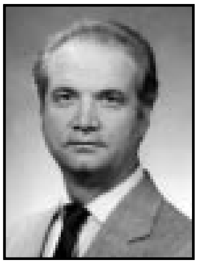

Advice & Counsel

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Hot About Heating Coils

Dear Advice & Counsel,
Could you write an article on the subject of installation of heating coils in chromium plating solutions? I have installed several titanium heating coils in our chromium plating tank and, on average, they last only about three months before they leak. What's going on?

Signed,
Hot Head

Dear Hot Head,
After a phone call to discuss your problem and find out some details, I decided that this might very well be a good subject (especially since I've suffered from writers' block this month), so here goes:

Corrosion Resistance of Titanium

It is possible that the failed heating coil was subjected to a corrosive, so let's first look at some of the corrosion properties of titanium.

Pure titanium is outstanding in corrosion resistance, resisting most acids, salt water, and highly corrosive gases such as chlorine. While a light amount of attack may occur with mineral acids—such as sulfuric and hydrochloric—titanium quickly builds a resistive film, and further corrosion is normally halted. Only hydrofluoric acid and fluorides have a detrimental corrosive effect. Titanium is the more noble metal in most galvanic couples with structural alloys, except for the following:

- Stainless steels and most nickel bearing alloys (*e.g.*, Inconel, Monel, Alumel, Chromel)
- Hastelloy(s)
- Precious metals

Galvanic couples with metals more noble than titanium normally would only create an oxide film on the titanium, resulting in no further deterioration, but in a chromic acid solution, titanium oxides are soluble (that's why titanium racks are not used for anodizing aluminum in chromic acid).

Titanium alloys are generally less corrosion resistant than pure titanium. Titanium alloys have a high level of corrosion resistance to oxidizing compounds, even at temperatures up to 1000 °F, making it uniquely qualified for aerospace applications (especially rocketry, where oxidizers such as nitrous oxide are used). Titanium is susceptible to stress corrosion when exposed to chloride-bearing compounds above 600 °F. It will form explosives if allowed to contact liquid oxygen or red, fuming nitric acid.

What the above information distills down to, is that the coil may fail as a result of exposure to fluorides. You cannot use titanium, therefore, in fluoride-bearing chromium plating solutions. Also, you must avoid galvanic couples of titanium with stainless steel, nickel-bearing alloys, Hastelloy(s) or precious metals, because if the titanium and any of these metals touch the plating solution, a battery will be set up, and the titanium may corrode. One possible bad galvanic couple would be the connection of the titanium coil to a stainless steel header (pipe), with or without an insulator. If both the stainless and the titanium become wet with chromic acid solution, corrosion of the titanium can occur. If you keep the insulator dry, the problem is essentially eliminated.

Further on the subject of corrosion: All heating coils should be regularly (weekly or bi-weekly) inspected for the presence of scale. Scale may set up corrosion cells as a result of oxidation potential differences between the area of the coil that is scaled up and an area that has less or no scale. The corrosion cell will eventually create pin-hole perforations of the coil. Scale should be cleaned off as soon as it is detected.

Your plating solution should be analyzed to confirm the absence of fluorides and chlorides, because their presence in a chromium plating solution can rapidly deteriorate a titanium coil. While titanium is considered a good corrosion-resistant material against chlorides, that is not the case in the presence of a strong oxidizer, such as chromic acid.

Cathodic Protection

In our phone conversation, you asked if you should try cathodic protection by placing a negative charge (~1.5 volts DC, using a lead anode) onto the coil, using a battery charger or small rectifier. While this can be tried on an experimental (trial & error) basis, I can't recommend it, because titanium has a tendency to become embrittled by hydrogen at temperatures above 170 °F, and the coil itself will probably be at least that high in temperature. The result might be fracture of the coil caused by brittle failure.

I also have seen literature references that indicate you should connect a wire from the **anode** bar to the coil to protect it from corrosion. While this may work in some plating solutions, it could cause attack of the titanium in chromium solutions.

Stray Currents

Because all plating operations have electrical power sources all over the place, the possibility of a stray current producing an anodic charge on the heating coil cannot be overlooked, especially in light of the short amount of time it takes for each coil to fail. Stray currents can reach the plating tank through the solution itself, or through piping, wet floors or any other wet surface. You can also have a condition called "bi-polarity." This is a phenomenon that causes an induced opposite charge in a metal that is brought near another metal that has an electric charge. For example, if you bring a rack of parts into a plating solution of low conductivity (such as a chromium plating solution) and place that rack of parts close to an anode that is positively charged, you can induce an opposite (negative) charge to the part closest to the anode. The negative charge on the area of the part closest to the anode causes another area on the part to become positive, which typically in plating causes the finish to have a poor appearance. If the same thing happens with your heating coil, however, the positively charged area on the coil will eventually develop a hole.

To avoid or minimize the effect of stray currents and bi-polarity, the incoming pipe to the heating coil must be insulated from the heating coil, using non-conductive plastics or ceramics. The metal used to hang the coil in the tank and keep it in place (spacers) must also be insulated from touching any other metal, especially at the lip of the tank. Don't allow the contact area between the coil hanger and the lip of the tank to become wet, even if it is insulated. The heating coil must be placed far enough away from the tank liner, so that the high heat won't destroy the liner, but also far enough away from the anodes that bi-polarity is eliminated. This may result in the anodes being too far away from the tank wall to be practical. In that case, a plastic (PVC or CPVC) shield placed between the anode and the heating coil (as illustrated in the figure) should do the job. Typical distances are three in. from the tank wall to the coil, three in. from the coil to the shield, and one–two in. from the shield to the anode. The shield should be tall enough to travel from the bottom of the heating coil to about six in. above the bottom of the anodes. It should not be perforated, because a hole will create a direct path between the anode and the coil. You can also consider placing the heating coil along a tank wall—away from the anodes, if that is possible.

Right now, some equipment sales representatives are probably dialing up to suggest you consider non-metallic heating coils or coils coated with non-metallics, and those are good suggestions to consider if, after review of the above, your next coil also fails. P&SF

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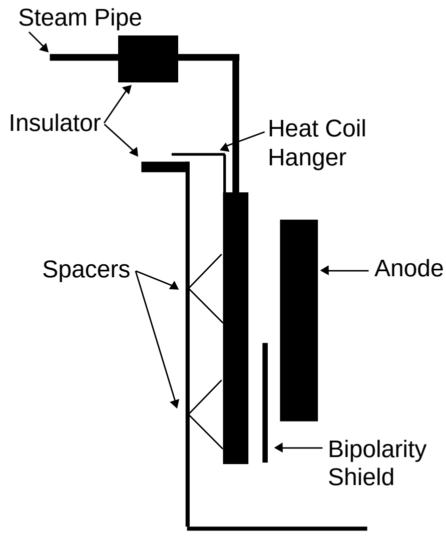

A plastic shield placed between the anode and heating coil will prevent "bi-polarity."