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AMERICAN SOCIETY FOR TESTING AND MATERIALS
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Standard Practice for Conducting the Washer Test for Atmopsheric Galvanic Corrosion[1]

This standard is issued under the fixed designation G 149; 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 practice covers the evaluation of atmospheric galvanic corrosion of any materials that can be made into washers.

1.2 The washer, or disk, test was used by H. O. Teeple in 1949[2] for a series of exposures for ASTM Committee B 03.08 on Corrosion of Non-Ferrous Metals and Alloys. Since that time, ASTM has refined the test and conducted other investigations using this practice.[3,4,5]

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:*

G 1 Practice for Preparing, Cleaning, and Evaluating Corrosion Test Specimens[6]

G 3 Practice for Conventions Applicable to Electrochemical Measurements in Corrosion Testing[6]

G 15 Terminology Relating to Corrosion and Corrosion Testing[6]

G 16 Guide for Applying Statistics to Analysis of Corrosion Data[6]

G 50 Practice for Conducting Atmospheric Corrosion Tests on Metals[6]

G 82 Guide for Development and Use of a Galvanic Series for Predicting Galvanic Corrosion Performance[6]

G 84 Practice for Measurement of Time-of-Wetness on Surfaces Exposed to Wetting Conditions as in Atmospheric Corrosion Testing[6]

G 91 Practice for Monitoring Atmopsheric SO_2 Using the Sulfation Plate Technique[6]

G 92 Practice for Characterization of Atmospheric Test Sites[6]

G 104 Test Method for Assessing Galvanic Corrosion Caused by the Atmosphere[6]

G 116 Practice for Conducting Wire-on-Bolt Test for Atmospheric Galvanic Corrosion[6]

3. Terminology

3.1 For definitions of terms used in this practice, refer to Terminology G 15. For conventions related to this practice, refer to Practice G 3.

4. Summary of Practice

4.1 The practice consists of atmospheric exposure of specimen assemblies, each consisting of a set of four washers, graduated in size with alternating anode and cathode materials, bolted together through center holes. Only the center two washers are used for the analysis, the outer washers being used only to establish the proper environment on the inner washers. Mass loss of the washers is determined after the exposure. Reference assemblies of the anode material are exposed concurrently to allow for separation of general and crevice corrosion effects from galvanic corrosion effects.

5. Significance and Use

5.1 The arrangement of the washers gives close to a 1:1 cathode-to-anode area ratio, making this test less severe than the wire-on-bolt test described in Practice G 116 and similar in severity to the plate test described in Test Method G 104. As in the plate test, typical exposure periods range from 1 to 20 years.

5.2 The major advantage of this test over other atmospheric galvanic corrosion tests standardized by ASTM is that material for this test may be easier to obtain than material for the other tests, in that only small pieces of thin sheet are required. In addition, the washer test is probably the easiest of the three tests standardized by ASTM to setup and evaluate.

5.3 The anode/cathode relationship of the materials involved need not be known beforehand, so information such as that in Guide G 82 is not required.

5.4 Unlike the plate test, the washer test yields only corrosion rate information, and it is difficult to determine corrosion morphology visually due to the shape of the components. It is

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[1] This practice is under the jurisdiction of ASTM Committee G-1 on Corrosion of Metals and is the direct responsibility of Subcommittee G01.04 on Atmospheric Corrosion.

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[2] Teeple, H. O., *Symposium on Atmospheric Corrosion of Non-Ferrous Metals, ASTM STP 175*, ASTM, 1955, pp. 89–113.

[3] Baboian, R., "Final Report on the ASTM Study: Atmospheric Galvanic Corrosion of Magnesium Coupled to Other Metals," *Atmospheric Factors Affecting the Corrosion of Engineering Materials, ASTM STP 646*, Coburn, S. Ed., ASTM 1978, pp. 17–24.

[4] Blum, W., *Symposium on Properties, Tests and Performance of Electrodeposited Metallic Coatings, ASTM STP 197*, ASTM, 1956, p. 49.

[5] *ASTM Proceedings*, Vol 41, No. 170, 1941.

[6] *Annual Book of ASTM Standards*, Vol 03.02.

also difficult to determine changes in mechanical properties with this test. Test Method G 104 is preferable for determining morphology and mechanical property changes.

6. Interferences

6.1 The manufacturing process used to make the sheet may affect corrosion potentials and polarization behavior. Material in this form may not behave galvanically the same as material in the form of interest, such as fasteners in sheet roofing for example.

