

GUIDELINES FOR EVALUATION OF COOLING WATER TREATMENT EFFECTIVENESS

**BY
WATER TREATMENT COMMITTEE
OF THE
COOLING TOWER INSTITUTE**

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GUIDELINES FOR EVALUATION
WATER TREATMENT EFFECTIVENESS

A. PREFACE

There are numerous methods which can be used to measure effectiveness of treatment in cooling tower water. Most are methods which may be generally applied to most systems or a specific method which can be generally applied with minor modifications. Some published methods are specific to an individual system. These guidelines attempt to cover only the first two methods. To accomplish this, three subdivisions were established; deposition, corrosion and biological. Subdivisions are split into a general section outlining the need for monitoring followed by a bibliography where the reader can find references to fit a specific need.

References are taken from articles published in major technical journals or from papers presented at national technical meetings. The task group which compiled this listing acknowledges that it is not complete, but hopefully it provides the user with sufficient diversity to discover a source for his specific needs.

The descriptive sentence following each source is an attempt to classify the article in the particular area of interest and is not an attempt to fully describe the content or overall value of the source.

Initial evaluation of a proposed water treatment method should be carried out by comparison with the results obtained under identical test conditions using an established water treatment method of known performance or using no water treatment.

B. DEPOSIT MONITORINGI. INTRODUCTION

Deposition in cooling water systems may be scale or fouling or, as is usually the case in operating systems, a mixture of the two. Scales are hard, dense crystalline deposits which form because the solubilities of the constituents at the temperature involved have been exceeded. Fouling occurs due to adherence or sedimentation of suspended matter on system surfaces.

Evaluation methods must be selected to reflect the nature of the deposits found in the operating system. Monitoring and evaluating deposition is not a precise science and depends on the degree of sophistication and care taken in operating the test unit.

II. DEPOSIT EVALUATION METHODS

Operating characteristics and appearance of the operating equipment are the only absolutely accurate evaluation methods. Because of the long term nature of such evaluation and the cost of waiting until problems develop, other methods are employed. These methods take a side stream of sample water through a test unit so that characteristics can be evaluated in a smaller unit without interrupting the production process.

Any side stream evaluation is relative since it is nearly impossible to exactly duplicate actual operating conditions. How well the side stream unit relates to the operating units depends upon the degree of complexity and sophistication used in building and operating the side stream unit.

A variety of deposit monitors have been successfully used. Test units or designs are available from water treatment suppliers and technical organizations. They vary from single tube units to multitube exchangers. Some are see-through and others are small duplicates of process exchangers. These units all tend to be variations of one or two schemes which have been used for many years.

A unit designed and built by The Heat Transfer Research Institute (HTRI) is one of the most sophisticated deposit and fouling monitors presently in use. It employs an electrically heated tube in a glass shell. The annular space for water flow on the outside of the tube is small so tube side flow velocities can be duplicated while the glass shell allows visual inspection of the surface. The HTRI unit employs sophisticated monitoring and control over water flow and heat rate. Continuous monitoring allows the calculation of fouling rates throughout a test run. The HTRI unit is expensive (\$40,000+) because of the monitoring and control. Less expensive variations of this concept have been used successfully. These less expensive units sacrifice accuracy of measurement or degree of control flexibility.

The other basic concept is a test heat exchanger such as designed for the National Association of Corrosion Engineers (NACE). The NACE heat exchanger employs 12 tubes which are metallurgically isolated so

different materials may be tested at the same time. Steam is used as the heat source. The specifications for the NACE unit are available in NACE Publication T5C1. Additional control and monitoring equipment is needed for proper control of flows, temperature, etc. Smaller test exchangers using the same principles with 1 or 2 tubes are available from most water treatment suppliers with some loss in flexibility.

III. CRITICAL FACTORS

Deposition for a particular water is most directly related to:

water velocity
heat flux
temperature

To be meaningful, any test unit must be able to measure and control these variables.

Water Velocity

Water velocity will greatly affect the tendency of water to scale or foul. Low velocity (<2 ft/sec) or fluctuation increases the tendency for fouling to occur and/or to form scale if high heat is used. Velocity in a test unit should be as close to operating velocities as possible. For evaluation purposes several velocities are normally used. (NACE recommends evaluations at 2, 5, and 8 fps.)

Heat Flux and Temperature

Potential scale forming constituents are normally inversely soluble with temperature. Calcium carbonate for example will tend to deposit in areas of highest temperature. The heat flux or heat input rate also affects the tendency to form scale or cause adherence of particles. Both the overall temperatures (skin temperatures and bulk water temperatures), and the heat rate must be close to those in the operating unit to make the test data meaningful.

