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The effect of payload on the temperature of the SCR-system

Dansk resumé:

Resultaterne præsenteret i den følgende rapport er en del af en større indsats, som den danske regering har gennemført i forbindelse med manipulation med SCR-systemer. Indsatsen fandt sted i 2019 og 2020.

Rapporten opsummerer en feltundersøgelse af 5 tunge køretøjer, hvor deres emissionssystemer blev overvåget med On Board Diagnose (ODB) -udstyr under almindelige drift betingelser.

De 5 køretøjer blev valgt ud fra indikationerne opnået i rapporter fra (Pöhler, 2020) og (Eriksson & Sventen, 2021). I de to rapporter blev det vist, at køretøjer med høj motoreffekt og lav nyttelast havde en uventet høj emission, da de blev målt med plume chasing og med SEMS-udstyr. Når et køretøj har et inaktivt SCR-system, vil emissionerne fra køretøjet være ca. 40 gange højere end når emissionssystemet er aktivt (AVL Sverige, 2020).

I rapporten fra (Pöhler, 2020) var det mest udtalt med inaktive SCR-systemet på EURO V køretøjer. Det skal dog bemærkes, at i denne rapporter blev der kun målt på køretøjer på motorvejen. I rapporten fra (Eriksson & Sventen, 2021) blev det rapporteret, at emissionssystemet for et EURO VI-køretøj med høj motoreffekt og lav nyttelast kunne være inaktivt under en bykørsel. På baggrund af de to rapporter er der udvalgt 5 køretøjer af forskellige mærker. Det er fælles for dem alle, at de har en motoreffekt på omkring 500 HK og derover. Derfor kan de betegnes som tunge køretøjer med høj motoreffekt. De tunge køretøjer kører den samme rute på motorvejen og i byen uden nogen nyttelast.

Undersøgelsen viser at de testede tunge køretøjer har problemer med at opnå en tilstrækkelig driftstemperatur for SCR-systemet til, at den katalytiske reaktion i SCR-systemet kan finde sted. Undersøgelsen viser, at problemerne er til stede både for EURO V og EURO VI-køretøjer under bykørsel samt for EURO V køretøjet ligeledes på motorvejen uden nyttelast. Det bemærkes at rapporten bygger på 5 tunge køretøjer og resultaterne derfor udelukkende er indikationer for hvordan SCR-systemet fungere når køretøjet er i drift.

Alle resultaterne er opnået med en udetemperatur på omkring 10°C. Den gennemsnitlige temperatur året rundt i Danmark er 8,3°C (DMI, ud). Derfor er tilstanden af SCR-systemet, der er præsenteret i rapporten, meget repræsentativ for den normale tilstand af SCR-systemet i Danmark. Litteraturundersøgelsen, som blev udarbejdet som en del af det nuværende arbejde, antyder, at effekten af et koldt SCR-system er mere udtalt, når den omgivende temperatur er lav. Derfor kan flere køretøjer have et velholdt SCR-system, som er inaktivt, når køretøjerne kører i byen på grund af en lav temperatur i udstødningssystemet. Den lave temperatur i SCR-systemet kan skyldes en lav nyttelast og en høj motoreffekt.

Færdselsstyrelsen

Abstract:

The work presented in the following report is part of a larger effort that the Danish government carried out in relation to tampering with SCR-systems. The effort took place in 2019 and 2020.

The report summarizes a field study of 5 HDVs where their emission-systems were monitored with OBD-equipment during regular driving. The 5 vehicles were selected based on the indications obtained in reports by (Pöhler, 2020) and (Eriksson & Sventen, 2021). In the two reports it was shown that vehicles with a high engine power and a low payload had an unexpected high emission when they were measured with plume chasing and with SEMS-equipment.

When a vehicle has an inactive SCR-system, the emission from the vehicle will be approximately 40 times higher than when the emission-system is active (AVL Sweden, 2020).

The inactive SCR-system was mostly pronounced when measuring on the EURO V vehicles (Pöhler, 2020), though it must be mentioned that in the study, the vehicles were only measured when driving on the highway. However, in the report by (Eriksson & Sventen, 2021) it was reported that the emission system for a EURO VI vehicle with a high engine power and a low payload could be inactive during a city drive.

On the basis of these two reports, 5 vehicles of different brands were selected. Common to all of them is that they have an engine power of more than 500 HP. Hence, they can be designated as heavy-duty vehicles (HDV) with a high engine power. The HDVs are driven without payload on the same route, both on the highway and in the city.

The present study shows that the tested HDVs have problems in achieving a sufficient operating temperature of the SCR-system for the catalytic reaction to take place. It is also shown that the problems are present for both EURO V og EURO VI vehicles during the city drive and for EURO V vehicles when driving on the highway without payload. It is noted that the present study only includes 5 vehicles and therefore the obtained results are indications on how the SCR systems are operating.

All the results are obtained with an outdoor temperature of around 10°C.The average temperature during the year in Denmark is 8.3 °C (DMI, u.d.), and the state of the SCR-systems presented in the report is therefore very representative for the normal state of the SCR-systems in Denmark.

The literature study reported as part of the current work suggest that the effect of a cold SCR-system is more pronounced when the surrounding temperatures are low. Hence, when the outside temperature is low more vehicles with a well-maintained SCR-system could be inactive when the vehicles drive in the city due to a low temperature in the exhaust system. The low temperature in the SCR-system could be caused by a low payload and a high engine power.

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Background

During the current effort against NO_x manipulation, it has been indicated that trucks with high engine power and low payload have a high NO_x emission during ordinary use despite a well-maintained SCR-system (Eriksson & Sventen, 2021) (Pöhler, 2020).

The high emission could be caused by a low payload which causes the exhaust system to have a low temperature. Hence, the SCR-system cannot reach a sufficient operating temperature for the catalytic reaction to take place. When a truck has an inactive SCR-system the emission from the truck will continue to be high (AVL Sweden, 2020).

Background literature study

SCR-system's effect as a function of temperature.

