Chapter 50
A Development Report of an Accurate Method of Detecting Systematic Refrigerant Leak Rate for Automotive HVAC Systems

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Abstract A useful and accurate refrigerant leak rate measurement approach is presented, which will find small leak rate as low as 3 g, by utilizing liquid nitrogen as cold recourse to cool down the recovery tank, and as an alternative, the dry ice (liquidized carbon dioxide) is tested too, but it is found that the recovery accuracy can reach to 10 only.

Keywords Automotive · HVAC · Leaking rate · Refrigerant · Recovery · Liquid nitrogen

50.1 Introduction

Refrigerant is filled in the HVAC system, e.g., R134A has been used for automotive AC as the working media for years. During the life cycle, the leaking happens all the time with different rate, depending on variation of the cooling lines, sealing type, tightening force, etc. In order to find right ways to avoid excessive losing of the working media, the automakers need to know how to measure the actual leak rate for the total system so that the tightness of the seals can be improved.

Refrigerant leaks cause a lot of problems either to the automakers for heavy service expenditure or to customers for "not cold enough." Additionally, the emission damages our fragile environment. Therefore, it is absolutely necessary to minimize the leaks.

In the world, the typical leak rate of refrigerant is 9–15 g/year [1] (Fig. 50.1), which means after 4 years of on the road, a vehicle will still have sufficient refrigerant in the system to provide comfortable cooling effects to the passengers. This explains why some imported vehicles may last 6 years or longer without demanding of refilling the medium.

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Fig. 50.1 The SAE publication indicates that refrigerant leak rate is 9–15 g/year for some typical vehicles

SAE J-2727r Mini-Shed Predictions versus IMAC SHED Data

	Original J-2727 Rating	J-2727r Rating	J-2727r SHED Rating	J-2727r SHED Emissions Estimate g /yr		Actual SHED Emissions Measured g /yr
W-Car	2.3	1.8	1.23	12.3	←→	9.5
Camry	2.6	2.0	1.62	16.2	←→	17.8
DC-Van	2.6	2.5	1.57	15.7	←→	15.3
Ford F-150	2.3	2.1	1.33	13.3	←→	tbd

In order to control the leaks, it is necessary to know what the current status of leaking is. Refrigerant recovery machines once were used to measure refrigerant leaking rate by comparing the differential of refrigerant charged and recovered; for instance, the known charge was 500 g and the recovered is 580 g; the difference of 20 g is found as the system leak rate in the duration of the vehicle in operation, which is usually counted as "per year" or "annual." Unfortunately, the recovery machines seem not working so well for leak measurement, indicated by complaints of only 100 g also could be identified by many times of trials in the past years. It is apparent that the number is too large to find out what is prominent type of reasons that cause the leaks. Consequently, in minds of the operators, it has been given up for leak test purpose.

However, it is noticed that, in the world, some automakers have shown very low leak rate on their vehicles, which were ranged from 3.6 g/year as the lowest to 9.9 g/year as the highest (Fig. 50.2).

Then, how to conduct so precise leak rate test? It's found that may be useful to use the methodology appearing in JASO Z123-2007 [3] to hit the goal after carefully review of the technical information.

50.2 Key Points of JASO Z123-2007

From the literature [3], some essential points have been drawn out to guide the experimental tests as follows:The dry ice test is resulted in 8–12 g recovery error

• Goal of leak-detecting accuracy	3 g
• Cold resource material	Liquid nitrogen
• Operation ambient temperature	15 °C+
• Vacuum pump capacity	20–30 L/m
• Vacuum time	30–60 min
• Vacuum level required	0.1 MPa
• Scale precision	±0.1 g
• Liquid nitrogen container volume	~1 L

