



Vehicle Level CRFM 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. This procedure describes the process for evaluating and measuring vehicle level noise and vibration (N&V) generated by powertrain cooling (PTC) fans.

1.2 Applicability. This procedure is applicable for all passenger cars, multi-purpose passenger vehicles, minibuses, and light commercial vehicles.

1.3 Remarks. This procedure is used to assess N&V performance of PTC fans including electric cooling fans (ECF) mounted on condenser, radiator, fan modules (CRFM) and engine driven fans coupled directly to the engine by a viscous clutch.

2 References

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

2.1 External Standards/Specifications.

IEC 61672 ISO 2631 ISO 5349

2.2 GM Standards/Specifications.

GMW14172 GMW14264

2.3 Additional References.

- Vehicle Technical Specification (VTS)

3 Resources

3.1 Facilities. All measurements shall be performed in a hemi-anechoic test room free from interfering noises with low noise exhaust gas extraction system or outdoors in a free-field area.

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. Two (2) random incidence microphones are preferred for vehicle interior locations. Free-field microphones may be used for interior locations if random incidence microphones are not available. Three (3) free-field microphones are preferred for vehicle exterior measurement locations. Random incidence microphones may be used at exterior locations if free-field microphones are not available.

3.2.2 Accelerometers. Three (3) 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.

3.2.3 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 is required. This hardware shall meet Class 1 accuracy corresponding to IEC 61672 or be equivalent for the application (precision ± 0.7 dB or $\pm 8\%$).

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3.2.4 ECF Equipment.

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

3.2.4.2 Variable Direct Current (DC) Power Supply. A variable 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.

3.2.4.3 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.

3.2.4.4 Tachometer. Optical or inductive sensor(s) capable of accurately measuring the fan(s) speed in revolutions per minute (rpm).

3.2.4.5 Current Meter. Optional current meter(s) for monitoring current of the fan motor(s).

3.2.4.6 Vehicle Network Interface. Optional neoVI device and Vehicle Spy software from Intrepid Systems (or similar equipment) can be used to monitor and control vehicle fan speed, engine speed, coolant temperature, etc.

3.2.5 Engine Driven Fan Equipment.

3.2.5.1 Clutch Engagement Control. A method is needed to engage and disengage the viscous fan clutch, allowing minimum and maximum slip across the clutch. For modulated fan clutches with a thermostatic bimetal control element, the engagement controlling bimetal may be removed or its position modified on the clutch so that the clutch remains fully engaged or disengaged with temperature changes. The fan bill of material (BOM) family owner (BFO), responsible release engineer or supplier can be consulted as to how to accomplish the bimetal modification. Alternately minimum slip (or maximum engagement) can be achieved by installing a hot slip viscous clutch. The fan and clutch can be completely removed for the disengaged fan tests. The hot slip viscous clutch will work for the steady state conditions, but sweep test conditions may not produce repeatable results.

For viscous fan clutches with electronic control using a PWM signal from the engine control module (ECM), a PWM controller can be used to effectively engage and disengage the clutch much like an ECF. Unless otherwise specified, disengagement can be achieved at 0% PWM duty cycle and maximum engagement (maximum speed) can be achieved at 100% PWM duty cycle.

3.2.5.2 Tachometers. Optical or inductive sensors capable of accurately measuring the engine speed and fan speed in rpm.

3.3 Test Vehicle/Test Piece. The tests shall be performed on a vehicle that represents the current release status. Deviations (e.g., obvious faults) shall be eliminated prior to test. With the exception of competitive benchmarking, fans should be tested at the maximum allowed unbalance tolerance. Document fan unbalance in the test project documentation section. If balance condition is unknown, document it as "unknown".

3.4 Test Time.

3.4.1 Electric Cooling Fans.

Calendar time: 2 d

Test hours: 6 h

Coordination hours: 6 h

3.4.2 Engine Driven Viscous Fans.

Calendar time: 5 d

Test hours: 12 h

Coordination hours: 24 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 define program specific discrete fan speeds may be used for steady state evaluations.

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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) qualified engineer or technician trained in the use of data acquisition equipment and having basic knowledge of N&V signal processing and one (1) mechanic are required.

4 Procedure

4.1 Preparation. Check the vehicle according to 3.3. The main fan system characteristics and design features shall be recorded in the test project documentation section. Record the number of fans, number of fan blades, approximate fan diameter(s), and fan motor pole pairs. For viscous-driven fan, record the engine speed to fan speed ratio. Reference Figure A1 in Appendix A for a viscous-driven fan schematic.

