SURFACE VEHICLE RECOMMENDED PRACTICE

J2721™ MAY2023

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Superseding J2721 NOV2011

(R) Recommended Corrosion Test Methods for Commercial Vehicle Components

RATIONALE

The chassis test procedure has been modified to fit into a standard 8-hour work day. This change was made because of user requests. The verbiage for the chassis and wheel end section has been modified to improve clarity. The flowcharts for these sections has been simplified and updated to correlate with the descriptions.

SAE J2721 has been reaffirmed to comply with the SAE Five-Year Review policy.

1. SCOPE

This document establishes recommended practices to validate acceptable corrosion performance of metallic components and assemblies used in medium truck, heavy truck, and bus and trailer applications. The focus of the document is methods of accelerated testing and evaluation of results. A variety of test procedures are provided that are appropriate for testing components at various locations on the vehicle. The procedures incorporate cyclic conditions including corrosive chemicals, drying, humidity, and abrasive exposure. These procedures are intended to be effective in evaluating a variety of corrosion mechanisms as listed in Table 1. Test duration may be adjusted to achieve any desired level of exposure. Aggravating conditions such as joint rotation, mechanical stress, and temperature extremes are also considered.

This document does not address the chemistry of corrosion or methods of corrosion prevention. For information in these areas, refer to SAE J447 or similar standard.

2. REFERENCES

2.1 Applicable Documents

The following standards and reference materials were consulted during preparation of SAE J2721. Some of these are referenced in the body of this recommended practice. Other are included simply as background material.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), www.sae.org.

SAE J400 Test for Chip Resistance of Surface Coatings

SAE J447 Prevention of Corrosion of Motor Vehicle Body and Chassis Components

SAE J840 Test Procedures for Shear Strength of Automotive Brake Pads and Brake Lining Assemblies

SAE J1455 Recommended Environmental Practices for Electronic Equipment Design in Heavy-Duty Vehicle Applications

SAE J2115 Air Brake Performance and Wear Test Code Commercial Vehicle Inertia Dynamometer

SAE J2139 Tests for Signal and Marking Devices Used on Vehicles 2032 mm or More in Overall Width

SAE J2334 Laboratory Cyclic Corrosion Test

2.1.2 ASTM Publications

Available from ASTM International, 100 Barr Harbor Drive, P.O. Box C700, West Conshohocken, PA 19428-2959, Tel: 610-832-9585, www.astm.org.

ASTM B 117 Standard Practice for Operating Salt Spray (Fog) Apparatus

2.1.3 ISO Publications

Available from American National Standards Institute, 25 West 43rd Street, New York, NY 10036-8002, Tel: 212-642-4900, www.ansi.org.

ISO/DIS 8044 Corrosion of metals and alloys—Basic terms and definitions

ISO 9227:1990 Corrosion tests in artificial atmospheres—Salt spray tests

ISO 10062:1991 Corrosion tests in artificial atmosphere at very low concentrations of polluting gas(es)

ISO/FDIS 10289 Methods for corrosion testing of metallic and other inorganic coatings on metallic substrates rating of test specimens and manufactured articles subjected to corrosion tests

ISO/DIS 11130 Corrosion of metals and alloys—Alternate immersion test in salt solutions

ISO 11306:1998 Corrosion of metals and alloys—Guidelines for exposing and evaluating metals and alloys in surface seawater

ISO 11463:1995 Corrosion of metals and alloys—Evaluation of pitting corrosion

ISO 11474:1998 Corrosion of metals and alloys—Corrosion tests in artificial atmosphere—Accelerated outdoor test by intermittent spraying of a salt solution (Scab test)

ISO 11845:1995 Corrosion of metals and alloys—General principles for corrosion testing

ISO/DIS 14993 Corrosion of metals and alloys—Accelerated corrosion testing involving cyclic exposure to salt mist, dry and wet conditions

2.1.4 NACE Publications

Available from NACE International, 1440 South Creek Drive, Houston, TX 77084-4906, Tel: 1-800-797-6223, www.nace.org.

TM0169 Laboratory Corrosion Testing of Materials

Forms of Corrosion Recognition and Prevention, NACE Handbook 1. Volume 1. Edited by C.P. Dillon

2.1.5 Military Standards

Available from the Document Automation and Production Service (DAPS), Building 4/D, 700 Robbins Avenue, Philadelphia, PA 19111-5094, Tel: 215-697-6257, http://assist.daps.dla.mil/quicksearch/.

MIL-STD-202 Test Method Standard Electronic and Electrical Component Parts

MIL-STD-810 Environmental Engineering Considerations and Laboratory Tests

TB 43-0213 Corrosion, Prevention and Control Including Rust Proofing Procedures for Tactical Vehicles and Trailers

2.1.6 General Motors Publications

Available from IHS Global Engineering Documents, 15 Inverness Way East, Englewood, CO 80112, Tel: 877-413-5184, www.global.ihs.com.

GM 9540P Accelerated Corrosion Test (Obsolete)

GMW14872 Cyclic Corrosion Laboratory Test

GMN9319

3. DEFINITIONS

For purposes of this document, corrosion is assumed to be one or more of the forms defined in Table 1. Refer to the appropriate document(s) for detailed descriptions.

TABLE 1 - CORROSION TYPES AND CONTRIBUTING FACTORS

	Type of Corrosion	NACE TM0169	SAE J447
1	Uniform Corrosion	Sect. 1.1	
2	High Temperature Corrosion	Sect. 3.2	
3	Microbial Effects	Sect. 3.3	
4	Dezincification (De alloying)	Sect. 2.3	Sect. 4.3.7
5	Localized Corrosion	Sect. 1.2	
6	Concentration Cell Corrosion	Sect. 1.2	Sect. 4.3.1
7	Intergranular Corrosion	Sect. 2.2	Sect. 4.4.5
8	Exfoliation Corrosion		Sect. 4.3.6
9	Galvanic Corrosion	Sect. 1.3	Sect. 4.4.3
10	Fretting Corrosion	Sect. 2.1	Sect. 4.3.8
11	Corrosion Fatigue		Sect. 4.3.9
12	Stress Corrosion		Sect. 4.3.4
13	Cracking Phenomena	Sect. 3.1	
14	Velocity Effects	Sect. 2.1	
15	Pitting Corrosion	Sect. 1.2	Sect. 4.3.2
16	Cavitation Corrosion	Sect. 2.1	Sect. 4.3.10

This document focuses on chemically induced corrosion resulting from operation in typical commercial vehicle environments. Non-chemical aggravating factors such as temperature, stress and erosion are also considered. However, microbial effects, fretting corrosion, and cavitation corrosion are outside the scope of this document.

4. INTENDED APPLICATIONS OF THIS DOCUMENT

4.1 As a General Reference

This standard provides an overview of the commercial vehicle corrosion environment and procedures that are useful for evaluating the performance of components intended for use in this environment.

4.2 Component Testing at the Vehicle Level

Vehicle level testing is discussed in 9.1. Vehicle testing tends to be more representative of real world testing than laboratory testing. However, test procedures must be tailored to accommodate varying environmental conditions at particular test facilities.

4.3 Component Testing in a Laboratory Setting

Laboratory testing is discussed in 9.2. While less representative of real world conditions, laboratory testing is generally more cost effective and repeatable than vehicle level testing.

