The Engineering Society For Advancing Mobility Land Sea Air and Space®
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SAE/USCAR-6

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STANDARD FOR D.C. BRUSH MOTOR – HVAC BLOWERS

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1.0 SCOPE

This standard sets forth the performance and durability requirements for 12-volt, D.C. brush-type electric motors used for automobile Heating, Ventilation, and Air Conditioning (HVAC) blowers and outlines Production Validation and Continuing Conformance testing.

2.0 REFERENCE DOCUMENTS AND DEFINITIONS

Requirement Hierarchy — In the event there is a conflict between this standard, and any drawings/specifications, prioritize requirements as follows:

1st - Applicable drawing(s)
2nd - Application Specific Requirements
3rd - USCAR standard
4th - Other related standards or specifications

2.1 Applicable Drawings/Specifications

The applicable drawings/specifications for the HVAC motor shall contain or reference the following:

- All dimensional requirements
- Performance requirements/conditions
- Supplier part number
- Direction of Rotation
- Positive terminal identification
- Reference to applicable portions of this and other standards
- The typical mating connector and terminals
- Federal Motor Vehicle Safety Standard (FMVSS) Requirements

Wherever possible the applicable electrical connector should be used in conducting the test sequences contained in this document to simulate actual in-vehicle conditions.

The circuitry shall be terminated using connectors that comply with SAE/USCAR-2, Standard for Automotive Electrical Connection Systems, and the SAE/USCAR-12, Wiring Component Design Guidelines.

2.2 Application Specific Requirements

The application specific requirements shall identify the parameters that differ from the general specifications in this document. The application specific requirements may or may not be an integral part of the applicable drawings.

2.3 Test Categories

2.3.1 Design Verification Tests

Design Verification tests are frequently used to evaluate specific areas of the design. They are a tool for evaluating design alternatives, proposed improvements, cost reduction proposals, or determining root causes of field problems.

2.3.2 Production Validation Tests

Production Validation tests are the acceptance tests for production part approval.

2.3.3 In-Process Validation (Continuing Conformance)Tests

In-process Validation tests are tests to ensure continuing conformance of production samples to the specified requirements.

3.0 OUTLINE

This engineering standard is a supplement to the released motor drawings/specifications and any applicable HVAC subsystem drawings/specifications. Details of test procedures are provided where necessary. Tests in each section shall be performed in the stated sequence. A glossary of terms and details for selected test fixtures and equipment are provided in this standard.

4.0 GENERAL REQUIREMENTS

4.1 Record Retention

Record retention shall comply with PPAP and QS-9000.

4.2 Sample Documentation

Engineering test samples shall be identified by part number, serial number, and motor build date unless otherwise noted.

4.2.1 Required Data Package

The required data package for the appropriate level of submission is to be included with the sample submission to the customer. The data package shall include the applicable test data for each performance parameter, and the serial number of each part in the submission.

4.2.2 Design Verification Samples

Design Verification samples are prototype motors representing the production intent design. Sample sizes are given in Appendix A.

4.2.3 Production Validation Samples

Production Validation samples are defined as motors taken from a 300-unit minimum production run generated from production tools and processed before the first volume shipment. Sample sizes are given in Appendix B.

4.2.4 In-Process Validation (Continuing Conformance) Samples

In-Process Validation samples are motors randomly selected for inspection from lots that have been subjected to all normal high volume production processing, including final packaging.

An inspection lot is defined as the total number of motors of a given basic design produced in one shift. An inspection lot may be divided into two or four sublots at the supplier's option. Each sublot shall be inspected in accordance with the Continuing Conformance tests described in Appendix C.

If variations of a basic motor design (termination, finish, etc.) are produced in a lot (or sublot), the sample size will remain the same but shall include as many of the variations as possible.

In-Process Validation samples are also subject to certain reliability tests. See Appendix C.

4.3 Safety/Environmental Requirements

When required, products and processes used by suppliers to manufacture products shall conform to employee and consumer health, employee safety, and environmental requirements contained in the customer's drawings/specification.

4.4 Materials and Process Standards

Suppliers are expected to subscribe to appropriate Materials and Process Standards that are called out by the customer. The supplier shall not change any material or process requirements subsequent to Design Verification approval without the written consent of the customer's releasing department.

Suppliers shall use the most recent versions of any applicable reference documents or standards.

