The Emissions Defeat Device

In 2015, Volkswagen found themselves under heavy public scrutiny as a response to their development and implementation of a tool to enhance vehicle performance. This tool would be known as an emission "defeat device" and was installed in Volkswagen and Audi branded cars from 2009-2015. The device was a carefully engineered piece of software that could constantly measure various conditions about the vehicle such as the steering wheel position, speed, duration of engine operation, and the barometric pressure. From these measurements the defeat device could accurately determine if the car was being driven normally, or if it was it was being tested for emission standards. During an emissions test, the car is subjected to a "dyno calibration" in which the steering wheel is locked, and the speed of the vehicles varies heavily from city driving to highway speeds all within a short time frame.

A dyno calibration is used as a standard method of monitoring the emission rates of vehicles. Since the conditions differ quite drastically from normal operation, the Volkswagen defeat device could accurately determine whether the vehicle was under inspection for its emissions output. Figure 1 summarizes this information.

As a result of this emissions defeat device, Volkswagen and other vehicles produced by the company emitted toxic gases such as nitrogen oxides (NO_x) at a rate that exceeded the maximum standard emission rates by up to 40%. Since 2015, Volkswagen has paid billions of dollars to various countries as a consequence of violating numerous emissions related regulations. In Canada alone, the company paid a settlement of $290.5 million for the recall of 20,000 diesel cars affected by the installed device.

