Designation: D2688 – 23

Standard Test Method for Determination of Corrosion Rate in a Water System 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.

1. Scope*

1.1 This test method covers the determination of the corrosion rate in a water system, in the absence of heat transfer.

1.1.1 This is accomplished by measuring the weight loss of metal specimens, also called coupons, and evaluating pitting. Weight loss provides the means to calculate the average corrosion rate. Pitting is a form of localized corrosion.

1.1.2 The rate of corrosion of a metal immersed in water is a function of both the characteristics of the water itself 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 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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D1129 Terminology Relating to Water

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

G31 Guide for Laboratory Immersion Corrosion Testing of Metals

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 corrosion rate of a material in water is determined in relative, rather than absolute, terms. The relative tendency for a material to corrode is 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 tendency of water to promote or inhibit corrosion can 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 added to the water. Examples of systems in which this method can be used

[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.

*A Summary of Changes section appears at the end of this standard include, but are not limited to, open recirculating cooling water, closed chilled water, and hydronic heating systems.

5. Composition of Specimens

5.1 The specimens (coupons) 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 The following is a list of the most common types of corrosion. It is not intended to be all-inclusive.

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

7.3 *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.

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

7.4 *Crevice Corrosion*—A pertinent factor to consider in corrosion testing, since active corrosion sites can develop in such locations. Crevices can exist at threads and joints and under deposits, as well as in corrosion specimens. In this method, crevice corrosion can 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.

7.5 *Edge Corrosion*—The increased corrosion that occurs at edges of corrosion specimens, where the metal might 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 can be evaluated by measurement of the specimen dimensions previous to and following exposure. Use of a specimen of less thickness can also reduce the edge effect in weight loss.

7.6 *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 might 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, fully-immersed in contact with flowing water, for a measured length of time. After removal from the system, these coupons are examined, cleaned, and reweighed. The corrosion rate in the water system is determined from the difference in coupon weight. The depth and distribution of pits, and the weight and characteristics of the foreign matter on the coupons offer additional subjective information.

10. Interferences

10.1 Deviation in metal composition or surface preparation of the coupons can 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, can constitute a source of error in the results.

10.3 Deviations in the velocity and direction of flow past the coupons can 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 can alter local corrosion effects and 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 can 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 Apparatus*—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. The other end is to have a flat surface and a hole at the other end suitable for attachment of the test specimen. The pipe plug shall have a suitable witness mark to indicate the orientation of the test specimen when it is mounted in the bypass rack. The specimen mounting apparatus is shown in Fig. 1.

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 (¾-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 can trap more debris. If a 16.8 mm