7. Procedure

7.1 *The Components*:

7.1.1 The components used to construct the specimen assemblies for this test are shown in Fig. 1.

7.1.2 Washers 1.6 mm (1⁄16 in.) thick of one material are manufactured with outside diameters of 25.4 mm and 33.5 mm (1.00 in. and 1.32 in.), while the other material in the galvanic couple is made into washers of identical thickness with outside diameters of 30.0 mm and 36.6 mm (1.18 in. and 1.44 in.). Washer dimensions are critical to maintaining the 1:1 area ratio

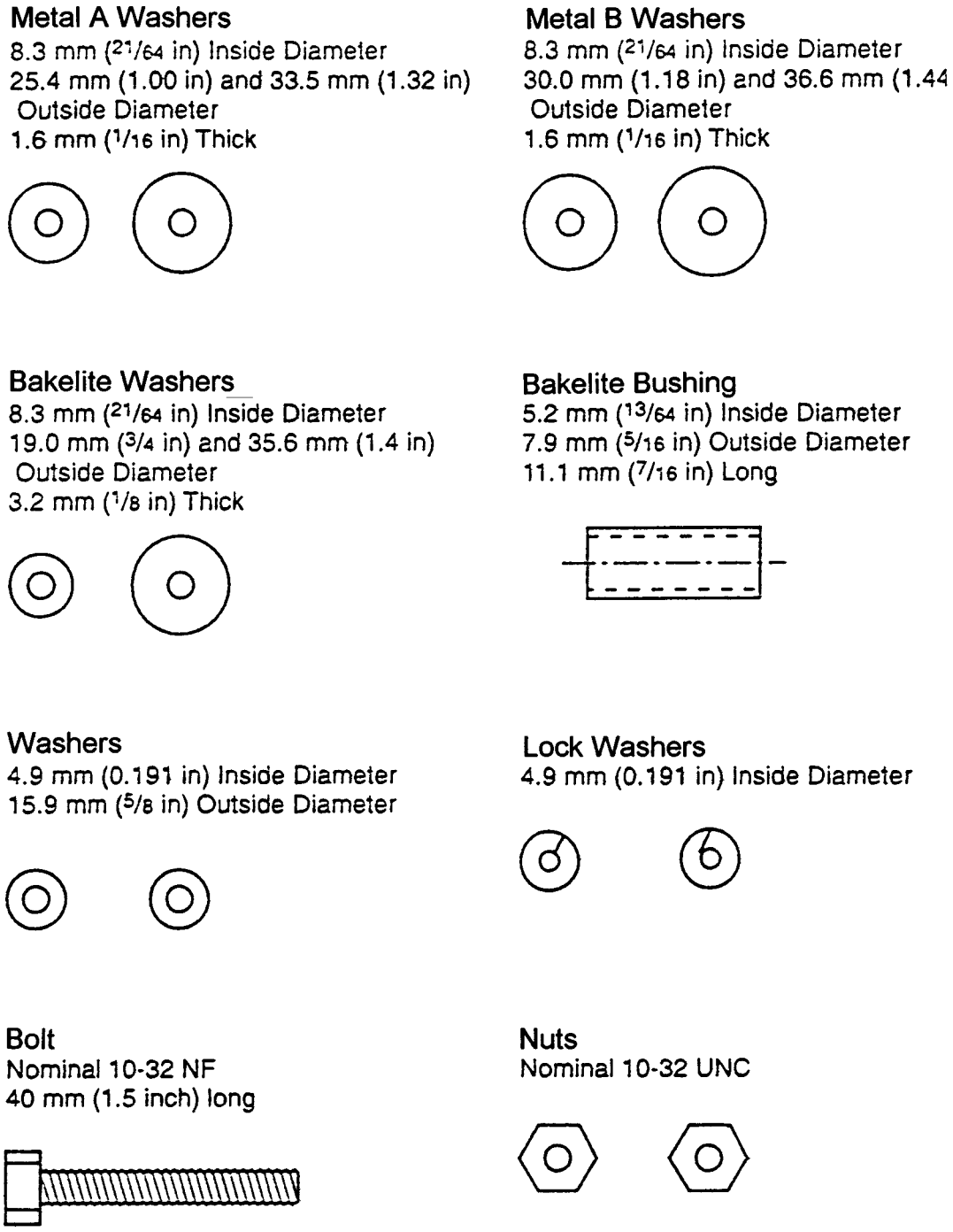

FIG. 1 Components for Making Washer Exposure Assemblies

fixed by the geometry. Thickness should be adjusted by surface grinding, if required.

