Incorporating NOx Test into Enhanced I/M

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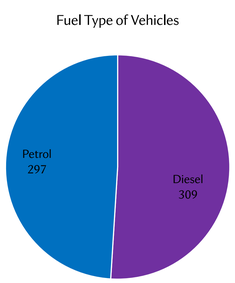
Introduction

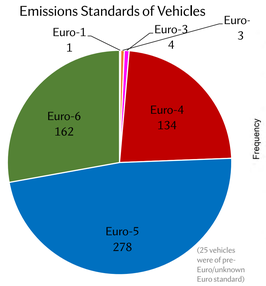
The current European Union (EU) Periodic Technical Inspection (PTI) does not consider oxides of nitrogen (NOx) emissions from vehicles. Consequently, the current PTI program is unable to identify the high emitters of current technology vehicles. It is therefore important to update the PTI test to quantify the NOx emissions in order to capture the pollutants of greatest air quality concern today. The precise form of the NOx test is still being debated, so any new research on this topic will help regulators to decide on the test procedures. This includes the conditioning requirements, the precise protocol of the test itself, and the thresholds for pass/fail at PTI.

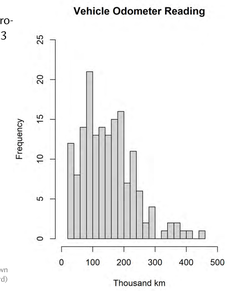
The aims of this project were to investigate various options for the integration of a NOx emission test into the EU PTI procedures. This includes a study of the different test types' repeatability, the representativity of their reporting metrics, and their agreement. Based on the dataset, threshold limits for the different types of test were calculated, and the agreement between fail results for the tested vehicles was quantified to see if simpler test types can be used as a preliminary scanning tool to save time/expense at test centers.

Methodology

The trial of an enhanced PTI emissions test was conducted at the Opus Bilprovning PTI test centre in Borås, Sweden. The trial ran from January 2021 to June 2022, and tested 606 passenger vehicles.



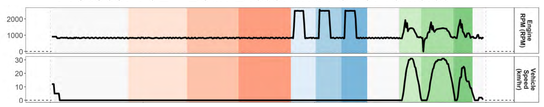




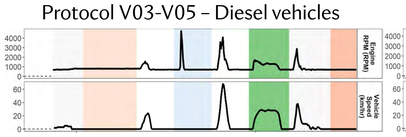
The equipment used for the enhanced PTI emissions test was a 3DATX parSYNC miniPEMS with a sample probe placed for tailpipe emissions sampling. This device measures NO and NO_2 using electrochemical sensors. The miniPEMS equipment also recorded a range of engine control unit (ECU) parameters using a HEM Data OBD Mini Logger, including vehicle speed, engine speed (RPM), lambda, mass air flow, engine coolant temperature, catalyst temperatures, engine load and EGR rate information.

Protocol Version	Extra Time Taken	No. of Vehicles	Idle	High Idle	Acceleration
V01	15 minutes	27	3 consecutive identical repetitions (3x30 s)	-	3 consecutive short drives (0 km/h → 30 km/h → 0 km/h)
V02	20 minutes	78	3 consecutive identical repetitions (3x30 s)	3 consecutive identical repetitions (5 s @ 2500 rpm)	3 consecutive short drives (0 km/h → 30 km/h → 0 km/h)
V03-V05	5 minutes	501	2 non-consecutive identical repetitions (2x60 s)	1, as per PTI requirements for diesel and petrol vehicles	1 short drive (0 km/h → 30 km/h → 0 km/h)

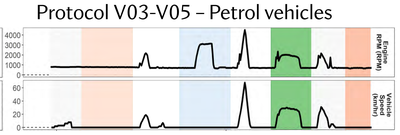
Protocol V02 – Both Diesel and Petrol vehicles



Protocol V03-V05 – Diesel vehicles



Protocol V03-V05 – Petrol vehicles



Results – Repeatability of test types

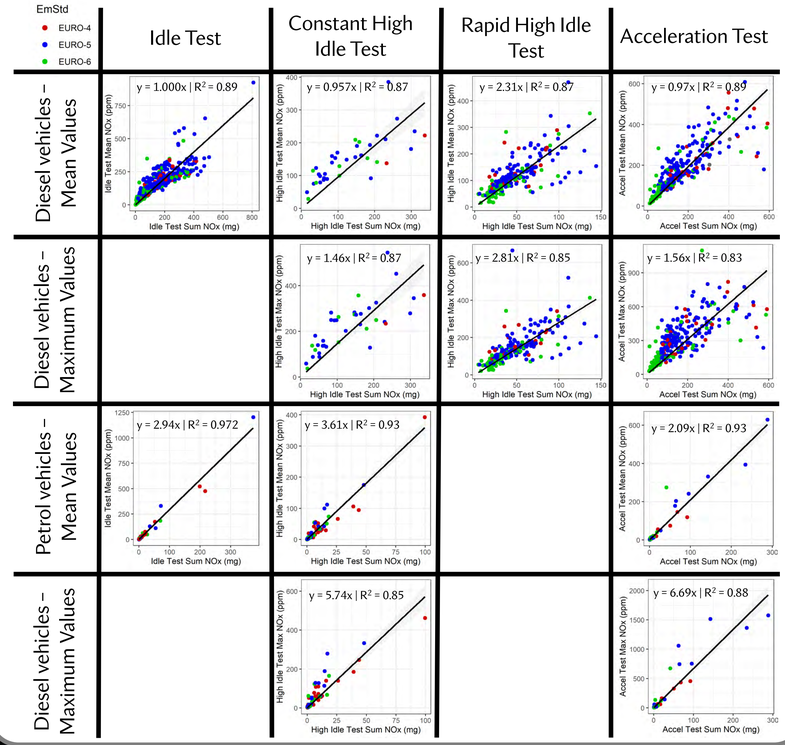
A range of statistical parameters are calculated from triplicate data of 106 vehicles tested on protocol versions V01-V02. The repeatability of these three test types is acceptable.

