



Autostop (Auxiliary System Noise at Idle Engine Off) 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. Define the process of quantifying vehicle level interior and exterior noise from auxiliary systems operating at idle engine off.

1.2 Applicability. This procedure applies to vehicle tests for all hybrid passenger cars, multi-purpose passenger vehicles, minibuses and light commercial vehicles that operate in an idle engine off condition.

1.3 Remarks. This procedure is a guideline for measuring the noise emission of auxiliary systems running at idle engine off (also known as Autostop), such as electric cooling pumps, electric brake pumps or electric Air Conditioning (A/C) compressors.

The noise from the auxiliary systems shall not be noticed as disturbing, even outside the vehicle.

Exterior noise from auxiliary systems must comply with noise regulations and must not be annoying to pedestrians.

2 References

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

2.1 External Standards/Specifications.

IEC 651

2.2 GM Standards/Specifications.

GMW14172

GMW14227

2.3 Additional References.

- Global Vehicle Technical Specification (VTS)
- LMS Test.Lab software tool from LMS, A Siemens company

3 Resources

3.1 Facilities. All measurements shall be performed in a hemi-anechoic test room free from interfering noises or outdoors in a free-field area (see GMW14227).

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. Six (6) free-field microphones are preferred for vehicle exterior measurement locations. Pressure microphones may be used at the exterior locations if free-field microphones are not available.

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3.2.2 Data Acquisition System. Multi-channel data acquisition hardware capable of calculating frequency domain results between 22 Hz and 11 200 Hz with a minimum of 80 dB dynamic range. This hardware shall meet Class 1 accuracy corresponding to IEC 651 or be equivalent for the application (precision ± 0.7 dB or $\pm 8\%$).

3.3 Test Vehicle/Test Piece. The tests shall be performed on a vehicle which represents the current part release status. Deviations (e.g., obvious faults) shall be eliminated or recorded.

3.4 Test Time.

Calendar time: 1 day
Test hours: 6 hours
Coordination hours: 2 hours

3.5 Test Required Information. Not applicable.

3.6 Personnel/Skills. To complete this test, one (1) engineer or qualified technician with knowledge of noise and vibration data acquisition, analysis, equipment usage and test setup is required.

4 Procedure

4.1 Preparation. Check the vehicle according to 3.3.

4.2 Conditions.

4.2.1 Environmental Conditions. The test shall be performed with the ambient air temperature 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.

4.3 Instructions.

4.3.1 Calibration Verification. Check equipment for valid calibration date. Replace out of date equipment. Perform microphone calibration verification. Record calibration tone if applicable (see GMW14172).

4.3.2 Install Data Acquisition Equipment. Install interior microphones in positions as specified in Appendix A. Standard microphone positions for left hand drive vehicles are Left Front seat, Right Ear (LFRE) and the Right Front seat (RF) with an optional Right Rear Seat (RR) position if there are auxiliary components operating in the rear of the vehicle. Standard positions for right hand drive vehicles are Right Front seat, Left Ear (RFLE) and Left Front seat (LF) with an optional Left Rear (LR) position if there are auxiliary components operating in the rear of the vehicle. Use center of seat location unless the seat is occupied.

Set up exterior microphones as specified in Appendix B for global exterior microphone positions M_{G1}, M_{G2}, and M_{G3}. If there are auxiliary components operating in the rear of the vehicle, M_{G8}, M_{G9}, and M_{G10} shall be used. Position all microphones at a distance of 1.6 m from the floor in the vertical direction and 1.0 m from the vehicle. Microphones M_{G2} and M_{G3} shall be positioned in line with the center of the front wheels of the vehicle. Position microphones M_{G8} and M_{G9} in line with the center of the rear wheels of the vehicle. Locate microphones M_{G1} and M_{G10} on the front and rear centerline of the vehicle. Orient all exterior microphones so that they are directed towards the vehicle parallel to the floor.

4.3.3 Vehicle Setup. The vehicle may need to be driven or operated at idle with the Internal Combustion (IC) engine running prior to data acquisition to ensure the Energy Storage System (ESS) is fully charged and the vehicle will operate in the idle engine off condition.

The vehicle should be unloaded except for the driver and test equipment as required. Adjust seats and headrests according to Appendix C.

Close all doors, windows, sliding roof, sunroof, and sunscreen. Roll up sun shields and roller load compartment shields.

