



TEST REPORT

Swedish In-Service Testing Programme 2011 on emissions from passenger cars and light duty trucks

Emissions from Light Duty Diesel Vehicles
tested at low ambient temperature
2011-03-02

By
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Certification & Regulation Compliance
On behalf of the Swedish Transport Agency
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1. Summary

On request of the Swedish Transport Agency, AVL MTC AB has carried out emission testing on six Euro5 diesel vehicles at two different ambient temperatures: +24°C and -7°C. The tests at +24°C have been performed as at Type I test whereas the tests at -7°C have been performed in the same way as a Type VI test but over the entire NEDC cycle instead of only the UDC. Apart from this, where the tests carried out as described in regulation EC/715/2007 with later amendments.

Type VI tests are not mandatory for diesel vehicles according to the regulation. The aim of this investigation was to gain more knowledge about how diesel vehicles perform regarding emissions at low ambient temperatures.

At a low ambient temperature, the test vehicles had no problems fulfilling the emission limits set for vehicles with a SI engine. However, in comparison to the tests performed at starting temperature +24°C, all vehicles showed increases of all emissions.



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2. Test information

2.1.	Test laboratory:	AVL MTC AB, Stockholm, Sweden
2.1.1.	Test cell no:	4
2.2	Test period:	2011-12-19 → 2012-02-05
2.3.	Type of chassis dynamometer:	AVL-Zöllner 48" Compact
2.3.1.	Type of emission sampling system:	Pierburg CVS 2000
2.3.2.	Type of analytical system:	Pierburg AMA 4000
2.4	Test fuel:	Preem Diesel EU5 B0 fulfilling EN590
2.5.	Dynamometer setting:	For the dynamometer settings, figures from the manufactures coast down times were used when available. Otherwise the coast down times according to the directive have been used.

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3. Test Cycle

New European Driving Cycle (NEDC)

The NEDC test starts, according to the legislation, with a cold engine at approximately 24 °C. The temperature is reached by letting the vehicle soak for at least 6 hours. NEDC is the test cycle for emission certification of light duty vehicles. The first 780 s includes four identical cycles, representing the Urban Driving Cycle (UDC). This part may be further divided into two parts of 390 s each (C_1+2 as UDC1 and C_3+4 as UDC2) in order to compare vehicle emissions from a cold engine and exhaust system with those from the engine and exhaust system at a proper operating temperature. The period from 780 s to the cycle end at 1180 s represents the higher speed part of the cycle, the Extra Urban Driving Cycle (EUDC).

The UDC part of the NEDC cycle is also used in order to verify the emissions of carbon monoxide (CO) and hydrocarbons (HC) at low ambient temperatures (-7°C) on vehicles equipped with spark ignited engines (Type VI test).

Figure 2 shows the breakdown of the Type I test (NEDC).

