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Comprehensive Corrosion Monitoring of Condensate

By Dick Hourigan; November 18, 2011

Note – This is the first of a series of articles on water treatment which is designed to help property managers and others with their water based HVAC systems. These articles differ in scope from other articles in that they not only explain problems and solutions, but they also provide you with one source to purchase the items needed to do everything outlined in the paper. We look forward to your feedback on this and future articles and will provide free on line assistance to help you with all of your water treatment concerns.

Condensate System Monitoring – To preserve the condensate piping in your boiler steam system, to prevent leaks from raising energy costs, to prevent further property damage in your facility, or to prevent loss of production; you will need to be proactive. You will need to achieve comprehensive corrosion monitoring of your boiler's condensate system. There are a number of tests that can be run to insure that you have this. If you run these tests you will become aware of minor problems before they become major ones. You do not necessarily need to run all of these tests, but the more that you run, the greater will be your confidence level that your system is being properly maintained. The testing and monitoring that we recommend include:

pH Testing — In most condensate systems, neutralizing amines are used to react with and neutralize carbonic acid. Left un-neutralized, carbonic acid will react with and destroy the condensate piping. You will need to test your condensate pH to determine if it is high enough to prevent carbonic acid corrosion from occurring. If you only sample your condensate in one place, you might only get a good average number that will conceal deeper problems. You should sample your condensate pH in more than one place to ensure that carbonic acid is not attacking small sections of the system. If some areas of low pH are found, you will have to take steps to model your amine dosage to better mimic the distribution of carbon dioxide in the steam system. Sometimes his can be done by merely using a different neutralizing amine with a different distribution ratio. In more complicated steam systems with multiple pressures you may need to use a blend of neutralizing amines with different distribution ratios. In even more complicated situations, you may need to use supplemental feed points. In large steam systems, particularly those with oxygen contamination or high steam losses, it may be necessary to use a filming amine. Modifying your boiler's make up system to include some form of dealkalization which will lower the carbonic acid concentration in your condensate is an excellent option to be considered in many boiler systems.

The first step in any neutralizing amine approach is to find the condensate system's pH low points. Due to the purity of condensate, it takes very little to alter the pH of the

sample. Samples that sit exposed to the air for too long are no longer representative of the original condensate. Thus, a condensate sample should be run as quickly as possible so it has little time to come into equilibrium with the atmosphere, and it should be cooled prior to testing.

We recommend the use of a cooling coil to bring the sample temperature down to less than 90°F. Carbon dioxide and amine can both flash off of a hot sample thus altering the pH. A cooling coil will prevent this. The sample coil should be throttled at the discharge end and not the intake, to avoid drawing air into the coil. This will prevent entrained air from altering the sample pH. We recommend a pH of 8.3 or higher to minimize the risk of corrosion on a neutralizing amine program.

Here is a link to a cooling coil that we recommend for this application:
http://www.richardhouriganinc.com/sunshop/catalog/boiler-sample-cooler-87.html

Here is a link to a pH test kit that we recommend for checking condensate pH:
http://www.richardhouriganinc.com/sunshop/catalog/k-3232-slide-lvp-comparator-ph-condensate-6.0-9.2-343.html

Or if you prefer, here is a link for a pH meter that we recommend for condensate pH:
http://www.richardhouriganinc.com/sunshop/catalog/ph100-meter-141.html

Iron Measurement — It is not always possible or practical to measure the pH everywhere in your condensate system. For this reason, it is useful to test for dissolved, insoluble, or total iron. Iron, as a corrosion by-product is an indirect measurement of either low pH or the presence of oxygen somewhere upstream of your condensate sampling point. Thus, you can learn if you are having a problem in an area that is not being checked for pH. The use of a continuously flowing sample is the best since opening a valve to draw a sample can generate a slug of iron from the valve. But it may not be possible or practical to have a continuously flowing sample in smaller facilities where a loss of condensate becomes a significant percentage of total flow. In these cases, flushing the sample lines and allowing them to run for a few minutes is usually satisfactory. If a slug of iron should break loose during sampling, dump that sample and collect a fresh one.

