Mr. Linc Wehrly, Director
Light Duty Vehicle Center
Compliance Division
Office of Transportation and Air Quality
2000 Traverwood Drive
Ann Arbor, Michigan 48105

March 2, 2017

RE: **FCA Group LLC Request for GHG Credit for Variable Crankcase Suction Valve Technology in Denso AC Compressors**

Dear Mr. Wehrly:

Pursuant to the provisions of 40 CFR 86.1869-12(d), FCA Group LLC ("FCA") requests 1.1 g/mi of greenhouse gas off-cycle credit for the use of the Denso SAS AC compressor with variable crankcase suction valve technology.

EPA has previously reviewed a similar request from General Motors dated December 2014 for this technology and approved the requested amount of 1.1 grams CO_2/mile. FCA plans the introduction of this compressor technology beginning with the 2019 MY Ram pickup truck. Additional applications of the SAS compressor are expected as we continue to roll out the technology to the fleet.

The technology description, test methodology, test results and durability discussion are described in the enclosures.

Please contact me should you have any questions with respect to this submission at 248-576-5464 or through email at Paul.Mendrick@FCAGroup.com.

Very Best Regards,

Paul Mendrick

Manager – Certification and Compliance Group

cc: Gary Oshnock, Manager-Fuel Economy/GHG Regulatory Development

Enclosure A-Technology Description Test Methodology Test Results Durability Discussion and Projected Volumes
Enclosure B-Denso SAS Compressor Presentation to EPA, April 2013
Enclosure C-Compressor Bench Test Data and LCCP Modeling
Enclosure D-AC17 Vehicle Test Data

Enclosure A: Technology Description, Test Methodology, Test Results, Durability Discussion and Projected Volumes

Technology Description

Compressor technology has become significantly more efficient within that last 15 years. Fixed displacement compressors (“FDCs”) were the norm throughout the 1990s and into the early 2000s. Variable displacement compressor (“VDC”) technology debuted at that time in AC systems as an efficiency improvement over the FDC compressor technology. VDCs tailored the amount of refrigeration necessary to the cabin load without having to reheat the incoming air, something that FDCs could not achieve. An example of this type of compressor technology would be Denso’s SBU compressor.

The latest compressor efficiency improvement can be found in the Denso SAS compressor. The SAS compressor has improved pressure drop through the cylinders and a crankcase suction valve that minimizes internal compressor losses at conditions other than maximum capacity. See Enclosure B - Denso SAS Compressor Presentation to EPA, April 2013 for a comparison of the SAS technology with the SBU technology.

Test Methodology

The Denso SAS compressor is an efficiency improvement over the baseline VDC compressor that can be quantified for greenhouse gas (“GHG”) credit. An off-cycle test methodology for capturing this improvement would be to bench test both the old and new compressor technologies to the same standard and then evaluate the CO_2 impact while correcting for climate throughout the USA.

The standardized testing tool is the Society of Automotive Engineers (“SAE”) standard for system performance measurement on a bench, *SAE J2765-Procedure for Measuring System COP of a Mobile Air Conditioning System on a Test Bench*. This standard uses 40 test points to evaluate an HVAC system or component against any other system of component. The technology being evaluated is active in 25 of the 40 test points of SAE J2765. These 25 test pointes were then evaluated for CO_2 impact according to the Life Cycle Climate Performance (“LCCP”) model given in *SAE J2766- Life Cycle Analysis to Estimate he CO2-Equivalent Emissions from MAC Operation*. Each compressor Test details between the Denso SAS Denso SBU compressors and the LCCP analysis are given in Enclosure C – Compressor Bench Test Data and LCCP Modeling.

Vehicle confirmation testing was performed on a 2014 Dodge Charger. The testing consisted of back to back testing of the Denso SAS and SBU compressors on the same vehicle to confirm the difference between the two compressors. The AC17 test cycle given in 40 CFR 86.167-17 was used to confirm the AC emissions benefit of the improved compressor technology. Test details and results are given in Enclosure D - AC17 Vehicle Test Data.

The difference between bench testing and vehicle testing is shown in the test results. The vehicle confirmation test result from the AC 17 test of 3.16 g/mi is much greater than the 1.1 g/mi requested for the technology. While the AC 17 test measures the technology impact over a drive cycle for constant temperature and humidity the bench tests consider the loading the technology will encounter and the LCCP analysis adjusts the result across the country.

Test Results

Each compressor was tested at 25 of the 40 total conditions given in SAE J2765 corresponding to conditions under which the crankcase suction valve operates. Coefficient of Performance ("COP") for each compressor at each of the 25 conditions was then loaded into the LCCP model to determine the CO_2 benefit of each compressor that is given in Table 1.

Compressor	LCCP Average CO2 Value
SBU	18.7 g/mi
SAS	17.6 g/mi
Difference	**1.1 g/mi**

Table 1. Average US Vehicle Indirect CO_2 Emissions Benefit Based on Bench Testing

Vehicle testing per the AC 17 test cycle confirmed a benefit to the crankcase suction valve technology. The A to B test values are shown in Table 2. The benefit of the Denso SAS compressor at the AC 17 vehicle test condition is an average of 3.16 g/mi.

Test Run	Compressor CO_2 Emissions
SAS Test 1	16.95 g/mi
SAS Test 2	17.25 g/mi
SAS Test 3	22.4 g/mi
SAS Test 4	19.55 g/mi
SAS Average	**19.04 g/mi**
SBU Test 1	23.15 g/mi
SBU Test 2	20.5 g/mi
SBU Test 3	21.75 g/mi
SBU Test 4	23.4 g/mi
SBU Average	**22.2 g/mi**
SAS Benefit over SBU	**3.1625**

Table 2. AC 17 Vehicle Test Runs on a 2014 Dodge Charger

Additional test details are given in Enclosure D - AC17 Vehicle Test Data.

Durability Discussion

The Denso SAS compressor is being developed and integrated into a full size pickup truck in its first application. From a development perspective there are no differences to the vehicle interface that need to be modified to take advantage of the crankcase suction valve technology. Normal development timelines and testing apply.

FCA requires compressor technology to live for the period of the vehicle's life. Design validation and reporting per USCAR templates are required of the supplier for component testing and from Engineering for vehicle level testing.

The Denso SAS compressor is expected to have the same or better durability than the Denso SBU compressor it replaces in this application and is warranted in the same way as its predecessor.

Projected Volumes

The first application of the Denso SAS compressor will be in the future RAM full-size pickup truck.

FCA Confidential Business Information

Forecast of FCA Indirect A/C Credits with Denso SAS Compressor

[redacted]

Indirect CO_2 Credit for DENSO SAS Compressor

April 5, 2013
DENSO International America, Inc.

DENSO

Agenda

- DENSO Corporation
- Background / Objective
- SAS Efficiency Improvement Mechanism
- Off-cycle Engineering Analysis Method
- Testing Details
- Test Results
- LCCP Results
- Conclusions

- Time permitting: Cold Storage Evaporator Discussion

DENSO

DENSO Corporation

- **Established: Dec. 16, 1949**
- **Capital: US$2.3 billion**
- **Net Sales: US$38.4 billion**
- **Net Income: US$1,086.5 million**
- **Employees: 126,000 in 35 countries**

