Cyclic Corrosion Laboratory Test

1 Scope

Note: Nothing in this standard supercedes applicable laws and regulations.

Note: In the event of conflict between the English and domestic language, the English language shall take precedence.

1.1 Purpose. This procedure describes an accelerated laboratory corrosion test method to evaluate assemblies and components. The test procedure provides a combination of cyclic conditions (salt solution, various temperatures, humidity, and ambient environment) to accelerate metallic corrosion. The procedure is effective for evaluating a variety of corrosion mechanisms, such as general, galvanic, crevice, etc. The test exposure/conditions can be individually tailored to achieve any desired level of corrosion exposure.

Also, synergistic effects due to temperature, mechanical and electrical cycling, along with other stresses, can be comprehended by this test. See Deviations Section (pages 21 and 22 of this document), for typical modifications.

1.2 Foreword. The test method is comprised of 1% (approximate) complex salt mist applications coupled with high temperature and high humidity and high temperature dry off. One (1) test cycle is equal to 24 h.

A cycle is made up of the daily events or test inputs illustrated in Figure A1. A cycle normally requires 1 day to complete. The test exposure is dictated by a targeted coupon mass loss. A target range for the number of cycles necessary to meet the required mass loss is provided in Table A1 for Method 1/2 and Method 3. The coupon mass loss values are used to verify that the correct amount of corrosion has been produced by the test. In addition to meeting mass loss requirements, the test must be conducted such that the number of cycles required to meet coupon mass loss requirements falls within the specified range.

1.3 Applicability. This is a cyclic corrosion test (refer to Figure A1) used for validation testing (cosmetic and/or functional/general durability), development testing, and quality control testing, for all global environmental regions (refer to GMW15272 for specific Method and applicable region).

The basic exposures for cosmetic corrosion are found below in exposures 0, A, B, and C. Exposure D is used for functional assessment (refer to Table A1). All corrosion mechanisms are accelerated at different rates on test. Completing the test may not ensure that a component passes the functional requirement. A comprehensive failure mode analysis must be conducted to ensure all failure modes are considered and life expectancy is met.

Exposure 0: All Areas (0 Year/Initial Delivery (ID)).

Exposure A: Underbody Components.

Exposure B: Underhood Components.

Exposure C: Exterior Components/Panels, Secondary Surfaces, and Interior Components.

Exposure D: All Components (Functional).

Note: For Exposure 0 (0 Year/ID) evaluate parts at two (2) cycles of the defined exposure linked to the associated vehicle area and mounting location as defined in Table A1.

Note: Reference the Deviations section of this document for optional modifications.

2 References

Note: Only the latest approved standards are applicable unless otherwise specified.

2.1 External Standards/Specifications.

ASTM D610	ISO 12103-1
ASTM D1193	SAE 2001-01-0640
ISO 6270-2	SAE J2329
ISO 8407	

2.2 GM Standards/Specifications.

GMW14700	GMW15357
GMW15272	GMW15358
GMW15282	GMW15359
GMW15356	GMW16277

2.3 Additional References.

SAE 1008-1010

3 Resources

3.1 Facilities. Laboratory (preferably with controlled ambient conditions).

3.2 Equipment.

3.2.1 Ambient Stage. The apparatus for the ambient stage shall have the ability to maintain the following environmental conditions:

- Temperature: 25 ± 3 °C.
- Humidity: 45 ± 10% Relative Humidity (RH).
- Duration: 8 h per cycle.

3.2.2 Humid Stage. The apparatus for the humid stage shall have the ability to ramp to (within 1 h) and maintain (for 7 h) under the following environmental conditions:

- Temperature: 49 ± 2 °C.
- Humidity: ~100% RH.
- Duration: 8 h per cycle.

The apparatus shall consist of a fog/environmental chamber, suitable water supply conforming to ASTM D1193 Type IV, provisions for heating the chamber and the necessary means of control.

3.2.2.1 Water Fog. The apparatus shall include provisions for a supply of suitably conditioned compressed air and one or more nozzles for fog generation. The nozzle or nozzles used for the generation of the fog shall be directed or baffled to minimize any direct impingement on the test samples.

At least two clean fog collectors shall be placed within the exposure zone so that no drops of solution from the test specimens or any other runoff source shall be collected. The collectors shall be placed in the proximity of the test specimens, one nearest to any nozzle and the other farthest from all nozzles. Collection rates for each 80 cm^2 of horizontal collection area should be in the range of 0.75 to 1.5 mL/h (on average) of water will be collected in each collector over a minimum duration of 16 h. Fog collection rates may be adjusted within this range as necessary to meet mass loss target rates.

Suitable collecting devices include glass or plastic funnels with the stems inserted through stoppers into graduated cylinders. Funnels with a diameter of 10 cm have an area of about 80 cm^2. Where samples cannot be read immediately upon completion of the humid stage, closed cell foam balls can be used in combination with the collections funnels (i.e., foam ball in mouth of funnel) to allow moisture to collect while minimizing evaporation.

3.2.2.2 Wet-Bottom. The apparatus shall consist of the chamber design as defined in ISO 6270-2. During wet-bottom generated humidity cycles, the tester must ensure that visible water droplets are found on the samples to verify proper wetness.

3.2.2.3 Steam Generated Humidity. Steam generated humidity may be used provided the source of water used in generating the steam is free of corrosion inhibitors. During steam generated humidity cycles, the tester must ensure that visible water droplets are found on the samples to verify proper wetness.

3.2.3 Dry Off Stage. The apparatus for the dry off stage shall have the ability to ramp to (within 3 h) and maintain (for 5 h) under the following environmental conditions:

- Temperature: 60 ± 2 °C.
- Humidity: ≤ 30% RH.
- Duration: 8 h per cycle.

The apparatus shall also have sufficient air circulation to prevent temperature stratification, and also allow thorough drying of the test samples.

3.2.4 Salt Mist Application. The solution shall be sprayed as an atomized mist, and should be sufficient to rinse away any salt accumulation left from previous sprays. The test samples and coupons shall be thoroughly wet/dripping. Suitable application techniques include using a plastic bottle, or a siphon spray powered by oil-free regulated air to spray the test samples and coupons.

Note: The force/impingement from this salt application should not remove corrosion or damage coatings/paints system of test samples.

3.2.5 Corrosion Coupons and Mounting Hardware. Coupons serve to monitor the average general bare steel corrosion produced by the test environment. Coupons consist of 25.4 wide x 50.8 long x 3.18 mm thick pieces of bare SAE 1008-1010 carbon steel, cold-rolled steel per SAE J2329 CR1E, uncoated, no post-coating treatment, which are stamped with an alphanumeric identification number (reference Figure A2).

The coupons shall be secured to an aluminum or nonmetallic coupon rack with fasteners as shown in Figure A3 and Figure A4. The bolt, nut and washers shall be made from a non-black plastic material, preferably nylon. Figure A4 shows a completed coupon rack configuration. The number of coupons recommended for different test durations are shown in Table A2.

3.3 Test Vehicle/Test Piece. The test sample (design, surface, and preparation) should be agreed to by the parties concerned (Design Engineer/Materials Engineer/Corrosion Engineer) and should simulate actual production materials and conditions when possible.

The number of test samples selected should be sufficient to ensure that the test results are statistically significant at some predetermined confidence level, unless otherwise specified. Any unusual observations made during sample preparation should be recorded and reported as part of the test results.

