Vehicle Environmental Regulatory Strategy & Planning
Sustainability, Environment & Safety Engineering
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December 2, 2019

To: Mr. Linc Wehrly
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Ann Arbor, Michigan 48105

To: Mr. James Tamm
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National Highway Traffic Safety Administration
1200 New Jersey Avenue SE
Washington, DC 20590

Subject: Request for Greenhouse Gas (GHG) and Fuel Economy Off-Cycle Credits

Per 40 CFR 86.1869-12(d), 49 CFR 531.6(b), and 49 CFR 533.6(b) Ford requests GHG off-cycle credits for the following technology:

- Valeo Air Conditioning Compressor with Variable Bleed Valve (VBV)

Pursuant to 40 CFR § 86.1869-12 and per 49 CFR 531.6, vehicle manufacturers may obtain off-cycle credits for the use of a technology whose benefits are not adequately captured on the Federal Test Procedure and/or the Highway Fuel Economy Test. This request for off-cycle credits is submitted in accordance with subsection (d) of that rule, which enables manufacturers to earn credits by demonstrating that the technology at issue results in a carbon-related exhaust emissions benefit when tested using an alternative methodology approved by EPA in consultation with NHTSA. 40 CFR § 86.1869-12(a) provides that off-cycle credits may not be earned for crash avoidance technologies, safety critical systems, technologies designed to reduce the frequency of vehicle crashes, or technologies installed to attain compliance with any vehicle safety standard or regulation set forth in CFR title 49. Ford hereby states that the above listed technology that is the subject of this request are not safety-related technologies and are therefore not subject to any of the exclusions set forth in subsection (a).

Ford kindly requests written/e-mail acknowledgment upon receipt and acceptance of this off-cycle credit proposal. If you have any questions about this letter and the related attachments, please contact Mr. Jeff Glodich at jglodich@ford.com or (313) 845-1579.

Sincerely,

Steve Henderson, Manager
Vehicle Regulatory Strategy & Planning

Request for Valeo Air Conditioning Compressor Credits

Pursuant to 40 CFR 86.1869-12(d), 49 CFR 531.6(b), and 49 CFR 533.6(b) Ford hereby requests approval for the following methodology to determine off-cycle CO2 credits from the Valeo air conditioning compressor with variable bleed valve technology.

Ford proposes the use of a single off-cycle credit value of 1.1 g/mi for all vehicle categories. This value is determined from bench testing procedures and corroborated by previously conducted vehicle testing. With this application Ford seeks approval for off-cycle credits based on the technology, credit level, and methodology detailed below.

Description of System

1. **Valeo A/C Compressor with Variable Bleed Valve (VBV)**

Valeo's air conditioning compressor with variable bleed valve improves energy consumption compared to the current generation compressor technology. The development goal was to improve the coefficient of performance during low and mid load conditions without deteriorating maximum operating performance and liquid start up times. Current technology is a compromise of all load conditions. The first priority is to have a high coefficient of performance at full stroke. This can be inefficient under low and average load conditions. The variable bleed valve improves the coefficient of performance under low and mid load conditions decreasing CO2 emissions. The variable bleed valve is designed to vary the bleed valve diameter, making it smaller to control internal control gas for improved coefficient of performance, but also be able to increase for liquid start up conditions. The optimized valves reduce losses within the A/C compressor increasing efficiency. The additional variable bleed valve improves the compressor over previous externally-controlled variable displacement compressor designs and provides complementary benefits to the other A/C efficiency technologies.

Basic Operation of Variable Displacement Compressors

To understand the benefits of the Valeo VBV compressor, it is first necessary to understand the basic operation of Variable Displacement Compressors. The basic designs of variable displacement compressors utilize a swash plate mechanism to move the pistons and pump the refrigerant. By changing the angle of the swash plate the displacement of the pistons is reduced thereby reducing the refrigerant flow and the cooling capacity of the A/C System. This is shown schematically in Figure 1.

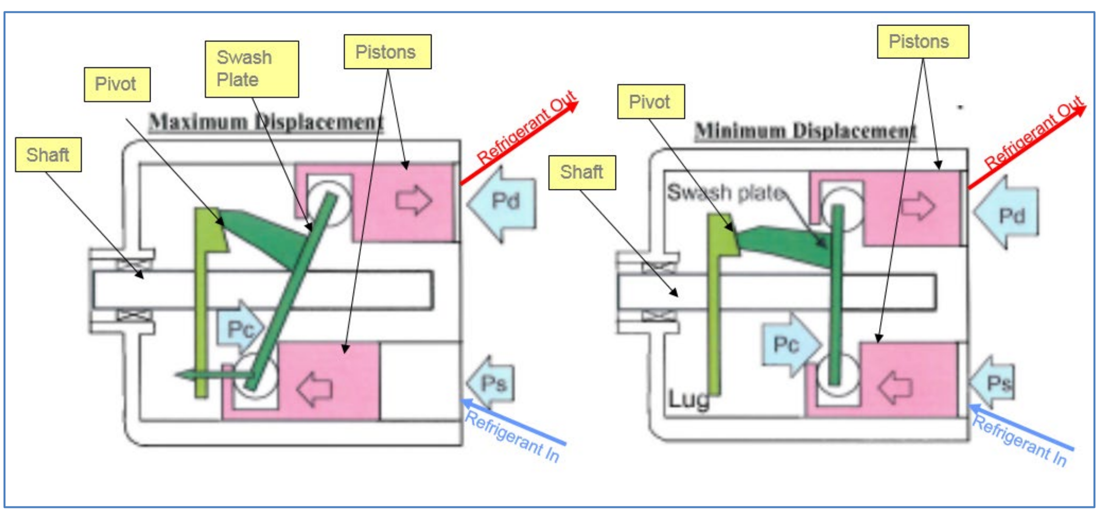


Figure 1

Management of the swashplate angle is accomplished by means of a control valve which controls the crankcase pressure, Pc. Figure 2 schematically shows the function of the control valve. When open, the control valve channels discharge gas into the crankcase. The relationship between the crankcase pressure, the discharge pressure Pd, and the suction pressure Ps determines the swash plate angle. When the Pc is high and closer to Pd, the result is minimum displacement. When the control valve is closed, Pc is equal to Ps, which results in maximum displacement. When the control valve is modulating, Pc is between Pd and Ps, which results in an intermediate displacement. In order for this method to function, a small bleed from the crankcase to the suction side allows the refrigerant to exit the crankcase. Otherwise the crankcase pressure would continue to increase, and the compressor would always be at minimum displacement. This means some of the compressor work is used to maintain a constant internal flow of refrigerant from the discharge side to the suction side which does not perform any cooling.

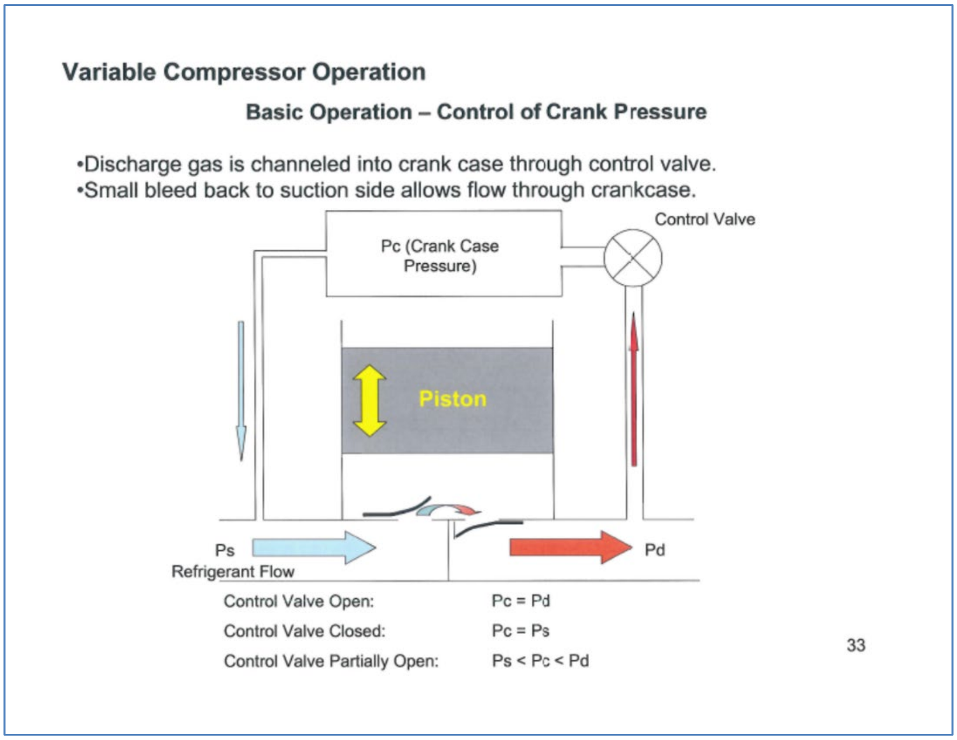


Figure 2

<u>Advantages of the Valeo VBV Compressor</u>

As shown in Figure 3, the Valeo VBV compressor improves the efficiency of the internal gas flow with the addition of the Variable Bleed Valve (VBV) which closes off the large bleed allowing the use of a Small Gas Bleed.

