TOYOTA

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December 7th, 2017

Mr. Linc Wehrly
Compliance Division
Light-Duty Vehicle Center
Office of Transportation and Air Quality
U.S. Environmental Protection Agency
2565 Plymouth Road
Ann Arbor, Michigan 48102

Subject: Request for 2013MY and later Off-Cycle Credits related to application of the DENSO SAS/SES Air Conditioning Compressor with CS Valve Technology.

This correspondence represents Toyota's application for Off-Cycle credit of 1.1 grams CO2 per mile for the use of the DENSO SAS/SES air conditioning compressor incorporating the variable crankcase suction (CS) valve technology. The credit amount has been determined using the alternative methodology outlined in 40 CFR § 86.1869-12(d), details of which can be found on the following pages of this correspondence.

Per 40 CFR § 86.1869-12, vehicle manufacturers may obtain off-cycle credits for the use of a CO2-reducing technology whose benefits are not adequately captured on the Federal Test Procedure and/or the Highway Fuel Economy Test. This application is submitted in accordance with the provisions of subsection (d), which enables manufacturers to earn credits by demonstrating that the applicable technology provides GHG reduction benefits via an alternative EPA-approved methodology.

Should any questions arise concerning this matter, please do not hesitate to contact our office at your earliest convenience.

Thank you very much for your consideration of Toyota's application and we would look forward to any additional dialog regarding this credit request.

Sincerely,

Takashi Nishikiori
Executive/Group Manager
TOYOTA MOTOR NORTH AMERICA
Unit Function and Powertrain | Powertrain Certification and Test Engineering

Attachment: **Request for GHG/CAFE Off-Cycle Credit for DENSO Variable Crankcase Suction Valve Technology Compressors**

Overview:

Pursuant to 40 CFR 86.1869-12(d), 49 CFR 531.6(b), and 49 CFR 533.6(c) Toyota requests approval of the following methodology to determine Off-Cycle CO2 credits from the DENSO variable capacity air conditioning (A/C) compressor with variable crankcase suction (CS) valve technology for 2013 model year and subsequent model year vehicles. Toyota proposes the use of a single off-cycle credit value of 1.1 g/mile for all vehicles equipped this A/C compressor technology. The credit value has been determined from bench testing procedures, verified by vehicle AC17 testing, and is consistent with results published from other manufactures.

- General Motor's received EPA's approval of this technology in September 2015
- Ford, BMW, & Hyundai have applied for off-cycle credit using this technology in 2017

Toyota's Off-Cycle credit application is seeking approval based on the same A/C compressor technology resulting in the same credit level as was covered in EPA's earlier approval of GM's request.

System Description:

When compared to current compressor technology, DENSO's SES & SAS A/C compressor incorporating variable CS valve offers improvements in energy consumption reduction. Current A/C compressor technology use a fixed CS throttle valve which is required to handle both high and low flow rate conditions. Designed in this manner proves to be inefficient at low and average flow rates because the CS valve needs to be sized to handle max flow rates of the system. Alternatively, the SES & SAS A/C compressor utilizes a variable CS valve which is able to adjust the flow rate to optimally handle these different flow rate situations, thus improving overall system efficiency.

For example,

(i). Under maximum flow conditions the larger CS valve opening can provide stable increased flow rate to achieve maximum capacity more quickly at compressor start up.

(ii). During lower flow rate operation, the valve can control the flow through the crank chamber reducing internal compressor losses and increasing efficiency at variable conditions.

(iii). The optimized valves reduce suction and discharge pressure loss within the A/C compressor.

As a result, the addition of the variable CS valve offers improvements to the compressor over the previous externally-controlled variable displacement compressor designs.

While SES & SAS Compressors both have the variable CS valve, the main difference between the systems is that the SAS compressor incorporates a compressor clutch while the SES does not. The inclusion of a clutch allows for

engine load reduction when the compressor is off during low mode operating conditions. Otherwise, both systems operate in a similar manner during mid load (AC17 test) and high load conditions. Therefore, verification of the GHG benefit via AC17 testing would lead to the same credit value for both systems.

