

METHOD 509.7
SALT FOG
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METHOD 509.7
SALT FOG

NOTE: Tailoring is essential. Select methods, procedures, and parameter levels based on the tailoring process described in Part One, paragraph 4.2.2, and Annex C. Apply the general guidelines for laboratory test methods described in Part One, paragraph 5 of this standard.

1. SCOPE.

1.1 Purpose.

The salt fog Method is performed to determine the effectiveness of protective coatings and finishes on materials. It may also be applied to determine the effects of salt deposits on the physical and electrical aspects of materiel.

1.2 Application.

Use this Method for screening purposes only to evaluate the effectiveness and quality of protective coatings and finishes on materiel and material coupons, and to locate potential problem areas, quality control deficiencies, design flaws, etc., in a relatively short period of time. Although not representative of the natural environment (see paragraph 1.3b), this test has been used to provide an indication of potential problem areas associated with the salt (marine) environment. In general, only apply this Method to materiel that will experience significant exposure (as opposed to infrequent or irregular) to high levels of salt in the atmosphere. Use of this Method to evaluate material coupons is not intended to be conducted in lieu of full assemblage testing.

1.3 Limitations.

This Method does not attempt to duplicate the complex environment but, rather, it provides a generally stressful situation that may reveal potential problem areas in materiel. Testing in the natural environment, whenever practical, may provide more valuable results. Specifically, this Method does not address:

- a. There is no relationship between this test and any real world exposure duration. The test is not intended to duplicate the effects of a marine atmosphere due to variations in chemical composition and concentrations of the various marine and other corrosive environments.
- b. It has not been demonstrated that a direct relationship exists between salt fog corrosion and corrosion due to other media.
- c. It has not been demonstrated that withstanding the effects of this test guarantees materiel will survive under all corrosive conditions. For acidic atmosphere tests, see Method 518.2. Consult ASTM G85, "Standard Practice for Modified Salt Spray (Fog) Testing" (paragraph 6.1, reference a) for information on introducing a sulfur dioxide environment. Caution: Introducing sulfur dioxide in the salt fog chamber may contaminate the chamber for future salt fog tests.
- d. This test has proven to be generally unreliable for predicting the service life of different materials or coatings.
- e. This test is not a substitute for evaluating corrosion caused by humidity and fungus because their effects differ from salt fog effects and the tests are not interchangeable.

2. TAILORING GUIDANCE.

2.1 Selecting the Salt Fog Method.

After examining requirements documents and applying the tailoring process in Part One of this standard to determine where atmospheric corrosion is anticipated in the life cycle of materiel, use the following to confirm the need for this Method and to place it in sequence with other methods.

2.1.1 Effects of Corrosive Environments.

Salt is one of the most pervasive chemical compounds in the world. It is found in the oceans and seas, the atmosphere, ground surfaces, and lakes and rivers. It is impossible to avoid exposure to salt. The worst effects occur, in general, in coastal regions. The effects of exposure of materiel to an environment where there is a corrosive atmosphere can be divided into three broad categories: corrosion effects, electrical effects, and physical effects. Consider the following typical problems to help determine if this Method is appropriate for the materiel being tested. This list is not intended to be all-inclusive.

2.1.1.1 Corrosion Effects.

- a. Corrosion due to electrochemical reaction.
- b. Accelerated stress corrosion.
- c. Formation of acidic/alkaline solutions following salt ionization in water.

2.1.1.2 Electrical Effects.

- a. Impairment of electrical materiel due to salt deposits.
- b. Production of conductive coatings.
- c. Corrosion of insulating materials and metals.

2.1.1.3 Physical Effects.

- a. Clogging or binding of moving parts of mechanical components and assemblies.
- b. Blistering of paint as a result of electrolysis.