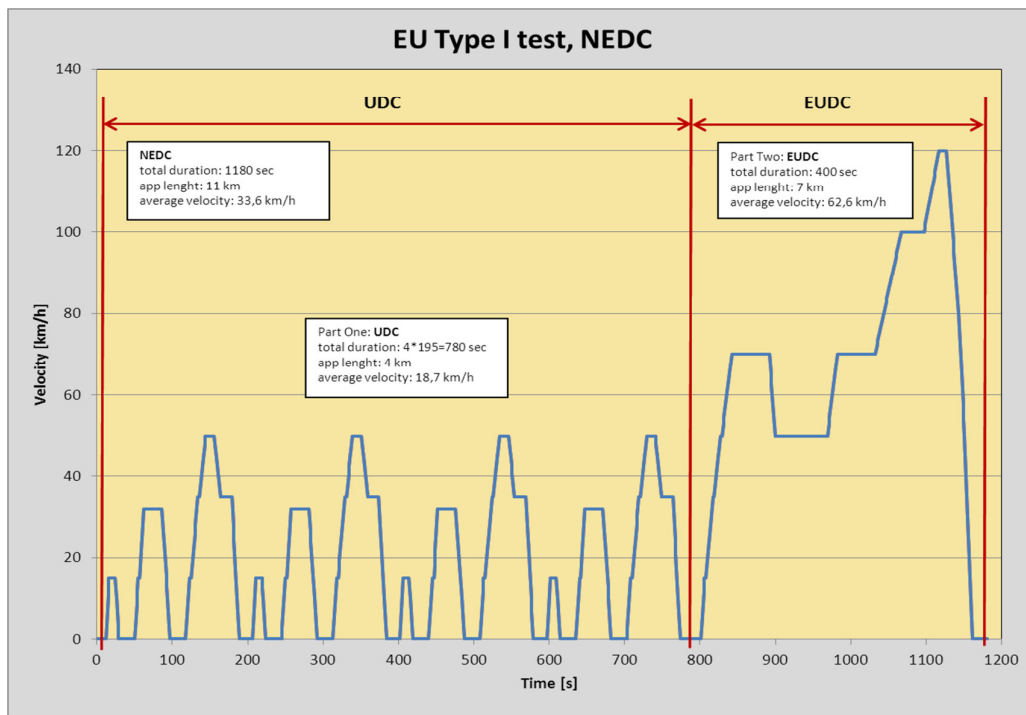


Figure 1 EU TYPE I Test - NEDC - New European Driving Cycle

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4. Test vehicles

The test vehicles were randomly selected by AVL MTC AB from vehicles in use on the market in Sweden.

The selected test vehicles were as follows:

Table 1 Selected vehicles

No	Manufacturer	Vehicle model	Transmission	Inertia (kg)	Odometer (km)	Dynamometer setting from manufacturers Coast down times
# 1	BMW	116d	M6	1360	1290	No
# 2	SKODA	Superb	M6	1590	3926	Yes
# 3	PEUGEOT	308	Aut	1450	22403	No
# 4	MINI	Clubman	M6	1360	6049	No
# 5	TOYOTA	Yaris	M6	1130	5077	Yes
# 6	VOLVO	V70	M6	1590	764	Yes

5. Control of test vehicles and maintenance prior to the test

In order to verify the condition of the vehicles, each test vehicle has been examined.

Following have been verified:

Engine fluids:	All vehicles were OK.
Exhaust system:	No leakage, all vehicles were OK.
Drive wheel brakes:	All vehicles were OK.
Fault codes:	No fault codes were recorded on any vehicle.

6. Test programme

- 6.1. The test vehicles have been subject to Type I test (verifying the average tailpipe emissions after a cold start (+24°C)). Emissions of carbon monoxide (CO), carbon dioxide (CO₂), hydrocarbons (HC and NMHC), oxides of nitrogen (NO_x) and particles (PM) where measured over the entire NEDC and the sub cycles UDC and EUDC.
- 6.2. The test vehicles have been subject to test similar to the Type VI test (verifying the average tailpipe emissions at low ambient temperature). Emissions of carbon monoxide (CO), carbon dioxide (CO₂), hydrocarbons (HC and NMHC), oxides of nitrogen (NO_x) and particles (PM) where measured not only in the UDC but also in the EUDC and over the entire NEDC.

Fuel consumption (F_c) was calculated by the carbon balance method.

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7. Results

Summary of test results

Table 2 NEDC Results BMW 116d

	CO (mg/km)	HC (mg/km)	NOx (mg/km)	HC+NOx (mg/km)	NMHC (mg/km)	PM (mg/km)	FC (L/100km)	CO ₂ (g/km)
+24 NEDC	105	20	157	177	13	0,35	5,3	139
-7 NEDC 1	1307	91	1096	1188	84	0,60	6,6	171
-7 NEDC 2	1675	143	1105	1249	135	0,48	6,7	173
-7 NEDC Average	1491	117	1101	1219	110	0,54	6,6	172
Stdev	260	37	6	43	36	0,08	0,07	1
<i>Certification values (+24)</i>	239,3	-	124,6	154,6	-	0,3	4,5	117
<i>Limit values (+24)</i>	500	-	180	230	-	4,5	-	-

Table 3 UDC and EUDC Results BMW 116d

	CO (mg/km)	HC (mg/km)	NOx (mg/km)	HC+NOx (mg/km)	NMHC (mg/km)	PM (mg/km)	FC (L/100km)	CO ₂ (g/km)
+24 UDC	283	44	178	222	30	-	6,5	172
-7 UDC 1	3451	196	1178	1374	178	-	8,9	228
-7 UDC 2	4362	279	1157	1436	259	-	9,0	229
-7 UDC Average	3906	237	1168	1405	218	-	8,9	229
Stdev	644	59	15	44	57		0,06	0
<i>Limit values (-7 UDC)</i>	15000	1800						
+24 EUDC	0,4	6	145	151	3	-	4,5	120
-7 EUDC 1	43,8	30	1048	1078	28	-	5,2	138
-7 EUDC 2	91,1	64	1074	1138	62	-	5,3	140
-7 EUDC Average	67	47	1061	1108	45	-	5,3	139
Stdev	33	24	19	42	24		0,07	2