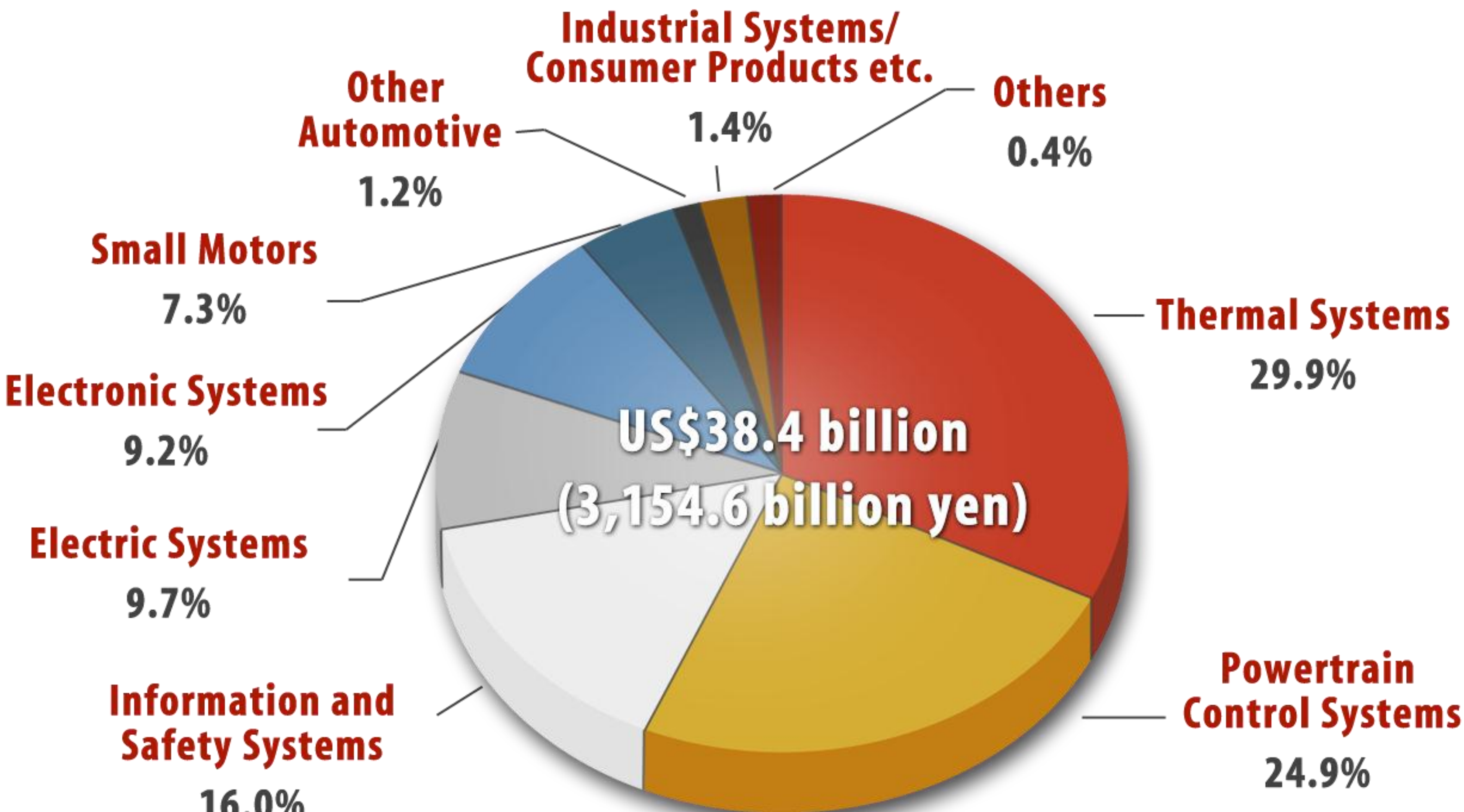
Data are consolidated base

- As of March 31, 2012
- U.S. dollar amounts have been translated from Japanese yen for convenience only at the rate of 82.19 yen= US$1

DENSO

Sales by Business Groups

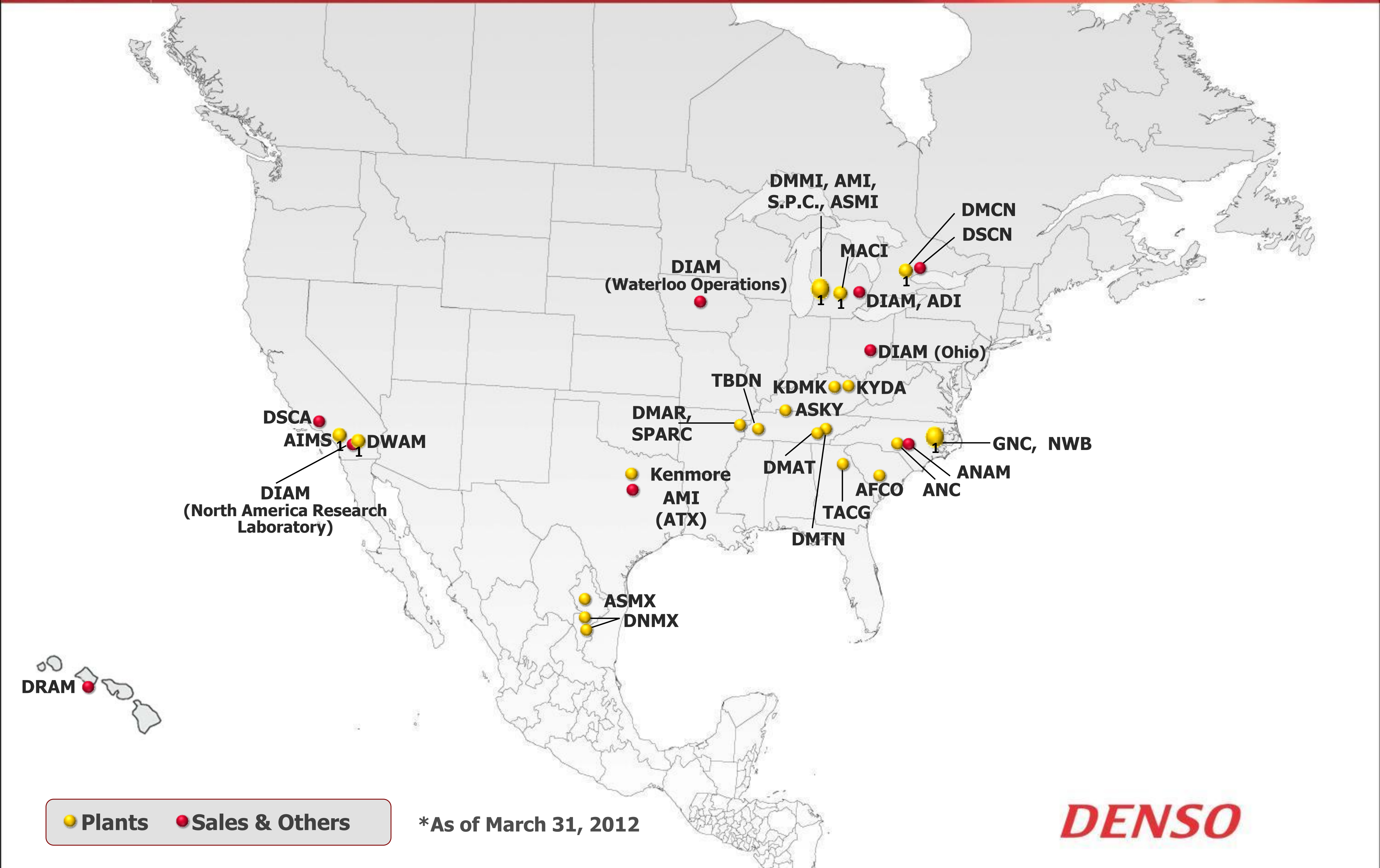
Consolidated Base



*For fiscal year ended March 31, 2012

DENSO

DENSO Operations in North America



Plants Sales & Others

*As of March 31, 2012

DENSO

Background / Objective

Federal fuel economy tests do not include A/C usage, but A/C usage generates CO_2 and reductions to these emissions benefit the environment.

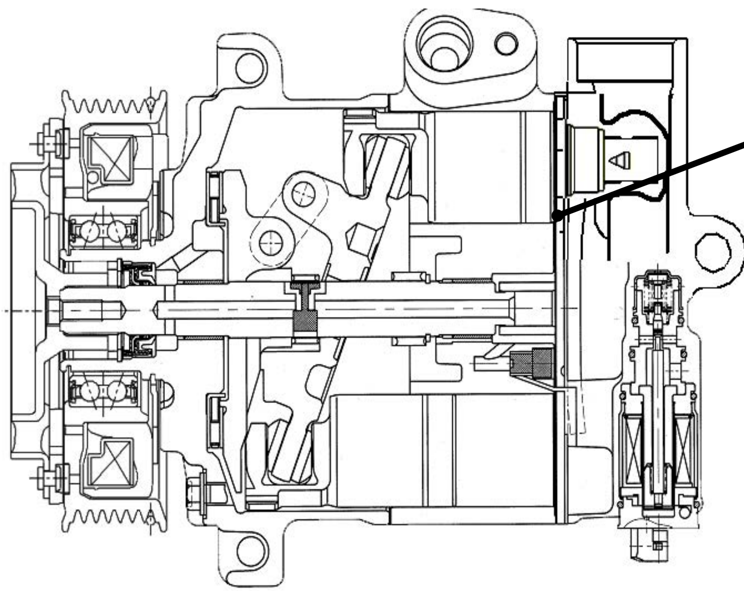
DENSO's new SAS external variable displacement compressor (EVDC) improves energy consumption compared to current generation technology. Therefore, we feel SAS compressor should qualify for CO_2 off cycle credits.

Objective: Perform an engineering analysis to quantify the amount of indirect CO_2 credit that the SAS compressor should receive. Use this information to support customer applications to the EPA for credit.

DENSO

SAS Efficiency Improvement Mechanism

The new SAS compressor has two efficiency improvements over the existing SBU compressor: optimized suction and discharge valves and a CS valve.