4.5 Default Test Conditions

When specific test conditions are not given either in the product design specification or elsewhere in this standard, the following basic conditions shall apply:

a) Room Temperature = 23 ± 2°C (73° ± 4°F)
b) Atmospheric Pressure = 650 - 800 mm Mercury
c) Voltage = 13.5 ± 0.1 vdc

4.6 Equipment

Unless otherwise specified, Table 1 represents recommended equipment.

TABLE 1 - Equipment

ITEM	DESCRIPTION	REQUIREMENTS
1	DC Power Supply (Regulated)	• 0-20 V • 0-125 A
2	Digital Multimeter	• Capable of measuring the following at ≥ 0.5% accuracy: – 0-50 Volts DC – 0-10 Amps DC – 0-10 Megohms
3	Current Shunts	• 100 A/100 mv @ ± .25 %
4	Millivolt Meter	• Capable of measuring 0-100 mvdc @ ≥ 0.5% accuracy
5	Thermocouples	• Type "J," "T," or "K," and as required
6	Data Logger	• As required
7	Temperature Chamber	• -40°C to + 110°C (-40°F to + 230°F) • 0 to 95% RH
8	Vibration Controller	• Random
9	Salt Spray Chamber	• Per latest revision of ASTM B117
10	Megohmeter	• Capable of measuring ≥ 1000 Megohms @ 500 Volts DC
11	Dynamometer	• Capable of measuring 0-800 oz. in. (0-6.00 N·m) • 1000 rpm Drag Torque ≤ 3.2 oz. in. (0.023 N·m) • Torque Resolution ≤ 1.6 oz. in. (0.01 N·m)

4.7 Measurement Resolution

Meters and gages used in measurements of the test sample shall be capable of measuring to one tenth of the specified resolution. For example, even though a 0.1 mm and 0.10 mm might be the same dimension, calipers capable of 0.01 mm resolution may be used to measure the first dimension but a micrometer with 0.001 mm resolution is required to measure the second dimension.

4.8 Equipment Calibration

Instrumentation shall be calibrated according to QS-9000.

4.9 Customer Notification of Nonconformance

Should a test nonconformance occur, notify the customer to determine what further actions are required.

4.10 General Endurance Objective

The objective of the design and construction of the blower motor is to be capable of operating in its intended environment and application, without malfunction, for at least 4000 hours on the agreed cyclic speed schedule.

4.11 Design Verification

The supplier shall conduct Design Verification tests on samples during each phase of motor development (as defined by the customer) according to Appendix A.

4.12 Production Validation

The supplier shall conduct Production Validation testing on production samples according to Appendix B before the first volume shipment.

4.13 Failure Mode and Effect Analysis (FMEA)

Within 90 days of source selection, the supplier shall prepare a preliminary design FMEA and review it with the customer. A customer-approved design FMEA shall be required before program tooling release. The supplier shall complete a Process FMEA and review it with the customer before the start of Production Validation testing.

4.14 Quality Control

- A supplier who furnishes finished parts is responsible for the quality of all components of the shipped assembly, whether component parts are processed/manufactured by the supplier or purchased from another source. If required, parts shall be purchased only from customer-approved sources. If required by the customer, an itemized list of important characteristics shall be submitted with motor approval samples.

- Any change to the components, processes, materials, or subcontracted suppliers requires prior customer approval.

- 100 Percent Production Tests

  a) Functionally test blower motors at room temperature at conditions which meet or correlate to those shown on the applicable drawing/specification.

  b) Subjectively evaluate the blower motors for noise. The minimum evaluation condition shall be a voltage sweep of the motor at no load throughout its low speed/high speed range; the sweep shall have a minimum duration of 6 seconds. A suitable listening environment is required. The motor shall not be noisier than a noise master motor or equivalent recording.

4.14 (Continued):

c) Observe the commutation wave form and confirm that the wave form is characteristic of a population of motors known to be in good working order.

4.15 Jury Evaluation

If a jury evaluation is conducted for specific or overall noise characteristics, the following rating scale, Table 2, is recommended with a minimum acceptable level specified by the customer.

TABLE 2 - Noise Rating Scale

RATING	CLASSIFICATION
10	Superior
9	Excellent
8	Very Good
7	Good
6	Satisfactory
5	Borderline
4	Unsatisfactory
3	Bad
2	Very Bad
1	Intolerable

5.0 PERFORMANCE REQUIREMENTS/TESTS

5.1 Motor Performance

5.1.1 Procedure

1. Mount the motor on a dynamometer capable of absorbing the output power of the motor on a continual basis, as well as being able to exceed its stall torque.

