

Method for Removal of Refrigerant from Mobile Air Conditioning System to Quantify Charge Amount

RATIONALE

The removal of refrigerant from a mobile air conditioning system to determine the direct refrigerant emissions is a difficult procedure to do accurately. As part of the SAE I-MAC Cooperative Research Program a detail study was conducted on accurate removal of refrigerant from a mobile air conditioning system. Additional studies on the removal of HFC-134a from mobile air conditioning systems have been completed by others in the automobile industry. Use of commercially available equipment, including equipment meeting SAE J Standards, will not allow complete removal of refrigerant from a mobile air conditioning system in order to determine the direct refrigerant emissions. It is difficult and unreliable to remove refrigerant from mobile A/C systems and use this to quantify system emissions.

1. SCOPE

This Standard provides an overview of results and requirements needed to remove refrigerant from a mobile air conditioning system for determining refrigerant emissions (leakage).

This reclaim procedure for use on fleet vehicles in a field service environment should produce an accuracy and repeatability sufficient to determine refrigerant loss within 2 g.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of SAE publications shall apply.

2.1.1 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or 724-776-4970 (outside USA), www.sae.org.

SAE J2788 HFC-134a (R-134a) Recovery/Recycle/Recharging Equipment and for Mobile Air-Conditioning Systems

SAE J2791 HFC-134a Refrigerant Electronic Leak Detectors, Minimum Performance Criteria

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http://www.sae.org/technical/standards/J2762_201102

2.1.2 Other Publications

I-MAC Report Team 1-Refrigerant Leakage Reduction, Final Report to Sponsors, Eugene Dianetti, Aug., 2007

Research study on the definition of the implementation of a method of measurement of annual leak flow rates (LFRs) of MAC systems, Dennis Clodic, -Ecoles Des Mines, Jan., 2006

3. BACKGROUND

3.1 The Effect of System Design on the Refrigerant Recovery Process

3.1.1 When refrigerant is removed from the system, the lowering of pressure results in some of the system components becoming cooler. This component cooling effect makes complete refrigerant removal in a short period of time more difficult. To remove as much of the refrigerant as possible during the recovery process, systems equipped with orifice tubes and accumulators require more time than systems equipped with expansion valves/receiver driers. This is mainly because of the design differences between accumulators and receiver driers (being larger than receiver driers, accumulators, located in the low pressure side of the system [where the refrigerant is cold and more refrigerant can be held by the oil], hold more refrigerant and oil than do receiver driers).

3.2 The amount of refrigerant recovered from a system depends on how much is in the system, and the temperature of the work area. When the refrigerant is recovered, the vacuum lowers the temperature of the various components in the system; the oil chills and forms a virtual barrier to reduce refrigerant evaporation.

3.3 I-MAC CRP Results

3.3.1 Refrigerant Recovery Standard for System Charge Level Determination Final Assessment

3.3.1.1 The procedure was tested on selected vehicles with a variety of A/C system configurations (CCOT, TXV, Dual systems). Different types of oil-less recovery pumps were investigated in an attempt to reduce variation of refrigerant recovery quantities.

3.3.1.2 The use of dry ice or liquid nitrogen was rejected as a viable option for field-testing due to availability and safety concerns. Refrigerant recovery quantities achieved by following the published procedure did not produce the desired accuracy and repeatability for all A/C system types. All testing was conducted at room temperature. Consistent evacuation levels and times were maintained.

3.3.1.3 Recovery variation is largely dependent on the refrigerant vaporization rate and the amount of refrigerant remaining in solution with the oil within the a/c system at evacuation terminus. It is believed that the amount of refrigerant recovered, and the associated repeatability, would be improved significantly by elevating the vehicle temperature to 30 °C during reclaim. This was also rejected as being impractical in a field environment.

3.3.1.4 It is difficult and unreliable to remove refrigerant from mobile A/C systems and quantify system emissions.

3.3.1.4.1 Tests performed for the SAE I-MAC research program indicates that the surrounding temperature greatly affects the recovery process. Equipment used is shown in Figure 1.



