we use the term "air" throughout this article to describe both air and fluid vapor.

When air (or vapor) becomes present within the lines, it creates inefficiencies within the system because, unlike liquid, air can be compressed. So when enough air fills the lines, input at the pedal merely causes the air to compress instead of creating pressure at the brake corners. In other words, when air is present within the system, the efficiency and effectiveness of the braking system is reduced. Usually, a small amount of air within the brake system will contribute to a "mushy" or "soft" pedal (since less energy is required to compress the air than is required to move fluid throughout the brake lines.) If enough air enters the brake system, it can result in complete brake failure.

So how does air enter the lines in the first place? Sometimes, it can be the result of a service procedure or an upgrade – such as replacing the stock flex lines with stainless steel braided lines. But often it is the result of high temperatures that cause brake fluid components to boil, thus releasing gasses from the boiling fluid into the brake hydraulic system.

#### **Brake Fluid Selection**

This leads one to contemplate the type of liquid that is used as brake fluid. In theory, even simple water would work – since, being a liquid, water cannot be compressed. However, it is important to remember that the fundamental function of the braking system is to convert kinetic energy into heat energy through friction. And the reality of this process is that certain parts of the braking system will be exposed to very high temperatures. In fact, it is not uncommon to see rotor temperatures during a race as high as 1200 degrees Fahrenheit – which can raise the temperature of the brake fluid to well over 300 degrees Fahrenheit. Since the boiling point of water is 212 degrees Fahrenheit, it is easy to see that water within the brake system could boil easily – and therefore release gases into the brake pipes – which would reduce the efficiency of the system. (Water would also present a big problem in cold weather if it froze to ice!)

The "obvious" solution to this problem is to utilize a fluid that is less sensitive to temperature extremes. Hence the development of "brake fluid." However, there unfortunately is no such thing as a "perfect" brake fluid. And like most things in the world, the addition of certain beneficial characteristics usually brings tradeoffs in other areas. In the case of brake fluid, we generally must balance the fluid's sensitivity to temperature against its cost and its impact upon other components within the system.

Stated more bluntly, it is possible to reduce a fluid's sensitivity to temperature by varying the ingredients of the fluid. However, certain combinations of ingredients can significantly increase the cost of the fluid and may react with OEM materials to damage seals and induce corrosion throughout the braking system.

The chemical composition and minimum performance requirements of the fluid are generally indicated through a rating such as "DOT3," "DOT4," or "DOT5." The DOT-rating itself is assigned after a series of government tests. However, this rating is NOT intended to indicate boiling points, even though higher DOT ratings generally do correspond with higher boiling points. Perhaps more importantly, the DOT rating does indicate the base compound of the brake fluid – which allows manufacturers to specify fluid types which are less likely to react negatively to known materials used within a particular braking system.

The greatest irony about brake fluid, however, is the fact that the chemical compositions that tend to be less sensitive to temperature extremes also tend to attract and absorb water! So even though the fluid itself is unlikely to boil (most glycol-based DOT3 fluids have a "dry boiling point" around 400 degrees Fahrenheit,) the water that it absorbs over time tends to boil easily (at 212 degrees Fahrenheit.) It is this characteristic of absorbing moisture that leads to the measure known as the "wet boiling point." The wet boiling point is the equilibrium boiling point of the fluid after it has absorbed moisture under specified conditions. Because brake fluid will absorb moisture through the brake system's hoses and reservoir, evaluation of the wet boiling point is employed to test the performance of used brake fluid and the degradation in its performance. (And it is why we still need to bleed the brakes frequently on racecars, even though we use racing fluid that costs upwards of \$75 per bottle!) The lesson: do NOT expect to avoid bleeding your brakes just because you bought expensive brake fluid.

As one might guess, "racing" fluids will use relatively "aggressive" chemical compositions which will tend to have higher wet boiling points and higher costs, while the average street fluids will

use more conservative compositions which will have lower wet boiling points and lower costs. In some cases – such as a purpose-built racecar – the tradeoffs of using the expensive racing fluid is outweighed by the competitive advantages. But for the average driver – whose driving style is less likely to induce brake temps as high as those seen on the track – the costs of the fluids and potential wear-and-tear factors upon system components may justify the use of a more conservative fluid with a lower wet boiling point.

### How-To

So, now that you understand the need behind bleeding your brakes, let us present just one procedure that can be utilized when servicing your own car. Note that unless you are replacing your master cylinder, the procedure is the same whether you have a vehicle equipped with ABS or not...

### Supplies Required

You will need the following tools:

- Box-end wrench suitable for your car's bleeder screws. An offset head design usually works best.
- Extra brake fluid (about 1 pint if you are just bleeding, about 3 if you are completely replacing).
- 12-inch long section of clear plastic tubing, ID sized to fit snugly over your car's bleeder screws.
- Disposable bottle for waste fluid.
- One can of brake cleaner.
- One assistant (to pump the brake pedal).