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Table 4 NEDC Results Skoda Superb

	CO (mg/km)	HC (mg/km)	NO _x (mg/km)	HC+NO _x (mg/km)	NMHC (mg/km)	PM (mg/km)	F _c (L/100km)	CO ₂ (g/km)
+24 NEDC	176	43	116	159	34	0,32	6,0	159
-7 NEDC 1	348	55	610	664	53	0,52	7,0	184
-7 NEDC 2	383	61	609	670	58	-0,01	7,0	185
-7 NEDC Average	365,5	58	610	667	56	0,255	7,0	184
<i>Stdev</i>	25	4	1	4	4	0,37	0,03	1
<i>Certification values (+24)</i>	376,7	-	138,3	185,7	-	0,1	5,5	145
<i>Limit values (+24)</i>	500	-	180	230	-	4,5	-	-

Table 5 UDC and EUDC Results Skoda Superb

	CO (mg/km)	HC (mg/km)	NO _x (mg/km)	HC+NO _x (mg/km)	NMHC (mg/km)	PM (mg/km)	F _c (L/100km)	CO ₂ (g/km)
+24 UDC	481	101	179,9	281	85	-	7,9	209
-7 UDC 1	931	135	765	900	127	-	9,9	261
-7 UDC 2	1019	153	748	901	144	-	9,9	260
-7 UDC Average	975	144	757	901	136	-	9,9	261
<i>Stdev</i>	62	13	12	0	12		0,01	0
<i>Limit values (-7 UDC)</i>	15000	1800						
+24 EUDC	-1,6	9	79	88	4	-	4,9	130
-7 EUDC 1	5,2	8	518	526	10	-	5,3	139
-7 EUDC 2	9,4	7	527	534	7	-	5,3	141
-7 EUDC Average	7	7	522	530	8	-	5,3	140
<i>Stdev</i>	3	0	6	6	2		0,05	1

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Table 6 NEDC Results Peugeot 308

	CO (mg/km)	HC (mg/km)	NO _x (mg/km)	HC+NO _x (mg/km)	NMHC (mg/km)	PM (mg/km)	F _c (L/100km)	CO ₂ (g/km)
+24 NEDC	137	16	159	175	11	0,27	4,6	122
-7 NEDC 1	478	66	560	626	44	0,18	6,1	160
-7 NEDC 2	390	49	518	567	34	0,35	5,9	156
-7 NEDC Average	434	57,5	539	597	39	0,265	6,0	158
<i>Stdev</i>	62	12	30	42	7	0,12	0,12	3
<i>Certification values (+24)</i>	279,3	-	132,0	175,0	-	0,4	4,4	114
<i>Limit values (+24)</i>	500	-	180	230	-	4,5	-	-

Table 7 UDC and EUDC Results Peugeot 308

	CO (mg/km)	HC (mg/km)	NO _x (mg/km)	HC+NO _x (mg/km)	NMHC (mg/km)	PM (mg/km)	F _c (L/100km)	CO ₂ (g/km)
+24 UDC	372,1	33	237,7	271	26	-	5,7	150
-7 UDC 1	1257	147	848	995	111	-	8,6	224
-7 UDC 2	1053	124	909	1033	89	-	5,9	156
-7 UDC Average	1155	136	879	1014	100	-	7,2	190
<i>Stdev</i>	144	17	43	26	15		1,85	48
<i>Limit values (-7 UDC)</i>	15000	1800						
+24 EUDC	0,3	6	113	120	3	-	4,0	105
-7 EUDC 1	21,8	18	392	410	5	-	4,7	123
-7 EUDC 2	4,2	6	291	297	2	-	4,3	114
-7 EUDC Average	13	12	341	353	3	-	4,5	118
<i>Stdev</i>	12	8	72	80	2		0,26	7

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Table 8 NEDC Results Mini Clubman