There are different Iron tests than can be run. Each has its own value, depending upon what you are trying to determine. Here are a few:

Millipore® Filter Suspended Iron Test — This test can measure insoluble (particulate) iron by passing a liter of condensate through a Millipore® membrane filter and then comparing the resultant color and intensity to that on the Babcock and Wilcox comparison charts. This test semi-quantitative, and does not measure soluble iron (predominately ferrous). It does allow you to make qualitative assumptions regarding oxygen contamination in the condensate. The presence of suspended ferric iron such as (Fe_2O_3 or Fe_3O_4 which is $FeO + Fe_2O_3$) must be the result of an oxidizing species in

the condensate. This would alert you that you need to deal with oxygen in your system, either through better deaeration, better oxygen scavenging in the boiler, or perhaps by the use of a volatile oxygen scavenger such as DEHA or Erythorbate. Suspended iron levels in excess of 50 ppb are generally regarded, in the utility or nuclear power industry, as an indication that serious corrosion is taking place in the system.

Here is a link to the Babcock and Wilcox Suspended Iron Test:
http://www.richardhouriganinc.com/sunshop/catalog/babcock-and-wilcox-suspended-iron-test-790.html

Ferrous, Total, and Ferric Iron Analysis — A more precise test for both Ferrous, and Ferric iron is a wet chemistry method test kit. This type of kit does not differentiate between dissolved iron (mostly ferrous) and suspended iron which can be a mixture of ferrous and ferric. Caution must be exercised to get an accurate reading from the suspended iron since it can precipitate with time in the collection vessel before you decant a small portion into a test cell. For most industries and commercial buildings a test result of 0.5 ppm or less is a good test result. You could add a pre-filter step to this test using a Millipore® membrane filter so that only dissolved iron is measured. This would eliminate the suspended iron error altogether.

Here is a link to a test kit that we recommend for Ferrous, Total, & Ferric Iron Analysis:
http://www.richardhouriganinc.com/sunshop/catalog/k-1239sc-midget-comparator-iron-ferric-ferrous-total-0-10-ppm-463.html

Here is a link to 25 mm Filter Paper, 0.45 micron for Suspended Iron removal:
http://www.richardhouriganinc.com/sunshop/catalog/25mm-filter-paper-0.45-micron-100-pk-829.html

Here is a link to a Filter Assembly to be used with the 25 mm Filter Paper:
http://www.richardhouriganinc.com/sunshop/catalog/filter-assembly-823.html

Total Iron Analysis — Just tracking total iron over time without regard to oxidation state can give you valuable feedback regarding the effectiveness of your condensate amine program. This test is simpler and faster than the iron test in the above paragraph. Even if there is some loss of suspended iron during transfer to the test cell from the collection vessel, that loss can be ignored provided that you are consistent in your procedure and timeliness of transfer. Even if the test is not completely accurate due to the loss of some suspended iron, it can still be regarded a fairly accurate trend line if you are consistent with your methodology. Again, you could add a pre-filter step to this test using a Millipore® membrane filter. This would eliminate the suspended iron error.

Here is a link to a test kit that we recommend for Total Iron Analysis:
http://www.richardhouriganinc.com/sunshop/catalog/k-1716-midget-comparator-iron-41.html

Here is a link to 25 mm Filter Paper, 0.45 micron for Suspended Iron removal:
http://www.richardhouriganinc.com/sunshop/catalog/25mm-filter-paper-0.45-micron-100-pk-829.html

Here is a link to a Filter Assembly to be used with the 25 mm Filter Paper:
http://www.richardhouriganinc.com/sunshop/catalog/filter-assembly-823.html

Copper Analysis — In some dairy plants where ammonia is used for pH control or in non-dairy plants where condensate pH is high (> 9.0) due to frequent boiler water carry over or the over feed of neutralizing amines, it is advisable to test for copper. The copper can come from an over feed of ammonia or amine which dissolves the copper out of the brass valves or fittings in the steam or condensate system. If there are no brass components then this is not a concern. We usually advise dairies to maintain a condensate pH of 7.0 to 8.0 when using ammonia. We recommend that copper be controlled to less than 0.1 ppm in the condensate.