FIGURE 1 - RECOVERY VACUUM PUMP AND CYLINDER USED IN LABORATORY REFRIGERANT RECOVERY PROCEDURE

- 3.3.1.4.2 If the system is opened, the remaining refrigerant will be vented to the atmosphere.
- 3.3.1.4.3 If the system recharges to specification, it will overcharge.
- 3.3.1.4.4 The development of SAE J2788 (December 2006 replacing SAE J2210) recovery/recharging equipment has improved refrigerant recovery capability during service. However, the equipment is not capable of recovering the entire amount refrigerant in a system.
- 3.3.1.5 Recovery at 21 °C with SAE J2210 recovery equipment left over 18% of the refrigerant in the system. At a work area ambient of 10 °C nearly 30% of the refrigerant remained in the system.

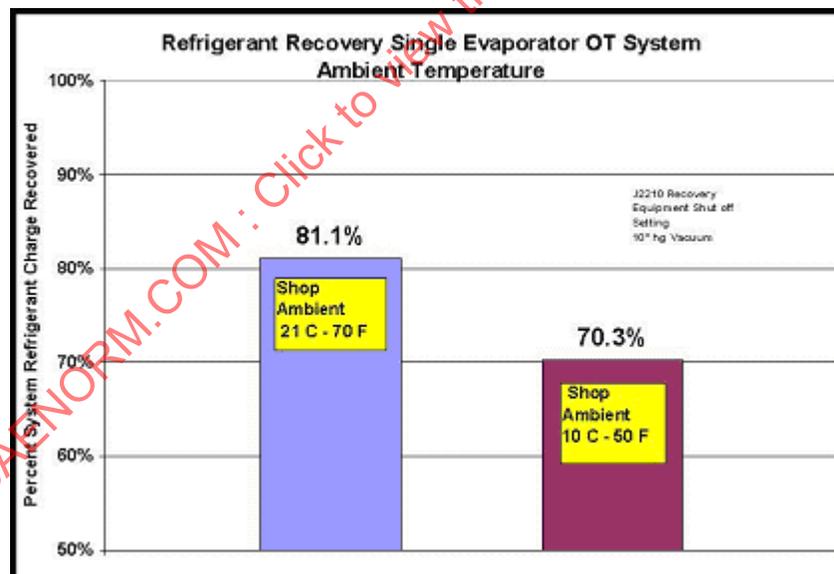


FIGURE 2 - RECOVERED REFRIGERANT WHEN USING SAE J2210 RECOVER/RECYCLE EQUIPMENT AT 10 °C AND 21 °C WORK AREA TEMPERATURE

3.4 Ecoles Des Mines Study Results

For each type of vehicle, in order to demonstrate that the refrigerant is recovered with a precision of less than 1 g, the refrigerant has been recovered just after the initial charge and after a half an hour of running the A/C system.

3.4.1 Background

The procedure as followed by the trained and experienced operators is presented in Annex 1. Prior to the ACEA fleet test the CEP laboratory had a long experience in recovery and was well aware of the number of difficulties associated with high precision for recovery and charge. So a procedure has been first written. Recovery equipment using an oil free compressor has been modified in order not to trap any refrigerant. A training period has been set where step by step all actions have been studied in order not to lose any refrigerant when connecting and disconnecting hoses, to limit oil recovery with the refrigerant and to control all surroundings conditions: garage temperature, engine compartment temperature, A/C system temperature.

3.4.2 Equipment

Special recovery equipment: oil free and without any tank or heat exchanger. Scale with a weighing precision of ± 0.1 g, special (low weight) recovery cylinder dedicated to each vehicle, recovery hoses, dedicated to each vehicle, temperature and pressure sensors to control the operating conditions.

3.4.3 First Recovery

The recovery system is connected to the low pressure service valve of the A/C system. The recovery mass flow rate is controlled by a throttling valve at the suction port of the recovery equipment in order to keep it slow and only in gas phase to avoid oil recovery with the liquid phase of the refrigerant. The 1st recovery operation ends when the final pressure is of 20 kPa abs. The recovery system (recovery equipment + recovery hoses + recovery cylinder) are weighed and the recovered refrigerant known by the difference between the evacuated recovery system and the recovery system with the 1st recovered refrigerant.