<Efficiency>
Change the structure of valve to optimize suction and discharge pressure loss.

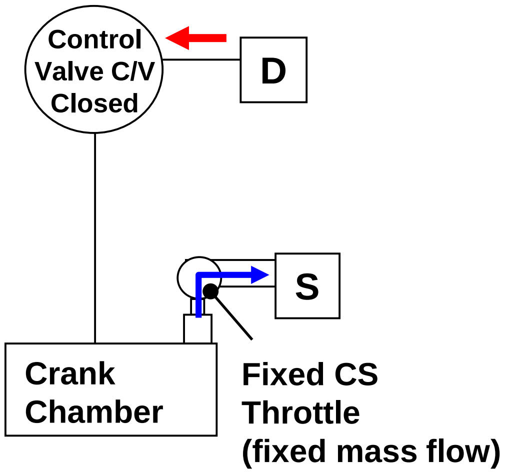
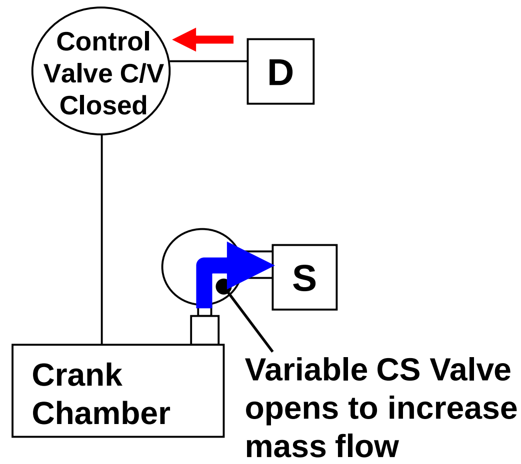
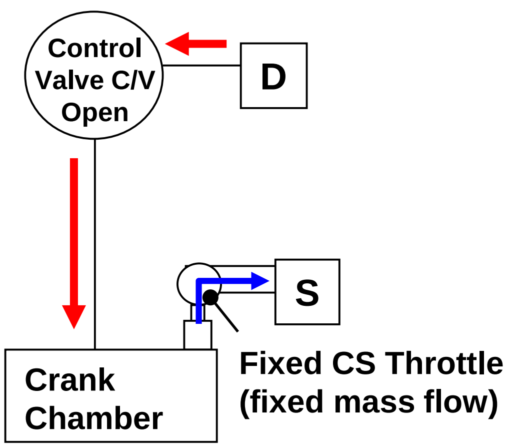
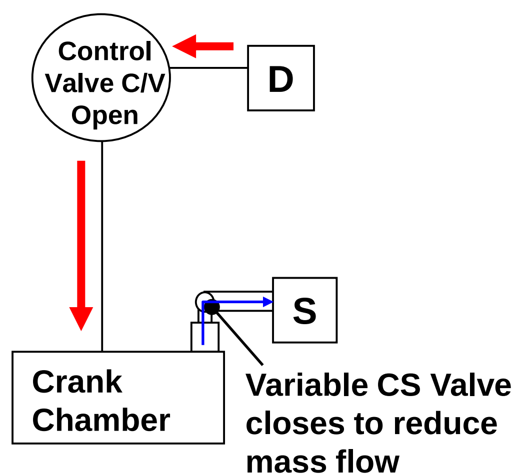
<Efficiency at Variable Condition>
Crankcase Suction Valve (CS valve)
(*optimize suction/ discharge pressure loss*)
(quick start-up under full liquid condition)

Clutch less version (called SES) is available and has same internal design.

The optimized valves reduce suction and discharge pressure loss within the compressor, increasing efficiency.

DENSO

SAS & SES Efficiency Improvement Mechanism

<table>
<tr><th>Condition</th><th>Current Design
(SBU)</th><th>New Technology
(SAS)</th><th>Benefit of Variable CS Valve</th></tr>
<tr><td>Max Capacity and Compressor Start-up</td><td>
</td><td>
</td><td>Large opening allows a large mass flow. This allows for a stable max capacity condition and for the compressor to achieve max capacity more quickly at compressor start-up.</td></tr>
<tr><td>Variable (Mid) Capacity</td><td>
</td><td>
</td><td>Small opening results in a reduction of contol gas flow through the crank chamber, thus reducing internal compressor losses and increasing efficiency at variable condition.</td></tr>
</table>

The CS valve increases efficiency of the SAS compressor at mid displacement.

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A/C Indirect CO_2 Credits

For A/C there are three CO_2 credit types available which can be used to meet the fleet average CO_2 emissions requirements:

Leakage credits for low refrigerant leakage rate or low GWP refrigerant.

Menu credits for improving system efficiency.

Off-cycle credits for advanced technology not on the menu. The technology must reduce emissions levels compared to current technology.

DENSO will do testing to show SAS/SES compressor may get off-cycle credits.

DENSO

Off-cycle Engineering Analysis Method

Bench Testing Per SAE J2765 for Each Compressor → Analysis Using LCCP Model (CO_2 Emission Per City) → Calculate US Average CO_2 For Each Compressor

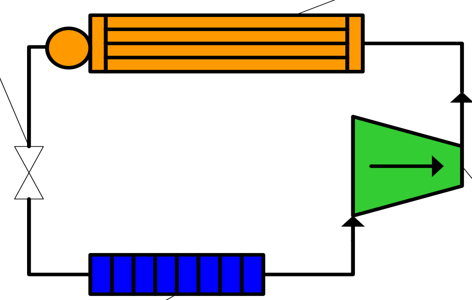
http://www.epa.gov/cppd/mac/compare.htm

LCCP is an existing method to estimate CO_2 impact of MAC systems. It was developed by EPA, GM, SAE, and JAMA.

LCCP analysis can be used as an acceptable engineering analysis method for determining the off-cycle CO_2 emissions impact for SAS compressor.

DENSO

Test Bench System



Condenser (DENSO MF4)
- W600mm x H422.4mm x D16mm
- Fin Height = 5.5 mm
- Tube Thickness = 1.0mm
- Fin pitch ~ 3.15mm
- Configuration: 1 Pass + Sub-cool (55-11)
- Integrated Receiver / Dryer

Thermal Expansion Valve (Fujikoki)
-Set Point = 2.1kPa @ 0°C (1.0ton)
- Slope = 0.7 bar

Compressor (6SBU14 & 6SAS14)
- Pulley Ratio = 2.15
- Oil Amount = 100 g
- Refrigerant Charge:
  R-134a: 650 grams

Evaporator (DENSO RS38)
-W306.5mm x H201mm x D38mm
- Fin Height = 5 mm
- 4 pass : 22-23-23-22
- Tube Thickness = 1.7 mm

All components were common during testing of the 6SBU14 and 6SAS14 compressors.

Test Conditions (J2765)

Test Name	Simulated Ambient Temp. [C]	Compressor Speed [RPM]	Cond Air In Temp [C]	Cond Face Velocity [m/s]	Evap Air In Temp [C]	Evap Humidity [%]	Air Mass Flow [kg/min]	Air Flow Volume [m3/h]	Air Flow Volume [CFM]	Simulated Air Selection	Evap Air Out Target Temp [C]
I60	45	900	60	1.5	35	25	9.0	475	280	Recirc	3
I45	45	900	45	1.5	35	25	9.0	475	280	Recirc	3
L45	45	1800	45	2.0	35	25	9.0	475	280	Recirc	3
M45	45	2500	45	3.0	35	25	9.0	475	280	Recirc	3
H45	45	4000	45	4.0	35	25	9.0	475	280	Recirc	3
I50a	35	900	50	1.5	35	40	9.0	477	281	OSA	3
I35a	35	900	35	1.5	35	40	9.0	477	281	OSA	3
L35a	35	1800	35	2.0	35	40	9.0	477	281	OSA	3
M35a	35	2500	35	3.0	35	40	9.0	477	281	OSA	3
H35a	35	4000	35	4.0	35	40	9.0	477	281	OSA	3
I40a	25	900	40	1.5	25	80	6.5	337	198	OSA	3/10
I25a	25	900	25	1.5	25	80	6.5	337	198	OSA	3/10
L25a	25	1800	25	2.0	25	80	6.5	337	198	OSA	3/10
M25a	25	2500	25	3.0	25	80	6.5	337	198	OSA	3/10
H25a	25	4000	25	4.0	25	80	6.5	337	198	OSA	3/10
I40c	25	900	40	1.5	25	50	6.5	334	197	OSA	3/10
I25c	25	900	25	1.5	25	50	6.5	334	197	OSA	3/10
L25c	25	1800	25	2.0	25	50	6.5	334	197	OSA	3/10
M25c	25	2500	25	3.0	25	50	6.5	334	197	OSA	3/10
H25c	25	4000	25	4.0	25	50	6.5	334	197	OSA	3/10
I30	15	900	30	1.5	15	80	6.5	322	190	OSA	3/10
I15	15	900	15	1.5	15	80	6.5	322	190	OSA	3/10
L15	15	1800	15	2.0	15	80	6.5	322	190	OSA	3/10
M15	15	2500	15	3.0	15	80	6.5	322	190	OSA	3/10
H15	15	4000	15	4.0	15	80	6.5	322	190	OSA	3/10