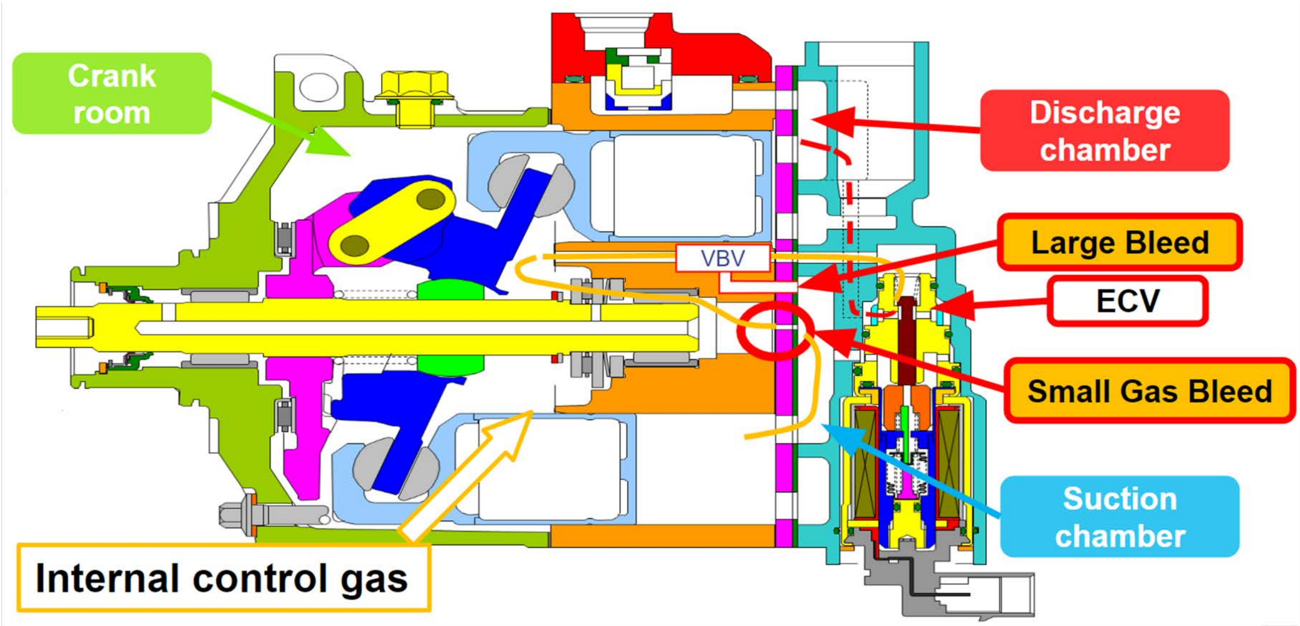


Figure 3

The VBV allows for optimum flow of the refrigerant that passes into and out of the crankcase as the compressor displacement is managed. In compressors without the variable bleed valve the bleed size is a compromise. When the A/C system is off, the compressor is at the minimum displacement, and all pressures are equal (Pd=Pc=Ps). In order, to quickly cool the vehicle, it is desirable to achieve maximum displacement as soon as possible. Under these conditions a large bleed from the crankcase to the suction side is best. However, as stated before, when the vehicle has reached a comfort level and the compressor displacement can be reduced, there is an internal flow of refrigerant from the discharge side to the suction side which is not used for cooling. Under these conditions a small bleed from the crankcase to the suction side is best. The VBV provides the best bleed size in all conditions. It especially improves efficiency when the compressor is between minimum and maximum displacement.

Rationale for Using The Alternative EPA-approved Methodology:

Since the Valeo A/C Compressor with variable bleed valve technology is not currently available as a credit on the pre-approved technology menu, Ford considered both the 5-cycle and alternative methodologies for this request. Although the 5-cycle methodology would capture a variety of driving conditions (e.g. vehicle speed, ambient temperature, A/C usage etc.), the key factor in determining the greenhouse gas benefit of the Valeo air conditioning compressor with variable bleed valve is the increased efficiency improvements when the air conditioning system is turned on. The 5-cycle test methodology would minimize the potential impact the Valeo compressor would have on the measured CO2 emissions for the following reasons. The SC03 cycle is the only cycle that incorporates A/C usage. The SC03 test requires A/C to be run a maximum during the cycle. Finally, the 5-cycle calculation suggests the A/C usage is only ~13% of VMT, while literature indicates that it is substantially higher (24 – 29%). Based on this it is determined that the improved air conditioning efficiency on a vehicle is not fully captured in the 5-cycle methodology.

For this reason, Ford is pursuing off-cycle credits under the alternative demonstration methodology pursuant to 40 CFR § 86.1869-12(d).

Proposed Alternative EPA-approved Methodology

1. **Bench Testing Results**

An engineering analysis of the Valeo A/C compressors was conducted by Valeo to demonstrate the benefit of the improved compressor design. The methodology used was developed during the Society of Automotive Engineers (SAE) Improved Mobile Air Conditioning Cooperative Research Program for evaluating U.S. system efficiency that has become a formal SAE standard. Bench testing was conducted per SAE J2765 for each compressor. SAE J2765 is the procedure for measuring system coefficient of performance (COP) for a mobile air conditioning system on a test bench. The procedure is designed to give maximum repeatability and minimum error in determining cooling capacity and efficiency of the refrigeration system of the mobile air conditioner. The SAE J2765 standard specifies a series of bench tests conducted at various compressor speeds to measure the system COP. The results were used in combination with the Global Refrigerants Energy & Environmental – Mobile Air Conditioning – Life Cycle Clime Performance model (GREEN-MAC-LCCP) jointly developed by GM, SAE, EPA, and the Japanese Automobile Manufacturers Association (JAMA). The LCCP model estimates greenhouse gas (GHG) emissions for mobile air conditioning systems based on harmonized inputs and has been adopted as SAE standard J2766.

Previous off-cycle applications have requested a credit value of 1.1 g/mi for the DENSO SAS A/C compressor which has deployed similar technology on their compressor line. The engineering analysis conducted by DENSO resulted in an average U.S. vehicle indirect CO2 emissions value of 18.7 g/mi based on the LCCP model for the DENSO SB compressor. The same analysis was conducted on the DENSO SAS compressor with the variable crankcase suction (CS) valve and resulted in an average U.S. vehicle indirect CO2 emissions value of 17.6 g/mi based on the LCCP model. The difference between these two results was the basis for an off-cycle credit for Ford and other OEMs claiming a credit of 1.1 g/mi for this technology.

Using the same methodology Valeo conducted its own engineering analysis using the LCCP model to quantify the benefits of the new variable bleed valve added to its A/C compressor line. Using the same A/C system, testing was conducted on a Valeo compressor without the VBV, a Valeo compressor with the VBV and the Denso SAS compressor with the CS valve. Based on the same LCCP model, the engineering analysis conducted by Valeo resulted in an average U.S. vehicle indirect CO2 emissions value of 18.0 g/mi for the Valeo compressor without the VBV, 17.3 g/mi on the Valeo compressor with the VBV and 17.7 g/mi on the Denso SAS compressor with the CS valve. The incremental improvement of the VBV is less than the improvement from the SB* to the SAS because the Valeo compressor is a newer design than the SB* and incorporates efficiencies in addition to the VBV. These results are documented in Appendix A, and comparatively shown in Figure 4 below. The results show that the Valeo A/C compressor with the variable bleed valve results in an average indirect CO2 emission that is lower than the Denso SAS compressor with CS valve that has already received approval as an off-cycle credit. Given that the DENSO SAS compressor with CS valve has already been approved for an off-cycle credit of 1.1 g/mi and the Valeo compressor with the variable bleed valve is shown to provide even larger CO2 reductions, Ford recommends that the conservative value already approved for the Denso SAS compressor of 1.1 g/mi also be approved for the Valeo compressor with the variable bleed valve. Ford also believes that any similar such advanced compressors from other additional suppliers should also be eligible for the same 1.1 g/mi credit level.

