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(R) Technician Procedures for Refrigerant Leak Detection in Service of Mobile Air Conditioning Systems

RATIONALE

With the implementation of new regulations for reducing refrigerant emissions, new issues have evolved concerning how to minimize refrigerant losses in the process of checking for refrigerant leaks in systems. The recommendations here address existing and new methods to optimize leak detection with minimum loss of refrigerant.

FOREWORD

The purpose of this SAE Standard is to establish guidelines for leak detection procedures when servicing motor vehicle air-conditioning refrigerant systems. There are many approaches for determining the existence and location of a refrigerant system leak. However, many of these approaches will not provide reliable leak detection. When servicing MAC systems, it is important that they be repaired to maintain their design intent concerning refrigerant containment rates, for system performance, refrigerant system safety, and to protect the environment.

Single evaporator MAC systems can have a design intent refrigerant charge quantity of less than 20 oz (567 g) and a refrigerant leakage rate of considerably less than 20 g per year. Identifying and repairing small system leaks is important, for system performance and reliability. In addition, some hybrid vehicles, or electric vehicles have larger refrigerant capacities than would normally be expected for vehicle size, because the vehicles incorporate an A/C refrigerant circuit for cooling high-voltage battery and/or control electronics under certain operating conditions. For these vehicles, refrigerant leak detection locations can also include other vehicle components other than the air conditioning system.

1. SCOPE

This SAE Recommended Practice applies to the use of generally available leak detection methods to service motor vehicle passenger compartment air conditioning systems.

2. REFERENCES

2.1 Related Publications

The following publications are provided for information purposes only and are not a required part of this SAE Technical Report.

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2.1.1 SAE Publications

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SAE J639 Safety Standards for Motor Vehicle Refrigerant Vapor Compression Systems

SAE J1627 Performance Criteria for Electronic Refrigerant Leak Detectors

SAE J2297 Ultraviolet Leak Detection: Stability and Compatibility Criteria of Fluorescent Refrigerant Leak Detection Dyes for Mobile R-134a and R-1234yf (HFO-1234yf) Air-Conditioning Systems

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

SAE J2913 R-1234yf [HFO-1234yf] Refrigerant Electronic Leak Detectors, Minimum Performance Criteria

3. REFRIGERANT LEAK DETECTION METHODS COVERED IN THIS DOCUMENT

- Visible oil leakage on system parts, often highlighted by road film, particularly at system joints.
- Water/soap solution bubbles.
- Using electronic leak detection devices, particularly those certified to SAE standards.
- Trace dye that meets SAE J2297 requirements.
- System vacuum and pressure decay [pressure change/loss over time]. Except where vacuum and/or pressure decay is used on an isolated component, they are intended to confirm the existence of a leak in the overall system. The complete system test will not pinpoint the location of the leak. One of the methods described above will be needed to pinpoint the location of the leak. Refer to No. 8, System Vacuum and Pressure Decay Procedures (pressure/vacuum change over time).

3.1 Using the Appropriate Leak Detection Procedure

It is important to understand that some of the methods have limited ability to identify a leak, and the use of some methods [i.e., pressurizing the system with nitrogen gas or with a high pressure refrigerant] could cause damage to the refrigerant system. The industry has developed service procedures and equipment that provide the most appropriate way to determine system refrigerant leakage and to minimize the use of additional refrigerant. In many cases, the technician will find it appropriate to use a combination of procedures to pinpoint a leak.

3.1.1 If the indicated leak is large, the technician should begin by confirming its existence by reviewing the vehicle A/C service history and visual inspection. A large leak is defined as one that results in a significant loss of the refrigerant charge within a single A/C cooling season, such as evidenced by failure to pass the vehicle manufacturer's cooling performance test. Very low or no pressure in the system when the vehicle is received might be an indication of a very large leak.