All conditions were run for each compressor

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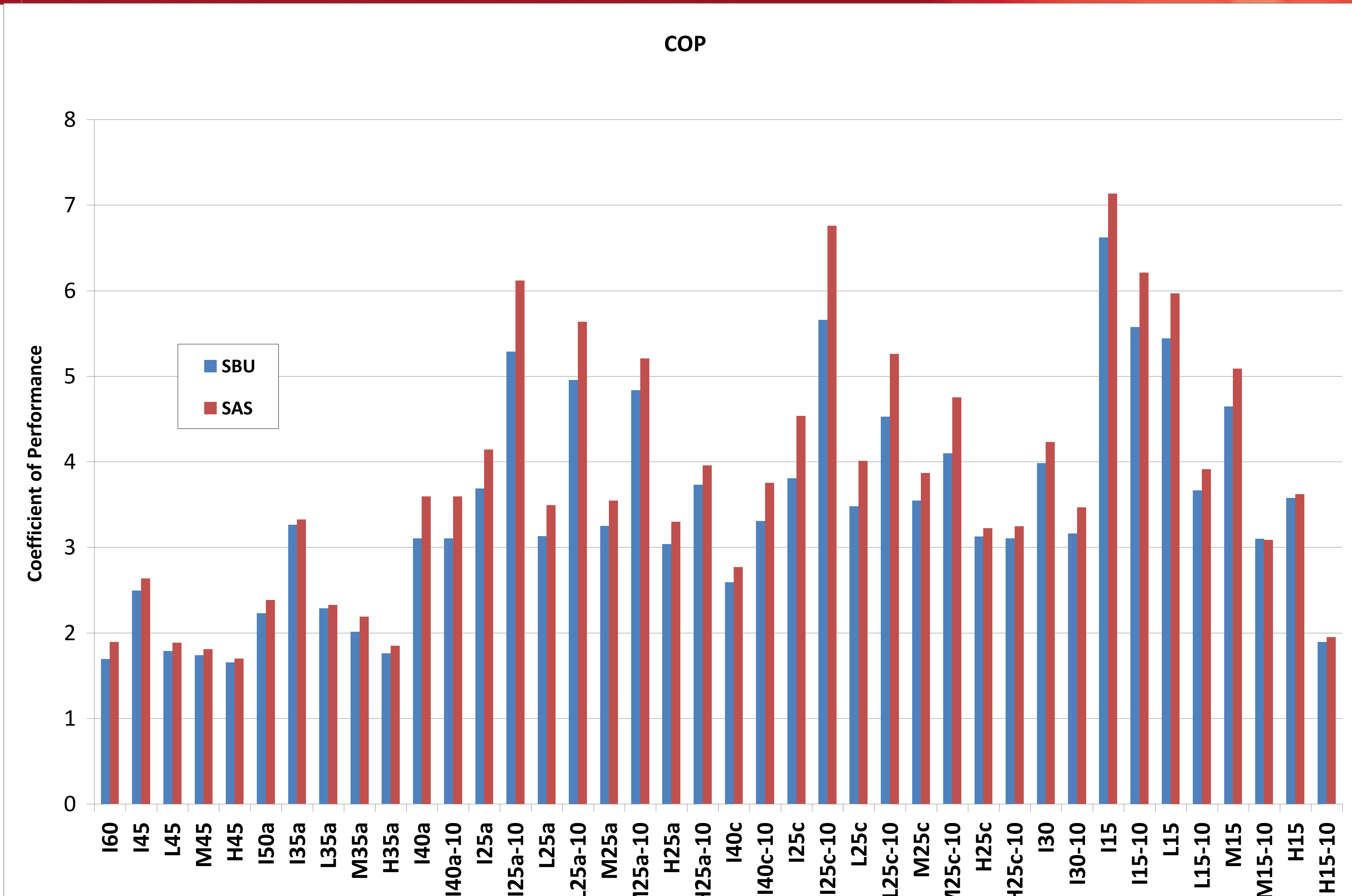
Test Results

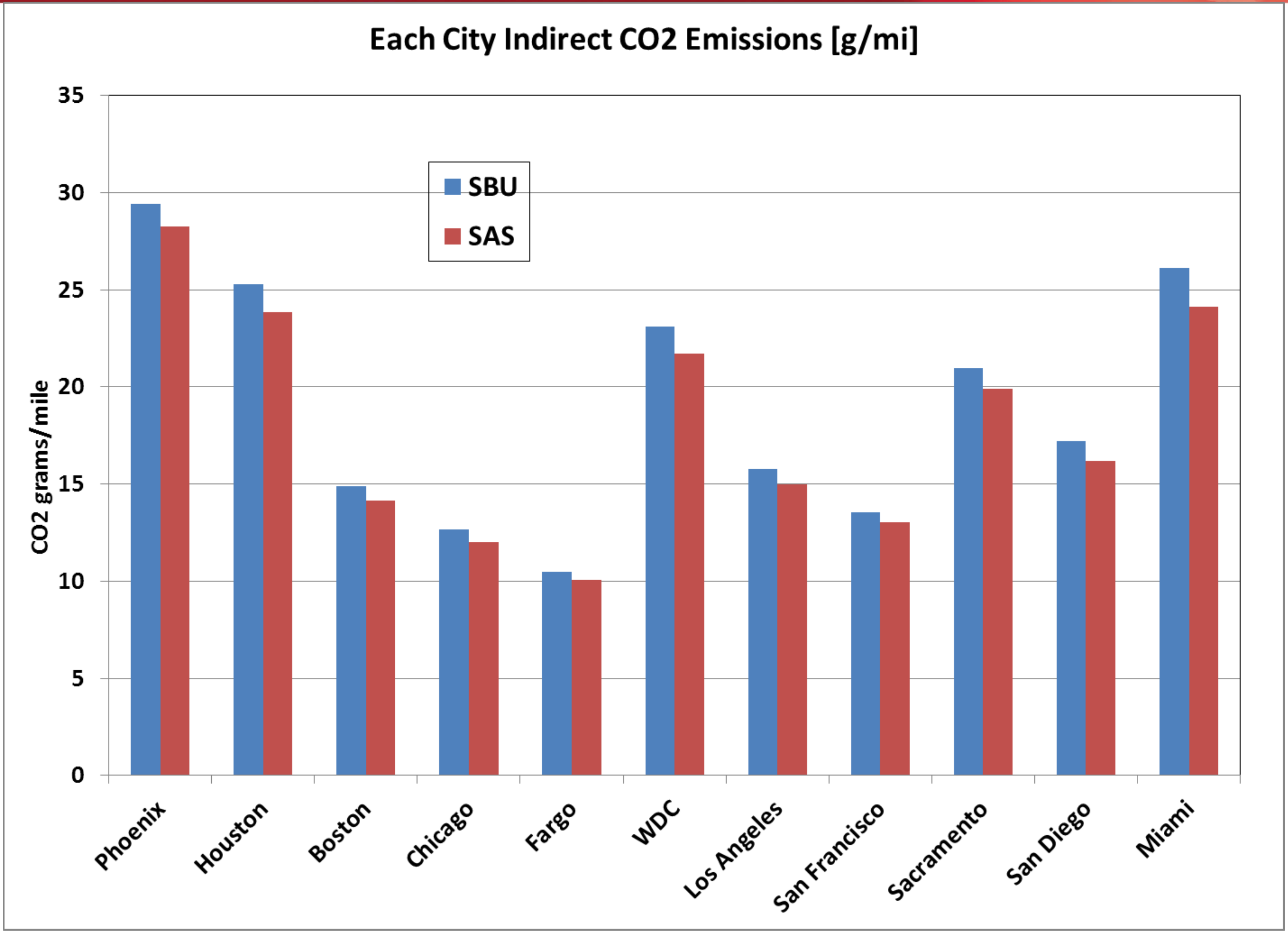


COP for SAS is higher at middle ambient (as expected due to CS valve)

These values were entered into the LCCP model.