Turn off the radio, Heating, Ventilation, Air Conditioning (HVAC) blower and other electronic devices. HVAC blower shall remain off during all measurements except where specified (HVAC **On** condition, electric A/C compressor **On** condition). For the A/C compressor measurements, the HVAC system shall be set to full cold with the HVAC blower on low and the airflow directed at the floor.

The fan noise for the ESS shall be minimized as to not influence the auxiliary system noise measurement.

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4.3.4 Data Acquisition. Prior to the start of the test, the instrument settings and the vehicle settings shall be checked again.

For competitive benchmarking:

Benchmarking measurements should include:

1. Background noise
2. Autostop has received (three (3) runs minimum)
3. Autostop with HVAC set to Fan Speed 1
4. Autostop with HVAC set to Fan Speed 1 and electric A/C compressor **On** (after checking for steady state compressor operation). If the compressor does not run at a consistent speed, perform the following:
 - a. Run the interior HVAC system at high speed and full hot temperature for at least 10 minutes
 - b. Reduce the blower speed to low and set the temperature to full cold. Immediately take a measurement with the compressor operating at maximum speed
 - c. Take another measurement while the compressor ramps down/up until it reaches a steady state operation condition (ambient)
 - d. Take a measurement once the compressor is running at a steady state operation condition
5. Autostop with brake system exercised (minimum six (6) events)
6. Idle in Park (optional)

Document all runs in a test log

For VTS validation or root cause/development work:

Control or activate the auxiliary system being measured so it is the only system operating. All other components that could corrupt the measurement should be turned off or unplugged. Reference Appendix D for additional details on auxiliary system operation for evaluation.

4.3.4.1 Steady State Data Acquisition. Set up data acquisition system to acquire A-weighted sound pressure level data capable of providing steady state narrow-band data using the following parameters:

Microphone measurements:

- Frequency Range: 22 Hz to 11 200 Hz
- Frequency Resolution: 1 Hz
- Window: Hanning
- Butterworth filter (or ANSI Base 10 equivalent)
- Use tracked measurement mode with time sufficient to capture the component operation (minimum 30 s). For short duration components, acquire enough samples of component operation to enable post-processing.
- Increment 0.5 s
- Bandwidth of 12 800 Hz for acoustic data

See Appendix E, Figures E1 through E20 for LMS Test.Lab specific test settings.

Optional accelerometer/vibration measurements:

Set up data acquisition system to acquire AutoPowers linear Root Mean Square (RMS) using the following parameters:

- Frequency Range: 5 Hz to 800 Hz
- Frequency Resolution: 1 Hz
- Window: Hanning
- Use tracked measurement mode with time sufficient to capture the component operation (minimum 30 s)
- Increment 0.5 s
- Bandwidth of 800 Hz for vibration data

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Store data as required for acquisition system.

For VTS validation or root cause work, repeat the measurement sequence in this section for each defined auxiliary system and operating condition. This includes but is not limited to electric cooling pumps, electric brake pumps, electric A/C compressors and ESS blowers.

5 Data

5.1 Calculations. Process noise and vibration data as defined in the following.

5.1.1 Steady-State Data. Process acoustic data to calculate overall sound pressure level in dB(A) relative to 20 μ Pa and one-third ($\frac{1}{3}$) octave band levels using a Butterworth filter (or ANSI Base 10 equivalent) for the 25 Hz to 10 000 Hz frequency bands.

5.1.1.1 Time tracked Data Processing.

Acoustic:

- Function: Autopowers Linear
- Window: Hanning
- Final weighting: A
- Format: RMS

Vibration:

- Function: Autopowers Linear
- Window: Hanning
- Final weighting: Linear
- Format: RMS

For sound pressure: Process data to obtain peak and average amplitudes (dB) as a function of frequency using frequency sections with a band pass starting at the lower level of the meaningful acoustic noise for the hemi-anechoic test room up to 11 200 Hz and one-third ($\frac{1}{3}$) octave band levels in the 22 Hz to 11 200 Hz frequency range.

For vibration: Process overall data levels of the vibration data over the 5 Hz to 800 Hz frequency range.

Optional use of Map statistics on individual and grouped channels.

The exterior microphones (M_{G1} , M_{G2} , M_{G3} , M_{G8} , M_{G9} and M_{G10}), interior microphones (LFRE, RF, RR or RFLE, LF, LR) and accelerometers are grouped for derived channels maximum calculations for each group. Map statistics is used for spectrum peak hold and spectrum averaged.

