



Standard Test Method for Corrosivity of Water in the Absence of Heat Transfer (Weight Loss Method)¹

This standard is issued under the fixed designation D2688; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

^ε¹ NOTE—An editorial correction was made to 13.3.2 in July 2016.

1. Scope

1.1 This test method covers the determination of the corrosivity of water by evaluating pitting and by measuring the weight loss of metal specimens. Pitting is a form of localized corrosion: weight loss is a measure of the average corrosion rate. The rate of corrosion of a metal immersed in water is a function of the tendency for the metal to corrode and is also a function of the tendency for water and the materials it contains to promote (or inhibit) corrosion.

1.2 The test method employs flat, rectangular-shaped metal coupons which are mounted on pipe plugs and exposed to the water flowing in metal piping in municipal, building, and industrial water systems using a side stream corrosion specimen rack.

1.3 The values stated in SI units are to be regarded as standard. The values given in parentheses are mathematical conversions to inch-pound units that are provided for information only and are not considered standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*²

[D1129 Terminology Relating to Water](#)

¹ This test method is under the jurisdiction of ASTM Committee D19 on Water and is the direct responsibility of Subcommittee D19.03 on Sampling Water and Water-Formed Deposits, Analysis of Water for Power Generation and Process Use, On-Line Water Analysis, and Surveillance of Water.

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² For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[D2331 Practices for Preparation and Preliminary Testing of Water-Formed Deposits](#)

[D2777 Practice for Determination of Precision and Bias of Applicable Test Methods of Committee D19 on Water](#)

[G1 Practice for Preparing, Cleaning, and Evaluating Corrosion Test Specimens](#)

[G16 Guide for Applying Statistics to Analysis of Corrosion Data](#)

3. Terminology

3.1 *Definitions*—For definitions of terms used in this standard, refer to Terminology [D1129](#).

4. Significance and Use

4.1 Since the two tendencies are inseparable for a metal to corrode and for water and the materials it contains to promote or inhibit corrosion, the corrosiveness of a material or the corrosivity of water must be determined in relative, rather than absolute, terms. The tendency for a material to corrode is normally determined by measuring its rate of corrosion and comparing it with the corrosion rates of other materials in the same water environment. Conversely, the relative corrosivity of water may be determined by comparing the corrosion rate of a material in the water with the corrosion rates of the same material in other waters. Such tests are useful, for example, for evaluating the effects of corrosion inhibitors on the corrosivity of water. Although this test method is intended to determine the corrosivity of water, it is equally useful for determining corrosiveness and corrosion rate of materials. Examples of systems in which this method may be used include but are not limited to open recirculating cooling water and closed chilled and hydronic heating systems.

5. Composition of Specimens

5.1 The specimens shall be similar in composition to the piping in the system in which the corrosion test is being made.

6. Effect of Cold Working on Corrosion

6.1 Cold working can be important in causing localized corrosion; however, plastic deformation can be minimized in specimen preparation by following proper machining practices (1)³ (for example, drilling, reaming, and cutting specimens).

7. Types of Corrosion

7.1 *General Corrosion*—Characterized by uniform attack of the metal over the entire surface.

7.2 *Pitting*—A form of localized corrosion, the depth, number, size, shape, and distribution of pits being pertinent characteristics. It may be evaluated by counting the number, by noting the size, shape, and distribution, and by measuring the depth of pits in representative areas. Both sides of the coupons must be examined.

7.2.1 A system may be devised for grading pitting (2).

7.3 *Crevice Corrosion*—A pertinent factor to consider in corrosion testing, since active corrosion sites may develop in such locations. Crevices may exist at threads and joints and under deposits, as well as in corrosion specimens. In this method, crevice corrosion may be in evidence where the specimen is fastened to the holder and at coupon markings. Providing a large specimen surface area relative to the crevice area reduces this influence on the overall corrosion results. Light sanding is necessary to remove edges of coupon marking.