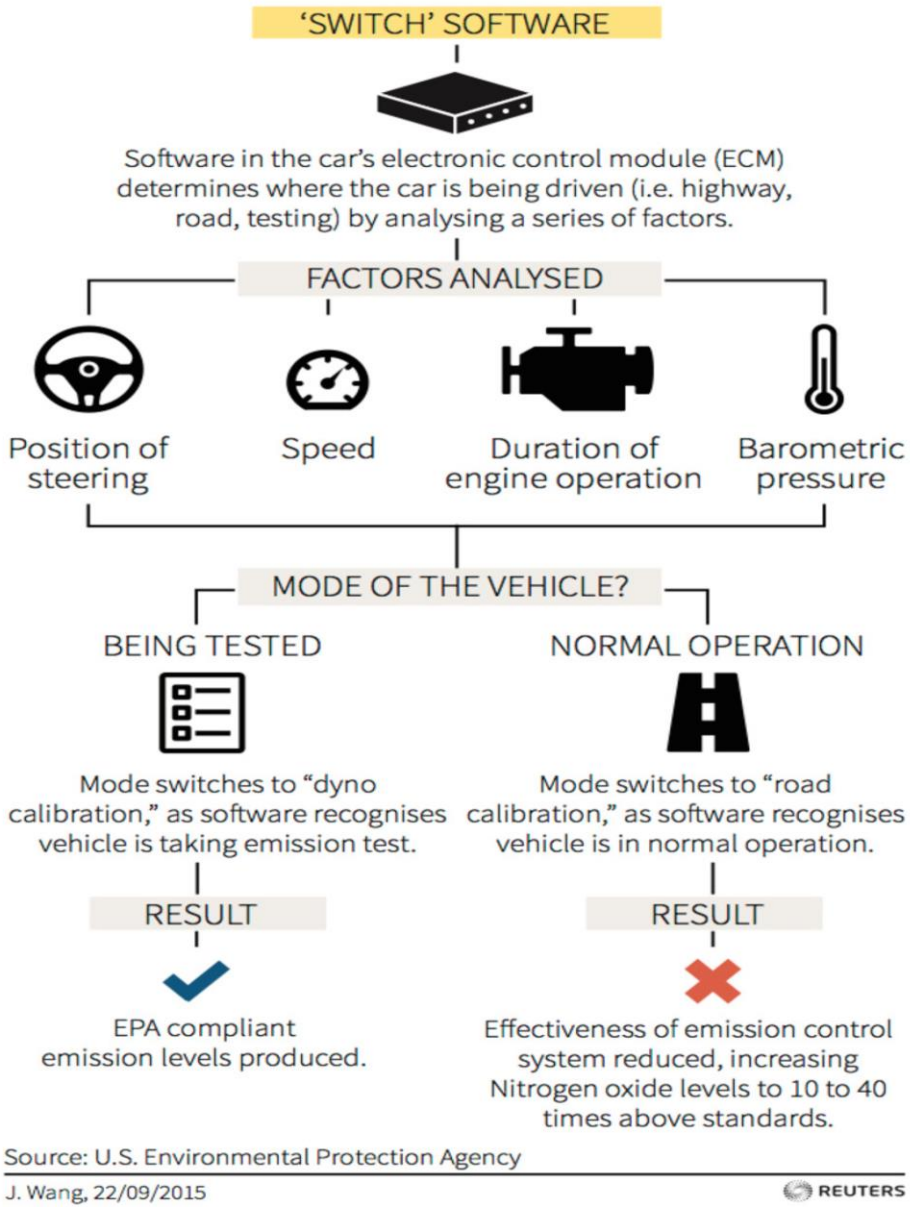

Figure 1. (https://medium.com/@QualsysEQMS/admitting-defeat-mercedes-and-the-latest-defeat-device-automotive-scandal-6090670f5836) The car's switch software control module analyses factors including position of the steering wheel, speed, duration of engine operation, and barometric pressure. Based on these, the mode of operation is determined to be either normal operation or being tested. When the softwares detects that the car is being tested, it switches to "dyno calibration" mode, resulting in EPA compliant emission levels. When the software detects that the car is being driven normally, the effectiveness of the emission control system is reduced, increasing nitrogen oxide emissions to 10-40 times above the allowed levels.

Selective Catalytic Reduction of Nitrogen Oxides

Nitrogen oxides (NO_x) are dangerous gases that are formed as a by-product of the combustion of diesel fuel. These gases are known to cause respiratory damage to humans as well as cause air pollution. NO_x is reduced in the catalytic converter of vehicles through the process of selective catalytic reduction. Selective catalytic reduction uses a urea reserve known as diesel exhaust fluid (DEF) in order to reduce NO_x into Nitrogen gas (N_2) and water vapour.