5.2 Interpretation of Results.

For Interior microphones: First, compare the one-third ($\frac{1}{3}$) octave sound pressure levels for each microphone for all conditions to background noise levels. Only report out one-third ($\frac{1}{3}$) octave band data in which the test condition is at least 5 dB louder than the background noise. Compare the narrow-band and one-third ($\frac{1}{3}$) octave sound pressure levels from each microphone to the VTS requirement levels. The sound pressure levels must not exceed the requirement levels for each microphone location. For the A/C On conditions, report out results from both the maximum compressor operation condition and the steady state (ambient) operating condition.

For Exterior microphones: Determine the maximum sound pressure level of the three (3) front exterior microphones in each one-third ($\frac{1}{3}$) octave band. Compare the narrow-band and one-third ($\frac{1}{3}$) octave sound pressure levels from the calculated maximum spectrum to the VTS requirement levels. The maximum exterior sound pressure levels must not exceed the requirement levels. For the A/C On conditions, report out results from both the maximum compressor operation condition and the steady state (ambient) operating condition.

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5.3 Test Documentation. Standardized formats contained in the VTS template shall be used to view data.

6 Safety

This standard may involve hazardous materials, operations, and equipment. This standard does not propose to address all the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

7 Notes

7.1 Glossary.

Vehicle Spy: GM Global Common Tool (software) used with NeoVI hardware to monitor/capture the serial data communications between the various controllers in a vehicle.

7.2 Acronyms, Abbreviations, and Symbols.

A/C	Air Conditioning
Acq.	Acquisition
CRFM	Condenser Radiator Fan Module
ESS	Energy Storage System
HEV	Hybrid Electric Vehicle(s)
HVAC	Heating, Ventilation, Air Conditioning
IC	Internal Combustion
LF	Left Front seat (with seat vacant, microphone is placed in center of seat position)
LFRE	Left Front seat, Right Ear Location (use with left hand drive vehicles when driver's seat is occupied)
LR	Left Rear seat (with seat vacant, microphone is placed in center of seat position)
M_{G1}	Global Exterior Microphone Location 1 (Centerline of vehicle, Front)
M_{G2}	Global Exterior Microphone Location 2 (Centerline of front wheels, Right)
M_{G3}	Global Exterior Microphone Location 3 (Centerline of front wheels, Left)
M_{G8}	Global Exterior Microphone Location 8 (Centerline of rear wheels, Right)
M_{G9}	Global Exterior Microphone Location 9 (Centerline of rear wheels, Left)
M_{G10}	Global Exterior Microphone Location 10 (Centerline of vehicle, Rear)
N&V	Noise and Vibration
NVH	Noise, Vibration, Harshness
RF	Right Front seat (with seat vacant, microphone is placed in center of seat position)
RFLE	Right Front seat, Left Ear Location (use with right hand drive vehicles when driver's seat is occupied)
RMS	Root Mean Square
RR	Right Rear seat (with seat vacant, microphone is placed in center of seat position)
SAS	System Actuated Sound
VPO	Vehicle Performance Owner
VSpy	Vehicle Spy (software)
VTS	Vehicle Technical Specification

8 Coding System

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

Test to GMW15533

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9 Release and Revisions

This standard was originated in December 2006. It was first approved by the N&V Global System Actuated Sound Harmonization Team in December 2006. It was first published in January 2007.

Issue	Publication Date	Description (Organization)
1	JAN 2007	Initial publication.
2	FEB 2014	Revised to current template. Added auxiliary system control details in Appendix D, added LMS Test.Lab specific data acquisition details in Appendix E. (N&V Global SAS VPO Team)

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Appendix A: Location of Vehicle Interior Measurement Locations