	<u>CO</u> (mg/km)	<u>HC</u> (mg/km)	<u>NOx</u> (mg/km)	<u>HC+NOx</u> (mg/km)	<u>NMHC</u> (mg/km)	<u>PM</u> (mg/km)	<u>Fc</u> (L/100km)	<u>CO₂</u> (g/km)
+24 NEDC	204	11,8	182,6	194,4	7,8	0,35	5,1	135
-7 NEDC 1	1880,8	191,1	843,5	1034,6	181,3	0,68	6,3	164
-7 NEDC 2	1841,5	173	848,3	1021,3	163,8	0,51	6,4	166
-7 NEDC Average	1861,15	182,05	846	1028	173	0,595	6,4	165
<i>Stdev</i>	<i>28</i>	<i>13</i>	<i>3</i>	<i>9</i>	<i>12</i>	<i>0,12</i>	<i>0,04</i>	<i>1</i>
<i>Certification values (+24)</i>	<i>243,6</i>	<i>-</i>	<i>173,6</i>	<i>195,3</i>	<i>-</i>	<i>0,1</i>	<i>3,9</i>	<i>103</i>
<i>Limit values (+24)</i>	<i>500</i>	<i>-</i>	<i>180</i>	<i>230</i>	<i>-</i>	<i>4,5</i>	<i>-</i>	<i>-</i>

Table 9 UDC and EUDC Results Mini Clubman

	<u>CO</u> (mg/km)	<u>HC</u> (mg/km)	<u>NOx</u> (mg/km)	<u>HC+NOx</u> (mg/km)	<u>NMHC</u> (mg/km)	<u>PM</u> (mg/km)	<u>Fc</u> (L/100km)	<u>CO₂</u> (g/km)
+24 UDC	283	44	178	222	30	0,35	6,5	172
-7 UDC 1	4881	377	821	1198	353	-	6,3	164
-7 UDC 2	4820	347	843	1190	325	-	6,4	166
-7 UDC Average	4851	362	832	1194	339	-	6,4	165
<i>Stdev</i>	<i>43</i>	<i>21</i>	<i>15</i>	<i>6</i>	<i>20</i>		<i>0,04</i>	<i>1</i>
<i>Limit values (-7 UDC)</i>	<i>15000</i>	<i>1800</i>						
+24 EUDC	0,3	6	113	120	3	-	4,0	105
-7 EUDC 1	85,79	80	857	936	79	-	5,3	140
-7 EUDC 2	92,5	71	852	923	69	-	5,3	141
-7 EUDC Average	89	75	854	929	74	-	5,3	141
<i>Stdev</i>	<i>5</i>	<i>6</i>	<i>4</i>	<i>10</i>	<i>7</i>		<i>0,02</i>	<i>0</i>

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Table 10 NEDC Results Toyota Yaris

	<u>CO</u> (mg/km)	<u>HC</u> (mg/km)	<u>NOx</u> (mg/km)	<u>HC+NOx</u> (mg/km)	<u>NMHC</u> (mg/km)	<u>PM</u> (mg/km)	<u>Fc</u> (L/100km)	<u>CO₂</u> (g/km)
+24 NEDC	131,3	14,9	119	133,9	10,1	0,07	4,2	112
	-	-	-	-	-	-	-	-
-7 NEDC 1	502,2	24,7	262,5	287,2	17,5	-0,07	5,2	136
-7 NEDC 2	494,3	22,7	258,7	281,4	15,9	0,14	5,2	137
-7 NEDC Average	498,25	23,7	261	284	17	0,035	5,2	137
<i>Stdev</i>	6	1	3	4	1	0,15	0,02	1
<i>Certification values (+24)</i>	192,9	-	141,1	151,1	-	1,1	3,9	104
<i>Limit values (+24)</i>	500	-	180	230	-	4,5	-	-

Table 11 UDC and EUDC Results Toyota Yaris

	<u>CO</u> (mg/km)	<u>HC</u> (mg/km)	<u>NOx</u> (mg/km)	<u>HC+NOx</u> (mg/km)	<u>NMHC</u> (mg/km)	<u>PM</u> (mg/km)	<u>Fc</u> (L/100km)	<u>CO₂</u> (g/km)
+24 UDC	348,48	31	147,55	179	22	-	5,1	135
-7 UDC 1	1340	61	429	490	45	-	6,9	180
-7 UDC 2	1335	56	418	474	42	-	6,9	181
-7 UDC Average	1338	59	424	482	43	-	6,9	181
<i>Stdev</i>	4	3	8	11	2		0,03	1
<i>Limit values (-7 UDC)</i>	15000	1800						
+24 EUDC	2,42	5	102	107	3	-	3,7	98
-7 EUDC 1	7,55	3	164	167	1	-	4,2	110
-7 EUDC 2	-1,07	3	165	168	1	-	4,2	111
-7 EUDC Average	3	3	165	168	1	-	4,2	111
<i>Stdev</i>	6	0	0	0	0		0,02	0

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Table 12 NEDC Results Volvo V70

