Designation: D 4938 – 89 (Reapproved 2002)

Standard Test Method for Erosion Testing of Antifouling Paints Using High Velocity Water[1]

This standard is issued under the fixed designation D 4938; 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 erosion rates for marine antifouling paint systems immersed in flowing natural seawater.

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 hazard statement, see Section 7.

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[2]

D 823 Practice for Producing Films of Uniform Thickness of Paint, Varnish, and Related Products on Test Panels[3]

D 1889 Test Method for Turbidity of Water[4]

D 2200 Pictorial Surface Preparation Standards for Painting Steel Surfaces[5]

2.2 *U.S. Military Specifications:*[6]

MIL-P-24441 Paint, Epoxy-Polyamide

DOD-P-24647 Paint, Antifouling, Ship Hull (Metric)

DOD-P-24655 Paint, Underwater Hull, Anticorrosion (Metric)

3. Summary of Test Method

3.1 Steel panels coated with the antifouling paint system under evaluation are positioned in a high velocity water channel, similar to the type shown in Figs. 1-3, parallel to the path of the flowing water.

3.2 Exposure conditions shall include at least one series of test panels evaluated at the standard water velocity of 12 m/s and shall specify the length of time, temperature, salinity, and pH. Additional velocities may be conducted at the discretion of the customer.

3.3 Color photographs and coating thickness measurements shall be taken prior to exposure, at specified time intervals, and repeated at the end of the test for comparison purposes.

4. Significance and Use

4.1 This test method is intended to measure the erosion rates of ablative antifouling paint systems exposed to flowing water at velocities designed to subject the paint system to shear stresses experienced in service.

4.2 Measurement of erosion rates are necessary to help in the assessment of ablative antifouling paint film thicknesses required for fouling control between scheduled drydockings of ships, in the selection of materials, in producing quality assurance, and in understanding the performance mechanism.

4.3 The test data is intended to serve as a guide for predicting the service life of ablative antifouling paints in order to calculate the necessary paint thickness to fit specified deployment cycles. Erosion rates of antifouling paints in service will vary depending on such factors as: berthing location, geographic area of operation, salinity, pH, and temperature of seawater. It should also be recognized that some areas of the ship are subject to different erosion rates.

4.4 The degree of correlation between results obtained from this test method and shipboard service has not been determined.

5. Apparatus

5.1 *Water Channel*:

5.1.1 High velocity flowing water in a contained channel, similar to the type shown in Figs. 1-3, is used to induce hydrodynamic shear stresses on painted panels to determine erosion rates of ablative antifouling paints.

5.1.2 The basic apparatus consists of a four-walled channel, rectangular in cross section, through which natural seawater flows at varying linear velocities to simulate ships' speeds.

5.1.3 All wetted materials supplying seawater to and within the channel shall be nonmetallic with the following exceptions:

5.1.3.1 Channel circulating pump impellers.

5.1.3.2 Thermowells.

5.1.3.3 Channel flow orifice plate.

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[1] This test method is under the jurisdiction of ASTM Committee D01 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 11.01.

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

[6] Available from Standardization Documents Order Desk, DODSSP, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5098.

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FIG. 1 High Velocity Flow Channel

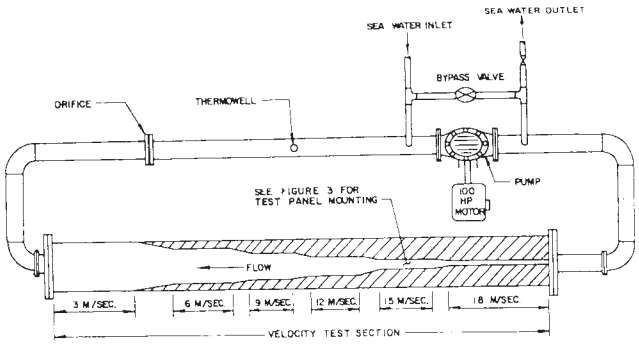
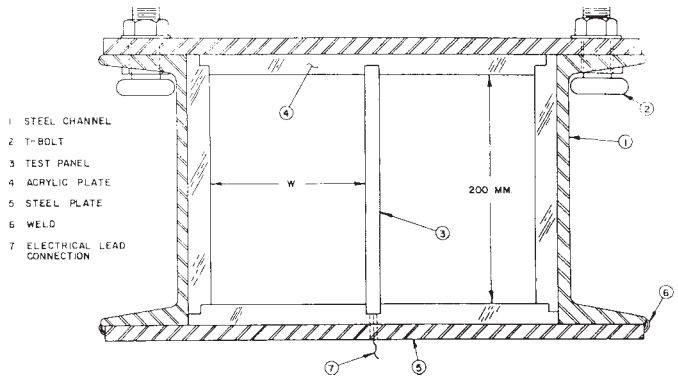