Figure A1: Coordinates of Measurement Points

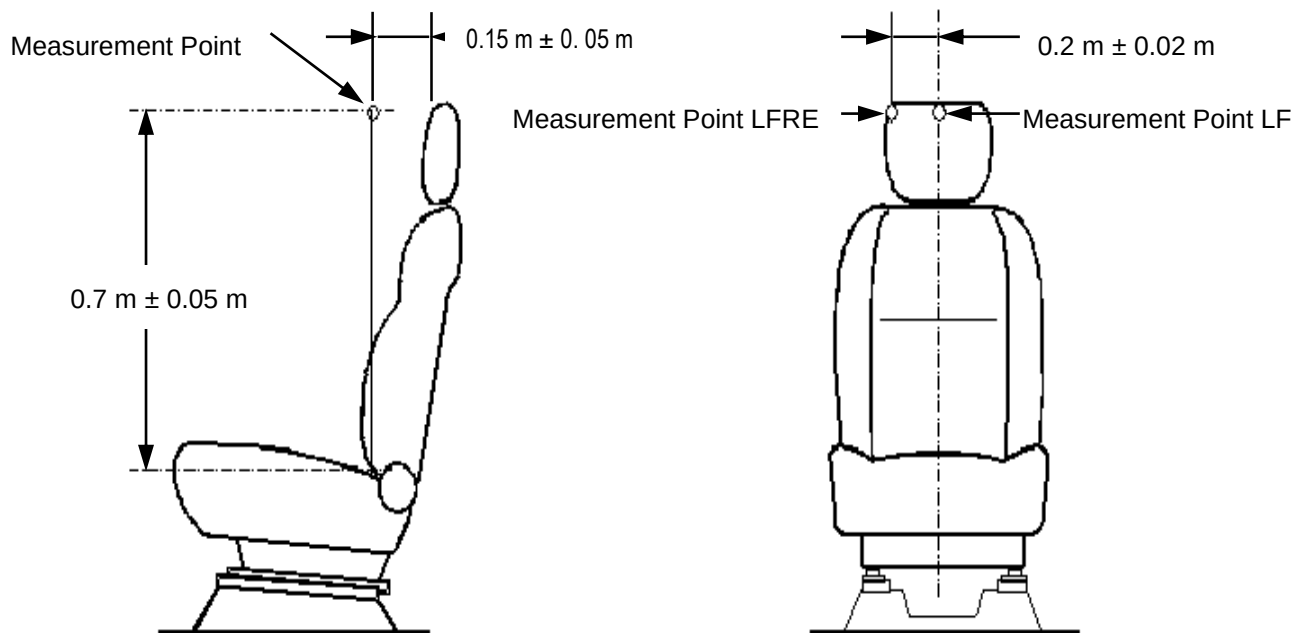
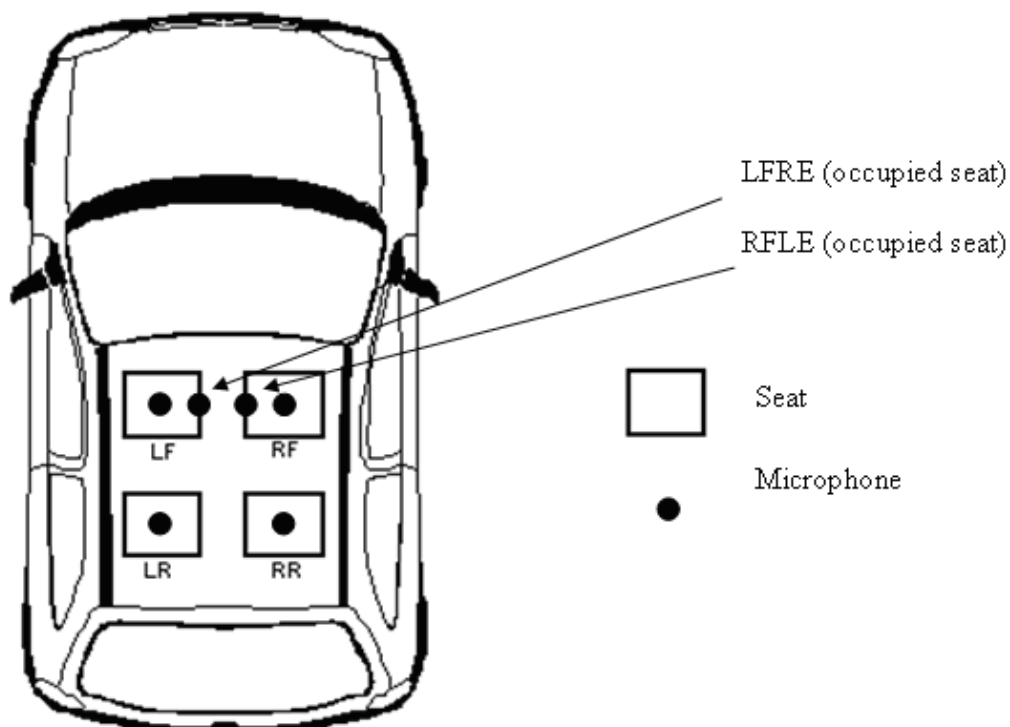


Figure A2: Definition of Possible Measurement Positions



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Appendix B: Location of Vehicle Exterior Measurement Points

Microphones are 1.0 m from the vehicle and 1.6 m above the floor.