A literature review indicates that it is a well-known effect for light vehicles that the warmup time of the SCR-system is dependent on the temperature of the surroundings. Hence, when the outside temperature is low, the time before the SCR-system is activated is longer, and therefore, the total emission for a fixed test drive is higher at low temperature. This is described by (Christian Weber, 2019).

It is also shown in the study that the general level of emissions has lowered over the last decade. However, the extra emission associated with cold starts does not seem to have decreased in the same manner, making the emission contribution from the cold starts increasingly significant. This is illustrated in Figure 1. The figure originates from a presentation by AECC in January 2021 (AECC, u.d.). The results are supported by findings in studies by (Ricardo Suarez-Bertoa C. A., 2018) and (Ricardo Suarez-Bertoa J. P.-G., 2019).

The figure shows the cumulative NO_x in mg as a function of km for low ambient temperature and normal ambient temperature. From the figure it is noted that the emission-curve levels out when the SCR-system has reached the operating temperature. Hence, at this point, the SCR-system becomes active. However, the emission before the SCR-system reaches the operating temperature is much higher at low temperature (7°C) than at 23°C.

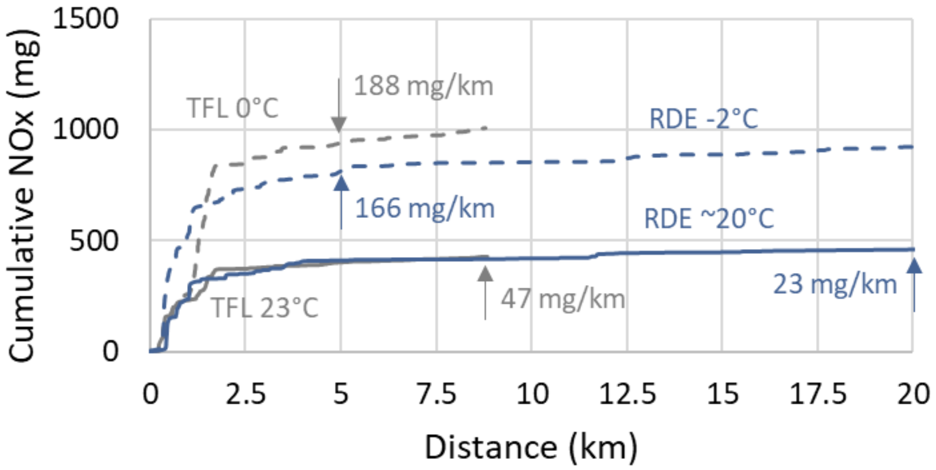

Figure 1: The cumulative NO_x (mg) as a function of km. The solid lines are recorded at 23°C while the dotted line is recorded at 7°C. Note that the steep slope in the beginning is representing the initial warmup of the SCR-system. Furthermore, it should be noted that the curve recorded at 23°C is leveling off approximately at half the level as the curve recorded at 7°C.

The above-mentioned data are all collected for light vehicles and passenger cars. It has not been possible to locate the same data for heavy duty vehicles (HDV). However, the behavior is presumable the same because the same SCR-technology is used in light and heavy-duty vehicles. It can be speculated that the effect of the temperature can be more pronounced among heavy duty vehicles, because the weight of the HDV itself represents a smaller part of the total weight of the HDV.

Theory regarding the influence of payload and engine power

Results from previously published projects (Eriksson & Sventen, 2021) and (Pöhler, 2020) strongly indicates that HDVs without or with a low payload have an inactive SCR system during the main part of the trip. The emission for an inactive SCR-system is at the same level as a HDV with a manipulated SCR-system (AVL Sweden, 2020).

In the report (Eriksson & Sventen, 2021) it was noted that the vehicle with high engine power and low payload had a longer warmup period compared to the vehicle with a standard engine power and a low payload. The warmup period was carried out by driving on the highway.

Furthermore, it was noted that the vehicle with high engine power cooled down faster when it stopped for delivery in the city. This strongly indicates that the temperature of the SCR-system throughout the trip was generally lower compared to the vehicle with a standard size engine.

As previously indicated, the warmup time for the SCR-system depends on the surrounding temperature. Therefore, based on the two reports, it can be assumed that the SCR-system on a HDV with a low payload and a high engine power does not necessarily reach a sufficient temperature and becomes fully operational. If the SCR-system is not fully operational, the emission level will be approximately 40 times higher and similar to the emission level for a manipulated vehicle (AVL Sweden, 2020).

Thus, the effect of a high engine power combined with a low payload prolongs the warmup time of the SCR-system, resulting in a higher total emission per trip from the vehicle.

Number of vehicles registered in Denmark

Based on the observations from the two studies (Pöhler, 2020) and (Eriksson & Sventen, 2021) the vehicles that can have the issue with a cold SCR-system is assumed to have an engine power more than 500 HP. It is noted that the limit is based on a very small number of vehicles. The limit is dependent on the outside temperature. Hence, if the outside temperature is low the limit will be lower, thereby a higher number of vehicles are included.

The graph in Figure 2 shows that the distribution of trucks as a function of engine power. The trucks are registered without a body implying that they only consist of a truck.
From the graph it can be calculated that approximately 40% of the vehicles registered in Denmark have an engine power of more than 500 HP. Hence, potentially 40% of the vehicles registered in Denmark when driving without a payload could have a cold SCR system.