7.4 *Edge Corrosion*—The increased corrosion that occurs at edges of corrosion specimens, where the metal may be of different composition or structure, must be given attention. In this method, specimens of a high ratio of surface area to edge area reduce this effect. If an abnormally high degree of edge corrosion is observed, the effect may be evaluated by measurement of the specimen dimensions previous to and following exposure. Use of a specimen of less thickness may also reduce the edge effect in weight loss.

7.5 *Impingement Attack (Erosion-Corrosion)*—associated with turbulent and high-velocity flow, particularly when soft metals and copper are involved, is characterized by continuous broader-type pits and bright metal from which protective films have been scoured away. Some under-cutting also may be present.

8. Water-Formed Deposits

8.1 Water-formed deposits observed on the specimens may be analyzed by the methods listed in Practices D2331. The most common constituents will be calcium, magnesium, aluminum, zinc, copper, iron, carbonate, phosphate, sulfate, chloride, and silica.

9. Summary of Test Method

9.1 Carefully prepared, weighed metal coupons are installed in contact with flowing water for a measured length of time. After removal from the system, these coupons are examined,

cleaned, and reweighed. The corrosivity and fouling characteristics of the water are determined from the difference in weight, the depth and distribution of pits, and the weight and characteristics of the foreign matter on the coupons.

10. Interferences

10.1 Deviation in metal composition or surface preparation of the coupons may influence the precision of the results.

10.2 The presence of different metals in close proximity to the coupon, (within 76 mm (3 in.)), even if they are insulated from the coupon, constitutes a source of error in the results.

10.3 Deviations in the velocity and direction of flow past the coupons may influence the precision of the results.

10.4 Results are directly comparable only for the water temperature to which the coupon is exposed.

10.5 Crevices, deposits, or biological growths may affect local corrosivity; results should therefore be interpreted with caution.

11. Apparatus

11.1 *Coupon Specimens*—Prepare coupons in accordance with Section 13.

11.2 *Insulating Washer, Screw, and Nut*—Use for attaching the coupon to the mounting rod. The insulating washer has a sleeve that fits into the coupon hole and around the screw.

NOTE 1—The insulating washer may be eliminated if a non-metal screw and nut are used. Screws and nuts of nylon or TFE fluorocarbon have been found satisfactory for this purpose.

11.3 *Specimen Mounting Plug*—Use a 152-mm (6-in.) length of 9.5-mm (0.375-in.) outside diameter PVC, CPVC, or TFE fluorocarbon rod, or equivalent, attached at one end to a drilled PVC, CPVC, or malleable iron pipe plug, and having a flat surface and a hole at the other end suitable for attachment of the test specimen. The pipe plug shall have a saw slot or other suitable witness mark to indicate the orientation of the test specimen when it is mounted in the bypass rack.

11.4 *Bypass Specimen Rack*, as illustrated in Fig. 1, for installation of coupon specimens. The piping, valves, and fittings of the corrosion rack shall be constructed of 2.5 cm (1 in.) Schedule 40 carbon steel, stainless steel, or Schedule 80 PVC or CPVC pipe. If necessary, the rack can be constructed of 16.8-mm (3/4-in.) Schedule 40 carbon steel, stainless steel, or Schedule 80 PVC or CPVC pipe. This allows for a lower flow rate to achieve adequate velocity but leaves less clearance around the coupon and may trap more debris. If a 16.8-mm (3/4-in.) rack is used, a strainer should be installed ahead of the rack to prevent debris from entering the rack.

11.5 *Dial Depth Gage*—A gage with a knife-edge base, pointed probe, and dial indicator for measurement of pit depth.

11.6 *Emery Paper*, Number 0.

12. Materials

12.1 *Vapor Phase Inhibitor Paper*—Envelopes constructed of vapor phase inhibitor paper are commercially available. Vapor phase inhibitor paper for wrapping coupons is also commercially available.

³ The boldface numbers in parentheses refer to the list of references at the end of this standard.