2.1.2 Sequence Among Other Methods.

- a. General. Use the anticipated life cycle sequence of events as a general sequence guide (see Part One, paragraph 5.5).
- b. Unique to this Method. If the same test item is to be used for additional testing, it is imperative that the test item be thoroughly cleaned following the Salt Fog test. Salt deposits can interfere with the effects of other tests. In most cases recommend the salt fog test be conducted after the other climatic tests. It is generally inappropriate to conduct the salt fog, fungus and humidity tests on the same test sample because the cumulative of effects from the three environments may be unrealistic. However, if it is necessary to do so, perform the salt fog test following the fungus and humidity tests. Although generally inappropriate, if sand and dust testing is required on the same test item, perform it following salt fog testing. Recommend conducting the sequence of testing in accordance with the LCEP.

2.2 Selecting Procedure Variations.

This Method has one procedure. Possible variations are described below.

2.2.1 Salt Solution.

Unless otherwise identified, use a 5 ± 1 percent salt solution concentration (paragraph 6.1, reference b.). Use water as described in Part One, paragraph 5.16. The intent is to not introduce contaminants or acidic/alkaline conditions that may affect the test results. (See paragraph 4.5.1.1.b.)

2.2.2 Test Item Configuration.

The configuration and orientation of the test item during the exposure period of the salt fog test is an important factor in determining the effect of the environment on the test item. Unless otherwise specified, configure the test item and orient it as would be expected during its storage, shipment, or use. The listing below offers the most likely configurations that materiel would assume when exposed to a corrosive atmosphere. For test purposes, choose the most severe/critical configuration.

- a. In a shipping/storage container or transit case.
- b. Outside of its shipping/storage container but provided with an effective environmental control system that partly excludes the salt fog environment.
- c. Outside of its shipping/storage container and set up in its normal operating mode.
- d. Modified with kits for special applications or to compensate for mating components that are normally present, but are not used for this specific test.

2.2.3 Duration.

Experience has shown that alternating 24-hour periods of salt fog exposure and drying conditions for a minimum of four 24-hour periods (two wet and two dry), provides more realistic exposure and a higher damage potential than does continuous exposure to a salt atmosphere (paragraph 6.1, reference b). If this option is not acceptable (e.g., security issues, LCEP information, or commodity requirements), perform 48 hours of exposure followed by 48 hours of drying. Increase the number of cycles to provide a higher degree of confidence in the ability of the materials involved to withstand a corrosive environment.

2.2.4 Temperature.

Maintain the temperature in the chamber at 35 ± 2 °C (95 ± 3.6 °F). This temperature has been historically accepted and is not intended to simulate actual exposure situations. Other temperatures may be used if appropriate.

2.2.5 Air Circulation.

Ensure the air velocity in test chambers is minimal (essentially zero).

2.2.6 Fallout Rate.

The collection of fog shall be such that each solution receptacle collects 1 to 3 ml of solution per hour for each 80 cm² of horizontal collecting area based on at least a 16 hr period. A minimum of two salt fog collection receptacles shall be located at the perimeter of the test item one at the point nearest to the nozzle and another at the point farthest from the nozzle. Position the receptacles such that they are not shielded by the test item and will not collect drops of solution from the test item or other sources. If using multiple nozzles or towers, the same principles apply.

2.2.7 Dryout Rate.

If corrosion levels from test to test are to be compared, and accepting that the rate of corrosion is much higher during the transition from wet to dry, it is critical to closely control the rate of drying.

3. INFORMATION REQUIRED.

3.1 Pretest.

The following information is required to conduct salt fog tests adequately.

- a. General. Information listed in Part One, paragraphs 5.7 and 5.9, and Annex A, Task 405 of this standard.
- b. Specific to this Method.
 - (1) Areas of the test item visually and functionally examined and an explanation of their inclusion or exclusion.
 - (2) Salt concentration if other than 5 percent.
 - (3) Resistivity and type of initial water.
 - (4) The appropriate exposure option, i.e., 24/24/24/24-hrs, or 48/48-hrs (see paragraph 2.2.3).
- c. Tailoring. Necessary variations in the basic test procedures to accommodate environments identified in the LCEP.