DENSO

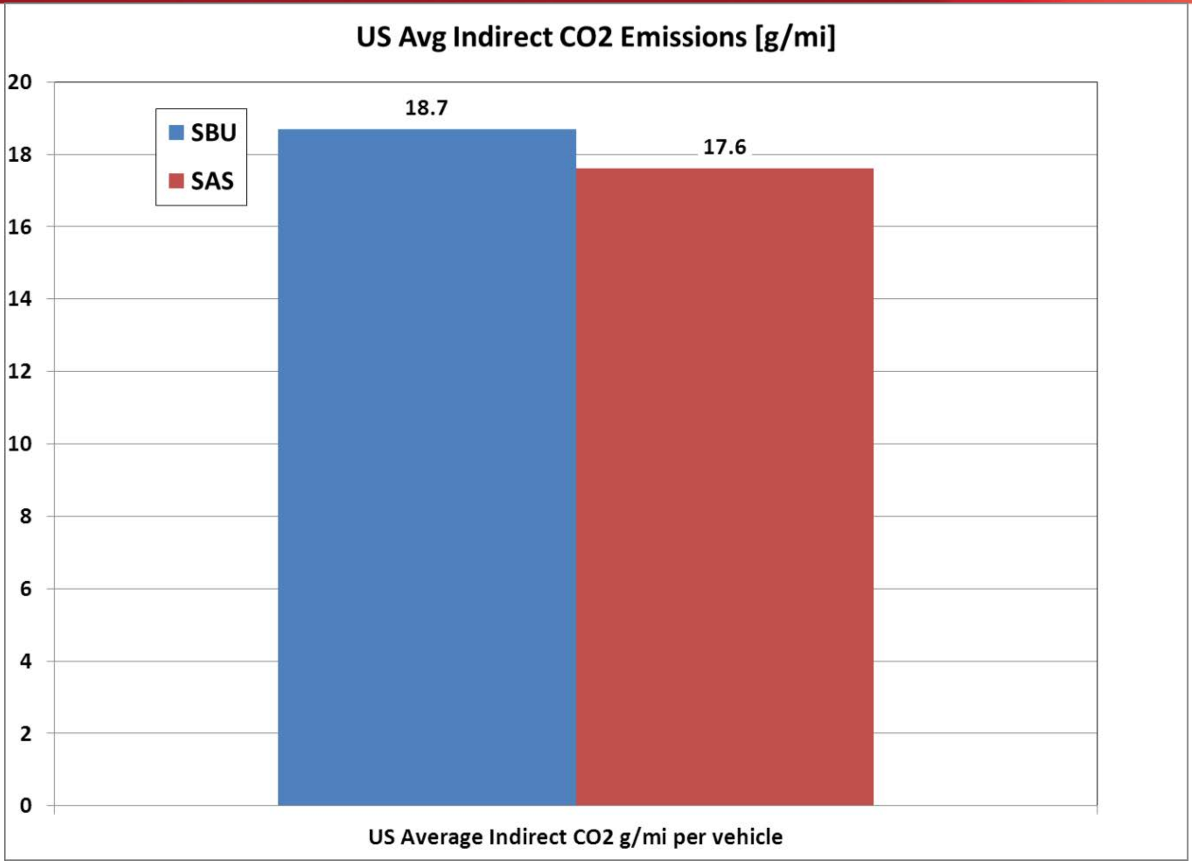
LCCP Results (per city)



Indirect CO_2 emissions for each US city.

DENSO

LCCP Results (US Average)



Average US Vehicle Indirect CO_2 Emissions	
SBU compressor	18.7 g/mi
SAS compressor	17.6 g/mi
Benefit of SAS compressor	**1.1 g/mi**

Off-cycle CO_2 credit of 1.1g/mi should be requested for the SAS compressor.

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Conclusion

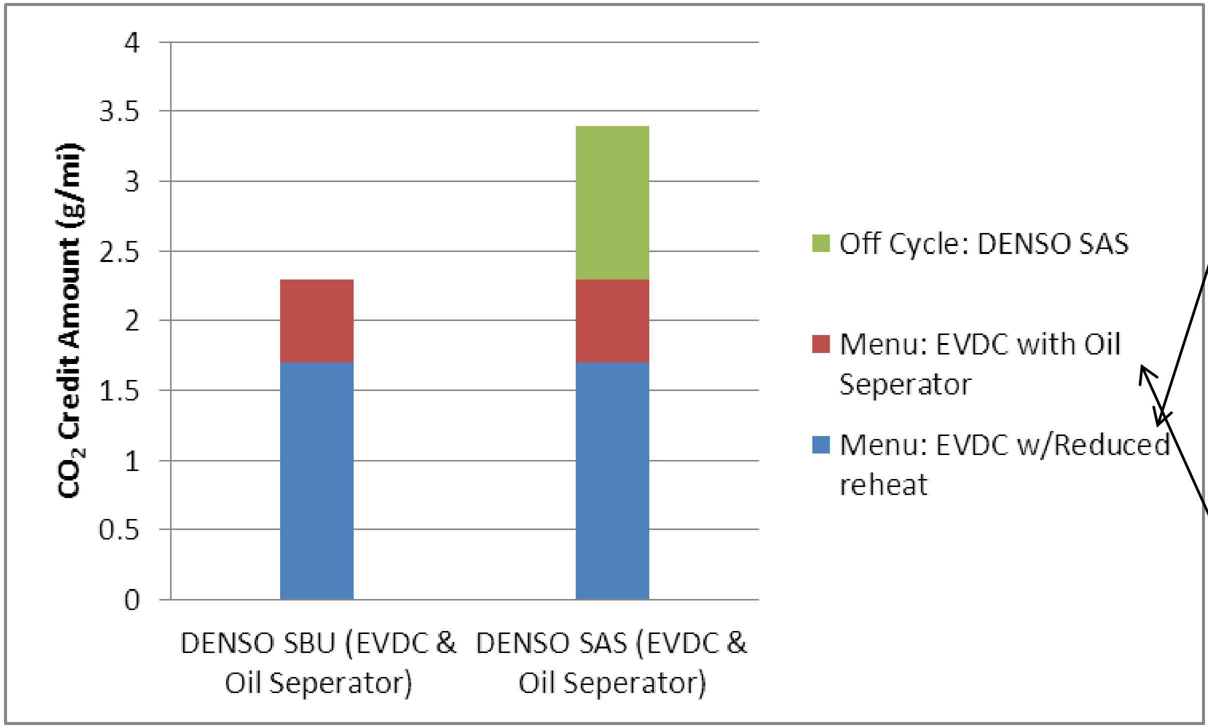


Table III.C.1-2 Efficiency-Improving A/C Technologies and Credits

Technology Description	Estimated Reduction in A/C CO_2 Emissions	A/C Efficiency Credit (g/mi CO_2)
Reduced reheat, with externally-controlled, variable-displacement compressor	30%	1.7
Reduced reheat, with externally-controlled, fixed-displacement or pneumatic variable-displacement compressor	20%	1.1
Default to recirculated air with closed-loop control of the air supply (sensor feedback to control interior air quality) whenever the ambient temperature is 75 °F or higher (although deviations from this temperature are allowed if accompanied by an engineering analysis)	30%	1.7
Default to recirculated air with open-loop control air supply (no sensor feedback) whenever the ambient temperature 75 °F or higher lower temperatures are allowed)	20%	1.1
Blower motor controls which limit wasted electrical energy (e.g., pulse width modulated power controller)	15%	0.9
Internal heat exchanger	20%	1.1
Improved condensers and/or evaporators (with system analysis on the component(s) indicating a COP improvement greater than 10%, when compared to previous industry standard designs)	20%	1.1
Oil Separator (with engineering analysis demonstrating effectiveness relative to the baseline design)	10%	0.6

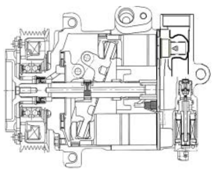
We believe the total benefit for SAS or SES compressor should be 3.4 g/mi credit (Menu Credits + Off Cycle)

Based on 2012-2016 Regulation

DENSO

Conclusion

SAS/SES Compressor Off-Cycle (1.1 g/mi)



- **OEM A**
  - C Segment 6SAS14
  - SUV 7SAS17
- **OEM B**
  - C Segment 6SAS14
  - Mini – Van 7SAS18
- **OEM C**
  - C Segment 6SES14

Our assumption is this data supporting the 1.1 g/mi credit can be applied to any vehicle using SAS or SES compressor.