3.2 Three levels of leak detection. Level 1 is for large leaks, and even if effective in pinpointing a large leak, should be followed by a subsequent level (Level 2 or Level 3) to ensure that all repairable leaks have been found.

3.3 The most effective and reliable refrigerant leak detection methods include the following steps, starting with methods that will locate major refrigerant leaks, to methods that will locate leakage rates of a few grams per year. It should be noted that to minimize MAC system refrigerant emissions and assure consumer satisfaction, identifying all potential system refrigerant leakage can only be accomplished by using the correct procedures and in conjunction with electronic and trace dye diagnostics.

4. INITIAL MAC SYSTEM INSPECTION LEVEL I PROCEDURE

4.1 Visual inspection for major leakage [install a gage set and check static pressure in the system].

4.2 Visible oil leakage on system parts should be the first step in any leak test procedure. If vehicle has low or no pressure in the system when it arrives for service, it is important to take time to carefully perform this step.

4.2.1 Leakage may be indicated by oily dirt, particularly at refrigeration system joints. If the leakage is almost entirely from a single location, a refrigerant system having a large leak may have some indication of oil collection on the surface of the refrigerant part, and with exposure time, the area will collect dirt. Visually inspect the system, looking for oily dirt at refrigerant line joints and where lines and components may make physical contact, and rub through to produce a leak. Check the hood liner or surface to check for excessive oil accumulation due to a compressor shaft seal leak from a high-mount compressor. [Note: a small amount of oil is not necessarily an indication of a shaft seal leak.] If accessible, check the condensate drain of the evaporator for signs of oil which may indicate an evaporator leak.

4.2.2 Leakage indicated by trace dye already in the system. Many vehicle makers install trace dye in the A/C system during manufacturing. If so, trace dye is likely to produce visible evidence. See Section 5 for use of trace dye.

4.3 Use of Water or Soap Water Solution

If there is no or very low pressure in the system, skip this step. Bubbles from water and soap solution applied to refrigeration system parts/joints are only effective in locating and pinpointing large refrigerant leaks, and therefore would require some recharging of the system first. Be sure to check for indication of dye before using water or soap water solution to avoid washing away the dye.

4.3.1 The limitations of using a liquid bubble leak detection method are indicated in the chart, Figure 1, which indicates that one bubble per second would be caused by leaks per year equal to double or triple the system capacity. Figure 2 compares the soap solution bubble method with leak detection using SAE J1627 and SAE J2791/J2913 electronic leak detectors.