3.2 During Test.

Collect the following information during conduct of the test:

- a. General. Information listed in Part One, paragraph 5.10, and in Annex A, Tasks 405 and 406 of this standard.
- b. Specific to this Method.
 - (1) Record of chamber temperature versus time conditions.
 - (2) Salt fog fallout quantities per unit of time (paragraph 4.1.4).
 - (3) Salt fog pH (paragraph 4.5.1.1b).

3.3 Post-Test.

The following post test data shall be included in the test report.

- a. General. Information listed in Part One, paragraph 5.13, and in Annex A, Task 406 of this standard.
- b. Specific to this Method.
 - (1) Areas of the test item visually and functionally examined and an explanation of their inclusion or exclusion.
 - (2) Test variables:
 - (a) Salt solution pH.
 - (b) Salt solution fallout rate (ml/cm²/hr).
 - (3) Results of examination for corrosion, electrical, and physical effects.
 - (4) Observations to aid in failure analysis (to include photographs).
 - (5) Any deviation from the approved test plan.

4. TEST PROCESS.

4.1 Test Facility.

Ensure the apparatus used in performing the salt fog test includes the following.

4.1.1 Test Chamber.

Use supporting racks that do not affect the characteristics of the salt fog mist. No part of the test setup that contacts the test item may induce electrolytic corrosion. Do not allow condensation to drip on the test item. Do not return any liquid that comes in contact with either the chamber or the test item to the salt solution reservoir. Vent the exposure area to prevent pressure buildup. Ensure the test chamber has a waste collection system so that all waste material can be analyzed prior to disposal. Dispose of any material determined to be hazardous waste in accordance with local, state and federal regulations.

4.1.2 Salt Solution Reservoir.

Ensure the salt solution reservoir is made of material that is non-reactive with the salt solution, e.g., glass, hard rubber, or plastic.

4.1.3 Salt Solution Injection System.

Filter the salt solution (Figures 509.7-1 and -2) and inject it into the test chamber with atomizers that produce a finely divided, wet, dense fog. Use atomizing nozzles and a piping system made of material that is non-reactive to the salt solution. Do not let salt buildup clog the nozzles. Suitable atomization has been obtained in chambers having a volume of less than 0.34 m^3 (12 ft^3) under the following conditions:

- a. Nozzle pressure as low as practical to produce fog at the required rate.
- b. Orifices between 0.5 and 0.76 mm (0.02 and 0.03 in.) in diameter.
- c. Atomization of approximately 2.8 liters of salt solution per 0.28 m^3 (10 ft^3) of chamber volume per 24 hours.

When chambers with a volume considerably in excess of 0.34 m^3 (12 ft^3) are used, the conditions specified may require modification.

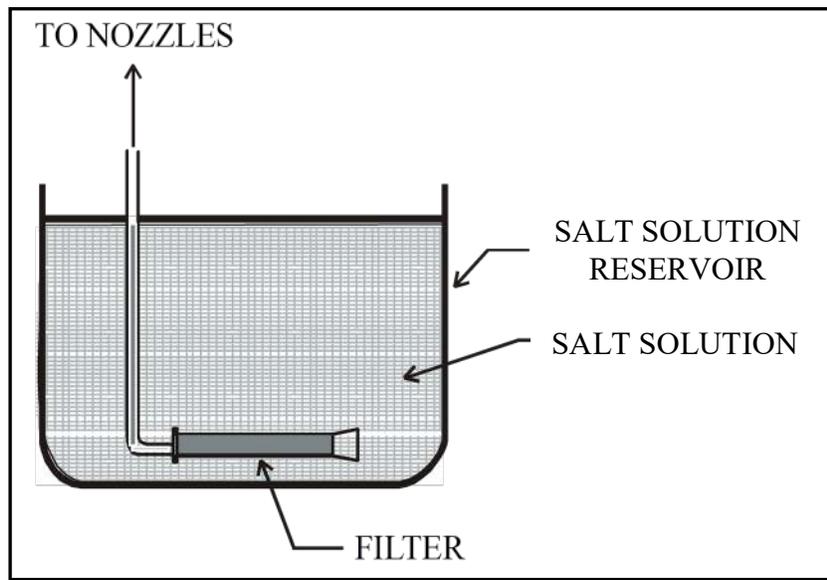


Figure 509.7-1. Location of salt solution filter.