2. Perform the following as indicated on the applicable drawing/specification:

a) Adjust the cooling air flow (5 CFM, unless otherwise specified).

b) Apply regulated voltage to motor terminals.

c) Adjust load for proper torque.

NOTE: The tolerances for the values used in step 2 are as follows:

Air Flow ± 0.50 CFM, Voltage ± 0.05 vdc, Torque ± 0.5 oz. in. (.0035 N·m)

5.1.1 (Continued):

3. Record the motor terminal voltage, current, speed, and torque after thirty (30) minutes of operation or longer, if necessary, to achieve temperature stabilization.

5.1.2 Acceptance Criteria

Each motor shall be capable of meeting the current, speed, and torque requirements at the operating conditions shown on the applicable drawing/specification when tested according to section 5.1.

5.2 Noise Tests

5.2.1 Quantitative Measurement (Room Ambient)

5.2.1.1 Procedure

1. Test the motor in a quiet room, with ambient noise level less than 30 dB(A).

2. Suspend the motor from the mounting plate by nonmetalic strings or mount on a suitably designed fixture. Ensure that the motor is oriented to simulate in-vehicle position. Achieve a motor no-load speed of 1500 rpm ± 10 rpm by applying the necessary voltage to the motor terminals. The total running time for each motor shall not be longer than 10 minutes.

3. Measure the average sound pressure level in dB(A) at each of the following three locations: 10 cm axially from the shaft extension end of the motor, 10 cm radially to the side centered on the frame of the motor and 90° from any cooling hole, and 10 cm axially to the rear of the motor.

4. Ensure that the free space around the motor is not less than 61 cm (24 in.), except for the noise meter and its stand.

5.2.1.2 Acceptance Criteria

Refer to applicable drawing/specification for the maximum allowable motor noise. If no maximum is specified, the limit shall be 48 dB(A) for the shaft extension end of the motor, and 45 dB(A) for each of the other two locations.

5.2.2 Subjective Noise Evaluation – Room Ambient Test

5.2.2.1 Procedure

1. Test the motor in a quiet room with ambient noise level less than 30 dB(A).

2. Suspend the motor from the mounting plate by nonmetalic strings or mount on a suitably designed fixture. Ensure that the motor is oriented to simulate in-vehicle position.

3. Subjectively evaluate the noise of the motor under no load throughout its speed range.

5.2.2.2 Acceptance Criteria

There shall be no objectionable noises such as ticks, howls, chirps, squeals, etc.

5.2.3 Subjective Noise Evaluation – Low-Temperature Test

5.2.3.1 Procedure

1. Place the motor in an environmental chamber at -40°C ± 2°C (-40°F ± 4°F) and allow it to stabilize for a minimum of 4 hours.

2. Conduct a subjective noise evaluation by applying 12 to 14 volts to the motor terminals; subsequently, reduce the voltage to sweep through the entire operating speed range over a period of one minute. Subjective evaluation may be conducted by either direct or correlated instrumented methods.

5.2.3.2 Acceptance Criteria – Low-Temperature Test

There shall be no objectionable noises, such as bearing squeal, at start-up or during the remainder of the test.

5.2.4 Chirp Test (Room Ambient)

5.2.4.1 Procedure

Note: The fixture for this test may be a simple rack or stand that supports the motor.

1. Install the proper blower wheel for the application and mount the motor and wheel on a fixture representative of the in-vehicle orientation.

2. Run motor continuously for 1000 hours at 1000 rpm ± 200 rpm.

3. Subjectively evaluate each motor for 30 seconds for the presence of chirp at least once every work day during the test period.

4. De-energize the motor and evaluate during coast down.

5.2.4.2 Acceptance Criteria

The motors are to have "No Chirp" throughout the test.

5.2.5 Chirp Test (Low Temperature)

5.2.5.1 Procedure

Motors for this test must have completed the test in section 5.2.4 (Chirp Test [Room Ambient]) procedure.

1. Mount the motor in a test fixture as described in section 5.2.4.1 (step 1).

2. Soak the motor and fixture in an environmental chamber at -40°C ± 2°C (-40°F ± 4°F) for a minimum of 4 hours.

3. Remove the motor and fixture from the environmental chamber and immediately run the motor at room ambient for 1 hour at 1000 rpm ± 50 rpm.

