



Air Conditioning Subsystem Level 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 test procedure defines the method for subsystem-level measurements of Noise and Vibration (N&V) attributes of Air Conditioning (A/C) systems, including but not limited to growl, hiss, whine, moan, and gurgle.

1.2 Applicability. This test procedure is applicable to all vehicular belt-driven A/C systems and can be used to quantify N&V issues from various components of the system, including but not limited to hoses, tubes, pipes, compressor, heat exchangers, and mufflers.

1.3 Remarks. Testing these components at the subsystem level offers distinct advantages to vehicle-level testing, since parts can be interchanged relatively quickly, packaging space is less restricted, and root-cause/development trials can be evaluated more readily.

2 References

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

2.1 External Standards/Specifications.

ANSI/ASA S1.4 Part 1 DIN 45631/A1

2.2 GM Standards/Specifications.

GMW14172

2.3 Additional References.

- Applied Processor and Measurement, Inc., E. Amherst, NY (www.appliedprocessor.com)
- Subsystem Technical Specification (SSTS)

3 Resources

3.1 Facilities.

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.

3.1.3 Bedplate. The test facility must be free of any vibration which may affect the test specimen. Bedplate should allow for measured vibration to be at least 10 dB higher than background levels in the frequency range of interest (20 Hz to 2000 Hz).

3.1.4 Noise. The test facility must be in a quiet area. An acoustically treated enclosed room is preferred, but not required.

3.2 Equipment.

3.2.1 Test Fixture. Brackets and stanchions securely attached to a bedplate to hold all test pieces and equipment in position as near as possible to vehicle-intent.

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3.2.2 Evaporator Heater. A small electric heater capable of producing a thermal load of approximately 750 W to the evaporator in the A/C system.

Note: The heater must be equipped with “tip-over” safety switches and a thermostat to keep the ambient air at or below 50 °C.

3.2.3 Heater, Ventilation, Air Conditioning (HVAC) Module Enclosure. Acoustically treated box capable of maintaining a separate air space containing the heater and HVAC module. Intent is to mimic the vehicle's passenger compartment.

3.2.4 Drive Motor. A quiet variable speed motor capable of producing approximately 15 kW at equivalent speed of 6000 compressor revolutions per minute (rpm), considering pulley ratio.

3.2.5 Belt. A multi-rib drive belt of appropriate length and width to connect drive motor pulley to the A/C compressor pulley.

3.2.6 Microphone. A random-incidence microphone is preferred. A free-field microphone may be used if random-incidence microphone is not available.

3.2.7 Accelerometer. A high sensitivity accelerometer with flat frequency response from 2 Hz to 2000 Hz and a temperature range of 10 °C to 50 °C or greater.

3.2.8 Pressure Transducers. Pressure transducers with a flat frequency response between 5 Hz and 1200 Hz, temperature range exceeding 0 °C to 135 °C, and pressure range appropriate to their usage, i.e., approximately 800 kPa for suction and > 3000 kPa for discharge.

3.2.9 Tachometer. An instrument grade tachometer signal probe, such as an optical tachometer pickup, capable of providing a 1 pulse per revolution signal.

3.2.10 Thermocouples. Optional thermocouples with conditioners capable of converting surface temperature of refrigerant piping (approximately -20 °C to +100 °C) to an acquirable signal.

3.2.11 Current Probe. An inductive clamp to measure the current flow to the Electronic Control Valve (ECV) in milliAmps (mA), with minimum 1 A range and a tolerance of $\pm 2\%$.

3.2.12 Pulse Width Modulation (PWM) Controllers. Device(s) capable of variable frequency and duty cycle digital control of PWM signal to the ECV, Blower Motor, and/or Engine Cooling Fan (ECF). Recommend Applied Processor and Measurement, Inc. Model 205 or similar. A separate PWM controller is required for each device being controlled.

3.2.13 Power supplies.

3.2.13.1 Two (2) Variable Direct Current (DC) power supplies with sufficient capacity to provide at least 15 V at 20 A are required to power the ECF and the HVAC Blower.

3.2.13.2 An additional 12 V power supply is required for powering the ECV. The ECV should have its own dedicated power supply.

3.2.13.3 A fourth 12 V power supply might be required to power compressor clutch, pressure transducers, and/or other equipment. The power supply for the HVAC blower and/or the ECF might be shared for this purpose if it is set to 12 V and the fan is controlled via PWM. The ECV power supply cannot be shared for compressor clutch or pressure transducers.

3.2.14 Data Acquisition Equipment. 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 ANSI/ASA S1.4 Part 1 or be equivalent for the application (precision ± 0.7 dB or $\pm 8\%$).

3.3 Test Vehicle/Test Piece.

3.3.1 Compressor. Vehicle representative compressor.

3.3.2 Condenser Radiator Fan Module (CRFM). An electric fan is required. If vehicle-intent component does not include an electric fan, an external, variable speed electric fan must be set up to provide airflow over the condenser. Although the radiator is not required to complete this testing, the radiator is typically part of the mounting system for ECF shroud. The radiator should be drained of fluid and its coolant ports should be capped.