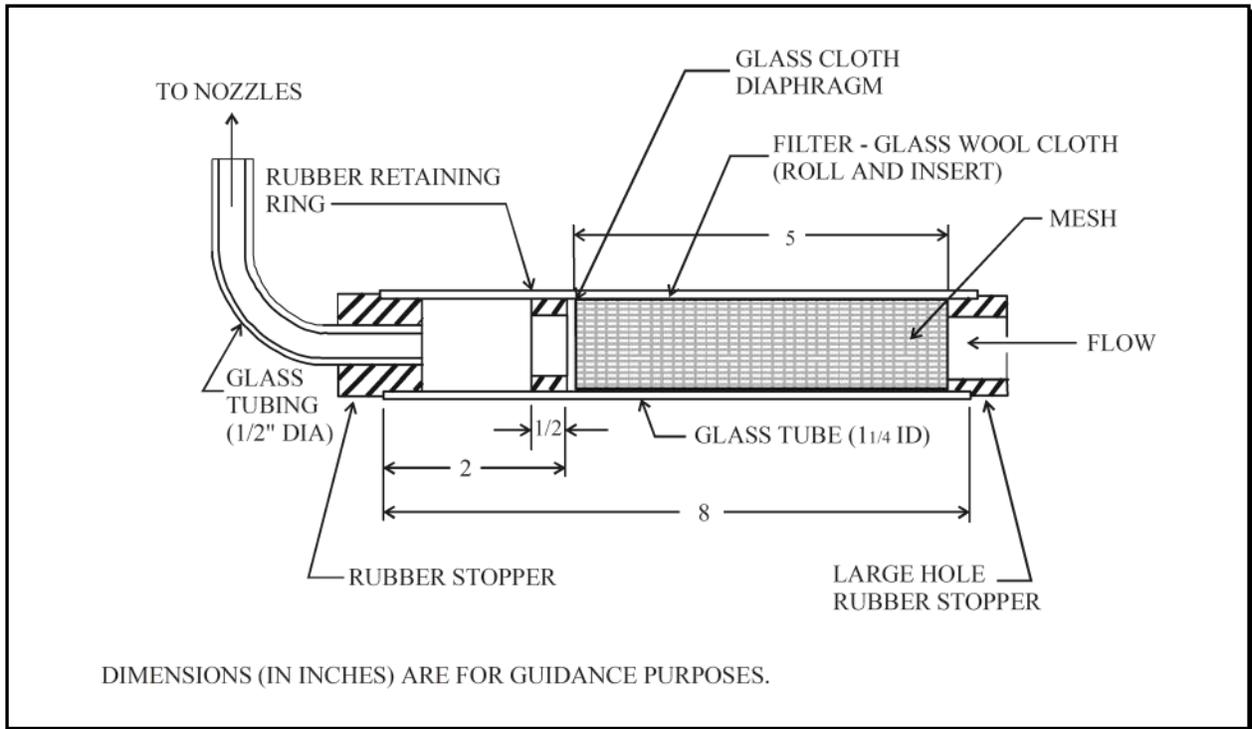


Figure 509.7-2. Salt solution filter.

4.1.4 Salt Fog Collection Receptacles.

Suitable collecting devices are glass or plastic funnels each with a diameter of 10 cm (3.94 in.). The funnel stems can be inserted into graduated cylinders (100 ml volume) or crystallizing dishes with same diameter can be used.

4.2 Controls.

Preheat the oil-free and dirt-free compressed air used to produce the atomized solution (to offset the cooling effects of expansion to atmospheric pressure) (see Table 509.7-I).