	CO (mg/km)	HC (mg/km)	NOx (mg/km)	HC+NOx (mg/km)	NMHC (mg/km)	PM (mg/km)	Fc (L/100km)	CO ₂ (g/km)
+24 NEDC	247,9	37,3	205,5	242,8	29,3	0,39	5,0	131
	-	-	-	-	-	-	-	-
-7 NEDC 1	1486,7	170,2	1167	1337,2	157,6	0,05	6,1	159
-7 NEDC 2	1113,3	170,1	1218,6	1388,7	155,7	-0,02	6,1	160
-7 NEDC Average	1300	170,15	1193	1363	157	0,015	6,1	159
<i>Stdev</i>	<i>264</i>	<i>0</i>	<i>36</i>	<i>36</i>	<i>1</i>	<i>0,05</i>	<i>0,01</i>	<i>1</i>
<i>Certification values (+24)</i>	<i>206,9</i>	<i>-</i>	<i>146,9</i>	<i>167,2</i>	<i>-</i>	<i>0,3</i>	<i>5,3</i>	<i>139</i>
<i>Limit values (+24)</i>	<i>500</i>	<i>-</i>	<i>180</i>	<i>230</i>	<i>-</i>	<i>4,5</i>	<i>-</i>	<i>-</i>

Table 13 UDC and EUDC Results Volvo V70

	CO (mg/km)	HC (mg/km)	NOx (mg/km)	HC+NOx (mg/km)	NMHC (mg/km)	PM (mg/km)	Fc (L/100km)	CO ₂ (g/km)
+24 UDC	661,29	84	275,56	359	71	-	6,2	162
-7 UDC 1	3893	378	1394	1772	346	-	8,6	219
-7 UDC 2	2932	387	1426	1813	350	-	8,6	221
-7 UDC Average	3412	383	1410	1792	348	-	8,6	220
<i>Stdev</i>	<i>679</i>	<i>7</i>	<i>22</i>	<i>29</i>	<i>3</i>		<i>0,02</i>	<i>2</i>
<i>Limit values (-7 UDC)</i>	<i>15000</i>	<i>1800</i>						
+24 EUDC	4,82	10	164	174	5	-	4,3	112
-7 EUDC 1	80,12	49	1034	1083	47	-	4,7	124
-7 EUDC 2	56,61	44	1098	1142	43	-	4,7	124
-7 EUDC Average	68	46	1066	1113	45	-	4,7	124
<i>Stdev</i>	<i>17</i>	<i>3</i>	<i>45</i>	<i>42</i>	<i>3</i>		<i>0,01</i>	<i>0</i>