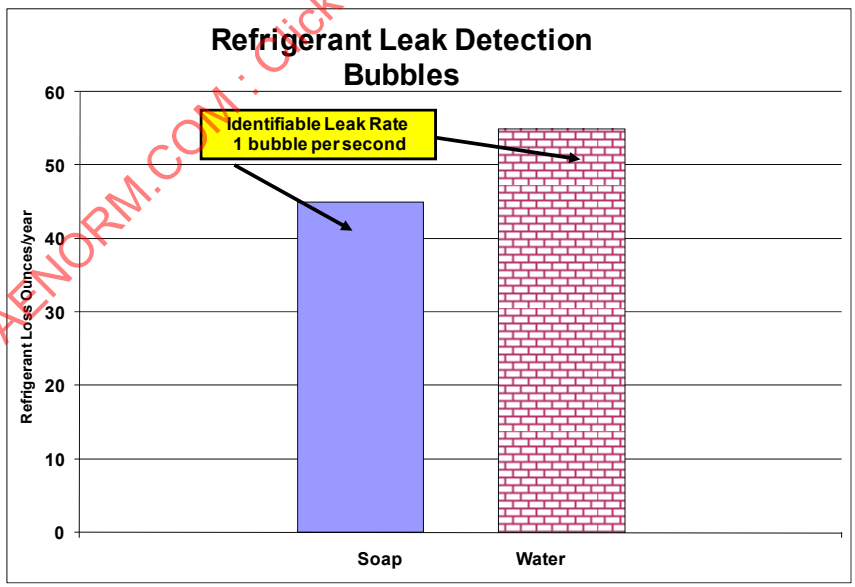

FIGURE 1

4.3.2 As seen in Figure 1, using water or water and soap and looking for bubbles will not identify small leaks, since one bubble per second indicates a refrigerant leak of over 45 oz (1276 g) per year exceeding over twice the total system refrigerant charge requirements for most cars. When attempting to determine if the system has a smaller leak, but still large enough to require service, refrigerant leak bubble identification is of little value, and use of SAE electronic leak detectors and/or trace dye is required.

4.3.3 Figure 2 compares water/soap detection for different SAE rated electronic leak detectors. One visible bubble per second indicates a refrigerant leak rate of approximately 45 oz/1276 g per year, as compared to using SAE J2791 or SAE J2913 electronic leak detectors certified to identify refrigerant leakage of 0.15 oz or 4 g/year.

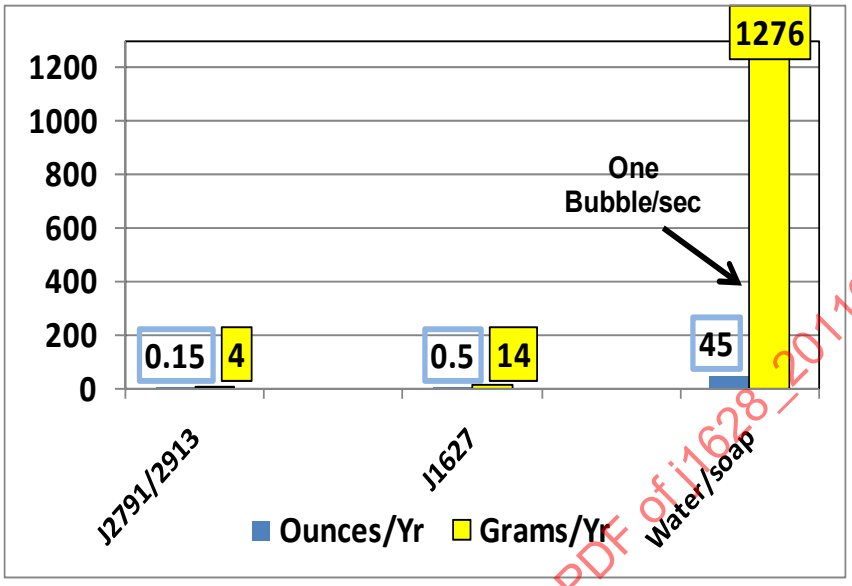

FIGURE 2 - REFRIGERANT LEAK DETECTION

4.3.4 For smaller capacity system refrigerant leaks, refer to procedures in Level IV in Section 8.

5. LEVEL II LEAK DETECTION PROCEDURES

5.1 A full refrigerant charge is not required to detect leaks. In general, the system pressure in psig is similar to the surrounding area temperature in degrees Fahrenheit of the system (work area temperature). If the work area temperature is in the range of 24 °C (75 °F) the system static pressure (no compressor operation) will indicate a gauge pressure reading in the range of 79 psig (543 kPa gauge) for HFC-134a, 82 psig (565 kPa gauge) for R-1234yf. The work area temperature must be warm enough (at least 15 °C [59 °F] for electronic leak detection per 5.2, and should result in a gauge pressure of approximately 57 psig (393 kPa)) for R-134a, 60 psig (414 kPa gauge) for R-1234yf. At high ambients, the pressure will be higher. Consult a refrigerant pressure-temperature chart and determine if the system pressure reading is correct for ambient in the work area, to ensure there is adequate refrigerant in the system.