Table 509.7-I. Air pressure and preheat temperature requirements for operation at 35 °C (95 °F).

Air Pressure (kPa)	83	96	110	124
Preheat temperature (°C) (before atomizing)	46	47	48	49

4.3 Test Interruption.

Test interruptions can result from two or more situations, one being from failure or malfunction of test chambers or associated test laboratory equipment. The second type of test interruption results from failure or malfunction of the test item itself during required or optional performance checks.

4.3.1 Interruption Due to Chamber Malfunction.

- a. General. See Part One, paragraph 5.11 of this standard.
- b. Specific to this Method.
 - (1) Undertest interruption. If an unscheduled test interruption occurs that causes the test conditions to exceed allowable tolerances toward standard ambient conditions, give the test item a complete visual examination and develop a technical evaluation of the impact of the interruption on the test results. Restart the test at the point of interruption and re-stabilize the test item at the test conditions.

- (2) Overtest interruption. If an unscheduled test interruption occurs that causes the test conditions to exceed allowable tolerances away from standard ambient conditions, stabilize the test conditions to within tolerances and hold them at that level until a complete visual examination and technical evaluation can be made to determine the impact of the interruption on test results. If the visual examination or technical evaluation results in a conclusion that the test interruption did not adversely affect the final test results, or if the effects of the interruption can be nullified with confidence, restabilize the pre-interruption conditions and continue the test from the point where the test tolerances were exceeded.

4.3.2 Interruption Due to Test Item Operation Failure.

Failure of the test item(s) to function as required during mandatory or optional performance checks during testing presents a situation with several possible options.

- a. The preferable option is to replace the test item with a “new” one and restart from Step 1.
- b. A second option is to replace / repair the failed or non-functioning component or assembly with one that functions as intended, and restart the entire test from Step 1.

NOTE: When evaluating failure interruptions, consider prior testing on the same test item and consequences of such.

4.4 Test Setup.

- a. General. See Part One, paragraph 5.8.
- b. Unique to this Method. Ensure the fallout collection containers are situated in the chamber such that they will not collect fluids dripping from the test item.

4.5 Test Execution.

The following steps, alone or in combination, provide the basis for collecting necessary information concerning the test item in a salt fog environment.

4.5.1 Preparation for Test.

4.5.1.1 Preliminary Steps.

Before starting the test, determine the test details (e.g., procedure variations, test item configuration, cycles, durations, parameter levels for storage/operation, etc.) from the test plan. (See paragraph 3.1 above.)

- a. Handling and configuration.
 - (1) Handle the test item as little as possible. Prepare the test item for testing immediately before exposure. Unless otherwise specified, ensure the test item surfaces are free of surface contamination such as oil, grease, or dirt that could cause a water break. Do not use corrosive solvents, solvents that deposit either corrosive or protective films, or abrasives other than a paste of pure magnesium oxide in any cleaning methods.
 - (2) Configure the test item as specified in the test plan and insert it into the test chamber.
- b. Preparation of salt solution. For this test, use sodium chloride containing (on a dry basis) not more than 0.1 percent sodium iodide and not more than 0.5 percent total impurities. Do not use sodium chloride containing anti-caking agents because such agents may act as corrosion inhibitors. Unless otherwise specified, prepare a 5 ± 1 percent solution by dissolving 5 parts by weight of salt in 95 parts by weight of water. Adjust to and maintain the solution at a specific gravity (Figure 509.7-3 and Table 509.7-II) by using the measured temperature and density of the salt solution. If necessary, add sodium tetraborate (borax) to the salt solution as a pH stabilization agent in a ratio not to exceed 0.7g sodium tetraborate to 75 liters of salt solution. Maintain the pH of the salt solution, as collected as fallout in the exposure chamber, between 6.5 and 7.2 with the solution temperature at $+35 \pm 2$ °C (95 ± 4 °F). To adjust the pH, use only diluted chemically pure hydrochloric acid or chemically pure sodium hydroxide. Make the pH measurement either electrometrically or colorimetrically.
- c. Chamber operation verification. Unless the chamber has been used within five days or the nozzle becomes clogged, immediately before the test and with the exposure chamber empty, adjust all test parameters to those required for the test. Maintain these conditions for at least one 24-hour period or until proper operation and salt fog collection can be verified. To verify the chamber is operating properly, measure the salt fog fallout after 24 hours. Monitor and record the test chamber temperature.