7.1.3 Bakelite washers 3.2 mm (⅛ thick by 19.0 mm and 35.6 mm (0.75 in. and 1.40 in.)) outside diameter are also manufactured. Also used in the assembly is a Bakelite bushing 5.2 mm (13⁄64 in.) inside diameter and 7.9 mm (5⁄16 in.) outside diameter, 11.1 mm (7⁄16 in.) long. Other materials besides Bakelite may be used provided they are non-conductive, hard, and are not affected by moisture.

7.1.4 Two 15.9 mm (⅝ in.) outside diameter end washers and a 4.8 mm (3⁄16 in.) by 38 mm (1.5 in.) bolt with two nuts and lockwashers complete the list of materials. The bolts, end washers, lockwashers, and nuts may be made of any material provided that the material will not degrade in the atmosphere for the duration of the exposure. Alloy 400 (UNS N04400) and titanium alloys are usually sufficient for more aggressive atmospheres, while aluminum of austenitic (18 % Cr, 8 % Ni) stainless steels may be sufficient for less aggressive atmospheres.

7.1.5 All washers of all test materials have a central hole just large enough to clear the 7.9 mm (5⁄16 in.) diameter bushing. The end washers should have an inside diameter just sufficient to clear the 4.8 mm (3⁄16) diameter bolt. Washers should not be made by punching directly to the final dimensions, as this introduces a deformed area near the edge. Washers may be made by first punching out disks a minimum of 3 mm (⅛ in.) diameter oversize and machining to final dimensions, then drilling holes in the disk centers. This procedure should avoid this problem.

7.1.6 Remove metal burrs from the edges of the specimens and bolt holes. All surfaces should be free from visible defects such as heat-treatment scale, blisters, cracks, porosity, scratches, and so forth. A surface finish of 0.4 to 0.5-µm (16 to 20 micro in.) is recommended.

7.1.7 Do not mark the specimens, since there is no appropriate place to do so, however metal tags may be affixed to the completed assemblies outside of the Bakelite washers, if desired.

7.1.8 Additional washers of the anode material must be prepared to enable the construction of reference assemblies, where all four washers are made of the anode material and exposed under identical conditions to the test assemblies. Where the anode material is not known beforehand, reference assemblies of both materials should be constructed. The reference assemblies are used to assess non-galvanic effects such as general or crevice corrosion, or exfoliation.

7.1.9 For reasonable statistical validity, at least three assemblies of each type should be prepared and tested for each exposure duration evaluated.

7.2 *Making the Assemblies*:

7.2.1 All parts should be thoroughly cleaned and degreased before assembly, according to Practice G 1. After degreasing, the plates should only be handled by the edges while wearing clean, cotton gloves.

7.2.2 If the relative anode/cathode relationship of the materials is not known at the start of the test, all plates should be massed before assembly, otherwise, only the anode plates need be massed.

7.2.3 The specimens are next assembled as shown in Fig. 2. The bolt should be tightened firmly with a wrench until good electrical contact is achieved between plates. Insufficient torque will cause too high a resistance between the washers, and too much torque will crack the bushing and cause the bolt to short to the washers. A good rule of thumb is to tighten until all components are in contract, then tighten an additional one quarter turn.

7.2.4 Verify an electrical resistance of less than 1 ohm between neighboring washers by the use of a resistance meter. Also, verify electrical insulation of the bolt from the washers, with the measured resistance no lower than 10 000 ohms. Repeat these electrical resistance checks on dry assemblies occasionally throughout the specimen exposure period, and if the resistance increases, re-tighten the bolts without disturbing the assemblies.

7.3 *Mounting and Exposure*:

7.3.1 Mount both the test and reference assemblies vertically in holes drilled in metal angle iron and held in place by lockwashers and nuts as shown in Fig. 3.

7.3.2 Mount the angle iron horizontally on racks such as described in Practice G 50.

7.3.3 Typical exposure periods range from 1 to 20 years, with removals spaced at logarithmic intervals such as 1, 2, 5, 10, and 20 years.

8. Measurements

8.1 It is desirable to characterize or monitor the atmospheric site during test by using one or more of Practices G 84, G 91, or G 92.

8.2 After exposure, visually inspect the washer assemblies. In particular, comparisons between the control and reference assemblies should be made. Visual examination should be made for tarnishing, the amount and color of corrosion products, and the character of attack (uniform, crevice, edge, and so forth).

