Designation: D 4939 – 89 (Reapproved 1996)

AMERICAN SOCIETY FOR TESTING AND MATERIALS
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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 D 4939; 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 *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.* For a specific hazards statement, see Section 8.

2. Referenced Documents

2.1 *ASTM Standards:*

A 569/A 569M Specification for Steel, Carbon (0.15 Maximum Percent), Hot-Rolled, Sheet and Strip, Commercial Quality[2]

D 1186 Test Methods for Nondestructive Measurement of Dry Film Thickness of Nonmagnetic Coatings Applied to a Ferrous Base[3]

D 2200 Pictorial Surface Preparation Standards for Painting Steel Surfaces[4]

D 3623 Method for Testing Antifouling Panels in Shallow Submergence[4]

2.2 *U.S. Military Specifications:*[5]

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*—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*—softens or weakens the outer layers, permitting the hydrodynamic shear stresses gradually to remove them, continually exposing a fresh antifouling surface.

3.1.3 *hydrodynamic shear stress*—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 Method D 3623 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 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 D 1186) 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

[1] This test method is under the jurisdiction of ASTM Committee D-1 on Paint and Related Coatings, Materials, and Applications and is the direct responsibility of Subcommittee D01.45 on Marine Coatings.

Current edition approved April 28, 1989. Published June 1989.

[2] *Annual Book of ASTM Standards*, Vol 01.03.

[3] *Annual Book of ASTM Standards*, Vol 06.01.

[4] *Annual Book of ASTM Standards*, Vol 06.02.

[5] Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094.

TABLE 1 Approximate Hydrodynamic Shear Stress, τ, For Rotating Drum Apparatus, lbf/ft² [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

$\frac{1}{\sqrt{C_f}} = -0.6 + 4.07 \log [R\sqrt{C_f}]$ (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/ft²,
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.

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.

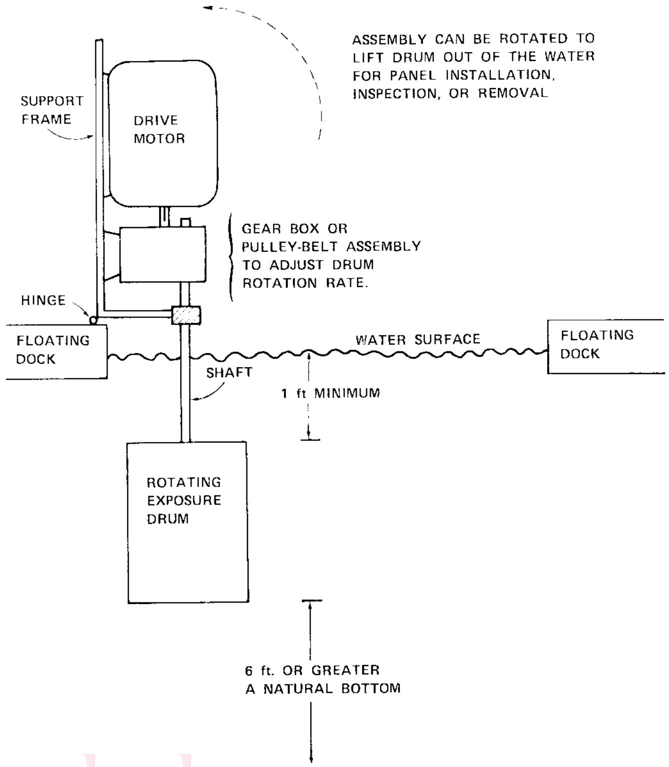
5.2 This test method is intended to provide a comparison with a control antifouling coating of known performance in protecting underwater portions of ships' hulls. This test method gives an indication of the performance and anticipated service life of antifouling coatings for use on seagoing vessels. 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 A 569/A 569M, ⅛ in. thick by 3 to 6 by 7 to 10 in. (3 mm thick by 80 to 150 by 180 to 250 mm) curved to fit the drum surface as shown in Fig. 2. Panel length must be selected in order to prevent gaps greater than 1/16 in. (1.6 mm).

6.3 *Static Exposure Rack*—The static exposure rack shall provide firm positioning of the specimen panels so that the



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

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 1 ft (0.3 m) and a maximum of 10 ft (3 m). In a rack where panels are stacked front to back, they should be spaced at least 2½ in. (64 mm) 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 ½ in. (13 mm).

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