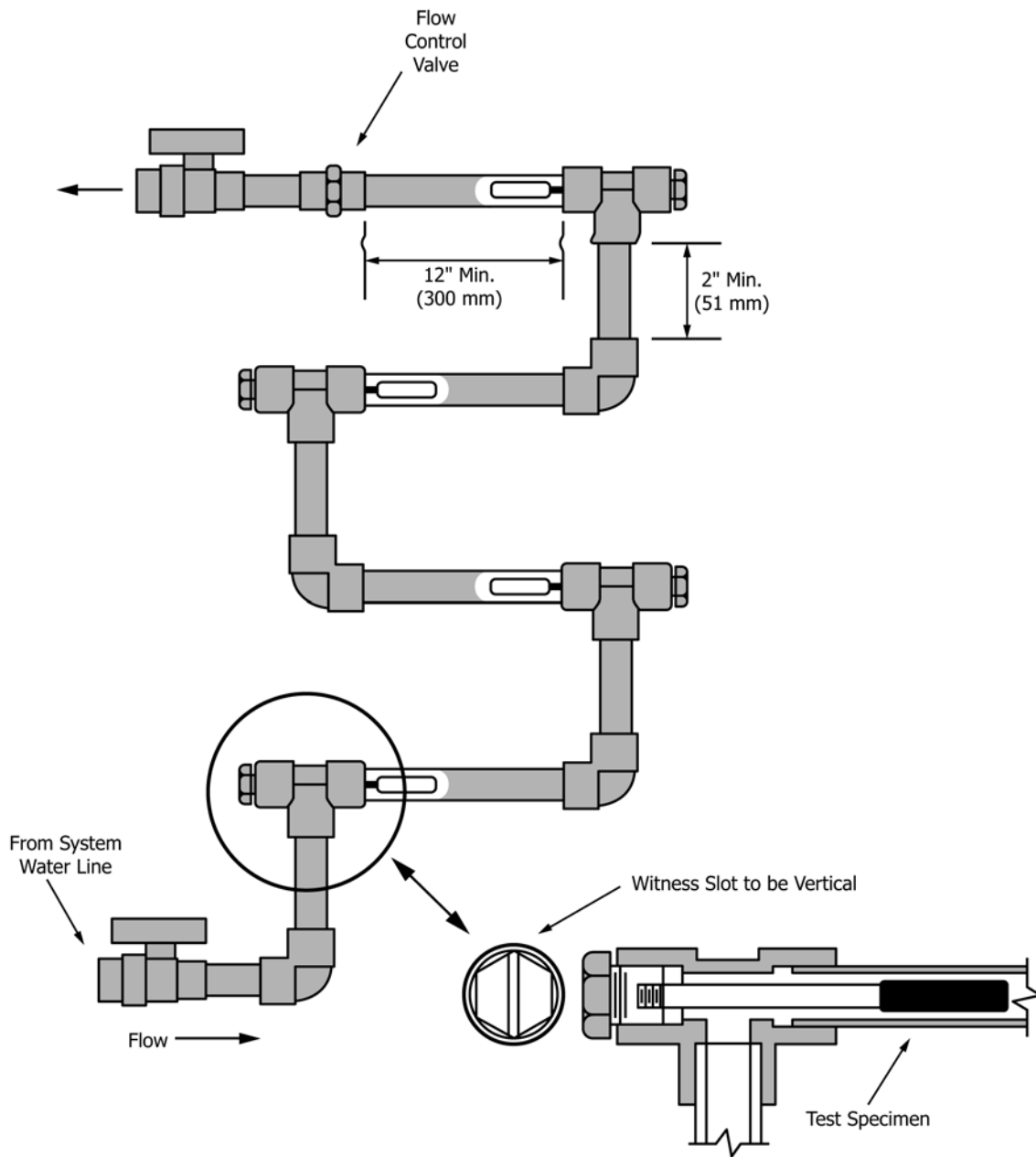


FIG. 1 Installation of Corrosion Coupons

13. Coupon Preparation

13.1 In this procedure, coupons are to be made principally from sheet metal; however, in a few cases, as with cast iron or cast bronze, it may be necessary to prepare coupons from castings.

13.2 Use a coupon size of 13 by 76 by 1.6 mm (0.5 by 3.0 by 0.0625 in.) for all sheet metals; and a 13 by 76 by 3 mm (0.5 by 3.0 by 0.125 in.) for cast metals. Other sizes are suitable, providing the total area is about 259 mm² (4 in.²), the principal requirement being to keep the flat area large compared to the edge area.

