Brake Fluid: What You Should Know (Part I)

Brake fluid is a central part of your brake system. It lubricates the internal mechanisms of the system and transfers the force your foot exerts on the pedal into the clamping force that stops your vehicle. For this reason, standards are put in place to ensure that the fluid meets key criteria and allows your brake system to work as designed.

Let’s take a step back and go over how a brake system works before we get started with the Key Characteristics. Consider the [very] simple work of art below.

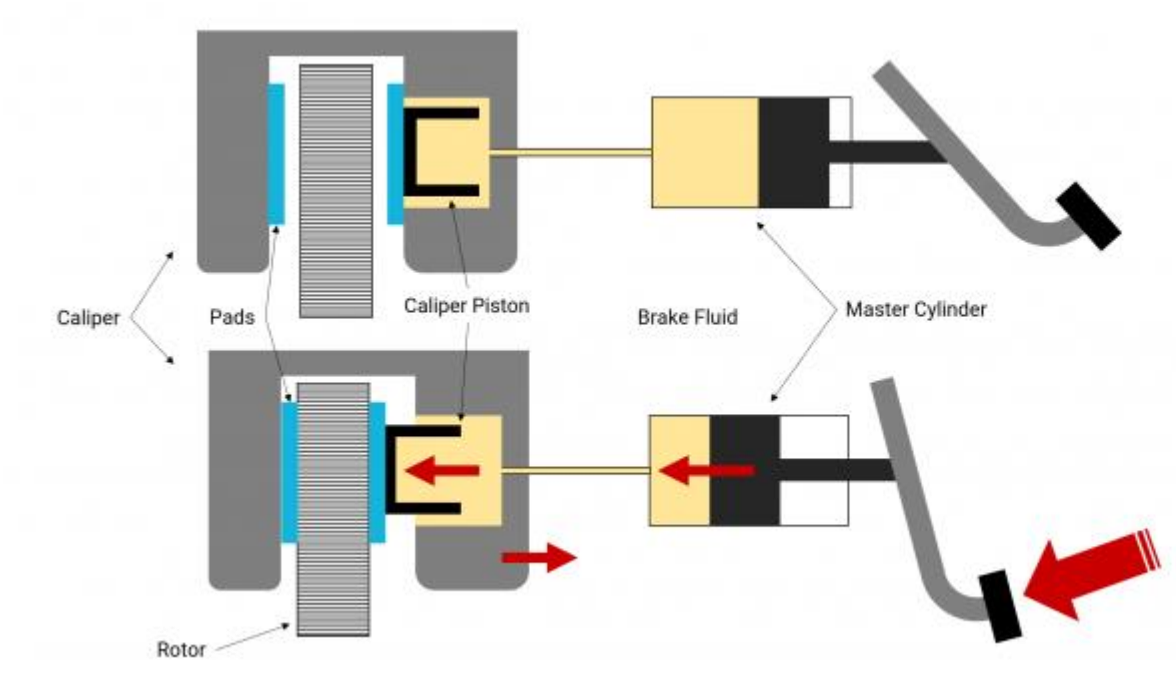


Figure 1: Brake System Schematic

The schematic shows how the brake fluid (light orange) is the medium in which force is transferred without a brake booster. The force of the pedal gets converted to pressure through the master cylinder. That pressure is transferred from the master cylinder to each caliper, through the brake fluid. The pistons in the calipers then convert that pressure to a force that clamps down on the rotors. Drum brakes work in much the same way.

For the system to work efficiently, the brake fluid must be able to move easily through the lines (**kinematic viscosity**) and must be able to efficiently transfer the pressure from the master cylinder to the piston. The efficient transfer of pressure relies on the incompressibility of the brake fluid. When we talk about brake fluid, incompressibility is related to the **boiling point** of the fluid. We’ll get into how later on in this article.

