Designation: D4939 – 89 (Reapproved 2020)

Standard Test Method for
Subjecting Marine Antifouling Coating to Biofouling and Fluid Shear Forces in Natural Seawater[1]

This standard is issued under the fixed designation D4939; 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 antifouling performance and reduction of thickness of marine antifouling (AF) coatings by erosion or ablation (see Section 3) under specified conditions of hydrodynamic shear stress in seawater alternated with static exposure in seawater. An antifouling coating system of known performance is included to serve as a control in antifouling studies.

1.2 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

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, health, and environmental practices and determine the applicability of regulatory limitations prior to use. For a specific hazards statement, see Section 8.*

1.4 *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]
A569/A569M Specification for Steel, Carbon (0.15 Maximum, Percent), Hot-Rolled Sheet and Strip Commercial (Withdrawn 2000)[3]
D1186 Test Methods for Nondestructive Measurement of

Dry Film Thickness of Nonmagnetic Coatings Applied to a Ferrous Base (Withdrawn 2006)[3]
D2200 Practice for Use of Pictorial Surface Preparation Standards and Guides for Painting Steel Surfaces
D3623 Test Method for Testing Antifouling Panels in Shallow Submergence

2.2 *U.S. Military Specifications:*[4]
MIL-P-24441 Primer, Epoxy (Formula 150, Formula Sheet 24441/1)
MIL-P-15931B Paint, Antifouling, Vinyl, Red (Formula 121/63)
MIL-S-22698A Steel Plate, Carbon, Structural

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*
3.1.1 *ablation, n*—in this test method, the removal or wearing away of the outer layers of coating caused by the combined action of hydrolysis and hydrodynamic shear stress. This action is often, but not necessarily, achieved by the combined effects of hydrolysis and hydrodynamic shear stress.

3.1.2 *hydrolysis, n*—softening or weakening of the outer layers, permitting the hydrodynamic shear stresses gradually to remove them, continually exposing a fresh antifouling surface.

3.1.3 *hydrodynamic shear stress, n*—the force tangential to the surface resulting from water in contact with and flowing parallel to the surface.

4. Summary of Test Method

4.1 The antifouling coatings to be tested and a control coating are applied to steel panels and exposed in natural seawater at a site where the fouling rate is high. The exposure consists of alternate static and dynamic cycles of typically 30 days each for a total length of time to be specified (such as one or two years) or until some selected degree of fouling is reached. The static exposure is conducted in accordance with Test Method D3623 except that the panels are smaller and are preformed to fit a rotating drum. The dynamic exposure consists of subjecting the test panels to a shear stress by

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rotating the drum underwater at some specified revolution rate; typically, that rate that gives a peripheral speed of 15 knots (7.6 m/s). See Note 1 for an example. Photographs and film thickness measurements (made in accordance with Test Methods D1186) are taken before exposure to seawater and, along with fouling ratings, at intervals during exposure.

NOTE 1—Consider antifouling paint for a ship about 500 ft in length that cruises at about 20 knots. From Table 2, the column for 20 knots shows the hydrodynamic shear stress, τ varying from 2.01 to 1.40 lbf/ft^2 over a flat plate with approximately the same length as the ship. From Table 1, a rotating drum with a radius of 0.75 ft with a peripheral speed of 15 knots gives a τ of 1.72 lbf/ft^2. To subject the paint to about the same range of τ as on the ship, the paint can be tested on the drum with τ of 1.72 lbf/ft^2. Because τ for the plate (and ships) decreases from the leading to the trailing edge, it is considered adequate to select τ for the drum as the approximate midrange of the plate values matched to the length and cruising speed of the vessels of interest.

5. Significance and Use

5.1 Effective antifouling coatings are essential for the retention of speed and reduction of operating costs of ships. This test method is designed as a screening test to evaluate antifouling coating systems under conditions of hydrodynamic stress caused by water flow alternated with static exposure to a fouling environment. A dynamic test is necessary because of the increasing availability of AF coatings that are designed to ablate in service to expose a fresh antifouling surface. Because no ship is underway continually, a static exposure phase is included to give fouling microorganisms the opportunity to attach under static conditions. After an initial 30-day static exposure, alternated 30-day dynamic and static exposures are recommended as a standard cycle. The initial static exposure is selected to represent vessels coming out of drydock and sitting pierside while work is being completed. This gives the paint time to lose any remaining solvents, complete curing, absorb water, and, in general, stabilize to the in-water environment.