5. BACKGROUND

5.1 Variability, Environment, and Component Capability

Components should be designed with corrosion resistance that will protect against the worst-case environmental conditions (Figure 1). Competitive designs may depend upon a number of factors that weigh cost versus risk and/or performance.

Variability in the environment and corrosion performance results from:

- Regional conditions in which the vehicle is operated
- The vehicle vocation (e.g., on-highway operation differs from refuse operation)
- Exposure to corrosive elements varies depending on where components are located on the vehicle
- Severity is dependent on length of exposure (not all components are designed for the life of the vehicle)

Variability in component performance results from:

- Process variation
- Material Variation

The situation is exacerbated because of constantly changing environmental constraints and regulations. The purpose of this standard is to establish test procedures that can be used to validate that designs have the intended corrosion resistance performance. Because the tests are accelerated in nature and intended to represent worst-case conditions, they are not representative of any particular “real world” conditions. Furthermore, end users of components should be aware that inadequate field performance may be due to:

1. Improper application of an appropriately designed and manufactured component
2. Design issues (inadequate provision for corrosion protection during the design phase)
3. Inadequate process controls control during manufacturing.

In order to take proper corrective action it is important to ascertain the root cause.

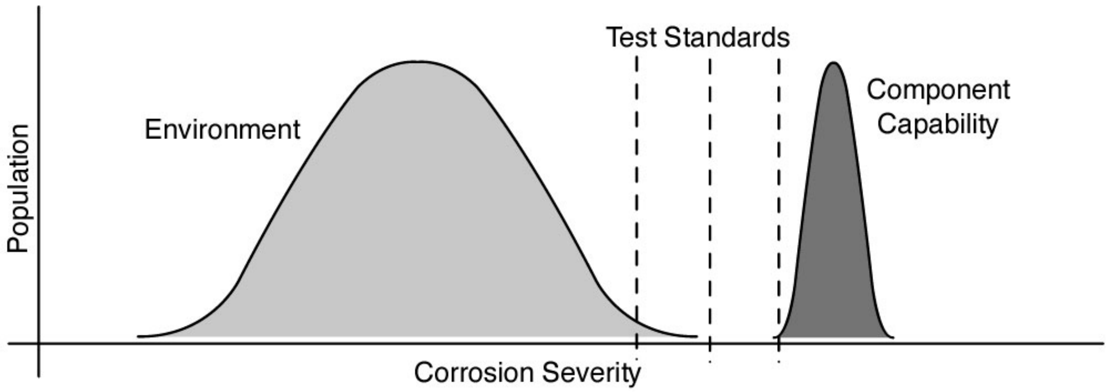


FIGURE 1 - CORROSION SYSTEM DESIGN MARGIN

5.2 Customer Expectations

Components must be designed to meet customer expectations. This includes both original equipment manufacturers and end users (e.g., fleet) that may have differing perspectives. Expectations include both performance and cost effectiveness. Typically the expectation is that a component should not require replacement during its useful life as a result of corrosion. This includes surface and cosmetic corrosion for components where surface appearance is important.

Sample criteria are given in Table 2. These targets are aggressive. Less aggressive targets may be chosen for economic reasons. It is important that specific performance and the associated pass/fail criteria be determined in agreement with the customer.

TABLE 2 - CUSTOMER EXPECTATIONS, YEARS OF CORROSION PERFORMANCE

Application	Heavy Duty	Medium Duty	Light Duty
Tractor	8	-	-
Truck	8	10	10
Trailer and Converter Dolly	16	-	-
Truck Body	10	16	10
Transit Bus	12	-	-
Military	25	-	-

6. CORROSIVE AGENTS AND CONDITIONS

6.1 Chemicals

The primary corrosive chemicals of interest are:

- Sodium Chloride (NaCl)
- Calcium Chloride ($CaCl_2$)
- Magnesium Chloride ($MgCl_2$)

Other chemicals such as sodium bicarbonate may be included as part of specific test solutions. Recommended corrosion test solutions are shown in Table 3.

TABLE 3 - CORROSION TEST SOLUTIONS (PERCENT BY MASS)

#	Historical Reference or Description	H_2O	NaCl	$CaCl_2$	KCl	$MgCl_2$	$NaHCO_3$	Other	PH	Application	T
1	ASTM B 117 MIL-STD-810 DIN 50021 Fed Std 151 a/811.1 SAE J2139	95 ± 1% Type IV Per ASTM D 1193	5 ± 1%	-	-	-	-	.3% Max impurities	6.5-7.2	0.6-1.5 bar, 1-2 ml/h 0.85-1.25 bar, 0.5-3 ml/h 0.8-1.2 bar, 0.75-2 ml/h	95 °F, +2,-3
2	SAE J2334	99.325%	0.5%	0.1%	-	-	0.075%	-	Do Not Adj.	immersion, spray or fog	20 °C
3	GM 9540P	98.75 ± 1%	0.9%	0.1%	-	-	0.25%	-	6-8	Spray	
4	GM 9319P	95 ± 1% Type IV Per ASTM D 1193	4 ± 1%	1%	-	-	-	Add 38 g “H-B Weathered Bond B Clay”/Liter to mixture	6.5-7.2	0.6-1.5 bar, 1-2 ml/h	
5	$MgCl_2$ Solution A (ASTM B 117 test with $MgCl_2$ instead of NaCl solution)	95 ± 1% Type IV Per ASTM D 1193	-	-	-	5 ± 1%	-	.3% Max Impurities	6.5-7.2 Per ASTM B 117 Sect. 7	0.6-1.5 bar, 1-2 ml/h	95 °F, +2,-3
6	$MgCl_2$ Solution B for Chassis and wheel-end testing	93%	1%	3%	0.5%	2.5%	-		Do Not Adj.	60-150 kPa (8.7-21.8 psi), 1-2 ml/h per 80cm^2 if using atomized fog option for testing per 10.2.2 or 10.3.2.	35 °C +1,-2 (95 °F, +1.8,- 3.6)
7	$MgCl_2$ Solution D Slurry Mixture	71.3%	3.9%	3.0%	-	2.5%	-	Az test dust med #3 2.5% Orange City Silica Sand #60 1.4% Lincoln Clay #9 15.4%	Do Not Adj.	Slurry tank: 400 ml/h per cm^2 (Measure with rain gauge)	20 to 27 °C
8	NaCl,$CaCl_2$ Conventional Slurry Mixture	73.8%	3.9%	3.0%	-	-	-	Az test dust med #3 2.5% Orange City Silica Sand #60 1.4% Lincoln Clay #9 15.4%	Do Not Adj.	Slurry tank: 400 ml/h per cm^2 (Measure with rain gauge)	20 to 27 °C

NOTE: Solutions 1, 3, 4, and 5 are included in this table for background purposes only.

6.2 Mechanical Effects

Mechanical effects such as abrasion and bending, and operating conditions that cause relative movement tend to disrupt corrosion protection systems. These effects include:

- Velocity Effects
- Pitting Corrosion
- Stress Corrosion
- Corrosion Fatigue
- Fretting Corrosion

If components are subject to these effects due to their location on the vehicle and operating conditions, corrosion testing must take these effects into account.

Any potential damage to corrosion systems due to installation practices must be taken into account during corrosion testing. In particular, possible damage to the corrosion coatings of rivets and other fasteners during installation should be simulated during testing.

