Cambustion

CLD500

Fast Response NOx Analyzer

Application Note: CLD 09v01

Transient NOx measurements from in-service EURO V and VI buses

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Transient NO_x measurements from in-service Euro V and VI buses

A joint project between Cambustion, Oxford University Engineering Science Dept, the Oxford Bus Company and Oxford City Council was undertaken following conversations between Dr. Felix Leach (Oxford Univ) and Mai Jarvis (Oxford City Council) about Oxford's clean air zone.

In the UK, buses have access to city centres where the presence of urban NO_x "hot spots" might have a negative impact on local air quality and the use of Cambustion's fast response NO_x analysers combined with accurate GPS allowed for the accurate measurement and positioning of the sites where significant NO_x "spikes" were emitted. The example in **Figure 1** shows tailpipe NO_x when pulling on to a mini-roundabout, accelerating away and gear changing (colours denote ppm).

Figure 1: Location of Euro VI bus NO_x emissions at mini-roundabout

Two buses were offered for measurement on routes involving city centre driving:

- A Euro V hybrid bus with OEM-fitted SCR system, 251,000 miles
- A Euro VI "micro-hybrid" (no hybrid traction), again with OEM-fitted SCR, 119,000 miles

Both buses were in regular service with no warning lamps illuminated. There was no easy access to engine parameters but an independent thermocouple was fitted to the exhaust of the Euro VI bus (see **Figure 2**).

Figure 2: Rear lower deck seats with fast NO_x analyzers and operators on rear seats. Sample probe access point to engine bay (circled).

Generally, it was noted that the relatively cold engine and exhaust temperatures near the start of the bus route correlated with higher and more numerous NO_x hot spots. Thereafter, the hot spots were more sporadic (see **Figure 3**).

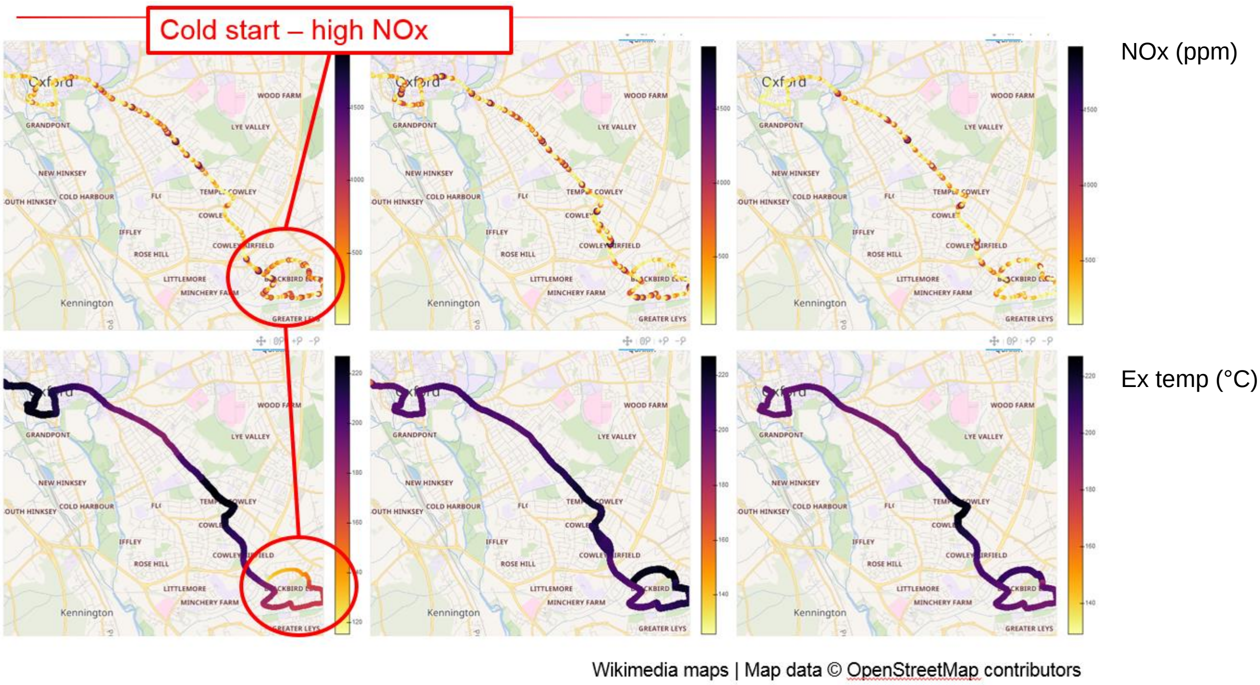

Figure 3: Variation in exhaust temperature comparing 3 successive north-bound journeys and the position of NO_x hot-spots

A correlation was noted between the position of bus stops and high levels of NO_x but also with the general transient driving associated with parked cars, speed bumps etc.

