



# TECHNICAL COLUMNS

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## CHEMISTRY CLASS

By **RON HRANAC**

How many times have you or someone you work with visited a subscriber's home in response to a service call about snowy pictures on some of the analog channels, and perhaps problems with some of the digital channels? The drop is disconnected from the ground block or splitter on the side of the home and connected to a signal level meter (SLM) or other instrument. Signal levels are fine, so the drop cable is reconnected. Amazingly, the snowy pictures are snowy no more, and any digital problems stopped being problems.

What the heck is going on here?

One explanation that has been the subject of lengthy discussions on the SCTE-List and elsewhere is the so-called capacitance effect. Disconnecting the drop and hooking it up to the test equipment somehow discharged a static or other mysterious charge buildup in the drop cable, solving the problem!

Bunk.

What's really happening

What's really going on isn't quite so mysterious as some undefined capacitance effect. This is nothing more than the basic chemistry of corrosion. Grab a cup of coffee - it's time for a little science.

Back in 1992 the Naval Facilities Engineering Command released a public document titled Corrosion Control. Among its 300+ pages is this simple definition of corrosion: "... the destructive attack of a metal through interaction with its environment." Most of us have at least some experience with corrosion - a rusty bolt or tarnished penny are pretty good examples. But why does corrosion happen?

Most metals exist in nature in chemical combination with other elements. We refine various ores to get relatively pure metals and alloys. The energy content of refined metals and alloys is higher than that of the original ores, so metals and alloys are constantly trying to change back into lower energy ores or ore-like compounds. This is what we call corrosion.

There are many different kinds of corrosion, but the basis of corrosion takes place through the action of electrochemical cells, typically involving an exchange of electrons. In electrochemical reactions, the electrons are produced by a chemical reaction in one area, travel through a metallic path and are consumed through a different chemical reaction in another area. Basic chemistry at work here.

The center conductor of most drop cables is copper-clad steel. Let's look at the copper cladding of a drop's center conductor as it oxidizes (the same thing happens with solid copper center conductors). Here's the basic chemical reaction:  $2\text{Cu(s)} + \text{O}_2\text{(g)} \rightarrow 2\text{CuO(s)}$

The term on the right side of the equation is copper oxide. In practice, there are two forms of copper oxide when copper oxidizes in the air. The first is copper (I) oxide, also known as cuprous oxide. This is  $\text{Cu}_2\text{O}$ , which often has a reddish or reddish brown color. The second is copper (II) oxide, or cupric oxide. Its



chemical designation is CuO, and it has a blackish color. For the rockhounds, the mineral cuprite is copper (I) oxide (Cu<sub>2</sub>O).

Metal oxides in general are not good conductors. Cu<sub>2</sub>O, for instance, is considered a p-type semiconductor. See where this is headed?

#### Other things

So far I've talked about what happens when copper is exposed to oxygen, but copper may be exposed to many things. Copper in moist air often takes on a green patina - the Statue of Liberty is a good example. That green color is a 1:1 mole mixture of Cu(OH)<sub>2</sub> and CuCO<sub>3</sub>:  $2\text{Cu(s)} + \text{H}_2\text{O(g)} \rightarrow \text{Cu(OH)}_2\text{(s)} + \text{CuCO}_3\text{(s)}$

The paper "Modeling and Rendering of Metallic Patinas" (Dorsey, P. and P. Hanrahan, Proceedings of ACM SIGGRAPH 1996) discusses natural patina formation on clean copper in marine, urban and rural environments. The copper's corrosion comprises multiple oxide layers. In all three environments, immediately adjacent to the clean copper surface is copper sulphide, followed by a layer of the mineral cuprite (Cu<sub>2</sub>O). Next is atacamite, or copper chloride hydroxide - Cu<sub>2</sub>Cl(OH)<sub>3</sub> - a halide mineral; and posnjakite, or copper sulphate hydroxide hydrate: Cu<sub>4</sub>(SO<sub>4</sub>)(OH)<sub>6</sub>·(H<sub>2</sub>O).

Depending upon the specific environment, other things that show up in the patina may include malachite, antlerite, brochantite, gerhardtite, and organic compounds.

Some of this stuff sounds like what you might find at the local rock shop! Before you get out the ol' rock pick, consider that the patinas just discussed are very thin, on the order of a few tenths of a micron to perhaps a few microns. The formation of copper sulphide - a brown tarnish - and cuprite - a reddish brown color - may happen relatively quickly, but the other layers generally take a fair amount of time.

#### Back to the drop

OK, back to our subscriber drop's center conductor. The F-connectors used by the cable industry are for the most part feed-through type, which means the cable's center conductor also is the connector's center conductor. Over time, the exposed bare copper center conductor (yes, the center conductor is considered exposed even when it's inside of a mating connector) will oxidize, and that brownish or reddish brown color means the originally clean copper now has a very thin patina of copper sulphide and/or cuprite, and perhaps other stuff depending on the environment and whether dissimilar metals are present in the mating interface. Cuprite, or copper (I) oxide, is not a particularly good conductor. Hmmm, sounds like an attenuator!

Disconnect the drop from the mating interface, hook it up to an SLM, and what happens? The scrubbing action of disconnecting the drop, connecting it to a piece of test equipment, then reconnecting it to the ground block or whatever, removes some of the center conductor's patina, exposing fresh copper. Remember, the patina is at most a few microns thick, probably less than a micron. It doesn't take much to scrape away some of the microscopically thin patina to get down to the copper. The result? Proper signal levels.

What can be done to prevent oxidation of the center conductor? Not much, really. It's possible to significantly slow down the process, but it's tough to stop it altogether. First and foremost is to keep the interfaces clean and dry. Some tips:

—Cap the exposed ends of those reels of drop cable in the truck or van (the warehouse, too). This will reduce the likelihood of moisture being wicked into the end of the cable. Whenever a length of coax is removed from the reel, replace the cap on the end of the remaining cable on the reel.



—Don't touch the exposed center conductor with bare fingers, and ensure that no visible dirt or other contaminants are present. Don't cut or scrape the center conductor with a knife or other sharp object.

—Torque the properly installed connector to 20-30 inch-pounds on the tap spigot, ground block, splitter/coupler, and drop amp mating interfaces. (Don't tighten connectors this tight on TVs, VCRs, etc.)

—Weatherproof the interfaces on all outdoor connectors, even those inside pedestals, vaults, and boxes on the sides of customers' homes. Most compression F-connectors have one or more integral o-rings to enhance weatherproofing, and the compression crimp provides a 360-degree seal on the jacket. Don't rule out the use of sealing sleeves on the threads or protective boots in harsh environments.

—Use ground blocks, drop passives and actives, and so forth that are made of materials that will not result in a dissimilar metals interface. Dissimilar metals mean galvanic corrosion. Discuss the center conductor seizing mechanism with the manufacturer. One that has a large contact surface area relative to the exposed center conductor - preferably with high contact force - is desirable.

—Use connectors and drop components whose physical interfaces meet relevant SCTE standards.

—A potentially controversial idea is to abandon the feed-through connector design in favor of pin-type F-connectors. We already use pin-type F-connectors on 7- and 11-series drop cables, so why not also on 59- and 6-series cables? Certainly, pin-type F-connectors are more expensive, but would the added materials cost be offset by a reduction in service calls and truck rolls? More research needs to be done here.

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