Application of US Fuel Economy Regulatory Mechanisms to the Kingdom of Saudi Arabia (KSA)

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Off Cycle and A/C Credits

Background

In the MY 2012-2016 Final Rule, the EPA introduced the off-cycle credits program.[1] The purpose was to provide auto manufacturers with an option to generate credits for employing new and innovative technologies that achieve GHG reductions that are not reflected on the current two-cycle test procedures.

In the MY 2017-2025 Final Rule, NHTSA applied the off-cycle credit program to CAFE[2]. NHTSA reasoned that the improved efficiencies of these off-cycle technologies provide real world fuel economy benefits and allow vehicles to go farther on a gallon of gas.

Separately, EPA and NHTSA also recognized that efficiency improvements in A/C systems aren't captured on the drive cycle.

In support of the MY 2017-2025 Final Rule, the agencies published a Technical Support Document (TSD).[3] In chapter 5.2 of the TSD, the Agencies delineate their support and scientific evidence for inclusion of credits for off-cycle technologies in both the EPA and NHTSA programs. Chapter 5.2 of the TSD states:

> EPA employs a five-cycle test methodology to evaluate fuel economy for fuel economy labeling purposes. For GHG and CAFE compliance, EPA uses the established two-cycle (city, highway or correspondingly FTP, HFET) test methodology. EPA recognizes that there are technologies that provide real-world GHG benefits to consumers, but that the benefit of some of these technologies is not represented on the two-cycle test.

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[1] Federal Register Vol. 70, No. 88, Environmental Protection Agency, Department of Transportation, Light Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards; Final Rule, Friday, May 7, 2010, pages 25234-25728.

[2] Federal Register Vol. 77, No. 199, Environmental Protection Agency, Department of Transportation, 2017 and Late Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards; Final Rule, Monday, October 15, 2012, pages 62623-63200.

[3] 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, page 5-25, 26.

> The estimates of these credits were largely determined from research, analysis and simulations, rather from full vehicle testing, which would have been cost and time prohibitive. However, actual vehicle testing was used to either support or refine the credit estimates in cases where it was available.

The TSD includes detailed scientific justification for reducing or offsetting electrical loads, waste heat recovery, high efficiency exterior lights, use of solar panels, use of active aerodynamic improvements, use of advanced load reductions, use of thermal and solar control technologies, use of glazing, active seat ventilation, use of solar reflective paint, and use of passive and active cabin ventilation.

Separately, in the GHG emission standards, the US EPA has developed and NHTSA has adopted a process by which manufacturers can earn credit for design changes to A/C systems that improve real world fuel economy. This process is required because the test procedure employed in the US does not include A/C operation. The credits for A/C design changes in the US are directly tied to the frequency of air conditioning use and the load of the A/C system. Both the frequency of use and the loads are in turn a function of local or regional environmental conditions such as temperature and relative humidity. There are differences in temperature and humidity between the US and KSA. Generally KSA temperatures are warmer than US average temperatures, which leads to more A/C use in KSA. Thus, the A/C credits in KSA should be somewhat greater than they are in the US. This following develops the proposed KSA A/C credits based on temperature differences in KSA and the US.

Environmental Differences

A/C credits in the US are based on the nationwide average usage and year-round environmental conditions. Based on various studies and models, EPA calculated 11.9 and 17.2 g/mi as the increase in CO_2 due to A/C usage for cars and trucks respectively.[4] Manufacturers can earn credit for up to 42% of this value, which is the fraction that EPA believes A/C technology can reduce the A/C based CO_2.

However, these values were developed based on 28% A/C on time and A/C loads corresponding to 81 degrees F ambient temperature.[5,6] As Saudi Arabia is generally warmer than the US, A/C is

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[4] Ibid, page 5-26

[5] Ibid, page 5-29

[6] The 28% on time is a weighted average of 23.9% on time for manual systems and 35% for automatic systems. Manual systems are 62% of the market; automatic systems are 38% of the market. (0.62*23.9+0.38*35=28)

used more frequently and operates under higher load. Three corrections should be made to adjust for the differing environmental conditions between the US and Saudi Arabia:

1. Increased A/C On Time
2. Increased A/C Compressor Load
3. Increased Compressor Duty Cycle

1) Increased A/C On Time

Of all 50 states, Arizona is most similar to Saudi Arabia. Figures 1-3 in the appendix show the average temperatures, the average high temperatures, and the dew points for the 4 largest cities in Saudi Arabia (Riyadh, Jeddah, Mecca, and Medina) and the 2 largest cities in Arizona (Phoenix and Tuscon). In general, the charts show that the average temperatures and average high temperatures of the major cities of Saudi Arabia are warmer than the cities of Arizona. The dew point chart shows that Phoenix and Tuscon are like Riyadh and Medina in the winter months but become more humid like Jeddah and Mecca in the summer months.