3.3.3 HVAC Module. Module should be parked in Full-cold mode to allow maximum airflow over the evaporator.

3.3.4 Thermal Expansion Valve (TXV). TXV is often considered part of the HVAC module. For this test, multiple TXVs might be tested.

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3.3.5 Accumulator/Drier (As Needed). Accumulator/drier is often part of the CRFM. If it is not, a separate accumulator/drier container should be included.

3.3.6 Internal Heat Exchanger (IHX) (Optional). Many vehicle A/C systems include IHX, which attaches to the TXV at one end, and both the Suction and Liquid Lines at the other end.

3.3.7 Suction Line. Includes a section of flexible hose, some metal tubing and usually a muffler and/or silencer. Suction Line also includes appropriate connectors to attach to the compressor and either the IHX, TXV or an accumulator/drier. Suction Line should also include ports to measure suction pressure at both ends of the flexible hose.

3.3.8 Discharge Line. Includes a section of flexible hose, some metal tubing and sometimes a muffler. Discharge Line also includes appropriate connectors to attach to the compressor and the condenser. Discharge Line should also include at least one (1) pressure transducer.

3.3.9 Liquid Line. Includes a section of metal tubing and often some flexible hose. Liquid Line also includes appropriate connectors for the condenser at one (1) end and the either the IHX or TXV at the other end.

3.4 Test Time.

Calendar time: 1.5 days

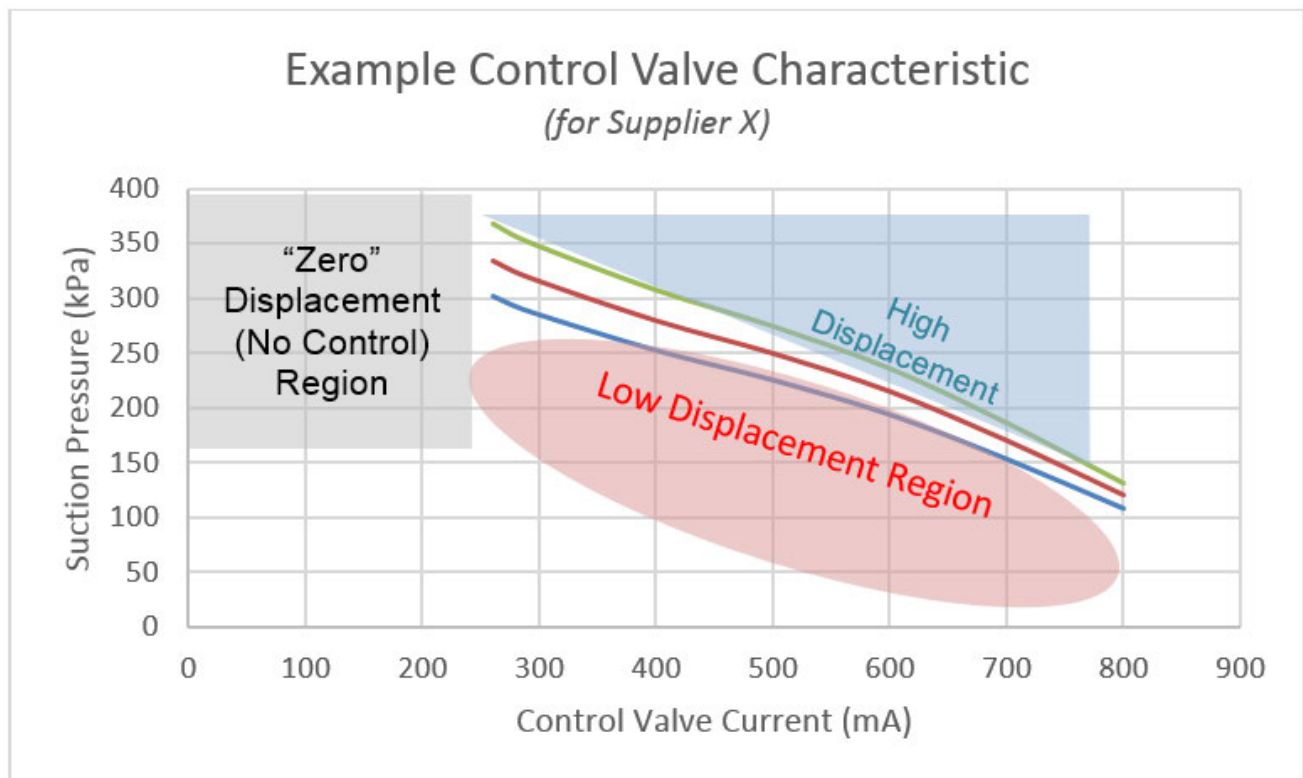
Test time: 2 hours

Coordination time: 10 hours

3.5 Test Required Information.

3.5.1 Control Valve Characteristic Curve. For Externally Variable Displacement Compressor (EVDC), the control valve characteristic curve describes minimum and maximum operating current for ECV along with a plot of expected suction pressure vs. ECV current for high and low compressor displacement. See Figure 1.