Additional details of the system are documented in Attachment A.

Rationale for Using EPA's Alternative Demonstration Methodology:

(1). The DENSO SES & SAS A/C compressor with variable CS valve technology is not currently available as a credit on EPA's pre-approved technology menu.

(2). In considering, the 5-cycle methodology which 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 DENSO SES & SAS A/C compressor with variable CS valve is the increased efficiency improvements obtained when the A/C system is turned on. However, the 5-cycle test methodology would not fully realize the impact of the measured CO2 emissions for the following reasons.

a) The SC03 cycle is the only cycle that incorporates A/C usage.
b) The SC03 test requires A/C to be run a maximum during the cycle.
c) 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 these reasons, it was determined that the improved air conditioning efficiency on a vehicle would not be fully captured using the 5-cycle methodology.

As this variable CS valve technology also provides benefit under milder ambient conditions when A/C is not operating at maximum capacity, Toyota has chosen to pursue off-cycle credits under the alternative demonstration methodology pursuant to 40 CFR § 86.1869-12(d).

Proposed Alternative Demonstration Methodology:

(1). Bench Test Results

An engineering analysis of the DENSO A/C compressors was conducted by DENSO to demonstrate the benefit of the variable CS valve. 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 formal SAE standards. 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.

The engineering analysis was conducted by DENSO and resulted in an average U.S. vehicle indirect CO2 emissions value of 18.7 g/mile based on the LCCP model for the DENSO base level A/C compressor without the variable CS valve (SBU A/C compressor). The same analysis was conducted on the DENSO new compressor with the variable CS valve (SAS A/C compressor) and resulted in an average U.S. vehicle indirect CO2 emissions value of 17.6 g/mile based on the LCCP model. Both A/C compressors are externally-controlled variable displacement compressors and the difference of these A/C compressors is just whether the variable CS valve is equipped or not. Then the analysis shows an improvement of 1.1 g/mile for the variable CS valve. These results are documented in Attachment A.

(2).Vehicle Testing Results

To validate the bench testing methodology a series of vehicle tests were also run using the two types of DENSO A/C compressors (with variable CS valve and without variable CS valve.) Due to issues previously discussed concerning the SC03 test, the AC17 test was chosen to quantify the compressor improvement as it is more representative of the average U.S. air conditioner operating conditions.

A 2014MY Corolla was chosen as the test vehicle because it is equipped with smallest displacement A/C compressor with variable CS valve. Since Toyota will apply a single credit value to all vehicles equipped with variable CS valve, Toyota considered the worst-case vehicle for determining variable CS valve credit value.

The Corolla was retrofitted to run a series of tests with both DENSO A/C compressors the SES (variable CS valve equipped) and the SEU (baseline technology level of SES and without variable CS valve technology). To validate the benefit, 3 tests were conducted with the variable CS valve SES A/C compressor installed and 3 tests were conducted with the fixed CS valve SEU A/C compressor installed.

The complete set of test data is available in Attachment B. The following tables summarize the results of both conditions the full data set.

Toyota AC17 Testing (Table1)

A/C compressor system	AC17 Test (A/C_ON-A/C_OFF) Results (g/mile)
SES A/C compressor (New compressor with variable CS valve)	23.7
SEU A/C compressor (compressor without variable CS valve)	25.1
Credit	1.4

The results demonstrate the actual GHG benefits resulting from the DENSO variable CS valve technology and also serves to validate the bench testing and modeling analysis that was previously conducted by DENSO. The resulting benefit of 1.4 g/mile is also comparable to the bench testing and LCCP model analysis conducted by DENSO. Additional validation comes from GM's vehicle test results of 1.3 g/mile that were used in establishing a credit 1.1 g/mile. Due to the variability that results from full vehicle testing and the AC17 test procedure, the more conservative value from the bench testing data conducted by DENSO will be applied to establish a credit value of 1.1 g/mile for vehicles equipped with this technology.