Ford requests approval for a credit of 1.1 g/mi for vehicle applications that include the Valeo A/C compressor with the variable bleed valve.

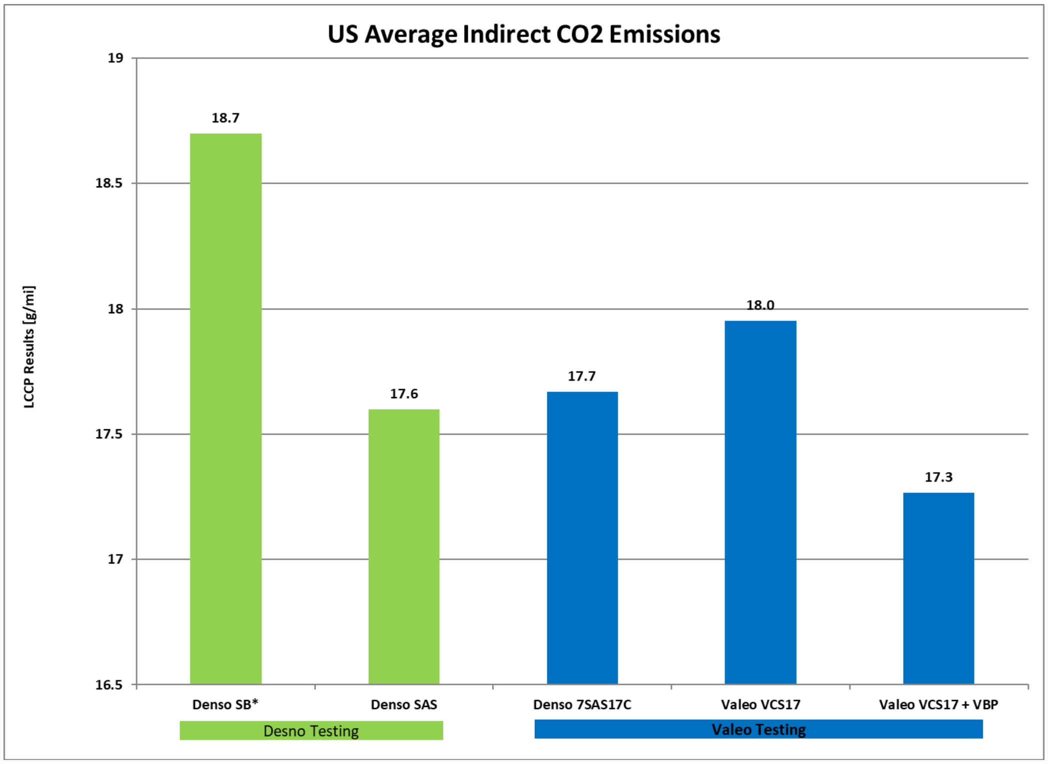


Figure 4: A/C compressor LCCP results

The difference in the results between the DENSO SAS A/C compressor testing conducted by DENSO and that conducted by Valeo is because different systems were used for the testing.

2. Vehicle Testing Results

Ford and other OEMs have conducted numerous full vehicle test programs that have repeatedly demonstrated that the LCCP model analysis accurately characterizes the benefits of these advanced compressor technologies. Due to these past results Ford believes it is no longer necessary to continue to validate the bench testing methodology that has been proven to be accurate. Furthermore, it has been repeatedly shown and discussed that full vehicle AC17 testing introduces numerous factors of variability resulting in a wide range of results. Due to the variability that results from full vehicle testing and the AC17 test procedure, it is recommended to continue to base the off-cycle credit for this technology on the more conservative and consistent values that result from the bench testing data conducted by Valeo and apply a credit value of 1.1 g/mi for vehicles equipped with this technology.

3. Durability

Air conditioning compressors installed within Ford vehicles are designed to meet all the durability requirements of 40 CFR § 86.1869-12(d) and are not subject to any deterioration factors that would reduce the benefits of the Valeo air conditioning compressor with variable bleed valve. Preliminary durability testing has been conducted signifying that designs meet Ford specifications and full useful life requirements. Full durability testing will be conducted on production equipment once manufactured to confirm the findings of the preliminary testing results and validate durability requirements.

4. Interaction of the Denso SAS and Valeo VBV Compressors with A/C Credit Menu Technologies

In "EPA Decision Document: Off-Cycle Credits for BMW Group, Ford Motor Company, and Hyundai Motor Company" EPA-420-R-17-010, December 2017, which included EPA's decision on Ford's application for off-cycle credits for the Denso SAS compressor, EPA indicated the additional credits of 1.1g/mi should fall under the limits or caps placed on CO2 credits for improving the efficiency of air conditioning systems as defined in 40 CFR §86.1868-12 (b). However, a more detailed look into the interactions of A/C Menu technologies with the Denso SAS compressor and Valeo VBV compressor results in the opposite conclusion.

Comparison of the Denso SAS with CS valve and Valeo VBV Compressors versus the Prior Generation Compressors

Using data previously presented within the Denso SAS off-cycle application we can show the change impacted on coefficient of performance measurements by comparing a baseline compressor to an advanced compressor with a crankcase suction valve, variable bleed valve, or other similar technology. As stated in Ford's prior off-cycle application, both the Denso SAS with CS valve and the Denso SB* generation compressors were bench tested per SAE J2765 in the same A/C system to measure the Coefficient of Performance (COP) improvement. Likewise, Valeo conducted bench testing per SAE J2765 on a Ford A/C System with the Denso SAS with CS valve and the Valeo compressor with and without the VBV. In all cases, the results were then analyzed using the LCCP model as shown in Figure 4. It should be noted that both the A/C system Denso tested and the A/C system Valeo tested utilized A/C efficiency technology that would result in the vehicle applications exceeding the cap per 40 CFR §86.1868-12 (b). This includes an Internal Heat Exchanger (IHX) and an Oil Separator. Per SAE J2765, 40 test points were run to simulate system operation at four ambient temperatures, and Idle, Low, Medium, and High speeds. Some conditions include operation at elevated evaporator temperature to simulate reduced reheat. The LCCP model yielded an improvement of 1.1g/mi for the SAS compressor with CS valve and an additional improvement for the Valeo VBV compressor. However, a detailed look at the bench test results is helpful in understanding the interaction of the SAS with CS valve and VBV compressor technology with the other A/C Credit menu technologies.

