BMW Group

January 19, 2017

Mr. Linc Wehrly, Director
Light-Duty Vehicle Center
Compliance Division
Office of Transportation and Air Quality
U.S Environmental Protection Agency
2000 Traverwood Drive
Ann Arbor, MI 48105

Subject: BMW Request for Greenhouse Gas Credit for Variable Crankcase Suction Valve Technology

Dear Mr. Wehrly,

Pursuant to the provisions of 40 CFR § 86.1869-12(d), the BMW Group requests an off-cycle greenhouse gas (GHG) credit of 1.1 grams CO2 per mile for the use of the Denso SAS air conditioner compressor with variable crankcase suction (CS) valve technology. This improved air conditioner (A/C) compressor was first used by BMW in 2- and 3-series cars with 4- or 6-cylinder gasoline engines. It is now implemented in additional BMW and MINI models and will be used more widely in the future. In December 2014, GM requested off-cycle GHG credits for the use of this identical Denso SAS A/C compressor and subsequently received EPA approval in September 2015. BMW's request for GHG Credit for Variable Crankcase Suction Valve Technology corresponds directly to GM's request in terms of background, technology description and off-cycle application, and therefore, is referenced accordingly (please see copy posted at https://www.epa.gov/vehicle-and-engine-certification/general-motors-gm-compliance-materials-light-duty-greenhouse-gas). BMW-specific data is included in the following paragraphs modified from this GM request.

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Bench Tests

The Denso SAS compressor was evaluated by Denso using the methodologies that were developed and used during the SAE IMAC Cooperative Research Program for its evaluations of U.S. average system efficiency. These methodologies have been formally adopted as publicly available SAE standards. The SAE J2765 standard specifies a series of 40 bench tests at various compressor speeds to measure the system coefficient of performance (COP). Twenty five of these bench test conditions are then selected as inputs to the GREEN MAC Lifecycle Climate Change Performance (LCCP) model jointly developed for comparative evaluations by General Motors, EPA, the Japanese Automobile Manufacturers Association, and SAE (GREEN is an acronym for Global Refrigerants Energy and Environmental). These twenty five data points replicate a broad range of operating conditions for various ambient climate conditions and air conditioner system modes. This LCCP model has been adopted as the SAE J2766 standard.

The GREEN MAC LCCP model includes U.S. climate data for numerous U.S. cities as well as vehicle on-road operation parameters. Data sources are thoroughly documented within the model, but some of the key parameters are temperature and humidity data from a U.S. Department of Energy (DOE) database that contains U.S. National Climatic Data Center data, annual driving distances for each city from the U.S. Energy Information Agency (EIA), and percentage of drive time at different ambient conditions based on research by the National Renewable Energy Laboratory (NREL). Combining the J2765 bench test COP data with the NREL, EIA and DOE climate and vehicle on-road data provides a simulation of annual U.S. average greenhouse gas emissions for an air conditioning system.

Bench tests were performed by Denso using the J2765 procedure for both the SAS and the SBU compressor. The results are contained in Attachment A. Denso reviewed this data with the EPA technical specialists for mobile air conditioners in April 2013 (see Attachment B for this Denso presentation). The feedback was positive, but Denso was instructed to work with an OEM on any greenhouse gas credit request. Denso subsequently approached GM and later on also BMW to jointly develop this credit application, and the subsequent testing and credit application preparation has been coordinated between Denso and BMW technical experts.

BMW did the LCCP analysis for the Denso SAS compressor, resulting in a U.S. average indirect emissions due to A/C vehicle operation of 16.2 grams CO2 per mile per vehicle. The same analysis was also performed for the Denso SBU compressor, which is a modern externally controlled variable displacement compressor (EVDC) design that does not have the variable CS valve technology. The SBU compressor is currently used on a variety of BMW vehicles, e.g. before implementing the new 4 cylinder and 6 cylinder gasoline engine family. The SBU compressor qualifies for the 1.7 grams CO2 per mile mobile air conditioner (MAC) credit under the EPA regulation, and, as such, constitutes a valid comparative baseline to determine if the SAS compressor with variable CS valve technology deserves an additional off cycle credit for emission reductions beyond those already achieved by compressors that qualify for the EPA EVDC MAC credit. (Both compressors also feature integrated oil separators, and both qualify for the MAC credit of 0.6 grams CO2 per mile.) The SBU compressor achieved an LCCP Indirect Emissions due to A/C Vehicle Operation result of 17.3 grams CO2 per mile, which is 1.1 grams CO2 per mile higher than the SAS compressor. Based on this analysis, vehicles equipped with the SAS compressor featuring variable CS valve technology should receive an off-cycle credit of 1.1 grams CO2 per mile (see Attachment C).