13.3 *Sheet Metal Coupon Preparation*—Obtain sheet metal of the type desired except for stainless steel; use cold-rolled

steel free of rust spots for ferrous metal. Obtain stainless steel with a No. 4 finish (3).

13.3.1 Shear 14-gage sheet metal material to the dimensions of 13 by 75 mm (0.5 by 3.0 in.).

13.3.2 Drill or punch a 5 mm (0.19 in.) hole with its center about 3 mm (1/8 in.) from one end of the coupon.

13.3.3 Deburr all sharp edges on the coupon specimen using a file or emery belt, and deburr the hole with an oversize drill.

13.3.4 Stamp identifying numbers or letters on the coupon area below the mounting hole.

13.4 *Cast Metal Coupon Preparation*—Obtain rough castings of the desired metal, measuring about 19 by 114 by 6 mm (3/4 by 4 1/2 by 1/4 in.) from a commercial foundry or elsewhere.

TABLE 1 Flow versus Velocity

Flow Rate	Schedule 40 Rack Steel or Stainless Steel Rack		Schedule 80 Rack PVC Rack	
	19 mm (¾ in.) Nominal Pipe Size; m/sec (ft/sec)	25 mm (1 in.) Nominal Pipe Size; m/sec (ft/sec)	19 mm (¾ in.) Nominal Pipe Size; m/sec (ft/sec)	25 mm (1 in.) Nominal Pipe Size; m/sec (ft/sec)
8 lpm (2 gpm)	0.37 (1.20)	0.23 (0.74)	0.45 (1.48)	0.27 (0.89)
11 lpm (3 gpm)	0.55 (1.80)	0.34 (1.11)	0.68 (2.22)	0.41 (1.34)
15 lpm (4 gpm)	0.73 (2.40)	0.45 (1.48)	0.90 (2.96)	0.54 (1.78)
19 lpm (5 gpm)	0.91 (3.00)	0.56 (1.85)	1.13 (3.71)	0.68 (2.23)
26 lpm (7 gpm)	1.28 (4.21)	0.79 (2.60)	1.58 (5.19)	0.95 (3.12)
38 lpm (10 gpm)	1.83 (6.01)	1.13 (3.71)	2.26 (7.41)	1.36 (4.45)
45 lpm (12 gpm)	2.20 (7.21)	1.36 (4.45)	2.71 (8.89)	1.63 (5.35)
53 lpm (14 gpm)	2.56 (8.41)	1.58 (5.19)	3.16 (10.37)	1.90 (6.24)
61 lpm (16 gpm)	2.93 (9.61)	1.81 (5.93)	3.61 (11.86)	2.17 (7.13)
64 lpm (17 gpm)	3.12 (10.22)	1.92 (6.30)	3.84 (12.60)	2.31 (7.57)

13.4.1 Surface grind to the dimensions of 13 by 102 by 3 mm (0.5 by 4.0 by 0.125 in.) and a surface roughness of about 124 μ m.

13.4.2 Drill a 7-mm ($\frac{9}{32}$ -in.) hole with its center about 8 mm ($\frac{5}{16}$ in.) from one end of the coupon.

13.4.3 Deburr all sharp edges on the coupon specimen using a file or emery belt, and deburr the hole with an oversize drill.

13.4.4 Stamp identifying numbers or letters on the small coupon area between the edge and the mounting hole.

13.4.5 The approximate weight of metal coupons, g, is as follows:

Steel	10.35
Cast Iron	11.65
Copper	13.33
Zinc	8.7
Lead	16.60

13.5 *Cleaning Metal Coupons*—Degrease and clean corrosion in specimens in accordance with Practice .

14. Procedure

14.1 Weigh the clean, dry specimens on an analytical balance to the nearest 0.0001 g.

14.2 After weighing, store the specimens in a desiccator until ready for use. If storing in a desiccator is inconvenient or impractical, use an alternative method for providing a corrosion-free atmosphere.

14.3 Store coupons in separate envelopes made from vapor phase inhibitor-impregnated paper or in envelopes and wrapped in vapor-phase inhibitor-impregnated paper.