Standard vehicle exterior microphone locations include the following:

- M_{G1} = Centerline of vehicle, Front
- M_{G2} , M_{G3} = Centerline of front wheels, Right and Left
- M_{G8} , M_{G9} = Centerline of rear wheels, Right and Left
- M_{G10} = Centerline of vehicle, Rear

Note: M_{G1} , M_{G2} and M_{G3} shall be used for this test; M_{G8} , M_{G9} , and M_{G10} are optional microphones.

Figure B1: Standard Vehicle Exterior Measurement Points – Vehicle Side View

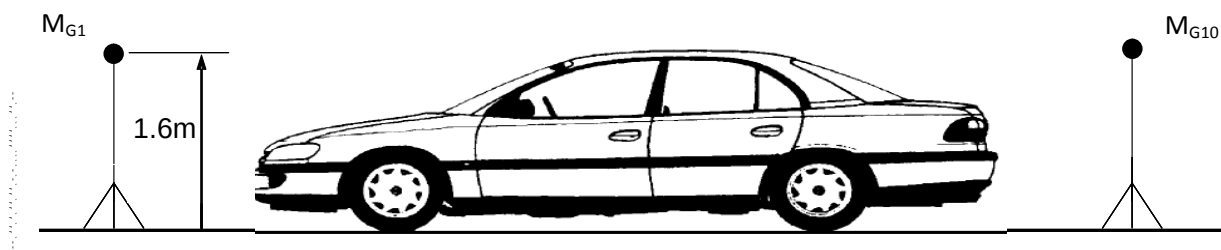
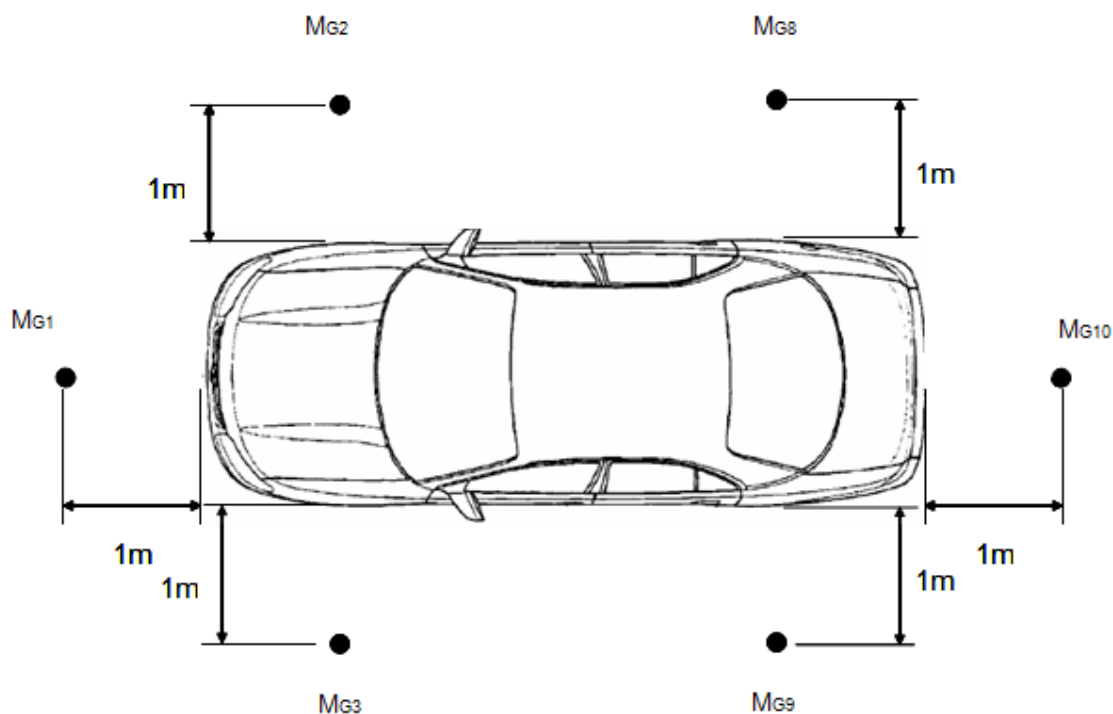


Figure B2: Standard Vehicle Exterior Measurement Points – Vehicle Top View



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Appendix C

C1 Mid-point Seat Locating Instructions.

