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Title: Request for 2017 model year and later GHG off-cycle credits

1. Regulatory background of this document

Title 40 of Code of Federal Regulations §86.1869-12, hereby referred to as §86.1869-12, allows manufacturers to generate credits for CO_2-reducing technologies where the CO_2 reduction benefit of the technology is not adequately captured on the Federal Test Procedure and/or the Highway Fuel Economy Test. These optional credits are referred to as "off-cycle" credits. The manufacturer must use one of the three options specified in §1869-12 to determine the CO_2 grams per mile credit applicable to an off-cycle technology. This application is requesting approval to apply off-cycle credit to all 2017 model year (MY) and later Honda and Acura vehicles for a high-efficiency alternator based on the method described in "Technology demonstration using alternative EPA-approved methodology" in §86.1869-12(d).

2. Description of our Methodology

2-1. Electrical power saving by improving alternator efficiency

An alternator is a generator that converts mechanical power from an engine into electrical power, which is consumed by the vehicle systems such as lighting, audio, and vehicle control systems. Improvement of alternator efficiency (as shown in Eq.1) reduces engine load thus leading to CO_2 reduction.

$$\frac{Electrical\ \ Power\ \ \text{(Watts)}}{Required\ \ Mechanical\ \ Power\ \ \text{(Watts)}} = Alternator\ \ Efficiency\ \ \text{(\%)}$$

・・・Eq.1

Using the 2010MY Accord as an example, Honda's in-house 2-cycle (i.e. FTP and HFET) test result in 237 Watts as an average electrical power output of alternator. An alternator with 67% efficiency requires engine mechanical power as calculated below:

$$\frac{237\ \ \text{(Watts)}}{Required\ \ Mechanical\ \ Power\ \ \text{(Watts)}} = 67\ \ \text{(\%)}$$

$$Required\ \ Mechanical\ \ Power\ \ \text{(Watts)} = 354\ \ \text{(Watts)}$$

Under the same electrical power output of alternator (237 Watts), the required engine mechanical power with a 70% alternator efficiency is calculated as below:

$$\frac{237\ \ \text{(Watts)}}{Required\ \ Mechanical\ \ Power\ \ \text{(Watts)}} = 70\ \ \text{(\%)}$$

$$Required\ \ Mechanical\ \ Power\ \ \text{(Watts)} = 339\ \ \text{(Watts)}$$

If the alternator with 67% efficiency was supplied with the 339 Watts mechanical power from engine, the electrical power which the alternator could produce is estimated as below.

$$\frac{Electrical\ \ Power\ \ (\text{Watts})}{339\ \ (\text{Watts})} = 67\ \ (\%)$$

$$Electrical\ \ Power\ \ (\text{Watts}) = 227\ \ (\text{Watts})$$

A summary of the above data is shown below in Table 1.

Table 1. Electrical power comparison by different mechanical power input

Alternator Efficiency	Mechanical Power Input (Watts)	Electrical Power (Watts)
67%	354	237
	339 (Required mechanical power input for 70% efficiency alternator to produce 237 Watts)	227

The 10 Watts electrical power difference above is considered "equivalent electrical power saving" of 70% alternator efficiency equipped on 2010MY Accord compared to "baseline" alternator with 67% efficiency.

In this application document, we use the 67% as the baseline alternator efficiency where the efficiency is determined in accordance with the Verband de Automobilindustrie (VDA) approach. Applying the VDA approach and the 67% VDA efficiency as the baseline alternator is common in the automotive industry and widely used in the Eco-innovation technology application under the European Union regulations[1].

2-2. Off-cycle credit depending on electrical load reduction

According to Table 2 below, which references EPA and NHTSA's "*Joint Technical Support Document: Final Rulemaking for 2017-2025 Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards (EPA-420-R-12-901, August 2012)*", hereby referred to as EPA and NHTSA's Joint Technical Support Document, reducing the vehicles electrical load by 100 Watts saves an average of 2.5 g/mile of GHG on the 2-cycle and 3.2 g/mile of GHG on the 5-cycle.