14.4 Attach the coupon to the mounting rod, using a plastic screw and nut or using an insulating washer to preclude any contact of coupon with the metal screw and nut assembly. For added protection, attach the specimen to the holder using a non-metal screw and nut.

14.5 The coupons should be placed into the corrosion coupon rack following the galvanic series in seawater. This means that the most active (least noble) metal be first in the flow path. Other coupons follow the galvanic series. This prevents the more noble metal from cathodically depositing on the more active metal or alloy.

14.6 Install the holder and coupon assembly in a suitable line or in a bypass piping arrangement as shown in Fig. 1.

14.7 Adjust the rate of flow of water in the test piping to a rate that gives a flow velocity that corresponds to the normal

flow in those parts of the system under prime consideration. Normally, the flow velocity will be in the range from 0.4 to 1.8 m (1.5 to 6 ft)/s. Check and readjust the flow as necessary to maintain the desired rate. See Table 1.

14.8 Remove specimens from the system at chosen intervals. Since the corrosion will be high initially and then fall to a lower, nearly constant rate, two time series should be chosen.

14.8.1 Use short time intervals for the first time series in order to establish the rate at which passivity occurs. Removal of three or four sets of coupons at 4 to 7-day intervals is recommended.

14.8.2 Use long time intervals for the second time series in order to establish the mean steady-state corrosion rate. Removal of the first coupons after 1 month and the remaining coupons at 1 to 3-month intervals is recommended.

14.9 Protect the specimen if it cannot be examined, cleaned, and reweighed immediately after removal from the system. Dry between paper towels. Store the ferrous metal coupons in separate envelopes made from vapor phase inhibitor-impregnated paper or wrap carefully in plastic film. For nonferrous metal coupons, wrap carefully in plastic film. The interim period between removal of specimens and reweighing should be kept to a minimum and in no case should it exceed 1 week.

14.10 Examine the specimen and record either by photograph or by description the appearance of the specimen, paying particular attention to the amount and nature of any adherent deposit. Chemical analysis of the deposit may be performed in accordance with Practices D2331, but this step is optional.

14.11 For ferrous coupons, use one of the following alternative procedures for cleaning the coupon prior to reweighing.

14.11.1 Clean the coupons as well as possible with a plastic knife. Remove oily and greasy deposits in accordance with Practice . Remove remaining loose corrosion products by brushing with a bristle brush. Remove corrosion products in accordance with Practice .

14.12 Subject a weighed blank coupon of the same material to the identical cleaning procedure used for the test specimens and reweigh to determine the blank correction factor to be applied to the coupon weight losses.

14.13 Reweigh each coupon to the nearest 0.1 mg.

14.14 If pitting (see 7.2) is apparent on the coupon, measure the depth of the pits in a representative area with the dial depth

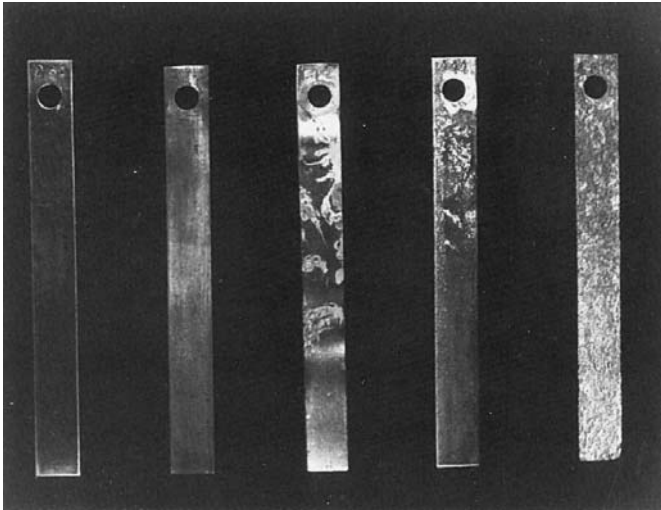


FIG. 2 Recording of Coupon Appearance

gage. Record the resultant values as pit depths. The number, size, shape, and distribution of the pits shall also be determined and recorded.