5.1.1 Step 1: Perform visual inspection as outlined in Level I as described in Section 4.

5.1.2 Step 2: Check pressure in system. If less than appropriate for the ambient temperature, slowly add small amounts of refrigerant until pressure rises above this level. Ambient temperatures should be above 15 °C. Check for hissing noises as refrigerant is added as another check for gross leaks. If noise is heard, stop adding charge, determine the source, and repair the leak before adding more refrigerant. Using the appropriate refrigerant type pressure-temperature chart can be used to determine the expected system pressure.

5.2 Quick Leak Check Repair

5.2.1 A charge amount of approximately 10 to 15% of the total charge will result in sufficient pressure to perform a leak check with an electronic detector. Adding additional refrigerant will not increase system pressure. If the system has been open and has air in it, adding refrigerant without evacuating will result in a slightly higher pressure. However, this will not result in an error in leak checking. Since the refrigerant shall be removed to complete service, the recovery/recycle equipment will process the refrigerant and remove the air before the final full charge is added to the system. The information in Figure 3 shows the addition of refrigerant into an empty system and reaching a saturated equalized pressure condition with pure refrigerant [after the system is evacuated] and refrigerant added to a system (with air) without evacuation.

5.2.1.1 For safety reasons, mixing refrigerant and air in the system, is not recommended. When using SAE J2843 R-1234yf equipment the automatic process will evacuate the system prior to refrigerant being charged into the system.

5.2.2 If the compressor is to be operated, such as to circulate trace dye, a full refrigerant charge amount should be added. [But this should not be done until all of the checks for gross leaks and the other processes in Level III - Section 6 - are completed.]

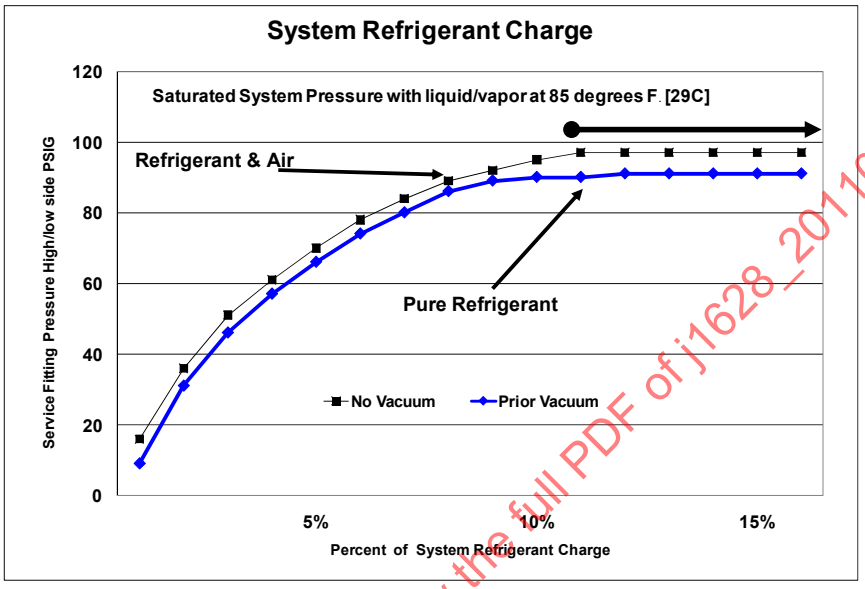

FIGURE 3

5.3 General Considerations

5.3.1 Only the system refrigerant itself has been validated by SAE leak detection standards as a safe, effective pressurizing substance for electronic leak detection in automotive A/C systems.

5.3.2 Using Other Means to Introduce Pressure into the MAC System

5.3.2.1 Without proper equipment and precautions, the use of other pressurizing substances can be costly, and the ability to identify small refrigerant leaks becomes difficult or impossible. It is not recommended that a technician use any other methods for field service to identify system refrigerant leaks. The use of other substances may also result in safety concerns or system contamination if the substance is not properly removed,

5.3.2.2 A pressurization substance other than the system's refrigerant, has not been tested to any SAE standard for suitability for A/C leak detection, and there are no affordable service shop usable, leak detection devices that have been tested to any SAE standard to demonstrate they can consistently measure the equivalent refrigerant leakage rate of less than 25 g per year. Current industry technology has not developed cost effective refrigerant leak detection equipment other than that meeting SAE J1627 and SAE J2791 Performance Criteria for Electronic Refrigerant Leak Detectors (R-134a) and SAE J2913 R-1234yf Refrigerant Electronic Leak Detectors, Minimum Performance Criteria.

