

METALS

Used in Brewing Equipment

So you are the proud owner of a new wort chiller or stainless steel keg. It looks great and makes brewing so much easier. Do you think you will still be enjoying it a year from now? While your answer may be a quick "yes," don't underestimate the potential for problems. Seemingly indestructible brewing equipment can be ruined by improper care or use. To protect against this, you'll want to familiarize yourself with the different metals used in brewing and the ways that they react with beer as well as the various cleansers and sanitizers available for your use.

In addition to buying gear, many homebrewers build some of their own stuff. Here again there is potential for problems as perfectly inert metals can become vulnerable to ruinous corrosion or toxic oxidation if mistreated during or after the fabrication process.

From these points, it should be clear that the following pages will cover what every homebrewer should know about the metals commonly used in brewing, including aluminum, copper, brass, carbon steel and stainless steel.

A primary concern in brewing is the purity of the product: we want to avoid any off-flavors due to the materials or processes used in production. One of the key concerns with metals is their potential interaction with beer and wort. We have a natural tendency to think of anything we drink as being neutral like water, but when it comes to beer this is far from the truth. Beer is an acidic substance with a moderately low pH (generally 4.0-5.0); wort is slightly less acidic, in the range from 5.0 to 5.5. This acidic characteristic requires special consideration when buying, building and using metallic objects in the production of beer. An important part of what we will discuss is how to prevent off-flavors that can come from these metals.

So that's our agenda: how to protect your precious metals from the fluids in your brewery and how to safeguard your beer from the off-flavors that might result. Let's start our review of brewing metals with a look at aluminum.

Aluminum

Aluminum is a good choice for brewpots and actively-heated mash/lauter tuns. It has high heat conductivity which helps prevent hot spots and scorching of the wort or mash, and is less expensive than stainless steel. The aluminum alloys most commonly used for cookware are alloys 3003 and 3004, which have very high corrosion resistance. Under the conditions of temperature and pH (4-8.5) normally encountered in brewing, aluminum (by itself) will not corrode and should not contribute any metallic flavor to your beer. However, when using aluminum for a brewing pot, do not clean the metal shiny bright between uses or you may get a metallic off-flavor. Like all metals, aluminum depends on a passive surface oxide for corrosion resistance, and scouring the metal shiny bright will remove the passive film. Allow it to grow dull and gray with use. To encourage a passive film in a brand new pot wash it thoroughly, dry it thoroughly, and then put it in your oven (dry) at 350°F for about 10 minutes. This will help the anhydrous

oxide layer to thicken. To clean aluminum, I recommend percarbonate-based cleaners like PBW, or an unscented dishwashing detergent. Do not use bleach because it can cause pitting of the aluminum.

Aluminum will corrode if placed adjacent to another metal like copper in wort or beer, but even this most aggressive situation is usually insignificant in home brewing.

Copper

Copper has a long history in brewing. It has high heat conductivity and is easy to form and was traditionally used for making the brewing kettles or “coppers.” These days professional brewers typically choose stainless steel because it is stronger, more inert, and easier to maintain. But for the homebrewer, copper and brass are still the cheapest and best choices for wort chillers and fittings. Copper is relatively inert to both wort and beer. With regular use, copper will build up a stable oxide layer (dull copper color) that will protect it from any further interaction with the wort.

You should be aware that copper can develop a blue-green oxidation called verdigris. Verdigris includes several compounds chemically — cupric acetate, copper sulfate, or copper chloride — and these blue-green compounds are quite toxic and should not be allowed to contaminate your beer or any

other food item. To clean heavy oxidation, including verdigris, use vinegar or oxalic acid-based cleansers like Revereware Copper and Stainless Steel cleaner.

For regular cleaning of copper and brass, unscented dish detergent or sodium percarbonate-based cleaners are preferred. Cleaning and sanitizing copper wort chillers with bleach solutions is not recommended. Copper is attacked by oxidizers like bleach and hydrogen peroxide. These cleaning agents will quickly cause copper and brass to blacken as oxides form. These black oxides do not protect the surface from further corrosion, and since they are formed under alkaline conditions, are quickly dissolved by the acidic wort. If a wort chiller is cleaned or sanitized with bleach, the yeast will be exposed to potentially harmful levels of dissolved copper. No off-flavors are associated with copper; almost all of it is removed from solution by the yeast.

