Most Cooling Water systems are continuously in use. Therefore it is rare to have access to inspect the actual system to observe or measure corrosion and corrosion inhibition. A number of ways to monitor the effects of corrosion, while the system is in operation, have been developed. One of the most popular means is through the use of corrosion coupons. Although this method is relatively effective, simple and inexpensive, it does have some limitations. These include:
1. The corrosion rates are the average of the corrosion experienced during the study. There is no means to determine the peak corrosion rates that may have occurred during a study.
2. The study represents a long-term effect, not short term or instantaneous.
3. The rate of corrosion can only be calculated after the coupon has been removed.
4. Short term studies tend to yield high corrosion rates, not representative of actual system conditions.

Corrosion

Corrosion can be thought of in terms of Mother Nature acting to return Human processed metals back to their natural state. Iron ore, found in nature is in an oxidized state (FeO, Fe₂O₃, Fe₃O₄). After processing in a furnace, the end result is elemental iron, Fe. When exposed to air (oxygen) and water, this elemental iron is then relentlessly attacked.

This attack is corrosion, which works to return the elemental iron to its natural oxide state. Corrosion related failures result in expensive system shutdowns and excessive maintenance costs. Many experts estimate that the cost of corrosion amounts to many billions of dollars annually.

Corrosion Monitoring

Most times, corrosion related problems are only detected after a failure has occurred. Clearly this is too late for any preventative action. The best choice would be to monitor the corrosion rates before a failure occurs. This is where the use of a Corrosion Coupon and Coupon Rack come into play. The coupon is simply a retrievable metal strip that has been pre-weighed, and is inserted into a premade piping arrangement that controls the flow rate of the water flowing through the rack and over/around the coupon.
The coupons are exposed to the treated, system water for periods of 30, 60, 90 days or longer. After the time period, they are removed and processed to determine the metal lost (weighed). This metal loss is expressed as a corrosion rate.

A corrosion rate obtained with this method is the average rate for the period of exposure. The average rate over a given period of time is then normalized to a one year overall corrosion rate, expressed as mils per year. The formula used is:

\[ MPY = \text{mils per year} = \frac{1}{1000} \text{inch/year} \]

If the type of attack (general, pitting) can be determined it will also be reported.

Operating Characteristics

There are a number of operating characteristics specific to the type of system and installation of the test rack that determine the outcome of the corrosion measurement.

Several of these design and operating characteristics are as follows:

1. Size of the coupon rack
2. Duration of the coupon test
3. Coupon placement in the rack
4. Orientation of the coupon
5. Flow rate of the water passing over the coupon
6. Turbulent flow characteristic
7. Temperature of the water passing through the corrosion rack
8. Water quality
9. Process or environmental contamination
10. Level and type of treatment

Corrosion Coupons

These are prepared from a variety of metals. The proper coupons are chosen to match the metal components of the water system being tested. Typical coupons used in coupon racks include mild steel, copper and galvanized steel.

Cheminc can supply pre-passivated steel coupons for those systems requiring quicker results.

The following coupon dimensions are recommended based on the size of the coupon rack:
Coupon Rack with ¾" Piping
• 3 inches long
• 3/8 inch wide
• 1/16 inch thick
• 1/8 inch diameter hole

Coupon Rack with 1" Piping
• 3 inches long
• ½ inch wide
• 1/16 inch thick
• 1/8 inch diameter hole

These coupon sizes are interchangeable provided the coupon does not touch the pipe walls.

Specimen Mount – The corrosion coupon holder is made from PVC plastic, nylon or stainless steel. The holders made from plastic materials are recommended for cooling water and chill water systems. Heating hot water and condensate systems should use stainless steel.

Corrosion Coupon Rack Assembly

The coupon rack is designed to subject multiple coupons to essentially identical conditions. It is a by-pass assembly typically consisting of 2, 3, or 4 coupon holder locations along with two isolation globe valves, a Y-strainer, and a flow control device.

The designed water flow velocity across the coupons should be 3 feet per second. To achieve this velocity, the flow rate in the ¾" rack should be 5 gpm and the 1" rack should be 8 gpm. A 5 gpm flow rate can be maintained using a flow control device such as a Dole valve. Rotometers can also be used in the rack and the flow rate controlled using the globe valve.