5.4 Other Safety Concerns

5.4.1 Pressurizing the entire closed circuit system over 1050 kPa (150 psig) could cause failure of an evaporator. The use of shop compressed air can introduce moisture, contaminates (rust) or shop air compressor oil into the system, saturate the desiccant and cause over-pressure damage the evaporator. Under no circumstances should shop air be used. The use of a higher-pressure refrigerant, such as R-22 (HCFC-22) can result in system chemical contamination. Do not use R-22, as it can contaminate the refrigerant recovered in the service equipment.

5.5 Hydrogen/Nitrogen

5.5.1 Pure hydrogen cannot be used to locate leaks because its escape velocity is so high it may move away from the leak site too rapidly to be detected. The use of hydrogen without adequate safety precautions may also create a flammability hazard. This is not a recommended procedure. Detectors using a mixture of hydrogen/nitrogen to minimize flammability have not been evaluated for meeting appropriate SAE leak detector performance requirements, for the ability to identify small leaks, for possible false-triggering or potential system contamination.

5.5.2 Nitrogen/helium can be used, but the nitrogen dilutes the helium, so a more sensitive detector is needed to locate leaks. Nitrogen at high pressure would tend to dissolve in the lubricant and be adsorbed by the desiccant, so a good vacuum would be needed to remove the residual gases after leak detecting is accomplished.

5.5.3 Leak detectors, using these technologies, have not been evaluated for correlation of refrigerant (R-134a, R-1234yf) leakage rates for meeting the appropriate SAE leak detector performance requirements.

5.6 For safety, under NO CIRCUMSTANCES shall any MAC system or service equipment be pressure tested or leak tested with air/or air and R-134a or R-1234yf mixtures.

5.7 R-1234yf refrigerant has an A2L listing (very low flammability) and SAE J2913 R-1234yf Refrigerant Electronic Leak Detectors can be used to identify refrigerant leakage. R-1234yf requires high energy sources to ignite, such as a hot, cherry red, surface or an open flame. However, only a detector that meets SAE J2913 has been designed and tested to assure safe operation with this A 2L refrigerant.

6. REFRIGERANT LEAK IDENTIFICATION PROCEDURES LEVEL III

6.1 Electronic Probe-Type Detector Instructions for Detecting Refrigerant Leaks

Use electronic leak detectors certified to SAE standards and the correct refrigerant type.

6.2 General Instructions

6.2.1 The electronic leak detector shall be operated in accordance with its manufacturer's operating instructions, and with reference to the basic procedures described in the appendix of SAE J1627, SAE J2791, or SAE J2913. Leak test with the engine and A/C system turned off.

6.2.2 With the system off, charge the A/C with sufficient refrigerant to attain a gauge pressure appropriate for the ambient temperature and the particular refrigerant. Using the appropriate refrigerant type pressure-temperature chart can be used to determine the expected system pressure. Do not continue to charge once this pressure is reached (unless the test is being performed at higher ambients, as noted in 5.1), as the pressure will not increase with added refrigerant once the saturation pressure is reached. At temperatures below 15 °C (59 °F), leaks may not be measurable, since this pressure may not be reached. As a preliminary check to find a gross leak, listen for hissing noise as refrigerant is added. If hiss is heard, determine the source and repair the leak before adding more refrigerant.

6.2.3 Refer to the operator’s manual to determine which chemicals may cause the particular detector to false-trigger. If any of these chemicals is present, using a dry cloth, clean where necessary.