IV. INTERPRETATION

Data from a test unit is relative and should not be expected to be exactly as found in the operating units.

Tests should be at least of 30-day duration. If a series of tests are run, their duration should all be the same. Evaluation is based on various temperature and pressure measurements from which fouling factor, heat transfer coefficients, and Reynolds number can be calculated. Data may be manually taken from instruments or automatically recorded. These calculations will give an indication of heat transfer loss and/or the degree of deposition occurring.

In addition to these calculations, the weight of deposit/unit area and the composition can be determined. Corrosion may also be evaluated visually and pit depths measured.

Useful data can be obtained from a well designed and closely monitored side stream test unit. The value of the results are directly related to how close conditions are to those in operating units and to the accuracy of the instrumentation.

C. CORROSION MONITORING

I. Introduction

Monitoring corrosion is an essential part of any evaluation program. The most common method is determining weight loss of coupon-type corrosion test specimens (corrosion coupons). An average corrosion rate is calculated over the period exposed, normally expressed as mils per year (mpy), or electrical measurement of "instantaneous" corrosion rate can be done using instruments such as manufactured by Rohrbach (Magna) or Petrolite. Instruments using linear polarization can measure the corrosion rate existing at the time of the test, and are available as a portable unit or as a permanent installation with continuous measurement and recording. The use of instantaneous monitoring units is ideal for troubleshooting since the immediate effects of pH excursions, plant upsets, lack of corrosion inhibitor, etc are shown.

II. Use of Corrosion Coupons

Corrosion tests with metal test specimens can be used to determine how corrosive a water is towards the metal used in the test. Coupon specimens are particularly useful in evaluating the effectiveness of a water treatment program in recirculating cooling water systems. The extent of both general and localized corrosion can be determined. Examination of specimens may provide information regarding deposit accumulation or microbiological slime growth.

Corrosion test coupons are readily available from many sources. The individual coupons are usually 1/2" to 3/4" wide by 3" to 4" long, and are 1/16" to 1/8" thick. Generally, carbon steel specimens are used; however, metals such as copper, copper alloys, stainless steels, etc. are available for special studies.

Since the goal of a corrosion testing program is to provide information regarding conditions within the operating system, the corrosion coupons should be exposed to conditions that reflect the system as a whole. Specific factors that affect measured corrosion rates are discussed separately and should be considered when installing corrosion test coupons. Although spot tests with corrosion coupons are useful, a continuing program is recommended to determine trends and recognize changes within the system.

Coupon type corrosion test specimens may be installed in "tees" by means of corrosion test assemblies which include a pipe plug, 3/4 to 1", plastic or phenolic rod and nylon nut and bolt for attaching the coupon to the rod. A bypass arrangement is recommended to facilitate installation and removal as well as the use of multiple specimens. PVC is preferred to eliminate electrical effects. Specifications for one type of test rack are shown in Figure 1 and may be used as a guide.

CAUTIONS:

- A. Flow through the corrosion test rack must be continuous and measurable. Flow meters are recommended. When a flow meter does not exist, flow must be measured by timing how long it takes to fill a container of known volume.
- B. Normally, water velocity through the corrosion test rack should be 3 to 5 ft/sec. The velocity in ft/sec for a given gpm flow for the standard 1-1/4" pipe is shown on the detailed drawing attached. Guidelines for line sizes are shown below:

<u>Velocity in ft/sec</u>	<u>1" line</u>	<u>Flow Rate (gpm)</u>	
		<u>1-1/4" line</u>	<u>1-1/2" line</u>
3	7.5	12.0	16.5
5	12.0	20.0	27.5

- C. Direction of flow should be as shown in Figure 1 to minimize turbulence around the specimen and insure that the rack remains full of water.
- D. Hanging a coupon in the basin does not give sufficient velocity and installing directly in a large line can give excessive velocity or turbulence resulting in poor comparative results.

III. Factors That Affect Measured Corrosion RatesTemperature

Corrosion rate is affected by the water temperature. The rate of corrosion increases with rising temperature. At higher temperatures, the water viscosity is reduced, the rate of oxygen diffusion increased and the electrical conductivity increased, all of which tend to increase corrosivity. To evaluate differences caused by temperature changes in the system, corrosion racks should be installed at both the cold (discharge from cooling tower sump) and hot water (return to tower). Specific critical exchangers may warrant the use of a corrosion test rack at the discharge of the exchanger.