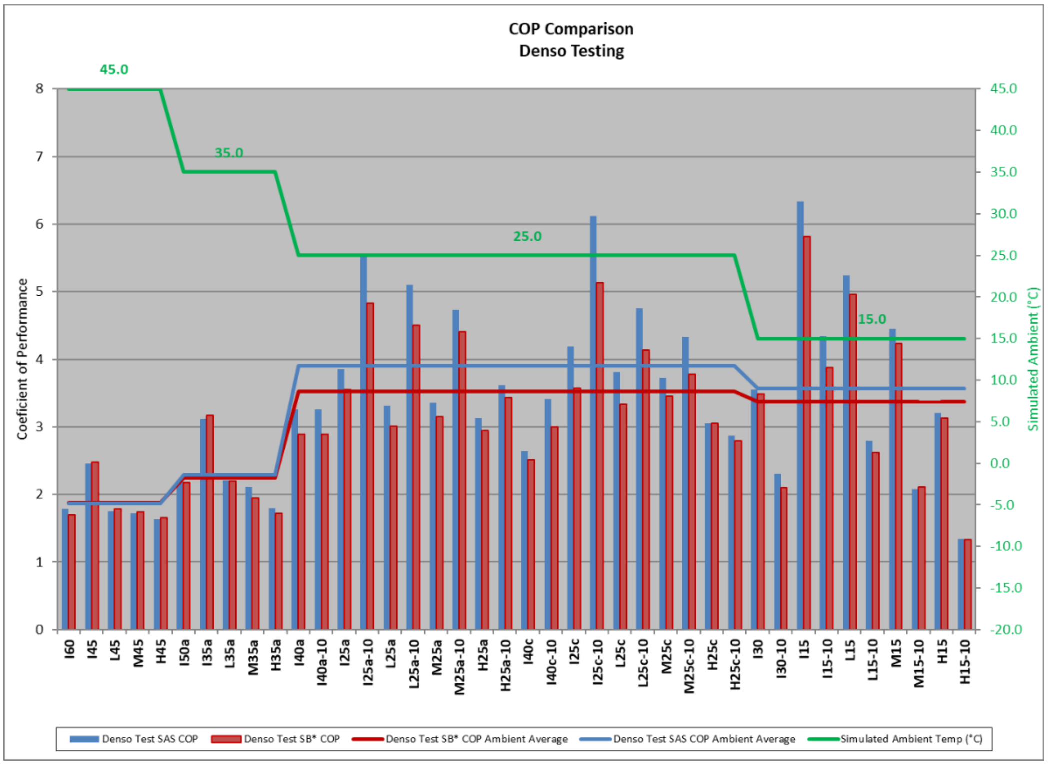


Figure 5

Figure 5 shows the COP for both the SAS with CS valve and the prior generation Denso SB* compressor at each of the bench test conditions. Also, shown is the simulated ambient temperature and the average COP at each simulated ambient temperature. Figure 6 shows the percent improvement in COP of the SAS compressor over the SB* compressor for each test condition and the average for each simulated ambient temperature. As shown in these figures, the COP of the SAS compressor is similar to that of the SB* compressor at the higher simulated ambient temperatures of 45°C and 35°C. It's significantly better at the cooler 15°C simulated ambient and shows the greatest improvement occurring at the moderate 25°C simulated ambient conditions. This is when the compressor is operating at an intermediate displacement confirming this is where the CS valve provides the biggest improvement.

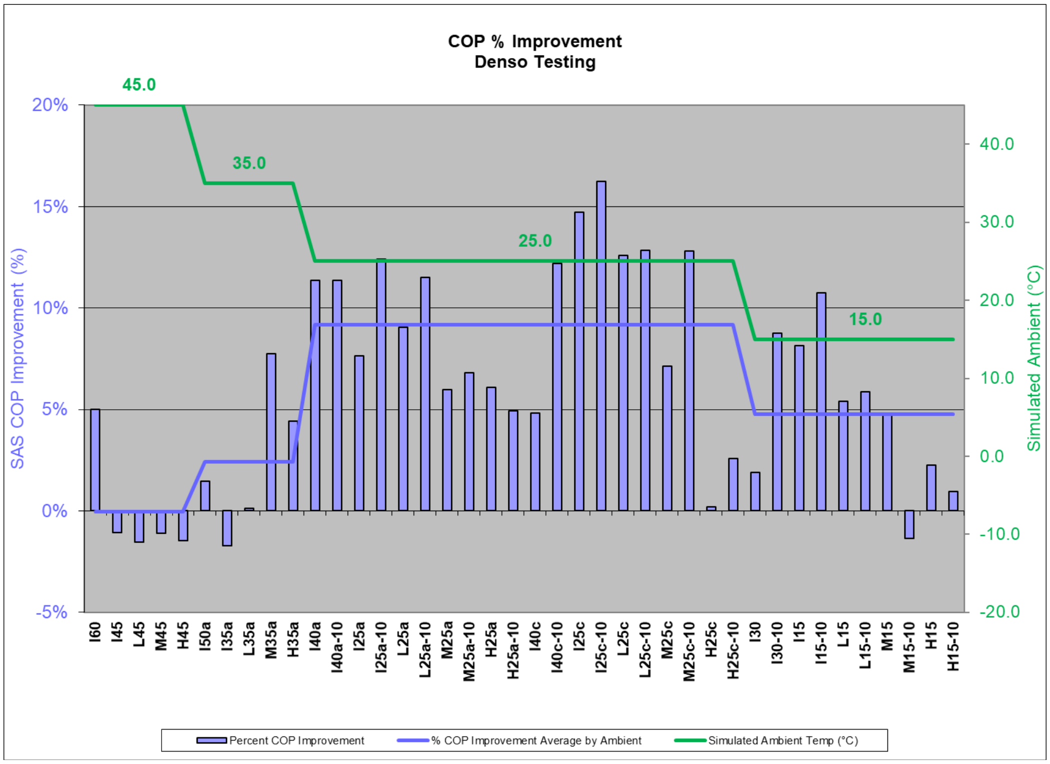


Figure 6

Similarly testing by Valeo shown in Figure 7 and Figure 8 shows the variable bleed valve design incorporated into the Valeo compressor provides similarly higher COP benefits in the cooler ambient conditions.

