



Refrigerant Charge Determination

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. The purpose of this test is to determine the refrigerant charge for air conditioning systems for either front only evaporator systems, front and rear evaporator systems, and/or systems with evaporators and refrigerant chillers. A correct refrigerant charge (this test) shall be determined before testing system performance including heat exchanger core freeze (GMW15775), city traffic A/C (GMW3202) and steady state A/C (GMW3037).

1.2 Applicability. This procedure applies to all passenger vehicles and light commercial trucks with an Air Conditioning (A/C) system.

1.3 Remarks.

1.3.1 The Thermostatic Expansion Valve (TXV) setting may impact the test result, therefore the TXV setting shall be determined prior to testing or this procedure must be repeated for confirmation after the final TXV setting is selected. Special operation modes such as fast charging of battery electric vehicles requires consideration of receiver drier size, as noted in 4.1.4.

1.3.2 Pressure measurements in this standard are Kilopascals Gauge Pressure (kPaG). It is permissible to collect data using measurement of Kilopascals Absolute (kPaA). Use care to avoid conversion error, and label clearly in databases and engineering reports if using kPaA units. Temperature differential measurements (differences between two individual temperature measurement locations) are noted in degrees Kelvin (°K) to avoid confusion with single temperature measurements noted in degrees Celsius (°C).

2 References

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

2.1 External Standards/Specifications.

SAE J2727

2.2 GM Standards/Specifications.

GMW3037

GMW3202

GMW15775

GMW15845

2.3 Additional References.

CG3947

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.

3.1.2.1 Refrigerant charge determination with refrigerant system computational simulation (i.e., eThermal) may be used prior to component availability.

3.1.2.2 Testing at alternate vehicle speeds and ambient temperatures shall be discussed with GM Engineering refrigeration experts.

3.1.2.3 A refrigerant system bench or laboratory can also be used provided measuring variable as specified in this standard shall be determined correctly with respect to their physical definition.

3.1.3 Climatic wind tunnel including a chassis dynamometer with adjusting possibilities for a vehicle speed of 100 km/h minimum, a wind speed of 100 km/h minimum, an ambient temperature of +50 °C minimum and a relative humidity of 50% minimum.

3.2 Equipment. Refer to GMW15845 for instrumentation technique and requirements.

3.2.1 Pressure measuring and recording equipment for the following for all systems.

3.2.1.1 Evaporator out refrigerant pressure (front, chiller and rear as applicable).

3.2.1.2 Compressor in refrigerant pressure.

3.2.1.3 Front Before Expansion Device (BXD) refrigerant pressure. Choose one of the three options as follows.

3.2.1.3.1 Direct mount of production vehicle 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. Direct mount protocol alleviate the need for a confirmation test without high side pressure (4.3.7).

3.2.1.3.2 Remote underhood transducers with common 1 m long instrumentation tubing (Nylaflow type tubing, see Glossary) 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. Underhood transducers following this protocol alleviate the need for a confirmation test without high side pressure (4.3.7).

3.2.1.3.3 Remote mount a single instrumentation grade transducer for BXD measurement is allowed. Remote mounting of high side pressure in this way requires a confirmation run without remote high side pressure measurement (4.3.7).

Note: Instrumentation options 3.2.1.3.2 and 3.2.1.3.3 require assurance of proper offset for the instrumentation refrigerant mass. All plots in test reports and databases are to be representative of a production vehicle (with no instrumentation).

3.2.1.4 Additional component high side pressure measurement (Compressor Outlet, Condenser Inlet, Condenser Inlet, Internal Heat Exchanger (IHx) high side, Chiller BXD, Rear Evaporator BXD, etc.) is restricted due to the induced error in charge mass. Direct (3.2.1.3.1) or underhood remote transducers (3.2.1.3.2) removes the restriction limit for high side pressure component locations. Other methods of remote high side component pressure measurement instrumentation must be removed from the test vehicle and sealed for this procedure.

3.2.2 Temperature measuring and recording equipment for the following at a minimum for all systems.

3.2.2.1 Evaporator in refrigerant pipe temperature (front and rear as applicable).

3.2.2.2 Evaporator out refrigerant temperature (front and rear as applicable).

3.2.2.3 Compressor in refrigerant temperature.

3.2.2.4 Compressor out refrigerant pipe temperature at the same location of the production high side transducer.

3.2.2.5 Condenser out refrigerant pipe temperature.

3.2.2.6 BXD refrigerant temperature stinger (thermocouple probe inserted directly into the fluid) at the front BXD and rear BXD (as applicable) at the location of the BXD pressure measurement.

