This will attempt to cut through all the B.S. out there and give you a thorough and factual overview of brake fluid. Additionally I will attempt to address some of the performance issues, dispel some of the myths and old bench racing tales and educate you as to what makes one brake fluid better or worse than another.

Before we start, you need to understand there is really no such thing as DOT certification for brake fluid. What it should be called is "DOT Compliancy" meaning the fluid meets the specifications as stated by DOT. (FWIW, the DOT specifications are taken almost exactly from SAE standards.) If fact, what you'll find on the label of many brake fluids is the statement, "…… meets or exceeds DOT 3 (or whatever)….." What the DOT specs do is to lay down baseline performance parameters for brake fluid and detail exactly how to test the fluid. This ensures that when you do look at a fluid's specifications, you are comparing apples to apples.

Let's start with an first an understanding of the terms and what they mean.. Following this is an overview of the different specifications and chemistry of brake fluid.

Brake Fluid Specifications:

All brake fluids must meet (comply with) Federal Motor Vehicle Safety Standard #116 (FMVSS 116.) Under this standard are three Department of Transportation (DOT) minimal specifications for brake fluid. They are DOT 3, DOT 4, and DOT 5.1 (for fluids based with Polyalkylene Glycol Ether) and DOT 5 (for Silicone based fluids).

Understanding Brake Fluid Terms:

Dry Boiling Point – Or more accurately termed Equilibrium Reflux Boiling Point (ERBP). In fluids deemed to be DOT compliant, this is the temperature at which the fluid begins to boil when tested in the manner described by the DOT.

Wet Boiling Point - Or more accurately termed Wet Equilibrium Reflux Boiling Point (Wet ERBP). In fluids deemed to be DOT compliant, this is the temperature at which the fluid begins to boil when tested in the manner described by the DOT. FWIW, the procedure for this a reference fluid is placed in the specified container at the same time as the testing fluid is placed in a similar container. When the reference fluid reaches 3.70±0.05% water content by weight, both the reference fluid and the testing fluid are removed. The testing fluid is then put through the same procedure as for Dry ERBP. That temperature point is noted as the Wet ERBP.

Note, this DOES NOT mean the testing (sample) fluid also had 3.7% water content. In fact, depending on the fluid, it may have less or it may even have a GREATER percentage of water content.

In reference to the DOT (or SAE) test, a typical Dot 3 fluid will contain approximately 3 - 3.5% moisture, a DOT 4 fluid will contain 4-4.5% moisture content by volume. However it is possible, although quite a bit more expensive, to create a Super DOT 4 fluid, like GS610, where the moisture content is closer (lower) to that of DOT 3 but still has a much greater tolerance for moisture. This means that even when the fluid has become contaminated with a greater percentage of water content, for example, 4.5 - 6% by weight, it continues to maintain is Wet ERBP performance and not degrade further.

Viscosity – Here's a really interesting specification. One where the DOT 3 spec could be perceived as actually being better for the micro passages of an ABS system than the DOT 4 spec. Webster's defines "viscosity" as, "Physics, the resistance of a fluid to flowing freely, caused by friction of its molecules." As you may recall from motor oil, the higher the viscosity number, the slower the flow of the oil. Well the same applies for brake fluid although the actual measurement technique is different. The DOT 3 specification for viscosity at -40°F is 1500 mm2/s and the specification for DOT 4 at -40°F is 1800 mm2/s. Yep, that's right, the DOT 3 fluid flows better at the testing temperature than the DOT 4. It should be noted the specification at 212°F for all DOT specifications is 1.5 mm2/s.

Compressibility – This is NOT a specific DOT specification however it listed in SAE J1705, Appendix A, A.2.2.8. under the heading, "Air Solubility." Here it states, “Air Solubility – It has been reported that dimethyl polysiloxane fluid, which is a major part of silicone based low water tolerant type brake fluids can typically contain dissolved air at a level of 16%±3% by volume at standard temperature and pressure. This compares with a typical level of 5%±2% by volume of dissolved air for glycol ether based type fluids. An increase in brake pedal travel may be experienced under severe operating conditions, especially at higher altitudes and high temperature conditions."

"The term “dissolved air” (air absorbed from the atmosphere) should not be confused with the term “entrapped” or “free air” since their effects on brake system performance can be entirely different. Air that has been absorbed from the atmosphere does not result in an increase in fluid or system volume, whereas entrapped air or free air does occupy system volume and can be easily compressed when force is applied to the system.“

The SAE standard continues, “A.2.2.9 – Compressibility – Silicone based brake fluids are more compressible than conventional brake fluids and the difference is magnified at higher temperatures.”

Compressibility is something you’ll find most, if not all other brake fluid brands completely ignoring. And with good reason! They don’t want you to know their fluid could or does contain as much as 7% dissolved air! No wonder certain "high end racing" fluids are known for their poor pedal feel.