Brake Fluid Kinematic Viscosity

Viscosity of a fluid, in simple terms, is how thick the fluid is. **Kinematic Viscosity** is a measure of how much the fluid resists flowing under the force of gravity. It’s measured in squared-millimeters per second (mm^2/s), also known as the unit Centistokes abbreviated as cSt.
In less-complicated wording: Imagine taking a jar of honey and pouring out all the honey. Kinematic viscosity is a measure of how slowly the honey pours out. The more time it takes, the higher the kinematic viscosity.

So, a fluid with a high kinematic viscosity tends to run slowly (as with the honey) and a fluid with low kinematic viscosity tends to run fast (think of water). To put some numbers to it, consider that the viscosity of water at room temperature is around 1.0 mm^2/s and the kinematic viscosity of honey is around 6,900 mm^2/s.

Figure 2: Viscosity Levels Can Be Compared To Water Versus Honey

For most fluids, viscosity tends to change depending on temperature. Fluids such as honey, for example, increase in viscosity as temperatures fall and decrease in viscosity as temperatures rise. The same can be said for brake fluid.

Kinematic viscosity is a key characteristic of brake fluid since the system must operate smoothly within a wide range of temperatures. Technologies such as ABS, Stability Control (ESP), and Traction Control, require fast-moving fluid (low viscosity) in order to operate correctly. These systems use fast activating valves to control the flow and pressure of the brake fluid at critical times of operation. If the viscosity of the brake fluid is high, then the movement of the fluid through the lines will be sluggish and difficult to control. The last thing you'd want is a brake system that doesn't want to work on a cold winter day!

Brake Fluid Boiling Point

The boiling point of brake fluid is another key characteristic and a fairly important one since at this point, the liquid turns into a gas. Gasses are compressible and will severely reduce the effectiveness of your brake system.

Compressibility of a fluid means how much a set mass of the fluid can change in volume when a pressure is applied. Compressible fluids will result in a very inefficient brake system: your pedal will need to travel further, the reaction time of the system is much slower, and the resulting clamping force to the brakes are significantly reduced.

All brake fluids are designed to be as incompressible as possible in their liquid state. However, if enough heat builds up in the caliper from excessive brake use, the fluid will boil and gasses will be produced. These gasses displace brake fluid in the lines and introduce compressibility, making for a very mushy and ineffective brake system.

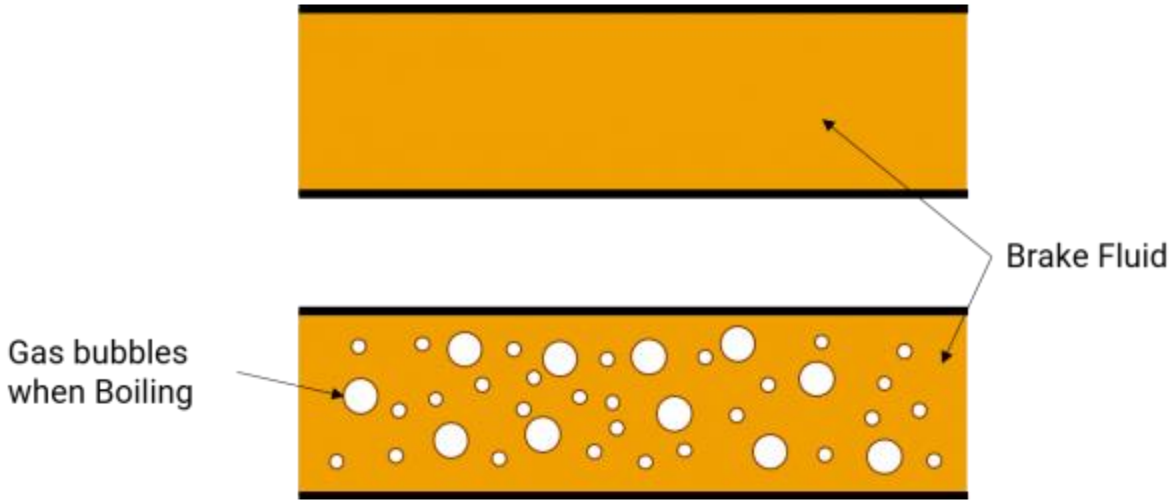


Figure 3: Illustration of Gas in Brake Lines

This boiling point is called the **Equilibrium Reflux Boiling Point (ERBP)**. The ERBP is the temperature at which the uncontaminated (moisture-free or "dry") brake fluid begins to boil… Which brings us to another point.