Note: Denso's absolute LCCP results differ slightly from BMW LCCP calculation, an offset which is probably caused by vehicle specific input data; the improvement of SAS versus SBU is the same: 1.1 grams CO2 per mile with Denso and BMW calculation.

Vehicle Tests

While this bench test procedure provides an accurate measurement of the expected benefits for U.S. national average climate conditions and driving patterns, consultation on potential off-cycle credit with EPA's off-cycle technical specialist revealed a desire to see the benefits documented through actual vehicle testing. The AC17 test – which is mandatory to apply for MAC credits and therefore widely accepted for representative A/C-caused CO2 emissions – was selected to measure benefits under conditions that are representative of average U.S. air conditioner operating conditions.

BMW chose a 3-series vehicle with a new 4 cylinder engine (B48) for "A to B testing"; it is already equipped with Denso 6SAS14 compressor. The predecessor of B48 engine – the N20 engine – was equipped with Denso 6SBU14 and it was possible to install this Denso 6SBU14 in the car with a B48 engine with minor modifications of the system. We could avoid side effects due to line routing changes or other interactions. This optimal comparison of SAS to SBU was only possible in this car family of 1-/2-/3-/4- series BMW models with rear wheel drive. Additional future vehicles using SAS compressors might have different passenger cabin volumes and A/C loads:

- slightly smaller in MINI, future BMW 1-series
- significant larger in BMW 5- to 7-series and BMW X-models

We consider the analysis in a 3-series car not at the minimum fleet A/C performance but certainly below the average BMW fleet A/C performance. By using the Denso SAS compressor, the average BMW fleet improvement in fuel consumption should be even higher than demonstrated in this BMW 3-series car. Therefore, the demonstrated improvement in fuel consumption and CO2 emissions in the 3-series car is a conservative representative for the BMW fleet.

Vehicle Test Results

Six full AC17 tests were conducted each of them with SC03 and HWFET cycles (three tests for the SAS compressor, three tests for the baseline SBU compressor). Detailed test results are contained in Attachment D. The following table summarizes the average data supporting an average savings of 1.2 grams CO2 per mile for the SAS compressor with variable CS valve technology:

Grams CO2 per mile	Combined
SAS Compressor average of three tests	26.4
SBU Compressor average of three tests	27.6
Differential (credit)	1.2

This vehicle data, measuring a 1.2 gram CO2 per mile benefit on the AC17 test, is consistent with the credit value of 1.1 grams CO2 per mile estimated from the bench tests data and U.S. LCCP calculations. We are basing our credit request on the LCCP Analysis using the bench test data, which reflects the annual U.S. average performance for an air conditioning system. However, the vehicle test data provide important confirmation that the benefits of the variable crankcase suction valve compressor technology are measurable in comparable amounts on actual vehicle tests.

Conclusion

Based on the bench test and vehicle test data presented in this petition, combined with calculation procedures in the Lifecycle Climate Change Performance tool, BMW hereby requests that EPA approve an off-cycle GHG of 1.1 grams CO2 per mile for all vehicles equipped with the Denso SAS compressor with variable crankcase suction valve technology. This 1.1 gram credit amount has been estimated to be representative of the fuel savings that can be expected from this technology in actual real-world usage in U.S. national average climate conditions.

BMW Group

Thank you for your consideration of this application for off-cycle GHG credits. Should you have any questions regarding this submission, please contact Stephen Sinkez of my staff at 201-571-5069 or stephen.sinkez@bmwna.com.

Sincerely yours,

Dr. Christian Cozzarin
Department Manager
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Attachment A – Denso Compressor Bench Test Data
Attachment B – Denso Presentation to EPA, April 2013
Attachment C – BMW LCCP Analysis
Attahcment D – BMW AC17 Vehicle Test Data