6.3 Thermal Effects

The temperature that components are subjected to in operation is a contributing factor to corrosion. This is the case for exhaust system components, brake components and for certain components located within the engine compartment. If components are subject to these effects due to their location on the vehicle and operating conditions, corrosion testing must take these effects into account.

6.4 Galvanic Corrosion

Galvanic corrosion can result when dissimilar metals are joined together. Components that could be subject to galvanic corrosion should be tested together with their mating parts and fasteners where practical. A portion of a mating part or a substitute with similar characteristics may be used when it is not practical to use the actual components because of size or weight constraints.

7. CORRELATION

7.1 Vehicle Testing versus Laboratory Testing

Vehicle testing gives the best opportunity to achieve conditions representative of actual use. This is the preferred approach but in many cases this is not practical. It is too expensive to test an entire vehicle to obtain results for a single component. Therefore component suppliers are more likely to prefer laboratory testing whereas OEMs may prefer vehicle level testing.

7.2 Accelerated versus Non-Accelerated Testing

For products that have long operational lives, validation testing, by necessity, must incorporate a degree of acceleration. Otherwise, new vehicle and new component introduction would be delayed beyond viability.

7.3 Mass Loss Coupons

Some means is needed to provide correlation between real world conditions and accelerated test conditions whether testing is conducted on vehicle or in a laboratory. An accepted method for establishing long-term correlation with field results is the use of mass loss coupons. Mass loss coupons are to be used both to estimate the severity of corrosion in the field and also inserted in test chambers with components to verify that the test severity correlates to real world conditions. The information in this document is to be supported and periodically updated by incorporating results from corrosion test coupons retrieved from fleet operations.

7.3.1 Recommended Test Coupons

Recommended corrosion test coupons are described in Table 4. The characteristics and dimensions are typical for coupons that are available from a variety of commercial sources. As an alternative, users can produce their own coupons from sheet steel.

TABLE 4 - RECOMMENDED TEST COUPONS

	Inch	Metric	Inch	Metric	Inch	Metric
Material	AISI 1006 - 1010 mild steel					
Density	0.284 lbm/in^3	7.86 g/cc	0.284 lbm/in^3	7.86 g/cc	0.284 lbm/in^3	7.86 g/cc
Thickness	0.0625 in (1/16 in)	1.59 mm	0.125 in (1/8 in)	3.175 mm	0.250 in (1/4 in)	6.35 mm
Length	2.00 in	50.8 mm	2.00 in	50.8 mm	2.00 in	50.8 mm
Width	1.00 in	25.4 mm	1.00 in	25.4 mm	1.00 in	25.4 mm
Hole dia.	0.265 in	6.73 mm	0.265 in	6.73 mm	0.265 in	6.73 mm
Volume	0.125 in^3	2048 mm^3	0.250 in^3	4097 mm^3	0.5 in^3	8194 mm^3
Hole volume	0.00345 in^3	56.49 mm^3	0.00689 in^3	113.0 mm^3	0.0138 in^3	226.0 mm^3
Vol, less hole	0.122 in^3	1992 mm^3	0.243 in^3	3984 mm^3	0.486 in^3	7968 mm^3
Mass	0.0345 lbm	15.68 g	0.0690 lbm	31.36 g	0.138 lbm	62.72 g
Surface area	4.323 in^2	2789 mm^2	4.646 in^2	2997 mm^2	5.292 in^2	3414 mm^2

Thinner samples permit better sensitivity when weighing samples. However, for long term cumulative use, a significant portion of the body mass will be lost. This could result in difficulty in maintaining a relatively constant surface area over the length of the test.

FIGURE 2A - CORROSION MASS LOSS COUPONS MOUNTED IN RACK – FRONT VIEW

FIGURE 2B - CORROSION MASS LOSS COUPONS MOUNTED IN RACK – TOP VIEW

7.3.2 Coupon Use

- Coupons serve to monitor the average general bare steel corrosion produced by the test environment. Coupon thickness selection depends on individual test needs. Thicker coupon sizes should be used for tests with long durations and high severity. It is not a good practice to intermix different coupon thicknesses on the same coupon rack.

- Theoretically, the aspect ratio of coupons is such that the surface area presented to the environment is essentially constant (i.e., surface area does not decrease significantly as corrosion occurs). Since coupons are bare, unprotected metal, they should experience corrosion related mass loss in direct proportion to the severity of the environment and the dwell time within the environment.

NOTE: Coupons, as discussed in the context of this document, are not intended to validate the effectiveness of particular corrosion protection systems. While coupons can be used in this manner, the result will generally be a pass/fail determination rather than providing continuous data regarding the severity of exposure to the environment.

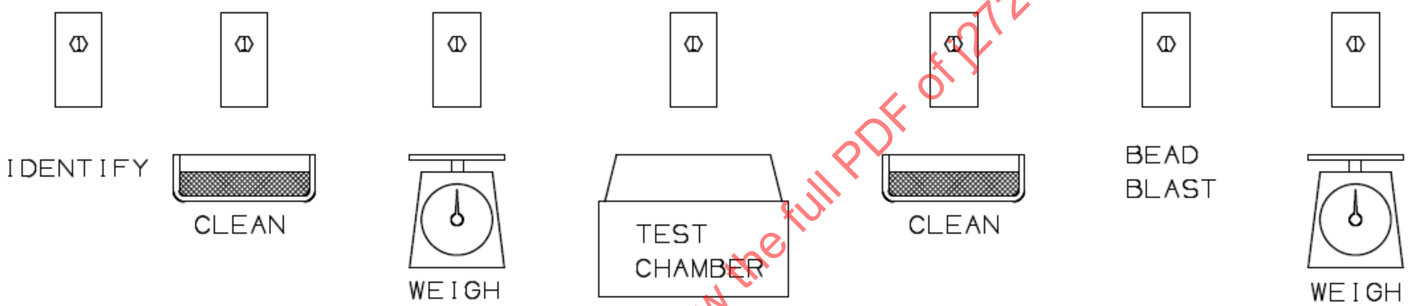


FIGURE 3 - COUPON PROCEDURES

7.3.3 Coupon Preparation

- Each coupon shall be permanently identified. A number may be stamped onto the surface but sufficient corrosion will obscure this number. A permanent marker can be used to identify the nylon bolt (see 7.3.4) then the bold must follow the coupon through all cleaning and weighing cycles. To ensure bolts and coupons are not mixed, only one coupon should be removed from its identifying bolt at a time.

- 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 wiping with methanol or acetone. Degrease coupon using a commercial degreaser and a nylon brush. Remove Degreaser residue with acetone. Remove acetone by spraying with clean dry air.

- The weight shall be recorded and retained for future reference.

7.3.4 Coupon Rack Preparation

- Prepare the coupon rack with sufficient coupons to monitor the test.

- The coupons shall be secured to an aluminum or nonmetallic coupon rack with fasteners as shown in Figure 2. The bolt, nut and washers shall be made from a plastic material, preferably nylon.

- The location of each coupon on the rack shall be identified and recorded using the prestamped numbers for reference.

- Allow a minimum 5 mm spacing between the coupons and the rack surface. All coupons shall be secured in vertical position and must not contact each other.

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

7.3.5 Post Processing

- At the end of the duration of the test, remove the coupons and allow to air dry for 1 h.