Brass

Brass is a group of alloys made from copper and zinc with some lead thrown in for machinability. The lead percentage varies, but for the alloys used in plumbing fittings it is 3% or less. Lead does not alloy or mix with the copper and zinc in brass, but instead exists as tiny globules. These globules act as a lubricant during machining and

result in a micro-thin film of lead being smeared over the machined surface. This lead that can be dissolved off by the acidic solutions of wort and beer. While this tiny amount of lead is not a health concern, most people would be happier if wasn't there at all.

Fortunately, this surface lead is very easy to remove by soaking the parts in a solution of vinegar and hydrogen peroxide. You can get these at the grocery store or drug store. You can use white distilled vinegar or cider vinegar, just check the label to be sure it is 5 percent acid by volume. The hydrogen peroxide should be 3 percent by volume. To make the solution mix them at a two-to-one volume ratio of vinegar to peroxide. The process takes about 5 minutes to clean and brighten the surface. The color of the brass will change to buttery yellow-gold when the process is finished. If the solution starts to turn blue or green and/or the parts start darkening, it means that the parts have been soaking too long, the peroxide is used up, and the copper is dissolving which will expose more lead. Make up a fresh solution and soak the parts again.

Excess zinc in wort resulting from the corrosion of brass (more than 5 ppm) can cause soapy or goaty flavors plus increased acetaldehyde and fusel alcohol production by the yeast. Like copper, brass will turn dull with regular use as it forms a stable oxide layer that protects it from the wort. Brass should be treated like copper for normal cleaning.

Carbon Steel

Carbon steel is predominantly iron, alloyed with carbon and other trace elements. In homebrewing it is commonly used for porcelain-enamel cookware and as rollers in grain mills. Many homebrewers get started in the hobby with a speckled, black brewpot because of their low cost. The drawback with these pots is that the porcelain can become cracked or chipped with use, exposing the steel to the wort. While a little extra iron/rust in your diet won't hurt you, it will taste bad. There is no practical way to fix these flaws in the porcelain, and the steel will rust between uses. A rusty pot will cause metallic, blood-like off-flavors in the wort.

Many brewers like to build their own roller mills for crushing grain. Carbon steel



is not stainless steel and needs to be protected against rusting by oiling or plating. If the roller steel is kept clean and dry between crushes, then it usually won't rust. It can be cleaned with a nylon or brass wire brush to remove any light rusting that may occur. Cleaning with steel wool or a steel wire brush will actually promote corrosion.

You can improve the corrosion resistance of carbon steel slightly by rubbing it with vegetable oil and buffing it off like car wax. By doing this you protect the surface oxides from hydration, producing a black oxide rather than rust. The black oxide is more adherent and will eventually cover the entire surface inhibiting further corrosion. The oil will become more wax-like too as the volatile components vaporize over time. This oxide/wax coating has limited corrosion resistance and direct contact with water will usually induce red rust. The rust can be cleaned away as described above to restore the more passive surface.

Stainless Steel

Stainless steel is the most common group of alloys used in the food and beverage industry. These alloys are typically American Iron and Steel Institute (AISI) 304 or 316 which are very corrosion resistant and are basically inert to beer.

All stainless steel is an iron-alloy containing at least 10.5 percent chromium (Cr) and with a carbon content of less than one percent. Various grades of stainless come from additions of other metals in the alloy, but the presence of chromium is what gives stainless steel its resistance to rust and corrosion. The 300 series has a nominal alloy content of 18 percent chromium and eight percent nickel. The carbon content is 0.15 percent or less.

Chromium on the surface of the alloy reacts with oxygen in the air (or in water) to create a passive coating of chromium oxide (CrO₂). This layer is only 130 Angstroms thick (one Angstrom equals 1x10⁻⁸ cm), yet it prevents acidic materials, like wort or beer, from reacting with the alloy and giving a metallic taste to your beer.

Stainless steel is referred to as being "passive" or "passivated" when the protective chromium oxide surface layer is unbroken. If this oxide layer is breached by iron (like from a wire brush or drill bit) or dissolved by

chemical action (like bleach) or compositionally altered by heat (brazing or welding), the stainless steel will rust or corrode. The problem with corrosion of stainless steel is usually not an off-flavor, but more often a hole in a valuable piece of equipment.

