



CRFM Electric Cooling Fan Noise and Vibration Evaluation Procedure

1 Introduction

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. To define subsystem level noise measurements of electric cooling fans (ECF) for engine and/or condenser cooling utilizing a complete Condenser, Radiator, Fan Module (CRFM). This procedure is used to gain knowledge of the Noise and Vibration (N&V) behavior of a cooling module at the component level before prototype vehicles are available.

1.2 Applicability. This procedure is appropriate for all passenger vehicle ECFs utilized for engine and/or condenser cooling as installed in a complete, production intent CRFM.

1.3 Remarks. N&V analysis on CRFM fans from component bench tests are only partially reliable for judging the sound quality of the CRFM mounted in a vehicle. Integration of the fan(s) in the engine compartment of the vehicle (including the radiator, condenser, shroud and the CRFM mountings) has a major impact on the noise emission of the cooling fan(s), especially on the blade passage tonal content. Subsystem noise measurements are valid for an initial assessment, but the final validation must be performed in a vehicle.

2 References

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

2.1 External Standards/Specifications.

IEC 61672

2.2 GM Standards/Specifications.

GMW14172

2.3 Additional References.

- Subsystem Technical Specification (SSTS)

3 Resources

3.1 Facilities. All measurements shall be performed in a hemi-anechoic test room free from interfering noises. Background noise must be a minimum of 10 dB(A) below the signal being measured. Background noise is considered to include test room ambient noise and test equipment noise.

3.1.1 Calibration. The test facilities and equipment shall be in good working order and shall have a valid calibration label.

3.1.2 Alternatives. Alternative test facilities and equipment may also be used. However, all measuring variables as specified in this standard shall be determined correctly with respect to their physical definition.

3.2 Equipment.

3.2.1 Microphones. Six (6) free-field microphones are preferred. Pressure microphones may be used if free-field microphones are not available. Microphone wind screens are required.

3.2.2 Microphone Stands. Microphone floor stands or equivalent method for supporting the microphones.

3.2.3 Accelerometers. Four (4) high sensitivity accelerometers with a flat frequency response from 2 Hz to 2000 Hz and a temperature range of 10 °C to 50 °C or greater shall be used.

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3.2.4 Data Acquisition System. Multi-channel data acquisition hardware capable of calculating both frequency domain and order domain results between 0 Hz and 11 200 Hz with a minimum of 80 dB dynamic range. This hardware shall meet Class 1 accuracy corresponding to IEC 61672 or be equivalent for the application (precision ± 0.7 dB or $\pm 8\%$).

3.2.5 Digital Voltmeter. Digital voltmeter for monitoring voltage of the fan motor at the terminal connector to the fan motor.

3.2.6 Power Supplies. A variable direct current (DC) power supply with sufficient capacity to provide at least 16 V at 55 A is required. One (1) power supply is required for each fan or one capable of simultaneously powering all fans. For fans with pulse-width modulation (PWM) control, a DC power supply with the appropriate voltage range per the PWM controller specifications is required for powering the PWM controller.

3.2.7 PWM Controller. A device capable of variable frequency and duty cycle digital control of PWM signal to the ECF is required for fans that use PWM control.

3.2.8 Tachometer. Optional optical or inductive sensor(s) capable of accurately measuring the fan(s) speed in revolutions per minute (RPM).

3.2.9 Current Meter. Optional current meter for monitoring current of the fan motor.

3.3 Test Vehicle/Test Piece. The complete CRFM subsystem representing the current part release status is required for this test. For validation measurements, fans with maximum unbalance tolerances must be used.

3.4 Test Time.

Calendar time:	1 d to 2 d
Test hours:	4 h to 8 h
Coordination hours:	4 h to 8 h

3.5 Test Required Information. For PWM controlled fans, PWM signal frequency, PWM minimum duty cycle and PWM maximum duty cycle values are required. Duty cycle values from the fan control calibration table that defines program specific discrete fan speeds may be used for steady state evaluations.

For fixed speed, resistor or series/parallel controlled fans, fan voltage and speed values are required. Nominal voltage to be used is 13 V.

3.6 Personnel/Skills. One (1) engineer or qualified technician with basic knowledge of N&V data acquisition is required to complete this test.

4 Procedure

4.1 Preparation. Ensure that the CRFM meets the requirements outlined in 3.3. Record the main fan system characteristics and design features including the number of fans, fan blades, fan motor pole pairs, unbalance level if known and any other design features important for N&V in the test project documentation section.

4.2 Conditions.

4.2.1 Environmental Conditions. The ambient air temperature shall be between 10 °C and 30 °C.

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.