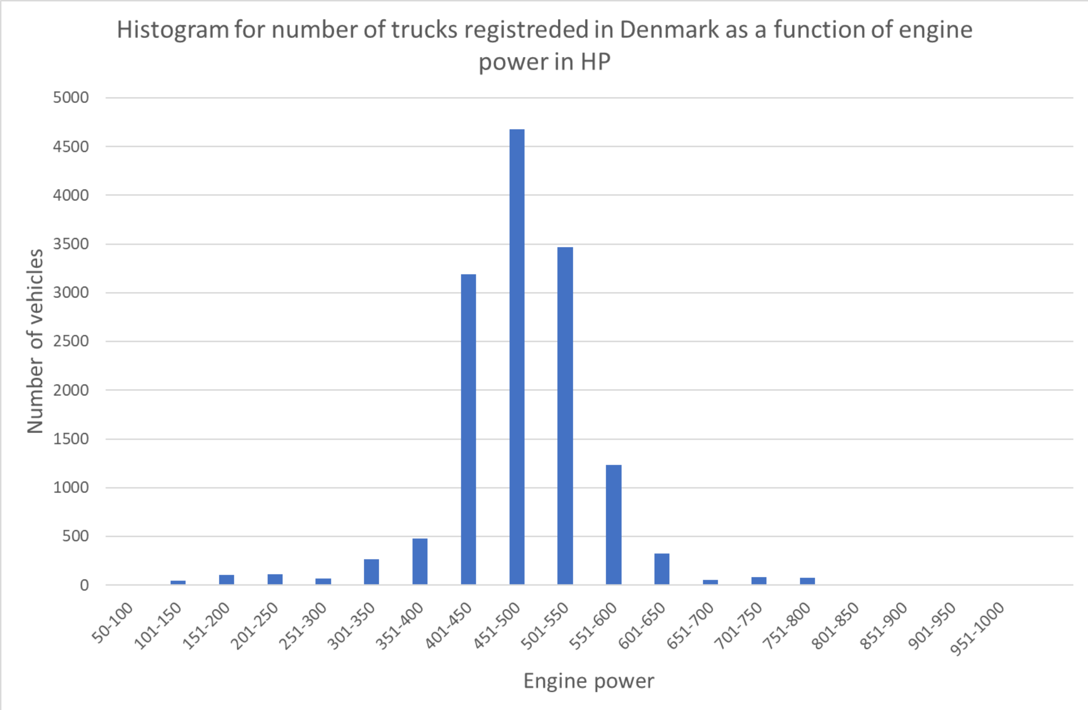

Figure 2: Number of trucks as a function of engine power registered in Denmark in April 2021. From (Eriksson & Sventen, 2021) and (Pöhler, 2020) it can be assumed that the vehicles with a high engine power are vehicles above 500 HP. From the graph it can be calculated that approximately 40% of the trucks registered in Denmark have an engine power of more than 500 HP. Hence, the vehicles when driving without a payload could drive around with a cold SCR-system.

Investigation

During the second plume chasing project conducted by the Danish Road Traffic Authority (Pöhler, 2020), it was noted that the issue with high emission was most pronounced with EURO V heavy-duty vehicles with low to no payload. However, the main focus of the second plume chasing project was to test the plume chasing equipment in real life scenarios, as part of the enforcement on the Danish highways. Not to investigate if the SCR-system was active or inactive when driving without a payload.

This study also subjected EURO VI vehicles to the same test procedures as EURO V vehicles in order to clarify if there were similar issues with high emission caused by a low payload.

Method

5 different HDVs were selected for the test. The 5 different vehicles are from three different manufactures. The vehicles used for the test were:

- HDV 1 EURO VI with ~510 HP
- HDV 2 EURO EEV with ~460 HP
- HDV 3 EURO VI with ~500 HP
- HDV 4 EURO V with ~500 HP
- HDV 5 EURO VI with ~520 HP

For the investigation it was not possible to obtain a Mercedes EURO V.

Highway test drive

Each vehicle was driven for approximately 70 km on the highway without payload. During the test drive, the vehicle performance was monitored with a On Board Diagnosis (OBD) system.

If the temperature of the emission system reaches a level where the NO_x levels were reduced, it can be concluded that the SCR-system was working even without a payload.

If the emission level continued to be high, the test drive was repeated with a load of 22 tons to ensure that the SCR-system was working properly.
The behavior of the SCR-system was evaluated from the data that could be obtained from the OBD system on the vehicle.

City test drive

The test procedure was repeated in the city, where it started with a cold engine and was driven for approximately 20 minutes. During the test drive, the engine was monitored with the OBD-system. The city drive was carried out without a payload because the highway test had already shown if the SCR-system was fully functional.

Results

The following section presents the results obtained in the project. The results show that all the vehicles had a well-maintained SCR-system that was activated when a sufficient temperature of the SCR-system was reached.

The results show that one out of three of the EURO VI vehicles tested in the project had a low emission both on the highway and during the city drive, which indicates an active SCR-system.

However, one of the EURO VI had a high emission level when driving in the city. This was measured even though the SCR-system was well-maintained and functional according to the current legislation.

The data for the city drive for the last EURI VI vehicle cannot be used to conclude whether or not the SCR-system was active during the city drive. Because the data obtained from the OBD system was inconclusive.

Only two EURO V vehicles were tested. One of the EURO V vehicles had a working SCR-system during the highway drive. Due to a defect OBD connection it was not possible to carry out the test drive in the city.

The SCR-system of the other EURO V vehicle was only active during the highway drive with a payload of 22 tons. When driving on the highway or in the city without a payload, the vehicle had an inactive SCR-system, which according to (AVL Sweden, 2020) means that it will have an emission level that is approximately 40 times higher and similar to the emission level of a manipulated vehicle.

The results from the individual vehicles are presented in the following sections.

HDV 1 EURO VI:

The results from the drive on the highway without a payload can be seen from Figure 3 to Figure 5. As noted from Figure 5, the tailpipe NO_x concentration is low throughout the test drive, which indicates that the SCR-system is active.
An initial high NO_x concentration at the tailpipe was expected. However, the non-existing drop in NO_x concentration in the tailpipe can be caused by the warmup period of the NO_x sensor, which appears to be longer than the warmup period of the SCR-system.

Figure 6 to 8 show the data from the city drive, where the behavior of the NO_x concentration measured before and after the SCR-system has a similar to the behavior as shown in the data from the highway. Hence, it can be concluded that the SCR-system of the HDV 1 EURO VI is well-functioning under normal driving conditions on the highway as well as in the city without payload added to the HDV.

Figure 3: The figure shows that speed in km/h of the HDV 1 EURO VI vehicle during the drive on the highway. The vehicle was driven without a payload. The speed of the vehicle is constant because it drives on the highway.