Another factor that affects the boiling point of the fluid is water. Most brake fluids are glycol ether- and borate ester- based brake fluids which absorb moisture (i.e. they are 'hygroscopic'). Because of this property, the moisture from the environment gets absorbed into the fluid and the boiling temperature is reduced (water has a lower boiling point).

This "wet" boiling point when moisture is mixed into the brake fluid is called the **Wet Equilibrium Reflux Boiling Point (Wet ERBP)**. The Wet ERBP is the temperature at which the fluid begins to boil after it has had time to absorb moisture from the surroundings. This temperature is a good indication of the limits of use of a moisture-contaminated fluid.

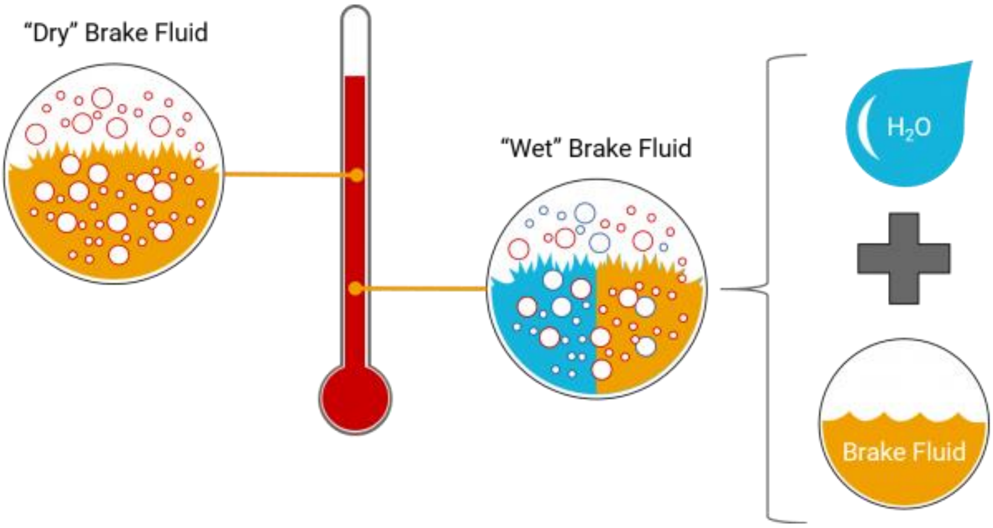


Figure 4: ERBP vs Wet ERBP.

Putting It All Together

Kinematic viscosity, ERBP and Wet-ERBP are key characteristics that define brake fluids. It is important to have a brake fluid that moves freely through the system at a wide range of temperatures so that you can take advantage of the proper use of technologies such as ABS. That's where Kinematic Viscosity comes in. You'll see in the next part of this series of articles that the Kinematic Viscosity in a fluid is measured at a minimum temperature of -40 C and a maximum temperature at 100 C. This is done to give a fairly good indication of how well the fluid performs at a wide range of temperatures.

Knowing the dry (ERBP) and wet (Wet-ERBP) boiling points of the fluid will give you a good indication of how much aggressive driving and contamination the fluid can take before your system becomes compromised.