An argument can certainly be made that A/C on time would be greater in Saudi Arabia than in Arizona based on the higher temperatures and more months of high temperatures. However, the value calculated by Meszler for Arizona in the NESCCAF report is recommended. [7] The A/C on percentage estimated in this report for Arizona is 58%. Since the A/C on time for the US average is 28%, this yields a correction factor of 2.07 for Saudi Arabia compared to the US.

2) Increased A/C Compressor Load and 3) Compressor Cycling

EPA used a vehicle simulation tool to calculate the 11.9 and 17.2 g/mi increases in CO_2 for cars and trucks respectively. The A/C load used in the simulation was for an A/C system operating in an ambient environment of 81 degrees F (27C). EPA noted that the A/C load used in the model incorporated the effects of compressor cycling. [3]

But EPA also recognizes that increasing the ambient temperature in which the A/C system operates will increase the load on the compressor and increase the compressor duty cycle. In support of the fuel economy label changes that started in 2008 MY, EPA developed relatively simple corrections for both load and duty cycle based on temperature. [8]

The equations are as follows:

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[7] Light Duty Vehicle Air Conditioning Final Report, prepared for Northeast States Center for a Clean Air Future by Meszler Engineering Services, July 28, 2004, page 37.

[8] Final Technical Support Document, Fuel Economy Labeling of Motor Vehicle Revisions to Improve Calculation of Fuel Economy Estimates, EPA-420-R-06-017, December 2006, page 74.

$$\text{Compressor Torque} = 1.70 + 0.084 * \text{Ambient Temperature (°F)}$$

And

$$\text{Compressor Engagement (fraction)} = 1.0535 \ln(\text{Ambient Temperature (F)}) - 3.9981$$

Using the ambient temperature for Arizona (86F) as representative of Saudi Arabia, and the US average (81F), corrections can be made for the differences between the US average and Saudi Arabia.

The correction for Compressor torque is as follows:

$$(1.7 + 0.084 \times 86)/(1.7 + 0.084 \times 81) = 1.05 \text{ correction factor}$$

This means compressor torque would, on average, be 5% higher in Saudi Arabia than in the US. The increased torque, at the same compressor speeds, means 5% more energy is used for A/C and 5% more fuel is used. Therefore, credits that save that fuel should also be 5% higher.

Similarly with the A/C compressor duty cycle:

$$(1.0535 \times \ln(86) - 3.9981)/(1.0535 \times \ln(81) - 3.9981) = 1.10 \text{ correction factor}$$

By similar logic as above, if the compressor is engaged 10% more, 10% more fuel is used and credits that save that fuel should be 10% higher.

Conclusion:

Based on the discussion above, A/C credits in KSA should be increased by factors of:

- 2.07 for the ratio of A/C on time
- 1.05 for the increase in load on the A/C compressor when the A/C clutch is engaged
- 1.10 for the increase in duty cycle of the A/C compressor