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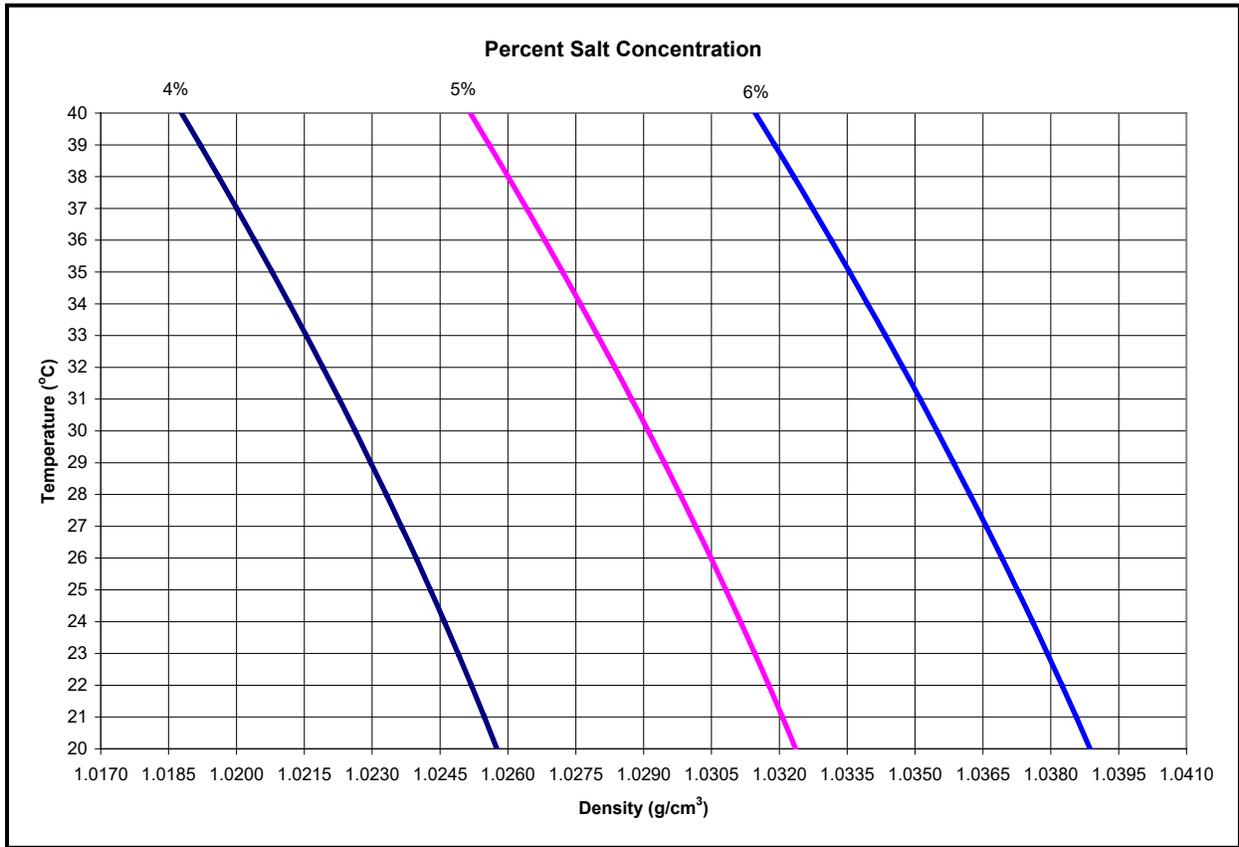


Figure 509.7-3. Variations of density of salt (NaCl) solution with temperature.¹

¹ Data derived from equation information found in paragraph 6.1, reference c.

