Transient NO_2:NO_x ratio

Introduction

The ratio of NO_2 : NO_x in the exhaust stream of a diesel engine depends on various engine parameters (load, EGR, AFR etc) but is of importance to those trying to minimise tailpipe emissions either through combustion optimisation or the addition of a suitable after-treatment system. NO_2 also plays a crucial role in the oxidation of soot on passive regen DPF systems. The modelling of NO_2 content is the subject of on-going research but the measurement of ***transient*** NO_2 as a proportion of total NO_x requires fast response analyzers is demonstrated below by way of example.

Engine

The engine on which this data was taken was a Euro 6 Light Duty Diesel engine. The CLD500 fast chemiluminesence analyzer ($T_{10\text{-}90\%}$ = 2ms for NO and 8ms for NO_x) was used with one channel measuring [NO] and the other channel measuring [NO+ NO_2= NO_x]. A standard bench CLD was also used for comparison. The data were then post-processed to calculate NO_2/NO_x x 100%.

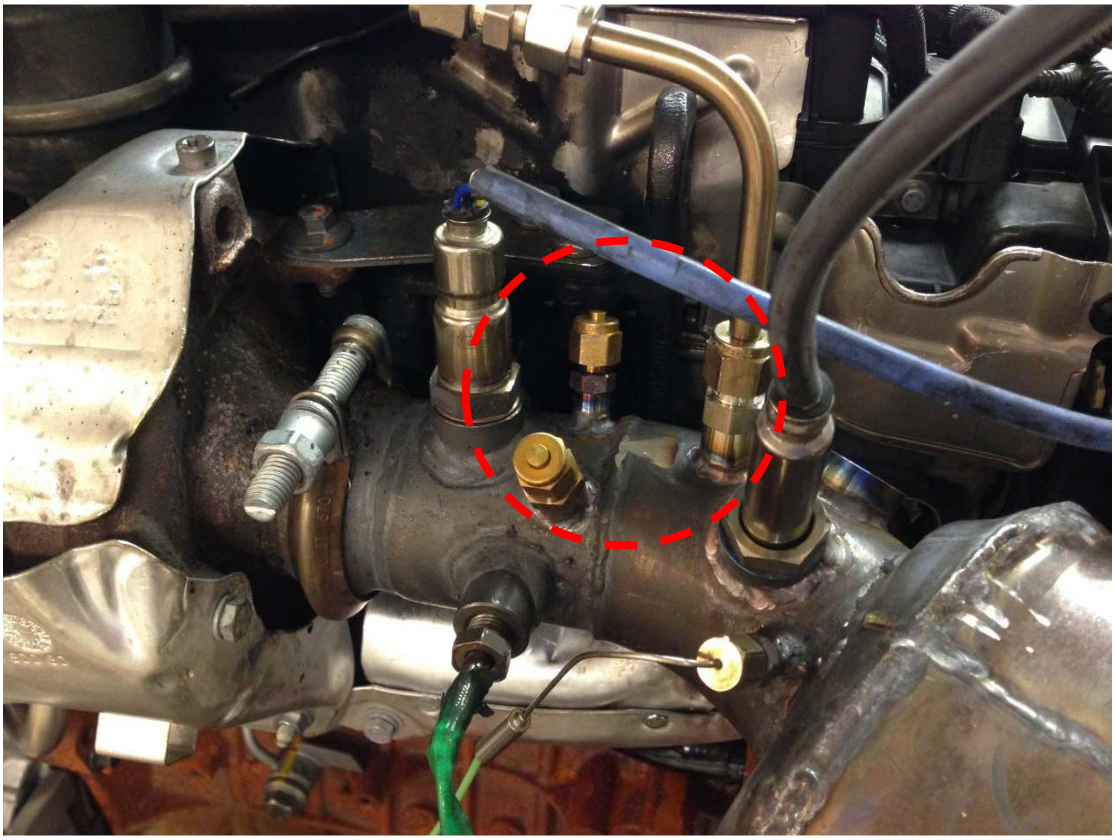

Figure 1: Engine-out sampling points for fast NO and NO_x

Measurements were taken at adjacent sampling points as shown in **Figure 1** at the post-turbo engine-out point. The fast NO and NO_x gases being sampled from the brass capped-off points and the standard bench CLD through the 8mm stainless pipe shown in the circle.