Where appropriate, test samples and/or control panels of known performance should be tested concurrently. These controls can allow the normalization of test conditions during repeated running of the test (supplementing the required mass loss controls) and may also allow comparison of test results from different repeats of the test.

Where actual/representative production samples are available and the in-service orientation is known, test samples should be oriented to simulate these conditions.

When using test panels and/or the in-service orientation is not known, the sample shall, in principle, be oriented such that it is facing upward and at an angle of 20 ± 5 degrees from vertical.

3.3.1. Preconditioning of Test Samples. The gravelometer and/or a scribing tool can be used to provide damage to coating layers prior to testing in order to better represent potential in-service damage when appropriate. The use of either of these preconditioning methods shall be agreed upon by the parties concerned and shall conform to the methods describe in the GMW14700 and/or the GMW15282.

3.4 Test Time. See cycle times in Table A1.

Calendar time:	0 days
Test hours:	0 hours
Coordination hours:	0 hours

3.5 Test Required Information. Not applicable.

3.6 Personnel/Skills. Not applicable.

4 Procedure

4.1 Preparation.

4.1.1 Salt Solution Preparation. The complex salt solution in percent (%) by mass shall be as specified below:

- Sodium Chloride (NaCl): 0.9%.
- Calcium Chloride ($CaCl_2$): 0.1%.
- Sodium Bicarbonate ($NaHCO_3$): 0.075%.

Sodium Chloride must be reagent grade or Morton Culinox 999 Food grade. Calcium Chloride must be reagent grade. Sodium Bicarbonate must be reagent grade (e.g., Arm & Hammer Baking Soda or comparable product is acceptable). Water must meet ASTM D1193 Type IV requirements.

Note: Either $CaCl_2$ or $NaHCO_3$ material must be dissolved separately in water and added to the solution of the other materials. If all solid materials are added dry, an insoluble precipitate may result.

Salt solution makeup calculator for the appropriate amount of sodium chloride, calcium chloride, sodium bicarbonate, and water examples are shown in Appendix B, Figures B1 through B6.

Additional contaminants (dust, grit, poultice, and exhaust condensate) called out in the Deviation Section are defined in Appendix C through Appendix F.

4.1.2 Coupon Preparation. Corrosion coupons should be cleaned with methanol or acetone solution and accurately weighed prior to use. The weight, in grams, shall be recorded and retained for future reference. If coupons are not used immediately, they should be stored such that they are corrosion free at the start of test.

It is critical that all forming or preservation oils/lubes be removed prior to exposure to allow for general/uniform corrosion of the coupon. This process can be aided by using a commercial grade degreaser prior to methanol or acetone clean.

4.1.3 Coupon Rack Preparation. Prior to start of test, prepare the coupon rack with sufficient coupons to monitor the test. The number of coupons recommended for different test durations are shown in Table A2.

The exact location of each coupon on the rack shall be identified and recorded using the pre-stamped numbers for reference as illustrated in Figure A4.

Allow a minimum 5 mm spacing between the coupons and the rack surface. All coupons shall be secured vertically with no more than 15 degree deviation from vertical and must not contact each other.

The coupon rack shall be placed in the general vicinity of the test samples being tested, such that the coupons receive the same environmental exposure as the test samples.

Note: Mass loss coupons are test monitoring devices and are not intended to be exposed to additional stresses which may be added to the base test (i.e., gravelometer, dust, grit, exhaust condensate, thermal exposure, etc.) Additional coupons may be required to monitor special test conditions (refer to Deviations section).

4.2 Conditions.

4.2.1 Environmental Conditions.

4.2.2 Test Conditions. Deviations from the requirements of this standard shall have been agreed upon. Such requirements shall be specified on component drawings, test certificates, reports, etc.

4.3 Instructions.

4.3.1 Test Execution. See Figure A1 (Flow Diagram) for the steps that comprise the test method. Repeat the cycle daily, as necessary, until the test exposure requirements are met. At the option of the test requestor, the test can be continued throughout weekends to decrease the overall test time provided that the number of cycles and mass loss requirements are met.

4.3.2 Salt Application. For each salt mist application, use the spray apparatus to mist the samples and coupons until all areas are thoroughly wet/dripping. The quantity of spray applied should be sufficient to visibly rinse away salt accumulation left from previous sprays. The first salt mist application occurs at the beginning of the ambient stage. Each subsequent salt mist application, when specified, should occur approximately 1.5 h after the previous application in order to allow adequate time for test samples to dry. A minimum of 1 h spacing between the end of a previous salt application and the subsequent salt application is required.

4.3.3 Test Options. The test may be modified to target specific component applications. Refer to Deviations Section at the end of this document.

4.3.4 Test Monitoring. Corrosion coupons shall be removed and analyzed after a predetermined number of cycles (typically 5) throughout the test to monitor the corrosion (less frequent for longer exposures that is > 40 cycles). To analyze coupons, remove one coupon from each end of the rack, clean to prepare for weighing, and an average mass loss determination. Although corrosion rate may vary somewhat during the duration of the test, an assumption of linearity may be useful in predicting the number of cycles to meet future mass loss targets.

4.3.4.1 Before weighing, clean the coupons using a mild sand/bead blast 80 ± 10 psi process to remove all corrosion by-products from the coupon surface. Wipe the coupons free of grit and weigh to determine the coupon mass loss using the formula:

Mass Loss = (Initial Mass) - (End-of-Exposure Mass).

Note: Although not preferred, corrosion by-product removal by chemical cleaning per ISO 8407 may be used.

4.3.4.2 Compare the actual mass loss to the targeted value. Refer to Table A1 for targeted mass loss values, in grams, for various test exposures as a function of the coupon's original thickness. Testing should be conducted as necessary to achieve necessary coupon mass loss. The number of cycles required to achieve required mass loss must meet that defined in Table A1.

Note: Coupon mass loss targets corresponding to incremental test exposures are not included in Table A1. The processes defined in section 4.3.4 Test Monitoring and section 5.3.1 Coupons may be used to check test progress and assure that the test is being run correctly. Corrosion mass loss should increase consistently between documented exposure values. If the actual mass loss does not fall within the targeted range for the specified exposure(s) as listed in Table A1, then the test should be repeated. Also, the reasons why the test did not fall within the target range should be investigated and corrected before resuming the test.

4.3.5 Test Acceleration. Temperature and humidity ramp times between the ambient stage and humid stage, and between the humid stage and dry stage, can have a significant effect on test acceleration. (This is because corrosion rates are highest during these transition periods.) Typically, the time from the ambient stage to the humid stage should be approximately 1 h and the transition time between humid stage and dry stage should be approximately 3 h. These ramp times can be adjusted to increase or decrease test acceleration in order to meet targeted mass loss. Any significant deviations from the ramp time described should be documented with the test results and requires prior approval by the parties concerned. Ramp time is to be included as part of the specified exposure period.

4.3.6 Extended Downtime. For any periods of extended downtime (i.e., greater than 4 to 5 days), it is recommended that test parts and associated coupons receive a fresh water rinse prior to the downtime period and are stored in ambient conditions to help minimize corrosive effects during this time. If downtime exceeds or is expected to exceed 17 consecutive days, this condition should be reviewed with test requestor. Additional special measures may be required to control the corrosion behavior of the test samples during this period. Storage in a desiccator, freezer, etc., may be appropriate. Extended downtime periods and any associated special measures should be included in the test documentation.