### Vehicle Preparation and Support

1. Loosen the lug nuts of the road wheels and place the entire vehicle on jackstands. Be sure that the car is firmly supported before going ANY further with this procedure!
2. Remove all road wheels.
3. Install one lug nut backward at each corner and tighten the nut against the rotor surface. Note that this step is to limit caliper flex that may distort pedal feel.
4. Open the hood and check the level of the brake fluid reservoir. Add fluid as necessary to ensure that the level is at the MAX marking of the reservoir. Do not let the reservoir become empty at any time during the bleeding process!

### Bleeding Process

1. Begin at the corner furthest from the driver and proceed in order toward the driver. (Right rear, left rear, right front, left front.) While the actual sequence is not critical to the bleed performance it is easy to remember the sequence as the farthest to the closest. This will also allow the system to be bled in such a way as to minimize the amount of potential cross-contamination between the new and old fluid.
2. Locate the bleeder screw at the rear of the caliper body (or drum brake wheel cylinder.) Remove the rubber cap from the bleeder screw – and don't lose it!
3. Place the box-end wrench over the bleeder screw. An offset wrench works best – since it allows the most room for movement.
4. Place one end of the clear plastic hose over the nipple of the bleeder screw.
5. Place the other end of the hose into the disposable bottle.
6. Place the bottle for waste fluid on top of the caliper body or drum assembly. Hold the bottle with one hand and grasp the wrench with the other hand.
7. Instruct the assistant to "apply." The assistant should pump the brake pedal three times, hold the pedal down firmly, and respond with "applied." Instruct the assistant not to release the brakes until told to do so.
8. Loosen the bleeder screw with a brief  $\frac{1}{4}$  turn to release fluid into the waste line. The screw only needs to be open for one second or less. (The brake pedal will "fall" to the floor as the bleeder screw is opened. Instruct the assistant in advance not to release the brakes until instructed to do so.)
9. Close the bleeder screw by tightening it gently. Note that one does not need to pull on the wrench with ridiculous force. Usually just a quick tug will do.
10. Instruct the assistant to "release" the brakes. Note: do NOT release the brake pedal while the bleeder screw is open, as this will suck air back into the system!
11. The assistant should respond with "released."
12. Inspect the fluid within the waste line for air bubbles.
13. Continue the bleeding process (steps 11 through 16) until air bubbles are no longer present. Be sure to check the brake fluid level in the reservoir after bleeding each wheel! Add fluid as necessary to keep the level at the MAX marking. (Typically, one repeats this process 5-10 times per wheel when doing a 'standard' bleed.)
14. Move systematically toward the driver – right rear, left rear, right front, left front – repeating the bleeding process at each corner. Be sure to keep a watchful eye on the brake fluid reservoir! Keep it full!
15. When all four corners have been bled, spray the bleeder screw (and any other parts that were moistened with spilled or dripped brake fluid) with brake cleaner and wipe dry with a clean rag. (Leaving the area clean and dry will make it easier to spot leaks through visual inspection later!) Try to avoid spraying the brake cleaner DIRECTLY on any parts made of rubber or plastic, as the cleaner can make these parts brittle after repeated exposure.
16. Test the brake pedal for a firm feel. (Bleeding the brakes will not necessarily cure a "soft" or "mushy" pedal – since pad taper and compliance elsewhere within the system can contribute to a soft pedal. But the pedal should not be any worse than it was prior to the bleeding procedure!)
17. Be sure to inspect the bleeder screws and other fittings for signs of leakage. Correct as necessary.
18. Properly dispose of the used waste fluid as you would dispose of used motor oil. Important: used brake fluid should NEVER be poured back into the master cylinder reservoir!

### Vehicle Wrap-Up and Road Test

1. Re-install all four road wheels.
2. Raise the entire vehicle and remove jackstands. Torque the lug nuts to the manufacturer's recommended limit. Re-install any hubcaps or wheel covers.
3. With the vehicle on level ground and with the car NOT running, apply and release the brake

pedal several times until all clearances are taken up in the system. During this time, the brake pedal feel may improve slightly, but the brake pedal should be at least as firm as it was prior to the bleeding process.

4. Road test the vehicle to confirm proper function of the brakes. USE CAUTION THE FIRST TIME YOU DRIVE YOUR CAR AFTER MODIFICATION TO ENSURE THE PROPER FUNCTION OF ALL VEHICLE SYSTEMS!

**How Often do I Need to Bleed My Brakes?**

In closing, here are a few rules of thumb to help you to determine the proper bleeding interval for your particular application:

1. Under normal operating conditions, and without brake system modifications, typical OEM braking systems have been designed to NOT require bleeding for the life of the vehicle unless the system is opened for repair or replacement. If you're just driving around town or on the highway to work, there is really no need to bleed! There are a few European vehicles which do recommend replacement on a semi-regular basis for other reasons though, so be sure to check in your owner's manual or at your service center for your particular application.
2. Those who choose to autocross or drive in a sporting manner may choose to upgrade their brake fluid and bleed on an annual basis - this is a good 'start of the season' maintenance item for low-speed competitors.
3. If your car sees significant amounts of high-speed braking, or if you choose to participate in driver schools and/or lapping sessions, bleeding prior to each event is a sound decision. More intense drivers at these events may choose to skip right past this step and on to #4...
4. Finally, dedicated race cars should be bled after every track session.

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