SURFACE VEHICLE RECOMMENDED PRACTICE

J3174™	SEP2022
Issued 2019-07	
Revised 2022-09	
Superseding J3174 JUL2019	

Recommended Practice for an Engineering Analysis for A/C Efficiency Credits

RATIONALE

This revision updates one of the formulas in one of the reporting templates included in the digital annex, a modification to the scaling limits for the IHX, the addition of the advanced technology air conditioning compressor with a variable crankcase suction valve and adding the “truck” vehicle type when RoK is selected for all templates.

1. SCOPE

Under U.S. GHG and CAFE regulations, manufacturers are required to perform confirmatory testing to validate indirect air conditioning credits (refer to 40 CFR 86.1868-12). The purpose of this SAE Recommended Practice is to provide manufacturers with updated criteria for the 2020 and later model years. This SAE Recommended Practice is also suitable for reporting credit using and Engineering Analysis to the California Air Resources Board (CARB).

This SAE Recommended Practice describes the work done by the IMAC GHG CRP to develop test procedures, publish SAE Standards, and determine performance requirements to demonstrate the performance of A/C technologies from the pre-approved credit menu meeting regulatory requirements.

Also, enclosed in this SAE Recommended Practice are instructions that can be used by vehicle manufacturers in establishing an engineering analysis in lieu of performing the AC17 test on a vehicle which does not incorporate the credit-generating technologies. These procedures for performing an engineering analysis should be sufficient to satisfy the requirements of the regulation to earn credits for indirect A/C technologies from the pre-approved credit menu.

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 +1 724-776-4970 (outside USA), www.sae.org.

SAE J2765 Procedure for Measuring System COP [Coefficient of Performance] of a Mobile Air Conditioning System on a Test Bench

SAE J3094 Test Procedure for Internal Heat Exchangers of Mobile Air-Conditioning Systems with R-134a or R-1234yf Refrigerant

TO PLACE A DOCUMENT ORDER: **Tel: 877-606-7323 (inside USA and Canada)**
Tel: +1 724-776-4970 (outside USA)
Fax: 724-776-0790
Email: CustomerService@sae.org
SAE WEB ADDRESS: **http://www.sae.org**

For more information on this standard, visit
https://www.sae.org/standards/content/J3174_202209/

SAE J3109 PWM HVAC Blower Controller and BLDC Motor Controller Efficiency Assessment

SAE J3112 A/C Compressor Oil Separator Effectiveness Test Standard

2.2 Related Publications

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

2.2.1 Code of Federal Regulations Publications

Available from the United States Government Printing Office, 732 North Capitol Street, NW, Washington, DC 20401, Tel: 202-512-1800, www.gpo.gov.

40 CFR 86.1868-12 CO_2 Credits for Improving the Efficiency of Air Conditioning Systems

2.2.2 Other Publications

MOE No. 662, 2019.12.12 Guideline for the Approval of Greenhouse Gas Emission Reduction and Fuel Economy Improvement of Motor Vehicles Achieved by Eco-Innovation Technology (available at www.kaida.co.kr)

SASO-2864 Saudi Arabia Corporate Average Fuel Economy Standard (Saudi Cafe) for Incoming Light Duty Vehicles (2021-2023) (available at www.saso.gov.sa)

3. DEFINITIONS

3.1 A/C CREDIT MENU OR PRE-APPROVED CREDIT MENU

The A/C credit menu or pre-approved credit menu is a list of technologies for improving the efficiency of A/C systems which qualify for CO_2 credits and CAFE credits under U.S. Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards as defined in 40 CFR 86.1868-12. The technologies included in the menu are: reduced reheat, default to recirculated air, blower motor controls which limit waste energy, improved condensers and/or evaporators, an internal heat exchanger (IHX), and an oil separator. Detailed definitions are contained in 40 CFR 86.1868-12(h).

3.2 SOFTWARE TECHNOLOGY

Software technology is a technology that improves the efficiency of the A/C system primarily via control software which changes the operation of the A/C system. Reduced reheat and default to recirculated air are the software technologies included in the A/C credit menu.

3.3 HARDWARE TECHNOLOGY

Hardware technology is technology that improves the efficiency of the A/C system primarily because the hardware is inherently more efficient or is added hardware that improves the efficiency without software. Blower motor controls which limit waste energy, improved condensers and/or evaporators, an internal heat exchanger (IHX), an oil separator, and advanced technology air conditioning compressor with a variable crankcase suction valve are the hardware technologies on the A/C credit menu.

3.4 "A" CONFIGURATION

A/C systems without credit-generating technologies are in the "A" configuration. "A" configuration, or "Aboriginal" configuration, does not incorporate the credit-generating technologies as defined in 40 CFR 86.1868-12(g)(2)(ii). To perform the AC17 test on a vehicle which does not incorporate the credit-generating technologies, the tested vehicle shall be similar to the vehicle tested under paragraph 40 CFR 86.1868-12(g)(2)(i) of this section and selected using good engineering judgment. The tested vehicle may be from an earlier design generation.

3.5 "B" CONFIGURATION

A/C systems with credit-generating technologies are in the "B" configuration. "B" configuration, or "Better" configuration, incorporates the credit-generating technologies as defined in 40 CFR 86.1868-12(g)(2)(i).

4. SYMBOLS AND ABBREVIATIONS

4.1 Abbreviations

CAFE: Corporate average fuel economy.

COP: Coefficient of performance (i.e., system energy efficiency). COP is the ratio of energy (heat) removed from the air (or other media) being cooled at the evaporator(s) to the energy (work) put into the compressor. Refer to SAE J2765 for additional details.

CRP: SAE Cooperative Research Program.

GHG: Greenhouse gas.

IMAC: Improved mobile air conditioning. Typically, in reference to a CRP from the mid-2000s, or a later CRP.

OCR: Oil circulation rate (refer to SAE J3112).

OCR.RE: OCR reduction effectiveness (refer to SAE J3112).

5. INTRODUCTION

Air conditioning (A/C) system validation testing and reporting requirements change for the 2020 and later model years, refer to 40 CFR 86.1868-12.

Current regulatory provisions allow two options to validate air conditioning indirect credits for the 2020 and later model years.

1. Manufacturers conduct two AC17 tests, one in the "A" configuration and one in the "B" configuration, i.e., with and without the credit-generating technologies. This can be done on the same vehicle in both the "A" and "B" configurations, or on two vehicles: one in the "A" configuration, and one in the "B" configuration. To claim credit and report data using option 1, follow the calculations in 40 CFR 86.1868-12(g)(2)(iii).

2. If there is no complete vehicle available in the "A" configuration, then test one vehicle in the "B" configuration per 40 CFR 86.1868-12(g)(3) and submit an engineering analysis to support specific credit values. To claim credit and report data, the additional process below can be used to establish an engineering analysis in lieu of performing the AC17 test in the complete "A" configuration. This does not preclude other methodologies for performing the engineering analysis.

If the manufacturer cannot identify an appropriate vehicle to test under paragraph (g)(2)(ii), they may choose the option to submit an engineering analysis that describes why an appropriate vehicle is not available or not appropriate, and include data and information supporting specific hardware and software credit values. For example, a vehicle may not be appropriate as a baseline for an "A"-to-"B" comparison if aspects of the vehicle unrelated to the A/C hardware or software change are significantly different. For example, a vehicle may undergo a major revision affecting the powertrain, aerodynamics, and weight concurrently with A/C system changes. The engineering analysis shall also include data using the AC17 test procedure and/or bench procedures using SAE standard test methods and good engineering judgment. The engineering analyses can be used regardless of vehicle model year or platform if it is determined the A/C hardware component or software functions with a similar efficiency, using good engineering judgment. An example of this would be if the hardware or software design technology remains the same across vehicle models or platforms. The engineering analysis can be carried over and credits can continue to be generated if changes are not expected to cause a change in the efficiency of the air conditioning system.

6. SOFTWARE ENGINEERING ANALYSIS

6.1 Background

Specific air conditioning efficiency credits for software technologies are defined in 40 CFR 86.1868-12(h)(1,2,3). These technologies can likely be tested on vehicles in an “A” and “B” configuration by modifying software or calibration. To confirm this method, one CRP OEM conducted a study on four vehicles: a sport coupe, a compact sedan, a three-row SUV, and a pick-up truck. The sport coupe and the SUV had both reduced reheat and defaulted to recirculated air technology, while the compact sedan and the pick-up truck only had default to recirculated air. The SUV, having three rows of seats, had a rear auxiliary evaporator unit. Multiple AC17 tests were conducted in each configuration, with the exception of testing of the SUV with the rear system off. This was due to test time availability. The results of the testing are shown in Figures 1 and 2.

