Industry Adopts Brake Fluid Replacement Guidelines

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There has been much controversy involving brake fluid over the years. Much of this controversy involves the issue of "when" and "why" to change the brake fluid. The controversy has increased in the last few years largely based on the following:

- The introduction of new brake fluid testing technology;
- Statements made by the "Big 3" domestic OEM manufacturers that the brake fluid in their vehicles lasts the life of the vehicle; and
- The fact that the last three stings involving the auto service industry involved some mention of brake fluid.

Fig. 1: Internal corrosion of caliper bore. Those of us that have been around long enough to have rebuilt calipers, recognize this picture. The brake fluid in the calipers is typically the worst in the system. This is due to the reason given above, plus the fact that they are the lowest point in the system.

While it is generally accepted that brake fluid should be changed periodically the justification for such a recommendation varies widely. Most technicians have based much of their recommendations on the fact that DOT 3 brake fluid is hygroscopic. Hygroscopic means the brake fluid readily absorbs water. Water is absorbed through all the rubber parts in the system, including the brake hoses and seals, and every time the reservoir cap is removed. It has long been thought that the moisture absorbed in the brake fluid was the sole source for the internal corrosion that takes place in the various brake parts.

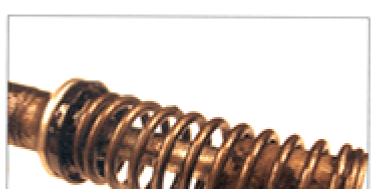
I will be the first to admit I, like many others have blamed this type of corrosion and sludge build-up entirely on the moisture content of the brake fluid. This position has recently been proven incorrect. The moisture content in the brake fluid is NOT the only cause of the corrosion that takes place in a brake system; it is only a contributing factor.

Fig. 2: Minor corrosion of a caliper piston

Fig. 3: Severe corrosion of the caliper piston.

It is not often that an entire industry's position on something can be shown to be incorrect but it can happen. The issue of brake fluid testing came under the scrutiny of the Maintenance Services Task Force of the AMRA (Automotive Maintenance and Repair Association) back in December of 2002. The task force was represented by members from the auto service industry, equipment manufacturers, parts manufacturers, education and the scientific community. Just recently, the task force released their findings. This article will serve to explain the process they went through and their ultimate conclusion.

The initial goal of the task force was to determine if industry-accepted guidelines could be adopted in the area of brake fluid flushing. Early on in the process, it was apparent to all those on the task force that the opinions about why brake fluid should be flushed varied widely and most of them had something to do with the moisture content of the brake fluid and its boiling point. The task force's direction evolved from the issue of fluid flushing to that of how to determine if a brake fluid flush should be suggested or required.



I, like many others am of the opinion that brake fluid represents the most neglected fluid in an automobile. So what's the big deal? The big deal is that the reason most shops give a customer for the reason why they should have a brake fluid flush has no basis in fact.

Fig. 4: This image shows the corrosion that can occur in the master cylinder.

The most common explanation given to a customer about why they should have their brake fluid flushed is based on the fluid's color.

If you watch some of the recent sting videos that have taken place on both a local and national level you will here things like, "Your brake fluid is dirty and needs to be changed". This was one of the first issues the task force dealt with. One of the things that must be understood about the objective of the task force is that if they were to make any recommendations on the issue of brake fluid flushing, they must be based on fact, not commonly accepted opinion.

Fig. 5: The sludge buildup in the unused bore of the master cylinder can cause primary cup seal damage if the brake pedal is depressed too far.

A number of independent sources pointed out that the color of brake fluid cannot be used as an indicator of its condition. One brake fluid manufacturer went on to explain that some new brake fluids have additives that will cause the brake fluid to change color when exposed to brake rubber parts. Another source provided data showing that brake fluid appearing almost pitch black can pass all available tests while other fluid samples appearing to be "good" could fail those same tests. So, one thing that became obvious early on was our industry has to stop recommending brake fluid flushes on the color of the brake fluid. If we don't stop, we will continue to end up on the evening news.

As the task force gathered more information on the topic, it became clear that most of the literature available put the focus on the moisture content and boiling point of the brake fluid as the leading concerns. It was also clear that the majority of the current test techniques available at the shop level center on providing a measure of the moisture content, or boiling point of the brake fluid.

Fig. 6: Corrosion can affect the conventional valving of a vehicle, as seen on the internals of this metering valve. As can be seen from the image, the amount of buildup is significant.

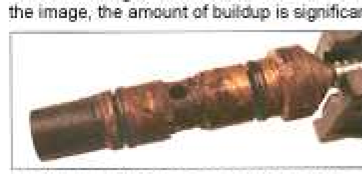


Fig. 7: This is from the proportioning valve shown in Fig. 6.