- **Kinematic Viscosity** is a measure of how much the fluid resists flowing under the force of gravity.
- **Equilibrium Reflux Boiling Point (ERBP)**: The ERBP is the temperature at which the uncontaminated fluid begins to boil. In this case, uncontaminated means free from moisture that may have been absorbed from the surrounding environment.
- **Wet Equilibrium Reflux Boiling Point (Wet ERBP)**: The Wet ERBP is the temperature at which the fluid begins to boil after it has had time to absorb moisture from the surroundings. This temperature is a good indication of the limits of use of a moisture-contaminated fluid.

Brake Fluid: What you Need to Know [Part 2] – Standards

Brake fluid is a central part of your brake system. It lubricates the internal mechanisms of the system and transfers the force your foot exerts on the pedal into the clamping force that stops your vehicle. For this reason, standards are put in place to ensure that the fluid meets key criteria and allows your brake system to work as designed.

In Part 1 of this series, we discussed how kinematic viscosity and the boiling point (dry and wet) of brake fluid affects the system's performance. In this article, we'll be discussing the different Standards and Grades of brake fluid to give you a better understanding of what they really mean.

The requirements for brake fluid is defined by a few internationally recognized standards organizations.

- The Federal Motor Vehicle Safety Standards (FMVSS) in the US, classifies three main grades of brake fluids under FMVSS 116.

These grades are DOT 3, DOT 4, and DOT 5. DOT 5 if further defined as DOT 5 – Silicone Based Brake Fluid (SBBF) or DOT 5.1 –Non-silicone Base.

- The International Standards Organization (ISO) classifies a few other grades of brake fluids under their ISO 4925 document: Class 3,

Class 4, Class 5.1, and Class 6.

- The Society of Automotive Engineers (SAE) classifies another three grades: SAE J1703, SAE J1704 and SAE J1705.

Each of these organizations define the minimum, maximum, and acceptable range of the key characteristics of brake fluid grade (such as the ERBP, wet-ERBP, and viscosities). They also go as far as defining the required packaging of the fluid to ensure no contamination occurs before it's actually used.

You'll realize that most of these organizations have different names for the grades/classes. Most of us in North America will probably be familiar with "DOT 3" or "DOT 4" brake fluid as defined by the FMVSS 116 standard. While the different standards offer different names, they tend to mostly all overlap and agree.

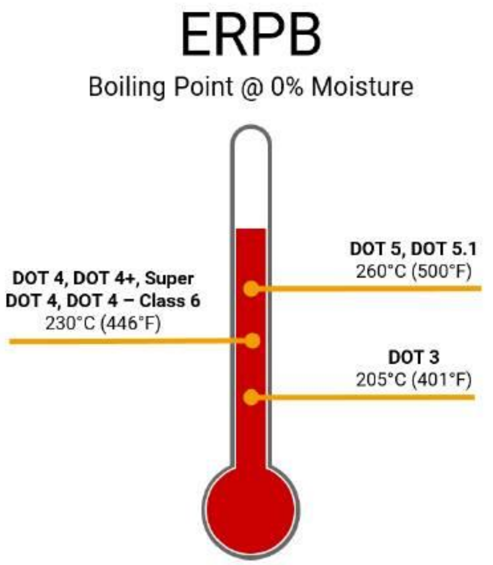
Here's a table that shows the specifications of each grade.