4.4 Cosmetic Corrosion Inspection. The test sample(s) shall be inspected for corrosion by means of GMW15356, GMW15357, GMW15358, GMW15359, and photographed (as necessary) at the end of predetermined cycles. Samples may be rated in terms of percent corroded area per ASTM D610 or some other comparable standard if agreed upon by test requestor and tester. If test samples containing plastic materials are being tested, any discoloration or degradation and/or adhesive bond failure (delamination) shall be noted and recorded.

If scribing is required, on test samples, follow the method described in GMW15282. This method includes measurement of corrosion creepback from a scribe line. This method should be used when reporting test results unless stated otherwise on drawings or agreed upon by test requestor and tester.

4.5 End-of-Test Functional Inspection. At the end of test the samples shall be rinsed with fresh tap water and allowed to dry before evaluating. End-of-test functional analysis may involve sectioning, microscopic analysis and/or removal of corrosion product to determine degree and extent of base metal attack.

5 Data

5.1 Calculations.

- Salt solution (reference Appendix B).
- Coupon mass loss (reference 4.3.4.1).

5.2 Interpretation of Results. Acceptance criteria shall be specified within Engineering documentation which may include: Material Specifications, Vehicle, Subsystem, Component Technical Specifications, Statement of Requirements, Part Drawings, etc.

5.3 Test Documentation.

5.3.1 Coupons. Coupon mass loss values are to be recorded periodically throughout test and included as part of the overall test documentation in order to provide evidence of test control and adherence to specified test targets. This data may be plotted using charts like the examples found in Figure G1 and Figure G2.

5.3.2 Test Reports. Test reports should include a description of the specific test cycle executed, description of test options or special instructions, test deviations and/or extended test downtime periods (including any special measures taken). Test reports should also include (at minimum) targeted and actual number of cycles run, as well as the targeted and actual coupon mass loss associated with the documented data collection points.

5.3.3 Test Equipment Documentation. The information in 5.3.3.1 through 5.3.3.14 shall be recorded and available upon request for each cabinet/exposure location used to conduct test conditions as appropriate.

5.3.3.1 Cabinet Manufacturer/Model.

5.3.3.2 Humidity Profile.

5.3.3.3 Temperature Profile.

5.3.3.4 Humidification Process.

5.3.3.5 Collection Rate.

5.3.3.6 Dehumidification Process.

5.3.3.7 Heating Process.

5.3.3.8 Cooling Process.

5.3.3.9 Air Circulation Process.

5.3.3.10 Capacity.

5.3.3.11 Size.

5.3.3.12 Calibration Process.

5.3.3.13 Frequency of Calibration.

5.3.3.14 Ramp Time Between Stages.

Cycle profiles (including typical steady state conditions and the ramp times between steady state conditions) should be maintained and available upon request.

Note: A form for Test Equipment documentation can be found in Appendix H. If information does not change from test to test, documentation of a representative test will be acceptable. All the specified information will be required if test results are in question.

5.3.4. Test Solution. The information in 5.3.4.1 through 5.3.4.5 shall be recorded and available upon request.

5.3.4.1 Frequency of Salt Solution Changes.

5.3.4.2 Method of Salt Application.

5.3.4.3 pH of Solution.

5.3.4.4 Salinity or Conductivity of Solution.

5.3.4.5 Solution Constituents.

Note: The form for Test Solution documentation can be found in Appendix J. All specified information will be required if test results are in question.

6 Safety

This standard may involve hazardous materials, operations, and equipment. This standard does not propose to address all the safety problems 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.

7 Notes

7.1 Glossary. Not applicable.

7.2 Acronyms, Abbreviations, and Symbols.

EXT	Exterior
g	Grams
h	Hours
ID	Initial Delivery (0 year)
INT	Interior
I/WS	Inside the weather strip
ND	Not Defined
O/WS	Outside the weather strip
PS	Protected from splash
RH	Relative Humidity
s	Seconds
sp	Salt sprays
SS	Secondary Surface
UB	Underbody
UH	Underhood

8 Coding System

This standard shall be referenced in other documents, drawings, etc., as follows:

Test to GMW14872

Test to GMW14872, vehicle area including mounting location, method, cosmetic and/or functional test exposure, (0, A, B, C or D) or where the drawing or material specification calls for a specific deviation. This deviation should specify an associated mass loss.

Example 1: For an underbody (UB) component pertaining to a global region specified as Class 3 cosmetic (including 0 year/ID, i.e., 2 cycles) and functional.

Test to GMW14872, (UB), All, 4 sp, Method 3, Exposures 0, A, and D.

Example 2: For a low, mid, or high underhood (UH) component pertaining to a global region specified as Class 1 or Class 2 cosmetic and functional with splash protection not defined.

Test to GMW14872, UH, All, 4 sp, Method 1/2, Exposures B and D.

Example 3: For a mid mounted and protected from splash underhood component pertaining to a global region specified in Method 3 cosmetic and functional.

Test to GMW14872, UH, Mid PS, 4 sp, Method 3, Exposures B and D.

Example 4: For a door hinge mounted outside the weatherstrip in a global region specified in Method 1/2 functional.

Test to GMW14872, Secondary Surface (SS) Outside the Weather Strip (O/WS), Method 1/2, Deviation Option 1, Duration 70 cycles.

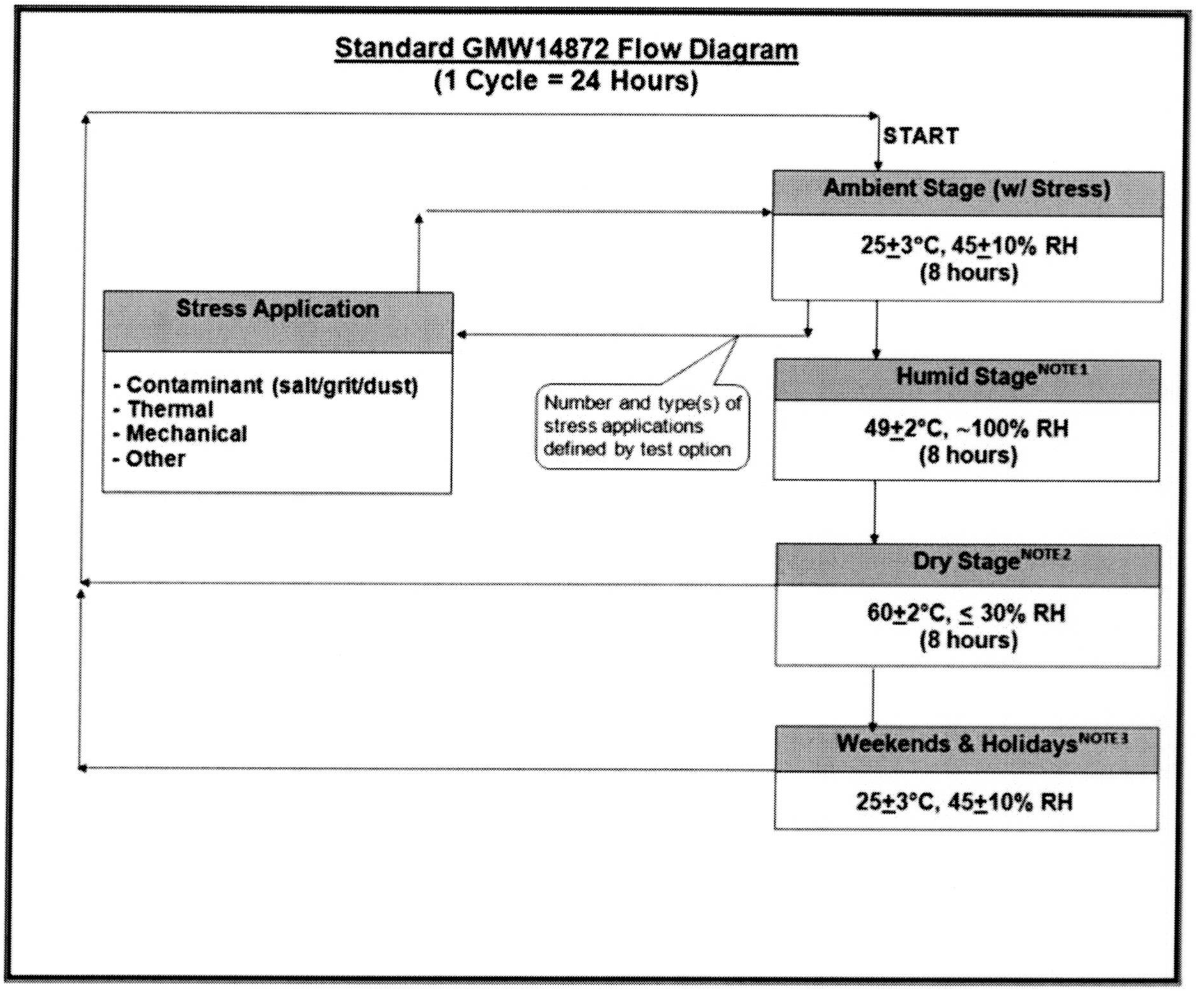
In addition, the criteria for making pass/fail determinations must be specified (i.e., Vehicle Technical Specification Paragraph Number, etc.)