DENSO

Enclosure C – Compressor Bench Test Data and LCCP Modeling

See separate excel file attachment:

Enclosure C-Compressor Bench Test Data and LCCP Modeling.xls

FIAT CHRYSLER AUTOMOBILES

SAS technology
Final AC17 Testing Results
& Bench Test Report

SAS COMPRESSOR RESULTS

Date	Test	g/mi	Ywm	Emissions Difference On/Off (g/mi)	Notes	Observations
3-Jan	SC03 - A/C On - Solar On	401.500	313.250	16.950	6	OK
	HFET - A/C On - Solar On	225.000				
	SC03 - A/C Off - Solar Off	374.000	296.300			
	HFET - A/C Off - Solar Off	218.600				
5-Jan	SC03 - A/C On - Solar On	401.100	312.000	17.250	5	OK
	HFET - A/C On - Solar On	222.900				
	SC03 - A/C Off - Solar Off	373.100	294.750			
	HFET - A/C Off - Solar Off	216.400				
11-Jan	SC03 - A/C On - Solar On	392.800	307.800	22.400	3	OK
	HFET - A/C On - Solar On	222.800				
	SC03 - A/C Off - Solar Off	367.000	285.400			
	HFET - A/C Off - Solar Off	203.800				
13-Jan	SC03 - A/C On - Solar On	406.600	316.700	19.550	4	OK
	HFET - A/C On - Solar On	226.800				
	SC03 - A/C Off - Solar Off	374.800	297.150			
	HFET - A/C Off - Solar Off	219.500				

SAS AVERAGE: 19.04 g/mi

SBH COMPRESSOR RESULTS

Date	Test	g/mi	Ywm	Emissions Difference On/Off (g/mi)	Notes	Observations
9-Dec	SC03 - A/C On - Solar On	411.600	320.500	23.150	4	OK
	HFET - A/C On - Solar On	229.400				
	SC03 - A/C Off - Solar Off	374.100	297.350			
	HFET - A/C Off - Solar Off	220.600				
12-Dec	SC03 - A/C On - Solar On	404.500	315.050	20.500	6	OK
	HFET - A/C On - Solar On	225.600				
	SC03 - A/C Off - Solar Off	373.300	294.550			
	HFET - A/C Off - Solar Off	215.800				
13-Dec	SC03 - A/C On - Solar On	403.400	312.800	21.750	5	OK
	HFET - A/C On - Solar On	222.200				
	SC03 - A/C Off - Solar Off	370.800	291.050			
	HFET - A/C Off - Solar Off	211.300				
14-Dec	SC03 - A/C On - Solar On	405.400	314.650	23.400	3	OK
	HFET - A/C On - Solar On	223.900				
	SC03 - A/C Off - Solar Off	370.100	291.250			
	HFET - A/C Off - Solar Off	212.400				

SBH AVERAGE: 22.20 g/mi

SAS Benefit to Emissions

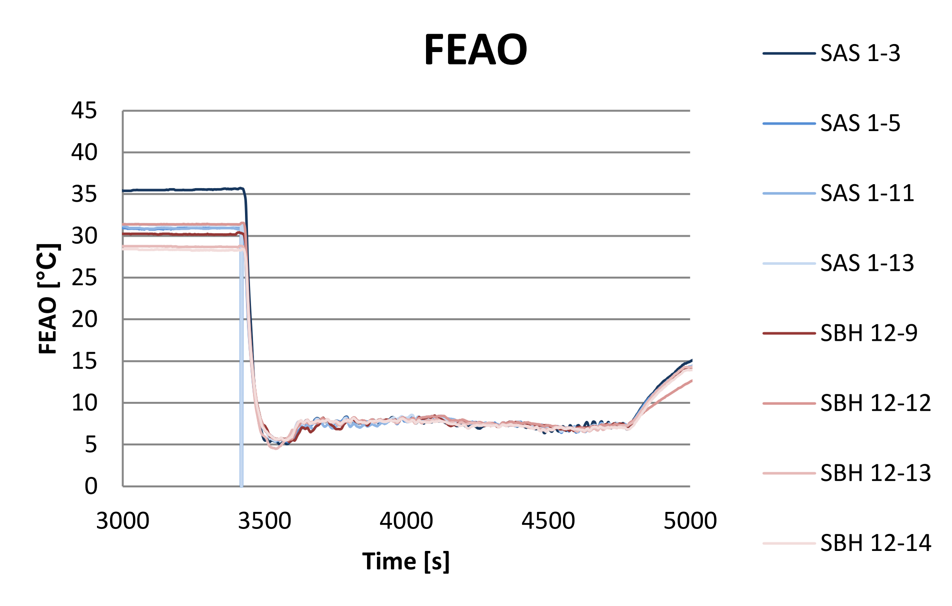
SBH AVERAGE: 22.20 g/mi
SAS AVERAGE: 19.04 g/mi → **SAS IMPROVEMENT ON VEHICLE: 3.16g/mi**

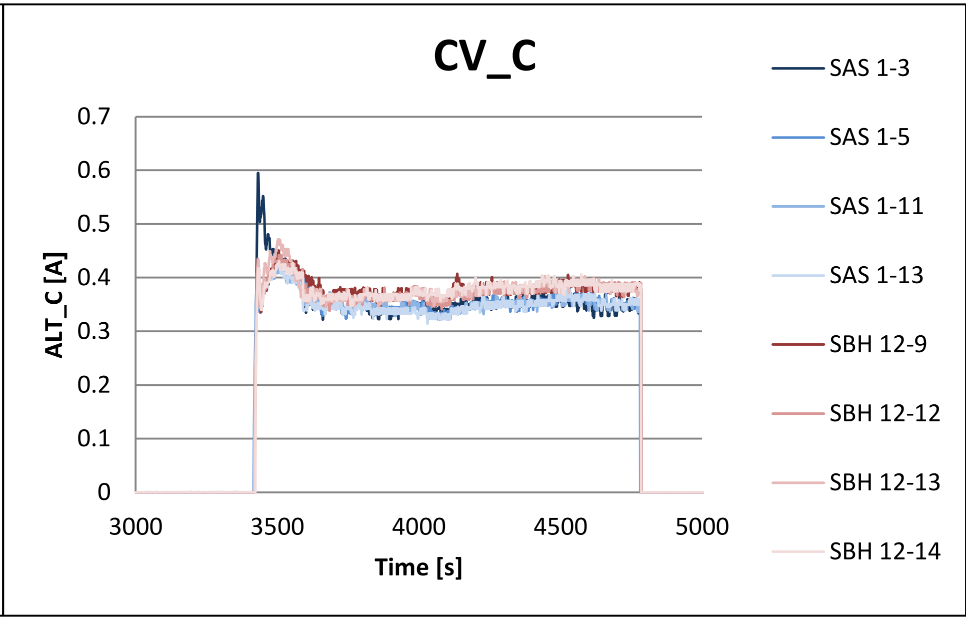
SAS compressor is shown to have an average emissions improvement of 3.16 g/mi.
DENSO opinion is that this vehicle emission improvement value meets expectations for SAS.
This result was expected based on previous test results.

The observed test-to-test variation meets DENSO expectation based on previous vehicle testing. This variation is likely due to fluctuation in performance of vehicle systems that were not monitored during the course of this test.

DENSO's request is to proceed with the credit value of 1.1 grams CO2 / mile observed from bench test data and U.S. LCCP calculations. The credit value based on bench test data can be considered to be more precise due less variation (as noted in the vehicle system). However, the vehicle test data provides valuable confirmation and supporting evidence.

Chrysler AC17 Testing – SBH / SAS Comparison





Key Conclusions of AC17 vehicle test:

1. FEAO pattern is repeatable for all 8 runs (4 SAS / 4 SBH) being used for comparison.
2. Control valve current is approximately 20-30mA lower for the 4 SAS runs.

We conclude that the compressor is working less to achieve the same evaporator air out temperature. This indicated that emissions would be lower for SAS than SBH (emissions values from previous data pages confirm this to be true).

→ Emissions improvement is achieved with SAS Compressor

This trend meets DENSO expectations for SAS performance vs. SBH performance.