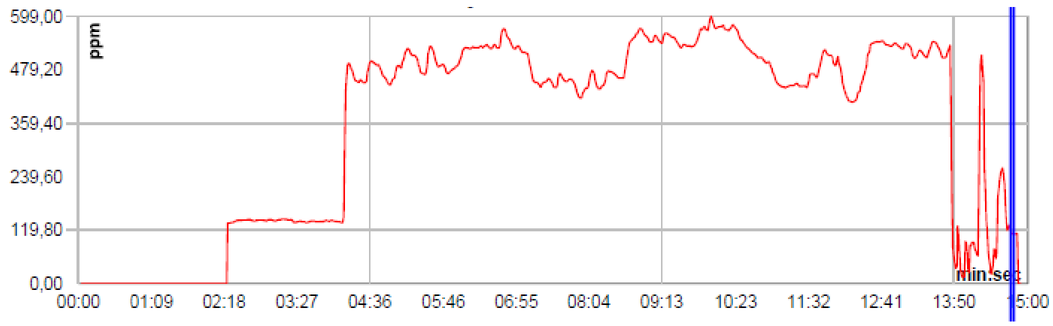

Figure 4: The NO_x concentration in ppm of the HDV 1 EURO VI vehicle measured before the SCR-system, reported by the OBD-system. The data is obtained on the highway. The vehicle was driven without a payload. It is noted that the NO_x concentration before the SCR catalyst rises to a stable level. This is expected because the speed of the vehicle is constant during the trip.

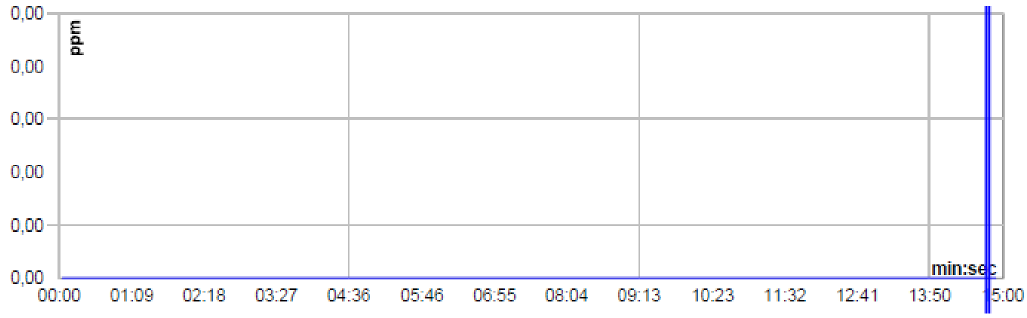

Figure 5: The NO_x concentration in ppm of the HDV 1 EURO VI vehicle measured after the SCR-system, reported by the OBD system. The data is obtained on the highway. The vehicle was driven without a payload. It is noted that the NO_x concentration continues to be low throughout the trip, indicating that the SCR-system is in good condition during highway driving.

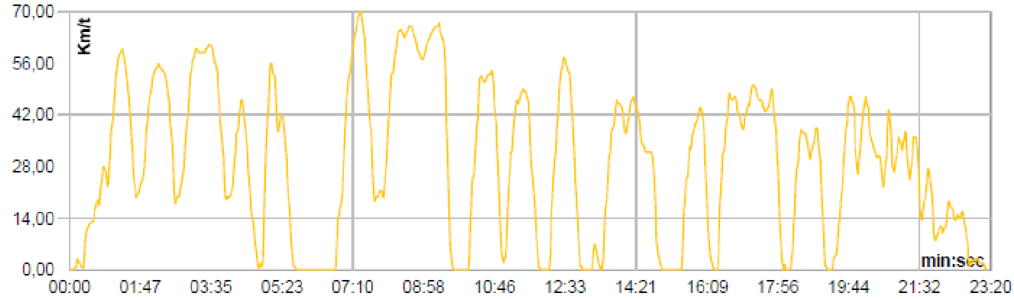

Figure 6: The speed in km/h of the HDV 1 EURO VI vehicle during the city drive. The vehicle was driven without a payload. The speed of the vehicle varies throughout the trip because the vehicle is driven in the city.

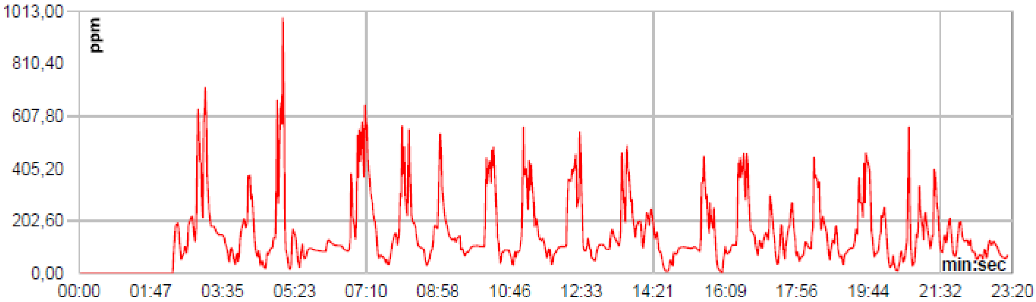

Figure 7: The NO_x concentration in ppm measured before the SCR-system for the HDV 1 EURO VI vehicle during the city drive. The vehicle was driven without a payload. It is noted that the NO_x concentration measured before the SCR-system varies during the trip. This is because the speed of the vehicle varies. The peaks are associated with acceleration of the vehicle.

