How Environmentally Friendly are Your Fastener's Finishes?

by Laurence Claus

At 9:45 a.m. on February 20, 1947 The O'Connor Electro-Plating Corporation of Los Angeles, California experienced a tremendous explosion levelling the company's facilities and much of the surrounding four block area. The aftermath of this disaster left 17 dead, 150 injured, and 116 buildings damaged or destroyed. The cause was an unstable mixture of perchloric acid and acetic anhydride, a substance nearly as explosive as nitroglycerin, used by O'Conner in an experimental aluminum polishing process.

Although this example is perhaps one-of-a-kind and certainly not characteristic of the normal consequences of a metal finishing process gone awry, it does illustrate the crucial nature of the processes employed and the serious consequences to human safety and the environment when things go wrong. Additionally, in recent years, stories of gross industrial negligence such as the poisoning of municipal water supplies or polluting the land an industrial facility is located on or near have become all too commonplace. In fact, some of these incidents have been raised to global awareness through television documentaries and films such as "Erin Brockovich" (the story of a California town's water supply tainted with hexavalent chromium).

Environmental awareness and regulations are now, more than ever before, part of the landscape of the metal finishing industry. Although these protections to safety and to the environment promote good stewardship and social responsibility, they have not come without costs. In fact, many of the changes in the last twenty years have forced the metal finishing industry to find new ways to provide equivalent levels of performance when compared to traditional methods. In some cases, the metal finishing industry hasn't been that successful, leaving fastener manufacturers and suppliers with new challenges to meet their customer's requirements. This article will look at some of these recent developments, the resulting challenges, and potential strategies for future improvements.

Cadmium

Cadmium electro- and mechanical platings have been utilized by many industries for many years. Cadmium provides some preferable performance benefits when compared with other metal electroplated finishes. In particular, cadmium provides good corrosion protection and a natural lubricity that is advantageous for torque-tension and not seen in other metal electroplated finishes. Unfortunately, cadmium carries a big downside. Long-term exposure has been found to be toxic to humans and, therefore, cadmium appears on just about all lists of hazardous and regulated substances, and is an on-going target for elimination or replacement from mainstream industrial uses.

Because of its dangers, the discussion regarding the elimination of cadmium plating from fasteners has been around for many years. In fact, cadmium was still a commonplace

finish when I entered the industry thirty years ago, although in the automotive sector, where I was focused, it was soon eliminated. The discussion, however, still goes on as some industry sectors, aerospace and military fasteners in particular, remain heavily invested in cadmium plating. These industry sectors in recent years have conducted significant investigation into replacements, and likely, will slowly wean themselves away from cadmium finishes on new parts.

Cyanide

For many years, most electroplating processes were conducted in plating baths containing cyanide constituents. Cyanide facilitates the breakdown of the anode, maintains even plating bath chemistry, and improves bath conductivity. Additionally, and perhaps most importantly, cyanide plating baths exhibit a wide tolerance for impurities. Cyanide is, however, an extremely dangerous substance. As a result, the safeguards and care required to work around plating baths and to handle waste products are significant, and, the risks to workers, site neighbors, and the environment are high.

The surface finishing industry, therefore, has evolved over the years to offer non-cyanide plating bath alternatives. Although these are significantly safer to work around and pose less risk to the environment, they are generally more challenging to operate. Subsequently, the industry has needed to continue to adapt and improve technology to raise these new processes to parity with the traditional ones.

Challenges and considerations when replacing a cyanide process with a non-cyanide process are:

- It may take several non-cyanide plating line solutions to replace a single cyanide plating line.
- Non-cyanide plating baths are far less tolerant of impurities. Therefore, pre-cleaning controls and processes must be better controlled and effective than in a cyanide process.

- Cyanide is an excellent complexer and thus more tolerant of particular impurities. Non-cyanide baths must be purged of iron and other contaminants more often. Non-cyanide baths almost always require filtration.
- Chromate color shades may be different from a non-cyanide process when compared with a cyanide process.
- Non-cyanide processes occasionally have adherence issues.
- Non-cyanide processes require more brighteners to obtain the same pleasing appearance.

Hexavalent Chromium

Perhaps the most significant environmental development in the last twenty years in the surface finishing industry is the wholesale elimination of hexavalent chromium. Chromium has two ionic states Cr3+ (trivalent) and Cr6+ (hexavalent). Hexavalent chromium has been found to be very reactive and toxic to humans and the environment. The consequence of hexavalent chromium contamination was sensationalized in the year 2000 Hollywood movie "Erin Brockovich", which told the real life story of a town whose water supply was contaminated by poor handling of hexavalent chromium at a local power generation facility.

In 2000 the European Union passed Directive 2000/53/EC commonly referred to as "End of Life Vehicles". Although this is a directive relative to recycling automobiles when they come to the end of their lives, it contains specific provisions about reducing or eliminating hazardous substances. One of those substances is hexavalent chromium. Even though this is a European Union Directive, it impacts anyone that wants to export automobiles into the European Union. As a result, it has global impact and in a relative short span of time, metal finishes that had previously contained hexavalent chromium substances were replaced with finishes that either eliminated chromium compounds entirely or substituted hexavalent chromium with the more benign trivalent form. Although the impacted industry was automotive, it was pretty well adopted universally. It is still possible to obtain chromates and other metal finishing substances that are hexavalent chromium based, but these are definitely the exception. In fact, many plating applicators will no longer stock or offer hexavalent chromium alternatives.