Figure 1 shows the efficiency improvement of the technology in grams per mile of CO_2 exceeded the menu value in all cases.

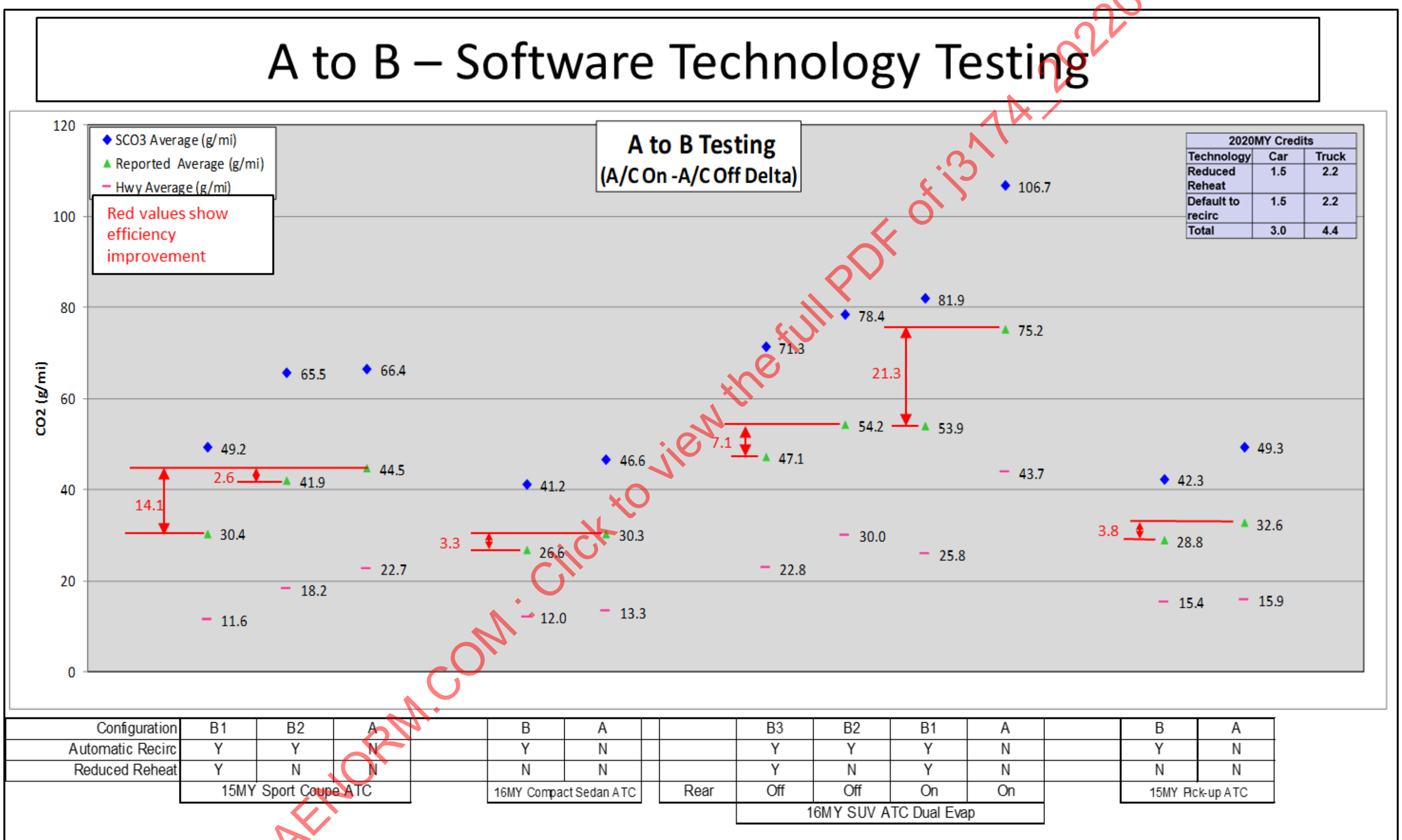


Figure 1

However, by comparing the error bars which show the range of results, Figure 2 shows in some cases the multiple tests were required to demonstrate the efficiency improvement. This is due the magnitude of the credit technology relative to the total CO_2 emissions which was within the test-to-test variation inherent in the AC17 test. For example, automatic recirc and reduced reheat values total 3.0 g/mile and total CO_2 emissions can exceed 400 g/mile. Therefore, the credit value is less than 1% of the total emissions.

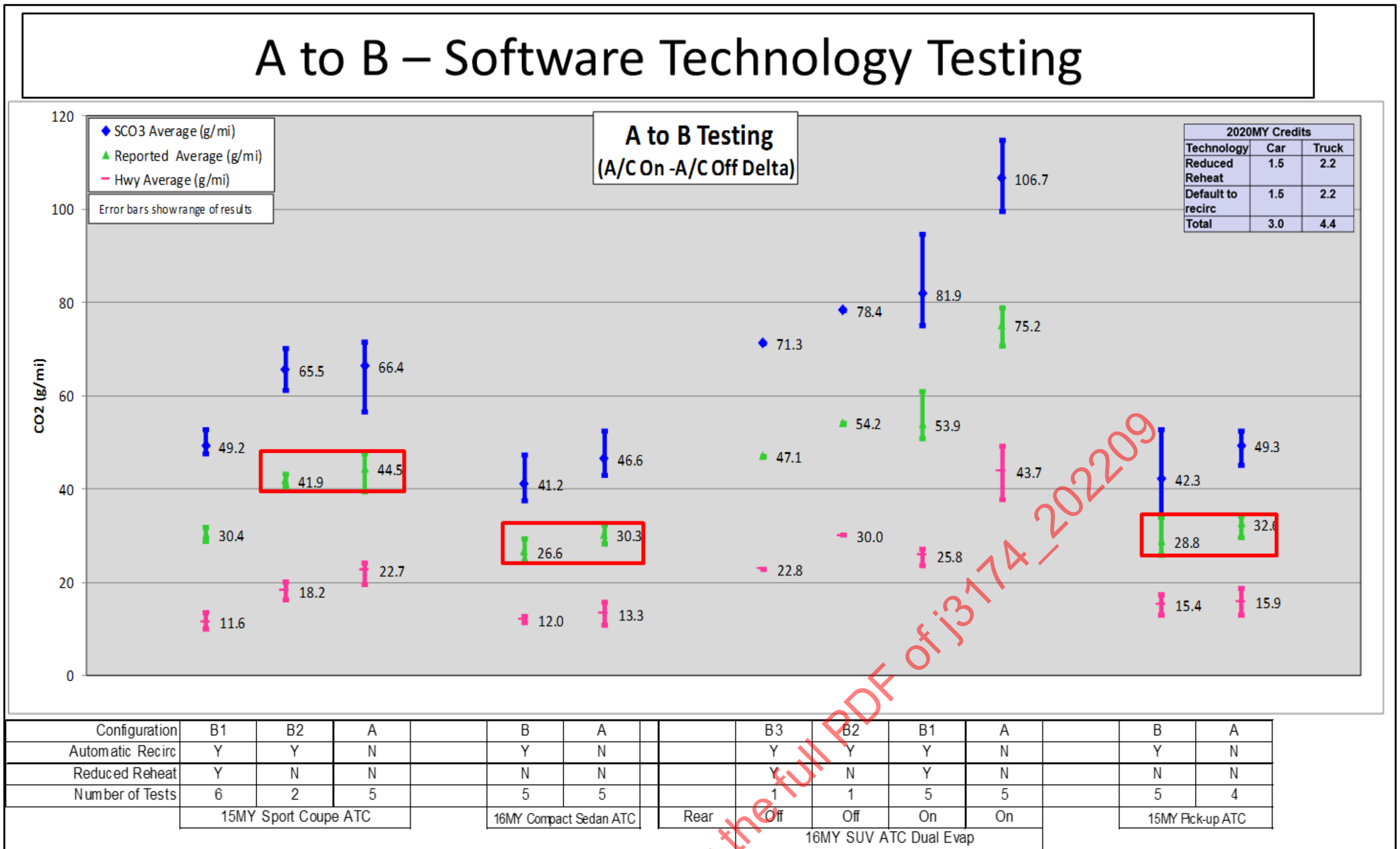


Figure 2

In summary, software technology was demonstrated by this OEM by conducting an “A”-to-”B” testing on a vehicle. However, in some cases, multiple tests in each configuration were required to demonstrate the benefit. The CRP considered this an acceptable method.