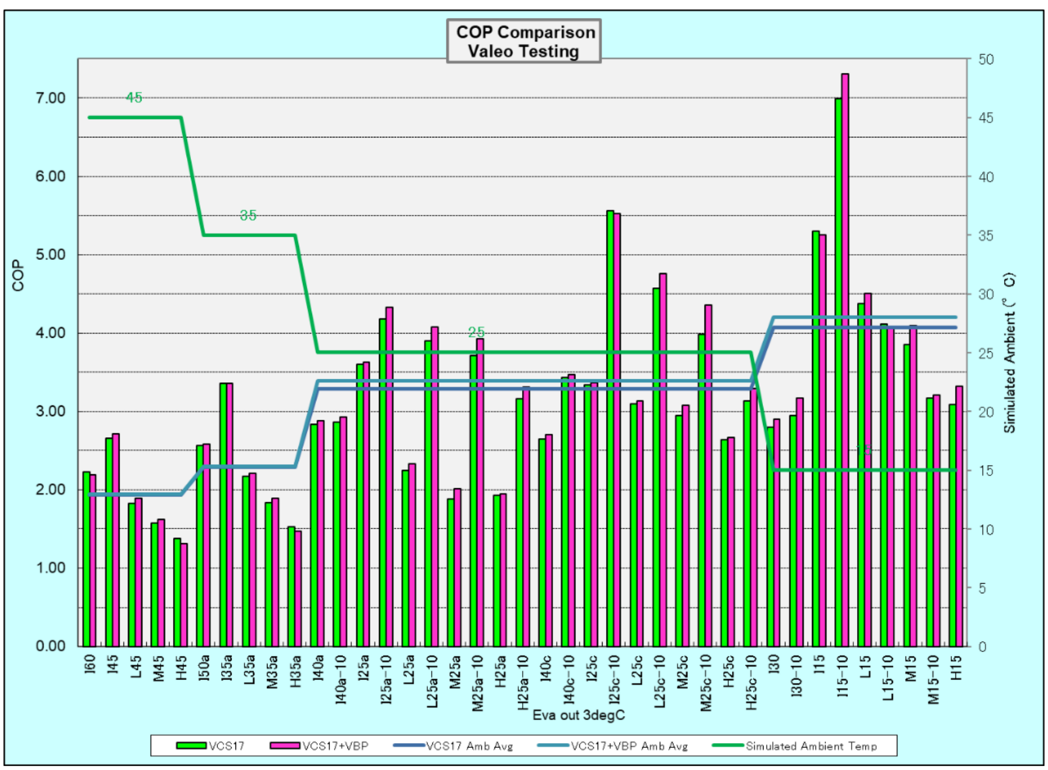


Figure 7

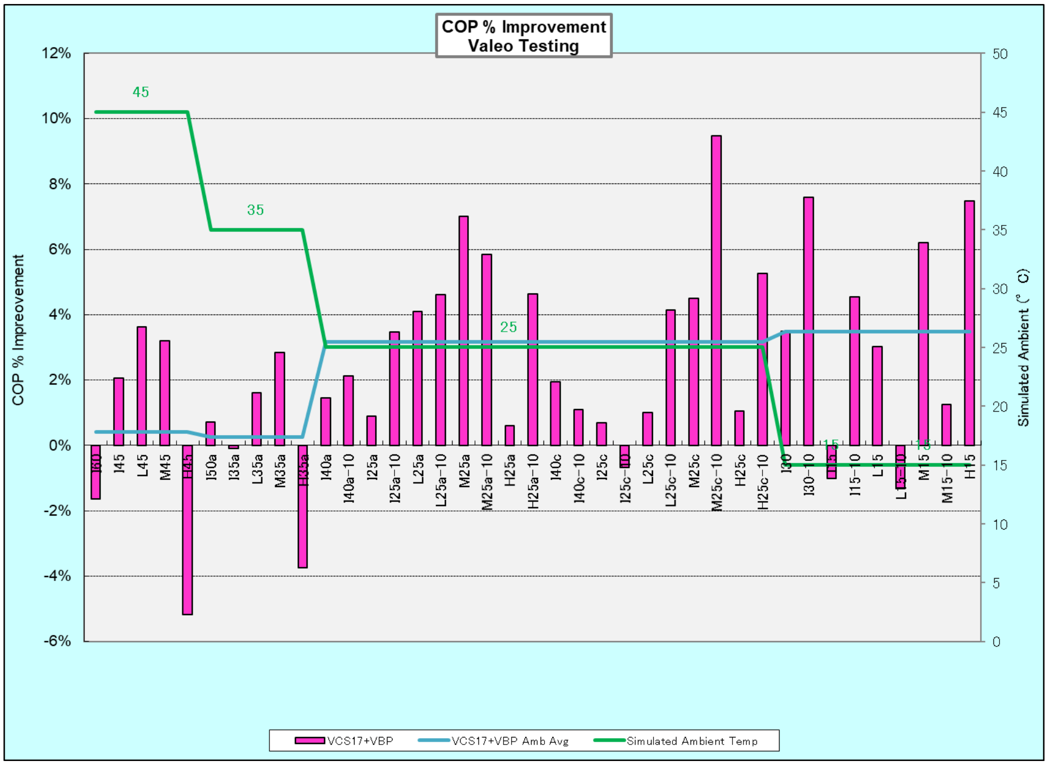


Figure 8

<u>Relationship of the Valeo VBV Efficiency Improvements to A/C Menu Credit Technology</u>
<u>Automatic Recirculation above 75°F</u>

Automatically switching to Recirc above 75°F reduces the cooling load on the A/C system because instead of cooling warm humid air entering the vehicle from outside, air from inside the vehicle which has already been cooled and dehumidified is being cooled. The lower cooling load means the variable displacement compressor will be operating at a lower displacement where the Denso SAS and the Valeo VBV compressors provide the biggest efficiency improvement. This can be seen in Figure 9 which shows two AC17 tests on the same vehicle. During the test shown on the top of the figure, Automatic Recirc was activated. During the test on the bottom of the figure, Automatic Recirc was disabled. The figure shows the target evaporator temperature and the actual evaporator temperature for each test. The variable displacement compressor will operate at full displacement until the evaporator temperature is cooled to the target temperature. From that point on the compressor displacement will be modulated to maintain the evaporator temperature at the target. In comparing the two tests, it can be seen that operation in recirc reduces time for the compressor to reduce displacement by approximately 50 percent. The result of this operation mode means the compressor will spend more time operating under the conditions when the Denso SAS and the Valeo VBV compressor will result in the biggest improvements in efficiency. Therefore, as efficiency technologies, Automatic Recirc and the improved compressor's valve technology are complementary meaning the SAS and VBV compressors do not reduce the benefit of operating in recirc but are enhanced by it.

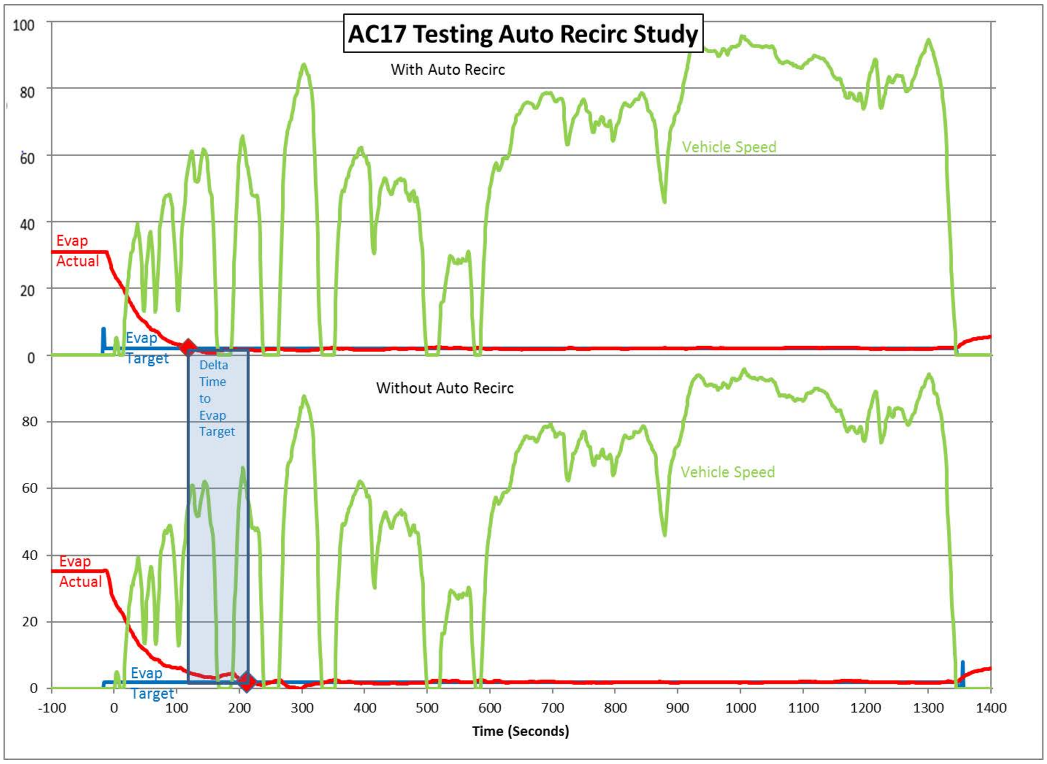


Figure 9

<u>Reduced Reheat</u>

The reduced reheat strategy reduces the cooling load on the A/C system by elevating the evaporator temperature when cooling to just above freezing is not required. Historically, A/C systems would operate with the evaporator temperature as low as possible at all times. When warmer air was required to prevent the occupants from becoming too cool, some air would be routed through the heater core, reheated and blended to a comfortable temperature. With reduced reheat, the evaporator temperature is elevated, and the amount of reheating is reduced. This usually occurs at moderate ambient temperatures once a vehicle is cooled down after a soak and comfort is achieved. The SAE J2765 standard includes testing at two evaporator target temperatures, 3°C and 10°C, at the 25°C and 15°C simulated ambient temperatures to assess the benefit of reduced reheat. Figures 10 and 11 show comparative data from Denso and Valeo showing the percent improvement in COP of the improved compressors over the respective base compressors for each test condition and the average for the 25°C and 15°C simulated ambient temperatures.