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1 COMMISSION IMPLEMENTING DECISION (EU) 2016/588 of 14 April 2016

Table 2. Reference to 17-25MY GHG/CAFE final rule's Technical support document

Table 5-18: Simulated GHG reduction benefits of 100W reduction in electrical load over FTP/HW and 5-cycle tests

Driving Cycle	Electrical Load	Small Car [g/mile]	Mid-Size Car [g/mile]	Large Car [g/mile]	Pick-up Truck [g/mile]	Average* [g/mile]
FTP/Highway	100W Load Reduction	156.8	187.7	246.5	416.6	
	Base	154.2	185.5	244.1	413.9	
	2-Cycle Difference	2.5	2.2	2.4	2.7	2.5
5-Cycle	100W Load Reduction	217.8	256.9	331	544.5	
	Base	214.6	254.1	327.9	541.1	
	5-Cycle Difference	3.2	2.8	3.1	3.4	3.2
	5-Cycle/2-Cycle Difference	0.7	0.6	0.6	0.7	0.7

* based on a sales average

Therefore, the GHG difference between 5-cycle and 2-cycle is calculated as follows:

$$\text{GHG Difference} = 3.2\frac{\text{g}}{\text{mi}} \times \left(\frac{\textit{Electrical power saving at 5 cycle}}{100 \text{ Watts}}\right) - 2.5\frac{\text{g}}{\text{mi}} \times \left(\frac{\textit{Electrical power saving at 2 cycle}}{100 \text{ Watts}}\right) \quad \cdots \text{Eq.2}$$

Considering the actual on-road electrical power saving, the "Electrical power saving at 5-cycle" is replaced with "On-road electrical power saving" in the equation (Eq.2) above and the Eq.2 is modified for calculating GHG off-cycle credit as follows.

$$\text{Credit} = 3.2\frac{\text{g}}{\text{mi}} \times \left(\frac{\textit{On-road Electrical Power Saving}}{100 \text{ Watts}}\right) - 2.5\frac{\text{g}}{\text{mi}} \times \left(\frac{\textit{Electrical Power Saving at 2 cycle}}{100 \text{ Watts}}\right) \quad \cdots \text{Eq.3}$$

In the following subsection 2-3 and 2-4, we verify the "On-road electrical power saving" and "Electrical power saving at 2-cycle" in the equation above (Eq.3) for our existing vehicles.

2-3. Verification of on-road electrical power saving

To determine the electrical power distribution from the alternator into each vehicle systems, we used existing on-road driving data for 2010MY Accord (Passenger Car) and 2010MY Acura MDX (Light Truck). The data was originally used for internal monitor purpose and was not originally intended for measuring on-road electrical power distribution.

The initernal monitor consisited of 2 parts. Part 1 was data collected from vehicles driven by Honda associates and their families in 3 locations. With part 2, Honda contracted with a third party agency to collect driving data from 2010MY Accord and 2010MY MDX owners in 9 locations throughout the United States. The on-road driving data from a total of 380 vehicles was collected and summarized in Table 3.

Table 3. Driving location and number of vehicles investigated

Driving area	Note	Number of vehicles
1. Los Angels County, CA	High Honda sales area	Accord = 16, MDX = 15 (Honda associates and their families)
2. Dallas, TX	High density Southwest	Accord = 15, MDX = 16 (Honda associates and their families)
3. Fulton County, GA	High density South	Accord = 15, MDX = 15 (Honda associates and their families)
4. Cook County, IL	High density Midwest	Accord = 15, MDX = 15 (Customers)
5. Maricopa County, AZ	Extreme dry heat weather	Accord = 15, MDX = 15 (Customers)
6. Jefferson County, AL	Hot humid weather	Accord = 16, MDX = 16 (Customers)
7. Salt Lake County, UT	High altitude, dry snow weather	Accord = 16, MDX = 17 (Customers)
8. Hennepin, Ramsey, MN	Extremely cold weather	Accord = 16, MDX = 16 (Customers)
9. Worcester County, MA	High wet snow weather	Accord = 16, MDX = 15 (Customers)
10. El Paso County, TX	Highest speeds	Accord = 21, MDX = 17 (Customers)
11. Queens County, NY	High density North	Accord = 15, MDX = 15 (Customers)
12. Multnomah County, OR	High rain fall	Accord = 15, MDX = 17 (Customers)