The total A/C credit multiplier is therefore 2.07 x 1.05 x 1.1 = 2.39

Attachment

Figure 1 – Average Monthly Temperatures in SA and Arizona

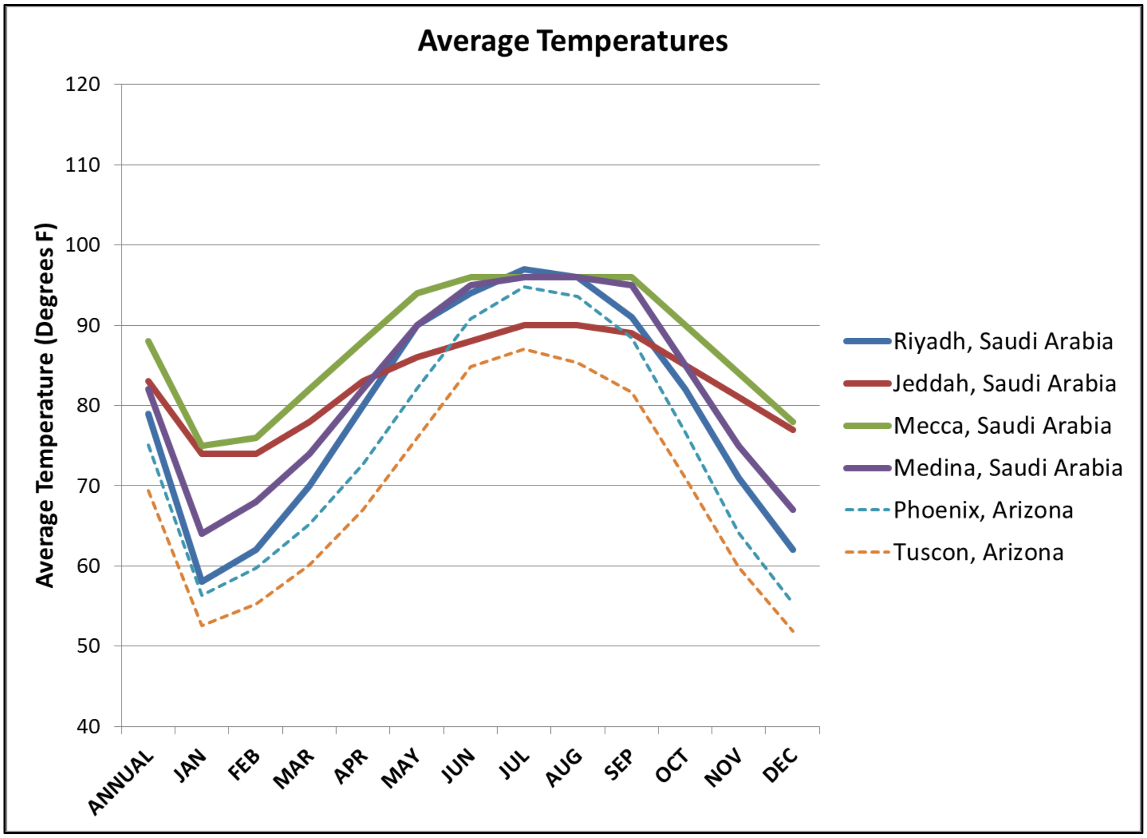
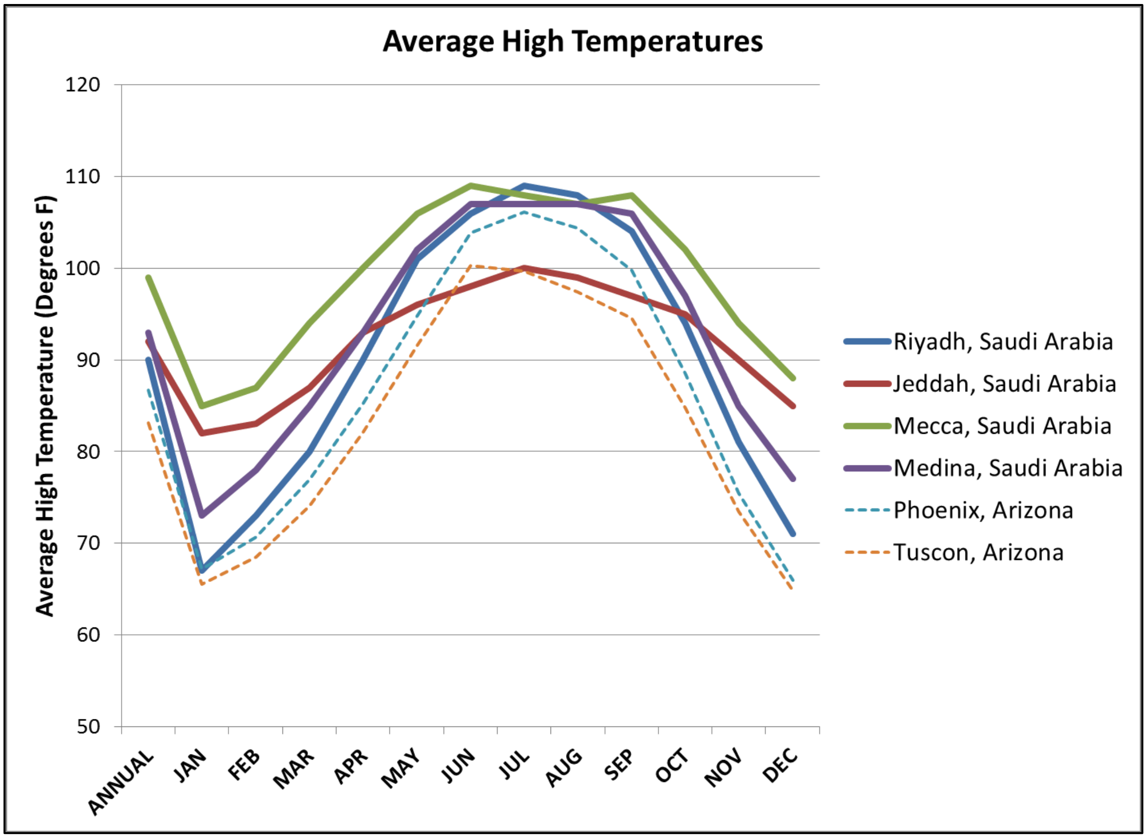
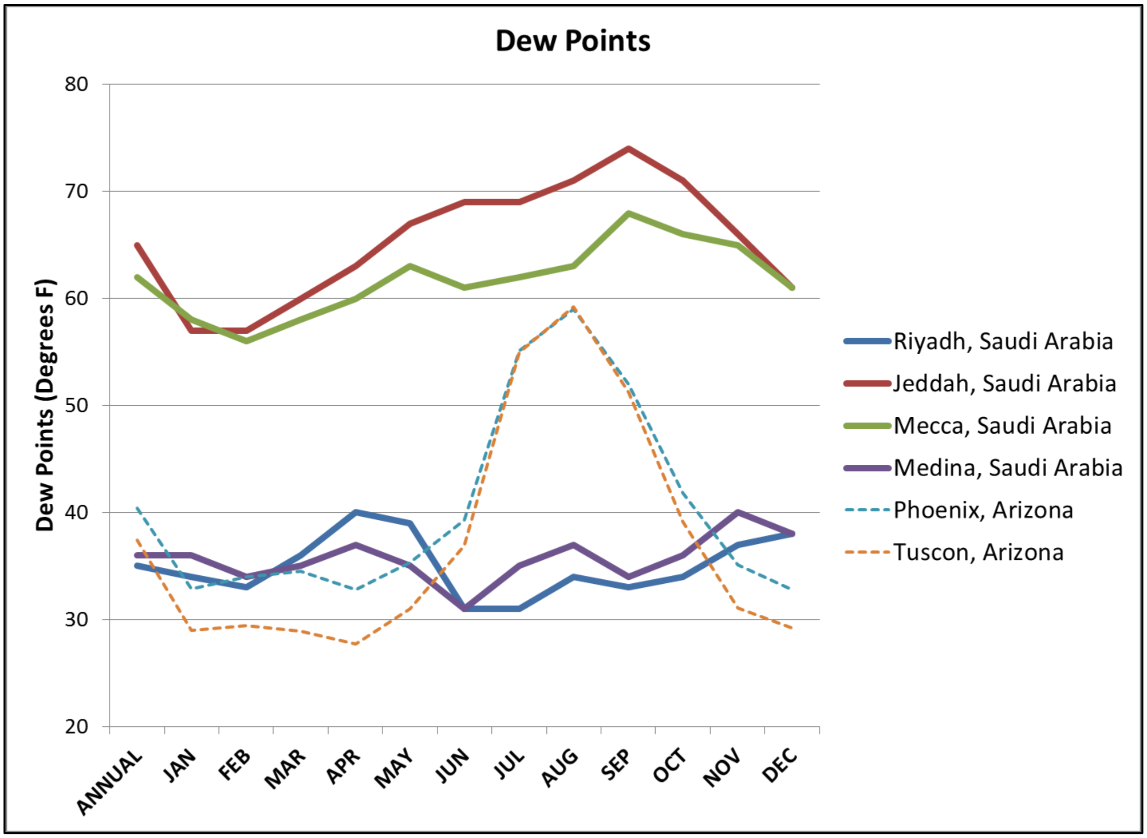


Figure 2. Average High Temperatures in SA and Arizona




Dew Points
Dew Points (Degrees F)
80
70
60
50
40
30
20
ANNUAL
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
Riyadh, Saudi Arabia
Jeddah, Saudi Arabia
Mecca, Saudi Arabia
Medina, Saudi Arabia
Phoenix, Arizona
Tuscon, Arizona