Water Velocity

Corrosion rates are affected by water velocity. Both low and high velocities can increase corrosion. Low velocities (<3 ft/sec) promote deposition and underdeposit corrosion as well as reducing the contact between the inhibitor and the metal surface. High velocities (>7 ft/sec) can lead to erosion or impingement attack. Constant flow must be maintained. Stagnant conditions invalidate coupon results.

To give meaningful results, coupons should be exposed to a water velocity (nominally between 3 and 5 ft/sec) with the specific rate being that found in exchangers within the system.

Exposure Time

A corrosion test coupon is an extremely active metal surface when first installed. Normal maintenance level corrosion inhibitor programs cannot form their protective films immediately. Therefore, the initial corrosion rate is high. Leaving a corrosion coupon in a system for long periods of time, over 90 days, becomes less meaningful because deposits and corrosion products can affect the corrosion rates, and short-term conditions may not be recognized.

To minimize these effects, the preferred exposure time should be between 30 to 90 days and all tests should be made over the same time period. Some coupons are pretreated to minimize the initial high corrosion rate effects. In any case the type of coupons employed in continuing tests should be the same.

Surface Conditions

Since corrosion is a surface phenomenon, irregularities on a coupon surface can initiate corrosion. Considerable care is taken in preparing the coupons to insure clean uniform surfaces and coupons are usually shipped in vapor inhibited bags to prevent corrosion between the time of preparation and installation in a system.

Fingerprints made when handling the coupon before or during installation will initiate corrosion cells. Do not handle the coupon directly with fingers while installing it. The surface of coupons is usually a flat, smooth finish as specified by ASTM Standard D2776-72. Sandblasted coupons are also used effectively; however, regardless of surface preparation, results are only comparable for surfaces of a similar nature.

Pretreatment

As mentioned, a freshly cleaned and prepared corrosion coupon is an extremely active metal surface, and tends to corrode rapidly when first placed in contact with test water. The corrosion inhibitor residuals normally used in cooling water systems are only adequate for repair of film breaks. The maintenance residual is not high enough to provide rapid passivation of a highly active surface such as a new coupon.

Pretreating coupons with high level of corrosion inhibitor before installation can be used to minimize initial corrosion by providing the initial passivating film. A variety of pretreatment methods are used. Since the pretreatment film rapidly decays after placing in the system, chromate is often used regardless of the actual inhibitor used in the system. In other cases, the coupons are pretreated with the actual inhibitor used in the system. For pretreatment, the coupon is usually soaked in 2000-5000 ppm solution of the inhibitor for 8 to 48 hours.

Pretreated coupons usually give lower measured corrosion rate than those that are not pretreated. The critical point is that corrosion coupon testing is used to establish trends and note changes. The method used must be consistent to be meaningful. Pretreated coupons should be identified as pretreated on the corrosion test evaluation reports and should only be directly compared to other pretreated coupons. Pretreatment of coupons is more important when extremely low residuals of corrosion inhibitors are used.

Metallurgy

Metals differ in their resistance to aqueous corrosion. Corrosion test specimens are commonly available in mild steel, copper, admiralty, 316 and 304 stainless steel and 3003 aluminum. Mild steel is by far the most commonly used because mild steel predominates in industrial systems and is readily corroded.

Galvanized coupons are not provided because meaningful weight loss corrosion measurement is impossible due to the two metals used (steel and zinc) and differences in resistance and density.

When using both mild steel coupons and copper or admiralty coupons in the same corrosion test rack, install the copper based coupons downstream from steel coupons. This avoids plating out copper on the mild steel producing galvanic attack on the steel.

IV. Special Uses in Cooling Water Systems

The corrosion test rack and metal coupons can also be used to give a visual evaluation of conditions within the system. When water flow is representative of velocities in the system, observing the condition of a coupon may indicate potential problems due to fouling. Valuable information regarding the effectiveness of microbiological control programs can be obtained by regularly removing a specimen and observing any evidence of slime accumulation or streaking on the coupon. Therefore, the coupon provides another evaluation tool to insure that slime and deposit control is adequate, allowing adjustment in the program before a problem becomes severe. A corrosion test rack and coupon can provide information on deposit control programs as well as corrosion control.

The coupon used for visually monitoring the deposit control program should not be the same one used for corrosion because regular removal of the coupon will affect corrosion rates. Unless the treatment program clean-up ability is monitored, the deposit control coupon should be wiped clean before it is reinstalled. To insure that the coupons used for corrosion monitoring are constantly exposed to water, the deposit control coupon should be the top most location on the rack so that even after removal of the deposit/slime control coupon, the other specimens remain covered with water.