Using the on-road driving data, we investigated the electrical power output of alternator for each vehicle across varied ambient temperatures between 15F to 130F. Data with ambient temperatures above 105F were excluded, because that condition is outside of the scope of the GHG regulation as shown in Table 4 below of EPA and NHTSA's Technical Support Document.

Table 4. Reference to 17-25MY GHG/CAFE final rule Technical support document

Table 5-28 MOVES data of vehicle miles traveled (VMT) as a function of ambient temperature.

VMT	tempAvg	Fraction	Temp Range VMT Fraction
1181.656796	-25	0.00000157	
4400.79767	-20	0.00000585	
12905.217	-15	0.00001714	
40874.20742	-10	0.00005429	
174939.1854	-5	0.00023235	
762497.0884	0	0.00101274	
1915732.576	5	0.00254446	
4924729.91	10	0.00654097	
12353230.63	15	0.01640743	0.21958689
23259876.93	20	0.03089353	(< 40 deg F)
31418211.75	25	0.04172934	
41033016.47	30	0.05449962	
49426375.28	35	0.06564760	
55404781.78	40	0.07358805	
60396251.48	45	0.08021767	
63018086.25	50	0.08369996	
68380740.42	55	0.09082259	
73176481.47	60	0.09719224	0.68343503
72473451.14	65	0.09625848	(> 40 deg F, < 80 deg F)
67073984.17	70	0.08908697	
54637578.9	75	0.07256906	
39382139.05	80	0.05230695	
24182451.73	85	0.03211888	
7635253.418	90	0.01014106	
1203687.536	95	0.00159873	0.09697809
593360.565	100	0.00078810	(>80 deg F)
18352.30991	105	0.00002438	
752904571.9	TotalVMT	1.00000000	

In addition, we excluded data of trips of 0.5 miles or less because these short trips are considered unrepresentative. We summarized the data as shown in Table 5 and Figure 1-1 and 1-2.

Table 5. Summary of on-road data collection

	2010MY Honda Accord	2010MY Acura MDX
Total number of trip	6,546	7,205
Total driving mileage	61,625	67,598
Average trip mileage	9.41	9.38
Average trip time (min)	21	21