Table 509.7-II. Temperature versus density data.²

Temperature °C (°F)	Density g/cm ³		
	4-percent Salt Concentration	5-percent Salt Concentration	6-percent Salt Concentration
20 (68)	1.025758	1.032360	1.038867
21 (69.8)	1.025480	1.032067	1.038560
22 (71.6)	1.025193	1.031766	1.038245
23 (73.4)	1.024899	1.031458	1.037924
24 (75.2)	1.024596	1.031142	1.037596
25 (77)	1.024286	1.030819	1.037261
26 (78.8)	1.023969	1.030489	1.036919
27 (80.6)	1.023643	1.030152	1.036570
28 (82.4)	1.023311	1.029808	1.036215
29 (84.2)	1.022971	1.029457	1.035853
30 (86)	1.022624	1.029099	1.035485
31 (87.8)	1.022270	1.028735	1.035110
32 (89.6)	1.021910	1.028364	1.034729
33 (91.4)	1.021542	1.027986	1.034343
34 (93.2)	1.021168	1.027602	1.033950
35 (95)	1.020787	1.027212	1.033551
36 (96.8)	1.020399	1.026816	1.033146
37 (98.6)	1.020006	1.026413	1.032735
38 (100.4)	1.019605	1.026005	1.032319
39 (102.2)	1.019199	1.025590	1.031897
40 (104)	1.018786	1.025170	1.031469

4.5.1.2 Pretest Standard Ambient Checkout.

All items require a pretest checkout at room ambient conditions to provide baseline data. Conduct the checkout as follows:

- Step 1. Prepare the test item in its required configuration in accordance with Part One, paragraph 5.8.1.
- Step 2. Record the room ambient temperature and humidity to determine if within standard ambient.
- Step 3. Conduct a complete visual examination of the test item with attention to:
 - (1) High-stress areas.
 - (2) Areas where dissimilar metals are in contact.
 - (3) Electrical and electronic components - especially those having closely spaced, unpainted or exposed circuitry.
 - (4) Metallic surfaces.
 - (5) Enclosed volumes where condensation has occurred or may occur.
 - (6) Components or surfaces provided with coatings or surface treatments for corrosion protection.
 - (7) Cathodic protection systems; mechanical systems subject to malfunction if clogged or coated with salt deposits.
 - (8) Electrical and thermal insulators.

² Data derived from equation information found in paragraph 6.1, reference c.

NOTE: Consider partial or complete disassembly of the test item if a complete visual examination is required. Be careful not to damage any protective coatings, etc. during disassembly or reassembly.

- Step 4. Document the results. (Use photographs, if necessary.)
- Step 5. Conduct an operational checkout in accordance with the test plan, and record the results for compliance with Part One, paragraph 5.9.
- Step 6. If the test item meets the requirements of the test plan or other applicable documents, proceed to Step 1 of the test procedure below. If not, resolve any problems and restart the pretest standard ambient checkout at the most reasonable step above.

4.5.2 Procedure.

- Step 1. With the test item in the chamber, adjust the test chamber temperature to 35 °C (95 °F), and condition the test item for at least two hours before introducing the salt fog.
- Step 2. Continuously atomize a salt solution of a composition as given in paragraph 4.5.1.1b into the test chamber for a period of 24 hours or as specified in the test plan (see paragraph 2.2.3). During the entire exposure period, measure the salt fog fallout rate and pH of the fallout solution at least at 24-hour intervals^{3/}. Ensure the fallout is between 1 and 3 ml/80 cm²/hr with a pH between 6.5 and 7.2.
- Step 3. Dry the test item at standard ambient temperatures and a relative humidity of less than 50 percent for 24 hours, or as otherwise specified (see paragraph 2.2.3). Minimize handling the test item or adjusting any mechanical features during the drying period.
- Step 4. If the 48/48-hrs option has been chosen, proceed to Step 5. Otherwise, at the end of the drying period, repeat steps 1 to 3 at least once.
- Step 5. After completing the physical and any electrical checkouts, document the results with photographs. See paragraph 5 for analysis of results. If necessary to aid in the follow-on corrosion examination, use a gentle wash in running water that is at standard ambient conditions, conduct the corrosion examination, and document the results with photographs.
- Step 6. Visually inspect the test item in accordance with the guidelines given in paragraph 4.5.1.2.