Results

The engine was run through a WLTC cycle which contains periods of hard accelerations and gear changes but also some moderate, gentle accelerations. The first area of interest was the set of accelerations and gear changes around 1170s and the associated NO & NO_x emissions which occurred during that period are shown in **Figure 2**.

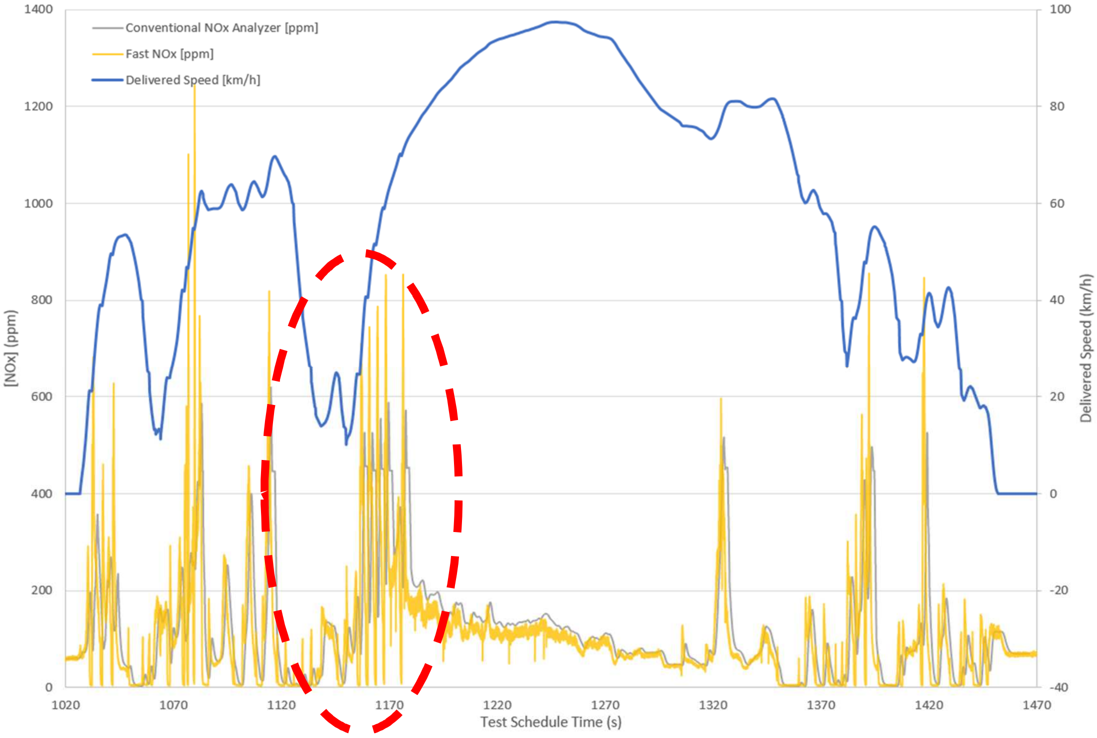

Figure 2: A portion of the highly transient WLTC drive cycle.

The data was then analysed in more detail by expanding the period 1150 to 1170s (see **Figure 3**) where individual gear changes and accelerations reveal the highly transient nature of NO_x production which is not visible using a conventional chemiluminesence analyzer. For example, the fuel shut-offs during decelerations associated with each gear change stop the production of NO_x and the signals can be seen falling to zero at these times but the conventional analyzer is unable fully to resolve these transients. There are also steps during each restart possibly associated with an EGR delivery delay feature.