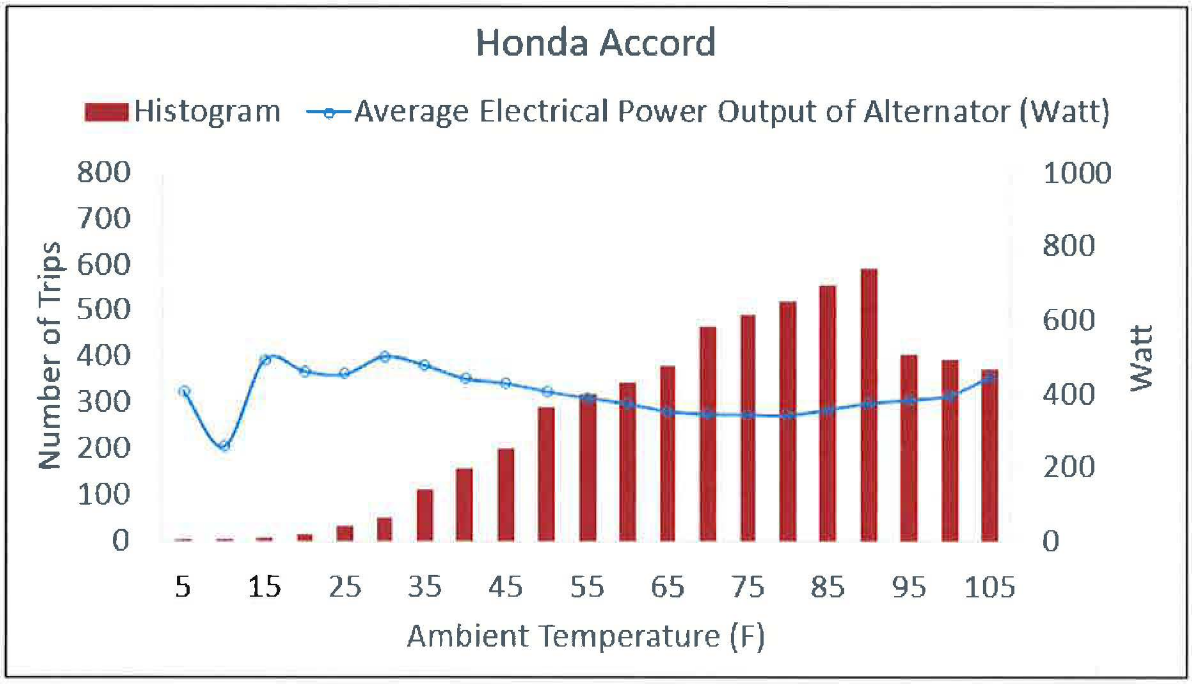

Fig. 1-1. On-road electrical power output of alternator (2010MY Honda Accord)

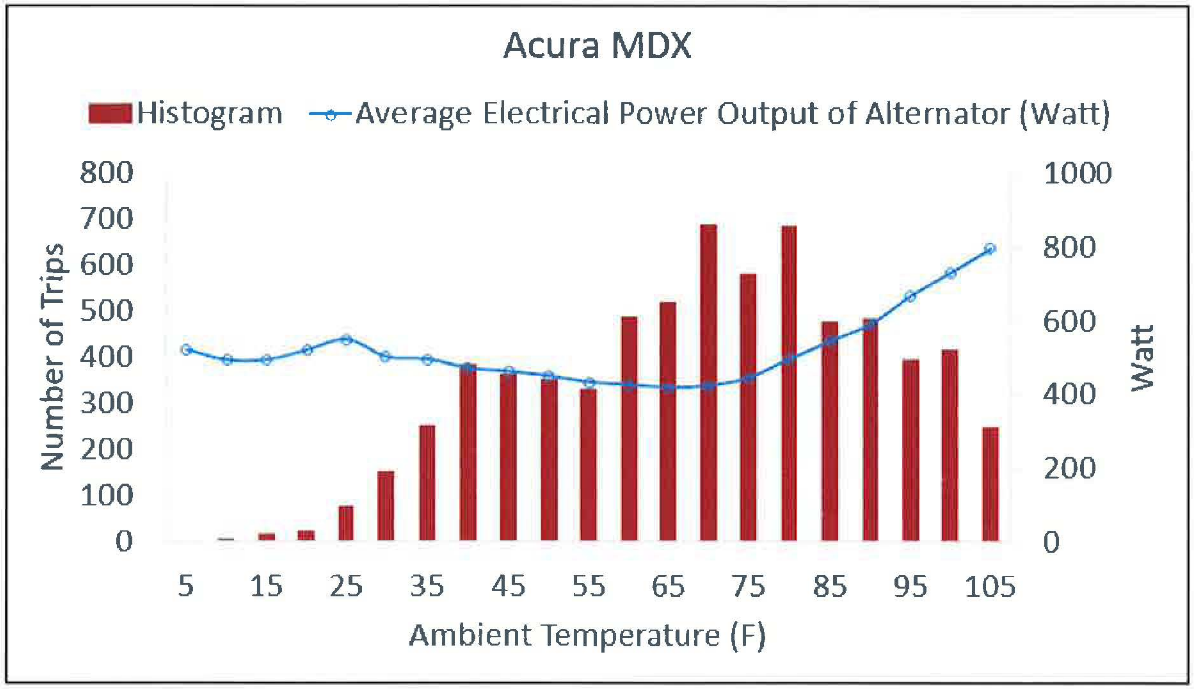

Fig. 1-2. On-road electrical power output of alternator (2010MY Acura MDX)