4.2.3 Standard Test Conditions.

4.2.3.1 Steady State Conditions. Fan steady state noise performance is assessed by operating all fans simultaneously at each of the following conditions:

- **Background Noise.** Noise with all fans off.
- **Lowest Fan Speed.** For resistor or series/parallel controlled fans use the voltages and fan speeds obtained in 3.5. For PWM fans, the lowest fan speed will be at minimum voltage (approximately 9 V) and minimum PWM duty cycle (approximately 20%).
- **Maximum Fan Speed or Single Speed.** For fixed, resistor or series/parallel controlled fans use the voltages and fan speeds obtained in 3.5. For PWM fans, the maximum fan speed will be at maximum voltage (approximately 16 V) and maximum PWM duty cycle (approximately 95%).

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- **Intermediate Fan Speeds.** For resistor controlled fans use the voltages and fan speeds obtained in 3.5. For PWM fans, test at nominal vehicle voltage (13 V) and PWM duty cycle values of 20%, 40%, 60% and 80% or program specific PWM duty cycle values from 3.5.

4.2.3.2 Fan Speed Sweep - Fixed, Resistor or Series/Parallel Controlled Fans. Set up a single DC power supply capable of controlling all cooling fans simultaneously. Perform the fan speed sweep test by incrementing the voltage applied to all fans from 4 V to 16 V over one minute. The test can be repeated for multi-fan systems testing each fan independently.

4.2.3.3 Fan Speed Sweep - PWM Controlled Fans. Set up a single DC power supply capable of controlling all cooling fans simultaneously along with PWM control utilizing the appropriate PWM signal frequency. Perform PWM duty cycle sweeps from minimum PWM duty cycle (approximately 20%) to maximum PWM duty cycle (approximately 95%) over one minute for the following conditions:

- Minimum voltage: 9 V
- Nominal voltage: 13 V
- Maximum voltage: 16 V

4.3 Instructions.

4.3.1 Test Setup. Using elastomeric cords, suspend the CRFM as oriented in the vehicle to approximate free-free boundary condition. Do not overly constrain the test piece. Elastomeric cord stiffness should be as low as possible. Adjust vertical height of CRFM such that the motor height is 0.5 m above the floor. For full- or mid-size truck CRFM applications, position the motor height to be 1.0 m above the floor. **Note:** This height change requires the microphone height change in 4.3.3.3 also.

4.3.2 Calibration Verification. Check equipment for valid calibration date. Replace out-of-date equipment. Perform microphone calibration verification (see GMW14172).

4.3.3 Install Instrumentation.

4.3.3.1 Fan Speed Sensor. Install optical or inductive speed sensor to each fan to accurately measure fan motor speed tachometer signal, in RPM, without disturbing the air flow or generating disturbing noises.

4.3.3.2 Fan External Power Supply. For fixed and variable speed fan systems, connect variable DC power supplies with appropriate PWM control if required. For PWM fans set power supply for appropriate PWM signal frequency and duty cycle as required for the test condition.

4.3.3.3 Microphones. Position microphones M1, M2, M3, M4, M5 and M6 around the CRFM using the locations shown in Figures A1 thru A3 in Appendix A. The microphone location descriptions are as follows:

- Microphone 1 (M1) is located on the front side (suction side) of the fan at the center-line of the CRFM, 0.5 m above the reflecting floor of the noise chamber and in a horizontal distance of 1 m in front of the front most part of the CRFM.
- Microphone 2 (M2) is located relative to microphone M1's position by rotating 45 degrees to the right of M1 (clockwise), 1 m from the front, centerline of the CRFM, and 0.5 m above the reflecting floor of the noise chamber.
- Microphone 3 (M3) is located relative to microphone M1's position by rotating 45 degrees to the left of M1 (counterclockwise), 1 m from the front, centerline of the CRFM, and 0.5 m above the reflecting floor of the noise chamber.
- Microphone 4 (M4) is located on the rear side of the fan at the centerline of the CRFM, 0.5 m above the reflecting floor of the noise chamber and in a horizontal distance of 1 m behind the rear most part of the CRFM.
- Microphone 5 (M5) is located relative to microphone M4's position by rotating 45 degrees to the right of M4 (counterclockwise), 1 m from the rear, centerline of the CRFM, and 0.5 m above the reflecting floor of the noise chamber.
- Microphone 6 (M6) is located relative to microphone M4's position by rotating 45 degrees to the left of M4 (clockwise), 1 m from the rear, centerline of the CRFM, and 0.5 m above the reflecting floor of the noise chamber.

Position the microphones so that they are pointing at the measured noise source. Use microphone windscreens.

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