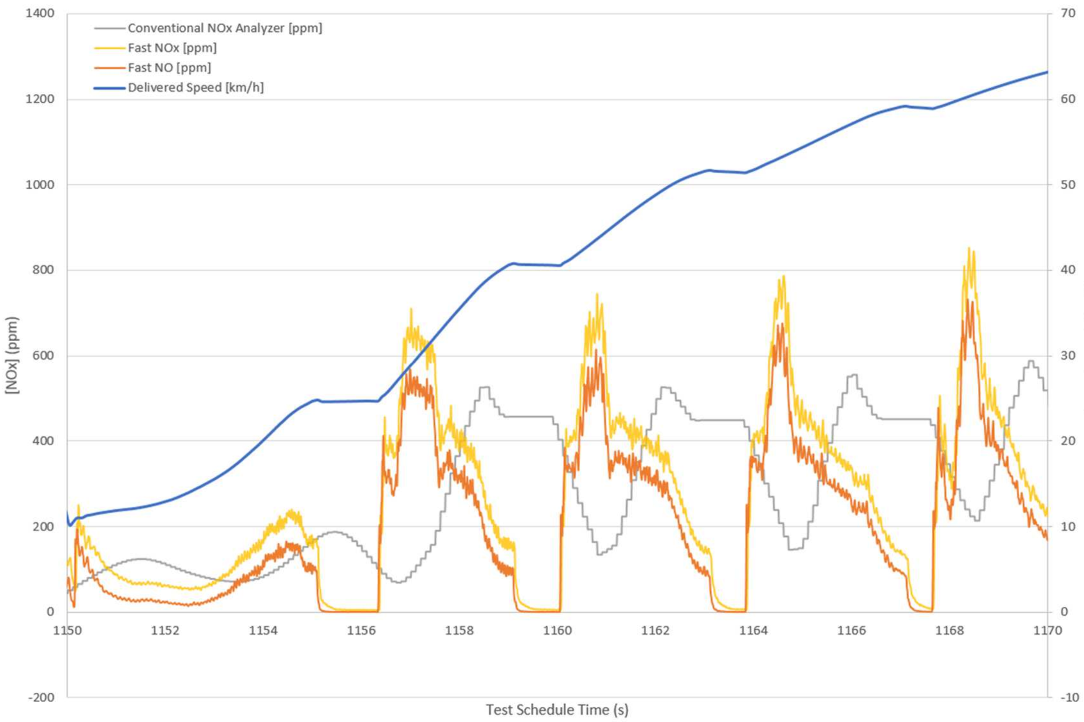

Figure 3: Detail of transient NO_x during hard accelerations and gear changes compared with a conventional NO_x analyzer

The [NO] and [NO_x] data during the same set of transients can then be used to calculate and plot the transient NO_2: NO_x ratio (**Figure 4**). This is seen to change between approximately 25% and 60% during these transients. Note that during the deceleration fuel shut-offs (where no combustion is occurring), the ratio is meaningless and is displayed as near 100%.