- Weigh each coupon. (= Post-Slurry Weight with corrosion).

- Use a degreaser and a nylon bristle bottlebrush or nail brush to remove the heaviest corrosion products from the surfaces of the coupon.

- Rinse with acetone.

- Remove acetone residue by spraying with clean dry air.

- Weigh each coupon. (= Post-Slurry Weight Brushed).

- Bead blast the coupon with 70-140 mesh glass bead or 12-20 walnut shell media to remove residual corrosion products from the surface. Minimize the force and time of bead blast to avoid eroding the base surface of the coupon.

- Weigh each coupon. (= Post-Slurry weight without corrosion).

7.3.6 Types of Mass Loss Coupons - Incremental and Cumulative

- Cumulative: Duplicate coupons for each test year desired are installed on racks located on the test item prior to initiating the test. After the completion of each test the two designated coupons for that particular test sequence are removed, corrosion products removed and weighed to determine mass loss/corrosion rate.

- Incremental: Typically, two designated coupons are installed on the coupon rack at the beginning of each simulated corrosion test year and removed after the desired number of corrosion cycles. After being removed, the coupons are bead blasted and weighed to determine mass loss/corrosion rate. The incremental coupons are replaced every test year.

With field data available from corrosion coupons, a number of cycles can be run on Design Validation samples to generate coupon mass losses found in the field. The number of cycles that gives a mass loss corresponding to 1-year of field operation is referred to as a phase.

7.3.7 Mass Loss Rates

Field data is limited at this point. However, it is intended that this document be updated on a regular and frequent basis as better data becomes available: It is presumed that mass loss rates are proportional to exposed surface area. The mass loss rates shown in Table 5 are proposed as a starting point.

TABLE 5 - CORROSION COUPON MASS LOSS RATES

Location	Mass Loss, g/mm^2 per year
Interior	1.7×10^{-6} to 2.0×10^{-6}
Body Exterior	3.5×10^{-5} to 1.0×10^{-4}
Under hood	5.2×10^{-5} to 1.5×10^{-4}
Chassis	1.7×10^{-4} to 2.0×10^{-4}
Wheel Ends	1.7×10^{-4} to 2.0×10^{-4}

8. EVALUATION

Once an accelerated corrosion test cycle is completed and correlation established with field results (based on mass coupon loss rates), it is necessary to have a systematic method of evaluating the performance of the components under test. For purposes of evaluation, corrosion can be divided into the categories shown in Table 6.

TABLE 6 - CORROSION EVALUATION

Type	Stage	Description	Example Appendix A
Cosmetic	0	No visible signs of corrosion or corrosive attack. No presence of white, red or black corrosion products. No presence of paint fill blistering indicating corrosive attack. Discoloration of a coating system, other than caused by corrosion, is permissible.	Figure A1
	1	General surface corrosion is present. White, corrosion products are present on the surface of the component being evaluated, but no significant attack is present. Minor blistering of the coating may have occurred.	Figure A2
	2	General surface corrosion is present. Red and/or black corrosion products are present on the surface of the component being evaluated, but no significant attack is present. Minor blistering of the coating may have occurred.	Figure A3
	3	Heavy corrosion products are present on the surface of the component. This is the beginning of metal loss; however, no significant loss has yet occurred. Moderate white, red and/or black corrosion products are present on the component surface. Severe blistering of the paint may have also occurred.	Figure A4
Functional	4	Corrosion has resulted in mechanical malfunction such as bearing seizure or loss of motion in sliding or moving parts. Electrical components experience shorts or opens resulting from corrosion.	Figure A5
Structural	5	Corrosive attack has resulted in significant base metal loss. Reduction in the cross-section thickness of the component has occurred. Voluminous white, red and/or black corrosion product present on the component. The structural integrity of the component may or may not be compromised. Pinholes have developed.	Figure A6
	6	Perforation of the base metal has occurred. No metal remains at the point of severest corrosive attack. The component has lost structural integrity.	Figure A7

9. RECOMMENDED TEST PROCEDURES (ACCELERATED TESTING)

Figure 4 gives an overview of corrosion test procedures. A test event consists of the application of a corrosive element using a prescribed procedure for a set amount of time. An event could be a salt spray event, a heating or drying event or a mechanical event such as joint exercise or application of an abrasive. A sequence of events forms a cycle. In many cases it may be convenient for a cycle to be completed in 24 h. What is important is that the events contained within the cycle adequately cover a range and severity that provide correlation with the real environment.