4. Subjectively evaluate the motor for the presence of chirp a minimum of 3 times during the 1-hour run at room temperature (once on start-up, in the middle, and at the end). Also document any start-up failures, including bearing squeal occurrences.

5. Repeat steps 2 through 4, 9 additional times, for a total of 10 cycles.

5.2.5.2 Acceptance Criteria

The motors are to have "No Chirp" throughout the test. Report any observations of cold-temperature-related noises, such as bearing squeal.

5.3 Demagnetization

5.3.1 Procedure

1. Motors for this test shall have successfully completed the performance requirements (sec. 5.1).

2. Measure the blower motor generated voltage while the motor is externally driven by a 2- or 4-pole synchronous motor in the intended direction of the rotation of the motor. Conduct test at 23°C ± 2°C (73°F ± 4°F).

3. Mount the motor in a housing simulating the vehicle application. Install the proper blower wheel for the application. Install the motor and wheel assembly into the test fixture. Stabilize at -40°C ± 2°C (-40°F ± 4°F) for a minimum of 6 hours.

5.3.1 (Continued):

4. Ensure that the power source is an automotive battery connected in parallel to regulated power supply pre-set to 13.5 vdc ± 0.1 vdc. The power source shall be in a room ambient condition of 23°C ± 2°C (73°F ± 4°F) during the test.

   a) Automotive Battery – Minimum 650-ampere cold crank rating at a minimum 80% state of charge. (Reference: Battery 12 volt - 650 cold cranking amps, SAE 34-650).

   b) Power Supply – DC-regulated power supply rated at a minimum of 125 amperes at 13.5 vdc. The power supply transient recovery time shall be less than 50 ms to within 300 mv of the original power supply setting following a load change from half load to full load or full load to half load.

5. Ensure that the wiring between the battery and motor terminals has a maximum resistance of 0.05 ± 0.005 ohms. The series electrical circuit shall be controlled by means of a heavy-duty knife switch, or equivalent, rated at 125 amperes.

6. Energize the motor three (3) times according to the following sequence:

   1. 5 ± 1 second ON
   2. 10 ± 1 second OFF

7. Stabilize the motor at 23°C ± 2°C (73°F ± 4°F) for a minimum of 6 hours.

8. Measure the blower motor generated voltage at the motor terminals while the motor is externally driven by a 2- or 4-pole synchronous motor in the intended direction of the rotation of the motor. Conduct test at 23°C ± 2°C (73°F ± 4°F).

5.3.2 Acceptance Criteria

The generated voltage as measured in section 5.3.1 (step. 8) shall not have decreased by more than 4% from the initial value obtained in section 5.3.1 (step. 2).

5.4 Axial Force

5.4.1 Procedure

1. Rigidly mount motor in a vise or similar retaining fixture.

2. Sequentially apply push/pull axial loads of a 22.7 kg (50 lb) to the armature shaft.

3. After removal of load, measure the armature end play resulting from the application of net (gravitationally exclusive) push/pull axial forces of 2.3 kg (5 lb).

4. Performance test the motor according to section 5.1.

5. Noise test the motor according to section 5.2.1.

5.4.2 Acceptance Criteria

1. After the test, the motor's armature end play shall continue to meet print specifications.

2. The motor shall meet performance requirements of section 5.1.

3. The motor shall meet noise requirements of section 5.2.1.

5.5 Electromagnetic Compatibility (EMC)

5.5.1 Procedure

The motor shall meet the EMC requirements of the customer. The supplier of the motor is responsible for conducting prescribed compliance tests for EMC requirements at a qualified test facility and submitting a test report to the customer.

Categories of testing will typically include the following:

- Conducted Electromagnetic Emissions
- Conducted Transient Emissions
- Electrical Supply Transient Susceptibility
- Over Voltage/Reverse Voltage Test
- Radio Frequency Interference (RFI)

Vehicle Testing

The final product test is with the motor installed in a representative vehicle. The customer may run vehicle level tests for EMC requirements; as a result, EMC requirements may be changed.

5.5.2 Acceptance Criteria

Supplier-conducted motor tests shall include the respective acceptance criteria within the test descriptions.

6.0 ENVIRONMENTAL REQUIREMENTS/TESTS

6.1 Random Vibration Test

6.1.1 Procedure

1. Motors for this test shall have successfully completed the performance requirements (sec. 5.1) and the motor noise level tests (sec. 5.2.1).

