

## CORROSION

### Overview

Metalworking processes employ oil-based, solvent-based and water-based fluids to interact with the various metals. At some point, the issue of protecting these metals from corrosion or staining is important to your customers. Some customers expect the metal removal fluid to provide the in-process and final corrosion protection. Others use some final process to apply a short-term to long-term corrosion preventive. Remember that the goal is to avoid corrosion. Bare metal (FeO), in the presence of air and water, reaches various states of oxidation. With corrosion, whether it is red rust (ferric oxide, Fe<sub>2</sub>O<sub>3</sub>) or black stain (ferrous oxide, Fe<sub>3</sub>O<sub>4</sub>) the process is similar. The oxidation of the metal is linked to reduction of other constituents in the process, such as the metalworking fluids.

### Definition

Chemically speaking, corrosion is the reduction of iron metal from Fe<sup>+3</sup> to Fe<sup>+2</sup> via the flow of electrons from a cathode to an anode. If you picture the terminals on an automotive battery, there is a positive pole (the anode) and a negative pole (the cathode). Depending upon the interior of the battery, the chemicals inside the battery carry the current, in the form of electrons, from one pole to the other. This is the same process that occurs to create rust. It is important to understand this process, because stopping the flow of electrons or disrupting the "reaction" at the cathode or anode controls the rust process.

### Necessities for Rust

Simply put, you need the following to create rust:

- The cell, consisting of a cathode and an anode
- Moisture to carry the current
- Oxygen to create the oxides

In a situation where the oxygen is prevalent (i.e. a lot of airflow is present), red rust will be generated. Where the oxygen is not as prevalent (i.e. constrained environments with parts stacked closely together and/or no airflow), the black oxide stains will be produced.

There are conditions that create a "typical corrosion cell" in which corrosion can be created. Examples of these conditions are listed in the table below.

CELL	ANODE	CATHODE
Steel with existing rust or scale	Steel	Rust or Scales
Steel with dust/fines	Steel	Dust/Fines
Steel with electrolyte on surface of variable concentration	Steel	Acid, salt or alkali
Steel with fingerprints	Steel	Residue from oily skin
Unevenly annealed steel	Stained Steel	Annealed steel (coarse crystals)
Steel with deep scratch (deep enough to alter surface oxides)	Scratched Steel	Unscratched steel

It must be remembered that corrosion preventives "prevent" corrosion from occurring. They cannot stop the corrosion that is already in existence. As identified in the table above, existing corrosion is part of the cell to create more corrosion. Steel dust and fines can also create more rust because of the tremendous surface area they possess. Different electrolytes in liquid form also impact the increase in corrosion. Most customers with an emphasis on avoiding corrosion require all workers to use protective gloves so that their fingerprints don't create rust. Surface oxides change during the annealing process. Unevenly annealed steel would alter the surface oxides. All steel surfaces are subject to scratches but deep scratches, that leave shiny steel exposed, are subject to corrosion.

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## Raw Materials Used

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Water-soluble machining and grinding fluids provide "temporary" corrosion protection. It is because these fluids are water soluble that the protection is temporary. Common ingredients used in these water-soluble products are metal sulfonates (mostly sodium) and amine salts. The salts depend upon the acid by which the amine is neutralized. Amine borates are common but can lead to sticky residues if used too high. Amine carboxylates are also used. Again, all of these ingredients should be water-soluble.

Each customer must define the term "temporary." Some customers just need a few hours of protection until the wet parts make it to the next process. Some customers bank parts for several days or a few weeks until they are needed. The storage conditions, as well as the condition of the coolant, are very important.

Things to consider are:

- The concentration must be at the correct level measured by more than just refractometer
- The fines in the coolant must be as low as possible
- The tramp oil levels should be minimized,
- The chloride and sulfate levels should be as low as possible
- The part must be well wetted by the coolant in the last application

Corrosion preventives are designed to provide longer-term results. Again, the length of time dictates the type of preventive required and, in some cases, the type of application selected to achieve that level of protection. Many corrosion preventives utilize metal sulfonates (calcium and sodium are the most common) to provide protection. However, not all metal sulfonates provide the same level of protection. Most of this has to do with solubility of the sulfonate in the carrier (base oil, synthetic ester, etc.) as well as how well it covers the metal surfaces it is intended to protect.

Quaker Houghton has learned that not all sulfonate suppliers treat their sulfonates the same way. These differences have a huge impact on the protection and duration.

## Caveats for Corrosion Protection

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There are many conditions that can exist in the real world that will impact corrosion protection.

These are:

- The condition of the corrosion preventive during plant application
- The quality of the application method
- The packaging used to enclose the part
- The storage environment
- Historical protection performance
- Surface cleanliness
- Prior process
- Quaker Houghton Protection Statement, for use with its FERROCOTE® product line, is the corrosion preventive can prevent corrosion of parts if the following conditions are satisfied:
  - Product meets all control specifications and limits prescribed by Quaker Houghton (i.e., Acid Number, % Ash, % Concentration via Ash, Viscosity, Dirt Content, % Moisture and Copper Corrosion)
  - Parts are completely rust free before the FERROCOTE® application
  - Application equipment is well maintained to deliver a consistent quantity of corrosion preventive product to the parts
  - After coating, and prior to packaging, handling practices are employed to insure the integrity of the protective film with minimal hand contact and proper use of gloves
  - Packaging to enclose the parts, if used, is of the highest quality and is not torn or damaged to permit direct access to the coated parts
  - The storage environment is controlled sufficiently to limit gross fluctuations of temperature (less than 15°F change in 24 Hours) and humidity (less than a 10% RH change in 24 Hours)



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## Corrosion Protection

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There are a number of short-term and long-term tests used to measure corrosion protection. All of these tests are designed to mimic real life conditions under accelerated conditions. Likewise, the interpretation of the test results can be just as important as setting up and controlling the conditions of the tests. In some cases it is possible to use customer parts in place of standard panels to assess the corrosion prevention.