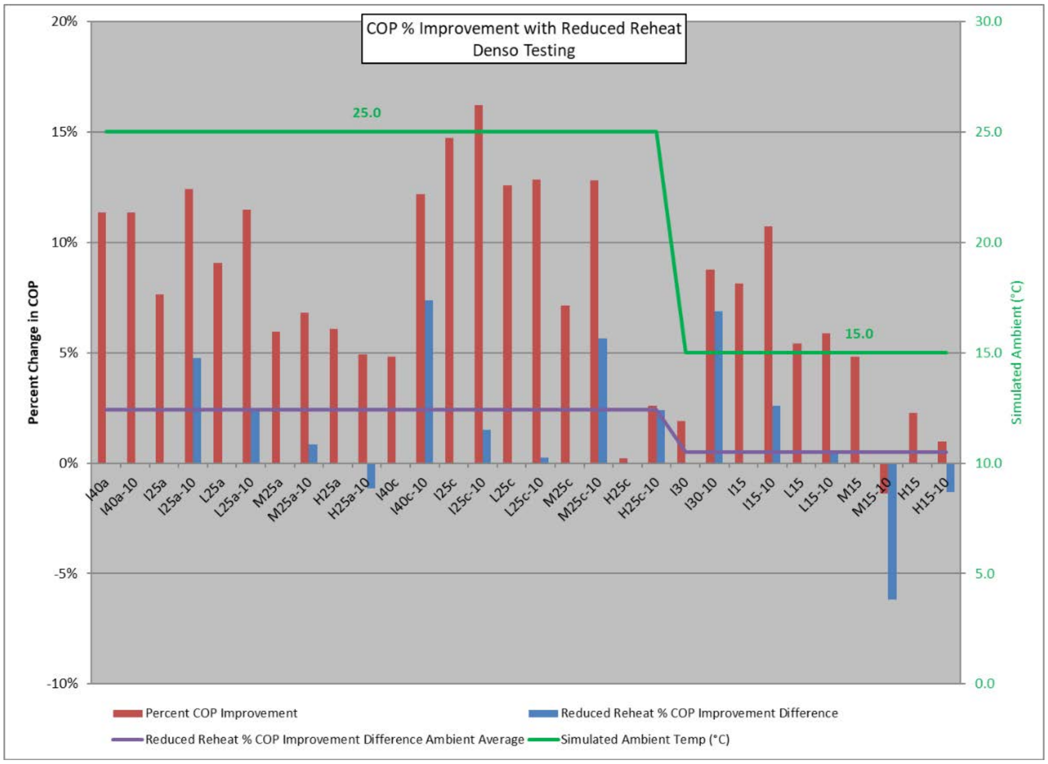


Figure 10

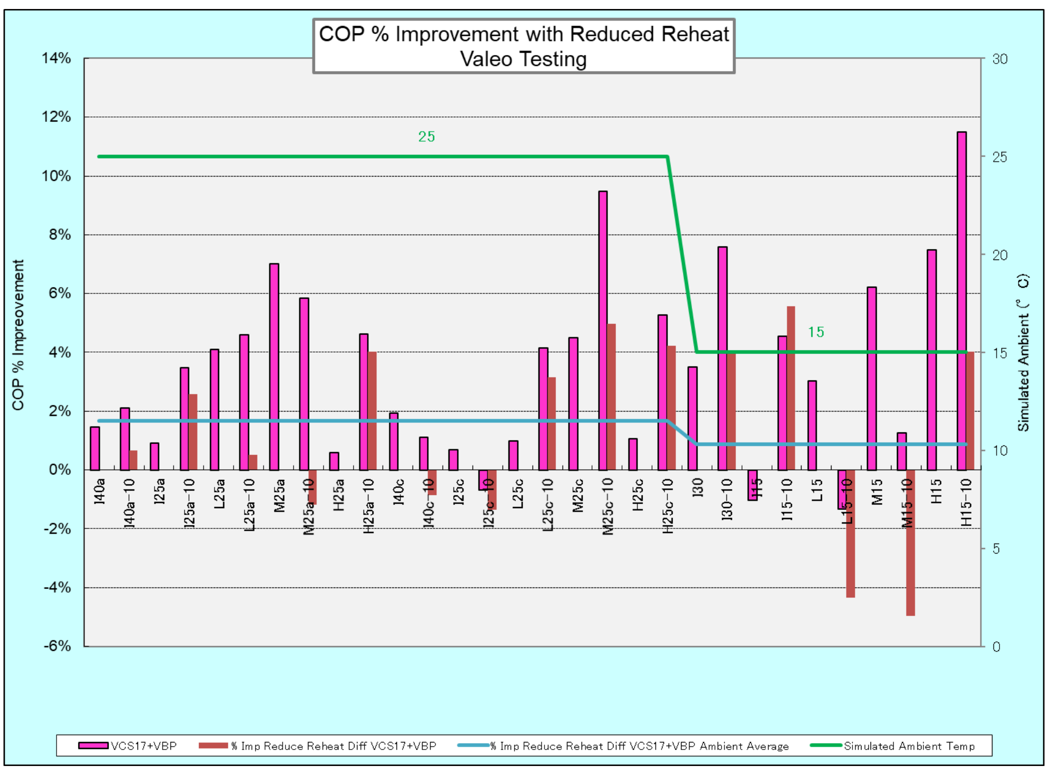


Figure 11

The test conditions designated as "-10" are the 10°C evaporator target temperature or simulated Reduced Reheat test points. Also shown is the difference in percent COP improvement of the reduced reheat test points versus the 3°C test points and the average difference in improvement for each simulated ambient temperature. In most cases the percent improvement in COP is higher for the Reduced Reheat conditions. This is because the compressor displacement is lower, and the benefit of the improved compressors valve technology is higher.

Review of Figure 12, which shows the AC17 test with Auto Recirc from Figure 9 on the bottom and an AC17 test on the same vehicle with both Auto Recirc and Reduced Reheat on the top, it can be seen that the Reduced Reheat elevates the evaporator temperature for most of the test. Therefore, as efficiency technologies, Reduced Reheat and the improved compressor's valve technology are complementary meaning the SAS and VBV compressors do not reduce the benefit of Reduced Reheat but are enhanced by it.

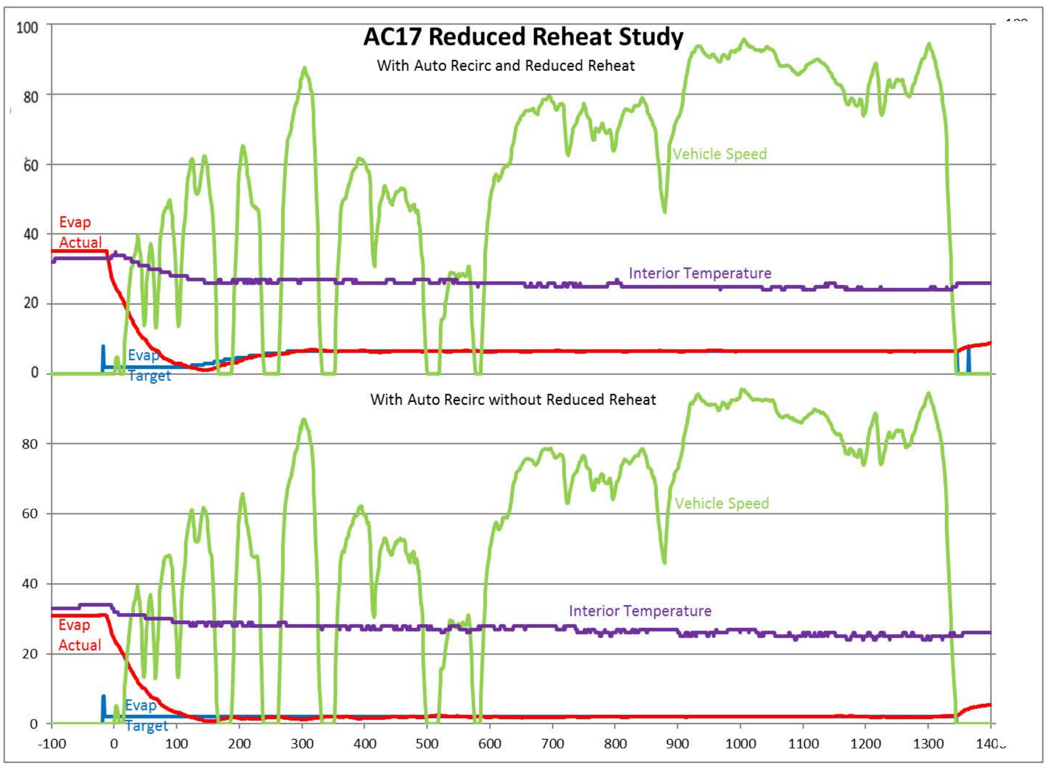


Figure 12

<u>Internal Heat Exchanger (IHX)</u>

An Internal Heat Exchanger reduces load on the compressor by transferring heat from the high-pressure liquid entering the expansion valve (TXV) to the low-pressure gas exiting the evaporator. Figure 13 shows the results of an analysis of an A/C system using R-1234yf refrigerant with and without an IHX. A schematic of each system is shown on the left side of each chart. The IHX increases the subcooling of the refrigerant as it enters the expansion valve increasing the change in enthalpy as the refrigerant passes through the evaporator. This result is improved performance and COP due to a reduction in refrigerant flow. The reduced flow rate means the compressor can operate at reduced displacement which is where the benefit of the SAS and VBV compressors are higher. Therefore, as efficiency technologies, an IHX and the improved compressor's valve technology are complementary meaning the SAS and VBV compressors do not reduce the benefit of an IHX but are enhanced by it.