2. Mount the motor and blower wheel in a test fixture as described in section 5.2.4.1 (step 1).

3. Ensure that the fixture does not have any resonances below 300 Hz. Between 5 and 300 Hz, there shall be no transmissibilities less than 0.71 or greater than 1.41. Between 300 and 2,000 Hz, there shall be no transmissibilities less than 0.1 or greater than 10.

4. Attach the motor/fixture assembly to a vibration table. The motor shall be oriented in a manner representative of the intended orientation in the vehicle application.

5. Apply the appropriate voltages (as indicated on the applicable motor drawing/specification) to the motor terminals to sequentially achieve 20-minute segments of high, medium, and low speed operation each hour.

6. The Power Spectral Density (PSD) profile shall be maintained within ± 3 dB. The rms of the profile shall be maintained within ± 5%. The recommended statistical degrees of freedom is 120. However, this value may be set as low as 100. The number of spectral lines shall be set as close to 800 as possible.

7. Apply random vibration to the fixture in accordance with the breakpoint frequencies and Power Spectral Density (PSD) levels shown in tables 3, 4 and 5 for the vertical, lateral, and fore/aft axes respectively. The duration of vibration in each axis shall be 45 hours.

8. Remove the motor from the test fixture upon completion, and perform the following:

   a) Performance Test (sec. 5.1)
   b) Noise Test (sec. 5.2.1)

TABLE 3 - Frequency Breakpoints vs. Vibration PSD (Vertical)
GRMS - 1.261

FREQUENCY (Hz)	g^2 / Hz
20	0.028996
45	0.001592
80	0.003845
115	0.000539
210	0.009061
335	0.000135
450	0.001910
860	0.000980
980	0.000066
2,000	0.000002

TABLE 4 - Frequency Breakpoints vs. Vibration PSD
(Lateral) GRMS - 0.968

FREQUENCY (Hz)	g^2 / Hz
20	0.012553
45	0.001491
100	0.002291
115	0.000235
140	0.001098
155	0.001161
170	0.000110
210	0.006747
265	0.000188
455	0.003138
525	0.000157
610	0.002354
715	0.000126
820	0.000235
1,015	0.000028
1,300	0.000094
2,000	0.000002

TABLE 5 - Frequency Breakpoints vs. Vibration PSD
(Fore/Aft) GRMS - 1.940

FREQUENCY (Hz)	g^2 / Hz
20	0.308557
25	0.289569
45	0.008545
55	0.001044
135	0.000427
210	0.006408
290	0.000064
330	0.000831
610	0.002255
655	0.000112
2,000	0.000024

6.1.2 Acceptance Criteria

1. Motor performance shall meet the requirements of section 5.1.

2. Motor noise shall not increase from initial measured values (sec. 6.1.1, step 1) by more than 5 dB(A).

3. Motor assemblies shall be analyzed for any signs of damage. Damage is broadly described as—but not limited to—any kind of failure ranging from nearly invisible hairline cracks to the most obvious of fractures. Such damage includes faults, that can induce either mechanical or electrical failure of the motor. The following are examples of failures:

   • loose magnets
   • loose end plates
   • noisy bearings
   • end play exceeding design limits
   • mounting flange movement, etc.

6.2 High Temperature Soak Test

6.2.1 Procedure

1. Motors for this test shall have successfully completed the performance requirements (sec. 5.1) and the motor noise level tests (sec. 5.2.1).

2. Mount the motor in an HVAC housing fixture that simulates the vehicle application.

3. Test the motor according to the following cycle:

   a) Soak the motor and test fixture for a minimum of 4 hours in an ambient temperature of 85°C ± 2°C (185°F ± 4°F). Note: Motor is not operated during this soak period.

   b) With the motor and test fixture still in the elevated temperature environment indicated above, apply the full voltage according to the applicable drawing/specification to achieve High speed operation for 10 minutes. (Use system wiring resistance, if required).

   c) Repeat steps 3(a) and 3(b) for a total of 4 cycles.

4. Cool the motor to room ambient and record motor performance as described in section 5.1.

5. Measure motor noise after the performance test is completed as described in section 5.2.1.

6.2.2 Acceptance Criteria

1. Motor performance shall meet the requirements of section 5.1.

2. Motor noise shall not increase from initial measured values (sec. 6.2.1, step 1) by more than 3 dB(A).

3. At the conclusion of the test, all parts including the bearings, brushes, commutator, and magnets shall be inspected and in good condition with no signs of impending failure.