Polyalkylene Glycol Ether type brake fluids are over 3 times less compressible than silicone (low water tolerant) type fluids, even when heated. And even within the scope of the Polyalkylene Glycol Ether fluids, there can be a difference of over 200% between a fluid like GS610 with minimal dissolved air and other fluids containing far more!

A research report from Union Carbide demonstrates a relationship between the compressibility of a brake fluid and its density (specific gravity.) The greater the density of a brake fluid the less compressible it is. GS610 is the most dense brake fluid on the market today!

pH – This is another DOT specification The range of pH to meet FMVSS 116 is 7 -11.5. pH is an indicator of a couple of important issues. One is the fluid's corrosion resistance and the other is it's high temperature stability. A higher pH will prevent corrosion for a longer time however higher pH values also reduce the fluid’s high temperature stability. If the pH is below 7, the system is on the acidic side and may produce corrosion within the system over time. Certainly if it is below 6 problems will occur. Steel does not corrode as long as the pH is above 9.5 but aluminum will be attacked if the pH goes above 11.5. A ph lower in the range will provide all the corrosion protection you need while maintaining maximum high temperature stability.

High Temperature Stability – This is a measure of how stable the dry ERBP temperature is as fluid temperature increases. And it applies universally to all grades of brake fluids. The specification per FMVSS 166 reads, “…. The ERBP shall not change by more than 5.4°F (3°C) plus 0.05 for each degree the ERBP of the fluid exceeds 437°F (225°C.)” For a fluid with the extreme ERBP of GS610 the ERBP could vary in either direction by as much as 14.05°F (9.97°C). That said, please note the High Temperature Stability of GS610 is actually 2°F (1°C)

Brake Fluid Descriptions:

DOT 3: This brake fluid has a glycol base with additives. It is clear to amber in color. It is hygroscopic (meaning it absorbs moisture) and has a minimum dry boiling point of 401°F (205°C) minimum and a minimum wet boiling point of 284°F (140°C). It will absorb 1 to 2 percent of water per year depending on climate and operating conditions. It is used in most domestic cars and light trucks in normal driving. It does not require cleaning the system and it can be mixed with DOT 4 and DOT 5.1 without damage to the system. The problem with it is that it absorbs moisture out of the air and thereby reduces its boiling point. It can also damage the paint on a vehicle.

DOT 4: This brake fluid also has a glycol in it but the SAE J1704 specification considers it to be a borate ester base fluid. Typically in the high performance fluids, it also contains other additives. It is clear to amber in color. It is hygroscopic (meaning it absorbs moisture) and has a minimum dry boiling point is 446°F (230°C) and minimum wet boiling point of 311°F (155°C). It is used in many European cars; also for vehicles in high-altitude, towing, or high-speed braking situations, or ABS systems. It does not require cleaning the system and it can be mixed with DOT 3 without damage to the system. The problem with it is that it absorbs moisture out of the air and thereby reducing its boiling point, however it absorbs moisture at a rate slower than DOT 3. It can also damage the paint on a vehicle.

DOT 5: This brake fluid has a silicone base. It is purple in color. It is NOT hygroscopic (meaning it cannot and will not moisture) and has a minimum dry boiling point of 500°F (260°C) and a minimum wet boiling point of 356° (180°C) It is not used in many brake applications, seeing primary duty in weekend, antique, and collector cars that sit for long periods and are never driven far. It does not mix with DOT 3, DOT 4, or DOT 5.1. It will not absorb water and will not

damage the paint on a vehicle. It is also compatible with the same rubber formulations as the DOT 3, 4 & 5.1 fluids. The problem with it is that it can easily get air bubbles into the system. The air bubbles are nearly impossible to remove and result in poor system performance and poor pedal feel. Although originally developed in the late 1960's by General Electric specifically for racing, it is unsuitable for racing for a variety of reasons. (Click here for the silicone story) If as little as one drop of water enters the fluid, severe localized corrosion, freezing, or vapor lock may occur. This can happen because water is heavier and not mixable with silicone fluids. It is unsuitable for ABS.

DOT 5.1: This brake fluid is similar to DOT 4 it has a base comprised primarily of Borate Ester. Often in the range of 70 - 80%. To meet specification, it also will contain other additives. It is clear to amber in color. It is hygroscopic (meaning it absorbs moisture) and has a minimum dry boiling point of 500°F (260°C) and a minimum wet boiling point of 356°F (180°C) minimum. It is almost exclusive to Europe, used in high performance cars. It can be mixed with DOT 3 or DOT 4 without damage to the system. It maintains higher boiling point than DOT 3 or DOT 4 fluids due to its even greater borate ester content. It is excellent for severe duty and racing applications. The problem with it is that it costs more than other fluids and there is limited availability in the USA. It also absorbs moisture out of the air and thereby reduces its boiling point. It can also damage the paint on a vehicle.