8.3 Next, disassemble the assemblies and note any additional observations, such as the condition of the contacting surfaces.

8.4 Clean the washers following the procedures in Practice G 1, rinse, dry, and store them in a dessicator for 24 h (to insure complete drying) prior to massing.

8.5 Determine final mass for mass loss calculations. If desired, metallographic samples can be taken from the washers to determine if the corrosion is intergranular, if exfoliation has occurred, and so forth.

9. Calculation and Interpretation of Results

9.1 The washers exposed in assemblies with identical materials are used for reference since they will have experienced no galvanic effects, while the test washers exposed on assemblies with alternating anode and cathode materials will have experienced additional galvanic action. It is the difference between the mass loss of the reference washers and the test washers which is an indication of galvanic corrosion.

9.2 Determine galvanic effects by calculating the percent difference in the mass loss between anode washers in the test and reference assemblies as indicated in Eq. 1:

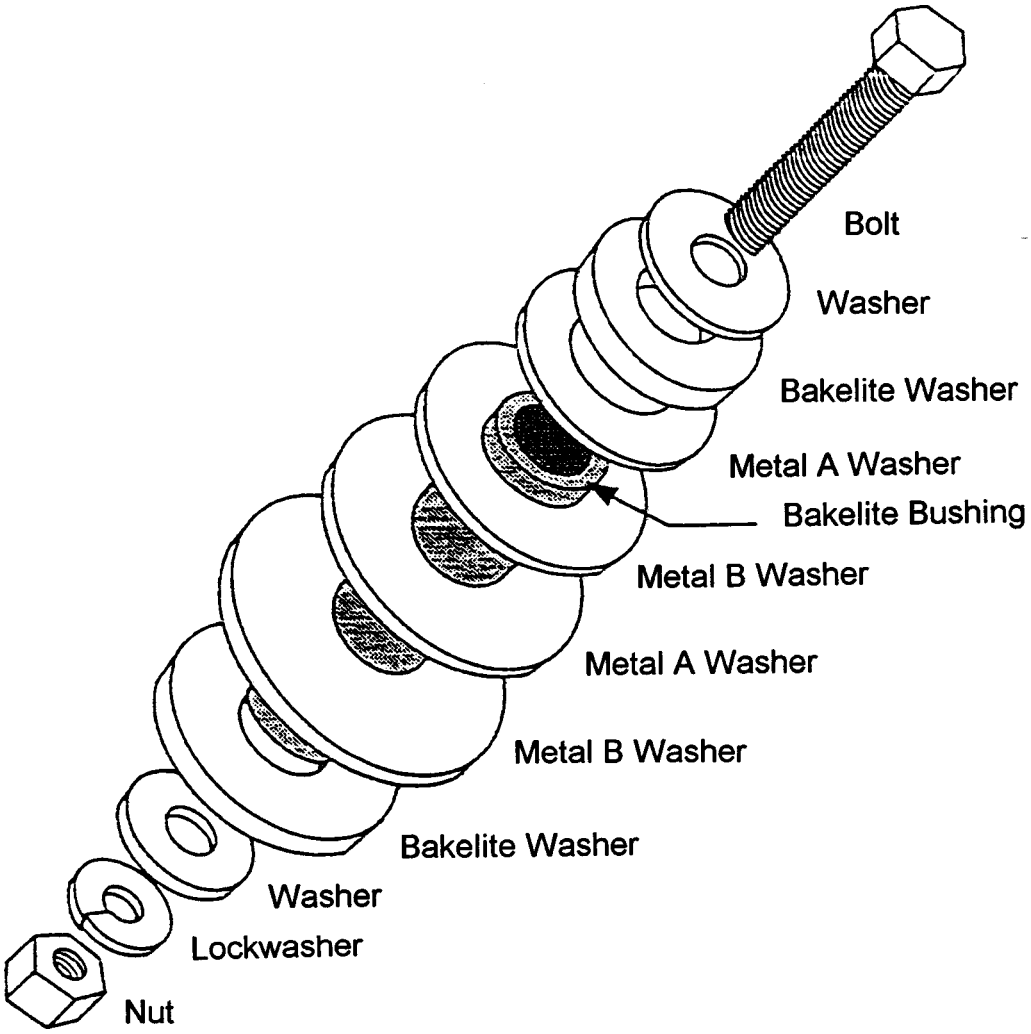

FIG. 2 Exploded View of Washer Bi-metal Assembly

$$\textit{galvanic effect}\ (\%) = 100\left[\frac{\textit{test mass loss}}{\textit{reference mass loss}} - 1\right] \quad (1)$$

9.3 Calculate the average and standard deviation for mass loss of test specimens and reference specimens. Perform the Students t test to determine if these mass losses are significant at the 95 % confidence level. If the difference is not significant, the galvanic effect should be reported as zero. Statistical analyses of the results should be done in accordance with Guide G 16.