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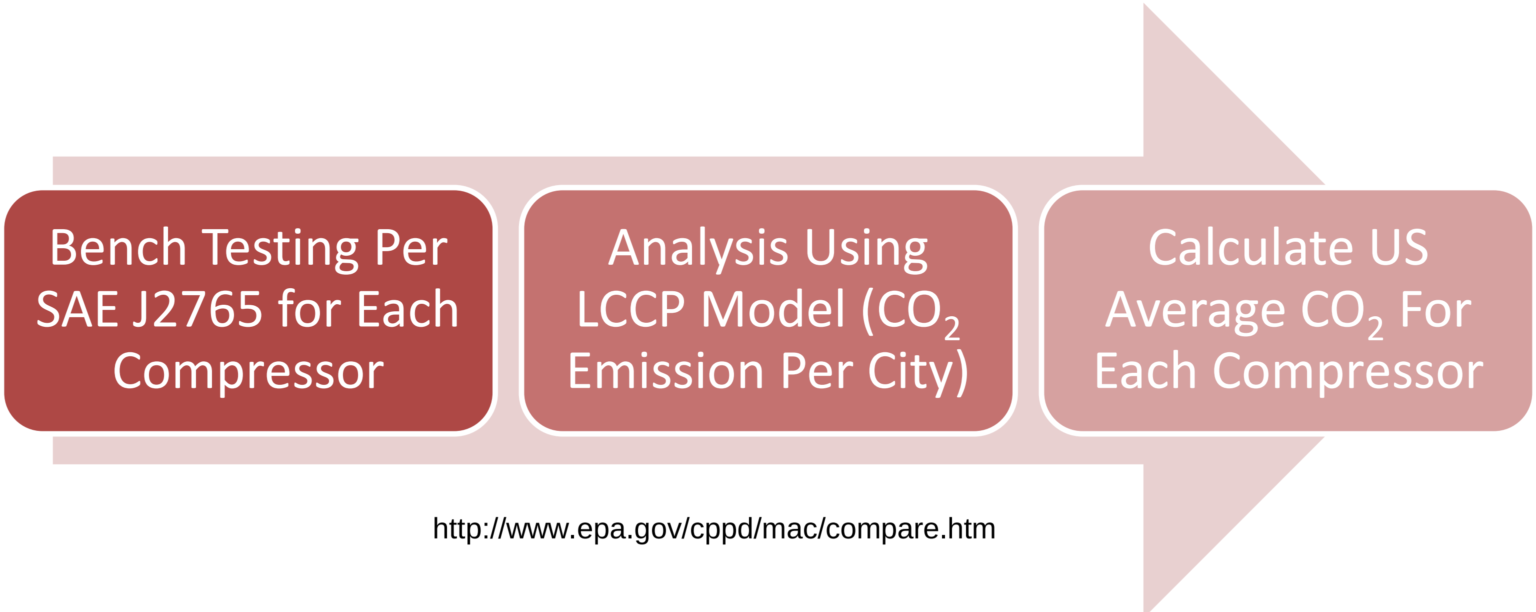
Bench Summary – Off cycle Engineering Analysis Method



http://www.epa.gov/cppd/mac/compare.htm

LCCP is an existing method to estimate CO2 impact of MAC systems. It was developed by EPA, GM, SAE, and JAMA.

LCCP analysis can be used as an acceptable engineering analysis method for determining the off-cycle CO2 emissions impact for SAS compressor.

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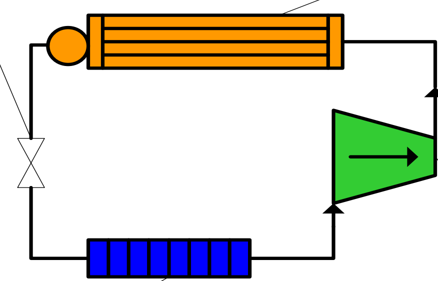
Test Bench System – Generic System



Thermal Expansion Valve
- Set Point = 2.1kPa @ 0°C (1.0ton)
- Slope = 0.7 bar

Condenser
- W600mm x H422.4mm x D16mm
- Fin Height = 5.5 mm
- Tube Thickness = 1.0mm
- Fin pitch ~ 3.15mm
- Configuration: 1 Pass + Sub-cool (55-11)
- Integrated Receiver / Dryer

Evaporator
- W306.5mm x H201mm x D38mm
- Fin Height = 5 mm
- 4 pass : 22-23-23-22
- Tube Thickness = 1.7 mm

Compressor 6SBU14 & 6SAS14
- Pulley Ratio = 2.15
- Oil Amount = 100 g
- Refrigerant Charge:
  R-134a: 650 grams

All components were common during testing of the 6SBU14 and 6SAS14 compressors.

DENSO

Test Conditions (J2765)

Test Name	Simulated Ambient Temp. [C]	Compressor Speed [RPM]	Cond Air In Temp [C]	Cond Face Velocity [m/s]	Evap Air In Temp [C]	Evap Humidity [%]	Air Mass Flow [kg/min]	Air Flow Volume [m3/h]	Air Flow Volume [CFM]	Simulated Air Selection	Evap Air Out Target Temp [C]
I60	45	900	60	1.5	35	25	9.0	475	280	Recirc	3
I45	45	900	45	1.5	35	25	9.0	475	280	Recirc	3
L45	45	1800	45	2.0	35	25	9.0	475	280	Recirc	3
M45	45	2500	45	3.0	35	25	9.0	475	280	Recirc	3
H45	45	4000	45	4.0	35	25	9.0	475	280	Recirc	3
I50a	35	900	50	1.5	35	40	9.0	477	281	OSA	3
I35a	35	900	35	1.5	35	40	9.0	477	281	OSA	3
L35a	35	1800	35	2.0	35	40	9.0	477	281	OSA	3
M35a	35	2500	35	3.0	35	40	9.0	477	281	OSA	3
H35a	35	4000	35	4.0	35	40	9.0	477	281	OSA	3
I40a	25	900	40	1.5	25	80	6.5	337	198	OSA	3/10
I25a	25	900	25	1.5	25	80	6.5	337	198	OSA	3/10
L25a	25	1800	25	2.0	25	80	6.5	337	198	OSA	3/10
M25a	25	2500	25	3.0	25	80	6.5	337	198	OSA	3/10
H25a	25	4000	25	4.0	25	80	6.5	337	198	OSA	3/10
I40c	25	900	40	1.5	25	50	6.5	334	197	OSA	3/10
I25c	25	900	25	1.5	25	50	6.5	334	197	OSA	3/10
L25c	25	1800	25	2.0	25	50	6.5	334	197	OSA	3/10
M25c	25	2500	25	3.0	25	50	6.5	334	197	OSA	3/10
H25c	25	4000	25	4.0	25	50	6.5	334	197	OSA	3/10
I30	15	900	30	1.5	15	80	6.5	322	190	OSA	3/10
I15	15	900	15	1.5	15	80	6.5	322	190	OSA	3/10
L15	15	1800	15	2.0	15	80	6.5	322	190	OSA	3/10
M15	15	2500	15	3.0	15	80	6.5	322	190	OSA	3/10
H15	15	4000	15	4.0	15	80	6.5	322	190	OSA	3/10

All conditions were run for each compressor

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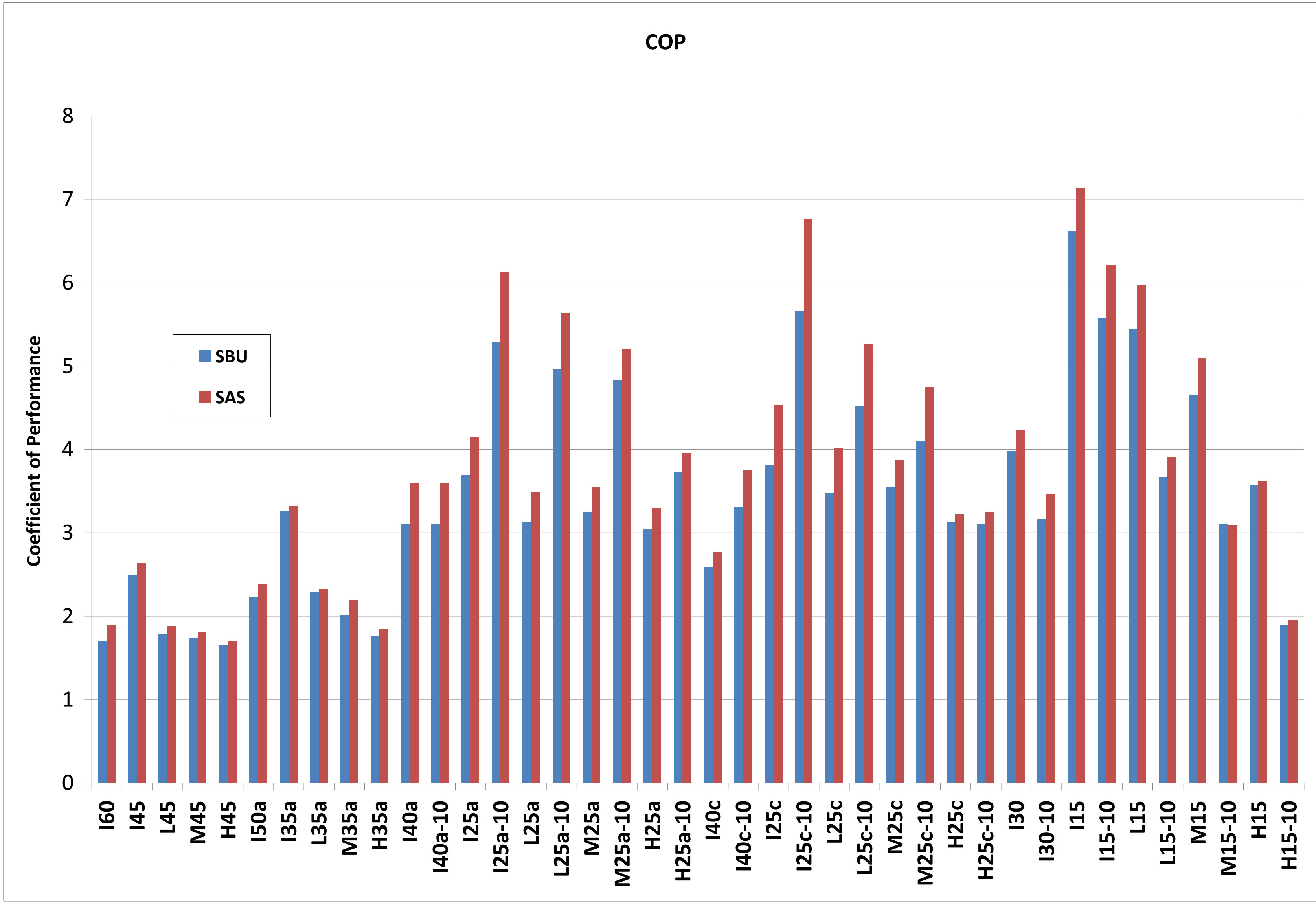
Test Result