Here is a link to a test kit that we recommend for Copper Analysis:
http://www.richardhouriganinc.com/sunshop/catalog/k-1738-midget-comparator-copper-cuprizone-32.html

If you would prefer a single test kit for both Copper and Iron Analysis, then this would be our recommendation:
http://www.richardhouriganinc.com/sunshop/catalog/k-1264-commercial-midgets-metals-copperiron-404.html

Professional Laboratory Analysis — Professional laboratory tests can be used to monitor copper and iron levels over time. Due to the professional accuracy of the results, these tests make very good trend indicators.

Here is a link that allows you to purchase Copper, Iron, and other Analyses on line:
http://www.richardhouriganinc.com/sunshop/catalog/specific-laboratory-water-analysis-824.html

Gas Measurement — There are two gasses that cause corrosion in condensate systems. These are oxygen and carbon dioxide. Both can be independently measured in either the steam or the condensate. Since they are both gases, once again a cooling coil should be used to capture a sample. Also, it would be impossible to measure the carbon dioxide or carbonic acid content of the steam or condensate in the presence of any neutralizing amine. Thus, it would be necessary to shut off the amine feed for several hours before taking a sample. This would allow time for steam traps to purge condensate with amine in it. Any dead legs where condensate might accumulate should also be drained to prevent amine from moving back into the steam lines. The tests to be used are as follows:

Carbon Dioxide: We recommend the LaMotte Carbon Dioxide Test Kit
Oxygen: We recommend the CHEMets® K-7599 Dissolved OxygenTest Kit.

To do this you will need to have a cooling coil installed. We recommend this one: http://www.richardhouriganinc.com/sunshop/catalog/boiler-sample-cooler-87.html

Here is a link to the LaMotte 7297-DR Carbon Dioxide Test Kit: http://www.richardhouriganinc.com/sunshop/catalog/lamotte-carbon-dioxide-test-kit-7297-dr-826.html

Here is a link to the CHEMets® K-7599 Dissolved OxygenTest Kit: http://www.richardhouriganinc.com/sunshop/catalog/chemetrics-visual-dissolved-oxygen-test-kits-827.html

Filming Amine Residual — The most commonly used filming amine used in boiler operations is Octadecylamine (ODA). We recommend a control limit of 0.2 to 0.6 ppm of Octadecylamine in the steam. Octadecylamine should be measured on a steam sample, not on a condensate sample. Octadecylamine works best between a pH of 6.0 to 8.0. Outside of this pH range, the film can strip off and cause steam trap deposits. Thus, this product may require supplemental neutralizing amine to be added. Once again we recommend a cooling coil to prevent the flashing off of steam which will concentrate your sample.

The cooling coil we recommend is once again this one: http://www.richardhouriganinc.com/sunshop/catalog/boiler-sample-cooler-87.html

Here is a link to the test kit that we recommend for Octadecylamine Residual: http://www.richardhouriganinc.com/sunshop/catalog/k-1243-slide-comparator-octadecylamine-oda-0-6-ppm-473.html

Neutralizing Amine Residual — There are limits for neutralizing amine dosages in food plants where steam may come in contact with food. These legal limits are issued by the U.S. Food and Drug Administration. They are published in the Federal Register. The following has been copied from 173.310, 21 CFR Ch.1 (4-1-06 Edition):

“ Boiler Water Additives may be safely used in the preparation of steam that will contact food under the following conditions:

- Cyclohexylamine – Not to exceed 10 parts per million in steam and excluding use of such steam in contact with milk and milk products.
- Diethylaminoethanol – Not to exceed 15 parts per million in steam and excluding use of such steam in contact with milk and milk products.
- Morpholine – Not to exceed 10 parts per million in steam and excluding use of such steam in contact with milk and milk products.
- Octadecylamine – Not to exceed 3 parts per million in steam and excluding use of such steam in contact with milk and milk products.”