3.2.2.7 Evaporator thermistor temperature (if system is equipped with thermistor, front and rear as applicable).

3.2.2.8 Individual panel air outlet temperatures and average panel temperature.

3.2.2.9 Evaporator air outlet grid temperature (optional and recommended) on the front evaporator.

3.2.2.10 Chiller inlet and outlet coolant temperature.

3.2.2.11 Chiller coolant flow rate (optional but required if coolant flow is not known).

3.2.3 Electrical recording and output equipment.

3.2.3.1 Front and rear (if applicable) blower voltage or duty cycle, as applicable.

3.2.3.2 Electric engine cooling fan voltage (if equipped).

3.2.3.3 Electric engine cooling fan (if equipped) – external power supply to ensure constant fan speed. The fan speed is to represent 80 km/h road load (level road) vehicle operation with a full refrigerant charge control for High blower panel mode A/C operation.

Note: Typically a fan speed close to 75% of high speed power is used unless the fan power is 1 kW or more. Vehicles with fan power of 1 kW or higher may choose a more appropriate speed of 50% of high speed.

3.2.3.4 Vehicle speed, engine speed, blower duty (See 3.2.3.1) compressor clutch operation, evaporator temperature sensor, compressor outlet pressure and chiller coolant pump duty cycle from the vehicle communication bus (as applicable).

3.2.4 Speed measurement and recording equipment.

3.2.4.1 Engine fan speed revolutions per minute (rpm).

3.2.4.2 Compressor rpm.

3.2.5 Additional equipment for use on Battery Thermal Chiller Systems. The following only applies to systems with a Battery Chiller.

3.2.5.1 A suitable HVAC bench may be used to determine refrigerant charge on this system. Condensing and front evaporator airflow volume and temperature conditions must match the expected vehicle conditions representative of a climatic tunnel test run under conditions defined in 4.1.3.

3.2.5.2 A fixed thermal load appropriate for the average battery thermal application (2.0 kW suggested) is required. The fixed chiller load is required as the thermal mass of a battery system and thermal condition confounds stable testing as the battery continues to change the chiller load during the procedure.

3.2.5.3 BXD pressure and temperature measurement at the chiller is required. Instrumentation technique described in 3.2.1.3. When the chiller is located in the under body, guidance in 3.2.1.3.2 applies in a similar manner regarding a 1 m tube.

3.3 Test Vehicle/Test Piece.

3.3.1 Passenger vehicles and light commercial trucks equipped with an A/C system.

3.4 Test Time.

Calendar time: 2 days

Test hours: Approximately (4 to 6) h

Coordination hours: Approximately 8 h

3.5 Test Required Information.

3.5.1 Approximate value of the expected refrigerant charge from knowledge of a similar refrigeration system (this value is used to determine the starting value for the test).

3.5.2 Refrigerant superheat and sub-cooling formulas as noted in 4.1.1.8.

3.6 Personnel/Skills.

3.6.1 One climatic tunnel operator and one driver (if necessary).

4 Procedure

4.1 Preparation.

4.1.1 The vehicle shall be prepared for the climatic tunnel and shall be equipped with devices according to 3.2.

4.1.1.1 See GMW15845 regarding vehicle instrumentation.

4.1.1.2 The Condenser Radiator Fan Module (CRFM) fan shall modify control operation to an unvarying condenser airflow per 3.2.3.3.

Note: Variable engine cooling fan speed confounds data analysis and is not permissible.

4.1.1.3 Bench tests shall set CRFM airflow to ensure representative vehicle fan-on airflow of 80 km/h.

4.1.1.4 Climate control systems are to be operated like manual systems during this test. Some systems will require additional equipment to override air inlet selection. This test requires the air inlet to be set to Production Outside Air Inlet Mode (P/OSA) for the entire test. Be sure the air inlet mode control (i.e., P/OSA-Recirculation) can be switched or defaulted during the test if necessary to maintain P/OSA.

Note: The nomenclature P/OSA implies that some vehicles are designed with a portion of the air recirculated within the vehicle with the air inlet control set to draw airflow from outside the vehicle. This customer selectable mixture of outside air is the condition to be tested when this procedure requests the system be set to P/OSA Mode. A recirculation flap, when present, is integral to the P/OSA designation. Recirculation flaps shall remain functional (production intent) for this test. Setting the system to P/OSA and unplugging the air inlet actuator may be the best testing solution to ensure the system stays in P/OSA throughout the evaluation.

4.1.1.5 A charge tube is required to connect the refrigerant source (bottle) to the test vehicle. This charge tube is to connect the source refrigerant bottle (placed on an accurate scale) to the low pressure service fitting of the vehicle refrigerant circuit. A valve is required on the tube exiting the source bottle to control the refrigerant flow. This charge tube must be purged of air/refrigerant during the vehicle evacuation shown in 4.1.1.6.