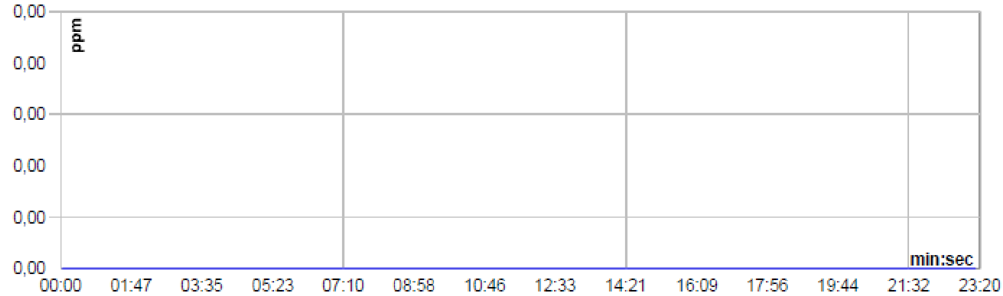

Figure 8: The NO_x concentration in ppm measured after the SCR-system for the HDV 1 EURO VI vehicle during the city drive. The vehicle was driven without a payload. The NO_x concentration continues to be low during the trip in the city. The SCR-system seems to be very efficient even during acceleration of the vehicle.

HDV 2 EURO EEV Motorway:

The demands in the legislation for the OBD-system for the EURO V or an EEV are not the same as the demands for a EURO VI vehicle. Therefore, the same data as from the EURO VI cannot be obtained for a EURO V or EEV vehicle.

The only data obtained for this EEV vehicle was the exhaust temperature measured after the SCR-system as noted in Figure 9. Where the temperature after the SCR-system is above the 220°C where the SCR-system goes into operation according to literature.

Hence it can be assumed that the catalyst is active when the vehicle is driving unloaded on the motorway. It was not possible to obtain data from a city drive.

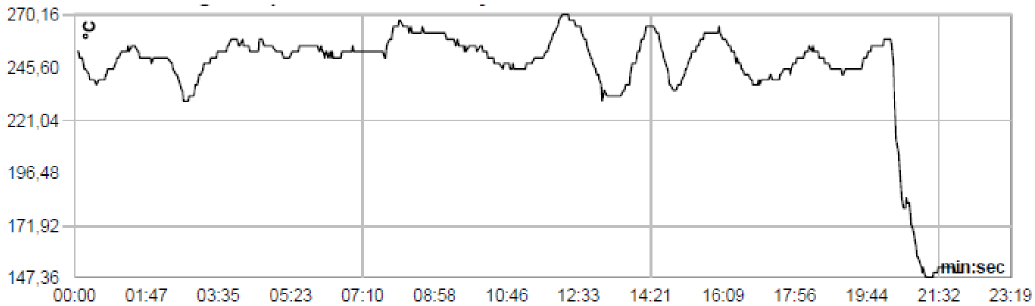

Figure 9: The exhaust temperature in °C after the SCR-system for the HDV 2 EEV vehicle. The vehicle is driven on the highway without a payload. It is noted that the temperature measured after the SCR-system is approximately 245°C during the trip. The level is stable because the speed of the vehicle is stable. The temperature indicates that the SCR-system is active during the trip.

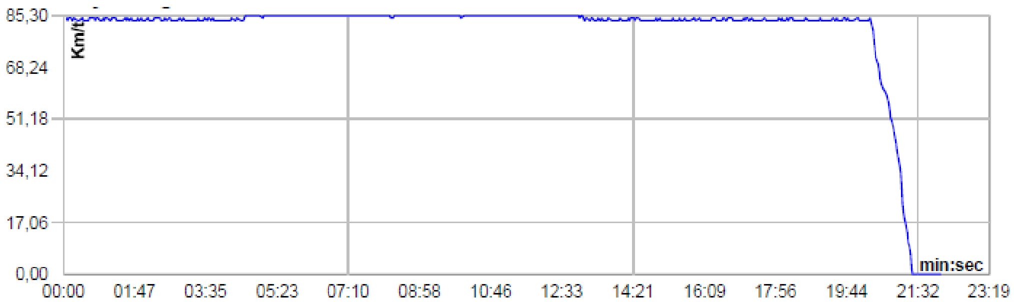

Figure 10: The speed in km/h of the HDV 2 EURO EEV during the highway drive. The speed is constant because the vehicle is driven on the highway.

HDV 3 EURO VI:

The results from the drive on the highway for the HDV 3 EURO VI is noted in Figure 11 and Figure 12. The NO_x sensor that measures the NO_x level after the SCR-system. The sensor shows that the NO_x level is below 100 ppm. Even though the NO_x sensor is not calibrated to an external standard, the results indicates that the SCR-system is active without payload on the highway.

The data obtained for the city drive cannot determine if the SCR-system is active during the city drive, because the NO_x sensors have some high peaks as noted in Figure 14 and Figure 15. Therefore, it is not possible to estimate the reduction level from the obtained data.

The temperature obtained from the temperature sensor before the SCR system is noted in Figure 13. The temperature indicate that the SCR-system might be inactive during the city drive.

The conclusions from the data for HDV 3 EURO VI are that the SCR-system is active on the highway, but that it is not possible from the current data to evaluate if the SCR-system is active during the city drive. However, the temperature before the SCR-system strongly indicates that the SCR-system is inactive during the city drive.

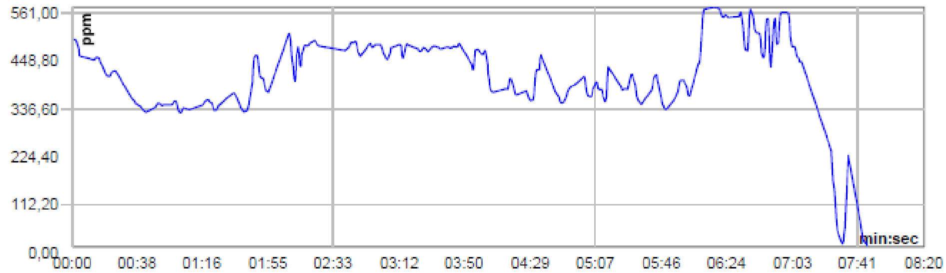

Figure 11: The NO_x concentration measured before the SCR-system for the HDV 3 EURO VI vehicle. The vehicle is driven on the highway. The NO_x concentration before the SCR catalyst is at a constant level because the speed on the highway is constant.