9 Release and Revisions

This standard was originated in November 2005. It was first approved by the Global Laboratory Corrosion Testing Harmonization Team in August 2006. It was first published in November 2006.

Issue	Publication Date	Description (Organization)
1	NOV 2006	Initial publication.
2	MAR 2010	Added Exposure 0: 0 year/ID to 1.2 and Table A1. Added **Notes** 1 to 3 to Figure A1. Updated 3.3 and added 3.3.1 Preconditioning of Test Samples. Moved 4.5 Test Monitoring to 4.3.4. Moved 4.4 Test Acceleration to 4.3.5. Added 4.3.6 Extended Downtime. Updated Underhood section of Table A1. Replaced Method SH/SM with Method 1/2 and Method SL with Method 3 in Table A1. Added additional source under Figure A4. Updated Deviations to include coupon exposure and mass loss. (Corrosion GSSLT - Global Subsystem Leadership Team)

Appendix A



Note 1: The typical ramp time from the ambient stage to the humid stage is 1 h and is part of the 8 h humid stage.
Note 2: The typical ramp time from the humid stage to the dry stage is 3 h and is part of the 8 h dry stage.
Note 3: For extended downtime refer to 4.3.6.

Figure A1: GMW14872 Flow Diagram

Table A1: GMW14872 Mass Loss Targets (3.18 mm thick coupons) – Cosmetic [Note 1] and Functional

Vehicle Area	Mounting Location of Component	Number of Salt Sprays (sp)	Method [Note 2]	Test Exposure: Cosmetic Mass Loss (Penetration [Note 3]) Requirements [Note 4] and Number of Test Cycles	Test Exposure: Functional Mass Loss Requirements [Note 4, Note 5] and Number of Test Cycles
Underbody (UB)	All	4 per cycle	Method 1/2	Exposure A 0.84 ± 0.14 g (38 ± 6 µm) 6 ± 1 cycles	Exposure D 9.47 ± 0.38 g (430 ± 17 µm) 68 ± 7 cycles
			Method 3	Exposure A 0.42 ± 0.07 g (19 ± 3 µm) 3 ± 1 cycles	Exposure D 4.74 ± 0.19 g (215 ± 9 µm) 34 ± 4 cycles
Underhood (UH)	All – Splash Protection Not Defined (ND) [Note 6]	4 per cycle	Method 1/2	Exposure B 1.32 ± 0.13 g (60 ± 6 µm) 9 ± 1 cycles	Exposure D 7.11 ± 0.28 g (323 ± 13 µm) 51 ± 6 cycles
			Method 3	Exposure B 0.66 ± 0.07 g (30 ± 3 µm) 5 ± 1 cycles	Exposure D 3.55 ± 0.14 g (161 ± 6 µm) 25 ± 3 cycles
	Mid – Protected from Splash (PS) [Note 6]	1 per cycle	Method 1/2	Exposure B 0.88 ± 0.09 g (40 ± 4 µm) 11 ± 2 cycles	Exposure D 4.74 ± 0.19 g 9215 ± 8 µm) 59 ± 6 cycles
			Method 3	Exposure B 0.44 ± 0.04 g (20 ± 2 µm) 6 ± 1 cycles	Exposure D 2.38 ± 0.10 g (108 ± 4 µm) 30 ± 3 cycles
	High – Protected from Splash (PS) [Note 6]	1 per cycle	Method 1/2	Exposure B 0.44 ± 0.4 g (20 ± 2 µm) 6 ± 1 cycles	Exposure D 2.38 ± 0.10 g (108 ± 4 µm) 30 ± 3 cycles
			Method 3	Exposure B 0.22 ± 0.02 g (10 ± 1 µm) 3 ± 1 cycles	Exposure D 1.19 ± 0.05 g (54 ± 2 µm) 15 ± 2 cycles
Exterior (EXT)	All	4 per cycle	Method 1/2/3	Exposure C 3.94 ± 0.28 g (179 ± 13 µm) 28 ± 3 cycles	Exposure D 7.23 ± 0.29 g (328 ± 13 µm) 52 ± 6 cycles
Secondary Surface (SS)	Outside the Weather Strip (O/WS)	1 per cycle	Method 1/2/3	Exposure C 1.98 ± 0.14 g (90 ± 6 µm) 25 ± 3 cycles	Exposure D 3.61 ± 0.14 g (164 ± 7 µm) 45 ± 5 cycles
	Inside the Weather Strip (I/WS)	1 per 5 cycles [Note 7]	Method 1/2/3	Exposure C 0.40 ± 0.3 g (18 ± 1 µm) 8 ± 1 cycles	Exposure D 0.73 ± 0.03 g (33 ± 1 µm) 13 ± 2 cycles
Interior (INT)	Low	1 per 5 cycles [Note 7]	Method 1/2/3	Exposure C 1.30 ± 0.09 g (59 ± 4 µm) 24 ± 3 cycles	Exposure D 2.38 ± 0.10 g (108 ± 4 µm) 43 ± 4 cycles
	Mid, High	1 per 5 cycles [Note 7]	Method 1/2/3	Exposure C 0.40 ± 0.03 g (18 ± 1 µm) 8 ± 1 cycles	Exposure D 0.73 ± 0.03 g (33 ± 1 m) 13 ± 2 cycles

Note 1: For Exposure 0 (0 Year/ID) evaluate parts at 2 cycles of the defined exposure linked to the associated vehicle area and mounting location.
Note 2: Refer to GMW15272 for applicable linkage of global region to test Method 1/2 or Method 3.
Note 3: Penetration factor based on material and dimension is 45.4.
Note 4: In addition to mass loss requirements, the test must be conducted such that the number of cycles falls within the specified range.
Note 5: Exposure D is used for functional assessment. All corrosion mechanisms are accelerated at different rates on test. Completing the test may not ensure that a component passes the functional requirement. A comprehensive failure mode analysis must be conducted to ensure all failure modes are considered and life expectancy is met.
Note 6: In order to be classified as Protected from Splash, the associated vehicle application(s) must effectively employ all Splash Shielding Best Practices and the component must be classified as "Dry" based on the Vehicle Splash Shield Performance Evaluation (GMW16277) Procedure.
Note 7: Number of salt sprays for 1 per 5 cycles should be sprayed at the start-of-test and every 5 cycles thereafter.