As another approach in order to reduce the testing burden an OEM can conduct a one-time study on a range of their product line of vehicles as the basis for the engineering analysis. By testing a range of vehicles and showing effectiveness on a number of programs, the one-time testing is valid as the basis of an engineering analysis as long as the software strategy and basic calibration is carried over.

Running the standard AC17 test procedure is useful to determine the total CO_2 penalty from an A/C-on to A/C-off condition. In fact, the test was developed for that purpose. When comparing the effect of a specific A/C efficiency technology, it may be best to compare just the A/C-on CO_2 results with the technology in use to the A/C-on CO_2 results with the technology not in use. The standard AC17 test procedure is subject to the variation of two different test segments: the A/C-on and the A/C-off portions. Both segments are subject to variations in driving cycle and tunnel test conditions. When looking at the effect of a specific technology (in use and not use) the complete standard AC17 test compounds the variation of four different test segments (A/C-on to A/C-off with the technology and A/C-on to A/C-off without the technology). Combining the variation of four different test segments can often make the benefit of a specific technology difficult to discern. Testing and comparing only A/C-on segments can reduce the variation. This technique is especially helpful with software technology that can be quickly turned on or off on the same vehicle. Testing without the software technology can be conducted immediately following testing with the software technology, or could be conducted at a separate time.

In order to support the conclusions of the engineering analysis, it may be beneficial to acquire additional data beyond the required AC17 instrumentation during “A”-to-”B” testing. This could include bus data, voltage, current, temperatures, pressures, etc., to show software parameters, HVAC system function, temperature, pressures, etc., are different between the “A” and “B” configurations during the testing, indicating the software is functioning and providing a benefit.

Stop-start systems which turn the engine off at idle can significantly worsen the test-to-test repeatability as variations in engine off times impact total CO_2 emissions. In addition, operation of the A/C system may inhibit stops at idle to maintain comfort. The varying number of stops makes a comparison difficult. Also, sunload detection in the emission test cell may not be representative of the real world leading automatic temperature control systems to operate differently leading to different engine stops than in the real world. This could mask or enhance the benefit of the software technology. OEMs should consider running the AC17 "A"-to-"B" tests with stop-start systems disabled.

6.2 Procedure

Perform the AC17 tests on a vehicle(s) that incorporates the air conditioning system with the software credit-generating technologies. This is the requirement to test the A/C system in the "B" configuration. "B" configuration incorporates the credit-generating software technologies. The tested vehicle(s) may be from an earlier design generation if it is determined the A/C software functions with a similar efficiency using good engineering judgment. Testing can be performed on a range of representative vehicles, selected using good engineering judgment, which may cover additional models that incorporate the same credit-generating software technologies.

Perform the AC17 test on the same vehicle(s) which does not incorporate the credit-generating software technologies. This is the requirement to test the A/C system in the "A" configuration. "A" configuration does not incorporate the credit-generating software technologies.

Acquiring additional data such as bus data, voltage, current, temperatures, pressures, etc., to show software parameters, HVAC system function, temperature, pressures, etc., are different between the "A" and "B" configurations during the testing, indicating the software is functioning and providing a benefit, is acceptable.

To limit the testing variation, it is acceptable to directly compare the A/C-on results with the technology to the A/C-on results without the technology. This reduces test to test variation to two test segments rather than four. When comparing A/C-on to A/C-on results, the "A" configuration can be tested immediately following the "B" configuration or at a later time. Testing can be conducted with "A" configuration following the "B" configuration, or vice versa.

When testing a vehicle in "A" and "B" configurations, ensure that the only modifications between "A" and "B" configurations relate to operation of the air conditioning credit-generating technology using good engineering judgment. For example, disabling stop-start systems for both configurations is acceptable.

Software technologies can be tested separately or in combination.

6.3 Acceptance Criteria

The software technologies shall be shown to meet the claimed air conditioning efficiency credits levels. The calculated "A" to "B" configuration test results (refer to 40 CFR 86.1868-12(g)(2)(iii)) can then be submitted as an engineering analysis in order to generate credits.

6.3.1 Full Credit

If the result is less than or equal to zero, the air conditioning software is not eligible to generate credits. If the result is greater than or equal to the total of the grams per mile credits from the pre-approved credit list, then the air conditioning software is eligible to generate the maximum allowable value.

6.3.2 Partial Credit

If the result is greater than zero but less than the total of the grams per mile credits determined from the pre-approved credit list, then the air conditioning software is eligible to generate credits in the amount determined by subtracting the "B" minus "A" CO_2 emissions and rounding to the nearest 0.1 g/mile.

6.3.3 Application of the Analysis

Software is considered carried over if the A/C technology performs with the same or higher efficiency using good engineering judgment. Carryover software can also carry over the engineering analysis and be used in subsequent model years. For example, strategy and calibration changes that do not affect the A/C system efficiency, using good engineering judgment, can be considered carried over.

6.4 Submission Template

The submission template “Software Technology Reporting Template for J3174.xlsx” is available as a digital annex. A sample is shown in Figure 3.

Software Technology Efficiency Assessment Summary													
United States of America										Country	Units	Vehicle Types	
Company								Date:		USA	g/mi	Car	Truck
				Software Technology Tested								Version:	1.1
Calendar Year	Model Year	Test Vehicle Description (Examples: Platform, Brand, Model, Powertrain, etc.) (Add columns if desired)	Vehicle Type	RREDVC or EAC	RRIVDC or RRFDC	RECIRC(with Feedback)	RECIRC(no Feedback)	AC17 Test Result with Credit Technology Active (g/mi)	AC17 Test Result with Credit Technology NOT Active (g/mi)	Measure Benefit of Credit Technology (g/mi)	Maximum Value of Credit Technology (g/mi)	Applicable Credit (g/mi)	Engineer
		Example	Car	1		1		30.2	35.4	5.2	3	3	
											N/A	No Credits	
											N/A	No Credits	
											N/A	No Credits	
											N/A	No Credits	
											N/A	No Credits	
											N/A	No Credits	
											N/A	No Credits	
											N/A	No Credits	
											N/A	No Credits	
											N/A	No Credits	

Figure 3 - Submission template for software technology

6.5 Other Methods for Demonstrating Software Technology

Due to the variation inherent in the AC17 test, some CRP members expressed concern software technology could not be reliably demonstrated by conducting vehicle “A”-to-”B” tests. The credit values for software technology range from 1.0 g/mile for default to recirculated air with open loop control or reduced reheat with a fixed displacement compressor on a car, to 4.4 g/mile when default to recirculated air with closed loop control is combined with reduced reheat with an externally controlled variable displacement compressor on a truck. Considering the CO_2 emissions during the A/C on portion of the AC17 test average ~400 g/mile, the credit value can easily be less than 1% of the total CO_2 emissions. This is well below typical test-to-test variation for vehicle emissions testing. Figure 4 shows the test results from one OEM where the results were inconsistent due to test-to-test variation.