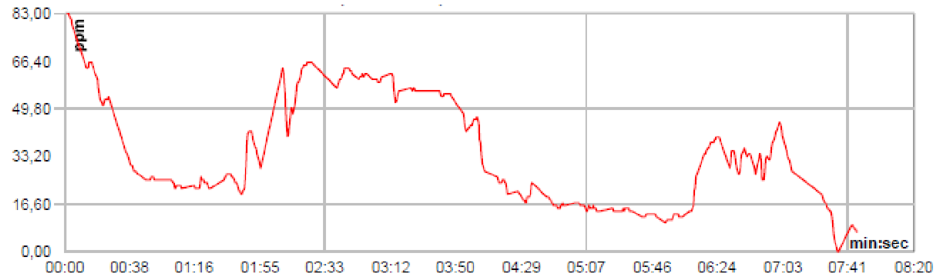

Figure 12: The NO_x concentration in ppm measured after the SCR-system for the HDV 3 EURO VI vehicle. The vehicle is driven on the highway. The NO_x concentration after the catalyst is at a lower level than before the catalyst, indicating that the SCR-system is active during the highway drive.

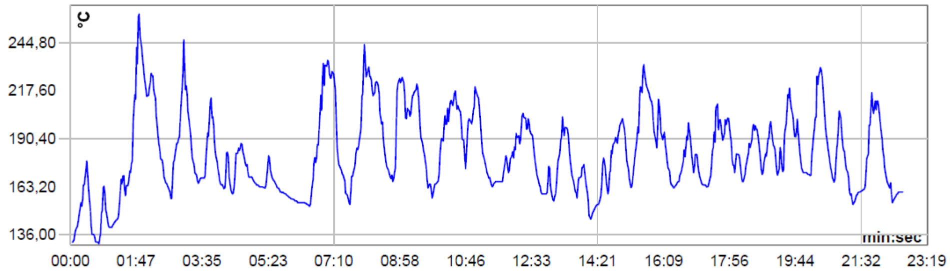

Figure 13: Exhaust gas temperature in °C for the HDV 3 EURO VI vehicles during the city drive. The temperature levels indicate that the SCR-system might not be active during the city drive.

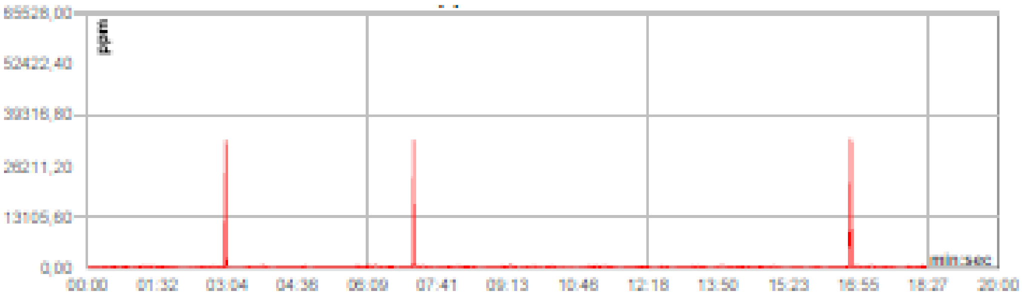

Figure 14: The NO_x concentration in ppm measured before the SCR-system for the HDV 3 EURO VI driven in the city. The data is inconclusive due to the high peaks on the graphs.

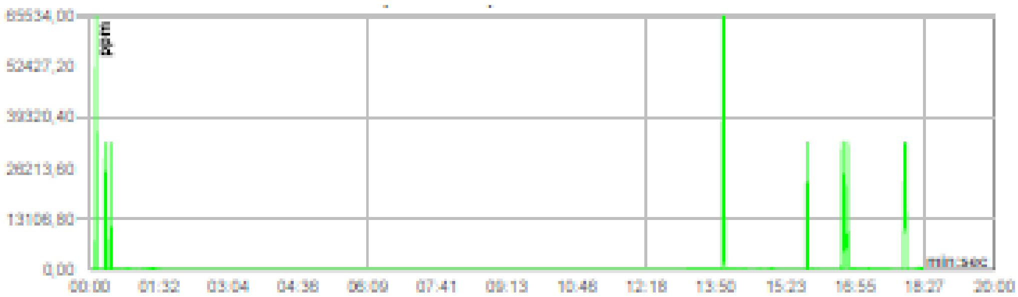

Figure 15: The NO_x concentration in ppm measured before the SCR-system for the HDV 3 EURO VI driven in the city. The data is inconclusive due to the high peaks on the graphs. It is not possible to determine if the SCR-system is active during the city drive from the NO_x concentration data alone.

HDV 4 EURO V:

The HDV 4 EURO V was subjected to the same distance on the highway as the previous vehicles.

However, the data from the vehicle shows that the engine temperature only reached 70-72°C without payload. The exhaust temperature only reached approximately 190°C. This is noted in Figure 16, which indicates that the SCR-system was not active.

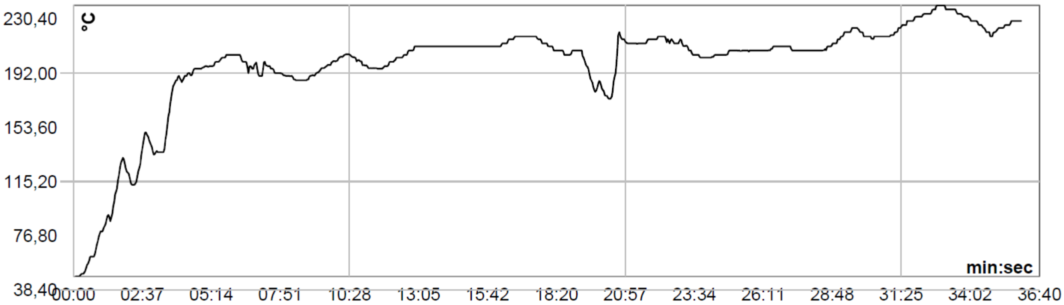

Figure 16: The exhaust temperature measured before the SCR -system for the HDV 4 EURO V vehicle. The temperature below 200°C indicates that the SCR-system was inactive during the highway drive.