3.4.4 Second Recovery

The engine compartment is heated in order the A/C system temperature to reach 40 °C during 30 min minimum. This operation is done in order to evaporate liquid refrigerant either trapped in the compressor, or in the oil, or in any part of the A/C system. From all vehicles it is noticed that the pressure inside the A/C system raises from 20 kPa up to 50 to 70 kPa. The second recovery is carried out identically to the 1st one down to 15 to 17 kPa abs. The recovery system is weighed. If the recovered refrigerant mass is superior to 1g (which is always the case) a third recovery is performed.

3.4.5 Third Recovery

Recovery is carried out with the same steps as described above and the 3rd recovery is the final one if the recovered refrigerant mass is lower than 1 g.

3.4.6 Recovery for Assessment of the Accuracy

The same steps are performed, as described for the initial recovery. Moreover verification of possible oil recovery is carried out. The recovery cylinder is heated to 40 °C and the refrigerant in gas phase is slowly recovered from the recovery cylinder. Then the remaining refrigerant is evacuated with a vacuum pump. Then the evacuated cylinder is weighed as done initially; if oil has been recovered with the refrigerant, its mass is the difference between the initial weighing and the last one.

When all those steps are carried out, the method is considered as validated if the recovered mass of refrigerant is the same as the charged one at 1 g difference.

In summary, the recovery process is performed as follows:

- an oil free compressor is used;
- the car engine compartment is heated up to 40 °C minimum;
- the recovery is performed after running the A/C system during 30 min;
- the recovery mass flow rate is very slow (about 4 to 7 g/min) in order to limit or to avoid any oil recovery;
- the recovery process is performed down to 15 to 17 kPa abs pressure, and several recoveries are necessary until less than 1 g of refrigerant is recovered;
- the recovered R-134a is then separated from possible oil in order to avoid misleading results due to oil recovery.

3.5 Procedure for Refrigerant Extraction

All refrigerant charge and recovery operations have to be performed according to the following procedures:

3.5.1 Record the room temperature when performing the operations measured at 20 cm in front of the car.

3.5.2 Record the following pressures:

1. the residual pressure of the system before the refrigerant charge,
2. the pressure of the MAC system after the refrigerant recovery,
3. the pressure of the recovery equipment before the refrigerant recovery,
4. the effective refrigerant charge, with the error calculation,
5. the recovered refrigerant mass, with the error calculation,
6. the mass of oil recovered from the refrigerant, with the error calculation.

3.5.3 Equipment

3.5.3.1 Scales, accuracy ± 0.1 g

3.5.3.2 Recovery equipment, oil-less without any container or heat exchanger, capable to lower the pressure of the MAC system down to 0.2 bar abs (20 kPa abs). The recovery equipment has a pressure sensor at the suction port capable to measure the pressure with an accuracy of 0.05% of the measurement scale from 0 to 100 kPa.

3.5.3.3 Recovery cylinder (empty weight smaller than 3 kg). The recovery cylinder has a high pressure sensor in order to verify the saturating pressure once the temperature equilibrium is reached after recovery (in order to verify the absence of non condensable gases).

3.5.3.4 Distillation cylinder used to transfer refrigerant from the recovery cylinder in order to weigh the oil content trapped in the recovery cylinder.

3.5.3.5 Leak detector with a sensitivity of 4 g/year according to SAE J2791 standard.

3.5.3.6 Heat generator in order to heat up the volume around the car at a minimum temperature of 20 °C and to heat up the engine compartment at a temperature in the range of 40 °C.

