



Air Conditioning Evaporator Condensate Freeze Development Procedure for Systems with Temperature Sensors

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. Evaporator core freeze events result in reduced compressor oil circulation and can result in compressor damage. The purpose of this test is to determine whether the control of the compressor (clutch control, variable displacement mechanism, or compressor speed) adequately protects the system from condensate freeze. A secondary purpose while collecting data is to demonstrate refrigerant superheat control under a variety of conditions. This procedure has the required instrumentation and test sequence for a superheat analysis without additional testing.

Note: The refrigerant charge variation included in this test is not sufficient to evaluate condensate freeze below an operational refrigerant charge (as defined by GMW7022), (i.e., GMW16571 is not a low refrigerant charge evaluation test).

Note: A change in the refrigerant used in a vehicle HVAC system has a significant impact on system performance and will require revalidation of evaporator freeze testing.

1.2 Applicability. This test procedure is intended for use on HVAC systems with temperature based control systems on a climatic test bench.

1.3 Remarks. This test procedure is intended to be used to collect data for climate control decisions during preliminary development of Heating Ventilation and Air Conditioning (HVAC) system.

- As a test technique to develop and verify the optimal location of the refrigerant control sensors (evaporator air or fin temperatures). A clear plastic window and/or camera to view and record frost formation on the evaporator (inside the HVAC module) is required.
- As a test technique to develop initial calibrations with a proposed sensor placement and control design that will provide robust protection from evaporator condensate freeze under applicable conditions expected to be encountered for a customer vehicle intended usage.

Note: GMW15775 is a complementary vehicle level test to perform final system verification around evaporator condensate freeze with production intent sensor designs/placements, controller, software and calibrations under a robust set of vehicle operating conditions.

1.3.1 Tests must be conducted with representative air handling conditions at the evaporator air inlet and exit (typically this means testing with a complete and representative HVAC module).

1.3.2 Tests must be conducted with production intent refrigeration components including the condenser, compressor and refrigerant expansion device(s). The compressor and expansion device control the flow of refrigerant and impact the location of the coldest location on the evaporator outlet face.

1.3.3 Tests must be conducted with functional refrigerant control software and calibrations as well as representative refrigerant control sensing devices (evaporator air or fin temperature sensors, high pressure transducers, low pressure switches or transducers, etc.)

2 References

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

2.1 External Standards/Specifications.

None

2.2 GM Standards/Specifications.

GMW7022

GMW15775

GMW15845

2.3 Additional References.

- VTS.

3 Resources

3.1 Facilities. Test to be run at a HVAC system bench capable of simulating defined conditions. This test requires visualization of ice formation on the evaporator core. A bench test is required due to the expected inability to visualize and quantify ice formation on the evaporator during vehicle operation. Use of a camera will enhance the data captured.

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 Input air conditions of (5 to 40) °C and relative humidity varying between (5 to 90)%.

3.1.4 Condenser airflow quantity and distribution to simulate (0 to 120) km/h vehicle speeds at (5 to 40) °C ambient airflow temperature.

3.1.5 Compressor rotational speeds (500 to 5000) revolutions per minute (rpm) (or as appropriate for electric drive compressors).

3.2 Equipment. The minimum instrumentation shall be used per procedure GMW15845 (Test Vehicle Instrumentation Procedure).

3.2.1 Pressure Measurement.

3.2.1.1 Front before Expansion Device (BXD) Refrigerant Pressure. Choose one of the three options as follows.

3.2.1.1.1 Direct mount of production vehicle Air Conditioner (A/C) pressure transducer for the front BXD and other components of the refrigerant circuit can be used. This method reduces the possible error caused by the remote high side transducer line refrigerant storage mass in instrumentation tubing. Direct mounting removes the need to correct refrigerant charge values for the data report.

3.2.1.1.2 Remote under hood transducers with common 1 m long instrumentation tubing (per GMW15845) for the front BXD and other desired component location may be used. This method requires the user to correct refrigerant charge mass for each 1 m high side tube employed. Under hood transducers following this protocol alleviate the need for a confirmation test without high side pressure (4.3.7).

3.2.1.1.3 Remote mount an instrumentation grade transducer for BXD measurement.

3.2.1.2 Evaporator outlet refrigerant pressure.

3.2.1.3 Compressor inlet refrigerant pressure.

3.2.1.4 Compressor outlet refrigerant pressure. Choose a method from options from 3.2.1.1 or capture the production vehicles A/C Compressor.

3.2.1.5 Compressor crankcase refrigerant pressure.

Note: Instrumentation methods 3.2.1.1.3 and 3.2.1.4 require assurance of proper refrigeration mass offset during this test for the instrumentation used in high pressure component measurements. All references of refrigerant charge in test reports and databases are to be representative of a production vehicle (with no pressure instrumentation).

3.2.2 Thermocouples.

3.2.2.1 Evaporator outlet refrigerant temperature.

3.2.2.2 Evaporator inlet refrigerant temperature.

3.2.2.3 BXD refrigerant temperature.

3.2.2.4 Compressor inlet refrigerant temperature.

3.2.2.5 Compressor outlet refrigerant temperature.

3.2.2.6 Thermocouple near (within 5 mm) Evaporator Air Temperature (EAT) sensor (if applicable) or tube thermocouple near (within 2 mm) evaporator fin temperature sensor (if applicable).

3.2.2.7 A 16 point thermocouple grid at evaporator air exit as described in GMW15845. Optionally, consider thermocouples measuring the evaporator tube metal temperature at critical similar locations. An advantage in using the additional tube metal temperatures is that as the delta temperature (temperature difference between the tube and outlet air) in thermocouple pairs increases, the large delta temperature provides an identification of local ice formation at locations that may not be visible in the evaporator core viewing window or camera angle.