These techniques include strip testing, boiling point analysis, refractometers and conductivity meters. Testing that provides an indication of the moisture content or boiling point of the brake fluid is usually using the DOT minimum wet boiling point of the brake fluid as a base line reference. As it turns out, the minimum wet boiling point is not meant to be used as an "in-use" specification. This paragraph excerpt from task force's conclusion helps explain this:

"Motor vehicle brake fluids are hygroscopic and absorb moisture when exposed to the atmosphere and in service. Water contamination from any source, including mechanical or accidental additions of free water, will appreciably lower the original boiling point of the brake fluid, and increase its viscosity at low ambient temperatures. Water contamination may cause corrosion of brake cylinder bores and pistons, and may seriously affect the braking efficiency and safety of the brake actuating system.

Fig. 8: This is the inlet filter to a RWAL/RABS valve. Notice the restriction starting in the top portion of the filter screen. I have seen these filters restrict to a point where there is little to no braking in the rears and also restrict the fluid flow back to the master cylinder. Every modulator I have ever disassembled has multiple filters. Due to corrosion, some of these filters are prone to plugging.

Source: SAE international standard (J1707, Revised January 2002).

While moisture is definitely an issue with brake fluids, no consistent and accurate measurement identifying the percentage of moisture that is detrimental to brake fluid performance has been found in the literature. In addition, no specification exists for an in-use brake fluid boiling point that can be identified by a testing procedure and therefore no recommendation for replacement based on moisture content can be made with confidence."

In summary, while the moisture content of the brake fluid remains a concern, no accurate test is available to determine when it should be replaced based on moisture content.

There is another reason to take the focus off of the moisture content of the brake fluid and place it where it belongs. There have been significant advances in the technology used to make the rubber that is used in brake hoses, square cut seals and wheel cylinder cup seals.

This technology has made the rubber much more resistant to moisture intrusion. The increased use of transparent reservoirs has reduced the need to remove the cap to check the fluid level. As a result of these changes, less moisture enters the brake system.

Fig. 9 & 10: Certain early Kelsey Hayes ABS rear-wheel and four-wheel ABS systems use reset switches to signal the end of an ABS cycle. The reset switch cap and piston for an EBC2 system are shown in Figures 9 & 10. Code 4, the result of a grounded reset switch, is one of the most common failures in this type of system. The reset switch return spring can't push the piston back to a rest position.

One of the task force members involved with the OEMs found out one of the OEMs did a study using test fleets comprised of thousands of vehicles from various locations that were approximately 8 years old. They tested the brake fluid for moisture and discovered an average of less than one percent over the entire fleet.

They said improved master cylinder reservoir design, brake fluid and brake hose materials significantly reduced moisture related problems with brake fluid. They did however find evidence of corrosion.

This last statement is the key to understanding the new twist being put on the entire topic of brake fluid testing. Corrosion was found without significant amounts of moisture in the system. To explain this we have to take a step back and discuss how one of the purposes of brake fluid is to prevent corrosion.

Corrosion inhibitors, pH stabilizers and antioxidants are added to brake fluid to improve the long-term corrosion protection of brake systems.

Fig. 11 & 12: Kelsey Hayes ABS systems use dump valves and low pressure accumulators in their modulators. The dump valve seat can corrode to a point where fluid is allowed into the low pressure accumulator during normal braking. See the related article for more detail. By-passing dump valves is a common problem on these systems and was noted in the NHTSA report referenced by force.

Over time these corrosion inhibitors can become depleted leaving the internal parts of the brake system vulnerable to corrosion. There are many variables involved in determining how long it takes to deplete the corrosion inhibitors including brake fluid chemistry, chemical and thermal stability, brake system design, driving habits of the operator, frequency of maintenance, temperature, and road surfaces. Another unrelated extensive study found that the buffer capacity and inhibitor concentrations "drop to less than 10% of their initial levels after only 30 months of service". (Jackson, SAE paper 971007,Corrosion Prevention SP-1265, 1997)

The rate of depletion is affected by many factors. One of the studies found the rate of depletion is fastest at the wheels. This is where the fluid is exposed to the highest degree of heat and the heat causes the corrosion inhibitors to breakdown.

Vehicles with ABS show even faster degradation due to the aggressive circulation of the fluid caused by the cycling of the ABS system. This, combined with the fact that ABS systems use close tolerance valves and other precision parts, makes them more susceptible to the affects of corrosion or deposits.

One of the task force members submitted a NHTSA (National Highway Traffic Safety Administration) report that demonstrates the affect of depleted corrosion inhibitors. In the report they stated:

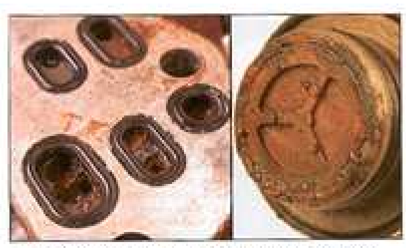


Fig. 13 & 14: These figures show the internals of a TEVES 4 ABS system. This modulator is mounted low on the vehicle so it suffers some of the same problems as the calipers. Figure 13 shows the modulator body passages and it is easy to see the amount of corrosioin that has taken place. Figure 14 shows one of the isolation valves and it is clear that the filter is being affected by the corrosion that has taken place.