5. ANALYSIS OF RESULTS.

In addition to the guidance provided in Part One, paragraphs 5.14 and 5.17, the following information is provided to assist in the evaluation of the test results.

- a. Physical. Salt deposits can cause clogging or binding of mechanical components and assemblies. The extent of any deposits resulting from this test may be representative of those induced by anticipated environments.
- b. Electrical. Salt deposits could cause electrical malfunctions.
- c. Corrosion. Analyze any corrosion for its immediate and potential long-term effects on the proper functioning and structural integrity of the test item.

NOTE: Moisture remaining after the 24-hour drying period could cause electrical malfunctions. If so, attempt to relate any malfunctions to that possible in service.

6. REFERENCE/RELATED DOCUMENTS.

6.1 Referenced Documents.

- a. ASTM B117, Standard Practice for Operating Salt Spray (Fog) Apparatus.
- b. Final Letter Report of Methodology Investigation on Evaluation of Test Procedures Used for Salt Fog Tests, TECOM Project 7-CO-PB7-AP1-018, Aberdeen Proving Ground, MD 21005; July 1979.

^{3/} Recommend more frequent intervals. Repeat the interval if fallout quantity requirements are not met.

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- c. Thermodynamic Properties of the NaCl + H₂O System II. Thermodynamic Properties of NaCl(aq), NaCl.2H₂O(cr), and Phase Equilibria; Published in: Journal of Physics and Chemistry Reference Data, Volume 21, No 4, 1992.

6.2 Related Documents.

- a. Synopsis of Background Material for MIL-STD-210B, Climatic Extremes for Military Equipment. Bedford, MA: Air Force Cambridge Research Laboratories, 24 January 1974. DTIC number AD-780-508.
- b. NATO STANAG 4370, Environmental Testing.
- c. NATO STANAG 4370, Allied Environmental Conditions and Test Publication (AECTP) 300, Climatic Environmental Tests, Method 309.
- d. Army Materiel Command Pamphlet AMCP-706-116, Engineering Design Handbook, Environmental Factors.
- e. MIL-HDBK-310, Global Climatic Data for Developing Military Products.
- f. NATO STANAG 4370, Allied Environmental Conditions and Test Publication (AECTP) 230, Climatic Conditions.
- g. AR 70-38, Research, Development, Test and Evaluation of Materiel for Extreme Climatic Conditions; Department of the Army Publications Website.
- h. Egbert, Herbert W. "The History and Rationale of MIL-STD-810 (Edition 2)," January 2010; Institute of Environmental Sciences and Technology, Arlington Place One, 2340 S. Arlington Heights Road, Suite 100, Arlington Heights, IL 60005-4516.

(Copies of Department of Defense Specifications, Standards, and Handbooks, and International Standardization Agreements are available online at <https://assist.dla.mil>.)

ASTM documents are available from the ASTM International Website.

Requests for other defense-related technical publications may be directed to the Defense Technical Information Center (DTIC), ATTN: DTIC-BR, Suite 0944, 8725 John J. Kingman Road, Fort Belvoir VA 22060-6218, 1-800-225-3842 (Assistance--selection 3, option 2), <http://www.dtic.mil/dtic/>; and the National Technical Information Service (NTIS), Springfield VA 22161, 1-800-553-NTIS (6847), <http://www.ntis.gov/>.