C1.1 Place seat in the full backward and full downward position.

C1.2 Measure horizontally from the furthest forward point on the rear seat that is directly behind the front seat to the front seat back.

C1.3 Move the seat to full forward and repeat step C1.2.

C1.4 Add the two distances (steps C1.2 and C1.3), divide by two, and move the front seat until the seat is located at the calculated distance from the rear seat.

C1.5 Measure vertically from the furthest forward position on the front seat to the floor.

C1.6 Raise the seat to its full upward position and repeat the measurement from step C1.5.

C1.7 Add the two distances (steps C1.5 and C1.6), divide by two. Move the seat all the way down and then raise it until the seat is located at the calculated distance from the floor. Record this dimension.

C1.8 Adjust headrests to full down position and to align with the seat back plane.

C1.9 Place microphone stand in seat with pivot against seat back.

C1.10 Adjust the pivot such that the microphone is horizontal, pointing forward when using a free-field microphone, and vertical, point up when using a pressure field microphone.

C1.11 Adjust seat back to be as vertical, as possible, while maintaining at least 15 cm from microphone.

C1.12 Measure horizontally from the furthest forward point on the rear seat that is directly behind the front seat to the front seat back. Record this dimension.

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Appendix D

D1 Auxiliary System Control for Evaluation

Three categories:

- Competitive Benchmarking Evaluation – Subject Matter Expert should conduct a subjective assessment of the vehicle first, then decide which components are objectionable and need to be measured.
- GM Vehicle VTS Validation - Subject Matter Expert should conduct a subjective assessment of the vehicle in a range of ambient temperature and humidity conditions. If any components are objectionable for noise during operation, measure Autostop at the worst case condition(s) and compare to VTS.
- GM Vehicle Development and Root Cause.

D1.1 A/C Compressor and Condenser Radiator Fan Module (CRFM) Control Evaluation.

Notes on electric AC compressor operation:

- Compressor broadband noise is easily dominated by CRFM fan noise, particularly at the driver's ear location.
- Compressor sound pressure level varies with compressor operating speed. Head pressure has no measureable effect on compressor noise.
- Steering wheel and seat track vibrations are also not affected by pressure variations.
- Compressor noise is more readily observed with exterior microphones than interior. Exterior microphones can detect compressor broadband noise when CRFM speed is low.
- Narrowband/tonal noise from the compressor is evident in both exterior and interior microphones.

D1.1.1 Competitive Benchmarking Evaluation.

Operate the compressor as outlined in 4.3.4. Note CRFM operation in test log.

D1.1.2 GM Vehicle VTS Validation.

Operate the compressor and/or CRFM at its worst case operating condition.

D1.1.3 GM Vehicle Development and Root Cause.

1. Determine the vehicle's range of CRFM and compressor operating speeds (minimum and maximum). This step is best done in a hot ambient environment at 35 °C to 40 °C (95 °F to 104 °F).
2. Define specific test setpoints for CRFM speeds and compressor speeds, perhaps five (5) of each.
3. Run/record the CRFM at each setpoint, with A/C **Off**. Vehicle Spy (VSPY) can do this for GM vehicles.
4. Run/record the compressor at each setpoint with CRFM **Off** or unplugged. Be careful to monitor head pressure and do not exceed 2750 kPa (400 psi) at any time.
5. Due to head pressure limitations, it will probably be necessary to run the CRFM at some low speed to achieve some of the higher compressor speeds. Pick a CRFM speed that you have already measured. Try to acquire 20 s of steady-state data. In some cases, you might only be able to achieve 10 s before pressure gets too high and the compressor cuts out.

D1.1.3.1 Data Analysis

1. Analyze tones for all operating cases.
2. Broadband noise on compressor will only be valid with "zero" or "low" fan speeds.
3. Vibrations at seat track and steering wheel will be best determined at "zero" or low fan speeds.

D1.2 Coolant Pump Control Evaluation.

D1.2.1 Competitive Benchmarking Evaluation.

Identify the vehicle operating conditions during which any pump has notable Noise, Vibration, Harshness (NVH) characteristics. Document which pumps are running. If desired, add a triaxial accelerometer on pump(s) at the location of highest amplitude (typically pump inlet, outlet or bottom of pump housing). Test the pump (other

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