If the protective oxide layer is compromised, stainless steel can be repassivated by thorough cleaning to remove the contamination. Usually this cleaning involves dipping the steel in nitric or citric acid to dissolve free-iron or heavy oxides. But before you head out to buy acid, let me emphasize that you do not need it to passivate your stainless steel. The key to achieving a passive surface is getting the steel clean and free of contaminants. The easiest way to do this at home is to use a kitchen cleanser made for cleaning stainless steel cookware. Three examples are Bar Keepers Friend, Kleen King, and Revereware Stainless Steel cleanser. The active ingredient in these cleansers is oxalic acid, and it serves the same cleaning purpose as nitric acid. Once the surface has been cleaned to bare metal, the passive oxide layer will reform immediately. These cleansers also work very well for cleaning copper.

What this means is that you can perform cutting, grinding, soldering, or welding on your stainless steel and with just a few minutes of work with cleanser and a green scrubby, it will be passive again. Be sure to rinse thoroughly with clean water afterward

so you don't leave any acid behind. Do not use steel wool or even a stainless steel scrubby, they will cause rust.

As you may be realizing, stainless steel is not invulnerable. Unfortunately, people tend to assume it is and then are shocked when it does corrode. From a homebrewer's perspective, perhaps the biggest Achilles heel for stainless steel is its vulnerability to chlorine—a common sanitizer. Chlorine can dissolve the protective oxides of stainless steel, exposing the metal surface to the environment. Let's suppose you are sanitizing a corny keg with bleach. If there is a scratch, or a rubber gasket against the steel creates a crevice, then these secluded areas can lose their passivation. Inside the crevice, on a microscopic scale, the chlorides can combine with the oxygen from the oxide to form chlorite ions. That crevice becomes a tiny, highly active site compared to the more passive stainless steel around it, so it corrodes. This mechanism is known as crevice corrosion.

The same thing can happen at the water's surface if the keg is only half full. In this case, the steel above the waterline is in air and the passive oxide layer is stable. Beneath the surface, the oxide layer is less stable due to the chloride ions, but it is uniform. With a stable area above, and a less stable but very large area below, the waterline becomes the "crevice." Usually this type of corrosion will manifest as pitting or pinholes. The mechanism described is *(continued on page 54)*

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accelerated by localization so a pit is most often the result and can cause pinholes in kegs within a few hours.

Bio-fouling (trub deposits) and beerstone scale (calcium oxylate) can cause corrosion of stainless steel by a similar mechanism. The metal underneath the deposit can become oxygen depleted via biological or chemical action. When this happens, it will lose passivation and become pitted. This is why the removal of beerstone from stainless

steel storage or serving tanks is important. The dairy industry has the same problem with calcium oxylate and uses phosphoric acid to dissolve the buildup. Phosphoric acid is a good choice as it does not attack the steel. Do not use swimming pool (muriatic) acid to dissolve beerstone or clean stainless steel. The acid used for swimming pools is actually hydrochloric acid, which is very corrosive to stainless steel.

A second way that chlorides can cause corrosion of stainless is by concentration.

Stainless Steel Protection

To prevent the stainless steel from being attacked and pitted by the use of chlorinated cleaning products like bleach, follow these three simple guidelines:

1. Do not allow a stainless steel vessel to sit for extended periods of time (hours, days) filled with bleach-treated water or another chlorinated cleaner solution.
2. If practical, don't use chlorine solutions at all. Use alternative cleaning and sanitizing products (See March/April 2001 *Zymurgy*) instead.
3. If you do use bleach or another chlorine-containing product for cleaning or sanitizing, rinse the vessel thoroughly with water and dry it to prevent evaporation concentration.

This mode is very similar to the crevice mode described above. By allowing chlorinated tap water to evaporate and dry on a steel surface, the chlorides become concentrated. The next time the surface is wetted, dissolution of the oxides at that spot will occur quickly, creating a shallow pit. The next time the keg is allowed to dry, that pit will probably be one of the last sites to dry, causing chloride concentration again. At some point in the life of the keg, that site will become deep enough for crevice corrosion to take over and the pit will corrode through.

Conclusion

This primer on brewing metals covers the basics that every homebrewer should understand. Armed with this knowledge, you should be able to avoid some common pitfalls that can lead to off-flavored beer and ruined vessels. In a future issue of *Zymurgy*, we'll continue this look at homebrewing metals by discussing galvanic corrosion and metal-joining techniques such as welding and brazing.

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