Designation: D 2688 – 05

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 D 2688; 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.

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 *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]

D 1129 Terminology Relating to Water

D 2331 Practices for Preparation and Preliminary Testing of Water-Formed Deposits

D 2777 Practice for Determination of Precision and Bias of Applicable Methods of Committee D19 on Water

G 1 Practice for Preparing, Cleaning, and Evaluating Corrosion Test Specimens

G 16 Guide for Applying Statistics to Analysis of Corrosion Data

3. Terminology

3.1 *Definitions:* For definitions of terms used in these test methods, refer to Terminology D 1129.

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 methods 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) (for example, drilling, reaming, and cutting specimens).

7. Types of Corrosion

7.1 *General Corrosion* is characterized by uniform attack of the metal over the entire surface.

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[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 of 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.

7.2 *Pitting* is 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* is 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 D 2331. 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 1 in. Schedule 40 carbon steel or Schedule 80 PVC or CPVC pipe.

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.

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 mm^2(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 (0.019-in.) hole with its center about 3 mm (⅛ 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.

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[3] *Metals Handbook*, Vol 1, American Society for Metals, Metals Park, OH 44073, 1961, p. 430.

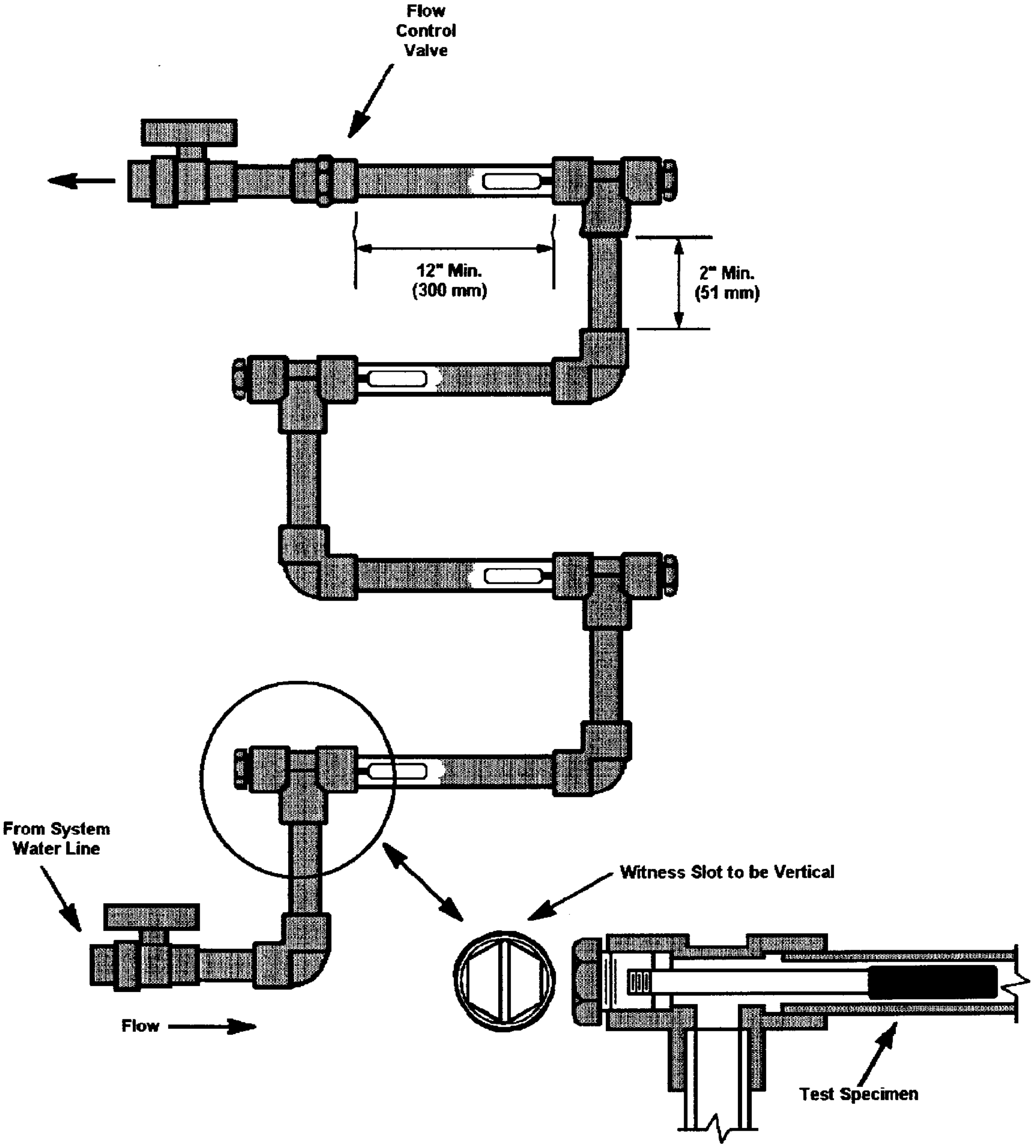

FIG. 1 Installation of Corrosion Coupons

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 41⁄2 by 1⁄4 in.) from a commercial foundry or elsewhere.