Test	Quantity	Mean Value	Std. Deviation	Std. Error	Coeff. of Variation
Idle	Average NOx (ppm)	75	14	8.3	19%
	NOx (mg)	119	14	8.4	26%
	Average Engine RPM	807	2.1	1.2	0.24%
	Average Load (%)	25	1.2	0.7	4.7%
	Average EGR (%)	19	3.3	2.0	45%
Constant High Idle	Average NOx (ppm)	82	13	7.5	21%
	NOx (mg)	107	14	8.4	26%
	Average Engine RPM	2332	77	44	3.3%
	Average Load (%)	19	1.2	0.7	6.4%
	Average Engine EGR (%)	20	1.3	0.8	34%
Acceleration	Average NOx (ppm)	184	44	25	33%
	Maximum NOx (ppm)	351	91	52	31%
	NOx (mg)	139	57	33	44%
	Average Engine RPM	1362	123	71	11%
	Maximum Engine RPM	2066	173	101	10%
	Average Load (%)	32	4.2	2.4	17%
	Maximum Load (%)	66	7.0	4.0	12%
	Average EGR (%)	22	2.6	1.5	23%
	Maximum EGR (%)	42	4.0	2.3	12%
	Average VSP_pos (kW/tonne)	31	8.9	5.2	29%
	va_{pos}[95] (m^2/s^3)	59	16	9.0	27%
	Relative Positive Acceleration (m/s^2)	2.9	0.6	0.3	20%

Abbreviations: RPM - revolutions per minute; EGR - exhaust gas recirculation; VSP - vehicle-specific power; vapos [95] - 95th percentile of the product of velocity and positive acceleration; RPA - relative positive acceleration.

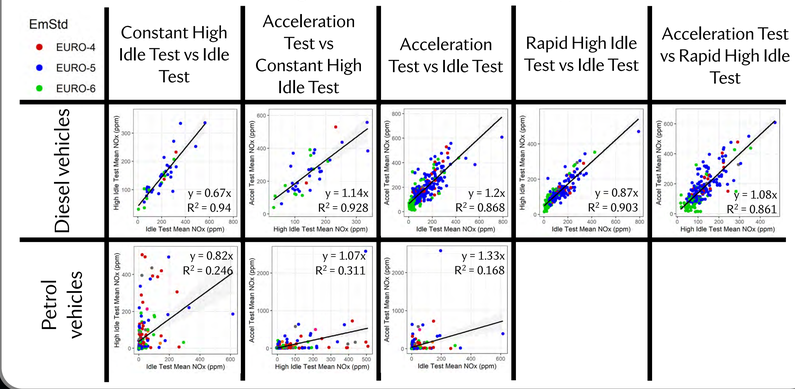
Results – Representativity of test type reporting metrics

The NOx concentrations have strong correlations to the mass emissions for each test type. The correlations are strongest on the idle and acceleration test types for diesel vehicles, and strongest on the idle test type for petrol vehicles. The correlations are stronger for petrol vehicles than diesel vehicles across all test types. The use of mean values is generally more representative than the use of maximum values, where applicable.



Results – Agreement between test types

Diesel vehicles show much stronger correlations between test types than petrol vehicles.



Results – Calculation and application of threshold values

The 95th percentile of the (vehicle fuel- and Euro standard- specific) fleet-average mean NOx values for each test type were calculated and used as the PTI pass/fail thresholds.

Test	Emission Standard	Idle Test Mean NOx (ppm)	Constant High Idle Test Mean NOx (ppm)	Rapid High Idle Test Mean NOx (ppm)	Acceleration Mean Test NOx (ppm)
Diesel	Euro 4	298	228	240	445
	Euro 5	306	312	234	400
	Euro 6	226	186	228	362
Petrol	Euro 4	130	392	NA	163
	Euro 5	138	220	NA	387
	Euro 6	71	138	NA	132

The percentage agreement between different test type fail results for the vehicles indicate that a fail on one test type is not well correlated to a fail on another test type for individual vehicles, when 95th percentile threshold is used. A higher threshold must be applied for simpler unloaded tests to be used as preliminary scanning tools, or use multiple test types.

Quantity	Total	Diesel	Petrol
Idle to Constant High idle test fail agreement (%)	33.3%	57.1%	25.0%
Idle to Rapid High idle test fail agreement (%)	40.0%	40.0%	NA
Idle to Acceleration test fail agreement (%)	35.9%	52.6%	20.0%
Constant High idle to Acceleration test fail agreement (%)	28.0%	33.3%	26.3%
Rapid High idle to Acceleration test fail agreement (%)	46.7%	46.7%	NA

Conclusions

- Multiple test methods can characterize vehicle NOx emissions in a repeatable manner,
- The mean NOx concentration values on the different test types is a good indication of the mass emissions on those tests,
- There is some agreement between test types for diesel vehicles, but little agreement for petrol vehicles tested,
- 95th percentile pass/fail thresholds were calculated from the test fleet,
- In order to catch high emitters on the road, the unloaded idle and high idle test types are not suitable substitutes for a dynamic acceleration test, particularly for petrol vehicles.

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