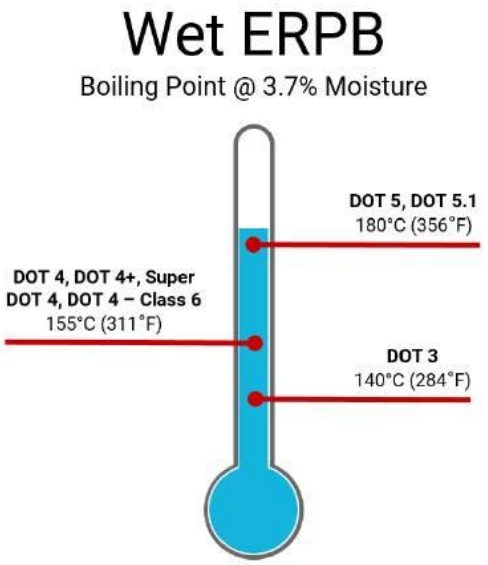
	DOT 3	DOT 4	DOT 4+ Super DOT 4 DOT 4, Class 6	DOT 5	DOT 5.1
Referenced Standards	FMVSS 116 ISO 4925, Class 3	FMVSS 116 ISO 4925, Class 4	ISO 4925, Class 6	FMVSS 116	FMVSS 116 ISO 4925, Class 5-1
Minimum ERPB	205C (401F)	230C (446F)	230C (446F)	260C (500F)	260C (500F)
Minimum Wet ERPB	140C (284F)	155C (311F)	155C (311F)	180C (356F)	180C (356F)
Max Kinematic Viscosity @ -40°C (-40°F)	1500 mm^2/s	1800 mm^2/s	750 mm^2/s	900 mm^2/s	900 mm^2/s
Min. Kinematic Viscosity @ +100°C (+212°F)	1.5 mm^2/s	1.5 mm^2/s	1.5 mm^2/s	1.5 mm^2/s	1.5 mm^2/s
Colour Requirements	Clear to Amber	Clear to Amber	Clear to Amber	Purple	Clear to Amber
Base components	Glycol ether, borate esters	Glycol ether, borate esters	Glycol ether, borate esters	Silicone based brake fluid (SBBF)	Glycol ether, borate esters

You'll notice that the table has columns named after the FMVSS 116 definitions of the grades except for the DOT 4+ column. The FMVSS defines DOT 3, DOT 4, DOT 5, and DOT 5.1 but It does not define the DOT 4+, the Super DOT 4, nor the DOT 4 – Class 6.

Technically, this "sub-grade" (let's call it Super DOT 4) of brake fluid is a DOT 4 fluid. It meets all the requirements of a DOT 4 grade but has better viscosity characteristics. The Super DOT 4 is specifically the ISO 4925, Class 6 grade.

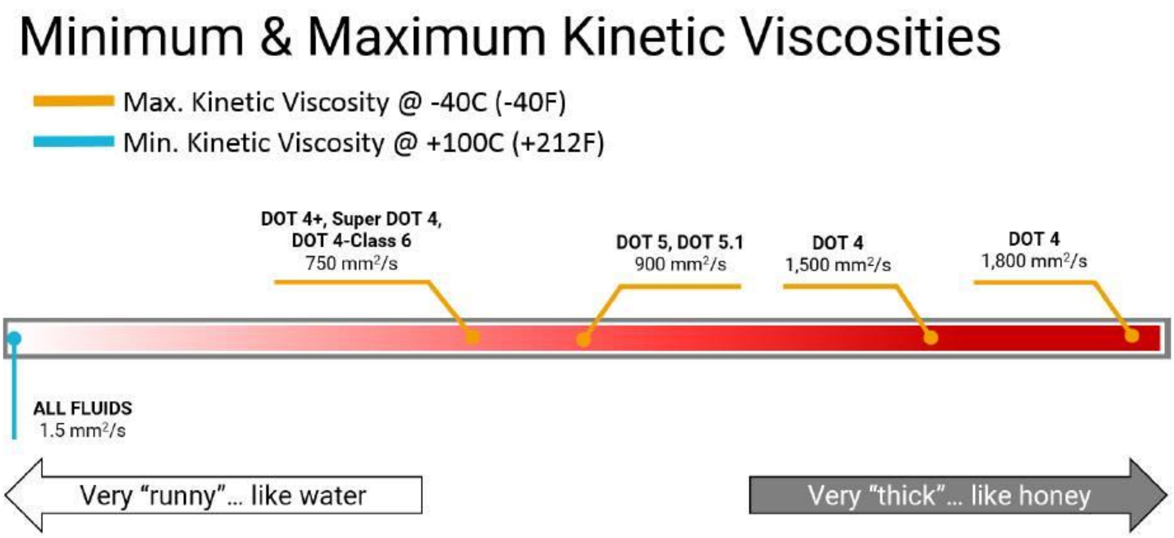
Boiling Temperatures





Boiling points for each fluid are shown in the illustration above. You'll notice that DOT 5, DOT 5.1 grades have the highest boiling points followed by DOT 4 (and its sub-grades) and then DOT 3.