4.2 Conditions.

4.2.1 Environmental Conditions. The ambient air temperature should remain between 10 °C and 30 °C. All interfering noise emissions from test stand devices must be eliminated.

For engine driven fan tests when using a hot slip clutch, the ambient air temperature should remain at 20 °C ± 2 °C as the clutch oil viscosity is very sensitive to temperature.

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. Acquire data for appropriate test conditions needed to satisfy requirements.

4.2.3.1 ECF Test Conditions.

4.2.3.1.1 ECF Steady States. Measure ECF noise with the engine off and ignition in the off position. Adjust the DC power supply voltage, as defined in 4.3.2.1, to match the required speed of each fan for each of the following steady state test conditions:

- **Background Noise.** 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 the minimum voltage (approximately 9 V) and the 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 the maximum voltage (approximately 16 V) and the maximum PWM duty cycle (approximately 95%).
- **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.

4.2.3.1.2 ECF Evaluation with Vehicle Idle. With the vehicle idling in drive for automatics and in neutral for manuals, measure or evaluate subjectively the ECF conditions tested in 4.2.3.1.1. Evaluate N&V performance at all program idle speeds, including idle boost speed to evaluate idle masking of fan noise and avoidance of beating noises (reference the subjective rating scale in GMW14264).

4.2.3.1.3 ECF 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 approximately 1 minute.

4.2.3.1.4 ECF Speed Sweep - PWM Controlled Fans. Set up 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 approximately 1 minute for the following conditions:

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

4.2.3.2 Engine Driven Viscous Fan Test Conditions. Measure engine driven fan noise with the vehicle stationary, the transmission in park or neutral, and the engine running.

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4.2.3.2.1 Engine Driven Fan Steady States. Adjust engine speed and clutch engagement for each of the following steady state test conditions:

- Fan Fully Engaged - Engine Idle.
- Fan Fully Engaged - 1500 Engine rpm.
- Fan Fully Engaged - 2500 Engine rpm.
- Fan Fully Engaged - 4000 Engine rpm.
- Fan Not Engaged - Engine Idle.
- Fan Not Engaged - 1500 Engine rpm.
- Fan Not Engaged - 2500 Engine rpm.
- Fan Not Engaged - 4000 Engine rpm.

Prior to each test, hold at the specified steady state engine speed for at least 30 s to make sure the speed is stable. Both engine and fan speeds in rpm should be recorded to confirm fan speed stability.

4.2.3.2.2 Engine Driven Fan and Engine Noise Sweep (Optional). Engage the viscous clutch to provide minimal slip. Sweep the engine speed from idle to 4500 engine rpm over approximately 1 minute with the viscous-clutch fully engaged.

4.2.3.2.3 Engine Noise Only Sweep (Optional). **Caution: Danger of Engine Overheating with Fan Disengaged.** Disengage or remove the viscous-clutch fan assembly to minimize fan generated noise. Repeat the sweep defined in 4.2.3.2.2 with fan noise eliminated. This test condition can be used to calculate noise generated by the viscous-driven fan.

4.3 Instructions.

4.3.1 Calibration Verification. Check equipment for valid calibration date. Replace out-of-date equipment. Perform equipment calibration verification (reference GMW14172).

4.3.2 Install Instrumentation.

4.3.2.1 ECF Control. Install instrumentation to monitor voltage, speed, and motor current (optional) for each cooling fan. 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.

4.3.2.1.1 Define Fan Stages. Define the number of vehicle controlled fan stages and fan logic condition. These depend on coolant temperature and air conditioning (A/C) compressor discharge pressure if equipped with air conditioning. Three methods to define the stages are suggested below:

- Request information from responsible release engineer or subsystem supplier.
- Some applications may allow control of the cooling system with external switches or workshop diagnosis equipment (such as Vehicle Spy).
- Gradually increase the coolant temperature and/or A/C discharge pressure to define the fan stages. Closely monitor system performance when using this method.

Record the voltage, speed, and (optional) current for each fan at each fan stage.

For benchmark testing of vehicles using variable fan speed logic, record the lowest and highest fan voltage, speed, and current (optional) for each fan.

4.3.2.2 Engine Driven Viscous Fans.

Caution: Danger of engine overheating with fan disengaged.