Note: Octadecylamine is not a neutralizing amine and was discussed earlier.

Given this information some prefer to directly test for the amine rather than rely on pH measurements. The pH merely measures effectiveness and not the actual dosage of the amine. To be most correct with regard to the regulation, the test should be run on a steam sample, not a condensate sample. Results between steam and condensate will most definitely be different.

To do this you will need to have this cooling coil installed:
http://www.richardhouriganinc.com/sunshop/catalog/boiler-sample-cooler-87.html

Next you will need a test kit to directly measure the neutralizing amines. Here is a link to the test kit that we recommend:
http://www.richardhouriganinc.com/sunshop/catalog/k-1682-drop-test-neutralizing-amine-1-drop--4-5-or-6-ppm-375.html

Oxygen Scavenger/Metal Passivator Test — A Diethylhydroxylamine (DEHA) Test Kit can be used to measure the residual of the volatile Oxygen Scavenger and Metal Passivator in the steam and condensate lines. This test is effective for both DEHA and Erythorbic Acid. It is a simple test with easy to follow instructions. Once again a cooling coil should be installed to cool the sample before testing to prevent the loss of the volatile chemicals which will occur if there is steam flashing. For this test, we recommend the LaMotte 4790 DEHA Test Kit.

To do this test you will need to have this cooling coil installed:
http://www.richardhouriganinc.com/sunshop/catalog/boiler-sample-cooler-87.html

Here is a link to the LaMotte 4790 DEHA Test Kit
http://www.richardhouriganinc.com/sunshop/catalog/lamotte-deha-test-kit-4790-825.html

Corrosion Coupons — By using pre-weighed strips of metal as close in composition to the metallurgy of the condensate system, corrosion rates of the system metal can be estimated. We usually recommend using a corrosion coupon rack that holds 3 coupons. You expose one coupon for 30 days, one for 60 days, and one for 90 days. Once removed, the coupons are mailed back to the laboratory where the weight loss is determined and a corrosion rate is calculated in mils per year (mpy). We offer the option of getting a report with or without a photo of the coupon and the ability to get an executive summary which thoroughly explains the results and offers advice on how to reduce the corrosion rate in the system being monitored. We recommend that the corrosion coupon rack be installed in the system in such a manner that the corrosion coupons remain flooded at all times.

Here is a link to a ¾ inch, Black Iron Corrosion Coupon Rack:
http://www.richardhouriganinc.com/sunshop/catalog/corrosion-coupon-rack-34-inch-black-iron-512.html

Here is a link to a 1 inch, Black Iron Corrosion Coupon Rack:
http://www.richardhouriganinc.com/sunshop/catalog/corrosion-coupon-rack-1-inch-black-iron-513.html

Here is a link to commonly used Corrosion Coupons:
http://www.richardhouriganinc.com/sunshop/catalog/corrosion-coupons-116.html
Note: Corrosion coupons made from more exotic metals are available upon request.
In addition to providing chemicals, test kits and equipment for the treatment of industrial and commercial water systems, we also offer technical assistance to ensure that everything that you purchase from us is functioning properly and that you have a clear understanding of what your test results mean. Feel free to contact us at anytime with your questions.

This article was written by Dick Hourigan, an Analytical Chemist who has been in the water treatment industry since 1972. He is a retired US Army Special Forces Lieutenant Colonel, and is the owner of Richard Hourigan, Inc. and its wholly owned subsidiary, www.TheWaterTreatmentStore.com.

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