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

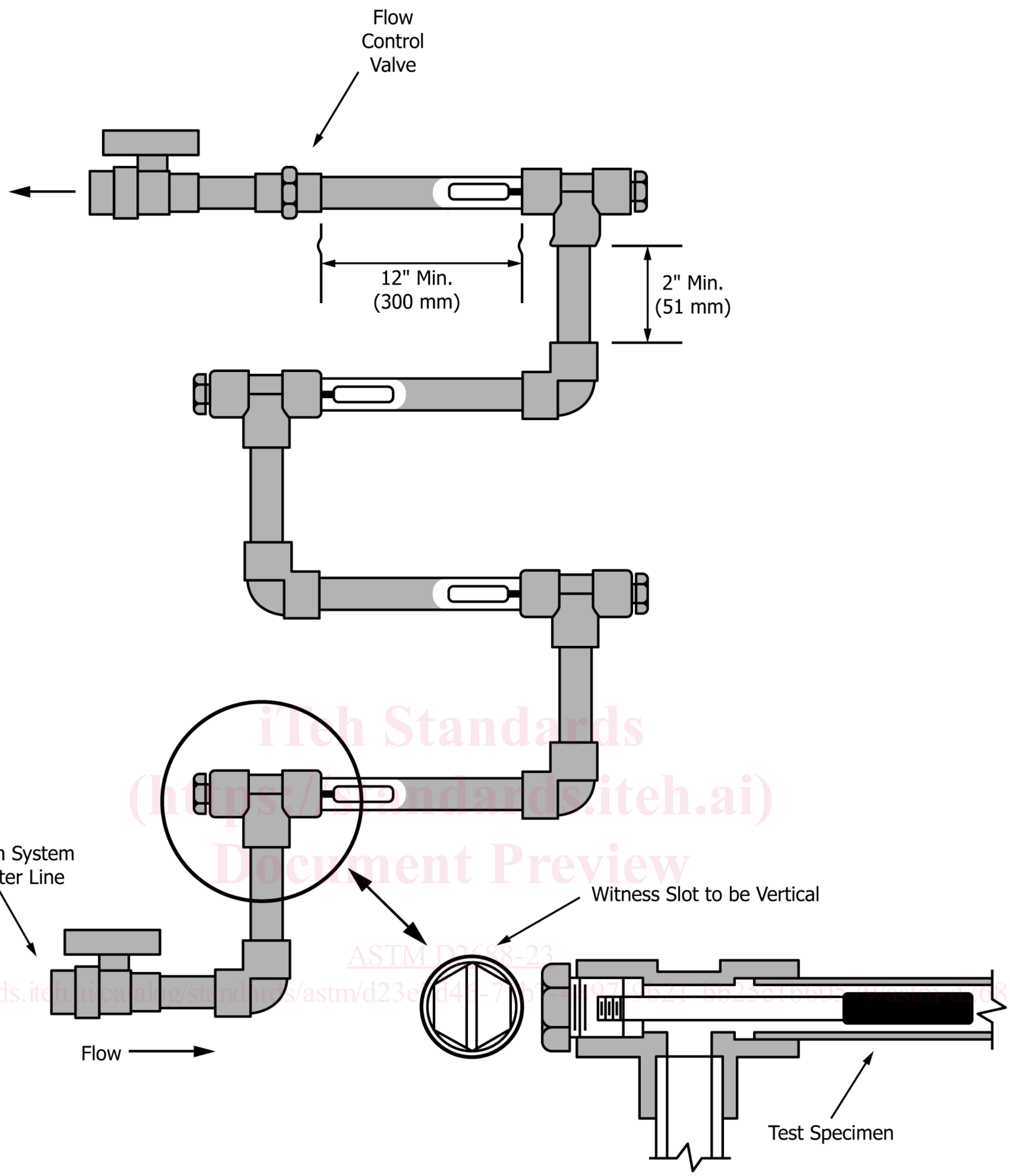

FIG. 1 Installation of Corrosion Coupons

(¾-in.) rack is used, a strainer should be installed ahead of the rack to prevent debris from entering the rack.

11.5 *Dial Depth Gauge*—A gauge 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.

13. Test Specimen Preparation

13.1 Test specimens should be manufactured from the material of interest, or a close approximation, to ensure that their corrosion behavior is consistent with that of the structure of interest.

NOTE 2—Sheet stock is typically used for test specimens because it lends itself to most manufacturing processes and is an economical solution. However, specimens can be manufactured from structural components such as tank plate, pipe wall, or a finished casting. This approach is more costly but can be necessary when commercially available sheet materials do not provide a close enough match.

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)

13.2 Specimens are manufactured to a size and shape that can be easily installed into the bypass rack. Additionally, the specimens have one or more mounting holes that are sized and spaced to properly mate with the holder, fasteners, and insulators (if used.)

NOTE 3—A rectangular specimen with a size of 13 mm by 76 mm (0.5 in. by 3.0 in.) is commonly used and will fit most bypass systems. A typical thickness is 1.6 mm (0.0625 in.) for specimens made from sheet stock, whereas specimens made from plate, pipe, and casting may be left thicker to reduce the amount of machining required to achieve the final thickness. Specimens from these forms are typically left at a thickness of 3 mm (0.125 in.).

13.3 Specimens and mounting holes can be cut using standard manufacturing processes. However, consideration should be given to the process selected and any possible impact it might have on the material being cut, such as cold-working, a heat affected zone, or a recast layer. Under certain conditions these things can lead to edge attack on test specimens. If edge attack is noted on specimens after exposure, it might be desirable to use a different cutting process on future test specimens, or to utilize some method to dress the affected edges after manufacturing.

13.4 Deburr the specimen edges, including the mounting hole rim(s).

13.5 Specimens should be uniquely identified to ensure that they can be tied back to their initial weight after exposure. This is typically done by marking the specimen directly, but when this is not possible or practical, specimens can be marked using removable (non-adhesive) tags.

NOTE 4—Impact stenciling is the most common way to mark coupons because it provides good legibility, and the characters are deep enough that they remain legible after considerable corrosion of the specimen has occurred. However, other marking methods are acceptable, provided that they do not significantly affect the corrosion behavior of the specimen in some way.

13.6 Specimens can be used in the unfinished condition, or they can have a surface finish applied. Unfinished specimens will have more imperfections and can more accurately depict the corrosion behavior of a pipe or vessel wall. However, a specimen with an applied finish will provide a more consistent and repeatable result.

13.7 *Cleaning Metal Coupons*—Degrease and clean specimens in accordance with Practice G1. After cleaning, the specimens should not be handled with bare skin.

13.8 Protect the specimens from corrosion during storage by wrapping them in a suitable VCI material.

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 a metal screw and nut with insulating washers to prevent metal-to-metal contact between the coupon and fasteners.

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 m/s to 1.8 m/s (1.5 ft/s 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 specimens 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.