One globe valve and the Y-strainer should be positioned in front of the rack. The flow control device can be installed after the Y-strainer, in the front of the rack or at the end of the rack. For racks operating below 120°F., Schedule 40 PVC can be used for interior installations and Schedule 80 for exterior installations. For systems operating above 120°F., use a rack constructed of steel pipe.

It is important that the rack be flooded at all times. Therefore, the rack should be perpendicular to the ground, and the water should flow from the bottom of the rack to the top of the rack.

When installing coupons in the rack, place the most active metal in the bottom of the rack, and proceeding up, place the remaining coupons in the order of decreasing activity. Thus the aluminum coupons are installed in the lowest holder, followed by the mild steel coupon, then the galvanized coupon, followed by the copper alloys, and finally the stainless steel coupon at the top of the rack. The coupons should be installed in the vertical position to avoid accumulation of debris.

Installation & Removal Procedure for Corrosion Coupons

Installation

1. Carefully remove the corrosion coupon from its package. Wear clean cotton or rubber gloves or handle the coupon with a clean handkerchief to prevent finger marks. It is important that the coupon receive minimal handling and that it be protected from contamination of any kind.

2. Secure the coupon to the coupon holder using a nylon screw and nut. Do not use a metal screw. The nylon screw/nut is used in order to eliminate the possibility of galvanic effects resulting from metal to metal contact.
3. Install the coupon holder with coupon attached in a coupon rack assembly located either in a suitable line or in the bypass piping arrangement. Be sure to exercise care so as to not damage the coupon in any way when inserting the coupon holder & attached coupon in the rack assembly. Do not allow the coupon to be scraped against the inside of a pipe and never use a fitting, housing or adapter, which scratches the coupon.

The use of a directional groove on the pipe plug end of the coupon holder will serve to check the position of the coupon in the pipe or vessel.

Pipe dope should not be used on the fittings because it may coat the coupon. For the same reason, rack assemblies and bypass piping should be free from any accumulation of oils.

4. Turn on the water and adjust the flow rate in the test piping to approximate the normal flow rate in that part of the system important to the corrosion study. The flow will usually have a velocity in the range of 3 ft./sec. to 5 ft./sec.

Maintain constant flow rates. The corrosion test results will not be comparative if the water flow is allowed to fluctuate. Under no circumstances allow the corrosion station to run dry.

5. Proper identification of corrosion coupons is vital. Keep a record of the relative position of the coupons in the corrosion test station. Record this information along with the name and address of the system, the type of system and any designation it may have differentiating it from other systems, the location of the coupon rack, information on the treatment program, and most important--the date the coupon was installed. A corrosion form is supplied with each coupon for this purpose.

Removal

1. Establish intervals for removing coupons from the corrosion test station. It is recommended that the first coupon be removed after one (1) month and the remaining coupons at one (1) to three (3) month intervals. Corrosion rates are usually higher for short term exposure, so use long term intervals to determine the "mean steady-state" corrosion rate.

ASTM G311 recommends that the expected exposure time, in hours, be calculated as follows:

\[
Exposure, \text{hrs} = \frac{2000}{\text{expected corrosion rate, mpy}}
\]

2. Isolate the Coupon rack by closing the inlet and outlet isolation valves. Remove the coupon holders, being careful not to damage the coupon.

3. Rinse the coupon with alcohol to remove all soluble matter and carefully unfasten it from the coupon holder.

4. Dry the coupon as thoroughly as possible by air drying or by patting it between paper towels, Kleenex or a clean cloth. Try not to dislodge any corrosion products from the surface of the coupon.

5. Place the dry coupon in an envelope marked with identification information and store in a plastic bag or wrap in a plastic film.

6. Record the removal date on the corrosion coupon form, then immediately return the coupon and the form to the laboratory.

7. The coupon must be protected during transportation to the laboratory. If the coupon is to be mailed, it should be packaged as described in Step 5 and placed along with the corrosion coupon form in an appropriate mailer. Add sufficient packing around the coupon to prevent excessive movement inside the mailer.