Viscosities



Viscosity of the brake fluid is measured at two points. The first point is at 100 degrees Celsius and the second point is at minus 40 degrees Celsius. At 100˚C (212˚F) most fluids tend to be free flowing and it's relatively easy to achieve a kinematic viscosity of 1.5mm2/s. At sub-zero temperatures of -40˚C (-40˚F), the fluids tend to "thicken" and it becomes diflcult to ensure that it can still flow freely. Most modern vehicles have advanced braking control and traction control and will need to use this technology at frigid temperatures so this characteristic is extremely important in such environment. For this reason, among others, most of modern vehicles will use a DOT 4 or Super DOT 4 grade since these grades address the need for low-temperature viscosity aimed at reducing ABS cycle response times.

Base Components

In the good old days, brake fluid (DOT and DOT 2) was a castor oil-based fluid that was use for lubrication as well as for actuation. These days, most brake fluids are glycol-ether based fluids. The exception is DOT 5 which is a silicone-based fluid. DOT 5 was initially developed for environments where the fluid's water resistance and low corrosion was important – such as military or marine. The downside of the DOT 5 silicone-based fluid is it's high compressibility when compared to the other grades. As such, it's usecase is limited to very specific applications.

Colour Requirements

Why have colour requirements? The simplest reason is to ensure you're using the right fluid. All ether-based fluids are clear to amber while all silicone-based fluids are purple.While the different colours give a quick indication as to the composition, the clarity can tell how contaminated the fluid is. Ideally, brake fluid should be clear and clean. Dark and murky fluid indicates that the fluid has collected dirt, debris, and even moisture from the system and it's now time to replace it.

Are the Fluids Interchangeable?

Vehicle systems are designed for to use a specific fluid grade. Ideally, the vehicle will continue to use that grade for the remainder of its life. The reason being that the internal components of the brake system have been designed, selected, and tested to work with that fluid.

Although DOT 3 and DOT 4 are all ether-based, the chemical composition of each fluid grade is different and will have a different effect on your system. To ensure your system works as it's designed to work, the best thing to do is stick to the manufacturer's suggested brake fluid(s).

Can you use a Super DOT 4 grade instead of a DOT 4 grade? NOT ALWAYS. Your vehicle's brake system would have seals, gaskets, valves, and sensors that have been designed to be used within a range of viscosities and temperatures. Using a Super DOT 4 in a DOT 4 system may present the system with a fluid that is too “think” to work correctly with the existing equipment. Check with your dealership or owner’s manual for a clear answer on this.

Summing It All Up

Brake fluid is deflned by a few internationally recognized standards organizations to ensure consistency in the performance of these brake fluids. These organizations and grades are:

- The Federal Motor Vehicle Safety Standards (FMVSS) under FMVSS Standard No. 116 defines grades DOT 3, DOT 4, DOT 5, and DOT5.1.
- The International Standards Organization (ISO) under ISO 4925 defines Class 3, Class 4, Class 5.1, and Class 6 brake fluids.
- The Society of Automotive Engineers (SAE) classifies the grades SAE J1703, SAE J1704 and SAE J1705

Each standard defines the minimum dry and wet boiling points, kinimatic viscosities, colour requirements, and base components for each grade.

Can you use different grades of fluid in your vehicle? If your vehicle is designed for non silicone based fluids then you will not be able to use DOT 5 fluid. For non-silicone based fluids, each vehicle should use the manufacturer’s recommended brake fluid to ensure the system works as designed. While, theoretically you may be able to change the fluid grades used, it is not recommended as it may affect the life of your system and its performance.