Field Test Data - 1

Vehicle	# of vehicle s	Single or dual	Test data (averaged)				
			Driving distance (km)	Comp. Running (hr.)	Clutch cycling (#)	Test period (yrs)	Averaged Leak (g/yr) (scattering)
Vehicle T-1 (Toyota Mark II)	3	S	17,323	138.9	50984	1.58	9.4 (Min.: 6.8, Max.: 13.0)
Vehicle T-2 (Toyota Corolla)	8	S	16,270	178.1	39645	1.58	9.1 (Min.: 6.4, Max.: 20.4)
Vehicle T-3 (Toyota Vista)	2	S	9,785	208.4	40423	1.59	7.3 (Min.: 5.5, Max.: 9.1)
Vehicle S-1 (Suzuki Lapin)	2	S	26,740	221.5	76,700	0.84	9.9 (Min:8.5, Max:11.3)
Vehicle N-1 (Nissan Cube)	3	S	21,473	187.3	8,619	1.42	8 (Min.: 4.2, Max.: 10.2)
Vehicle N-2 (Nissan Premera)	3	S	17,884	362.4	3,280	1.64	7.1 (Min.: 3.6, Max.: 12.0)
Vehicle N-3 (Nissan Cedric)	2	S	26,383	654.3	3,146	1.66	7.8 (Min.: 6.6, Max.: 9.0)
Vehicle N-4 (Nissan Tino)	2	S	24,031	297.4	41,024	1.66	8.1 (Min.: 7.8, Max.: 8.4)
Vehicle N-5 (Nissan Bluebird)	3	S	18,711	295.7	17,868	1.38	9.8 (Min.: 9.6, Max.: 10.2)
Vehicle N-6 (Nissan X-trail)	2	S	35,629	363.9	1,572	1.25	4.5 (Min.: 3.6, Max.: 5.4)

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Fig. 50.2 The JAMA publication shows the fleet leak test resulted in 3.6–9.8 g/year

50.3 Dry Ice Test

Dry ice is a popular natural refrigerant, and its operational temperature is approximately −40 °C, at saturation pressure of 1.0 MPa. As the fist stage of the tests, it was taken as cold resource to cool down the recovery tank.

The test setup and instrumentation had been arranged as shown in Fig. 50.3, but with small non-ideal variations due to limited supply at the time, which includes:

- The recovery tank is weighted as 8,000 g with volume of 10 L, over 10 times of the targeted refrigerant of 600 g;
- The electronic scale used is 1 g rated;
- The actual links of refrigeration lines are too complex to be rational.

With 3 times of confirmation tests, the results have shown positively that a low level of recovery errors from 12 to 8 g is obtained. The tendency looks consistent

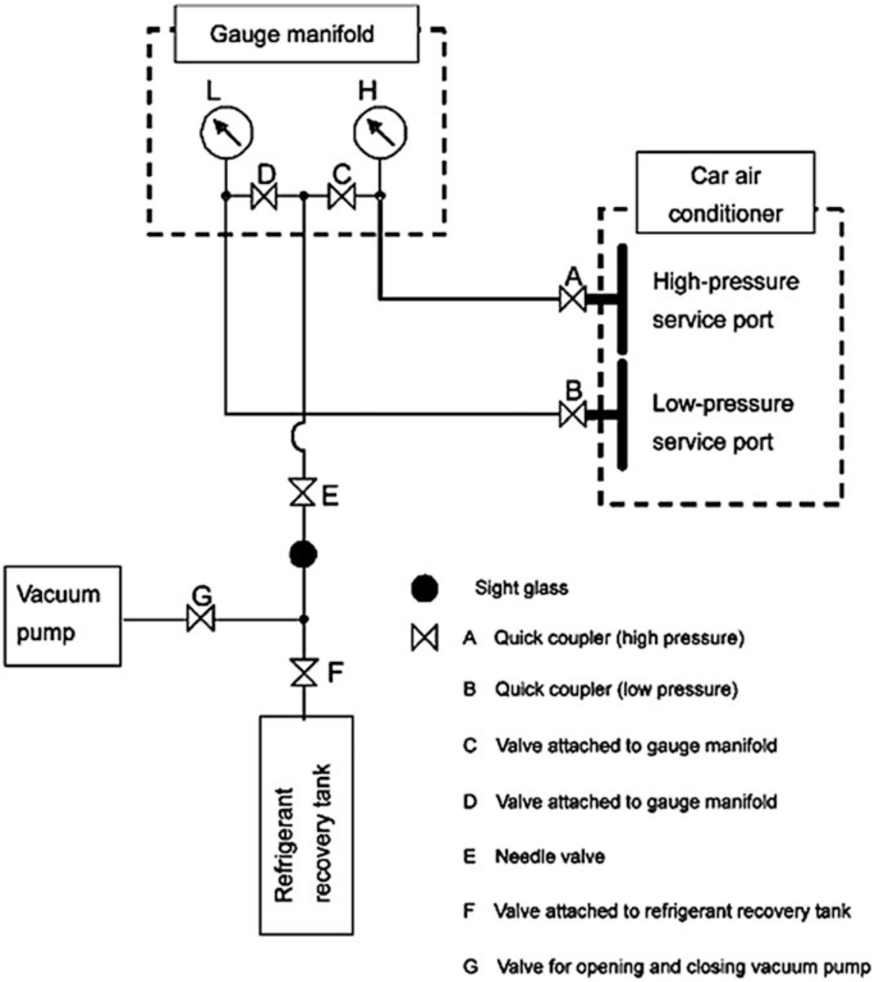

Fig. 50.3 The test setup per JASO Z123

for each test. However, the recovery duration looked very long which may take 90 min, only for the recovery procedure. In addition, the errors seem not to be further lower. See Table 50.1 for the test results.