By using Vehicle Mileage Travelled (VMT) for each ambient temperature in "MOVES", we weighted each electrical power usage with each ambient temperature. The average on-road electrical power output of alternator is shown in Table 6.

Table 6. Average on-road electrical power output of alternator

2010MY Accord	2010MY MDX
400 Watts	464 Watts

Using the methodology shown in subsection 2-1 of this document, the "On-road electical power saving" in equation "Eq.3" was calculated as shown in Table 7.

The measured wattage only captured variable power consumption and not the constant power consumption (e.g. ECU, etc.), thus resulting to a more conservative calculation.

Table 7. Calculation process of on-road electrical power saving

	Note	Accord	MDX
A. On-road electrical power output of alternator		400 Watts	464 Watts
B. Required mechanical power (70% alternator efficiency)	A / 0.7	571 Watts	663 Watts
C. Equivalent on-road electrical power production by 67% efficiency alternator in case required mechanical power for 70 % efficiency alternator was supplied	B x 0.67	383 Watts	444 Watts
D. On-road electrical power saving	A - C	17 Watts	20 Watts

2-4. Verification of "2-cycle electrical power saving".

Honda investigated the electrical power output of alternator at 2-cycle certification testing for 2010MY Accord and MDX. In the equation in subsection 2-2 (Eq.3), the "2-cycle electrical power saving" data was used to calculate the results shown in Table 8.

Table 8. Calculation process of 2-cycle electrical power saving

	Note	Accord	MDX
a. 2-cycle electrical power output of alternator		237 Watts	242 Watts
b. Required mechanical power (70% alternator efficiency)	a / 0.7	339 Watts	346 Watts
c. 2-cycle electrical power production by 67% efficiency alternator in case required mechanical power for 70 % efficiency alternator was supplied	b x 0.67	227 Watts	232 Watts
d. 2-cycle electrical power saving	a - c	10 Watts	10 Watts

2-5. Off-cycle credit for alternator efficiency improvement

By substituting the calculated results in subsection 2-3 and 2-4 into the equation in subsection 2-2 (Eq.3), the off-cycle credit for a vehicle with 70% efficiency alternator is calculated as follows, where the on-road and 2-cycle electrical power saving is arithmetic average of Accord and MDX.

$$\text{Credit} = 3.2\frac{\text{g}}{\text{mi}} \times \left(\frac{On\text{-}road\ Electrical\ power\ saving}{100\ \text{Watts}}\right) - 2.5\frac{\text{g}}{\text{mi}} \times \left(\frac{Electrical\ power\ saving\ at\ 2\ cycle}{100\ \text{Watts}}\right)$$

$$\text{Credit} = 3.2\frac{\text{g}}{\text{mi}} \times \left(\frac{18.5\ \text{Watts}}{100\ \text{Watts}}\right) - 2.5\frac{\text{g}}{\text{mi}} \times \left(\frac{10\ \text{Watts}}{100\ \text{Watts}}\right)$$

$$\text{Credit} = 0.342\ \text{g/mi}$$

(at 70% alternator efficiency)

The credit calculation using methodologies in section 2-3 through 2-5 was repeated for varying alternator efficiencies and the results are shown in Table 9.