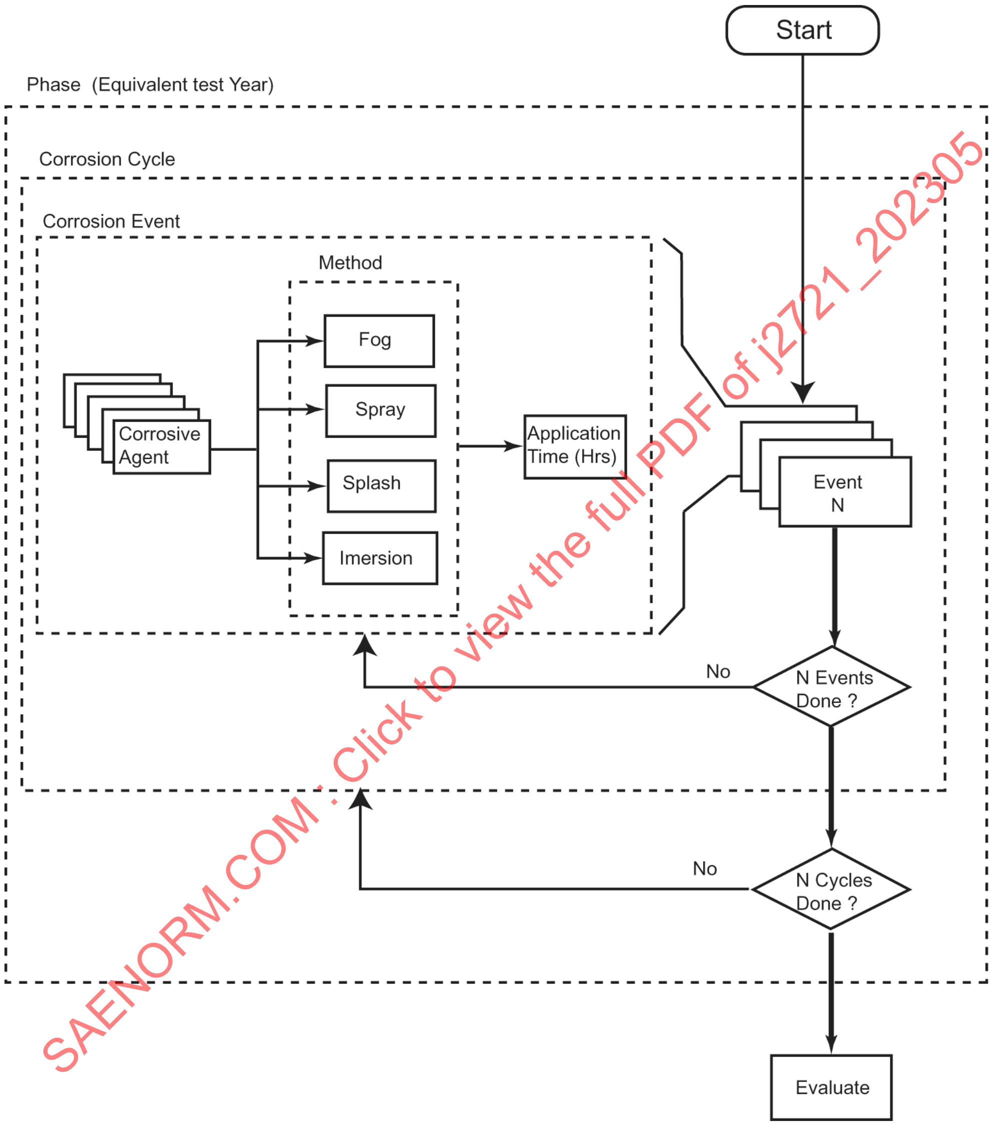


FIGURE 4 - CORROSION EVENTS, CYCLES AND PHASES

9.1 Vehicle Testing

A number of vehicular proving grounds offer vehicle level corrosion testing. Vehicle level testing is a preferred method since it has the best possibility of being representative of real life conditions. The opportunity to combine corrosion testing and durability testing is also attractive. However, because of climatic differences, test procedures vary from facility to facility. Procedures must also be adjusted on a continuing basis to compensate for weather conditions. Furthermore, because test set-ups are rather large, flexibility in providing corrosion agents and application methods may be limited.

The following discussion (based loosely on experience at Aberdeen Proving Ground) provides general guidelines that can be used by facilities interested in providing this sort of testing.

As shown in Figure 4, the procedures consist of phases or equivalent years that are made up of a number of cycles. Each cycle in turn consists of a number of events with an associate methodology and exposure time. For the Aberdeen Proving Grounds a typical acceleration factor is generation of 1 year of equivalent corrosion exposure in 1 month.

9.1.1 Events

Typical events include splash trough/mist booth, grit trough, and high-temperature/high-humidity chamber (typically for 8 h). General durability operation on a variety of surfaces and storage at ambient conditions makes up the remainder of the operational exposure.

9.1.2 Cycle

As a starting point, a typical cycle may consist of 4 splash trough/mist and 4 grit trough events plus 400 endurance kilometers (250 miles).

9.1.3 Corrosive Agent

It is recommended that solution 6, listed in Table 3 be used for splash trough testing and that solution 7 be used for grit trough events.

9.1.4 Simulated Test Tear of Corrosion (Phase)

The number of years of simulated corrosion testing should be determined based on the application and customer requirements. Refer to Table 2. For reference, a typical test might consist of 15 cycles + 2 to 5 humidity chamber events. (More humidity events are required during winter months when humidity is lower.)

9.1.5 Humidity Application

The purpose of the humidity chamber is to create high temperature and humidity conditions that will accelerate the natural corrosion process. In effect, the booth will accelerate the reaction of the contaminants applied by the different test events with any exposed material on the vehicle. The humidity chamber must have a working area sufficient to hold the vehicle being tested. Appropriate equipment is required to measure and also control the temperature and humidity at the specified levels. Circulation fans must be present to provide a moderate flow of the high humidity air throughout the chamber. The temperature should be held at 50 °C, ±2 degrees. The relative humidity will be maintained at 100% in a condensing state. The resulting water fog will provide a condensation rate of 1 to 2 ml/h in collection devices having a horizontal collection area of 80 cm^2. During designated test cycles, the vehicle will be placed into the humidity chamber for an 8 h period. The temperature and humidity will be maintained at the specified levels for the duration of exposure.

The test vehicle will be placed into the humidity chamber as frequently necessary to achieve the target corrosion rate as shown in Table 5.

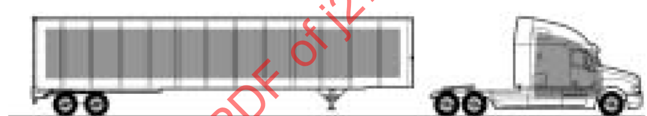
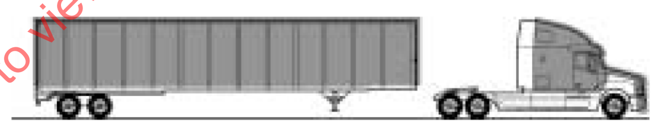
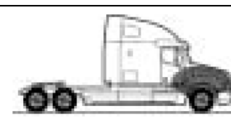
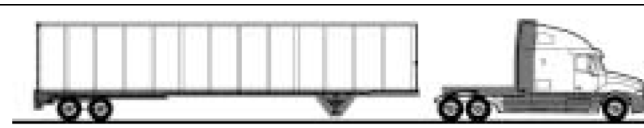
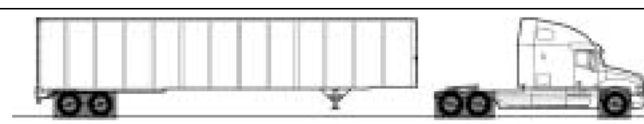
9.2 Laboratory Testing

Accelerated laboratory testing is a preferred method of testing in many cases. It has the advantage of being cost effective and, in most cases, better controlled and therefore more consistent than vehicle level testing. An appropriate test method should be selected based on the intended location of components on the vehicle and their operation.

Electrical devices should be powered and functional during testing. Mechanical components should be stressed as part of their normal function, i.e., mounting straps under tension. Where practical, components should be mated and fastened to similar materials as would be installed on the vehicle. Ideally this would be a part of the intended mounting location to account for possible galvanic action, e.g., exhaust clamp mated to exhaust pipe. Where not prescribed, the devices under test will be positioned in their normal mounting orientation.

10. HEAVY DUTY VEHICLE CORROSION ENVIRONMENT

TABLE 7 - HEAVY VEHICLE CORROSION ENVIRONMENT

7.1 Interior areas Cab - floor Cab - Instrument Panel Cab - inside door Cab- Head liner Cab - Bunk area, storage compartment Interior (aft of Cab) Interior -Trailer, Dry Van Interior -Trailer, Refrigerated Interior -Trailer, Bulk Haul, Tanker	
7.2 Body Exterior Cab and Trailer Forward Vehicle, (Bumper, Grill) Under floor Rear Top Doors Front of trailer	
7.3 Under Hood Engine (upper portion) Bulkhead	
7.4 Chassis (suspension, axles, air tanks, etc.) Frame rails and below Engine (lower portion)	
7.5 Wheel Ends Wheel Ends, Wheel Wells	

10.1 Interior (Cab, Aft of Cab, Trailer)

10.1.1 Components

- Floor
- Instrument Panel
- Inside door
- Head liner
- Bunk storage compartment
- Trailer Interior

10.1.2 Recommended Test Procedure (Based on SAE J2334)

For interior components, use the procedure described in Table 8. Based upon the experience of SAE Committee members running other accelerated corrosion tests, a phase or equivalent test year may be approximately 8 cycles. However coupon mass loss should be used as the primary criterion.