6.3 Take care not to contaminate the detector probe tip if the part being tested is contaminated. If the part is particularly dirty, it should be wiped off with a dry shop towel or blown off with shop air. No cleaners or solvents shall be used, since many electronic detectors are sensitive to their ingredients.

6.3.1 If not already performed as part of Section 4 Level I inspection, visually trace the entire refrigerant system, and look for signs of air-conditioning lubricant leakage, damage, and corrosion on all lines, hoses, and components.

6.4 Warm up the detector. Based on the estimated leakage rate of the entire system, set the detector to the appropriate sensitivity. A detector that meets SAE J2791 and SAE J2913 has three operator-selectable settings, for 4 g/year, 7 g/year, and 14 g/year. SAE J1627 leak detectors do not provide the same level of leak detection capability as the newer detectors. Check each questionable area with the detector probe, as well as all fittings, hose to line couplings, refrigerant controls, service ports with caps in place, brazed and welded areas, and areas around attachment points and hold-downs on lines and components.

6.5 Regardless of the system refrigerant charge amount, it is likely that performance issues will occur when the leak rate is 14 g/year and higher. On late-model small-capacity systems, identifying smaller leaks is important, so it is recommended that the technician use electronic detectors meeting SAE J2791 or SAE J2913 to identify leaks as small as 4 g/year. It is important to minimize system refrigerant loss to assure that maximum cooling performance is achieved. System design leakage will vary depending upon the component technology of the system being serviced, and this must be considered in diagnosis. Comparing the identifiable gram/year leak rate of all connections for the system being serviced should be considered when identifying components that need replacement.

6.5.1 As noted, new, small capacity systems are likely to have leak rates of under 4 g/year for joints, so a greater leak rate from a joint is likely to be serviceable. On large capacity systems of older system designs, most of the joints checked had a leakage rate of less than 14 g/year. Any leak greater than 14 g/year indicates that the leak needs to be repaired. Using the leak detector probe, follow the refrigerant system around in a continuous path so that no areas of potential leaks are missed. If a leak is found, always continue to test the remainder of the system.

6.6 Electronic leak detectors that are certified to an SAE Standard use different technologies that may affect its usage. It is advisable to consult the manual supplied with the leak detector for proper instructions on its use.

6.6.1 At each area checked, move the probe around the location, at a rate no more than 75 mm/s (3 in/s), and no more than 9.5 mm (3/8 in) from the surface, completely encircling fittings, joints, service valves, switches and sensors. Slower and closer movement of the probe greatly improves the likelihood of finding a leak. However, resting the probe against a leak source may cause the detector to silence, as premium infrared detectors require a moving probe to create the voltage difference between the actual leak point versus an adjacent area. A heated-sensor detector that is parked (held) on a leak may sound a continuous alarm until moved.

6.7 One way to verify a suspected leak is to blow shop air into the area of the suspected leak to clear the area of refrigerant, and if necessary, repeat the check of the area. In cases of very large leaks, blowing out the area with shop air often helps locate the exact position of the leak. Another method, using an SAE J2791 or SAE J2913 - certified detector, is to recheck for the leak with the sensitivity switch on higher (and if applicable lower) sensitivity switch positions. This also may help the technician estimate the size of a leak.

6.8 When testing for a leak at the compressor, move the probe along the compressor body joints, around the pressure relief valve and any switches, then all around the compressor nose area (compressor shaft seal). Inasmuch as many compressor shaft seal leaks only occur during compressor operation, quantifying leakage rate, or even just verifying the existence of a shaft seal leak poses special problems, as the electronic leak detector test is made with the system off. The shaft seal is on the low-pressure side of the system, which adds to the difficulty. Leak testing of the evaporator core also poses special issues. [See Section 9.] Although some refrigerant loss past shaft seals is normal, any triggering of a SAE J2791 or SAE J2913 electronic leak detector on settings below 14 g/year with the system off may indicate a significant leak has been found if no other leaks can be located. Refer also to Sections 6 and 7.