14.15 Record the appearance of the cleaned, weighed coupon as “protected,” “moderate localized,” “moderate pitting,” or “severe pitting,” by comparing the coupon with the illustrations given in Fig. 2.

15. Calculation

15.1 Corrosion rates are normally calculated as an average penetration in millimeters per year (or as mils per year) or millimeters per year assuming that localized attack or pitting is not present and that the corrosion is general (4).

15.2 Calculation of the Corrosion Rate:

15.2.1 To calculate the corrosion rate (4-6) in mm per year for each coupon, use Eq 1:

$$\text{Corrosion Rate (mm per year)} = \frac{K \times W}{a \times t \times d} \quad (1)$$

where:

- K = a constant with the value 8.76×10^4 ,
- W = weight loss, g,
- d = density of the metal, g/cm^3 ,
- a = exposed area of coupon, cm^2 , and
- t = time, hrs.

15.3 The densities of various metals (g/cm^3) are:

Admiralty brass	8.17
Copper	8.9
Yellow brass	8.02
Aluminum	2.70
Low carbon steel	7.85
Lead	11.34

15.4 Calculate the pitting rate using Eq 2:

$$\text{Pitting Rate, mm per year} = \text{maximum pit depth} \times 365/T \quad (2)$$

where:

T = exposure time, days.

15.5 To convert from mm per year to mils per year, multiply by 39.4.

15.6 See Practice for other values of the rate constant K that are useful for converting the corrosion rate to other units.

16. Interpretation of Results

16.1 It should be recognized that the following deviations between the coupons and the corresponding material of construction may lead to the following erroneous interpretations:

16.1.1 Deviations in composition or surface preparation,

16.1.2 Deviations in velocity and direction of flow, and

16.1.3 Deviations in crevices, deposits, or biological growths.

17. Quality Control

17.1 The coupons should come from a reliable and consistent source. The alloy must meet ASTM specifications.

17.2 All handling steps of the coupons before and after service must be very consistent and repeatable. The coupons should not be handled with bare fingers. This can affect the results by transferring oils from the fingers to portions of the coupon. This can prevent consistent contact of the water with all portions of the coupon surface.

17.3 The test is designed to be conducted at a single flow rate. However, process conditions may impact flow rate. Changes in process conditions can result in periods of low flow or even periods of no flow (stagnant conditions). Periods of low flow or stagnant conditions should be noted in the report.

17.4 After removal, the coupon should be air dried before being placed back in the envelope.

17.5 The accuracy of the analytical balance should be checked by weighing a calibrated weight.

18. Precision and Bias

18.1 The precision and bias of this test method for measuring corrosivity of water in the absence of heat transfer (weight loss method) are as specified in Practice G1. The Precision and Bias statement contained in Practice G1 is repeated in X1 for the benefit of the reader.

18.2 Because this test method is for a continuous sampling method, it is exempt from the requirement of a round-robin test in accordance with Practice D2777, paragraph 1.3.3.

19. Keywords

19.1 bypass corrosion specimen rack; cooling water corrosion test; corrosion test specimen; coupon corrosion test; distribution water corrosion test method

ANNEXES**(Mandatory Information)****A1. INSTALLATION OF THE BYPASS SPECIMEN (TEST) RACK**

A1.1 When tapped into a horizontal pipe run of the recirculating water system, the tap should be into the side if the pipe, not the top or bottom. For vertical runs, any side is acceptable.

A1.2 To minimize turbulence at the specimen, the test rack should be constructed and installed so that the flow of water is from the specimen mounting plug towards the corrosion specimen.

A1.3 Attach the test rack to a wall or column with proper support. DO NOT suspend it from the supply and return piping connections alone.

A1.4 To prevent air binding, pipe the test rack so that water will flow upward through it, and in such a manner that it will remain full of water at all times and not backdrain when the main recirculating system shuts down.

A1.5 For measurement of corrosion at points of highest temperature in the recirculating system, the water supply to the test rack should be from the exit of the heat exchanger(s). Average corrosion rate measurements may be obtained by supplying the test rack with water from the main riser, and so forth.