9.4 Depending on the material combinations selected and corrosivity of the atmosphere, longer or shorter exposure durations may be needed to get measurable mass loss or to prevent disintegration of the washers during exposure.

10. Report

10.1 Report the following information:
10.1.1 Anode material and form,
10.1.2 Cathode material and form,
10.1.3 All washer masses,
10.1.4 Exposure site location,
10.1.5 Any atmospheric conditions monitored,
10.1.6 Exposure duration,
10.1.7 Results and calculations,
10.1.8 Any unusual occurrences during the test,
10.1.9 Any unusual post exposure appearance, and
10.1.10 Statistical analyses of results if performed.

11. Variability

11.1 Variability of the results obtained from this practice will depend on the materials tested, the particular environment to which they were exposed, and the exposure duration. For this reason, no statement about intra-laboratory or inter-laboratory variability can be made.

12. Keywords

12.1 architectural materials; atmospheric corrosion; atmospheric corrosivity; corrosion; corrosion test; corrosivity; galvanic corrosion; washer test

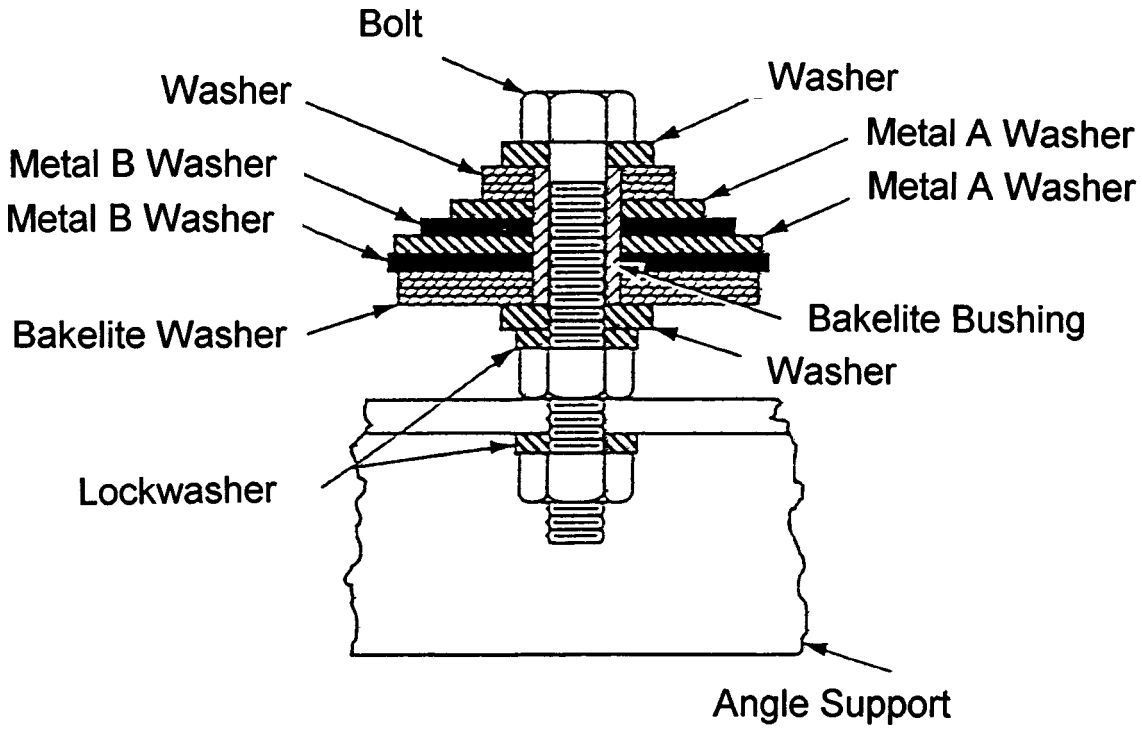

FIG. 3 Cross Section of Washer Bi-metal Assembly