TABLE 8 - BODY INTERIOR RECOMMENDED CORROSION CYCLE

Event	Title	Corrosive Agent	Application	Time	Comment
a	Wet Soak	-	50 °C 100% R.H.	6 h	• Ref SAE J2334
b	Application of corrosive agent	Table 3 Solution 2	25 °C ± 2 °C	15 min	• Ref SAE J2334 • For upper cab use salt fog • For lower cab and trailer interior use spray
c	Dry Soak	-	60 °C 50% R.H.	17 h, 45 min	• Ref SAE J2334

10.2 Body - Exterior of Cab/Trailer

10.2.1 Components

- Bumper, Grill
- Floor, Underside
- Rear Cab/Trailer
- Top Cab, Trailer
- Doors, Mirrors, Exterior
- Front of trailer

10.2.2 Recommended Test Procedure

For body exterior components use the procedure describe in Table 9. Based upon the experience of SAE Committee members running other accelerated corrosion tests, a phase or equivalent test year may be approximately 8 to 20 cycles. However coupon mass loss should be used as the primary criterion.

TABLE 9 - BODY EXTERIOR RECOMMENDED CORROSION CYCLE

Event	Title	Corrosive Agent	Application	Time	Comment
a	Wet soak	-	50 °C 100% R.H.	6 h	• Ref SAE J2334
b	Salt application	Table 3 Solution 6	25 °C ± 2 °C	15 min	• Similar to SAE J2334 but includes KCl and $MgCl_2$ in solution. • For upper cab, grit, doors, etc., use spray. • For bumpers and other components that are occasionally under water use dip procedure.
c	Dry soak	-	60 °C 50% R.H.	17 h, 45 min	• Ref SAE J2334

10.3 Engine Compartment (Upper Portion and Bulkhead)

10.3.1 Components

- Turbo Chargers
- Radiators
- Brake valves
- Hydraulic booster/Master cylinder
- Windshield Wiper Components
- Under-hood electronic control units

10.3.2 Recommended Test Procedure

For engine compartment components, use the procedure in Table 10. Based upon the experience of SAE Committee members running other accelerated corrosion tests, a phase or equivalent test year may be approximately 8 to 20 cycles. However coupon mass loss should be used as the primary criterion.

TABLE 10 - RECOMMENDED CORROSION TEST CYCLE -
ENGINE COMPARTMENT UPPER PORTION AND BULKHEAD

Event	Title	Corrosive Agent	Application	Time	Comment
a	Wet soak	-	50 °C 100% R.H.	6 h	• Ref SAE J2334
b	Salt application	Table 3 Solution 6	25 °C ± 2 °C	15 min	• Similar to SAE J2334 with different corrosive agent
c	Dry soak	-	125 °C 50% R.H.	17 h, 45 min	• Similar to SAE J2334 but higher temperature consistent with engine compartment

10.4 Chassis (Suspension, Axles, Air Tanks, etc.)

10.4.1 Components

Chassis components are generally considered to be those components mounted directly or indirectly to the frame in the lower portion of the vehicle. These components are subjected to the environmental elements of the road surface. This also includes the backside of the cab that can be subjected to debris, road splash, and contaminants originating from the road surface. Areas such as wheel ends, wheel wells, and lower engine components have their own special requirements and are covered under separate sections.

- Frame Rails and cross member, Mounting brackets
- Drive Train Components including:
  Axles assemblies, Transmissions, Oil coolers, Drive shafts, Universal joints
- Steering gear and Linkages
- Access Steps, Deck Plates, hand holds
- Suspension Components, including
  shocks, springs, air bags, suspension heights sensors
- Fifth Wheel and Locking Mechanisms
- Trailer Decking other than Wood, Trailer Landing Gear
- Fuel system components, including:
  Fuel Lines, Fuel Tank Straps, Fuel Tanks
- Air system components, including:
  Air Dryers, Air Lines, Air Tanks, Air Valves, glad hands
- Brake Components, including:
  Brake Chambers, Brake Lines, ABS Components, slack adjusters
- Electronic Components, including:
  Electrical Connectors, Electronic Brake System Components, Electronic Modules, SAE J560 components, sensors other than wheel end, Lighting components, Wiring harnesses
- Fasteners
- Ferruling
- Exhaust Components, including:
  piping, mufflers, particulate traps and filters

10.4.2 Recommended Test Procedure

Refer to Table 11 for the recommend chassis test procedure.

Based upon the experience of SAE Committee members running other accelerated corrosion tests, it is expected that approximately 8 to 20 cycles will achieve a corrosion exposure level equivalent to 1 year. Adjust the number of cycles as needed to obtain the mass loss rate designated in Table 5.

Run as many test phases as needed based on customer requirements (Table 2).

TABLE 11 - CHASSIS CORROSION TEST EVENTS

Event	Repeat	Title	Corrosive Agent	Method	Time	Comment
a	Do not repeat	Pre-treatment	Gravel (Water worn road gravel)	Per SAE J400		• Discretionary between supplier and OEM (not required for devices mounted in protected areas) • Coupons need not be subject to gravel bombardment • Repeat as agreed upon prior to moving to Event b
b Option 1	4 times	Mist or Spray	Table 3 Solution 6	Spray ≥95% R.H.	Wet thoroughly every 2 h	Standard components See note 1 and note 2
		Dry	-	Ambient 40 to 50% R.H.	Remainder of 2 h	
b Option 2	2 times	Mist or Spray	Table 3 Solution 6	Spray ≥95% R.H.	Wet thoroughly every 2 h	Use for exhaust components in place of opt 1
		Dry	-	Ambient 40 to 50% R.H.	Remainder of 2 h	
	1 time	High Temp	-	500 °C Oven	4 h	
b Option 3	2 times	Mist or Spray	Table 3 Solution 6	Spray ≥95% R.H.	Wet thoroughly every 2 h	Use for items near exhaust in place of opt 1
		Dry	-	Ambient 40 to 50% R.H.	Remainder of 2 h	
	1 time	High Temp	-	250 °C Oven	4 h	
c	Every other cycle	Grit/ Slurry	Table 3 Solution 7	Spray/ Splash (Ambient Temp)	8 h	Substitute Event “c” for Event “b” every other cycle. (Adds elements of crevice corrosion, coating wear and moisture retention)
d	1 time	Humidity		49 °C ± 2 °C (120 °F) ≥95% R.H.	8 h Incld 1 h ramp up	See note 3
e	1 time	Drying		60 °C ± 2 °C (140 °F) <30% R.H.	8 h Incld 3 h ramp down	See note 3

- Note 1: Electrical devices should be powered and functional during testing.
- Note 2: Mechanical components should be stressed as part of their normal function, i.e., mounting straps under tension. Where practical, components should be mated and fastened to similar materials as would be installed on the vehicle, ideally this would be a part of the intended mounting location to obtain any galvanic action, i.e., exhaust clamp mated to exhaust pipe. Where not prescribed, the devices under test will be positioned in their normal mounting orientation.
- Note 3: Humidity ramp times between the ambient and wet condition and between the wet and dry conditions are critical to test acceleration because corrosion rates are highest during this period. The time from ambient to the wet condition should be approximately 1 h and the transition time between wet and dry conditions should be approximately 3 h. If a test is conducted with ramp times different than described above, the number of cycles to reach coupon mass loss targets may increase or decrease.
- Note 4: If testing is suspended over weekends, store components at ambient temperature and humidity.