6.9 Following any service to the vehicle's air conditioning refrigerant circuit, a leak test of the repaired components, the service ports, and the entire refrigerant circuit to assure there are no additional system refrigerant leaks should be performed.

7. USE OF TRACE DYE GENERAL INSTRUCTIONS

7.1 Trace dye (illuminated by ultraviolet “black” or “blue” light aimed at the leak source) has been found to be a useful tool in service shops to locate repairable refrigerant leaks. However, trace dyes have some limitations based on the type, amount and time the dye has been in the system, and the fact that a trace dye does not indicate the size of leak. These factors can affect the likelihood of a visual indication of the refrigerant leak, and additional service procedures may be required.

7.2 Trace dye mixes with oil and is distributed throughout the refrigeration system, so it may take some system operating time for the oil/dye mixture to circulate to provide identification of a leak point. Recent refrigerant systems, for improved cooling performance, have reduced system lubricant circulation, with newer compressors that retain oil within the compressor. In conjunction with the reduced refrigerant charges on MAC systems, this can make it more difficult for trace dyes to be circulated in the entire refrigerant circuit, often increasing the time necessary.

7.2.1 Unlike the electronic leak detector, which is used with the system off, trace dye requires normal compressor operation and a full refrigerant charge. Trace dye may be useful to highlight smaller leaks or those that may be in less visible locations.

7.2.2 Some vehicle manufacturers may have installed trace dye in the production system, and it is unnecessary to add more dye unless the system has been flushed. It is likely a leak can be located on these vehicles without recharging the system or further system operation.

NOTE: Some manufactures include dye in the replacement drier so when the drier is replaced no additional dye is needed.

7.3 Important issues to consider when using trace dye material for identifying refrigerant leakage:

7.3.1 Use only a trace dye that meets SAE J2297, and that has been tested for compatibility to SAE J2670. Weak dyes may not fluoresce adequately, particularly with small leaks, or if in the system for an extended period.

7.3.2 High-voltage compressors require a specific dye, and only that type should be used in high-voltage compressor systems. Only install trace dye that is approved by the vehicle manufacturer for the particular system.

7.3.3 Install only the correct amount of trace dye for the system (single versus dual evaporator system), following the manufacturer’s instructions for his particular dye injection equipment. Excessive dye, when mixed with refrigeration oil, can affect the viscosity of the lubricant, and excessive trace dye can reduce the lubricating capability resulting in a compressor failure.

7.4 It is advisable to use accurate refrigerant charging equipment, such as that which meets SAE J2788 (HFC-134a) or SAE J2843 (R-1234yf). Install a full charge of refrigerant into the system. After the system has been recharged, operate it for at least 0.5 h, and inspect all the system refrigerant components for leaks using the appropriate lamp and/or glasses that are required by the manufacturer of the trace dye that has been installed. More powerful lamps will aid in finding small leaks, but typically are physically larger and may not fit into tight quarters, so inspecting with small “flashlight” type lamps also may be helpful, and trace dye producers have introduced flashlight-type lamps as powerful as older lamps of greater size. Use fluoresce-enhancing goggles supplied by the manufacturer of the dye. Note: if the leak is small or is in a location where field of view is poor, it may be necessary to allow several days of vehicle operation for the leak to show up.

8. REFRIGERANT LEAK IDENTIFICATION MANUAL PROCEDURES LEVEL IV

8.1 Smaller capacity system refrigerant leaks may not be indicated with a Level I procedure. This procedure provides an additional operation in determining a potential system refrigerant leakage.

8.1.1 System Vacuum and Pressure decay service procedure [pressure change/loss over time] for determining a possible system refrigerant leak.

8.1.1.1 Install system pressure measuring device (service gauge(s)).