FIG. 2 Simplified Schematic of Flow Channel



W, mm	Velocity, m/s
50	18
60	15
75	12
100	9
150	6
300	3

FIG. 3 Cross-Section View of Test Panel Mounted in Flow Channel (Low Velocity Section)

5.1.4 One section of the channel shall permit testing of the panels at a standard test velocity of 12 m/s. All sections of the channel shall provide flow with fully formed turbulent characteristics. A minimum Reynolds number of 1 000 000 shall be achieved in each velocity test section. The Reynolds number, *R*, is calculated as follows:

$$R = (D \times V \times P)/U \quad (1)$$

where:

D = equivalent diameter = 4 × (area of flowing liquid/wetted perimeter), m,
V = velocity, in m/s,
P = density of medium, kg/m ^{3}, and
U = viscosity, P/s.

For a channel with a rectangular cross section and a test panel placed in the middle of the channel, the equivalent diameter would be calculated as follows:

$$4 \times [(A \times B)/(2A + 2B)] \quad (2)$$

where:
A = width of channel from side wall to panel face, m, and
B = height of channel, m.

5.2 *Erosion Rate Determination*—Erosion rates of ablative antifouling paints are determined by using noneroding reference points and measured in accordance with Section 8 with the following equipment:

5.2.1 Microtome or encapsulating/polishing equipment.

5.2.2 Microscope with photomicrographic capability.

5.3 *Seawater Requirements*:

5.3.1 Seawater will be circulated through the channel at a constant rate permitting testing at different flow velocities as shown in 9.3.

5.3.2 Natural seawater shall be continuously supplied to the channel during operation to eliminate stagnation or concentration effects. During operation of the channel the following data shall be obtained and recorded on a daily basis:

5.3.2.1 Seawater circulating rate.

5.3.2.2 Seawater salinity and pH.

5.3.2.3 Incoming seawater temperature and the channel seawater temperature.

5.3.3 Provisions shall also be made for supplying filtered seawater to the channel. A suitable filter is one which can reduce turbidity to ½ Jackson Turbidity Unit in accordance with Test Method D 1889.

5.3.4 As a minimum, the seawater chemistry in the channel, averaged over the course of the test run, shall be within the limits specified below:

	Maximum	Minimum
Salinity, ppm	35 000	27 000
pH	8.3	7.6

5.4 *Test Panels*:

5.4.1 Steel test panels conforming to Specification A 569/A 569M shall be used in the channel. The panels shall measure 18.75 cm high, 15 cm long, and 1.25 cm thick. The painted test panels shall be subjected to a double sided exposure with both sides exposed to similar hydrodynamic conditions.

5.4.2 Test panels painted in accordance with Practice D 823 are positioned vertically and parallel to the flowing water to simulate sheer stresses experienced by paints on the ship's underwater hull.

5.4.3 The coating systems shall be applied in accordance with the manufacturer's instructions for both the anticorrosion and the antifouling paints.

5.5 *Operation*—The channel shall be operated on a continuous basis during the test period except for downtime for panel inspection and seawater filtering system backwashes. The total running time of the test is defined as the total hours of actual channel operation under fully flowing conditions.

6. Application of Paints

6.1 Antifouling paints under evaluation may be applied by spray over a primer from the same manufacturer in accordance with the manufacturer's directions or over 9 mils of epoxy polyamide paint conforming to Military Specification MIL-P-24441 with an appropriate tie-coat if necessary. Application shall be in accordance with Practice D 823.

7. Hazards

7.1 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 local, state, and federal government regulations and recognized industrial and technical standards. Spills, overspray, and unused material shall not be flushed down the drain but shall be disposed of as hazardous waste.

8. Procedure

8.1 Abrasive blast a minimum of three test panels for each system being evaluated to near-white metal, Grade 2½ in accordance with Pictorial Standard D 2200, to obtain a 1.0 to 3.0 mils (25 to 75 μm) surface profile.

8.2 Apply an epoxy anticorrosion primer in accordance with Military Specifications DOD-P-24655 and MIL-P-24441, or the manufacturer's recommendations, whichever applies.

8.3 Apply an antifouling topcoat in accordance with Military Specification DOD-P-24647 or the manufacturer's recommendations, whichever applies.