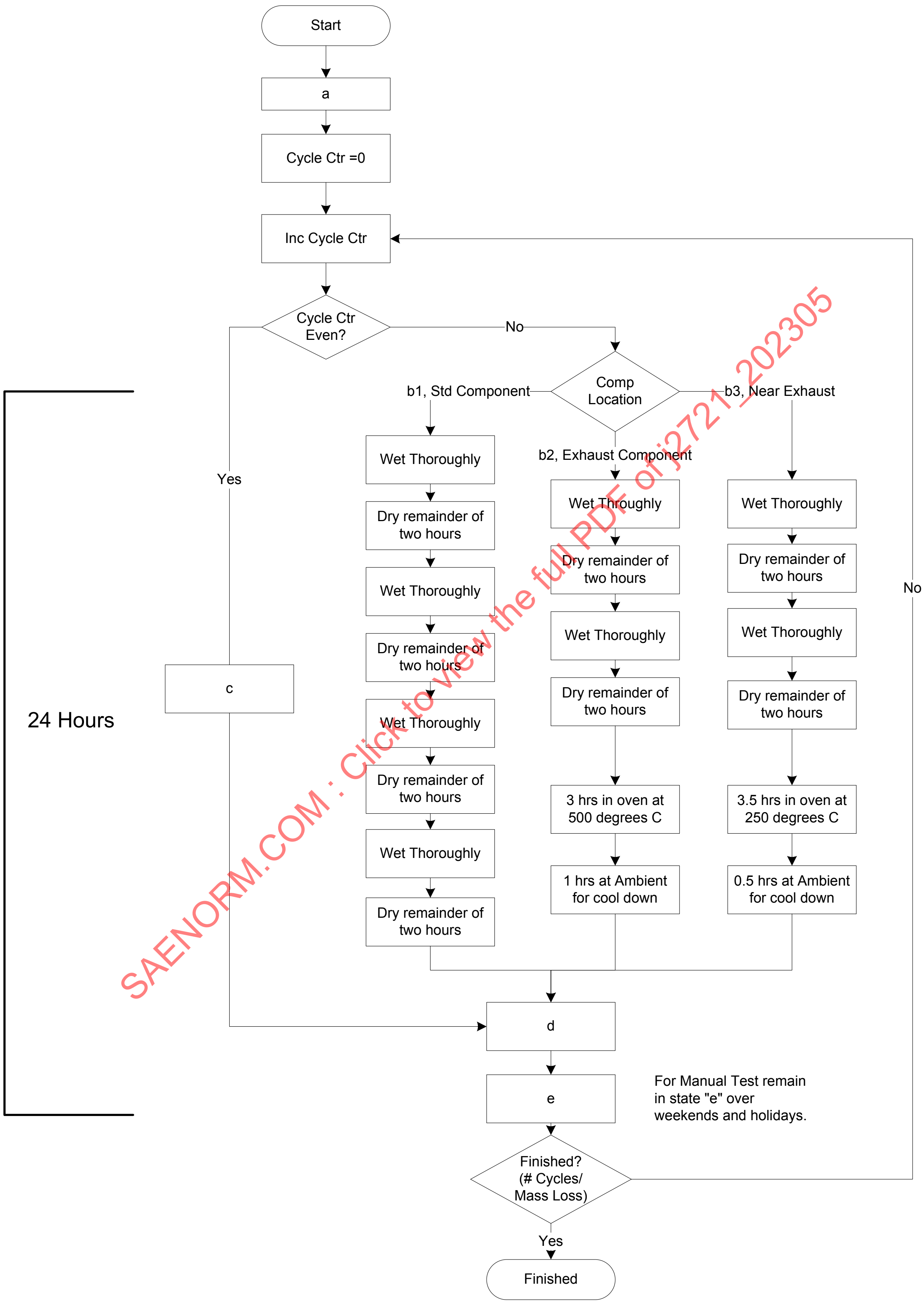


FIGURE 5 - CHASSIS CORROSION CYCLE - FLOW CHART

10.5 Corrosion Test Procedures for Wheel End Components

Vehicle wheel ends are exposed to heavy road splash, which can contain de-icing salts including sodium chloride, calcium chloride and magnesium chloride. Centrifugal force can drive road splash into the interior sections of the wheel end. Heat generated by braking can provide rapid drying cycles and also damage corrosion protective coatings.

10.5.1 Components evaluated by this test include

- wheel wells
- wheel assemblies
- hub assemblies
- rotors
- brake drums
- S-cams
- calipers
- fasteners
- tone rings
- speed sensors
- wiring harnesses
- Tires and hoses are not evaluated, but may be used for assembly tests.
- Incomplete wheel ends and wheel end subcomponents may be tested by this procedure without testing an entire wheel end assembly. In such case, only the procedures, which correspond to the tested parts, apply.

10.5.2 Preparation – Special Procedure for Tone Rings

If the components to be tested include a tone ring for speed signal generation, perform the following first. Measure the voltage amplitude of the output signal at 20 rpm. If the tone ring is intended to mate with a push-in type speed wheel speed sensor, condition the tone ring as follows:

a. Assemble the tone ring with those mating components that support the tone ring and the wheel speed sensor. Torque all fasteners to the mid-point of any torque specification range, and record the torque value.

b. Mount the assembly on an axle or on a rotating test fixture that simulates an axle.

c. Measure run-out and adjust as necessary to keep it less than any vehicle requirement for run-out (typically 0.18 mm (0.007 in) max TIR).

d. Insert the sensor less friction sleeve (to permit free movement). Using a compression spring or similar method, apply 180 N (40 lbf) to force the sensor against the tone ring. This is the recommended pushout force for sensors with lubricated friction sleeves. The use of a laboratory method of applying force is recommended to avoid the extreme variation that can result when using standard friction sleeves and holders. Rotate the tone ring through 10 revolutions. This will simulate the abrasive impact that the auto-adjustment feature may induce on the protective coating on the tone ring.

10.5.3 Procedure

Refer to Table 12. Based upon the experience of SAE Committee members running other accelerated corrosion tests, it is expected that approximately 8 to 20 cycles will achieve a corrosion expose level equivalent to 1 year of field service. However, adjust the number of cycles as needed to obtain the mass loss rate designated in Table 5.

10.5.4 Inspection

- Refer to Table 6
- The general criterion is full functionality

10.5.5 Final Test

- Disassemble all units and record torque-to-disassemble.
- Measure the voltage amplitude of the output signal at 20 rpm and verify that the signal level and quality is acceptable.