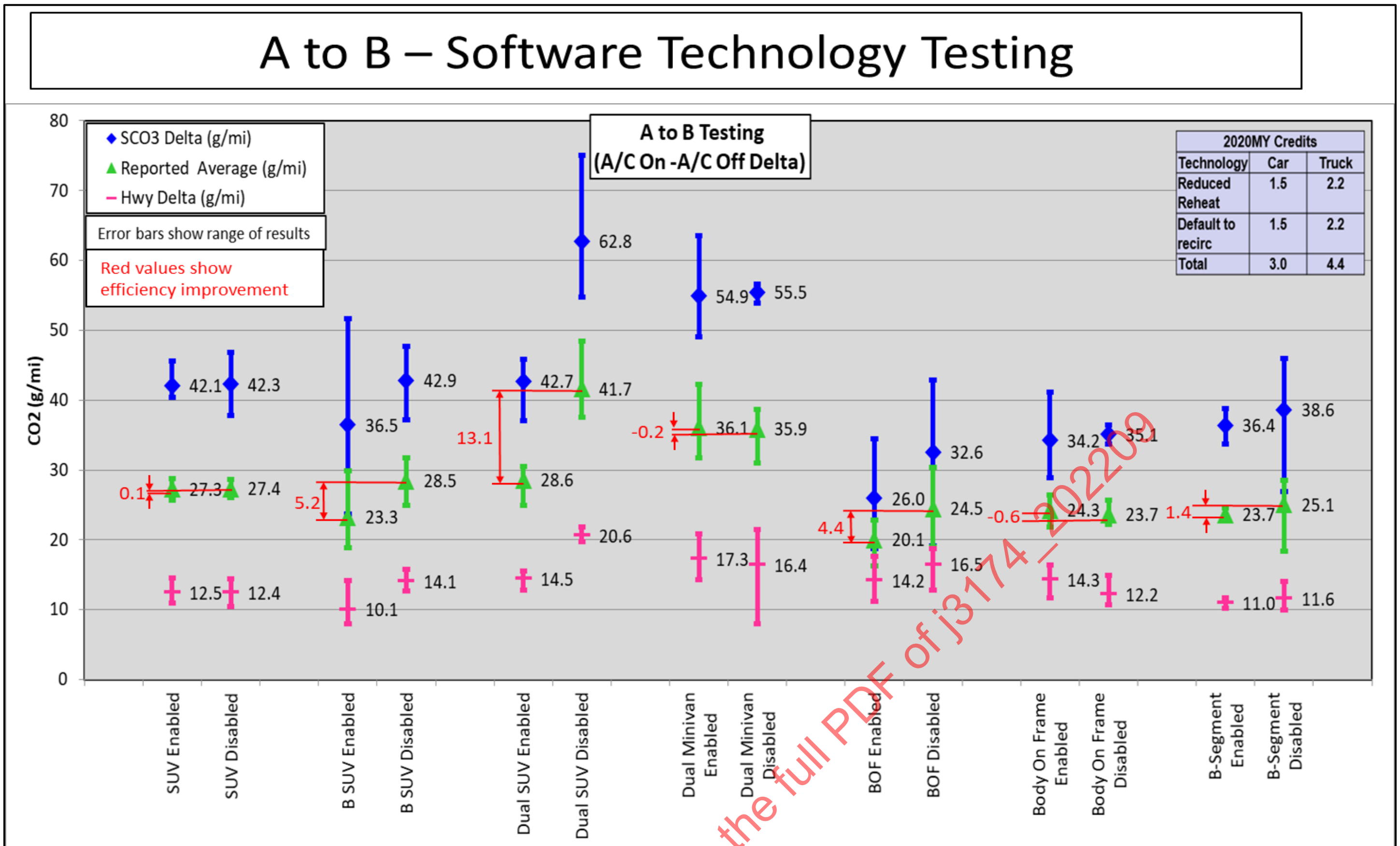


Figure 4

Therefore, other methods for demonstrating software technology may be desirable. Although no other methods have currently been developed, some possible alternatives are listed below. These and other methods may be used by OEMs and/or added to later versions of this standard. As long as these are based on sound engineering principles, these methods should be considered acceptable for an engineering analysis.

1. Correlating the results of the AC17 test to a system bench test of a similar system:

   By conducting AC17 tests on a thoroughly instrumented vehicle with the software technology enabled and disabled, and then duplicating the same conditions on the system bench with a series of steady state test points, the system bench could be correlated to the AC17 vehicle test. Since bench test results are more accurate, stable, and repeatable, the results could then be used to determine the CO_2 benefit of the software technology using a mathematical analysis based on engine efficiency.

2. Correlating vehicle CO_2 emissions testing to the LCCP model:

   By conducting steady state vehicle CO_2 emissions tests on a thoroughly instrumented vehicle at the test conditions required for input into the LCCP model with software technology enabled and disabled the LCCP model could be used to determine the benefit of the software technology.

3. Measurement of the A/C system loads during the AC17 test:

   Measurement of compressor torque, A/C system pressures and temperatures, blower and fan motor power, etc., during AC17 tests with software technology enabled and disabled could be used to calculate CO_2 benefit of software technology. This method has the advantage of direct measurement of the A/C system and excluding variation that could occur in other vehicle systems such as the electrical system.

4. Conducting AC17 tests at other ambient conditions:

   Different A/C credit technologies have different benefits based on ambient conditions. For example, automatic recirc will be more effective at higher ambient, whereas reduce reheat will show a larger benefit at moderate ambient. Conducting AC17 tests at different ambient conditions could be used to better demonstrate the benefit of software technology and with appropriate analysis be the basis for an engineering analysis.

7. HARDWARE ENGINEERING ANALYSIS

7.1 Background

Specific air conditioning efficiency credits are established for hardware technologies in the table defined in 40 CFR 86.1868-12(a)(2). Individual hardware technologies defined in 40 CFR 86.1868-12(h)(4,5,6) can be tested to the following SAE test methods and meet the performance criteria. The results of the tests can then be submitted as an engineering analysis in order to generate credits. Below are some specific acceptable test procedures for air conditioning efficiency hardware technologies.

7.2 Application of the Analysis

Hardware is considered carried over if the A/C technology has the same or higher efficiency using good engineering judgment. An example would be an oil separator where a bench test can determine the effectiveness of this A/C hardware. In this case, the bench test covers the determination of efficiency and the required engineering analyses. The engineering analyses can be carried across multiple vehicle platforms and model years.

7.3 For blower motor controls which limit waste energy, refer to 40 CFR 86.1868-12(h)(4).

7.3.1 Background

Via a working group of SAE and blower controller suppliers, SAE J3109 was created to define a measurement technique for measuring the efficiency of an HVAC blower motor controller and a HVAC BLDC controller. Methods to standardize operating points at different duty cycles were also developed by this working group based on empirical data.

While SAE J3109 provides a means of measuring the efficiency of a blower controller at different operating points, the annual usage is required in order to estimate the reduction in GHG emissions. The two keys for usage are time/mile as well as percentage of operation time at different duty cycles.

For operation time, an estimation of 393.8 hours per 12500 miles based on usage from a MEMA submission (November 25, 2009). The vehicle lifetime miles are assumed to be 195264 miles for car and 225865 miles for trucks from the EPA Final Rule. This leads to 393.8 hours/12500 miles * 195264 miles = 6151.6 hours of blower operation in lifetime for a passenger car.

For usage, three main sources of information were used: test fleet data from a tier 1 supplier, USCAR six-blower durability profile, and an OEM blower motor durability test profile (three versions based on quantity of settings). These five profiles were interpolated into a five-step blower profile and then averaged to provide the following duty cycle usage profile for SAE J3109.

Table 1

Condition	Weighting Factor (%)
Low	35%
Medium Low	22%
Medium	21%
Medium High	12%
High	10%
Weighted Average Efficiency:	

The following assumptions were made for calculating the emissions savings:

- 42% engine efficiency (the efficiency is the incremental efficiency from additional load instead of the absolute efficiency). Source: OEM CRP member.
- 80% alternator efficiency (the efficiency is the incremental efficiency from additional load instead of the absolute efficiency). Source: OEM CRP member.
- 52.4% usage-weighted efficiency for a linear power module. Source: Test data from CRP supplier.
- 114000 BTU/gallon of gasoline.
- 8887 g_CO2/gallon of gasoline.
- 24 A of blower current draw at 12.5 V. Source: High current limitation; 1 A from typical blower controller.

Table 2

Setting	Usage (%)	Voltage (VDC)	Current (A)	Power (W)
Low	35	4.0	5.5	22
Medium Low	22	6.0	8.5	51
Medium	21	8.25	13	107.25
Medium High	12	10.5	18	189
High	10	12.5	24	300
Usage Weighted Blower Power				94.1225

Weighted average blower power/Weighted average controller efficiency = Weighted average total power.

Thus, 94.1225 W/52.4% = 179.62 W of blower motor + controller power consumption for a non-PWM based controller.

Thus, the blower controller power is = 179.6231 - 94.1225 = 85.5 W.