Figure 1: Example Control Valve Characteristic Curve



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3.5.2 HVAC Blower PWM Operating Frequency and Duty Cycle Limits. Brushless blower motors can only be operated if PWM operating characteristics are known.

3.5.3 ECF PWM Operating Frequency and Duty Cycle Limits. Brushless ECF motor can only be operated if PWM operating characteristics are known.

3.5.4 Compressor Operating Speeds. For N&V testing, typical compressor operating speeds range from vehicle engine idle to approximately 3000 engine rpm. Engine idle speed and crankshaft-to-compressor pulley ratio are required to determine compressor operating speed.

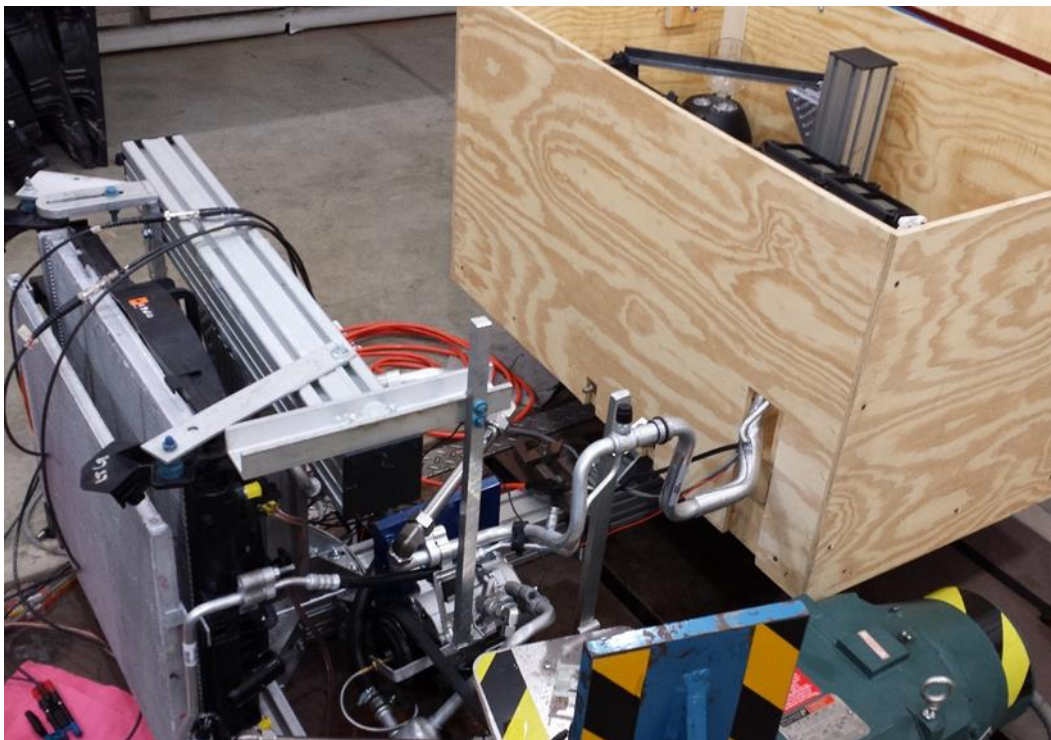
3.6 Personnel/Skills. One (1) qualified engineer or technician trained in the use of data acquisition equipment and having basic knowledge of both N&V signal processing and A/C operation.

4 Procedure

4.1 Preparation.

4.1.1 A/C Subsystem Component Mounting. Compressor, CRFM, HVAC Module and all A/C refrigerant lines should be fixtured and secured as close as possible to vehicle-intent position. CRFM, HVAC module, and refrigerant lines can be mounted to a single fixture to maintain proper positioning. See Figure 2.

Figure 2: Example A/C Subsystem Component Mounting



4.1.1.1 Compressor. Compressor should be attached to a fixture of sufficient mass such that very little vibration energy from the compressor is transmitted to other components. In general, a fixture with a first natural frequency of 300 Hz or higher and a mass ratio of at least 2:1 relative to the compressor is desirable. The compressor fixture should be rigidly attached directly to the bedplate, along with the drive motor positioned to maintain proper belt tension. To avoid transmitting structure-borne noise to the HVAC module enclosure, the compressor fixture should not be attached to the common fixture with the CRFM and HVAC module.

4.1.1.2 CRFM. CRFM should include its vehicle-intent isolators.

4.1.1.3 HVAC Module. Module can be attached directly to the common fixture and enclosed in an acoustically treated container such as a wooden box. Acoustic treatment should produce an ambient environment that is 10 A-weighted decibels (dBA) lower than the sound being measured.

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