8.4 Apply additional coats of antifouling paint in accordance with Military Specification DOD-P-24647 or the manufacturer's instructions, whichever applies. The last coat shall dry for a minimum of 7 days before any erosion testing.

8.5 Both sides of the painted test surfaces are provided with noneroding reference (NER) points before immersion in the test environment. The NER is an insoluble, tightly adherent vinyl or other suitable, compatible coating 2 ± 0.5 cm/diameter applied in the center of the panel which will blanket a portion of the eroding surface. The NER preserves the original outer surface of the antifouling and thus offers a reference for comparison with the eroded surface during later microscopic examination.

8.6 Take film thickness measurements before and after testing (see 5.2).

8.7 Panels are to be photographed prior to starting the test for comparison with photographs taken at the conclusion of the test.

8.8 A specimen of exposed antifouling paint is carefully removed for examination in a single flake which includes a fragment of the noneroding reference. This specimen is mounted for microscopic analysis in a suitable medium such as paraffin wax or epoxy resin. Care is required to ensure that the specimen is not damaged by solvent attack or heat evolution during this encapsulation.

8.9 Specimens are prepared for examination by microtome sectioning or by abrasive polishing to a plane surface.

8.10 Subsequent microscopic examination yields the typical image shown in Fig. 4 and Fig. 5. The material lost during the duration of the test is clearly shown as measurement *d* in Fig. 4. An actual photomicrograph is shown in Fig. 5.

9. Calculation

9.1 The material loss is expressed as the erosion rate of the ablative antifouling paint.

9.2 The erosion rate is calculated by dividing the micrometers of surface erosion by the duration of the test expressed in months at a specified speed.

9.2.1 *Example*—A 20-µm erosion in 3 months equals 6.7 µm/month.

9.3 The speed of the water in the channel expressed in metres per second is correlated to a ship's speed expressed in knots in accordance with the following table:

Speed in Channel, m/s	Speed, knots
3	5.8
6	11.7
9	17.5
12	23.3
15	29.1
18	35.0

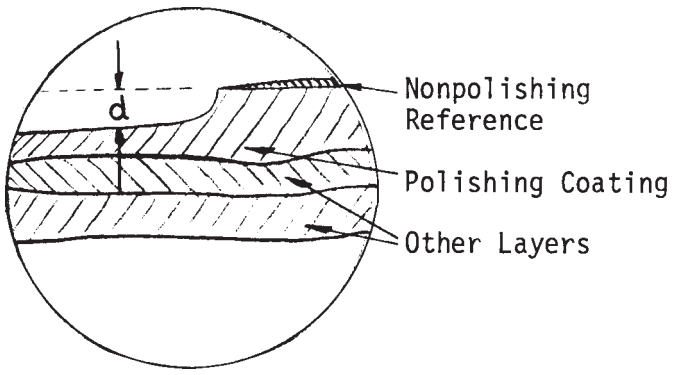


FIG. 4 Illustration of Material Lost During Testing

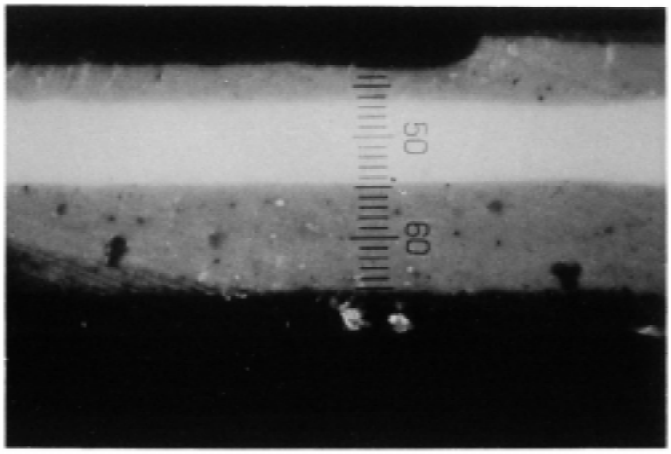


FIG. 5 Actual Microphotograph

9.3.1 *Example*—A typical erosion rate is reported as 6.7 µm/month at 17.5 knots, etc.

10. Report

10.1 The final test report shall include the following data:

10.1.1 List of the paints tested,

10.1.2 Test duration—date started and date ended,

10.1.3 Thickness readings before and after exposure. Report total paint film loss at the standard test velocity and any auxiliary test velocities,

10.1.4 Daily measurements of the seawater temperature, salinity, and the pH,

10.1.5 Speed of test water correlated to knots,

10.1.6 Observation of the overall condition of painted panel, and

10.1.7 Initial and final photographs of the test panels.

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