COP for SAS is higher at middle ambient (as expected due to CS valve)

These values were entered into the LCCP model.

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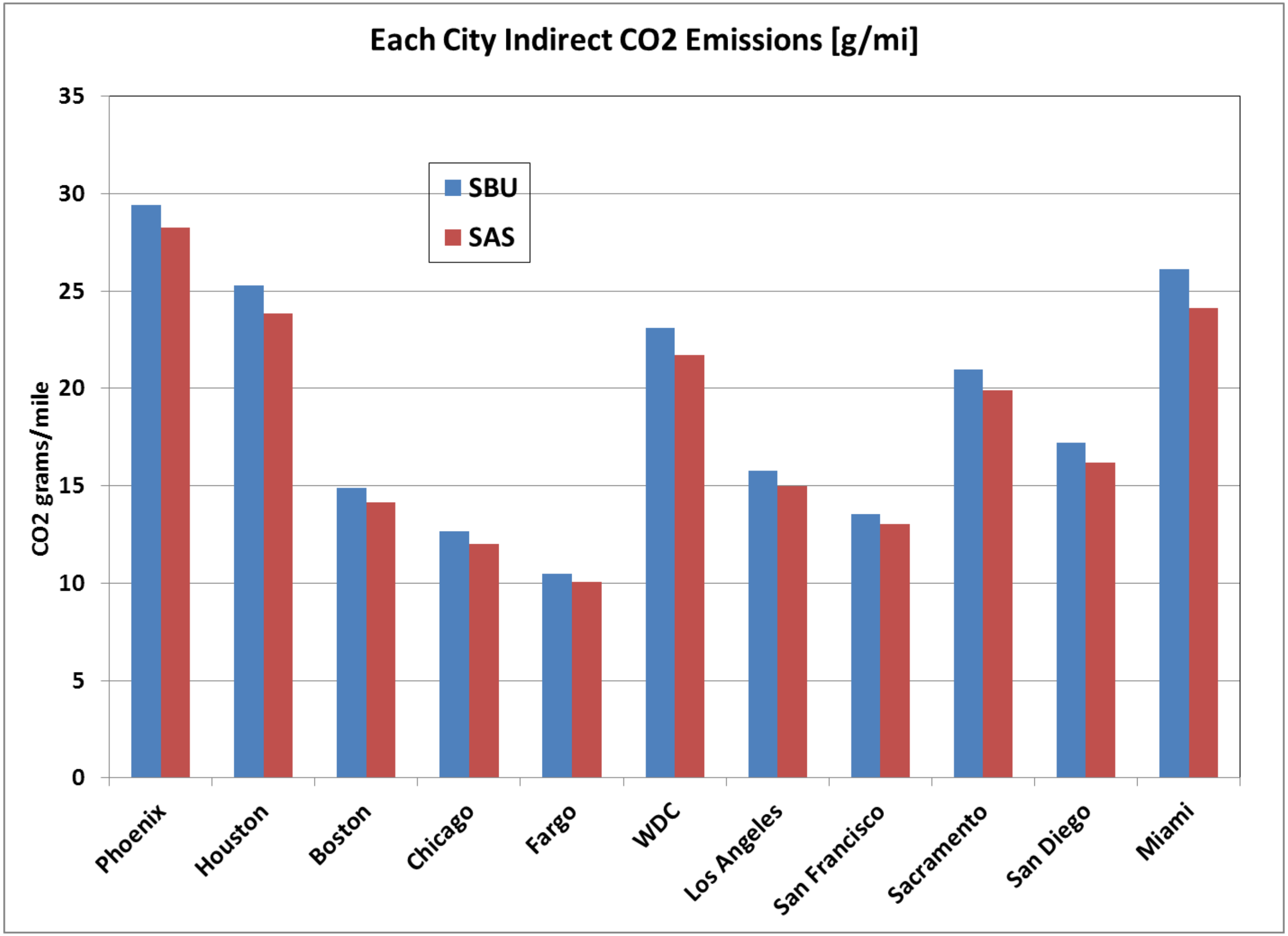
LCCP Results (per city)



Indirect CO_2 emissions for each US city.

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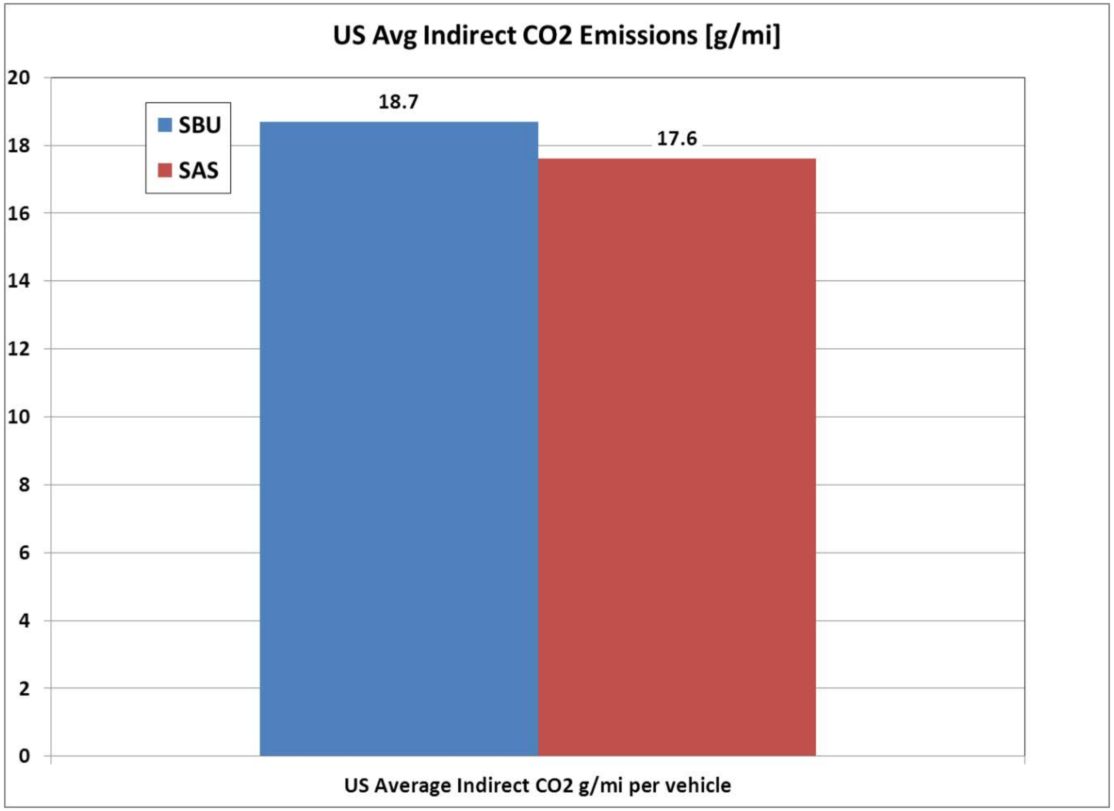
LCCP Results (US average)



Average US Vehicle Indirect CO_2 Emissions	
SBU compressor	18.7 g/mi
SAS compressor	17.6 g/mi
Benefit of SAS compressor	**1.1 g/mi**

Off-cycle CO_2 credit of 1.1g/mi should be requested for the SAS compressor.

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