For metal removal fluids, there are tests used to assess the interaction of the fluid and metal chips that are generated in a typical metal removal process. If the chips are not consistent relative to alloy type, chip size and cleanliness of the chips (i.e. no fines on the chips), the results will be inconsistent. Most "chip tests" involve a fixed amount of chips covered by a measured amount of coolant. The wet chips are then set on filter paper or metal blocks to determine the rust potential. Most tests last a few hours up to overnight.

Corrosion preventives have more stringent requirements and better defined test methods. Some of the more common tests involve cabinets whereby the temperature, humidity and environment are controlled. In addition, the handling of coated panels must be controlled relative to the amount of corrosion preventive that is applied to the surface. Most testing is conducted with duplicate or triplicate panels. The water source must be pure to eliminate any contaminants (chlorides or sulfates) that could negatively impact the results.

The Joint Army Navy (JAN) Cabinet Test goes back to World War II. In the JAN cabinet, the temperature is maintained at 120°F with 100% relative humidity in a condensing environment. The condensing environment means that the water will collect on the surface of the test panel and run down through the panel and the coating.

The Salt Spray Cabinet (ASTM B-117) is a very hard test as panels are exposed to a 5% salt spray in the form of a fog. In addition, the temperature is maintained at 100°F. This is considered to be a very difficult test to pass.

Another common test is referred to as the GM 10-Cycle Test. Obviously, this was created by General Motors to evaluate corrosion preventives and it has been adopted by many suppliers to be in alignment with GM.

This method is similar to the JAN but it runs at 100°F in a non-condensing environment. In addition, a single cycle involves 18 hours in the cabinet and 6 hours out of the cabinet. Ten cycles is the duration of the test.

## Troubleshooting

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When you first investigate a rust issue, it is important to understand what the metal surface has been exposed to. You need to trace back through all of the processes to determine where the corrosion began. The investigation should involve every process and fluid that contacts the parts. By tracing through the entire process, you can generally find the application(s) that has the greatest impact on the corrosion problem. The fluids involved in the process can be inspected for "fitness for use" relative to fresh fluid.

There are "fishbone" diagrams that assist in walking through a process. The diagram itself looks like a fish with just the bones displayed. The head of the diagram is the problem with the various contributors as larger bones. Each larger bone has smaller bones that connect showing the individual problems that can contribute to the problem. (See the rust and the corrosion preventive diagrams on the last page.)

## Fluid Analysis

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Quaker Houghton's corrosion preventives can be checked via Fluid Analysis. The parameters that are examined are listed below along with an explanation as to what that parameter means.

**Acidity** - this measures the amount of free acid in the product. High values will promote corrosion and an increase of acidity may be due to overheating of the product, contamination or excessive solvent evaporation. Low acidity might be attributed to over dilution with solvent or contamination.

**Moisture** - the presence of moisture/water in an oil or solvent-based corrosion preventive will promote rust or stain. An elevated level is usually associated with residual film present on the incoming parts.

**Dirt Content** - this is usually associated with particles present on the surface of the part entering the corrosion preventive application. Dirt can be iron fines, sand, or air-borne particles. These solid particles present on the surface can act as corrosion sites for rust or stain. As the corrosion preventive is applied, drained, and reapplied, the dirt level will continue to rise.



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## Fluid Analysis

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**Copper Corrosion** – This test is used to assess the corrosion preventive's propensity toward stain. Poor copper corrosion performance is usually associated with contamination that results from the soil present on the part as it enters the corrosion preventive. Poor copper corrosion results usually occur due to high sulfur levels getting into the bath. One source of sulfur is honing oil.

**Percent (%) Solids** – the solids content can be used to determine concentration. Low concentration can occur from contamination or over dilution with solvent. High solids can occur due to contamination or solvent evaporation. Low solids means low concentration which translates to less corrosion protection.

**Calcium** – this is the direct measure of the key raw material used to provide the corrosion protection. Low calcium levels typically indicate low concentration, the result of excessive contamination or over dilution with solvent. High calcium levels may indicate solvent evaporation, excessive contamination or the presence of water.

**Viscosity** – this is the measure of the product's ability to flow over (i.e. "wet out") the part. This is critical to ensure a continuous, uniform barrier film covers the entire part. The oil film thickness that remains on the part is directly related to the corrosion protection. Thinner films typical provide less corrosion protection while thicker films provide more. Low viscosities can result from low concentration, excessive contamination or dilution with too much solvent. High viscosities usually indicate high concentration from solvent evaporation or excessive contamination.

**Specific Gravity** – this is sometimes referred to as density and can be used to provide a fair indication of contamination. Low specific gravity values typically indicate low concentration, excessive contamination or dilution with too much solvent. High specific gravity usually indicates high concentration from solvent evaporation or excessive contamination.

## Conclusion

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Protecting the metal is the final step in the use of the customer's part. Rust is an obvious problem when it arises. Helping your customer stay out of rust problems would certainly make you more valuable to them.



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