TABLE 1 Approximate Hydrodynamic Shear Stress, τ, For Rotating Drum Apparatus, lbf/ft^2 [A]

Drum Radius, ft	Peripheral Speed of Drum, knots					
	10	15	20	22	25	30
0.75	0.82	1.72	2.91	3.48	4.39	6.14
1.0	0.78	1.64	2.78	3.31	4.19	5.86
1.25	0.75	1.58	2.68	3.20	4.05	5.68
1.5	0.73	1.53	2.60	3.11	3.94	5.52

[A] Values calculated as follows:

$\tau = \frac{1}{2} C_f \rho v^2$

$v = r \omega$

$R = \frac{vr}{\nu}$, Reynolds Number

$\frac{1}{\sqrt{C_f}} = -0.6 + 4.07 \log\left[R\sqrt{C_f}\right]$ (from Dorfman, *Hydrodynamic Resistance and the Heat Loss of Rotating Solids*, Oliver and Boyd, London, 1963, p. 176.

where

τ = shear stress on drum surface, lbf/ft^2,
ρ = water density = 1.99 slugs,
v = peripheral speed of drum surface, knots,
C_f = shear stress (drag) coefficient,
ω = Rotational speed of drum, radions/s, and
r = drum radius, ft.

5.2 This test method is intended to provide a comparison with a control antifouling coating of known performance in protecting underwater portions of ships' hulls. This test method gives an indication of the performance and anticipated service life of antifouling coatings for use on seagoing vessels. However, the degree of correlation between this test method and service performance has not been determined.

6. Apparatus

6.1 *Rotating Drum Assembly*—The basic system consists of a rotating drum assembly as shown in Fig. 1. The drum diameter and rotational rate shall be calculated to give the desired hydrodynamic shear stress. The drum diameter shall be not less than 18 in. (460 mm).

6.2 *Panels*—The panels shall be made from medium low-carbon steel plate in accordance with Specification A569/A569M, 3 mm thick by 80 to 150 by 180 to 250 mm (⅛ in. thick by 3 to 6 by 7 to 10 in.) curved to fit the drum surface as shown in Fig. 2. Panel length must be selected in order to prevent gaps greater than 1.6 mm (1/16 in.).
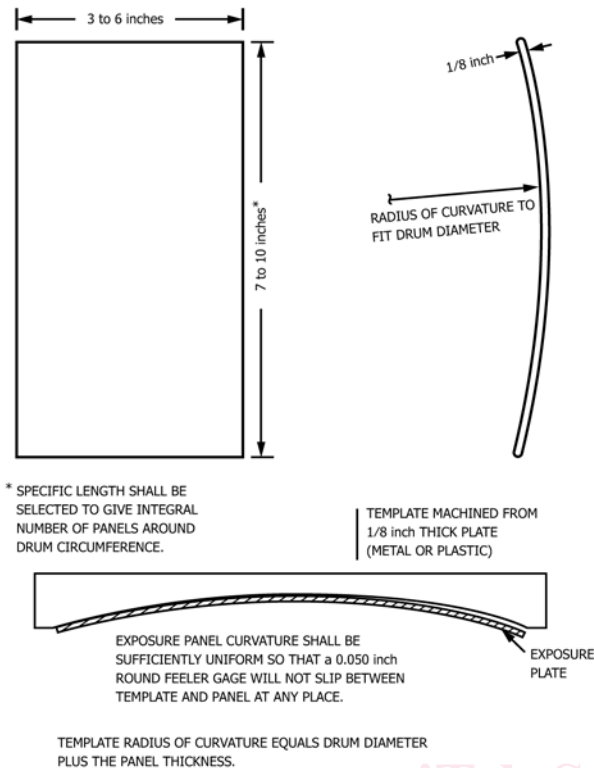
6.3 *Static Exposure Rack*—The static exposure rack shall provide firm positioning of the specimen panels so that the coated surfaces are held vertically in place in spite of the current and are electrically insulated from metallic contact with the rack or other panels. The rack shall be so positioned that the prevailing tidal currents move parallel to the panel face, and the panels are immersed to a depth of a minimum of 0.3 m (1
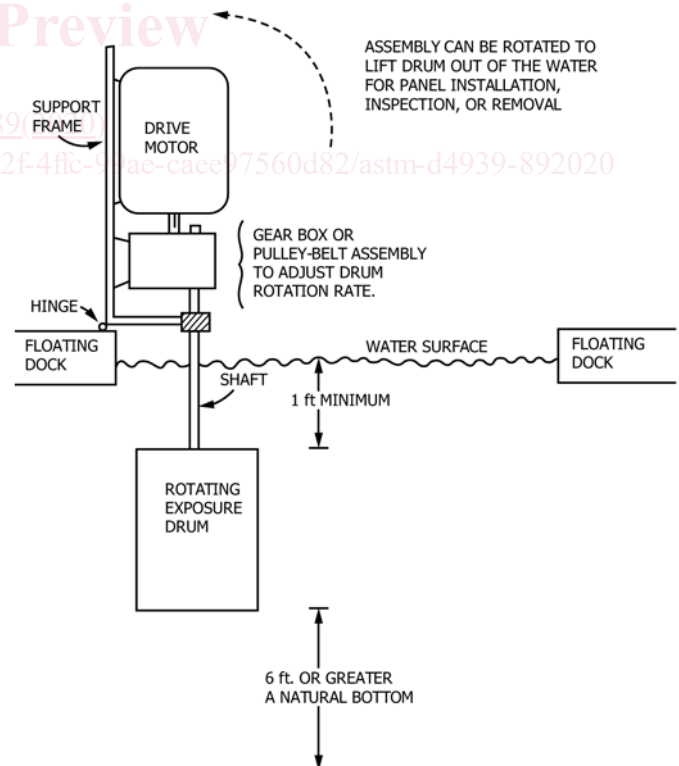
NOTE 1—Specific components and arrangements may vary to suit user and site requirements.
NOTE 2—1 ft = 305 mm.
FIG. 1 Rotating Drum Assembly

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* SPECIFIC LENGTH SHALL BE
SELECTED TO GIVE INTEGRAL
NUMBER OF PANELS AROUND
DRUM CIRCUMFERENCE.