Fluid Compatibility

Brake fluid must be compatible with the brake system materials. Compatibility is determined by chemistry, and no amount of advertising, wishful thinking or rationalizing can change the science of chemical compatibility. DOT 3, 4, 5 and 5.1 fluids must, to meet the specification of Federal Motor Vehicle Safety Standard 116 (FMVSS 116) be compatible with all specified brake system materials except in the case of DOT 5 silicone. Some rubber external components such as caliper piston boots, may be attacked by silicon fluids and greases.

Water Absorption and Corrosion

What most don't understand is some degree of water absorption is desirable. DOT 3-4-5.1 glycol based fluids will readily absorb water. Like many other things, this is a good thing (to a degree) as your brake system does contain water and there is nothing you can do about it. However there are corrosion inhibitors in the brake fluid formulation that handle this. Since the inhibitors are gradually depleted as they do their job, glycol brake fluid, just like antifreeze, needs to be changed periodically. The one caveat to this is the DOT 5 silicone fluids, not being water miscible, must rely on the silicone (with some corrosion inhibitors) as a barrier film to control corrosion. Water is not absorbed by silicone as in the case of DOT 3-4-5.1 fluids, and will remain as a separate globule sinking to the lowest point in the brake system (typically the caliper), as water is more dense. The other issue with this is now you have water coming in contact with the metal components of the brake system. This can actually exacerbate the corrosion issue.

How fast does brake fluid absorb moisture?

It depends on the fluid and environment. A typical high performance DOT 4 fluid like, Motul, AP, Castrol SRF, Wilwood and ATE SuperBlue, in a high humdity evironment will absorb as much as 4.5-5% moisture in as short a period as 2 weeks. In real world testing (several daily driver cars, GS610 absorbed <1% moisture in 3 years. This was measured from the brake fluid in the resevoir where the vehicle's brake system is most likly to contain the greatest contaimination of moisture.

How does brake fluid become contaminated?

Water/moisture can be found in nearly all brake systems. Moisture enters the brake system in several ways. One of the more common ways is from using old or pre-opened fluid. Keep in mind, that brake fluid draws in moisture from the surrounding air. Tightly sealing brake fluid bottles and not storing them for long periods of time will help keep moisture out. When changing or bleeding brake fluid always replace master cylinder caps as soon as possible to prevent moisture from entering into the master cylinder. Condensation, (small moisture droplets) can form in lines and calipers. As caliper and line temperatures heat up and then cool repeatedly, condensation occurs, leaving behind an increase in moisture/water. Over time the moisture becomes trapped in the internal sections of calipers, lines, master cylinders, etc. When this water reaches 212º F the water turns to steam. Many times air in the brake system is a result of water that has turned to steam. The build up of steam will create air pressure in the system, sometimes to the point that enough pressure is created to push caliper pistons into the brake pad. This will create brake drag as the rotor and pads make contact and can also create more heat in the system. Diffusion is another way in that water/moisture may enter the system.

Diffusion occurs when over time moisture enters through rubber brake hoses. The use of hoses made from EPDM materials (Ethlene-Propylene-Diene-Materials) will reduce the amount of diffusion OR use stainless steel braided brake hose with a non-rubber sleeve (usually Teflon) to greatly reduce the diffusion process.

What happens if I try to switch from a glycol based fluid to a silicone based fluid?

If silicone is introduced into an older brake system, the silicone will latch onto the sludge generated by gradual component deterioration and create a gelatin like goop which will attract more crud and eventually plug up metering orifices or cause pistons to stick. If you have already changed to DOT 5, don't compound your initial mistake and change back. Silicone is very tenacious stuff and you will never get it all out of your system. Just change the fluid regularly. For those who race using silicone fluid, I recommend that you crack the bleed screws before each racing session to insure that there is no water in the calipers.

What causes a mushy pedal?

There are a number of factors some mechanical and some chemical that can manifest themselves as a mushy pedal. For this discussion we'll stick to the fluid causes.

The most common issue is the amount of dissolved air within the fluid. All brake fluid has dissolved air in it (yes, even GS610) the critical question is , "How much?" This is explained in greater detail above.

Silicone (Low Water Tolerant) Brake Fluids

Silicone based fluids are non-hygroscopic meaning that they will not absorb or mix with water. When water is present in the brake system it will create a water/fluid/water/fluid situation. Because water boils at approximately 212º F, the ability of the brake system to operate correctly decreases, and the steam created from boiling water adds air to the system. It is important to remember that water may be present in any brake system. Therefore silicone brake fluid lacks the ability to deal with moisture and will dramatically decrease a brake systems performance.