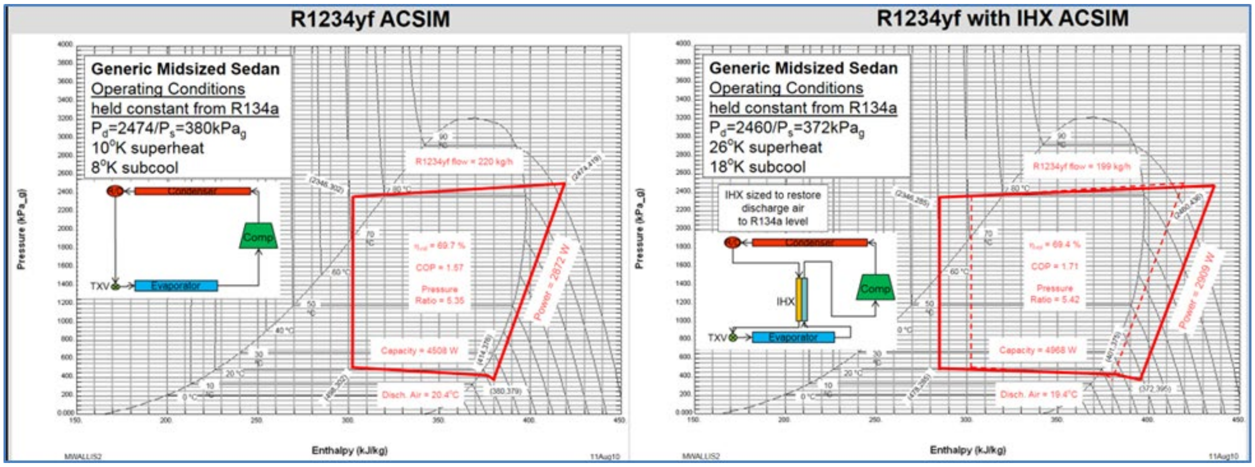


Figure 13

Compressor with Internal Oil Separator

The oil in the A/C system that lubricates the compressor is typically circulated throughout the system. The circulated oil also coats the internal surfaces of the heat exchangers reducing the heat transfer between the refrigerant and the heat exchangers. It also requires energy to pump the oil through the system. A compressor with an internal oil separator improves efficiency by retaining most of the oil in the compressor where it is needed thus improving the effectiveness of the heat exchangers and reducing pumping requirements. Because the oil separator improves the system performance, the A/C system will reach conditions where reduced displacement is required sooner and more often. Since this is where the benefit of the SAS and VBV compressors is higher, the SAS and VBV compressors do not reduce the benefit of an oil separator but are enhanced by it.

Improved Evaporators and Condensers

Improving the efficiency and effectiveness of the heat exchangers will allow the A/C system to reach conditions where reduced displacement is required sooner and more often. Since this is where the benefit of the SAS and VBV compressors is higher, the SAS and VBV compressors do not reduce the benefit of an Improved Evaporator and Condenser but are enhanced by them.

Blower Motor Controls that Limit Wasted Electrical Energy

Blower motor controls that limit wasted energy improve efficiency by using technologies such as Pulse Width Modulation (PWM) which reduces the amount of electrical energy which generates wasted heat. PWM controllers typically have efficiencies above 70%, compared to motor controllers such as resister cards or Linear Power Modules with efficiencies in the low to mid 50's. The efficiency of these other controllers is lowest at the lower blower speeds, whereas a PWM controller typically has similar efficiency under all operating conditions. This means the benefit of the PWM controller is greatest under the same conditions where the SAS and VBV compressors provide the biggest benefit. Because the blower motor control is part of the electrical system and the SAS and VBV compressors are part of the refrigerant system, there is no interaction between the two. However, because the biggest benefit of both the SAS and VBV compressors and the PWM blower controllers occurs under lower cooling loads the two technologies complement each other.

Summary

The interactions of the Denso SAS and the Valeo VBV compressor and the A/C Credit Menu technologies are summarized in the table below:

Interaction of Denso SAS & Valeo VBV Compressors with A/C Credit Menu	
A/C Credit Menu Technology	**Interaction**
Automatic Recirc above 75°F	Enhanced
Reduced Reheat	Enhanced
Internal Heat Exchanger (IHX)	Enhanced
Compressor with Internal Oil Separator	Enhanced
Improved Evaporators and Condensers	Enhanced
Blower Motor Controls that Limit Wasted Electrical Energy	Complementary

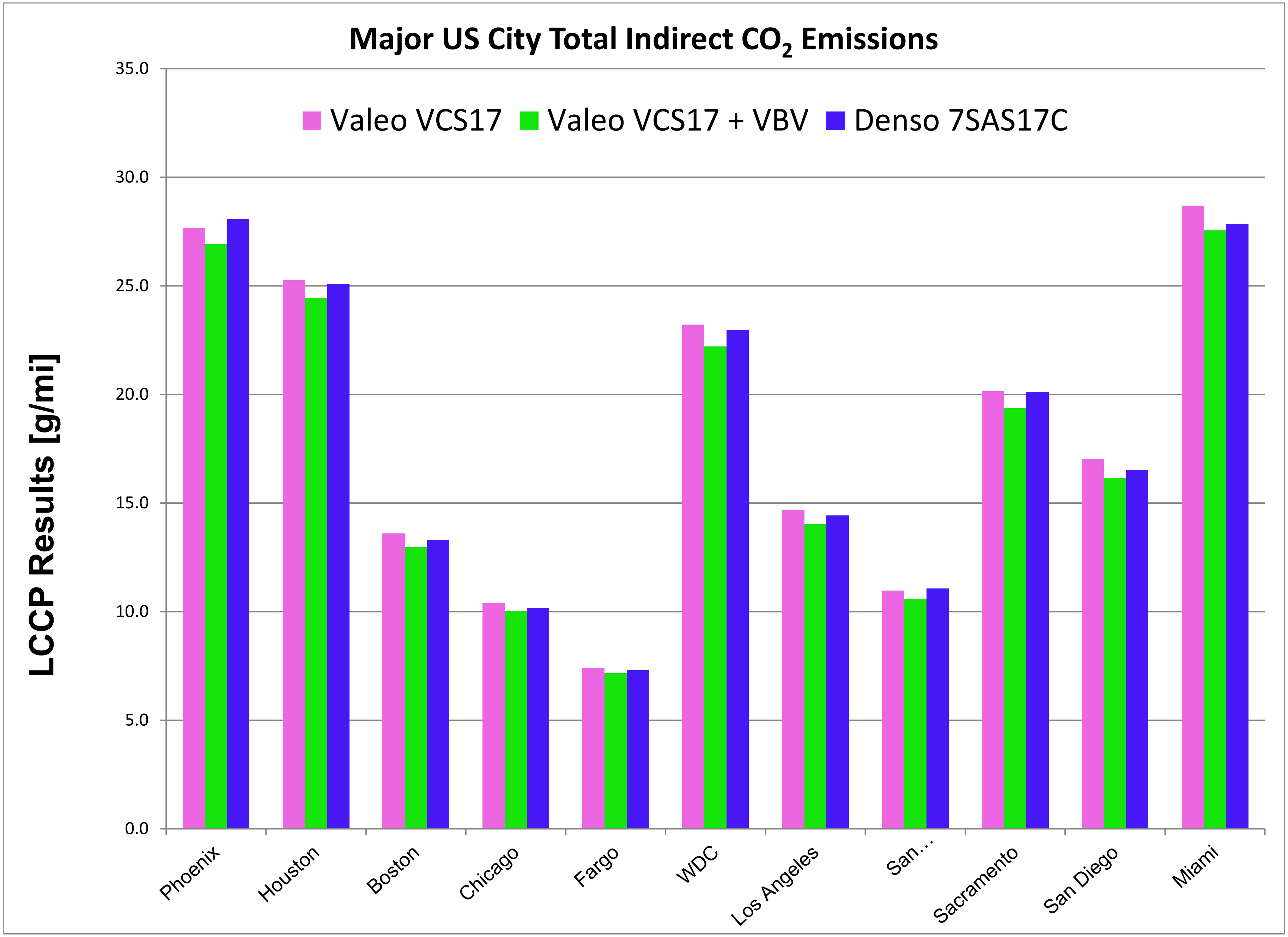
Therefore, it should be concluded that the credits for the Valeo VBV compressor and the previously approved credits for the Denso SAS compressor should not be included under the A/C Credit Menu caps of 5.0g/mi for Car and 7.2g/mi for Truck. They should be uncapped under the off-cycle alternative methodology.