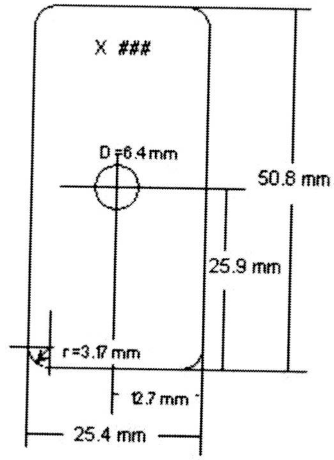
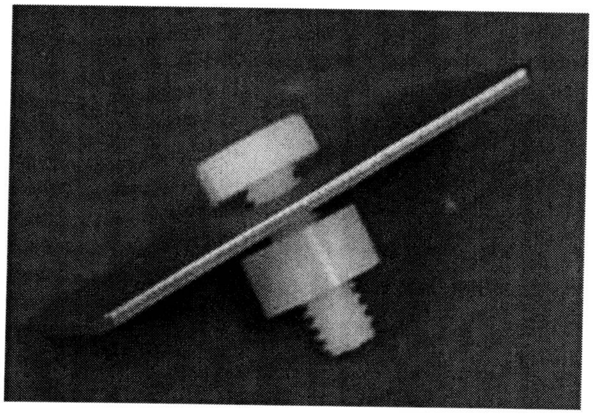


Figure A2: Coupon Schematic



Nylon bolts and washers suitable are as follows:

Bolt: ¼"-20 x ½ in hex head cap screw, solid nylon

¼"-20 x 3/7 in hex head cap screw, solid nylon

Washer: ½ x .257 x .197 in thick flat washers

Nut: ¼"-20 nut, solid nylon

Figure A3: Coupon Hardware Illustration

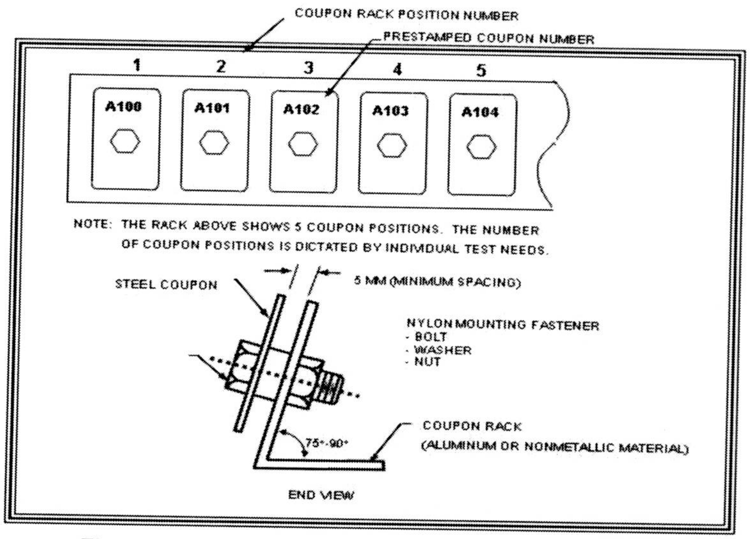


Figure A4: Coupon Bracket Assembly Illustration

Suitable coupons and/or coupon rack assemblies along with salt solution, dust, grit, poultice, and exhaust condensate can be purchased from the following:

ACT Test Panels
273 Industrial Drive
P.O. Box 735
Hillsdale, Michigan 49242
(517) 439-1485

Auto Technology Company
20026 Progress Drive
Strongsville, Ohio 44149
800-433-8336

National Exposure Testing
3545 Silica Road
Suite E
Sylvania, Ohio 43560
(419) 841-1065

Table A2: Recommended Number of Coupons and Removal Frequency

Number of Required Cycles	Number of Coupons	Removal Frequency
≤ 10 cycles	6	5 Cycles
11 to 20 cycles	10	5 Cycles
21 to 30 cycles	14	5 Cycles
31 to 40 cycles	18	5 Cycles
41 to 80 cycles	18 Note 1	10 Cycles

Note 1: Additional coupons may be required if earlier evaluations must be conducted.

Appendix B

Composition (% by mass)

Sodium Chloride:	NaCl =	0.90%	170.3 grams	
Calcium Chloride:	$CaCl_2$ =	0.10%	18.9 grams	= 18.9 grams $CaCl_2$ + 0 grams H_2O
Hydrates $CaCl_2 \cdot XH_2O$:	X =	0	Composition is **100%** $CaCl_2$	
Sodium Bicarbonate:	$NaHCO_3$ =	0.075%	14.2 grams	
Water (Type IV):	H_2O =	98.925%	18723.7 grams	
Batch Volume =		5	Mass = 18927.1 grams	
Units:		gallons		

Figure B1: GMW14872 Salt Solution Calculator for Anhydrous (X=0) Calcium Chloride Based on a Five Gallon Batch Solution

Composition (% by mass)

Sodium Chloride:	NaCl =	0.90%	170.3 grams	
Calcium Chloride:	$CaCl_2$ =	0.10%	22.0 grams	= 18.9 grams $CaCl_2$ + 3.1 grams H_2O
Hydrates $CaCl_2 \cdot XH_2O$:	X =	1	Composition is **86.03%** $CaCl_2$	
Sodium Bicarbonate:	$NaHCO_3$ =	0.075%	14.2 grams	
Water (Type IV):	H_2O =	98.925%	18720.6 grams	
Batch Volume =		5	Mass = 18927.1 grams	
Units:		gallons		

Figure B2: GMW14872 Salt Solution Calculator for One Hydrate (X=1) Calcium Chloride Based on a Five Gallon Batch Solution

Composition (% by mass)

Sodium Chloride:	NaCl =	0.90%	170.3 grams	
Calcium Chloride:	$CaCl_2$ =	0.10%	25.1 grams	= 18.9 grams $CaCl_2$ + 6.2 grams H_2O
Hydrates $CaCl_2 \cdot XH_2O$:	X =	2	Composition is **75.49%** $CaCl_2$	
Sodium Bicarbonate:	$NaHCO_3$ =	0.075%	14.2 grams	
Water (Type IV):	H_2O =	98.925%	18717.5 grams	
Batch Volume =		5	Mass = 18927.1 grams	
Units:		gallons		

Figure B3: GMW14872 Salt Solution Calculator for Dihydrate (X=2) Calcium Chloride Based on a Five Gallon Batch Solution

Note: An electronic copy can be obtained upon request. Please contact GMNA Corrosion Engineering.