A1.6 Return water may be piped to the recirculating pump suction header, cooling tower basin, or other suitable point with sufficiently low pressure to insure proper flow through the rack.

A1.7 Flow velocities should be from 0.45 to 1.8 m (1.5 to 6 ft)/s and not be variable. Avoid extremely high or low velocity conditions. A suitable flow control device should be installed on the leaving side of the test rack to insure constant velocity.

A1.8 To facilitate installation and removal of corrosion specimens, shutoff valves shall be installed on the inlet and outlet to the test rack.

A2. INSTALLATION OF CORROSION (TEST) SPECIMENS

A2.1 Keep the test specimen in the special treated envelope before and after exposure.

A2.2 Use clean latex or rubber gloves when handling the test specimen. DO NOT leave fingerprints on it. Do not use tools that will scratch or gouge the test specimen. Fingerprints and tool marks will lead to false corrosion readings.

A2.3 Attach the test specimen to the Specimen Mounting Plug using suitable hardware as described in 11.2.

A2.4 Test specimens should always be installed so the water flows first over the plastic mounting rod and then over the coupon. Water flowing directly onto the specimen may cause erosion-corrosion and lead to false weight loss measurements.

A2.5 Use only TFE tape on the threads of the mounting plug. Do not use pipe dope.

A2.6 Insure that the test specimen does not touch the interior pipe wall in the test rack.

A2.7 The witness slot on the mounting plug should be parallel with the flat surface of the test specimen. Install the mounting plug in the tee and align the witness slot (and specimen) in the VERTICAL position as shown in Fig. 1.

A2.8 A log sheet should be used to record the date of installation, system name and location, specimen identification number and metallurgy.

A3. REMOVAL OF CORROSION (TEST) SPECIMENS

A3.1 Typical specimen exposure times are 30, 60, or 90 days, with 30 days being the recommended minimum. Longer exposures may be used in systems with low corrosion rates.

A3.2 Mounting plugs may be removed for brief visual inspection of the specimens. Care should be taken not to clean or touch the coupon during inspection. It should be immediately returned to the test rack and flow restored.

A3.3 At the end of the desired exposure period, the test specimen should be carefully dismantled from the holder and immediately dried with a blast of hot air or blotted with a paper towel or clean rag. **DO NOT CLEAN**. Reinsert the specimen in the envelope in which it was received.

A3.4 Add the date of removal to the log sheet in **A2.8** and return the specimen and log sheet to the laboratory for cleaning and evaluation.

APPENDIX

(Nonmandatory Information)

X1. PRECISION AND BIAS STATEMENT FROM PRACTICE

X1.1 The factors that can produce errors in mass loss measurement include improper balance calibration and standardization. Generally, modern analytical balances can determine mass values to ± 0.2 mg with ease and balances are available that can obtain mass values to ± 0.02 mg. In general, mass measurements are not the limiting factor. However, inadequate corrosion product removal or overcleaning will affect precision.

X1.2 The determination of specimen area is usually the least precise step in corrosion rate determinations. The precision of calipers and other length measuring devices can vary widely. However, it is not generally necessary to achieve better than ± 1 % for area measurements for corrosion rate purposes.

X1.3 The exposure time can usually be controlled to better than ± 1 % in most laboratory procedures. However, in field exposures, corrosive conditions can vary significantly and the estimation of how long corrosive conditions existed can

present significant opportunities for error. Furthermore, corrosion processes are not necessarily linear with time, so the rate values may not be predictive in the future deterioration, but only are indications of the past exposure.

X1.4 Regression analysis on results, as are shown in Fig. 1 (of Practice **G1**) can be used to obtain specific information on precision. See Guide **G16** for more information on statistical analysis.

X1.5 Bias can result from inadequate corrosion product removal or metal removal caused by overcleaning. The use of repetitive cleaning steps, as shown in Fig. 1 (of Practice **G1**), can minimize both of these errors.

X1.6 Corrosion penetration estimations based on mass loss can seriously underestimate the corrosion penetration caused by localized processes such as pitting, cracking, crevice corrosion, and so forth.

REFERENCES

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