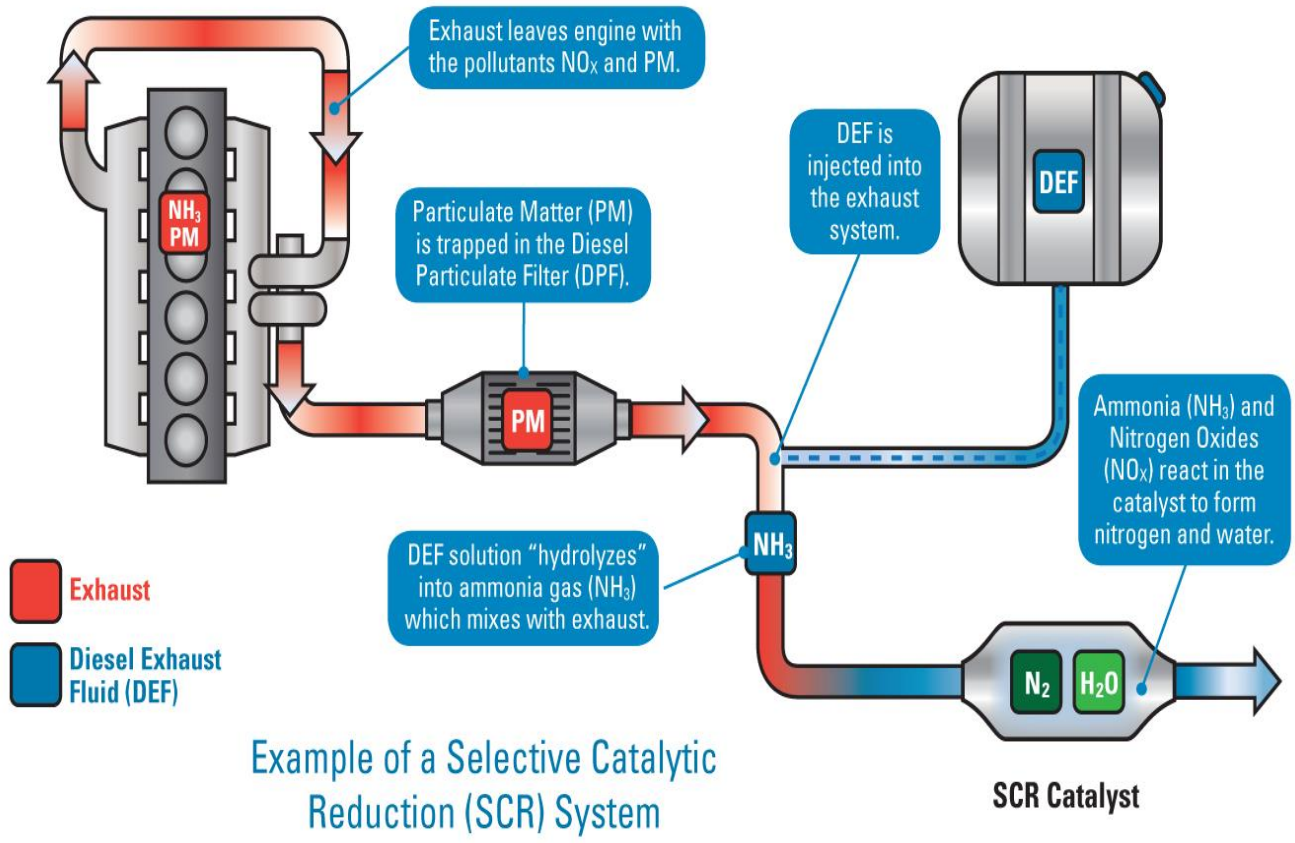

Figure 2. (https://www.tersusdef.com/about/how-selective-catalytic-reduction-scr-works/) In a gas flow system, exhaust leaves the engine containing the pollutants NO_x and particulate matter (PM). PM is trapped in the diesel particulate filter, after which diesel exhaust fluid (DEF) is injected into the exhaust system. The DEF solution is hydrolyzed into ammonia gas which mixes with the exhaust gases. The mixture is passed through the SCR catalyst where the ammonia and nitrogen oxides react to form nitrogen gas and water.

Student Instructions

You are an engineer hired by Volkswagen Canada to develop a system to automatically shut off the Selective Catalytic Reduction (SCR) system in their new line of diesel cars. This will eliminate the power consumption associated with SCR operation, thereby improving fuel economy during normal driving conditions. The company hopes that this better mileage will increase sales of their new cars. The device you are to design will be able to detect when the car is in normal driving conditions and when the car is being emissions tested. Upon successful completion and implementation of this device the new Volkswagen cars will no longer undergo the reduction of NO_x so long as the car is being driven normally.

Questions

1) With the defeat device turned off, the car will undergo the reduction of nitrogen oxide (NO) via selective catalytic reduction by reacting NO, O_2, and the urea reserve to produce nitrogen gas (N_2), carbon dioxide and water vapour.

a) Write the balanced equation for this reaction.

b) What is the stoichiometric ratio in which NO reacts with urea?

c) Based on this ratio, if 0.5 moles of Urea are injected into the catalytic converter at a given time while 0.8 moles of NO gas are present, how many moles of N_2 and CO_2 can be produced?

d) How many grams of each should be produced?

e) Hypothetically, if 16.6 g and 21.4 g of CO_2 and N_2 were produced respectively, what would be the percent yield of each gas?

The device you made was successful and the sales for these new cars have exceeded company expectations. However, Environment Canada have now grown suspicious of whether these new cars pass emission standards. The car under investigation has an engine of 150 horse power (110 kW).

2 a) Using Table 1. How much NO_x and CO_2 are produced to the nearest gram if this car is emitting NO_x and CO_2 at its maximum allowed emission rate in 7 hours?

Table 1. Maximum allowed Emission Rates from Environment Canada

Power of engine (kW)	**Maximum allowed Emission rate of NO_x (g/kW/hr)**	**Maximum allowed Emission rate of CO_2 (g/kW/hr)**
100-150	1.5	2.6
151-200	1.5	3.0
201-300	3.0	4.0
301-450	3.5	6.0

https://www.canada.ca/en/environment-climate-change/services/canadian-environmental-protection-act-registry/publications/guidance-document-engine-emission-regulations/chapter-6.html#toc6-1 (Accessed Jan. 18, 2019)

b) Environment Canada performed many emissions tests and concluded that the cars that have your device installed exceed standard emission rates by 40%. Based on these results, how many moles of NO are produced by these vehicles over a 7-hour period?

3) As a result of these emissions tests, why are catalytic converters important in diesel cars? What actions should Environment Canada recommend be done?