"The NIST (National Institute of Standards and Technology) study does show that internal corrosion does take place as a result of depletion of the corrosion inhibitors in the brake fluid and the accumulation of water in the brake fluid over time."

The report went on to offer the following proof of corrosion:

1. Visual evidence of corrosion damage is observed on iron alloy components approximately one-third of the time (typically no damage is observed to stainless steel);

2. The damage observed usually consisted of shallow pitting similar to that reported by Jackson's SAE paper;

3. In most cases, when corrosion pits were found on iron, copper deposits of varying morphology were also found;

4. The small copper particles were found both inside and outside of the shallow pits on the iron, and

5. The copper sponge and the copper nugget morphology were found in the shallow pits associated with, and usually under, the gel-like substance.

At this point in the task force's process, I was asked to put together a slide show of examples of corrosion. This was done to allow the members to see a visual representation of what corrosion could do to the various brake components.

Most technicians won't disagree that corrosion takes place in the brake system. The above information only offers proof of the fact. What technicians are not aware of is the process that takes place that allows the corrosion to take place. What the task force found through these reports was that copper was the first principle contaminate that appears in brake fluid. From the task force's report:

Copper has direct role in the corrosion of the brake system, as well as providing an indirect relationship to the age of the brake fluid.

In the NIST report, Ricker et al [1], hypothesizes "the copper in the brake lines corrodes at a slow rate over several months or years resulting in copper ions in the brake fluid. These ions then act as oxidizers and plate out in the ABS valves when the corrosion inhibitors can no longer prevent corrosion of the ferrous components. According to this hypothesis, copper corrosion starts when the vehicle is new and proceeds at a rate that is limited by the oxidizer content of the brake fluid, mass transport of this oxidizer, and the effectiveness of the corrosion inhibitors in the brake fluid at retarding copper corrosion."

Copper is the first or "Alpha Contaminate" and will corrode before other metals in brake system according to Ricker et al [3] because "even though copper is in galvanic contact with more active metals, the low conductivity of the brake fluid allows copper corrosion to proceed."

You might be asking how does copper get in the brake fluid? The answer is from the brake lines. The inside surface of the brake lines is coated with a copper brazing alloy. Brake lines represent perhaps the largest surface area in the brake system. The rate of corrosion of the copper is dependent on the level of corrosion inhibitors in the brake fluid. This is the position taken by one of the brake fluid test product manufacturers.

This copper corrosion acts as an early warning for the next type of corrosion that will appear in the system. One of the reports cited by the task force, noted the following results:

"Dissolved iron appears in the brake fluid after the initial ammine corrosion inhibitors are significantly depleted and dissolved copper levels rise to around 200 ppm. According to the same report, by the time you see significant levels of iron in the brake fluid, severe corrosion is active. The moisture content of the brake fluid also plays a role in this process, but not the way you might think. According to the report, as brake fluid absorbs moisture, it will result in the precipitation of copper oxides and the formation of hydrogen ions causing corrosion of iron components. Once iron corrosion begins, copper acts as a catalyst to speed corrosion."

Based on the reports reviewed by the task force, the following position can be taken in regards to copper contamination of the brake fluid:

Copper ions in brake fluid have been proven to:

1. interfere with proper ABS valve operation;

2. act as an oxidation catalyst;

3. provide a precursor warning to active iron corrosion;
4. correlate to the age and mileage of vehicular service; and
5. correlate to the buffering capability of the brake fluid.

Based on this, the task force adopted the following in regards to when to recommend brake fluid flushing and has incorporated them in to a Motorist Assurance Program's (MAP) Uniform Inspection and Communication Standards:

SUGGEST testing brake fluid at OE-recommended brake system inspection service intervals to insure copper content is below 200 ppm.

REQUIRE brake fluid replacement if copper content exceeds 200 ppm.

SUGGEST brake fluid replacement at vehicle-specific OE replacement intervals (if they exist).

At this point, you might be asking: "How do you accurately determine the copper content of the brake fluid?"


Figure 15

The answer comes in the form of test strips that provide a way to determine the "virtual age" of brake fluid (See Figure 15). The patented FASCAR® technology used provides a measure of the copper in the brake fluid which indirectly provides a measure of the level of corrosion inhibitors in the system.

The test is simple and straightforward. Simply dip the strip in the brake fluid of the reservoir for one second. In 30 to 120 seconds, the reaction zone will change colors depending on the condition of the brake fluid (See Figure 16). Compare the color of the reaction zone and make the appropriate recommendation.

Through the hard work of the task force members, the industry has replaced much of the myth surrounding brake fluid with fact and has adopted an industry accepted testing technology. Technicians at shops following these procedures will be able to confidently educate their customers on the benefits of a brake fluid flush.

Don't be surprised when your customer makes a statement such as: "Nobody else has ever told me I should change my brake fluid." You will have to be prepared for this and include the necessary information to educate your customer as to the need and what you are basing it on.