To ensure that the SCR-system was in a working condition, a payload of 22 tons was added to the vehicle. The 10 first minutes are not relevant for the analysis, since the vehicle was being loaded and was yet to be set in motion.

The data shows that the SCR-system became active when the vehicle reached the highway. This is supported by the data from the ad-blue valve. Furthermore, it was noted that the engine temperature was higher when the payload was added to the vehicle. The data is noted in Figure 17 and Figure 18.

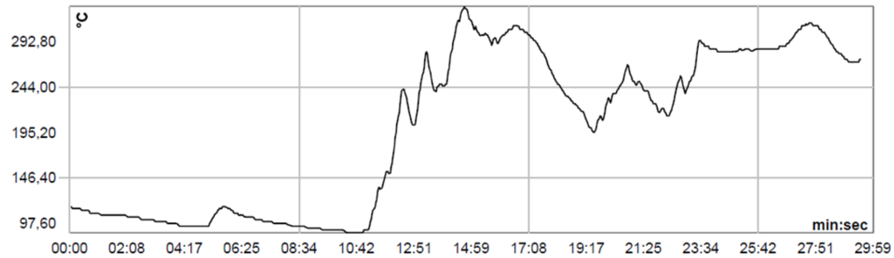

Figure 17: Exhaust temperature in °C measured before the SCR-system for the HDV 4 EURO V vehicle with a payload of 22 tons. The vehicle was driven on the highway. When the payload is added to the vehicle, the temperature in the exhaust system rises, indicating that the SCR-system becomes active due to the extra weight. The first 10 minutes is not part of the analysis because the vehicle drove around on the parking lot when being loaded.

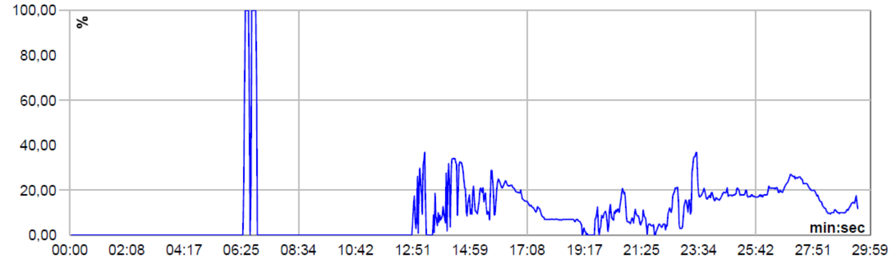

Figure 18: The ad-blue valve for the HDV 4 EURO V vehicle during the drive on the highway. The payload is 22 tons. The state of the reduction valve indicates that the SCR-system is active when the vehicles drives on the highway with a payload of 22 tons.

The data from the city drive shows that the SCR-system of the HDV 4 was inactive. The ad-blue valve was closed, and the exhaust temperature was low. This is noted in Figure 19 and Figure 20.

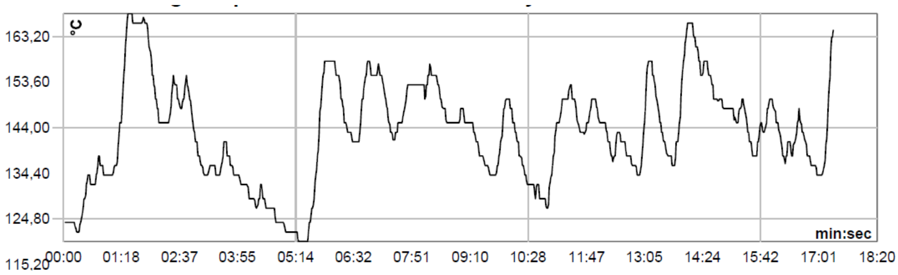

Figure 19: The exhaust temperature in °C measured before the SCR-system for the HDV 4 EURO V vehicle when driven without a payload in the city. The temperature of the SCR-system was low during the city drive, which indicates that the SCR-system was inactive. Hence the vehicle has the same emission level as a vehicle with a manipulated SCR-system.

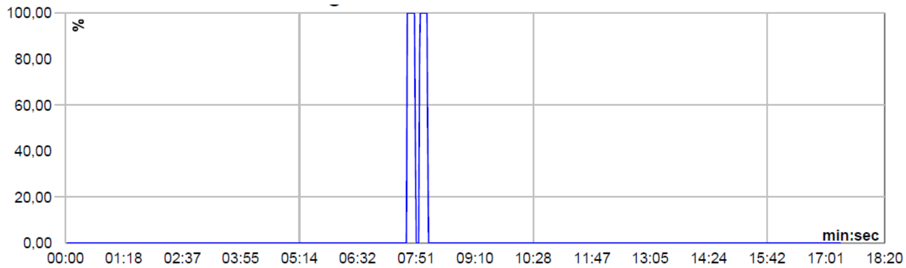

Figure 20: The ad-blue valve for the HDV 4 EURO V vehicle during the city drive without a payload. The state of the valve supports the indications from the temperature graph. Hence, SCR-system is inactive during the city drive resulting in a high emission level.

HDV 5 EURO VI:

The Scania EURO VI was driven without payload on the highway. The data obtained from the vehicle shows that the temperature measured before the SCR-system was approximately 225°C. This indicates that the SCR-system was active on the highway without a payload added to the vehicle, as shown in Figure 21.

However, this is only an indication because the SCR-system, according to literature, becomes active between 220°C and 250°C.

A payload of 22 tons was added to the vehicle, and the vehicle was driven on the highway. The temperature measured before the SCR-system shows approximately 250°C. Hence the SCR-system was active when the payload was added to the vehicle, as shown in figure 21. So, the vehicle has a well-functioning SCR-system.

When the vehicle was driven in the city without payload, the temperature measured before the SCR-system was approximately 190°C, which makes it unlikely that the SCR-system was active, as shown in figure 23.