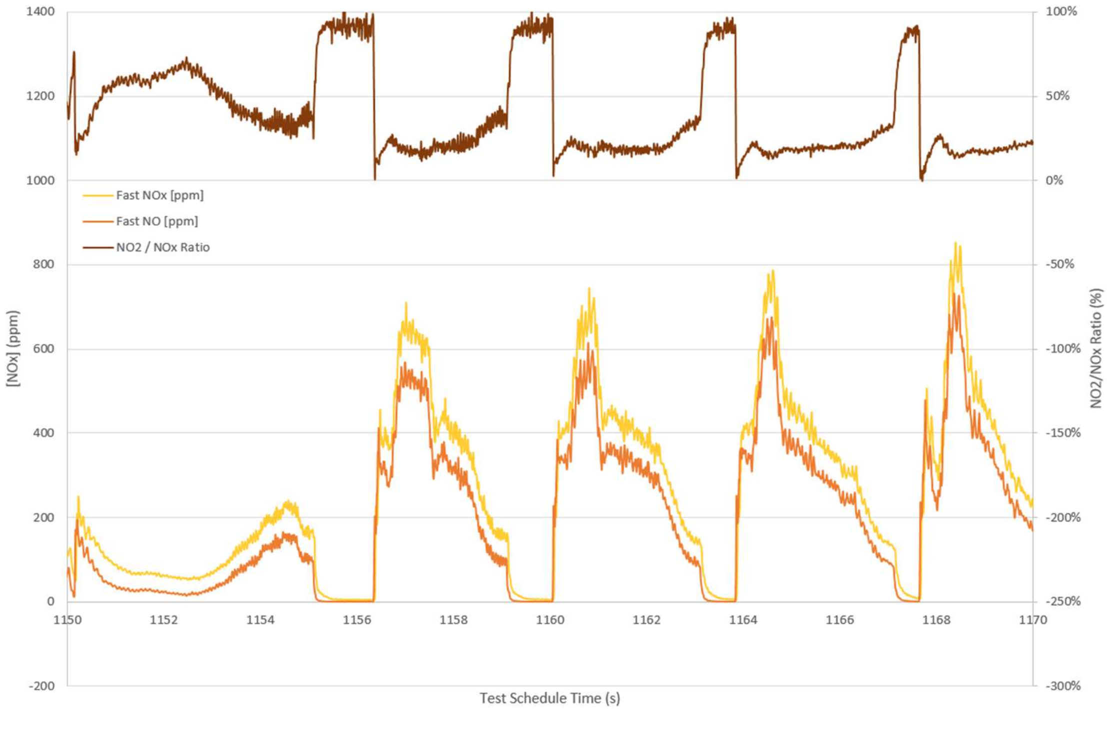

Figure 4: Transient NO_x during hard accelerations and gear changes

Earlier in the WLTC, there are transients and gear changes at more moderate loads (**Figure 5**). Broadly, the proportion of NO_2 is higher at low load because the decomposition reaction of NO_2 to $NO+O_2$ is quenched by the cooler post-flame temperatures.