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 µin.

13.4.2 Drill a 7-mm (9⁄32-in.) hole with its center about 8 mm (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 G1.

14. Procedure

14.1 Weigh the clean, dry specimens on an analytical balance to the nearest 0.1 mg.

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 ferrous metal coupons in separate envelopes made from vapor phase inhibitor-impregnated paper. Store nonferrous metal coupons in sealed plastic envelopes or wrapped in plastic film.

14.4 Attach the coupon to the mounting rod, 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 Install the holder and coupon assembly in a suitable line or in a bypass piping arrangement as shown in Fig. 1.

14.6 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.

14.7 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.

14.7.1 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.

14.7.2 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.

14.8 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.

14.9 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 D 2331, but this step is optional.

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

14.10.1 Clean the coupons as well as possible with a plastic knife. Remove oily and greasy deposits in accordance with Practice G1. Remove remaining loose corrosion products by brushing with a bristle brush. Remove corrosion products in accordance with Practice G1.

TABLE 1 Flow vs. Velocity

Flow Rate	Velocity Sched 80 PVC Rack	 Sched 40 Carbon Steel Rack
19 lpm (5.0 gpm)	0.67 m/s (2.2 ft/s)	0.58 m/s (1.9 ft/s)
30 lpm (8.0 gpm)	1.1 m/s (3.6 ft/s)	0.91 m/s (3.0 ft/s)
37.9 lpm (10.0 gpm)	1.4 m/s (4.5 ft/s)	1.3 m/s (3.7 ft/s)
45.4 lpm (12.0 gpm)	1.6 m/s (5.4 ft/s)	1.4 m/s (4.4 ft/s)

14.11 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.

14.12 Reweigh each coupon to the nearest 0.1 mg.

14.13 If pitting (see 7.2) is apparent on the coupon, measure the depth of the pits in a representative area with the dial depth gage. Record the resultant values as pit depths. The number, size, shape, and distribution of the pits shall also be determined and recorded.

14.14 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 mils per year or millimetres per year assuming that localized attack or pitting is not present and that the corrosion is general (**3**).

15.2 *Calculation of the Corrosion Rate*:

15.2.1 To calculate the corrosion rate (**3, 4, 5**) in mils per year for each coupon, use Eq 1:

$$\text{Corrosion Rate (mils per year, mpy)} = 22.3 \quad W/(dat) \tag{1}$$

where:

W = weight loss, mg,
d = density of the metal, g/cm^3,
a = exposed area of coupon, in.^{2}, and
t = time, days.

15.2.2 To calculate the corrosion rate in micrometers per year for each coupon, use Eq 2:

$$\text{Corrosion Rate (micrometers per year, µm/y)} = 3650\ W/(dat) \tag{2}$$

where:

W = weight loss, mg,
d = density of the metal, g/cm^3,
a = exposed area of coupon, cm ^{2}, and
t = time, days.

15.3 The specific gravities 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 3:

$$\text{Pitting rate, mils (mm) per year} = \text{maximum pit depth} \times 365/t \tag{3}$$

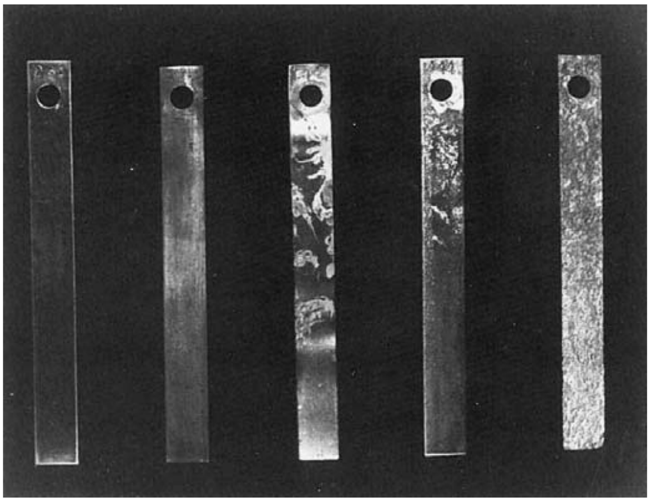

FIG. 2 Recording of Coupon Appearance

where:

t = exposure time, days.

15.5 To convert from mils per year to millimetres per year, multiply by 0.0254.

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. Precision and Bias

17.1 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 G 1. The Precision and Bias statement contained in G1 is repeated in the Appendx for the benefit of the reader.

17.2 Because this standard is for a continuous sampling method, it is exempt from the requirement of a round-robin test per Practice D 2777, paragraph 1.3.3.

18. Keywords

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

ANNEXES

A1. INSTALLATION OF THE BYPASS SPECIMEN (TEST) RACK

A1.1 When tapped into a horizontal pipe run of the recirculating water sysem, 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 my 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 dismounted 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

X1. PRECISION AND BIAS STATEMENT FROM PRACTICE G1

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 that ±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

(1) *Metals Handbook*, Vol. 3, Machining, American Society For Metals, Metals Park, OH 44073, 1967, p. 75.

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