Note: In all cases, avoid a situation where a thermocouple wire modifies or blocks the flow of air to the evaporator air grid and/or the refrigerant capacity control sensor.

3.2.3 Climate Control Commands.

3.2.3.1 Blower voltage and current draw.

3.2.3.2 Compressor clutch voltage, if applicable.

3.2.3.3 Vehicle A/C (high side) refrigerant pressure transducer and evaporator air or fin temperature sensors.

3.2.4. Video Equipment.

3.2.4.1 Camera to capture frost formation internal to the HVAC module (optional).

3.3 Test Vehicle/Test Piece.

3.3.1 Test Bench. Components of the refrigeration system representative of production intent and equipped with instrumentation as described in GMW15845 (Test Vehicle Instrumentation Procedure).

3.3.2 Components. Insert an evaporator face view window (clear plastic window) or HVAC module internal camera to allow vision of frost formation on the airflow outlet face of the evaporator core.

3.4 Test Time.

Calendar time: 3 days

Test hours: 32 h

Coordination hours: 4 h

3.5 Test Required Information. Not applicable.

3.6 Personnel/Skills. Bench setup requires personal with knowledge of HVAC test instrumentation and refrigerant circuit fabrication.

4 Procedure

4.1 Preparation.

4.1.1 Prepare bench instrumentation as described in GMW15845 (Test Vehicle Instrumentation Procedure).

4.1.2 A transparent plastic window or internal camera in the HVAC module case to aid in evaporator core downstream viewing is required.

4.1.3 Climate control temperature setting shall be adjusted to full cold and locked in this position for all tests.

4.1.4 Intake door shall be in the production intent fresh air position (Production Outside Air (P/OSA)). Lock the intake door in the fresh air position unless this is not representative of a customer selectable intake position.

4.1.5 Collect evaporator core airflow distribution data from 25% and 100% blower airflow conditions. This data will be used as an input for sensor placement.

4.2 Conditions.

4.2.1 Environmental Conditions. Thermal conditions (ambient air temperature and relative humidity) are specified in Table 2. Humidity does not apply to condensing airflow.

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. Table A1 and Table A2 are to be completed prior to the test.

4.2.3 Refrigerant Charge Conditions. The environmental conditions of Table 2 shall be tested.

4.2.3.1 Charge 1. Operational refrigerant charge as defined by GMW7022. This will represent the refrigerant charge at the end of the vehicle life.

4.2.3.2 Charge 2. Production refrigerant charge (operational charge plus reserve charge) as defined by GMW7022.

4.3 Instructions.

4.3.1 HVAC System Bench Setup Instruction.

4.3.1.1 The bench shall be configured to provide total condenser flow and compressor speed as measured from prior vehicle tests. Appendix A, Table A1 is used to collect information for the required condenser and compressor conditions.

4.3.1.2 Utilize Appendix A, Table A2 to collect information for the front blower speed at the test conditions.

4.3.1.3 The rear heat exchanger blower (if equipped) shall be turned off for Charge 1 tests. The rear heat exchanger blower (if equipped) shall be at the minimum customer selectable speed for Charge 2 tests (low blower).

4.3.1.4 The compressor operation speed shall be representative of 110 km/h unless noted otherwise.

Note: Utilize an initial evaporator fin or air temperature freeze control calibration (denoted in Figure 1 as IC2' in Chevron 1 and IC1' in Chevron 2) that are expected to cause minor ice formation ($\approx 7 \text{ cm}^2$ area). This calibration is dependent on the particular system and would expect to be in the range of (0 to 1) °C for an air sensor or (-1 to 0) °C for a fin sensor. Proper location of the temperature sensor requires knowledge of the geometry of initial formed ice. This knowledge will be gained during the completion of this procedure. It will be necessary to move the fin or air sensor if the sensor is not responsive to evaporator temperature after minor ice formation. Correct sensor placement from an icing risk perspective is a cold location, but not the first location of icing. Criteria for evaluating sensor placement, in addition to manufacturing and vehicle service constraints include:

4.3.1.5 Criteria 1 defines minor ice formation shall not block airflow to the sensor.

4.3.1.6 Criteria 2 defines the sensor shall become cooler once minor ice is formed on the evaporator core when compared to the temperature before ice formation during the same test point.

Note: When (a) airflow to the sensor is restricted by ice formation and/or (b) the measured temperature of the sensor trends warmer after localized ice formation, then move the sensor to an alternate location with a proper temperature response and unrestricted airflow with minor ice. Use the evaporator temperature distribution captured by the evaporator outlet grid along with previously established evaporator air velocity measurements to select a location that is responsive to the trend in core temperature (colder after ice formation) and high in airflow.

4.3.2 Chevron 1 Initial Sensor Placement.

4.3.2.1 Charge the refrigeration system for the "Charge 2" condition (see 4.2.3.). Figure 1 provides an overview and detail of the test process.

4.3.2.2 Stabilize the tunnel or HVAC system bench the ambient condition defined in Figure 1, Chevron 1. Stabilization is defined by compressor outlet pressure stability of $\pm 15 \text{ kPa}$ and evaporator grid average temperature stability of $\pm 1^\circ \text{C}$ or cyclic peak stability as applicable for every test point noted in Figure 1.

4.3.2.3 After the system has stabilized, follow the process from Figure 1 and record the following refrigeration data (Table 1).