6.3 Salt Spray Tests

Motors for this test shall have successfully completed the performance requirements (section 5.1) and the motor noise level tests (section 5.2.1).

6.3.1 Salt Spray Test (Functional) – Engine Compartment Applications

6.3.1.1 Procedure

1. Conduct a salt spray test according to ASTM B117-95.

2. Mount motors with a production released wheel, blower housing, and vent tube to simulate vehicle operating conditions. Only the outside of the motor, blower housing, and vent tube that is exposed to the engine compartment is to be exposed to the salt spray atmosphere. The motor is powered at 13.5 ± 0.1 vdc. The test is to be run at 23° ± 5°C in a salt spray chamber and shall consist of 4 repetitions of the following test cycle:

   • Motor running for 4 hours in salt spray atmosphere
   • Motor off for 16 hours in salt spray atmosphere
   • Motor off for 4 hours to dry in clean air

3. Leave motors outside the chamber to dry for 48 hours after the test has been completed.

4. Performance test the motors according to section 5.1.

5. Noise test the motors according to section 5.2.1.

6.3.1.2 Acceptance Criteria

1. Motor performance shall meet the requirements of section 5.1.

2. Motor noise shall not increase from initial measured values (sec. 6.3) by more than 5 dB(A).

6.3.2 Salt Spray Test (Appearance)

This test shall be conducted on motors subject to an engine compartment environment and may be extended to passenger compartment upon customer request. Motor is not operated during this test.

6.3.2.1 Procedure

1. Determine whether a test fixture is to be used when performing this test. If so, it shall be approved by the customer.

2. Test the motor (with fixture, if applicable) to ASTM B117-95 for one hour of salt spray. Allow the motor to dry in clean air for the remainder of one week.

3. Repeat step 2, 3 additional times.

6.3.2.2 Acceptance Criteria

At least 99.5% of the external motor surface visible in the application, exclusive of the armature shaft and staking surfaces, shall be free of red rust.

6.4 Dust Test

6.4.1 Dust Test (Laboratory)

Optional upon customer approval of test procedure.

6.4.2 Dust Test (Vehicle)

6.4.2.1 Procedure

1. Motors for this test shall have successfully completed the performance requirements (sec. 5.1) and the motor noise level tests (sec. 5.2.1).

2. Supplier shall submit motors for testing at a customer proving ground facility that includes significant dust exposure.

3. Upon conclusion of the above testing, the following tests shall be performed:

   a) Performance (section 5.1).
   b) Noise (section 5.2.1).

6.4.2.2 Acceptance Criteria

1. Motor performance shall meet the requirements of section 5.1.

2. Motor noise levels shall not exceed 5 dB(A) from the initial measured values (section 6.4.2.1, step 1).

3. Upon laboratory inspection at the conclusion of the test, all parts including—but not limited to—the bearings, brushes, commutator, and magnets shall be in good condition with no signs of impending failure.

7.0 DURABILITY REQUIREMENTS/TESTS

7.1 Endurance

7.1.1 Procedure

7.1.1.1 Preparation

1. Thermocouple Installation (when required by the customer)

   - Attach one thermocouple to each bearing, or over the bearing area on the exterior surface of the motor housing.
   - Attach one thermocouple to each brush box or directly to each brush.
   - Attach one thermocouple to the magnet at the warmest anticipated location.
   - Ensure that thermocouples are numbered in accordance with Table 6.

TABLE 6 - Thermocouple Numbering

THERMOCOUPLE	LOCATION
1	Positive Brush/Brush Box
2	Negative Brush/Brush Box
3	Magnet
4	Bearing – Shaft Extension End
5	Bearing – Opposite Shaft Ext. End

   - Ensure that the attachment method used is able to withstand temperatures generated by the motor.

2. Measure motor performance as described in section 5.1, at the same time record the motor commutation (current) wave form. The motor shall meet the requirements of section 5.1 and have a normal commutation wave form. A normal commutation wave form is one that is characteristic of a population of motors known to be in good working order.

3. Measure motor noise level, as described in section 5.2.1. Motor noise shall meet the requirement of section 5.2.1.2.

4. Record the armature end play resulting from the push/pull application of a 1.5 kg (3.3 lb.) axial of force. It shall meet the print specifications.

7.1.1.1 (Continued):

5. Use an HVAC housing fixture for this test that simulates the vehicle application. If the motor is self-ventilated, it shall be shielded from drafts and extraneous air turbulence.