Composition (% by mass)

Sodium Chloride:	NaCl =	0.90%	90.0 grams	
Calcium Chloride:	$CaCl_2$ =	0.10%	10.0 grams	= 10 grams $CaCl_2$ + 0 grams H_2O
Hydrates $CaCl_2 \cdot X H_2O$:	X =	0	Composition is **100%** $CaCl_2$	
Sodium Bicarbonate:	$NaHCO_3$ =	0.075%	7.5 grams	
Water (Type IV):	H_2O =	98.925%	9892.5 grams	
Batch Volume =	10	Mass =	10000.0 grams	
Units:	liters			

Figure B4: GMW14872 Salt Solution Calculator for Anhydrous (X=0) Calcium Chloride Based on a Ten Liter Batch Solution

Composition (% by mass)

Sodium Chloride:	NaCl =	0.90%	90.0 grams	
Calcium Chloride:	$CaCl_2$ =	0.10%	11.6 grams	= 10 grams $CaCl_2$ + 1.6 grams H_2O
Hydrates $CaCl_2 \cdot X H_2O$:	X =	1	Composition is **86.03%** $CaCl_2$	
Sodium Bicarbonate:	$NaHCO_3$ =	0.075%	7.5 grams	
Water (Type IV):	H_2O =	98.925%	9890.9 grams	
Batch Volume =	10	Mass =	10000.0 grams	
Units:	liters			

Figure B5: GMW14872 Salt Solution Calculator for One Hydrate (X=1) Calcium Chloride Based on a Ten Liter Batch Solution

Composition (% by mass)

Sodium Chloride:	NaCl =	0.90%	90.0 grams	
Calcium Chloride:	$CaCl_2$ =	0.10%	13.2 grams	= 10 grams $CaCl_2$ + 3.2 grams H_2O
Hydrates $CaCl_2 \cdot X H_2O$:	X =	2	Composition is **75.49%** $CaCl_2$	
Sodium Bicarbonate:	$NaHCO_3$ =	0.075%	7.5 grams	
Water (Type IV):	H_2O =	98.925%	9889.3 grams	
Batch Volume =	10	Mass =	10000.0 grams	
Units:	liters			

Figure B6: GMW14872 Salt Solution Calculator for Dihydrate (X=2) Calcium Chloride Based on a Ten Liter Batch Solution

Note: An electronic copy can be obtained upon request. Please contact GMNA Corrosion Engineering.

Appendix C

Dust Type

Arizona Dust conforming to ISO 12103-1, A2 Fine, procured from Powder Technology Incorporated of Burnsville, Minnesota. Dust may also be purchased from ACT Test Panels, Auto Technology Company, and National Exposure Testing.

Spray Apparatus

A simple garden duster is suitable for dust application (refer to Figure C1 for example).

Dust Application

Dust should be applied such that a semi-transparent layer is applied to the entire part or focal area of the part. Keep the applicator agitated to ensure proper dust application (agitate/shake duster between applications).

Figure C1: Garden Duster Example

Note: For bulk supply use suppliers defined above. Smaller quantities may be purchased from ACT Test Panels, Auto Technology Company, and National Exposure Testing (refer to Appendix A for contact information).

Appendix D

Grit Specification

Grit Trough Solution Mix (typical recipe to be mixed with 18.9 L of water (5 gal) – total solution amount can be increased or decreased by multiplying or dividing as necessary).

Solid Contaminants:

Fire Clay – 900 g

Cinders – 900 g

Sand – 900 g

Ottawa Lakes Screening – 1080 g

1% Complex Salt Mix:

NaCl (sodium chloride) – 170.37 g

$CaCl_2 \bullet 2H_20$ (calcium chloride dihydrate) Note 1 – 25.07 g (18.93 g – anhydrous)

Note 1: It is permissible to use hydrated salts.

$NaHCO_3$ (sodium bicarbonate) – 14.2 g (baking soda is also suitable and can be purchased at a grocery store).

Mixing Instructions:

Add 18.9 L (5 gal) of the 1% complex salt solution to the premix bag of solid ingredients (or if you do not have pre-mixed bags, weigh out the materials, put them in a container able to hold at least 22.7 L (6 gal) and then add the water). Thoroughly mix liquid and solids together with moderate agitation. If spraying the solution, immediately after agitation or during agitation, siphon solution from the top half of the mix for use in spraying on test samples. An alternative method would be to build an automatic spray system incorporating a pumping device that either prescreened the coarse solids or drew liquid from the top half of the solution. In the case of a test where a part is to be submerged in the solution and then cycled/stroked, make sure that the part stays in the top 2/3rds of the solution to avoid ingestion or damage due to large particles that fall out of solution and reside in the bottom of the mix.

Note: Be sure to pour/douse the grit solution on all areas of the part that would potentially experience splash in the field. Depending on number of samples, level of contamination, and exposure of test, it may be appropriate to collect and reuse grit solution. A fresh batch of grit solution should be made at minimum once a month for the duration of the test.

Table D1: Grit Trough Constituent Supplier Information Note 1

Constituent	Supplier	Address	Phone/Contact
Cinders	Snow's Nursery	5485 W. Dunbar Road, Monroe, MI 48161	(734) 242-5126
Fire clay – 20 Mesh DMFC sacked	Harbison Walker	28777 Goddard Road, Romulus, MI 48174	(734) 955-6025
Sand – unwashed play sand or 2NS	Local Hardware	Milford Proving Ground – Corrosion Engineering	(248) 431-9789
Ottawa Lakes Screening	Stoneco Michigan	15203 S. Telegraph Road, Monroe, MI 48161	(734) 241-8966

Note 1: For bulk supply use suppliers defined. Smaller quantities may be purchased from ACT Test Panels, Auto Technology Company, and National Exposure Testing (refer to Appendix A for contact information).

Appendix E

Poultice Specification

Solid Contaminants: Fire Clay – 22.5% by weight

Sand – 72.5% by weight

Calcium Chloride – 5% of the combined Fire Clay and Sand weight

Mixing Instructions:

Combine fire clay and sand. Add 5% Calcium Chloride to the combined weight of the fire clay and sand. Next, distilled or deionized water per ASTM D1193 Type IV is added to the solid ingredients in small amounts until desired poultice consistency. Poultice is to be packed (approximately 6.35 mm (¼ in) thick) on test specimens.

Example: (100 g batch)

Mix 22.5 g of fire clay and 72.5 g of sand. Add 5 g of Calcium Chloride to the fire clay and sand mixture. Thoroughly mix solid constituents together. Add small amounts of water at a time while thoroughly mixing liquid and solid constituents until it creates a thick and moist poultice consistency. Apply poultice to test specimen packing the poultice to approximately 6.35 mm (¼ in) thick.

Note: For bulk supply use suppliers defined in Table D1. Smaller quantities may be purchased from ACT Test Panels, Auto Technology Company, and National Exposure Testing (refer to Appendix A for contact information).

Appendix F

Table F1: Exhaust Condensate Specification (Reference SAE 2001-01-0640)

Number	Ingredients	Level (Weight Percent)	Amount per 113.56 L (30 gal)
1	Activated Carbon	0.5%	5715.2 g
2	Ammonia (as Ammonium Hydroxide, 29.7%)	0.25%	959.0 g
3	Sulfate (as Ammonium Sulfate)	0.125%	195.2 g
4	Acetate (as Ammonium Acetate)	0.04%	59.3 g
5	Sulfite (as Ammonium Sulfite)	0.025%	47.5 g
6	Formaldehyde (37%)	0.025%	76.7 g
7	Nitrate (as Ammonium Nitrate) Note 1	0.012%	17.6 g
8	Formic Acid (88%)	0.01%	13.2 g
9	Chloride (as Ammonium Chloride)	0.005%	8.5 g
10	Water	Balance	

Note: Total for nitrite and nitrate.

Procedure:

Dissolve each of ingredients number 2 through number 9 in distilled water and add while stirring one by one to the prepared container. Add rest of water and number 1 (activated carbon). Mix thoroughly. Keep in tightly closed container.