With a 70% PWM weighted average efficiency:

94.1225/70% = 134.4607 W of weighted average total power.

134.4607 - 94.1225 = 40.3 W of PWM blower controller consumption.

Total Savings = 85.5 - 40.3 = 45.2 W weighted average savings.

225865 miles * 7115.651 hours * 3.41214 BTU/h/W/(80% alternator efficiency * 111400 BTU/h/gallon gasoline * 42% engine efficiency) = 28.63 gallons of gasoline.

28.63 gallons of gasoline * 8887 g_CO_2/gallon = 254407.2 g_CO_2.

254407.2 g_CO_2/225865 miles = 1.13 g_CO_2/mile, which is near the credit limit for trucks.

7.3.2 Procedure

Blower motor controls which limit waste energy are required to provide an engineering analysis using the bench test procedures described in SAE J3109.

7.3.3 Acceptance Criteria

7.3.3.1 Full Credit

The technology shall yield a weighted efficiency of 70% or greater in order to qualify for the full credit amount from the pre-approved credit menu.

7.3.3.2 Partial Credit

Blower motor controls which yield a weighed efficiency greater than 53%, but less than 70%, can earn partial credit by scaling the results to the menu credit value, with 53% being the baseline and rounding down to the nearest 0.1 g/mile. 53% is the weighted efficiency for a linear power module. Rounding down is used to error on the side of conservatism or fewer credits. If the weighted efficiency is 53% or less, the blower controller is not eligible for credit.

7.3.4 Submission Template

The submission template “SAE J3109 PWM or BLDC ReportingTemplate for J3174.xlsx” is available as a digital annex. Included are a worksheet for blower motor controller performance data per SAE J3109, and a summary worksheet to identify the vehicle applications and calculate the credit value. Samples are shown in Figures 5, 6, and 7.

SAE J3109 Methods	
Enter data/information only in cells of this color	Calculations
Model:	
Supplier:	
Date:	
Revised Date:	
BLDC Controller	

Required Data	
Characteristic	**Unit**
BLDC Controller Input Voltage	VDC
BLDC Controller Input Current	A
Input Setprint (PWM input or LIN decimal value)	% or increments
Output Power Phase 1 N (time averaged)	W
Output Power Phase N (time averaged)	W
Total Output Power (time averaged)	W
Time (recored length also specify number of acquisistions used for averaging if applicable)	s
Motor Speed	Rpm
Motor Torque (if dynamometer is used)	N-m

Required Test Duty Cycles and Ouput Power		
Conditon	Speed (rpm)***	Input Power (W)
Low	37% x Maximum*	7% x Hi**
Medium Low	52% x Maximum*	17% x Hi**
Medium	70% x Maximum*	36% x Hi**
Medium High	88% x Maximum*	63% x Hi**
High	Maximum*	Hi**

***Only applicable when a dynomometer is used.

**Hi is the defined as associated BLDC controller input power related to the input power set at 1 Amp beneath the lower tolerance of the rated current. For example, if the component is listed as having a current rating of 28 ± 3 A, the "Hi" current used for this test would be 24 A.

*Maximum is the measured speed while at maximum input setpoint and the torque adjusted to achieve the Hi** current draw.

Part Number: (Optional)	

Condition	Input Setpoint (Duty Cycle / LIN)	Rotor Speed	Torque (if dynomometer used)	BLDC Controller Input Voltage	BLDC Controller Input Current	BLDC Controller Input Power	BLDC Controller Output Power	Efficiency	Weighting Factor
	[%] or [inc]	[rpm]	[N-m]	[VDC]	[A]	[W]	[W]	[%]	[%]
Low						0		#DIV/0!	35%
Medium Low						0		#DIV/0!	22%
Medium						0		#DIV/0!	21%
Medium High						0		#DIV/0!	12%
High						0		#DIV/0!	10%
Weighted Average Efficiency:			**#DIV/0!**	-					

Figure 5 - BLDC blower motor controller performance worksheet

SAE J3109 Template	
Enter data/information only in cells of this color	Calculations
Model:	
Supplier:	
Date:	
Revised Date:	
PWM	

Required Data	
Characteristic	**Unit**
PWM Controller Input Voltage	VDC
PWM Controller Input Voltage (avg)	VDC (avg)
PWM Controller Input Current	A
PWM Controller output Current (avg)	A
Input Setpoint (Duty Cycle or LIN)	%

Requried Test Voltages and Currents		
Condition	Voltage (Vavg)	Current (Iavg)
Low	4.00	23% x Hi
Medium Low	6.00	35% x Hi
Medium	8.25	54% x Hi
Medium High	10.50	75% x Hi
High	12.50	Hi*

*Hi is defined as 1 Amp beneath the lower tolerance of the rated current. For example, if the component is listed as having a current rating of 28 ± 3 A, the "Hi" current used for this test would be 24 A.

Part Number: (Optional)	
Indicate high side or low side:	Low Side

Condition	Duty Cycle	PWM Controller Input Voltage	PWM Controller Input Current	PWM Controller Input Power	PWM Controller Output Voltage	PWM Controller Output Current	PWM Controller Output Power	Efficiency	Weighting Factor
	[%]	[VDC]	[A]	[W]	[VDC_{avg}]	[A]	[W]	[%]	[%]
Low				0			0	#DIV/0!	35%
Medium Low				0			0	#DIV/0!	22%
Medium				0			0	#DIV/0!	21%
Medium High				0			0	#DIV/0!	12%
High				0			0	#DIV/0!	10%
Weighted Average Efficiency:			**#DIV/0!**	-					

Figure 6 - PWM blower motor controller performance worksheet

PWM HVAC Blower Controller and BLDC Motor Controller Efficiency Assessment Summary						Credit Value			
United States of America						Country	Units	Car	Truck
Company						USA	g/mi	0.8	1.1
			Date:				Version:	1.1	
Calendar Year	Model Year	Vehicle Description (Examples: Platform, Brand, Model, Powertrain, etc.) (Add columns if desired)	Vehicle Type	Controller Type	Blower Controller Description (Examples: Model, Supplier, Part Number, etc.) (Add columns if desired)	Weighted Average Efficiency	Applicable Credit (g/mi)	Engineer	
		Example	Car	BLDC		#DIV/0!	#DIV/0!		
							No Credits		
							No Credits		
							No Credits		
							No Credits		
							No Credits		
							No Credits		
							No Credits		
							No Credits		
							No Credits		
							No Credits		

Figure 7 - Blower controller summary worksheet

7.4 For improved condensers and/or evaporators, refer to 40 CFR 86.1868-12(h)(5).

7.4.1 Background

Improved efficiency evaporators and/or condensers are required to provide an engineering analysis using the bench test procedures described in SAE J2765.

7.4.2 Procedure

To limit the amount of testing required, use the same analysis as the SAE IMAC team did to normalize the data for weather and traffic patterns across the nation. This reduces the SAE J2765 test matrix to six data points (I45, L45, I35a, M35a, I25a, and M25a) and weighting the results to normalize the data for national weather conditions as described in Tables 3 and 4 as done by the SAE IMAC CRP. Other test points and weighting may also be acceptable, supported by good engineering judgment.

Table 3 - Temperature weighting

Temperature (°C)	Weighting (%)
25 °C	94.70%
35 °C	5.10%
45 °C	0.20%
Total	100%

Table 4 - rpm weighting

<table>
<tr><th>Comp Speed (rpm)</th><th>Weighting (%)</th><th>Adjusted (Idle and Driving)</th></tr>
<tr><td><1000</td><td>17.00%</td><td>17.00%</td></tr>
<tr><td>1500</td><td>43.00%</td><td rowspan="3">83.00%</td></tr>
<tr><td>2500</td><td>35.00%</td></tr>
<tr><td>>4000</td><td>5.00%</td></tr>
<tr><td>Total</td><td>100%</td><td>100%</td></tr>
</table>

For test points I25a and M25a, the OEM shall choose the appropriate target air temperature downstream of evaporation, 3 °C or 10°C, depending on whether a reduced reheat strategy is employed by the OEM.

The national annualized COP will be determined by the following equation:

$$COPAnnual = (I45*0.2\%*17\%)+(L45*0.2\%*83\%)+(I35a*5.1\%*17\%)+(M35a*5.1\%*83\%)+(I25a*94.7\%*17\%)+(M25a*94.7\%*83\%)$$

7.4.3 Acceptance Criteria

7.4.3.1 Full Credit

The technology shall yield improvements in the system COP of greater than 10% for the full credit amount from the pre-approved credit menu.