Figure 4: NOx levels produced by the Euro VI bus negotiating parked cars and congestion

There was also a strong effect of temperature on the emissions caused by decelerating towards a bus stop which can be seen clearly within this video: https://www.youtube.com/watch?v=buA1yqXwHso

…and the subsequent spikes of NO_x produced at pull-away from the bus stop:

Figure 5: NO_x spikes caused by pull-away from bus-stop; 2nd spike caused by gear change.

A further video showing the emissions associated with a roundabout (especially the pulling away from the exit and subsequent gear changes) is shown here: https://www.youtube.com/watch?v=RynJVXIZEqI

The geography of part of the Euro V bus route serving a school provides some interesting insights in to the interaction of the bus, the terrain and the resulting NO_x emissions. This is summarised in **Figure 6**. As the bus approaches the school (from top right of map) it is climbing a hill and the exhaust and aftertreatment is hot with very effective reduction of NO_x. However, the slower speeds caused by driving through parked cars combined with the reduced gradient cool the exhaust and NO_x breakthrough occurs. The speed control speed bumps outside the school cause exhaust cooling during the decelerations on approach to each speed bump followed by a burst of NO_x caused by the acceleration away from each speed bump. The final downhill departure from the school would cool the aftertreatment again, but given that the engine is under little load, the (engine-out) NO_x emissions are likely to be low anyway.

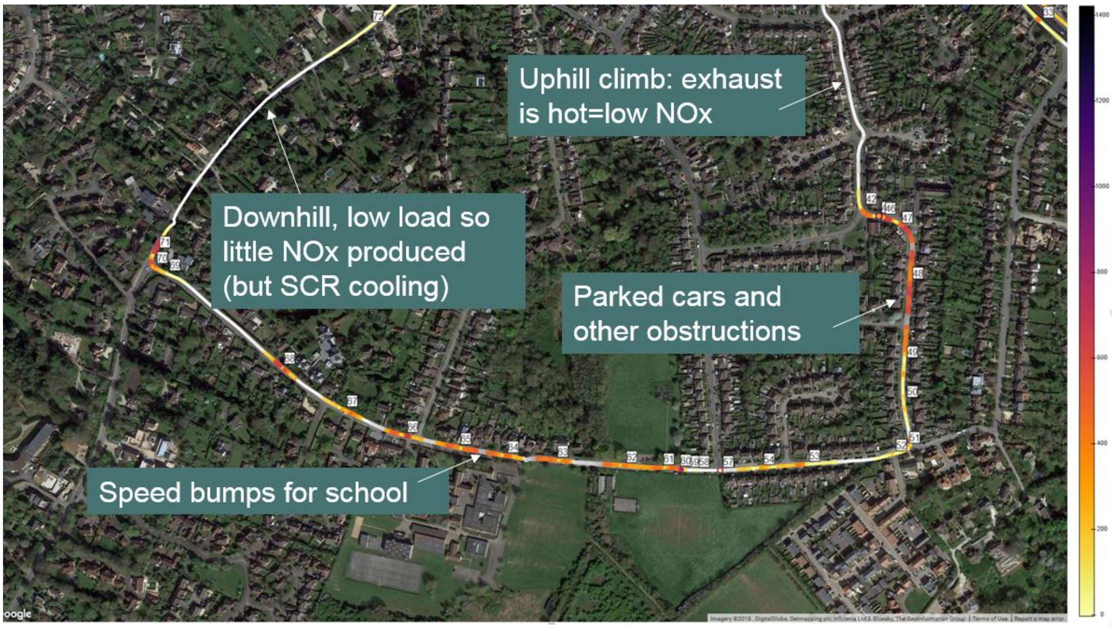

Figure 6: Euro V bus NO_x emissions caused by street layout and congestion surrounding school

Summary

It was clear from comparison of the ppm levels from these buses with similar measurements made for certification purposes that the buses were emitting higher than expected NO_x levels, but without access to ECU or other data containing exhaust mass flow data, it was impossible to make a gravimetric comparison. Euro VI data is shown here in preference to Euro V because the hybrid part of the Euro V bus was inoperative and no exhaust thermocouple had been fitted. However, its NO_x emissions were somewhat worse – especially over speed bumps associated with a school which was part of its route.