TABLE 12 - WHEEL-END CORROSION TEST PROCEDURE

Event	Repeat	Title	Corrosive Agent	Method	Time	Comment
a	1 time only Do not repeat	Tone Ring and Sensor Pretreat	Abrasive rubbing between mating components	10.5.2 above	-	Special procedure for tone rings with self adjusting sensors
b	1 time only Do not repeat	Pretreat (Burnish Test)	Heat plus abrasive rubbing between mating components	Ambient with self heating	Approx 15 h	Prior to testing, brake components shall be subjected to a standard burnish test similar to that described in FMVSS-121, S6.2.6 or FMVSS-105, S7.4.2.1. See also: • SAE J2115, Section 6 for drum brakes • SAE J2707, Section 6 for disc brakes
c1	1 time only Do not repeat			480 °C (900 °F)	3 h	Disc brake pads and components directly exposed to heat resulting from proximity to disc brakes. See Note 2
c2	1 time only Do not repeat			205 °C (400 °F)	12 h	Drum brake shoes and wheel end components exposed to high temperature due to proximity to drum brake components. See Note 2
d	4 Times	Mist or spray	Table 3 Solution 6	Spray ≥95% R.H.	Wet thoroughly	
		Dry	-	Ambient	Remainder of 2 h	
e	Every other cycle	Grit/ Slurry	Table 3 Solution 7	Continuous Spray (Ambient Temp)	8 h	Substitute Event “e” for Event “d” every other cycle.
f		Humidity		49 °C ± 2 °C (120 °F) ≥95% R.H.	8 h Incld 1 h ramp up	See note 3 (Adds elements of crevice corrosion coating wear and moisture retention)
g		Drying		60 °C ± 2 °C (140 °F) <30% R.H.	8 h Incld 3 h ramp down	See note 4

- Note 1: If active electrical devices are used in wheel end applications they should be powered and functional during testing.
- Note 2: If actual operating temperatures for components are known from available data, use this instead of the temperatures shown in Table 12. Cite the temperature used for testing and justification in the summary test report.
- Note 3: Humidity ramp times between the ambient and wet condition and between the wet and dry conditions are critical to test acceleration because corrosion rates are highest during this period. The time from ambient to the wet condition should be approximately 1 h and the transition time between wet and dry conditions should be approximately 3 h. If a test is conducted with ramp times different than described above, the number of cycles to reach coupon mass loss targets may increase or decrease.
- Note 4: If testing is suspended over weekends, store components at ambient temperature and humidity and note the storage time.

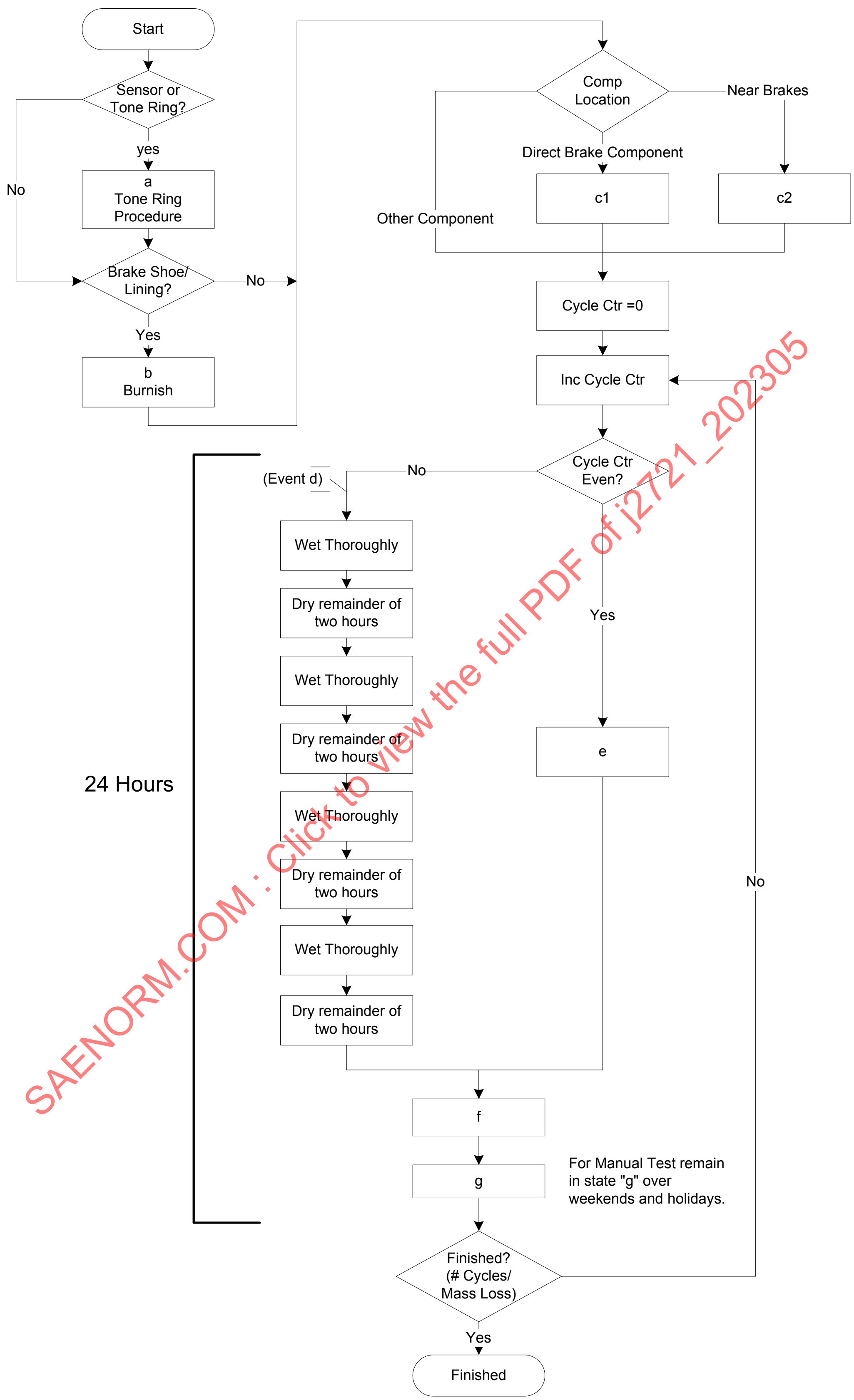


FIGURE 6 - WHEEL END CORROSION TEST PROCEDURE - FLOW CHART

10.6 Alternative Slurry Test

This test procedure exposes components to an aggressive slurry test environment that accelerates the wear and corrosion effects usually experienced in the field environment. This test (10.6) may be run as an alternative to the procedure described in 10.4 or 10.5. The slurry test procedure is particularly recommended for components used in military and other off-highway applications.

Based upon the experience of SAE Committee members running other accelerated corrosion tests, it is expected that 1-3 cycles will achieve a corrosion exposure level equivalent to 1 year (1 cycle requires 1 week of testing). Adjust the number of cycles as needed to obtain the mass loss rate designated in Table 5.

This test procedure is subject to continuing development. In its current form, the original 2.5% magnesium chloride solution has been removed because it causes a significant reduction in acceleration factor.

TABLE 13 - ALTERNATIVE SLURRY TEST

Event	Repeat	Title	Corrosive Agent	Method	Time	Comment
a	1 time only Do not repeat	Pre-treat (Burnish Test)	Heat Abrasive rubbing between mating components	Ambient with self heating	Approx 15 h	Prior to testing, brake components shall be subjected to a standard burnish test similar to that described in FMVSS-121, S6.2.6 or FMVSS-105, S7.4.2.1 See also: SAE J2707, Section 6 for disc brakes
b	As reqd to achieve mass loss rates per Table 2 and Table 5 (multiply appropriate values from Tables 2 and 5)	Slurry Applica-tion	Table 3 Solution 8	20 to 27 °C	120 h	For brake components • For service brake actuators, connect vent to hose directed outside of slurry tank • For brake actuators, connect service side ports to free breathing hose vented outside of slurry tank and operate park brake actuator at 2 cycles per min at 120 psig For other components • Where it is relevant provide rotational drive to wheel end via belt or chain at a rate of 10 to 60 rpm
c		Dry	-	20 to 27 °C	48 h	Components should be suspend above the fluid level in the slurry tank and allowed to dry at ambient without being cycled.