7.4.3.2 Partial Credit

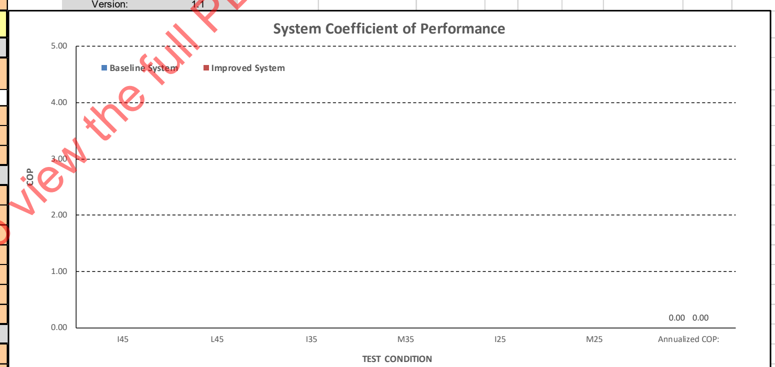
Heat exchangers which yield an improved COP of greater than 0%, but less than 10%, can earn partial credit by scaling the results to the menu credit value and rounding down to the nearest 0.1 g/mile. Rounding down is used to error on the side of conservatism or fewer credits. If the COP change is less than 0%, the heat exchangers are not eligible for credit.

7.4.4 Submission Template

The OEM should provide dimensional characteristics of the baseline and improved evaporator and/or condenser such as tube configuration/thickness/spacing/number of tubes, face area, and fin density. A description of other system components used for the comparison such as compressor, TXV, refrigerant and refrigerant charge amount, and modifications required to make a representative comparison is also required. The submission template “SAE J2765 Improved HX Template for J3174.xlsx” is available as a digital annex. A sample is shown in Figure 8.

Improved Evaporators and/or Condensers Efficiency Assessment Summary		
United States of America		
Company		
	Date:	
SAE J2765	Enter data only in cells of this color	Calculation
	BASELINE SYSTEM INFORMATION	IMPROVED SYSTEM INFORMATION
Vehicle Model, Model Year, &/or System Description		
Vehicle Type	Car	
Refrigerant		
Refrigerant Charge (g)		
Oil Charge (g)		
System Components	Part Number, Description, &/or Comment	Part Number, Description, &/or Comment
Compressor		
Condenser		
Evaporator		
Discharge Line		
Liquid Line		
Expansion Device		
Suction Line		
Test point	COP Test Results	
I45		
L45		
I35		
M35		
I25		
M25		
Annualized COP:	0.00	0.00
COP Improvement	#DIV/0!	
Credits Eligibility	#DIV/0!	
Applicable Credits	#DIV/0!	

Credit Value			
Country	Units	Car	Truck
USA	g/mi	0.8	1.1
Version:	1.1		



Instructions: Contact xxxxxx xxxxxx for review before submitting and with questions		
Dropdown	Description	Requires input
Use dropdowns for E3 and B8		
Minimum COP improvement for Maximum Credit is 10%. Maximum Credits are shown in cells G3 and H3		
Partial credits if COP improvement > 0% but less that 10%		
Rows 23 through 26 are calculations		Calculation, no input required
Annualized COP is calculated using below formula -		

$$COPAnnual = (I45 * 0.2\% * 17\%) + (L45 * 0.2\% * 83\%) + (I35a * 5.1\% * 17\%) + (M35a * 5.1\% * 83\%) + (I25a * 94.7\% * 17\%) + (M25a * 94.7\% * 83\%)$$

Figure 8 - Improved HX template

7.5 For internal heat exchanger (IHX), refer to 40 CFR 86.1868-12(a)(2).

7.5.1 Background

As new vehicle A/C systems are designed with an internal heat exchanger (IHX) as a standard component there is no “A” configuration line set to test for “A” to “B” CO_2 reductions. Certainly, a one-of-a-kind line set could be created specifically to run this test, but the engineering, packaging, mass optimization, and routing would not be fully developed, nor would TXV settings, charge levels, and other HVAC calibrations that are likely to affect performance. The opportunity would also exist to compare a vehicle with an IHX to one with a poorly designed low and high side line that would inflate the benefits of the IHX. With this in mind, SAE J3094 was developed to create standard and consistent set of test conditions for an IHX to be evaluated.

SAE J3094 allows for a common configuration test sample to be evaluated that can be scaled to length to achieve a certain heat transfer amount, as well as the ability to test a production sample (modified to be tested on a calorimeter) which can also be scaled to length. Either configuration is acceptable because typical sized automotive IHX lines have a linear heat transfer function, where heat transfer is directly proportional to the flow rate and to the heat transfer surface within certain limits. Early versions of SAE J3094 allowed a linear scaling factor (target slope/measured slope) of up to 1.4 and down by 0.714, if a larger IHX was tested. However, later testing of various length IHXs of the same crosssection design revealed scaling up yielded performance results greater than the actual, whereas scaling down yielded performance results lower than actual. Subsequently, the allowed scaling limits were modified to up to 1.1 and down 200 mm. As a result, the reporting template has been updated to enforce the new scaling limits.

The SAE standard defines the inlet conditions for both sides of the IHX at three different flow rates relating to low, average, or high flow rate refrigerant conditions. To cover as many flow conditions as possible, the low flow condition is representative of a small A/C system at moderate conditions or a larger A/C system in cooler conditions. The high flow rate condition is more representative of high load, dual evaporator systems.

The performance criteria to qualify for the credit was developed based on running SAE J2765 test conditions at an independent lab on a typical production automotive A/C system (designed without an IHX) and then tested with various size and configuration production IHX samples from other vehicles. The capacity and COP data generated in the testing allowed the lifecycle climate performance (IMAC-GHG LCCP) model to be used to correlate to an average tailpipe emissions improvement based on and weighted to vehicle and weather patterns across different cities in the U.S. Those same IHX samples were then tested on a calorimeter at the three SAE J3094 flow conditions.

Knowing the average emissions effect of each IHX, as well as the IHX heat transfer at the standard test points of SAE J3094, allowed the heat transfer data to be scaled to achieve the credit menu values of 1.0 g/mile for cars and the 1.4 g/mile for trucks. The smaller IHX designs were not sufficient to qualify for full credit, and the required heat transfer was scaled up. The larger ones were sufficient, and the required heat transfer was slightly scaled back. After scaling the heat transfer required to meet the credit values for each IHX, an overall average was calculated to define the average target heat tranfer required to meet the credit.

As previously mentioned, the heat transfer of an IHX is linearly proportional to the flow at the three conditions in SAE J3094, and the zero-flow condition does in fact corelate to no heat transfer. This allows the slope of the heat transfer data (W) plotted against flow (kg/h) from SAE J3094 (liner regression plotted through 0,0) to be used as the comparison against the target line. For R-1234yf, a slope of 1.94 was required to meet the average heat transfer for the 1.0 g/mile car credit, and a slope of 2.71 was required to meet the truck credit of 1.4 g/mile. The values for R-134a are slightly lower as shown in Figure 9. To account for testing variation and to promote a consistent target for the auto manufacturers and IHX suppliers, it was decided that the more difficult slopes of 2.71 for trucks and 1.94 for cars should be used to qualify for either credit, ensuring that any averaging errors fall to the conservative side of reduced tailpipe emissions.

The slope of the target line for R-134a and R-1234yf were very close, so the more difficult R-1234yf slope was also chosen. This also allows testing of an IHX with either refrigerant. See the diagram below.

7.5.2 Procedure

IHX credit submissions shall include an engineering analysis using the bench test procedures described in SAE J3094. Linear scaling limits are up to 1.1 mm and down to 200 mm.

7.5.3 Acceptance Criteria

7.5.3.1 Full Credit

To qualify for the credit, the heat transfer across the IHX is measured for the three test points and plotted against mass flow in a best-fit liner regression with an intercept of zero, where the slope is compared to the qualification standard slope of 1.94 for car and 2.71 for truck as shown in Figure 9.