Chromium compounds can be found in many metal finishing constituents. However, the most prevalent application is for the chromate conversion coating on electroplated parts. This post-plating process will improve corrosion protection and often supplies the parts with a characteristic color. Chromium compounds are also found in paints and other coatings.

Like the two items preceding this one, the unexpected need to replace hexavalent chromium presented a major challenge for the metal finishing industry. Hexavalent chromium has a number of properties not exhibited in trivalent chromium compounds. Perhaps the two most desirable are: "self-healing" capability, meaning that small scratches and surface damage will repair itself, and the multiple resulting color options from chromating. The lack of "self-healing" properties is problematic because it can dramatically reduce the ability to resist corrosion. To answer this challenge most electroplated finishes today receive a sealer as the very final operation of the process. The sealer increases the corrosion resistance to an equivalent or improved state from the hexavalent chromium option. However, it only accomplishes this with an added operation, which adds cost. The elimination of hexavalent chromium also significantly reduced the available color options. With hexavalent chromium there were very good color solutions for clear (or silver), black, yellow, olive drab, and a variety of in-between hues. At the beginning, trivalent chromium solutions only produced a dependable clear (or silver) option. Today solutions have been developed that provide adequate yellow and black options as well.

U.S. Regulations

The U.S. metal finishing industry is highly regulated and applicators must be vigilant about safeguarding the safety of their employees and the environment. The federal agencies that carry the bulk of the enforcement for these activities are the Environmental Protection Agency (EPA) and the Occupational Safety and Health Administration (OSHA). In addition to federal enforcement, most states and local municipalities place additional and, perhaps, even more stringent requirements on applicators in their jurisdictions.

The primary regulations that U.S. metal finishers must be aware of and follow are:

- The Clean Air Act (CAA)- This act restricts emissions into the atmosphere and includes protections against ozone depleting emissions as well as toxic/noxious emissions. Coaters that apply finishes that involve volatiles have to be particularly conscious of these requirements.
- The Clean Water Act (CWA) - This act enforces wastewater treatment, reclamation, and discharge of water. The requirements here are especially important to electroplaters, phosphaters, and annodizers.
- The Resource Conservation and Recovery Act (RCRA) - This act enforces the proper handling of hazardous waste products.
- The Emergency Planning and Community Right-to-Know Act (EPCRA) - This act enforces the communication and disclosure of toxic chemical usage.
- The Toxic Substance Control Act (TSCA) - This act enforces proper control and use of toxic substances.

European Regulations

A number of European regulations, known as directives, have had a significant global impact on fasteners and the metal finishing industry. Although these regulations are not enforced outside of the European Union, they impact trade associated with the European Union. Therefore, multinationals and companies seeking business within the European Union must understand and adapt globally to these regulations.

End of Life Vehicles (ELV) – European Union Directive 2000/53/EC: This directive stipulates goals regarding the recycling of automobiles and other motor vehicles as they reach the end of their useful life and are repurposed. Essentially this legislation identifies the difficulty in effectively recycling a vehicle if there are components that contain hazardous substances. Therefore, it enforces limits or exclusions of materials containing identified hazardous materials. In this case, it was the catalyst for the elimination of hexavalent chromium from fastener finishes.

Restriction on the Use of Certain Hazardous Substances in Electrical and Electronic Equipment (RoHS) – European Union Directive 2002/95/EC: This directive specifically restricts the use of certain hazardous substances such as lead, hexavalent chromium, and cadmium. This means that fasteners that need to be RoHS compliant must not contain any of these or the other restricted substances in the directive.

Regulation, Registration, Evaluation, Authorization and Restriction of Chemicals (REACH): This directive seeks to identify and classify hazardous substances into several categories and place limitations on those substances classified as the worst offenders. Since REACH applies the limits based on weight percentage of the entire article, it is likely that most finishes will not result in enforcement of limits on the fasteners to which they are applied, however, for multinationals and importers to the European Union, this directive is one that must not be ignored.

Future Directions

As society continues to grow more concerned about its stewardship of the environment, the metal finishing industry will continue to improve upon existing processes and technologies. Several of the current areas of study and improvement for the future are:

- Working to improve existing technology to near perfect levels of efficiency or zero discharge of waste or pollutants
- A suitable replacement of cadmium plating
- Improvements in process control and monitoring technologies
- Going “Green” where possible
- Changing from “wet” to “dry” processes
- Changing substrate materials from metal to non-metals, for example, increasing the use of reinforced carbon fiber structures
- Developing new materials that reduce the need for surface finishing
- Nanotechnology

Conclusion:

Over the past thirty years the metal finishing industry has evolved in a number of key areas in an effort to be more environmentally friendly and reduce the risk of catastrophe to those working in metal finishing, end users, or those living nearby an applicator. These changes have not always been easy and have occasionally presented significant technical challenges to implementation. Diligence, however, has paid off and will continue to pay dividends in the future, resulting in the fastener industry producing safer and more environmentally friendly products. ◘