Appendix G

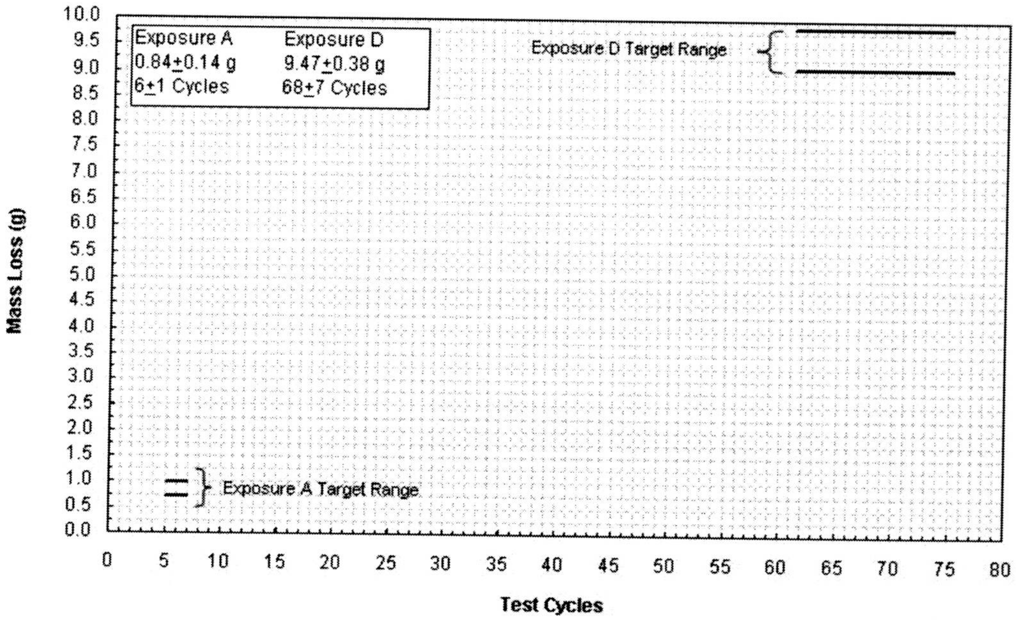


Figure G1: GMW14872 Underbody (UB) Mass Loss Target Chart for Method 1/2

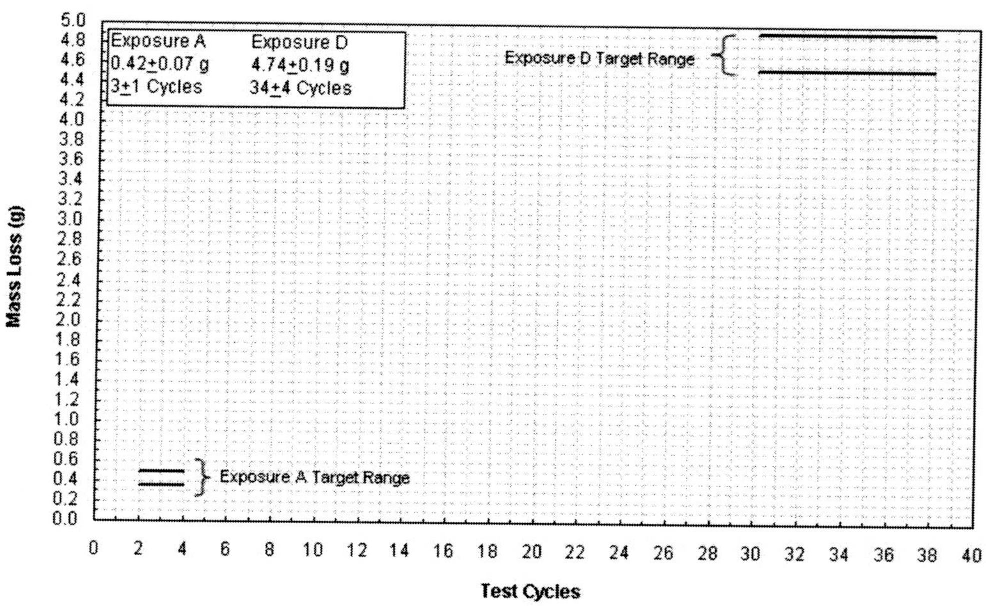


Figure G2: GMW14872 Underbody (UB) Mass Loss Target Chart for Method 3

Note: An electronic copy for both corrosion severities (i.e., Method 1/2 and Method 3) and all of the vehicle component areas (i.e., underbody, underhood, exterior, secondary surface, and interior) can be obtained upon request. Please contact GMNA Corrosion Engineering.

Appendix H - Test Equipment Documentation Form (Page 1 of 2)

Project Number(s):	
Start-of-Test (Date):	End-of-Test (Date):

General Information	Description of any test interruptions (fill in table below):	
	Date	Description of Test Interruption
	Operation (Manual (5 days)/Automatic (5 or 7 days)):	
	Average Temperature (Lab or Operating Environment) (Range) (°C):	
	Average Humidity (Lab or Operating Environment) (Range) (% RH):	
	Are coupons placed In the location as test samples within the chamber (Yes/No)?	
	Are samples and coupons rotated within the chamber during the exposure (Yes/No)? If yes, frequency:	
	☐	Chart or data (temperature and humidity) documenting at least 1 weekend (include date(s))

Ambient Stage	Cabinet Identification (Name/Number):	
	Cabinet Manufacturer:	Cabinet Model:
	Cabinet Serial Number:	Air Movement (high/moderate/low and units):
	Cabinet Size:	Cabinet Capacity:
	Last Calibration (Date):	Next Calibration (Due Date):
	Average Temperature (Range) (°C):	
	Heating Process:	
	Cooling Process:	
	Average Humidity (Range) (% RH):	
	Typical Time (minutes) to Dry Between Sprays for Standard Test Sample (Paint Panel):	
	Duration Of Individual Salt Applications (s):	
	Time Between Individual Salt Applications (minutes):	
	Ramp Time For Humidity To Return To Specified Ambient Humidity Following Salt Spray (minutes):	
	☐	Chart or data (temperature and humidity) documenting at least 1 cycle of this stage (include date(s))

Appendix H - Test Equipment Documentation Form (Page 2 of 2)

<table>
<tr><td rowspan="19">Humidity Stage</td><td colspan="5">Cabinet Identification (Name/Number):</td></tr>
<tr><td colspan="3">Cabinet Manufacturer:</td><td colspan="2">Cabinet Model:</td></tr>
<tr><td colspan="3">Cabinet Serial Number:</td><td colspan="2">Air Movement (high/moderate/low and units):</td></tr>
<tr><td colspan="3">Last Calibration (Date):</td><td colspan="2">Next Calibration (Due Date):</td></tr>
<tr><td colspan="5">Ramp Time (Ambient to Humidity Stage):</td></tr>
<tr><td colspan="5">Average Temperature (Range) (°C):</td></tr>
<tr><td colspan="5">Heating Process:</td></tr>
<tr><td colspan="5">Average Humidity (Range) (% RH):</td></tr>
<tr><td colspan="5">Humidification Process:</td></tr>
<tr><td colspan="5">☐ Chart or data (temperature and humidity) documenting at least 1 cycle of this stage (include date(s))</td></tr>
<tr><td colspan="5">Collection Rate (fill in table):</td></tr>
<tr><td>Sample Cycle Period</td><td>Actual Number of Cycles</td><td>Collection Rate (mL/h/80 cm²per 8 h exposure)</td><td>Date of Collection</td><td>Moisture Visible on Samples (Yes/No)</td></tr>
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</table>