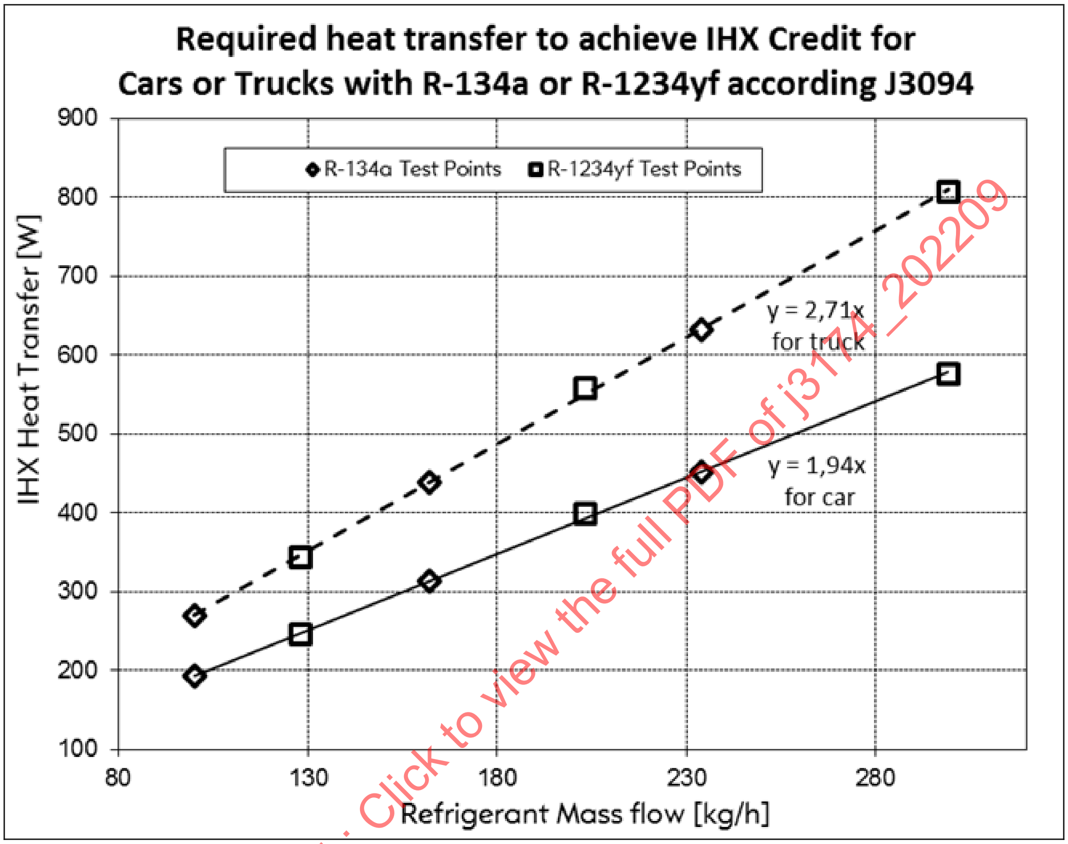


Figure 9 - IHX slope required for full credits

An IHX with heat transfer slope greater than the standard can only qualify for the credit and can not be scaled up for additional credit.

7.5.3.2 Partial Credit

When the full credit is not achieved, scaling of the credit for the IHX will be based on the ratio of the slope of actual SAE J3094 IHX heat transfer line and the target slope to achieve the credit. As an example, for the target heat transfer slope at the defined SAE J3094 conditions of 2.71 (y = 2.71x) for a truck, and if the actual slope is 1.8, then 1.8/2.71 = 0.66 times the credit value is the maximum that can be claimed (rounded down to the nearest 0.1 g/mile) or 0.9 g/mile for truck. Rounding down is used to error on the side of conservatism or fewer credits.

7.5.4 Submission Template

The submission template "SAE J3094 IHX Reporting Template for J3174.xlsx" is available as a digital annex. Included is a worksheet for IHX performance data per SAE J3094, and a summary worksheet to identify the vehicle applications and calculate the credit value. Samples are shown in Figures 10 and 11.

Enter data only in cells of this color	
Supplier Name:	ABC Company
IHX Type:	COAXIAL TUBE IHX
IHX Measurement Option (A, B, C):	Option 'A' (Standardized Coaxial)
IHX Description:	Coax Gen 4
IHX Test Length: (mm)	500
Refrigerant:	R-134a

		Test Results		
	Unit	Condition 1	Condition 2	Condition 3
Heat transfer rate HP side	W	218	325	495
Heat transfer rate LP side	W	212	320	490
Average heat transfer (HP and LP side)	W	215	322.5	492.5
Max. pressure drop LP side	kPa	1.14	3.36	6.87
Max. pressure drop HP side	kPa	1.81	4.15	9.21
IHX effectiveness	%	0.35	0.33	0.34
Refrigerant mass flow	kg/h	100	162	234
Oil Circulation Rate	%	1	0.9	1.1
IHX Heat Transfer Agreement (Must be ≤3%)	%	2.8%	1.6%	1.0%

Test Slope	2.08	
	Car	Truck
Required Minimum Slope for Maximum Credits	1.94	2.71
Minimum Length for Full Credit (Reference Only)	468	653

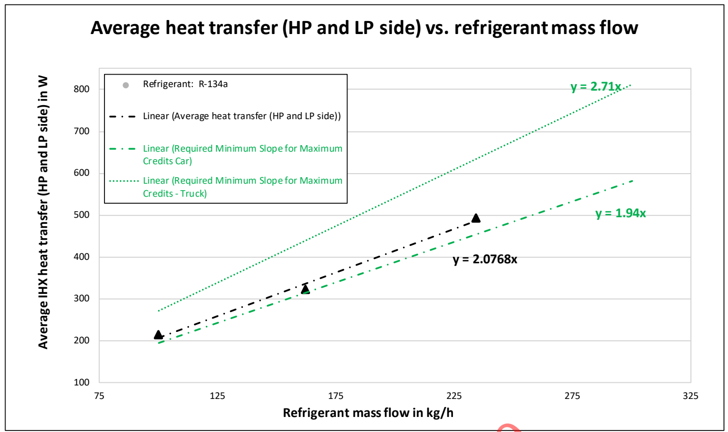


Figure 10 - SAE J3094 IHX performance data worksheet

Internal Heat Exchanger (IHX) Efficiency Assessment Summary	Credit Value			
United States of America	Country	Units	Car	Truck
Company	USA	g/mi	1	1.4
Date:	Version:	1.1		

CY	MY	Vehicle Description (Examples: Platform, Brand, Model, Powertrain, etc.) (Add columns if desired)	Refrigerant ("R-134a" or "R-1234yf")	Vehicle Type	IHX Type	IHX Description (Examples: Model, Supplier, Part Number, etc.) (Add columns if desired)	Length of IHX Tested (mm) ("N/A" for NON-COAXIAL TUBE IHX)	Tested IHX Linear Slope	Minimum Required IHX Length for full credits (mm)	Length of Actual IHX Used (mm) ("N/A" for NON-COAXIAL TUBE IHX)*	Linear Slope of Actual IHX Used	Acceptable for credits	Applicable Credit for IHX (g/mi)	Engineer
		Example	R-134a	Car	COAXIAL TUBE IHX		500	2.08	468	550	2.28	Yes: Scaling Limited	1	
									N/A		0.00	#DIV/0!	#DIV/0!	
									N/A		0.00	#DIV/0!	#DIV/0!	
									N/A		0.00	#DIV/0!	#DIV/0!	
									N/A		0.00	#DIV/0!	#DIV/0!	
									N/A		0.00	#DIV/0!	#DIV/0!	
									N/A		0.00	#DIV/0!	#DIV/0!	
									N/A		0.00	#DIV/0!	#DIV/0!	
									N/A		0.00	#DIV/0!	#DIV/0!	
									N/A		0.00	#DIV/0!	#DIV/0!	
									N/A		0.00	#DIV/0!	#DIV/0!	

Figure 11 - IHX summary worksheet

7.6 For oil separator, refer to 40 CFR 86.1868-12(h)(6).

7.6.1 Background

Generally speaking, reducing the amount of oil circulating through the refrigerant circuit of a mobile air conditioning system will improve the overall system energy efficiency (COP), by increasing the overall heat transfer coefficient of the heat exchangers in the system.