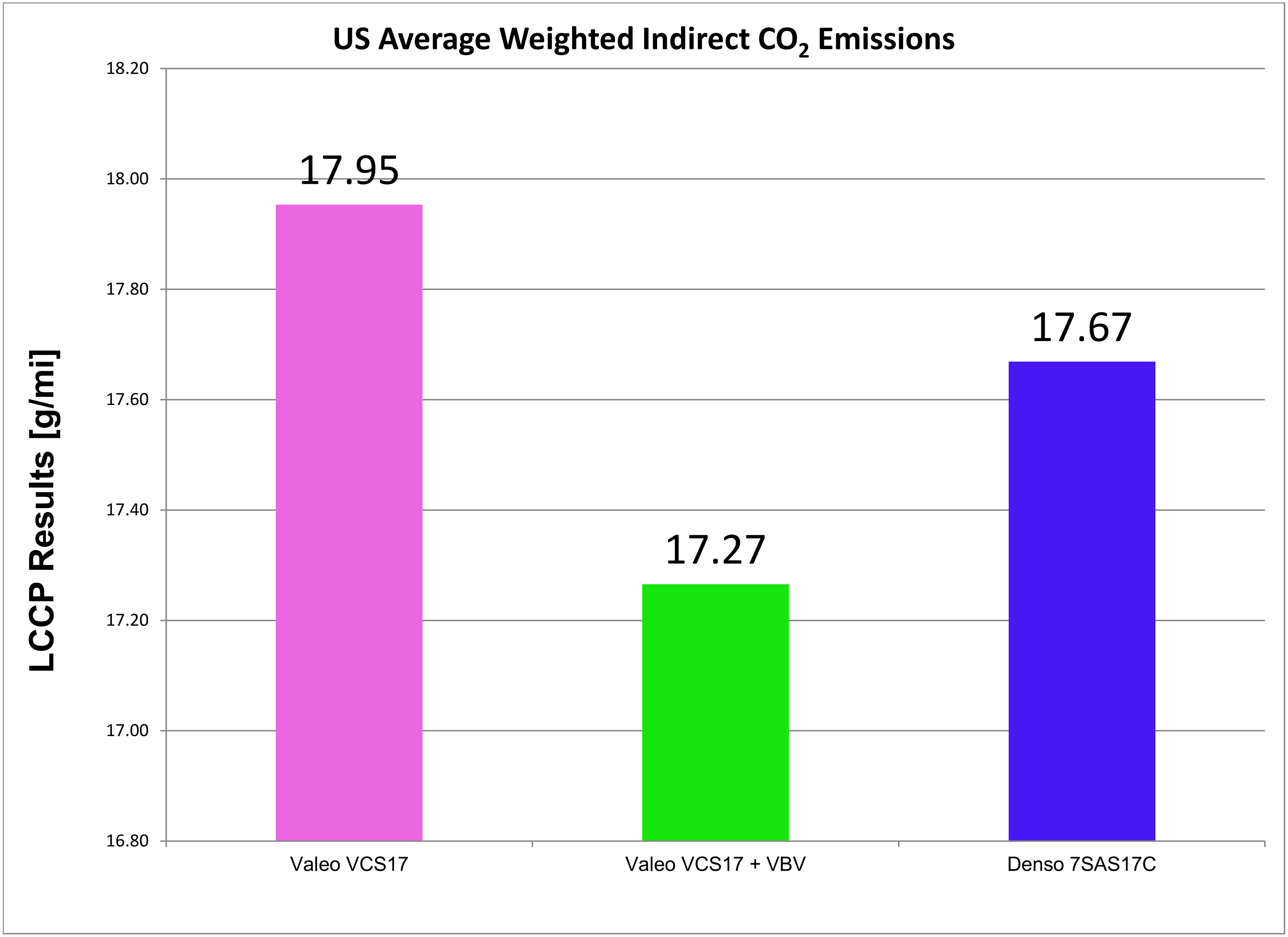
Conclusion

Based on the data presented Ford recommends the use of a 1.1 g/mi credit for all vehicles equipped with the Valeo air conditioning compressor with variable bleed valve technology. Since a similar technology has already been approved at this same credit level Ford urges the authorities to expeditiously approve this off-cycle credit request for a similar technology deployed by an additional supplier. Per the methodology described above regarding credit determination, we intend to apply the methodology described above for each compressor application using the Valeo compressor with variable bleed valve technology. The fleet credit will be calculated based on credit for each type of vehicle, vehicle lifetime miles and U.S. sales volume for future model year products. Based on the details and rationale outline within this application Ford believes that the Valeo VBV compressor should be approved as an off-cycle technology under the provisions of 86.1869(d) and not be applicable to the A/C efficiency caps of 86.1868(b). Additionally, Ford urges EPA to reconsider the previous decision document issued approving the DENSO SAS compressor credits and remove the restriction that they be constrained within the A/C efficiency cap under 86.1868(b).

Appendix A: Valeo VBV Compressor LCCP Results

		United States	United States	United States	United States	United States	United States	United States	United States	United States	United States	United States	US Totals
		Phoenix	Houston	Boston	Chicago	Fargo	WDC	Los Angeles	San Francisco	Sacramento	San Diego	Miami	g/mi
	% of Country	2.91%	13.16%	8.11%	23.97%	10.25%	13.61%	7.64%	1.52%	0.92%	2.52%	15.39%	
	Driving Distance (km)	20,050	19,635	19,665	19,635	20,050	20,050	20,050	20,050	20,050	20,050	19,832	
	Vehicle Lifetime (Yrs.)	9	9	9	9	9	9	9	9	9	9	9	g/mi
Valeo VCS17	Indirect Emissions due to A/C Vehicle Operation	3,102	2,774	1,496	1,139	831	2,603	1,646	1,229	2,259	1,906	3,179	
weighted avg	weighted CO2 per city	0.8	3.3	1.1	2.5	0.8	3.2	1.1	0.2	0.2	0.4	4.4	17.95
Ford System(IHX)	Indirect Emissions due to A/C Vehicle Operation	3,102	2,774	1,496	1,139	831	2,603	1,646	1,229	2,259	1,906	3,179	
Each city indirect C02 emissions	CO2 total per city	27.7	25.3	13.6	10.4	7.4	23.2	14.7	11.0	20.1	17.0	28.7	
Valeo VCS17 + VBV	Indirect Emissions due to A/C Vehicle Operation	3,017	2,682	1,427	1,101	804	2,490	1,572	1,189	2,170	1,812	3,054	
weighted avg	weighted CO2 per city	0.8	3.2	1.1	2.4	0.7	3.0	1.1	0.2	0.2	0.4	4.2	17.27
Ford System(IHX)	Indirect Emissions due to A/C Vehicle Operation	3,017	2,682	1,427	1,101	804	2,490	1,572	1,189	2,170	1,812	3,054	
Each city indirect C02 emissions	CO2 total per city	26.9	24.4	13.0	10.0	7.2	22.2	14.0	10.6	19.4	16.2	27.5	
Denso 7SAS17C	Indirect Emissions due to A/C Vehicle Operation	3,146	2,754	1,464	1,118	819	2,575	1,617	1,241	2,255	1,853	3,089	
weighted avg	weighted CO2 per city	0.8	3.3	1.1	2.4	0.7	3.1	1.1	0.2	0.2	0.4	4.3	17.67
Ford System(IHX)	Indirect Emissions due to A/C Vehicle Operation	3,146	2,754	1,464	1,118	819	2,575	1,617	1,241	2,255	1,853	3,089	
Each city indirect C02 emissions	CO2 total per city	28.1	25.1	13.3	10.2	7.3	23.0	14.4	11.1	20.1	16.5	27.9	


Major US City Total Indirect CO_2 Emissions
Valeo VCS17
Valeo VCS17 + VBV
Denso 7SAS17C
LCCP Results [g/mi]
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Phoenix
Houston
Boston
Chicago
Fargo
WDC
Los Angeles
San…
Sacramento
San Diego
Miami


US Average Weighted Indirect CO_2 Emissions
LCCP Results [g/mi]
18.20
18.00
17.80
17.60
17.40
17.20
17.00
16.80
17.95
17.27
17.67
Valeo VCS17
Valeo VCS17 + VBV
Denso 7SAS17C