Install instrumentation to monitor engine and fan speeds. Engine coolant temperature should also be monitored.

Install and confirm ability to fully engage and disengage the viscous fan clutch.

Disconnect any ECF used with engine driven fans.

4.3.2.3 Interior Microphones. Install interior microphones in positions as specified in Figure B1 and Figure B2 in Appendix B. The standard positions are the left front seat (LF) and the right front seat (RF). Use the center of seat location unless the seat is occupied.

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4.3.2.4 Exterior Microphones. Set up the exterior microphones as specified in Figure C1 and Figure C2 in Appendix C for microphone positions **M1**, **M2**, and **M3**. Locate microphone **M1** at the centerline of the vehicle, 1 m from the front bumper in the horizontal direction, and 0.5 m above the floor. Position microphone **M2** relative to **M1** by rotating 45 degrees to the right of **M1** (clockwise) in the horizontal direction. Position microphone **M3** relative to **M1** by rotating 45 degrees to the left of **M1** (counterclockwise) in the horizontal direction.

For full and mid-size trucks, change all of the exterior microphone locations to be 1 m above the floor.

4.3.2.5 Accelerometers. Install tri-axial accelerometers so that the X direction aligns with fore/aft of the vehicle, the Y direction aligns with the cross-car (lateral) direction of the vehicle and the Z direction aligns with vertical. Install accelerometers at the driver interfaces. The standard driver interface locations include the 12:00 o'clock position on the steering wheel in the fore-aft, lateral and vertical directions plus the front outboard and rear inboard positions on the driver's seat track in the vertical direction.

4.3.3 Vehicle Setup. Replace all exterior and interior trim panels that were removed to instrument the vehicle.

The vehicle should be unloaded except for the driver and the test equipment as needed. Adjust seats and headrests according to Appendix D. If equipped with tilt/telescoping steering, position the steering column in the center position of travel for both tilt and telescope. Close the engine compartment hood, trunk, sliding roof, sunscreen, doors, and windows.

Switch off the air conditioning at least ten minutes before the start of the test. For idle test, set Heating, Ventilating and Air Conditioning (HVAC) fan speed to off. Ensure all customer actuated systems are off including radio and other accessories.

4.3.4 Data Acquisition.

4.3.4.1 ECF Data Acquisition.

4.3.4.1.1 ECF Steady State Data Acquisition. Adjust the DC power supply voltage and PWM control if applicable to match the appropriate speed of each fan for each test condition defined in 4.2.3.1.1 and/or 4.3.2.1.1, as appropriate for specific applications or VTS validation.

Set up the data acquisition system to acquire A-weighted sound pressure level (SPL) data in both one-third octave and narrowband spectral formats and linear vibration narrowband spectra (a single acquisition for all analysis formats is preferred) using the following parameters:

- Acoustic frequency range: 22 Hz to 11 200 Hz.
- Vibration frequency range: 0 Hz to 200 Hz.
- Frequency resolution: 1 Hz.
- Window: Hanning, Energy Correction.
- Amplitude: RMS.
- Averaging: 50 Averages, 50% Overlap.

Acquire data for each steady state condition, as required from 4.2.3.1.1/4.3.2.1.1. Store data as required for acquisition system. Record the voltage settings for each fan. With the vehicle engine idling, acquire data or complete subjective evaluations as required for 4.2.3.1.2.

4.3.4.1.2 ECF Speed Sweep - Fixed, Resistor or Series/Parallel Controlled Fans. Set up a single DC power supply to control all fans simultaneously during the speed sweep. Sweep fans by incrementing the fan connector voltage from 4 V to 16 V over approximately 1 minute.

Set up the data acquisition system to acquire fan speed based data capable of providing the following:

- Overall A-Weighted SPL.
- A-Weighted SPL order cuts at integer fan orders up to and including 40th order.

Time data and waterfall data are required for post processing. Acquire data for full 4 V to 16 V fan sweep.

4.3.4.1.3 ECF Speed Sweep - PWM Controlled Fans. Set up the DC power supply and PWM controller to control all fans simultaneously during the sweep. Set the voltage to the PWM controller to nominal vehicle voltage of 13 V. Set the PWM controller to the appropriate signal frequency and the minimum PWM duty cycle. Sweep the fans by incrementing the PWM duty cycle from the minimum to the maximum value over approximately 1 minute.

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