Table 9. Calculated off-cycle credit of high efficiency alternator

Alternator efficiency (%)	Unrounded credit (g/mi)	Rounded credit (g/mi)
67 or less	N/A	N/A
68	0.1330	0.1
69	0.2090	0.2
70	0.3420	0.3
71	0.4465	0.4
72	0.5350	0.5
73	0.6485	0.6
74	0.7370	0.7
75	0.8345	0.8
76	0.9355	0.9
77	1.0045	1.0
78	1.1145	1.1
79	1.1995	1.2
80	1.2810	1.3

2-6. Simulation using EPA's GHG simulation tool "ALPHA"

EPA provides a vehicle GHG simulation tool called "ALPHA". The Fig.2 below compared our proposed credit (triangle plots) and GHG reduction simlated by ALPHA (circle plots) for each alternator efficiency. The simulation result by ALPHA showed good correlation with our proposed credit providing support that Honda's proposed methodology and calculation are valid.

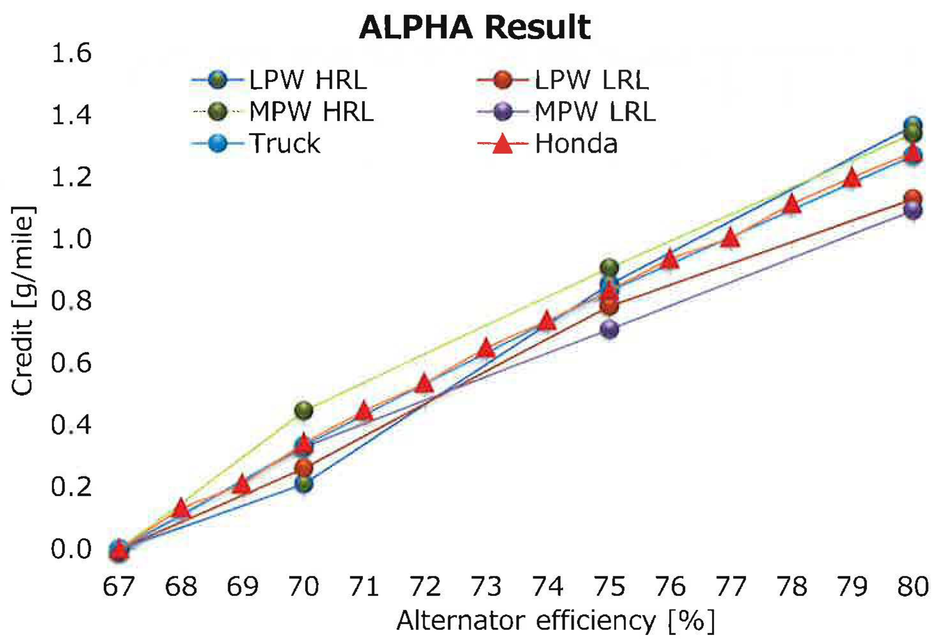

Fig. 2. Comparison of proposed credit (Honda) and simulation by ALPHA

3. Compliance Statement

High-efficiency alternators installed on Honda and Acura vehicles meet Honda internal specifications and durability is assured for the full useful life of applicable GHG regulatory requirements. In addition, §86.1869-12 says "Off-cycle credits may not be earned for technologies installed on a motor vehicle to attain compliance with any vehicle safety standard or any regulation set forth in Title 49 of the Code of Federal Regulations." We state that alternator installed on our vehicle is not a technology to attain compliance with any vehicle safety standard or any regulation set forth in Title 49 of the Code of Federal Regulations.

4. Reference

- "Application for High Efficiency Alternator Off-Cycle GHG Credit", Ford Motor Company, June 21, 2016.
- "EPA Decision Document: Off-Cycle Credits for BMW Group, Ford Motor Company, and Hyundai Motor Company", EPA-420-R-17-010, December 2017, U.S. Environmental Protection Agency

5. Request of EPA's approval

Honda kindly requests EPA to approve the off-cycle credit values for high efficiency alternators as proposed in Table 9 of this document for all 2017 model year and later Honda and Acura vehicles.

Respectfully submitted,

By:____________________

Printed Name: Tommy Chang

Senior Manager

American Honda Motor Co., Inc.