Note: Prior practice may have been to start with this charge tube full. This line is attached to the low side of the vehicle, therefore the vehicle system will pull liquid from this line leaving only gas during test. If the line starts with saturated liquid, this results in an inaccurate zero charge condition. At the completion of the test, the system will return to saturation pressure and the vehicle may introduce liquid back into this line. Note that the vehicle will require a recharge when this line is later removed.

4.1.1.6 Ensure that you have a properly evacuated system including refrigerant entrained in the oil. This evacuation requires 60 minutes for a single evaporator system and 90 minutes or longer for a multiple heat exchanger system. The charge tube noted in 4.1.1.5 is to be connected to the vehicle and source bottle with the control room valve closed and the connecting tube evacuated during this process. After evacuation, the source bottle scale is set to zero and this reading is noted as the vehicle zero charge scale reading.

4.1.1.7 Externally controlled variable and electric compressors systems shall utilize a control system to maintain about 210 kPaG evaporator outlet pressure unless this pressure cannot be maintained at the maximum permissible compressor operating rpm for the vehicle condition.

Note: The intent is for the compressor to operate at full stroke once the evaporator superheat is at 20 °K or less, when testing a variable displacement compressor system. It may be necessary to force the control system to obtain full compressor displacement, depending on the control system and calibration.

Note: Operation at low refrigerant charge mass can result in evaporator icing that will confound the later test data. If icing on a heat exchanger is observed, turn off the A/C compressor and dissipate the ice before continuing.

4.1.1.8 The test description for this test requires changes in charge increments based on front BXD sub-cooling and evaporator outlet superheat calculations. A method to display active front BXD sub-cooling and evaporator outlet superheat (see CG3947) during the procedure is necessary to execute this test.

4.1.1.9 This procedure requires the addition of refrigerant until Compressor Outlet Pressure (COP) reaches 2600 kPaG. This is to document the rate of pressure rise with additional charge over the production charge. The brief cycle evaluation in this procedure (Cycle 1 to Cycle 6) does not ensure safe customer operation, as evaluation at alternate conditions is necessary to determine if a given overcharge is acceptable. See 4.2.2 and 5.2.2.5.

4.1.2 Settings for Front-Only Systems. For automatic and manual front-only systems, the vehicle ventilation system controls shall be as follows.

4.1.2.1 Vent outlet mode, production outside air mode (P/OSA).

4.1.2.2 Maximum cold temperature lever position.

4.1.2.3 Maximum front blower speed.

4.1.3.4 Electric engine cooling fan should be set to a constant representative speed (see 4.1.1.2).

4.1.2.5 Deviations are described in 4.2.2.

4.1.3 Settings for Front and Rear Evaporator Systems. For automatic and manual systems with both front and rear evaporators, the vehicle ventilation system controls shall be set to conditions noted in 4.1.2 and rear system set as follows.

4.1.3.1 Ceiling or beltline air distribution mode for rear system.

4.1.3.2 Maximum cold rear temperature lever positions.

4.1.3.3 Maximum blower speed for rear system (review test description for when the rear blower is operated).

4.1.4 Settings for Front Evaporator and Chiller Systems. For systems with both front evaporator and a refrigerant chiller, the vehicle ventilation system controls shall be set to conditions noted in 4.1.2 and chiller load set as follows.

4.1.4.1 A simulated load, representing a battery load (2.0 kW suggested).

4.1.4.2 Coolant to the chiller shall be at 32 °C, at designed maximum chiller flow rate (10 L/minute suggested) when the chiller is operational in the test.

4.1.4.3 Coolant shall return to an appropriate temperature (about (25 to 35) °C) when the chiller is not operating with the chiller flow pump stopped to represent a condition without chiller operation.

Note: An Electric Vehicle (EV), Plug-in Hybrid Electric Vehicle (PHEV), or Extended Range Electric Vehicle (EREV) equipped with a fast vehicle charger may require specific testing to evaluate charge performance at unique conditions. Consult with GM Engineering refrigeration experts.

4.1.5 Settings for Front and Rear Evaporator Systems with Chiller System. For systems with both front evaporator, rear evaporator and refrigerant chiller, the vehicle ventilation system controls shall be set to conditions noted in 4.1.3 and chiller set to 4.1.4.

4.2 Conditions.

4.2.1 Environmental Conditions.

4.2.1.1 Temperature: (+38 ± 1) °C.

4.2.1.2 Dew Point: (22 ± 0.5) °C (Relative Humidity: 40%).

4.2.1.3 Wind Speed: 80 km/h unless otherwise noted.

4.2.1.4 Road Speed: 80 km/h unless otherwise noted. Alternate road speed may modify the calculated charge.

4.2.1.5 Solar Load: Solar lamps not required.

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. Unless otherwise noted, the vehicle is to be tested with the transmission in the highest available gear unless an alternate gear is more appropriate for customer usage at the speed being tested.