TEMPLATE MACHINED FROM
1/8 inch THICK PLATE
(METAL OR PLASTIC)

EXPOSURE PANEL CURVATURE SHALL BE
SUFFICIENTLY UNIFORM SO THAT A 0.050 inch
ROUND FEELER GAGE WILL NOT SLIP BETWEEN
TEMPLATE AND PANEL AT ANY PLACE.

TEMPLATE RADIUS OF CURVATURE EQUALS DRUM DIAMETER
PLUS THE PANEL THICKNESS.

Note 1—1 in. = 25.4 mm.
FIG. 2 Curved Exposure Panels for Rotating Drum

ft) and a maximum of 3 m (10 ft). In a rack where panels are stacked front to back, they should be spaced at least 64 mm (2½ in.) apart, with the two end positions filled with blank panels. In a rack where the panels are mounted side by side, the distance between adjacent panels should be not less than 13 mm (½ in.).

7. Materials

7.1 *Control Coating System*—The control antifouling coating system shall consist of the following system unless an alternative control coating system is specified.

7.1.1 *Polyamide Epoxy Anticorrosive Coating,* conforming to U.S. Military Specification MIL-P-24441 (Navy Formula 150, Type I).

7.1.2 *Vinyl Antifouling Coating,* conforming to U.S. Military Specification MIL-P-15931B (Formula 121/63), B revision only.

7.2 *Test Coating System*—The antifouling coating under test may be applied to the control primer system or to any other suitable anticorrosive primer system agreed upon between the parties concerned. The application procedure is to be in accordance with the manufacturer's instructions.

8. Hazards

8.1 Antifouling paints contain toxic materials that could cause skin and eye irritation on contact and adverse physiological effects if ingested or inhaled. In the preparation of panels and the application of various types of antifouling paints the use of appropriate protective clothing and equipment is required consistent with applicable regulations, and recognized

industrial and technical standards. Do not flush spills, overspray, and unused material down the drain, but dispose of as hazardous waste.

9. Procedure

9.1 Abrasive blast clean the required number of panels (six panels for each coating system being tested) to near white metal (Grade Sa 2½ of Pictorial Standard D2200) to obtain a profile from 1 to 1.5 mils (25 to 40 µm).

9.2 On the clean, dry, uncontaminated, blast-cleaned surface apply to each standard panel one coat of epoxy polyamide primer conforming to MIL-P-24441 to give a dry film thickness of approximately 3 mils (75 µm). After about 24 h, (for temperatures above 70°F and below 90°F), apply a second coat of the primer to the panels. After a second 24-h period, apply the third coating of primer to give a total dry film thickness of approximately 9 mils (230 µm).

9.3 Apply the vinyl antifouling coating conforming to MIL-P-15931B before the final coat of epoxy paint has hardened. The epoxy should be slightly tacky when the first coat of the topcoat is applied. If the epoxy is hard (usually after 8 h) apply a tack or mist coat of 1 to 2 mils wet film thickness and allow to dry to a slightly tacky state before applying the first coat of the topcoat. Allowing a minimum of 2 h and a maximum of 24 h drying after the first coat, apply the second coat of the antifouling coating conforming to MIL-P-15931B to give a nominal dry film thickness of the antifouling paint of 4 mils (100 µm).

9.4 Before immersion, permit the second coat of antifouling coating to dry a minimum of 24 h or until fully cured in accordance with the manufacturer's recommendations and a maximum of one month, the latter time allowing for shipping the panels to the immersion site. Measure dry film thickness at ten locations on the panel in accordance with Test Methods D1186 prior to immersion at the site. To accurately locate the thickness measurement locations on the panels for repeated measurements, use a mask with two rows of five holes equally spaced over the surface.

9.5 Exposure consists of alternating static and dynamic phases at an immersion site with a high incidence of fouling (that is fouling resistance of 50 % or less determined in accordance with Test Method D3623) as indicated by attachments to a dark nontoxic surface such as slate.

9.5.1 Place the panels on the stationary exposure racks, handling them only by the edges, and expose them in accordance with Test Method D3623. Static exposure may be accomplished by leaving the panels attached to the drum and not rotating it. The time the panels are out of the water must be kept to a minimum. When any panels are removed from the stationary racks or the rotating drum, they are to be kept in containers of seawater except during actual rating, photography, or thickness measurement. If the time out of water exceeds 10 min, this fact should be recorded and reported.

9.5.2 Subject the test panels to dynamic exposure by mounting them on the drum and rotating it at a peripheral speed