8. The laboratory will clean, evaluate and calculate the corrosion rates in accordance with the ASTM G-1.4.
Evaluating Corrosion Rates

According to the AWT, the following values are used to evaluate corrosion rates (in MPY):

**Aluminum**
- \(< 0.5\): Excellent
- \(0.5 – 2.0\): Good
- \(2.0 – 5.0\): Fair
- \(5.0 – 10.0\): Poor
- \(> 10\): Unacceptable

**Carbon Steel**
- \(< 1.0\): Excellent
- \(1.0 – 3.0\): Good
- \(3.0 – 5.0\): Fair
- \(5.0 – 10.0\): Poor
- \(> 10\): Unacceptable

**Copper and Copper Alloys**
- \(< 0.1\): Excellent
- \(0.1 – 0.2\): Good
- \(0.2 – 0.3\): Fair
- \(0.3 – 0.5\): Poor
- \(> 0.5\): Unacceptable

**Stainless Steel**
- \(< 0.1\): Acceptable
- \(> 0.1\): Unacceptable

\[
\text{Corrosion Rate, mpy} = \frac{\text{Area Factor} \times \text{Weight Loss}}{\text{Exposure Time}}
\]

Many water treaters wonder what the reported corrosion rates mean in terms of real world effects for their customers. They take over an account from a competitor, and reduce the mild steel corrosion rate from 10 mpy to less than 1 mpy. They know that they have improved the results significantly, but they are unable to quantify that for the customer. The examples below should help to put the numbers into perspective.

The time for a pipe, of a given wall thickness, to fail can be calculated as follows:

\[
\text{Time to Fail, yrs} = \text{thickness, inch} \times \frac{250}{\text{corrosion rate, mpy}}
\]

Now let’s compare how differing corrosion rates affect typical pipes or metals in treated systems...

**Condenser Tubes:**

The overwhelming majority of chiller condensers are coming off the assembly line with copper tubes that have a wall thickness of \(\frac{25}{1000}\) inch (0.025").

If your system has a copper corrosion rate of 5 mpy, then the new condenser tube will last only 1.25 yrs (assuming no pitting):

\[
\text{Time to Failure} = \frac{25}{1000} \text{ inch} \times \frac{250}{5 \text{ mpy}}
\]

\[
\text{Time to Fail} = 1.25 \text{ yrs}
\]

Similarly, a corrosion rate of 0.1 mpy means that the average condenser tube will last 62.5 yrs.

\[
\text{Time to Fail} = \frac{25}{1000} \text{ inch} \times \frac{250}{0.1 \text{ mpy}}
\]

\[
\text{Time to Fail} = 62.5 \text{ yrs}
\]

**Steel Piping:**

Consider that a 4 “diameter, schedule 40, steel pipe has a pipe wall thickness of 0.237 inches. A 10 mpy
corrosion rate means that the average length of 4 inch pipe will last 5.925 yrs (assuming no pitting).

\[
\text{Time to Fail} = 0.237 \text{ inch} \times \frac{250}{10 \text{ mpy}}
\]

\text{Time to Fail} = 5.925 yrs

Similarly, a corrosion rate of 1 mpy means that the average length of 4 inch pipe will last 59.25 yrs.

\[
\text{Time to Fail} = 0.237 \text{ inch} \times \frac{250}{1 \text{ mpy}}
\]

\text{Time to Fail} = 59.25 yrs

Use these tables to determine the relative useful life of piping systems.

Steel pipe applications:

Most steel piping systems found in the U.S. are fabricated using either, SCH 40, SCH 80 or SCH 160 pipe.

<table>
<thead>
<tr>
<th>Steel Pipe Thickness, inch - ANSI B36.10</th>
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</thead>
<tbody>
<tr>
<td>Nominal Size</td>
</tr>
<tr>
<td>1</td>
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<td>1 1/4</td>
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<td>1 1/2</td>
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<td>20</td>
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</table>

Copper pipe applications:

Most Air-Conditioning and Refrigeration systems will use Type L. Underground Water Services specify at least Type M for straight lengths with Type L preferred where coils are needed.

<table>
<thead>
<tr>
<th>Copper Pipe Thickness, inch - ASTM B88</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal Size</td>
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<tr>
<td>Inch</td>
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Typical chiller - enhanced tube wall thickness

0.025"