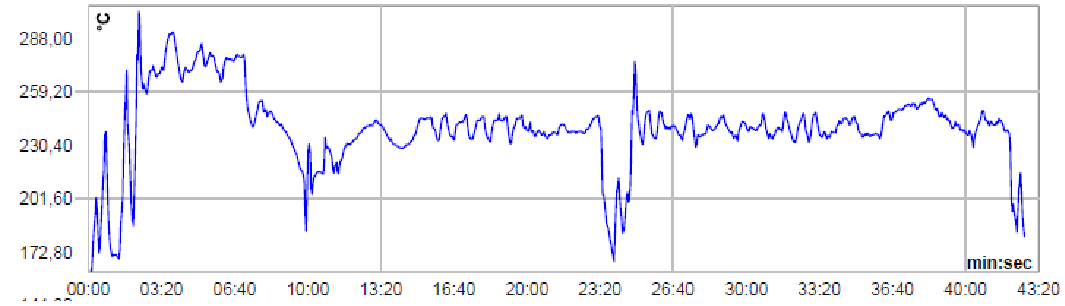

Figure 21: Temperature in °C of the exhaust system measured before the SCR-system for the HDV 5 EURO VI vehicle driven on the highway without payload. The temperature level indicates that the SCR-system was active during the drive on the highway without a payload.

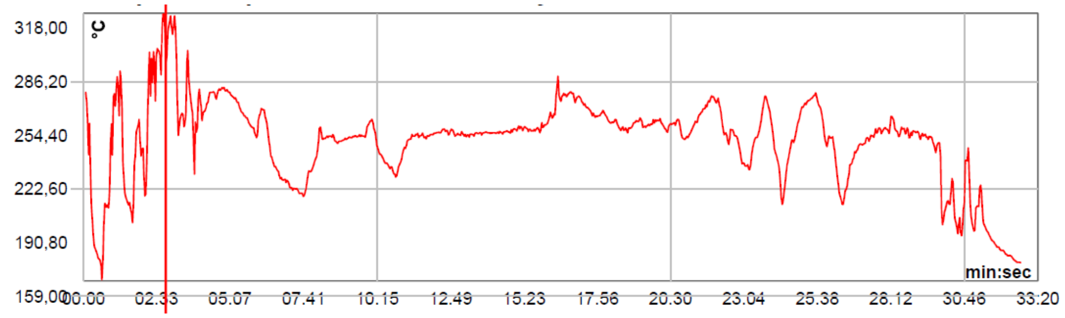

Figure 22: Temperature in °C of the exhaust system measured before the SCR-system for the HDV 5 EURO VI vehicle driven on the highway with a payload of 22 tons. The temperature level indicates that the SCR-system was active.

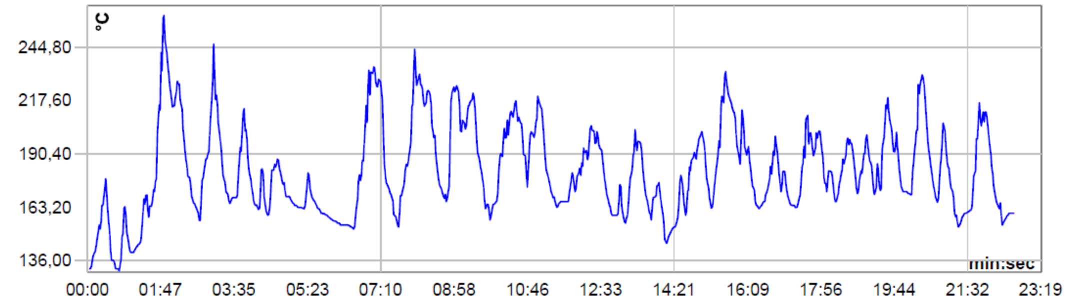

Figure 23: Temperature in °C of the exhaust system measured before the SCR-system for the HDV 5 EURO VI vehicle driven in the city without payload. The temperature below 200°C indicates that the SCR-system was inactive during the city drive. Hence, the emission level of the vehicle was the same as the emission level of a vehicle with a malfunctioning SCR-System or a manipulated SCR-system.

Considerations based on the study

The obtained OBD-data have some uncertainties because the data is limited.

However, some trends are very clear. The data shows that the engine temperature is dependent on the added payload for some of the vehicles. Furthermore, the data shows that for some of the vehicles, the SCR-system is inactive when driven in the city even though the SCR-system is well-functioning. This is noted both for the HDV 4 EURO V og HDV 5 EURO VI.

Hence, the study supports the results obtained in the reports by (Pöhler, 2020) and (Eriksson & Sventen, 2021) where it was noted that vehicles with a high engine power and non to low payload cannot obtain a sufficient high temperature so that the SCR-system can be activated. Therefore, the emission will be high throughout the drive and similar to that of a manipulated SCR-system (AVL Sweden, 2020). The problem is more pronounced when the vehicle is driven in the city.

References

Retrieved from AECC: https://www.aecc.eu/

AVL Sweden. (2020). *Stationary NOx mearuements - A way to detect high NOx emitting vehicles.*

Christian Weber, I. S. (2019). Comparison of regulated emission factors of EURO 6 LDV in Nordic temperatures and cold start conditions: Diesel- and gasoline direct injection. *Atmospheric Environment*, pp. 208-217.

DMI. Retrieved from https://www.dmi.dk/klima/temaforside-klimaet-frem-til-i-dag/temperaturen-i-danmark/

Eriksson, L., & Sventen, M. (2021). *Report – Real Driving Emission in Copenhagen.* Miljøstyrrelsen.

Pöhler, D. (2020). *HDV NOx emission measurement with mobil remote sensing (plume chasing) and subsequent inspection of high emitters.*

Ricardo Suarez-Bertoa, C. A. (2018). Impact of cold temperarure on EURO & passenger car emissions. *Environmental Pollution*, pp. 318-329.

Ricardo Suarez-Bertoa, J. P.-G. (2019). Effect of low ambient temperature on emission and electric range of plug-in hybrid electric vehicles. *ACS Omega*, pp. 3159-3168.