50.4 Liquid Nitrogen Test

With the same setup as the dry ice test, the effort is to use the liquid nitrogen as the cold resource. Nitrogen is popular and environmental friendly too, but working temperature is much lower than dry ice, which normally operates at −180 °C at

Table 50.1 The dry ice test is resulted in 8–12 g recovery error

Date of the testing	Average ambient T (°C)	Refrigerant charged (g)	Initial weight of the recovery tank after vacuumed (g)	The tank weight after recovery (g)	Recovered refrigerant weight (g)	Error of the recovery (g)
2014.3.6	16	551	2,056	2,595	539	12
2014.3.20	16.5	539	4,142	4,671	529	10
2014.3.20	16.5	541	4,142	4,675	531	8

Fig. 50.4 Liquid-state nitrogen is proved as a right way to find smaller leak rate

0.46 MPa of saturation pressure (Fig. 50.4). The lower temperature makes identically differences for the recovery processing shown by much quicker recovery time as short as 20 min, in contrast to the 90 min, plus the improved recovery errors,

Table 50.2 The liquid nitrogen test is resulted in 4–6 g error of recovery

Date of the testing	Average ambient T (°C)	Refrigerant charged (g)	Initial weight of the recovery tank after vacuumed (g)	The tank weight after recovery (g)	Recovered refrigerant weight (g)	Error of the recovery(g)
2014.3.28	17.5	542	4,339	4,877	538	4
2014.3.28	17.5	541	4,339	4,874	535	6

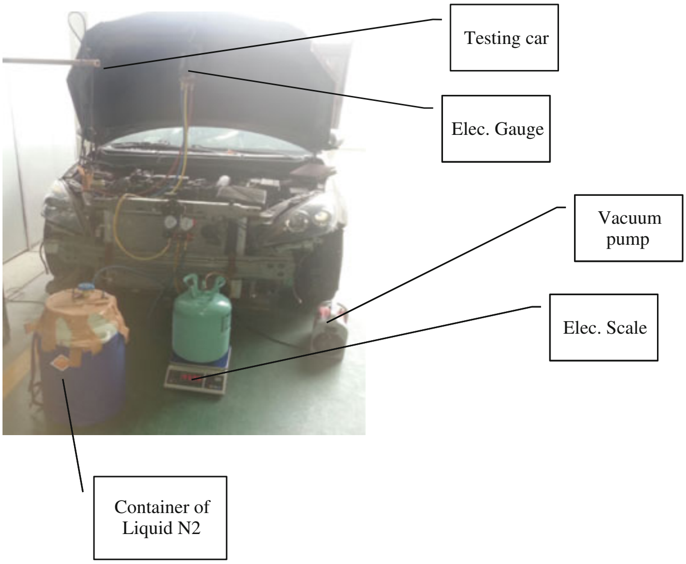

Fig. 50.5 The vehicle test setup with nitrogen liquid as the cold resource

which were in range of 4–6 g. As a result, the liquid-state nitrogen has been chosen as standard cooling source for the leak tests in Changan Automobile (Table 50.2 and Fig. 50.5).

50.5 Conclusions

- Liquid nitrogen is the optimal cooling resource for the recovery tank to detect lower leak rate as low as 3 g, which reflects 10 g/year actual vehicle leak rate with ±10 % of error, although the experiments have reached 4–6 g level at present;
- The experimental tests conducted give the impression of being repeatable and reliable;
- The standardization of the systematic leak test for the vehicles is improving to reach the goal of 3 g, which including:
  - Reduce the gross weight of current recovery tank to 2,000 g from the original 8,000 g;
  - Improve the scale accuracy from 1 to 0.1 g;
  - Optimize the connection in the tests to simplify the refrigerant lines to reduce the errors from the longer hoses.

References

1. Baker JA (2006) SAE interior climate control standards committee,“Revising J-2727”, SAE alternate refrigerants symposium, June 28
2. Ikegami T, Kikuchi K (2006) Field test results and correlation with SAE J2727, 1/22 SAE 7th alternate refrigerant systems symposium, June 26–29
3. Japanese automobile standard, JASO Z123-2007