Note: A vehicle to be sold in an extreme climate market should evaluate the selected production charge as described in 5.2.2.5. A lower refrigerant charge amount may need to be selected, if no further condensing (including front-end sealing) improvement is feasible.

Six climatic tunnel cycles are described as follows.

- Cycle 1 – Front Evaporator System (Single Refrigerant Heat Exchanger) with TXV expansion device.
- Cycle 2 – Front and Rear Evaporator System with TXV expansion devices.
- Cycle 3 – Front Evaporator and Battery Chiller System with TXV expansion devices.
- Cycle 4 – Front and Rear Evaporator with Refrigerant Chiller System and TXV expansion devices.
- Cycle 5 – Front Evaporator only with Orifice Tube expansion device.
- Cycle 6 – Front Orifice Tube with Rear TXV System.

4.3 Instructions.

4.3.1 Test Description for Cycle 1 - Front Evaporator System with TXV Expansion Device. See Table 1.

C_i = Initial Charge (in grams).

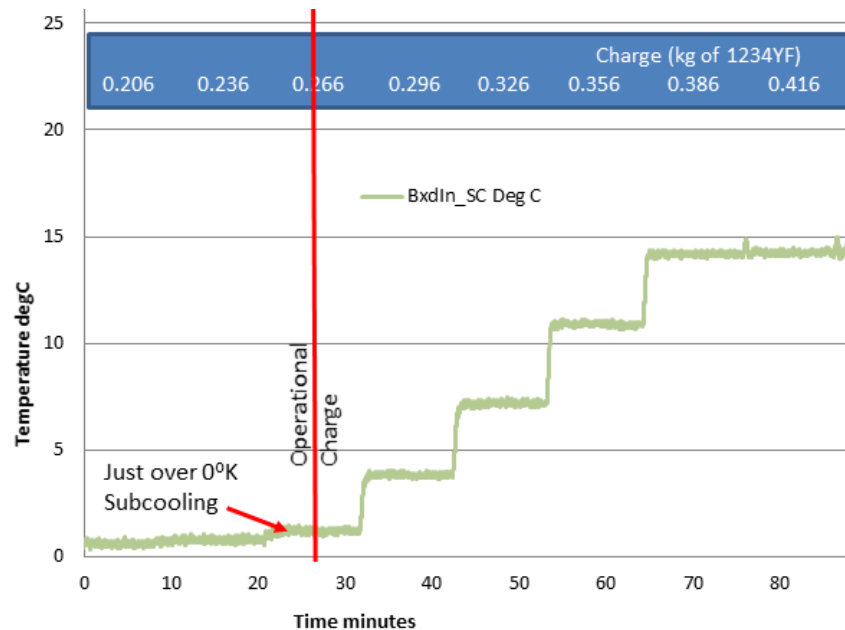
$C_i + 50$ = Charge incremented by 50 g when evaporator out superheat is > 30 °K.

$C_i + 30$ = Charge incremented by 30 g after superheat is < 30 °K.

C_o = Operational Charge (when sub-cooling is just above 0 °K, see Figure 1).

$C_o + 50$ = Charge incremented by 50 g after Operational Charge is determined, until at least 2600 kPaG Compressor Outlet Pressure is achieved.

C_{2600} = Charge in the system when first over 2600 kPaG Compressor Outlet Pressure.



Note 1: Production charge selection is discussed in 5.2.

Figure 1: Operational Charge Example ^{Note 1}

Table 1: Climatic Tunnel Cycle 1 - TXV System (Front Only)

Charge Determination Test - TXV System (Single Evaporator, No Chiller)								
(C_i) g	C_i	$C_i + 50$	$C_i + 30$	+30	C_o	$C_o + 50$	+50	COP 2600
Increment Time (minutes) ^{Note 1}	10	10	10	10	10	5	5	5

Note 1: See 4.3.1.3 regarding stabilization criteria as the time above is the minimum permissible.

4.3.1.1 Test Instructions for Cycle 1. Prior to the start of test, ensure evacuation described in 4.1.1.6 has just been completed. With the climatic tunnel stabilized to test temperature, charge the system with 30% of the expected refrigerant charge. If a value of expected charge is not available, estimate the condenser and condenser out (liquid) line internal volume in m^3 . Multiply that by the density of refrigerant liquid of $1100 \text{ kg}/m^3$. Then take 50% of this value as the starting charge. Do not be concerned with the density difference of R134a or R1234yf for this calculation.

4.3.1.2 With the vehicle settings as given in 4.1.2, start the engine and increase the vehicle speed to 80 km/h using the highest available gear. If compressor out temperature becomes > 125 °C, immediately add 50 g of more