Durability:

Air conditioning compressors installed within Toyota vehicles 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 DENSO variable CS valve. Durability testing is conducted to meet Toyota specifications and meet full useful life requirements.

Conclusion:

Based on the bench test and vehicle data presented in this application, combined with the calculation procedures in the LCCP model, Toyota hereby requests that EPA approve the use of a 1.1 g/mile CO2 credit for all vehicles equipped with the DENSO SES & SAS A/C compressor utilizing this variable

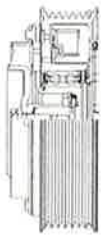
CS valve technology. This 1.1 g/mile credit amount has been estimated to be representative of the indirect fuel savings and subsequent GHG emissions reductions that can be expected from this technology in actual real-world usage in US national averaging climate conditions.

The credit will be applicable for vehicles with the technology installed for 2013 and subsequent model years. A list of the vehicle models which are equipped with the technology and projected future vehicles along with an estimate of the off-cycle benefit by vehicle model is provided in Attachment C. The fleet credit will be calculated based on credit for each type of vehicle, vehicle lifetime miles and U.S. sales volume for 2013 model year products and beyond.

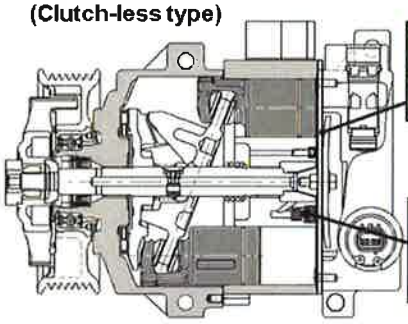
Attachment A - **System Description and Compressor Bench Test Data by DENSO**

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

SAS
(Clutch type)



SES
(Clutch-less type)



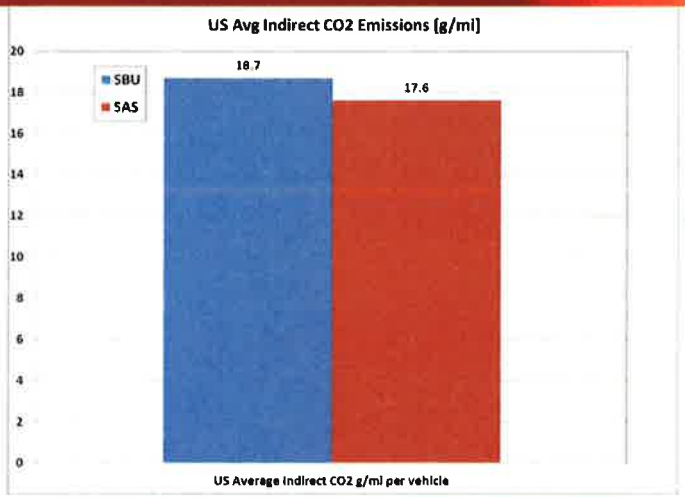
<Efficiency>
Change the structure of valve to optimize suction and discharge pressure loss.

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

***SAS is clutch type, SES is clutch-less type. Their compressor internal design are same.**

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

LCCP Results (US Average)



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

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

Attachment B - **AC17 Toyota Vehicle Test Data**

AC17 vehicle test result

		New Technolgy	Base Level Technology	
		SES w/ variable CS valve (g/mile)	SEU w/o variable CS valve (g/mile)	
AC17 Test Results	N1	26.6	26.3	
	N2	19.9	23.3	
	N3	24.6	25.6	"result from SEU" – "result from SES"(g/mile)
	Ave.	23.7	25.1	1.4

Attachment C - **A list of the vehicle models which are equipped with variable CS valve technology.**

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