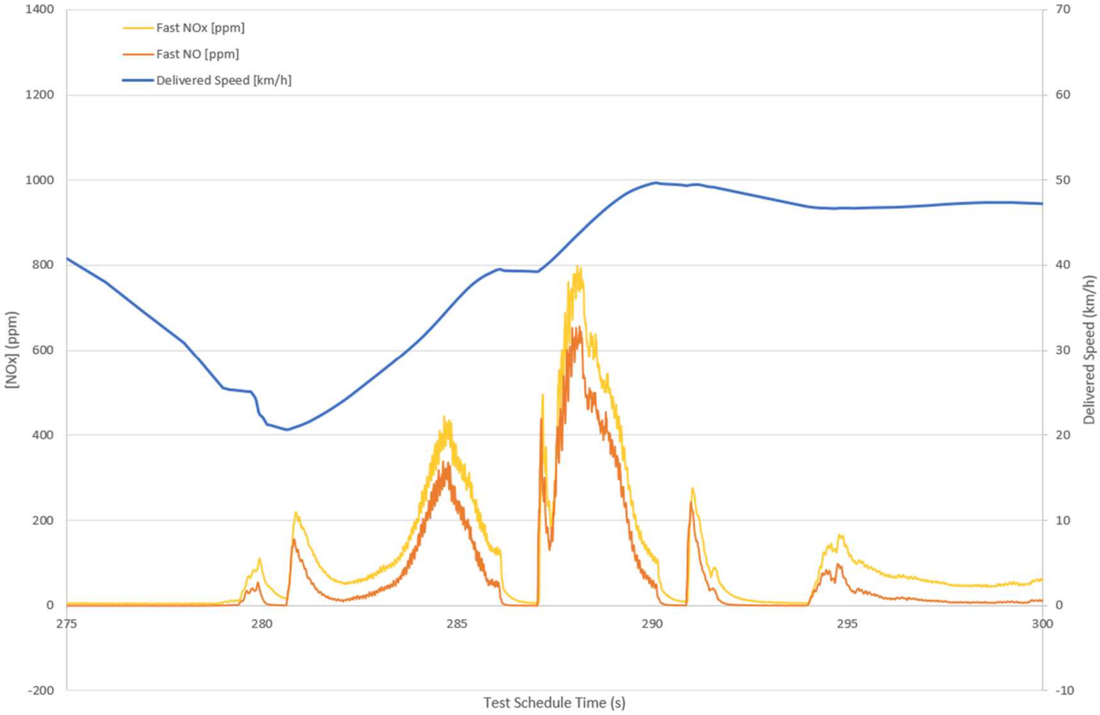

Figure 5: Moderate transients associated with more gentle gear changes

The NO_2: NO_x ratio under these lower load conditions (again, ignoring fuel cuts) varies between about 10% and 70% as shown in **Figure 6**.

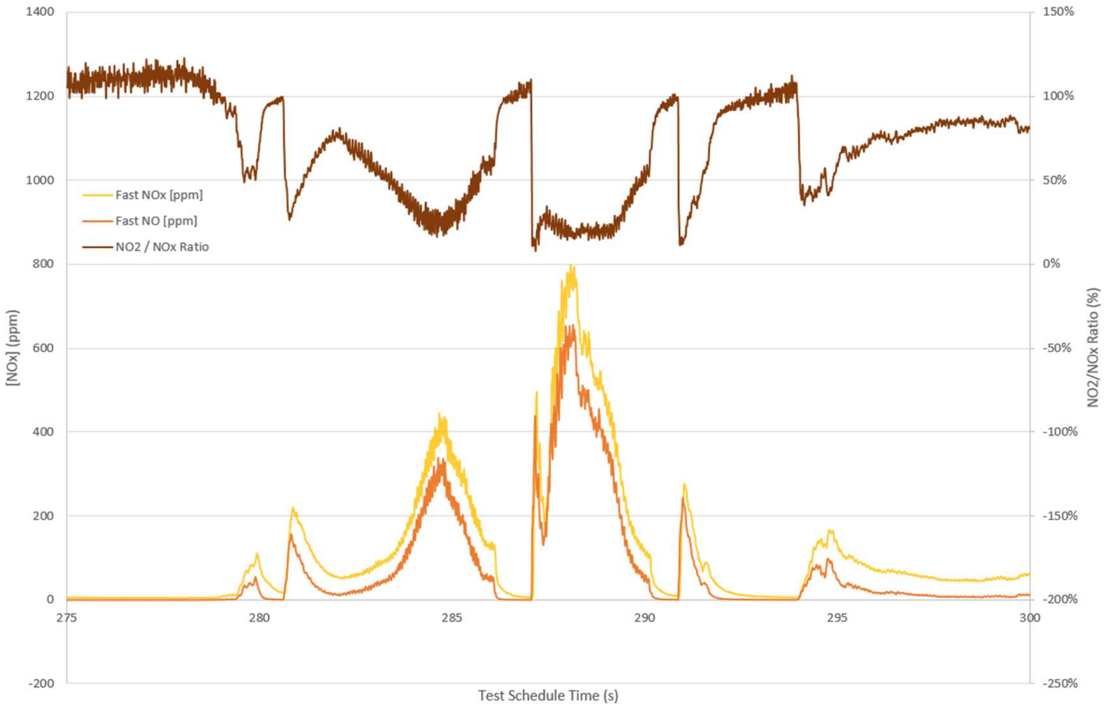

Figure 6: NO_2: NO_x ratio during moderate transients

Summary
Fast analysis of transient NO and NO_x provides insights in to the causes of very short term pollutant production with the possibility of correlating with other real time engine parameters (e.g. lambda, EGR, load). The real time transient ratio of NO_2:NO_x also has implications for after-treatment systems (e.g. SCR) and the modelling thereof.