<table>
<tr><td rowspan="11">Dry off Stage</td><td colspan="2">Cabinet Identification (Name/Number):</td></tr>
<tr><td>Cabinet Manufacturer:</td><td>Cabinet Model:</td></tr>
<tr><td>Cabinet Serial Number:</td><td>Air Movement (high/moderate/low and units):</td></tr>
<tr><td>Cabinet Size:</td><td>Cabinet Capacity:</td></tr>
<tr><td>Last Calibration (Date):</td><td>Next Calibration (Due Date):</td></tr>
<tr><td colspan="2">Ramp Time (Humidity to Dry off Stage):</td></tr>
<tr><td colspan="2">Average Temperature (Range) (°C):</td></tr>
<tr><td colspan="2">Heating Process:</td></tr>
<tr><td colspan="2">Average Humidity (Range) (% RH):</td></tr>
<tr><td colspan="2">Dehumidification Process:</td></tr>
<tr><td colspan="2">☐ Chart or data (temperature and humidity) documenting at least 1 cycle of this stage (include date(s))</td></tr>
</table>

Appendix J - Test Solution Documentation Form

Test Solution

Water Type (refer to ASTM D1193):						
Volume of Batch (L or gal):						
Sodium Chloride (NaCl) (g):						
Sodium Bicarbonate (NaHCO3) (g):						
Calcium Chloride ($CaCl_2 \bullet X\ H_2O$) (g):					X =	
Test Solution Monitoring (fill in table for each test solution batch):						
Date of Initial Use	Initial pH	Initial Conductivity (µS @ 25 °C)	Date of Last Use	Total Number of Test Cycles	Final pH	Final Conductivity (µS @ 25 °C)
Spray Pressure (units):			Spray Flow (units):			

Deviations

The following procedure deviations are based on field knowledge combined with Engineering judgment to enhance the test's ability to predict field performance. Prior to making additional modifications or to assist in determining the appropriateness of one of the following options, please contact GMNA Corrosion Engineering.

Deviations are generally made during the ambient stage to include additional test inputs such as dust applications, grit sprays, poultice applications, dynamic cycling, electrical cycling, thermal inputs, gravelometer, exhaust condensate spray, and acid rain spray.

The test inputs associated with deviations apply only to the test parts. Mass loss coupons are test monitoring devices and should not be exposed to additional inputs that deviate from the base test cycle (refer to Table A1).

If corrosion rate monitoring is required to cover both the base test cycle and the deviation conditions, an additional set of coupons will be required and should see the same test conditions as the samples.

Option 1: Dust Application and Fresh Water Rinse Addition.

Modification to Ambient Stage:

Number of salt sprays per cycle as defined in Table A1.

One (1) dust application every 5 cycles starting with the 1st cycle (dust should be applied immediately following the last daily salt spray application to test parts only) (refer to Appendix C for dust specification).

One (1) fresh water rinse applied to test parts only and allowed to dry prior to the salt application on days when dust is applied.

A list of component examples for dust and fresh water rinse addition is provided below:

- Side Door Latches.
- Hood Latches (assume no weatherseal protection).
- Door Cavity Hardware.

Note: Coupons only receive the salt sprays defined in Table A1. The dust application and fresh water rinse should only be applied to the test parts.

A list of component examples for dust addition is provided as follows:

Door Hinges, Hood Hinges, Fuel Filler Door Hardware, Decklid Hinges (assume no weatherseal protection), Door Detent (assume no weather seal protection), and Windshield Wiper System.

Test duration to evaluate functional corrosion is 70 cycles with a minimum mass loss of 9.4 g (applicable for test conditions that require 4 salt sprays per cycle), 5.4 g (applicable for test conditions that require 1 salt spray per cycle), or 4.0 g (applicable for test conditions that require 1 salt spray per 5 cycles).

Option 2: Air Conditioning Compressor Addition.

Modifications to Ambient Stage:

One (1) salt spray every 5 cycles starting with the 1st cycle – compressor running.

One (1) grit spray every 5 cycles starting with the 5th cycle – compressor static (refer to Appendix D for grit solution).

Compressor run time of 1.5 h (cycling 12 s on and 3 s off).

Note: Coupons only receive the salt sprays defined in Option 2. The grit application should only be applied to the test parts.

Test duration to evaluate functional corrosion is 70 cycles with a minimum mass loss of 4.0 g.

Option 3: Key Cylinder Addition.

Modification to Ambient Stage:

One (1) hose salt spray per cycle (approximately 10 s application, ¾ to 1 in hose, 22.7 L (6 gal) per minute supply).

One (1) dust application (both sides of test sample in fixture) every 5 cycles starting with the 1st cycle (dust should be applied immediately following the salt spray application) (refer to Appendix C for dust specification).

One (1) fresh water rinse applied and allowed to dry prior to the salt application on days when dust is applied.

Note: Coupons only receive the salt spray defined in Option 3. The dust application and fresh water rinse should only be applied to the test parts.

Test duration to evaluate functional corrosion is 70 cycles with a minimum mass loss of 5.4 g.

Option 4: Thermal Soak Addition.

Modification to Ambient Stage:

Oven Soak (number of hours) followed by 25 ± 3 °C, 45 ± 10% RH (number of hours).

Note: When thermal soak is 4 h in duration and 4 sprays per cycle are required, perform 1st and 2nd salt spray prior to oven soak with remaining 2 salt sprays spaced 1 h apart. When thermal soak is 2 h in duration and 4 sprays per cycles are required, perform 1st salt spray prior to oven soak with remaining 3 salt sprays spaced 1 h apart. When thermal soak is used in conjunction with a test that specifies 1 salt spray per cycle or 1 salt spray per 5 cycles, then that salt spray shall occur prior to oven soak.

A list of component examples for thermal soak addition is provided below:

- Transmission Oil Cooler Line: 121 ± 2 °C (2 h).
- Muffler and Tailpipe: 204 to 260 °C (4 h).
- Exhaust Manifold, Flex Coupling: 482 ± 2 °C (4 h).

Note: Coupons only receive the salt spray defined in Table A1. The thermal soak should only be applied to the test parts.

Test duration to evaluate functional corrosion is 70 cycles with a minimum mass loss of 9.4 g (applicable for test conditions that require 4 salt sprays per cycle), 5.4 g (applicable for test conditions that require 1 salt spray per cycle), or 4.0 g (applicable for test conditions that require 1 salt spray per 5 cycles).

Option 5: Exhaust Condensate Addition.

Modification to Ambient Stage:

Three (3) salt spray per cycle spaced 1.5 h apart (for test parts and 4 salt sprays for coupons).

One (1) exhaust condensate spray 1.5 h after last salt spray (for test parts only; refer to Table F1 Exhaust Condensate).

A component example for exhaust condensate addition is provided below:

- Rear Bumper and Exhaust Tip.

Note: Coupons should receive the salt sprays defined in Table A1. The exhaust condensate should only be applied to the test parts.

Test duration to evaluate functional corrosion is 70 cycles with a minimum mass loss of 9.4 g.

Additional options can be customized to specific components or subsystems to increase the ability to conduct validation or development testing. General guidelines defined in Table A1 may be used as a building block for customizing a test. Prior to making additional modifications or to assist in determining the appropriateness of one of the options, please contact GMNA Corrosion Engineering.