- 3.5.3.7 Soft electrical resistance to heat the recovery cylinder.
- 3.5.3.8 Two temperature sensors: one connected directly to the suction line in order to verify possible liquid trapping, and the other connected to the compressor to check the temperature.
- 3.5.4 Initial Recovery
- 3.5.4.1 Preparation of the Recovery Conditions
- 3.5.4.1.1 The garage ambient temperature around the car is raised up to 20 °C minimum using the heat generator.
- 3.5.4.1.2 The car is run during 20 min in order to heat up the engine compartment.
- 3.5.4.1.3 The A/C system is run in a forced mode if the A/C is automated control. The evaporator blower velocity is on position 3, and the A/C system is run at least 15 min in order to heat up the compressor and to permit first out-gassing of the refrigerant out of the oil.
- 3.5.4.1.4 The A/C system and the engine are turned off.
- 3.5.4.1.5 The hood is opened and possible leaks are searched using the leak detector, first on the compressor, and then on all the visible fittings.
- 3.5.4.2 Preparation of the Recovery System
- 3.5.4.2.1 The recovery cylinder is evacuated with a vacuum pump down to 20 Pa abs.
- 3.5.4.2.2 The recovery cylinder is weighed without any connections.
- 3.5.4.2.3 All the recovery system, i.e., the recovery cylinder, the hoses, and the recovery equipment, is evacuated with a vacuum pump down to 20 Pa abs.
- 3.5.4.2.4 The recovery equipment plus the connecting hoses plus the recovery cylinder (empty) are weighed all together.
- 3.5.4.3 Recovery Process
- 3.5.4.3.1 First Recovery
- 3.5.4.3.1.1 The recovery process begins after the leak search by connecting the hoses to the low and high pressure service valves when available.
- 3.5.4.3.1.2 The throttling valve at the suction port of the recovery equipment is progressively opened so that the oil flush does not occur. This is confirmed by observing the sight glass attached downstream of the throttling valve.
- 3.5.4.3.1.3 When the pressure in the A/C system starts lowering, the throttling valve is progressively opened in order to keep the mass flow rate in the same range of 20 g/min.
- 3.5.4.3.1.4 During the recovery process the engine compartment is heated by the additional heating system at about 40 °C. The evaporator blower shall be on its highest setting and the car engine may be used to increase the temperature. The compressor should be turned off prior to running the engine and if the vehicle is equipped with a clutchless compressor, it is not recommended to run the engine. [In this case, some other source of added heat such as a heated blower might be used.]

- 3.5.4.3.1.5 The first recovery process is performed lowering the system pressure to 20 kPa abs.
- 3.5.4.3.1.6 The hose valves are closed and the recovery hoses are disconnected.
- 3.5.4.3.1.7 The caps are put on the service valves in order to avoid any air infiltration.
- 3.5.4.3.1.8 The complete recovery system is weighed including the recovery equipment itself, its connections, and the recovery cylinder all connected together.
- 3.5.4.3.1.9 This first recovered refrigerant mass is calculated by the weight difference between the mass of the recovery system prior and after this first refrigerant recovery.

3.5.4.3.2 Second Recovery

- 3.5.4.3.2.1 The engine compartment is heated up with the additional heating system. The temperature is verified by a temperature sensor. The A/C system is preferably at a temperature around 40 °C all along the circuit.
- 3.5.4.3.2.2 After half an hour minimum and/or the temperature of the A/C system is at 30 °C minimum, the second recovery process is performed.
- 3.5.4.3.2.3 The suction hoses are connected to the service valves of the A/C system.
- 3.5.4.3.2.4 The pressure is measured on the pressure sensor of the recovery equipment. This pressure is registered on the operation form. If the pressure is identical to the final pressure, the recovery process is ended. If not, the second recovery is performed.
- 3.5.4.3.2.5 The additional recovered refrigerant mass is weighed according to the procedure defined in the previous section.

3.5.5 Final Verification

If refrigerant has been recovered during the second recovery process the A/C system is heated up a new time and the process as defined above is performed again until less than 1 g of R-134a is recovered.

3.5.6 Caution

- 3.5.6.1 If the pressure raises significantly after the second recovery, the saturation pressure of the recovery cylinder has to be analyzed in order to verify that no air was infiltrated in the system.
- 3.5.6.2 If the system is obviously not leak-tight, it has to be put under pressure of R-134a and a thorough leak detection has to be performed.

The successive recovered refrigerant masses are registered as well as the pressures at the end of the recovery processes, if there are more than one.

3.5.7 The mass of the charged refrigerant is calculated as follows:

Charge $R_{-134a} = (\text{charge cylinder} + \text{vacuum hose} + \text{blue connecting valve})_{\text{initial state}} - (\text{charge cylinder} + \text{hose under final pressure} + \text{blue connecting valve})_{\text{final state}}$

3.5.8 Running the MAC System

- 3.5.8.1 Turn the engine ON and run it at 2000 rpm.
- 3.5.8.2 Turn the A/C system ON and run it with the engine at 2000 rpm over half an hour with the evaporator fan at maximum speed and heating the air in front of the car.