   1. Install the proper blower wheel for the application.

   2. Install the motor and wheel assembly into the test fixture. Ensure that there is no interference between the blower wheel and test fixture, and that the cooling tube (where applicable) is properly installed. Ensure that there is no excessive air leakage past the fixture seals and gaskets.

   3. Calibrate the test fixture to simulate the conditions in section 5.1.1 (step 2). This setting shall be maintained throughout the test.

7.1.1.2 Speed Cycle Testing

1. Set the speed cycle as follows:

   a) Low Speed - 30 minutes @ 4.0 ± 0.2 vdc
   b) Medium Speed - 15 minutes @ 9.0 ± 0.2 vdc
   c) High Speed - 10 minutes @ print-specified voltage
   d) Off - 5 minutes

2. Perform the above cycle according to the following schedule:

   a) 3000 hours at room ambient, 23°C ± 5°C (73°F ± 9°F)
   b) 500 hours at -12°C ± 2°C (10°F ± 4°F)
   c) 500 hours at 52°C ± 2°C (126°F ± 4°F)

3. During the test period, record the following at least 3 times per week covering all the speed settings:

   a) Voltage
   b) RPM
   c) Current
   d) Temperature
   e) Unusual motor noise (if any)

4. After 150, 500, 1000, 2000, and 3000 hours of testing, perform the following:

   a) Noise test motor in accordance with section 5.2.1.
   b) Record the motor commutation wave form.

7.1.1.2 (Continued):

5. After completing the above 4000 hours of testing, record the following:

   a) Motor performance in accordance with section 5.1
   b) Motor noise in accordance with section 5.2.1
   c) Motor commutation wave form
   d) Armature end play

6. Twenty-five percent of the durability tested motors shall be run to failure at room ambient. Record cumulative test hours (including the original 4,000), and indicate the failure mode. Supplier shall perform Weibull analysis based on endurance test results. Data is to be recorded once a week.

7.1.2 Acceptance Criteria

1. The maximum allowable change in motor performance, after completing 4,000 hours of endurance testing, shall be less than or equal to 10% (for motor speed and current) when compared to the motor performance characteristics obtained in section 7.1.1 (step 1.2).

2. Motor noise shall not increase from the initial measured values after 150 hours (sec. 7.1.1, step 2.4) by more than 5 dB(A).

3. The commutation wave form shall not show signs of brush or armature defects, such as stuck brushes, coil-to-coil shorts, or commutator/fusing defects.

4. End play shall not increase by more than 0.254 mm (0.010 in.) after completing 4,000 hours of testing from the originally measured end play recorded in section 7.1.1 (step 1.4). The end play shall not be less than the minimum indicated on the drawing/specification.

5. The remaining 75% of the motors shall be disassembled and inspected and shall meet the following requirements:

   a) The armature windings shall not show signs of charring or deterioration.

   b) All parts including—but not limited to—the bearings, brushes, commutator, and magnets shall be in good condition with no signs of impending failure.

8.0 RELIABILITY REQUIREMENTS/TESTS

8.1 Production Validation Testing Requirements

New motors shall undergo Production Validation testing and carryover motors shall undergo annual revalidation testing according to Appendix B. Agreement to merge similar designs under worst case application should be negotiated with the customer on a case-to-case basis.

8.2 In-process Validation Testing Requirements

Throughout production, motors shall undergo the following continuing conformance testing according to Appendix C.

8.2.1 Continuing Conformance Characteristics

Statistical process control shall be applied to the motor characteristics identified in Appendix C.

8.2.2 In-Process Durability Test (short term)

A short-term durability test shall be performed for 2 hours at an ambient temperature of 23°C ± 5°C (73°F ± 9°F) on a blower motor(s) that successfully passed all (assembly line) end-of-line tests.

8.2.2.1 Procedure

1. Mount the motor in a customer-approved test fixture.
2. Adjust the applied voltage, cooling air flow, and loading torque to meet the intended operating conditions as indicated on the applicable motor drawing/specification. These conditions shall be maintained throughout the test.
3. Upon start-up, record motor current, speed, and applied voltage; observe the commutator wave form.
4. Continue to operate the motor for 2 hours. Record the motor current, speed, and voltage.

8.2.2.2 Acceptance Criteria

The motor speed and current shall be within the tolerance limits indicated on the applicable drawing/specification.