Circulation of a refrigerant-miscible oil throughout the entire refrigerant circuit of a mobile air conditioning system is the conventional means of returning oil to the compressor for lubrication purposes. However, circulating oil reduces the effectiveness of the heat exchangers in the refrigerant circuit by leaving a thin film of oil on the inside heat exchanger surface, which adds to the total resistance to heat transfer between the refrigerant and the air flowing over the outside surface of the heat exchanger. Therefore, a compressor that can reduce the OCR of the refrigerant circuit, through the use of an oil separator and/or other means, can improve the overall energy efficiency of the A/C system.

Incorporating an oil separator to the compressor is the most common means of reducing OCR in the refrigerant circuit. Compressors with oil separators will include design feature(s) for separating some portion of the oil from the refrigerant, either internal to the compressor or as the mixture is leaving the compressor, and returning the oil to the inlet of the compressor. By separating oil from the refrigerant, the oil separator maintains the oil amount necessary in the compressor for proper operation and durability, while preventing the oil from circulating through the refrigerant circuit and compromising system COP.

Although an oil separator is the most common method of reducing OCR for COP improvement, other means which facilitate reduction in the initial oil charge amount needed by the compressor can also be employed, which will also reduce OCR, since there is less oil to circulate through the system to begin with. Providing means for reducing the initial charge amount of oil can be accomplished through advanced design techniques such as use of high strength and/or low-friction materials, modifying internal component geometry to reduce the amount of force between components at sliding interfaces, etc. This Recommended Practice and referenced SAE J3112 can be used to evaluate the effectiveness of all features utilized by a compressor for reducing OCR, regardless if they are used in conjunction with, or independent of, an oil separator.

40 CFR 86.1868-12(h)(6) defines a technology that qualifies for the oil separator A/C menu credit as “a mechanism which removes at least 50% of the oil entrained in the oil/refrigerant mixture exiting the compressor and returns it to the compressor housing or compressor inlet, or a compressor design which does not rely on the circulation of an oil/refrigerant mixture for lubrication.” Accordingly, SAE J3112 has been established to determine OCR.RE for a given compressor as the means of testing to this requirement.

7.6.1.1 SAE J3112 Method 1 Baseline OCR Selection

Selection of the Method 1 baseline OCR values was determined through consensus of the SAE IMAC GHG CRP membership, with supporting data provided by one OEM member and two compressor supplier members of the CRP. Selection of the baseline values were not intended to represent lowest OCR values available for compressors without oil separator, or to accommodate compressors with the highest OCR values, but to provide a reasonable representation of the state of the industry overall prior to the introduction of oil separators. Figure 12 shows the baseline OCR values selected for the I45 and M45 test conditions specified in SAE J3112, along with the OCR data for compressors without oil separators provided by the CRP member companies. Through review of the provided data and discussion among CRP members, the values of 7.5% for the I45 condition and 8.5% for the M45 condition were agreed to as reasonable baseline OCR values for compressors without oil separators.

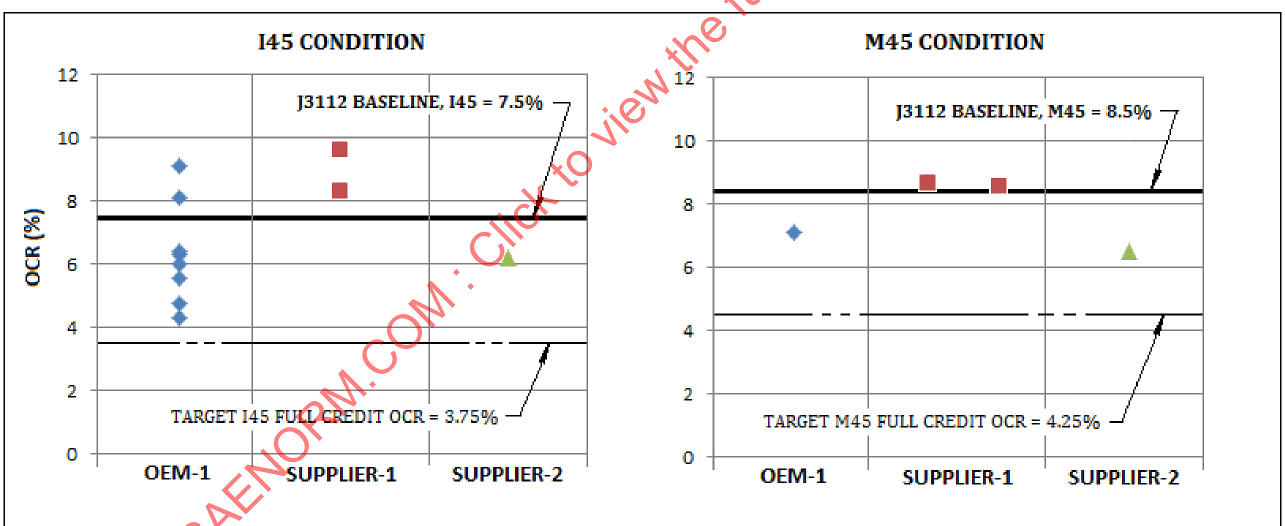


Figure 12 - SAE J3112 baseline OCR values with CRP data for compressors without oil separators

7.6.2 Procedure

OEMs seeking to qualify for the oil separator menu credit are required to provide an engineering analysis. One method is using the bench test procedures described in SAE J3112.

In order to calculate the OCR.RE of a compressor, a baseline OCR value must be established. SAE J3112 provides the choice between two methods of determining baseline OCR.

Method 1 uses a pre-defined baseline OCR as the basis of comparison, based on industry consensus and data provided to the IMAC GHG CRP during the course of development of SAE J3112 (as illustrated in Figure 12). Method 2 provides for means of determining the baseline OCR based on testing of a similar compressor not having the OCR reducing features. The advantage of Method 1 is that only the new compressor needs to be tested, though in some cases the industry established baseline OCR defined in SAE J3112 may be lower than a given supplier's baseline compressor; hence, the option under Method 2 to establish the baseline through actual testing of a baseline compressor.

For all vehicle credit applications, the system refrigerant and oil charge conditions for applicability of results as specified in SAE J3112 shall apply, and vehicle-specific system refrigerant and oil charge amounts shall be included in the application for credit.

7.6.3 Acceptance Criteria

SAE J3112 specifies testing to SAE J2765 test conditions I45 and M45 as the basis for quantifying OCR.RE for a given compressor.

7.6.3.1 Full Credit

7.6.3.1.1 Method 1

The results shall show an OCR.RE greater than or equal to 50% when utilizing the SAE J3112 default baseline OCR values of 7.5% at the I45 condition and 8.5% at the M45 condition, with an I45/M45 average OCR of 8.0%, in order to qualify for the full credit amount from the pre-approved credit menu.

7.6.3.1.2 Method 2

The results shall show an OCR.RE greater than or equal to 50% when compared to the baseline compressor in order to qualify for the full credit amount from the pre-approved credit menu. The baseline system selected for Method 2 shall be a comparable system to the system where the compressor to be evaluated is applied. The baseline compressor by definition will not include an oil separator or other advanced features for reducing OCR.

7.6.3.2 Partial Credit

Compressors which yield an average OCR.RE of greater than 0% but less than 50% for I45 and M45 test conditions can earn partial credit by scaling the average OCR.RE result at the I45 and M45 test conditions to the menu credit value and rounding down to the nearest 0.1 g/mile (e.g., if the average OCR.RE is 48.5%, the awarded credit shall be 48.5/50 = 0.97 times the full credit value rounded down to 0.4 g/mile for a car, 0.6 g/mile for a truck). Rounding down is used to error on the side of conservatism or fewer credits.

If the OCR.RE is less than 0% for both test conditions, the compressor is not eligible for credit.

7.6.4 Submission Template

The submission template "SAE J3112 Oil Separator Reporting Template for J3174.xlsx" is available as a digital annex. Included are worksheets for Method 1 and Method 2 data per SAE J3112, and a summary worksheet to identify the vehicle applications and calculate the credit value. In addition, a data sheet for the optional R_{FOT} method for estimating OCR.RE for certain classes of compressors is included with the Method 1 and Method 2 worksheets. A worksheet for confirming applicability of test results for systems using SAE J3112 range of applicability criteria is included as well. Samples are shown in Figures 13 through 17.