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Emission test results

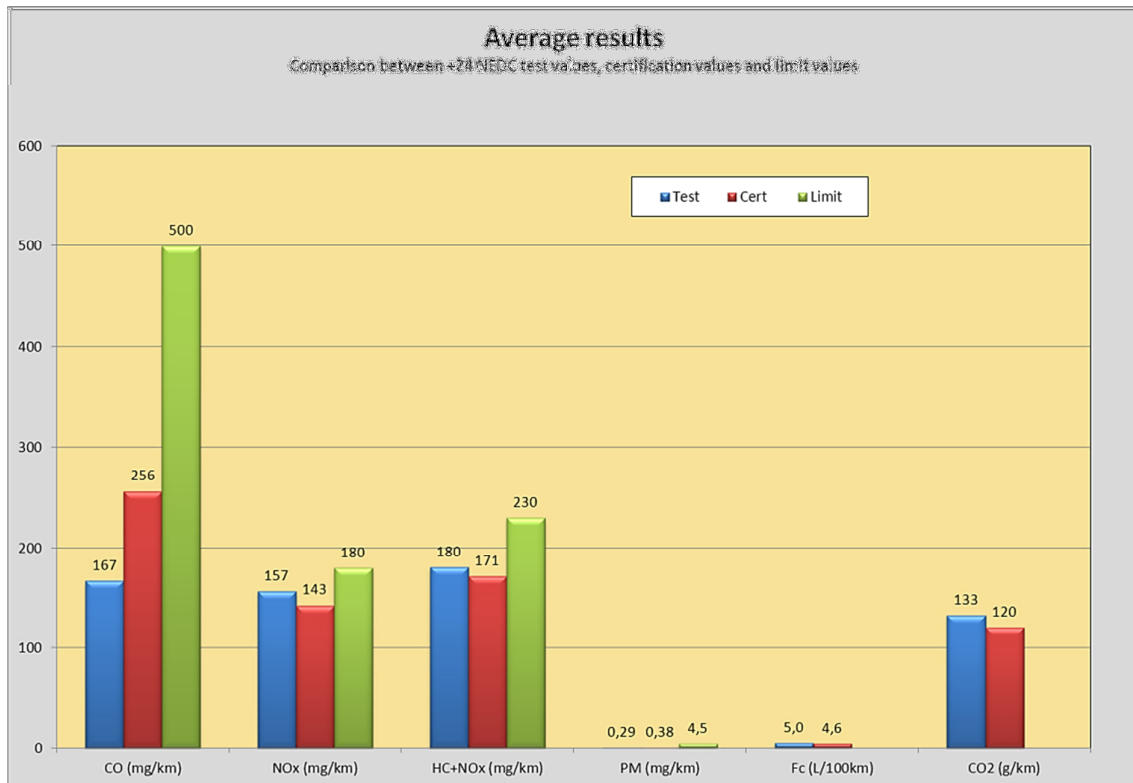


Figure 2 Comparison of NEDC test values, type approval values and Euro 5 emission limit values

None of the cars had any problems fulfilling the limit values regarding CO, HC+NOx and PM when tested at +24°C. Two of the cars exceeded the NOx emission limit value.

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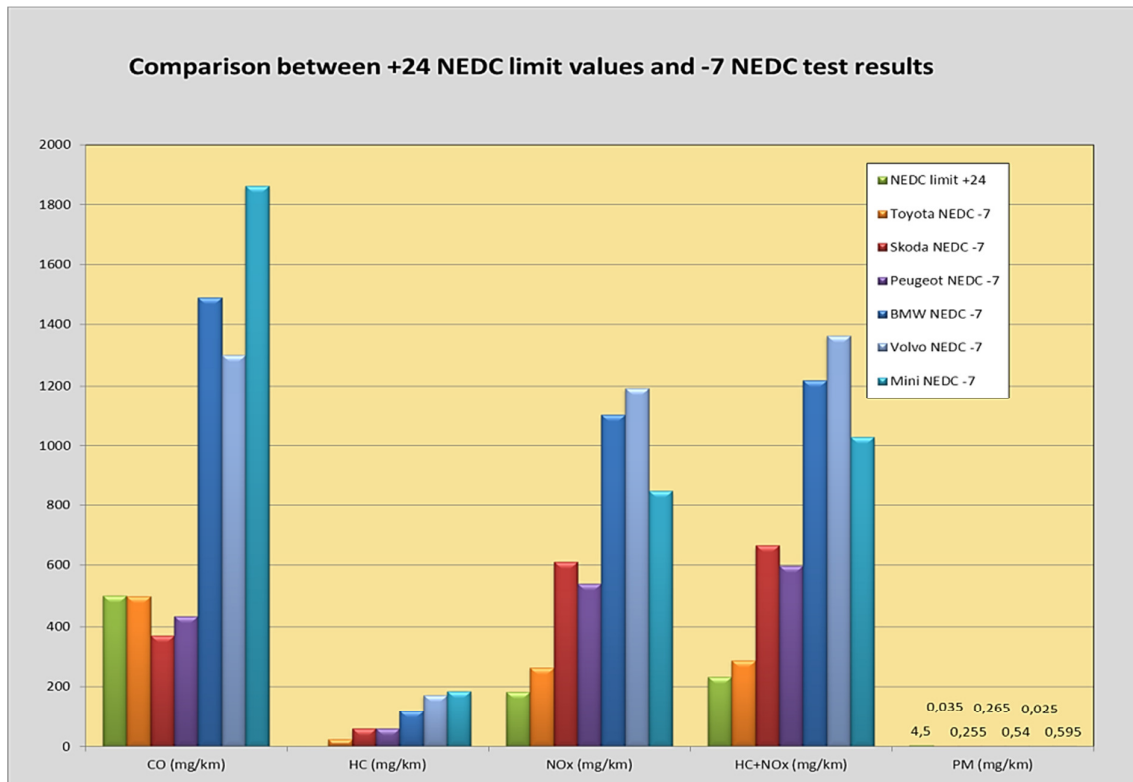


Figure 3 Comparison between NEDC test values when tested at ambient temperatures +24°C and -7°C

When tested at -7°C, three vehicles exceeded the CO emission limit (+24°C). All vehicles exceeded the NOx and HC+NOx emission limits. None of the vehicles had problems regarding the PM emission limit.

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Table 14 Change of CO, HC and NOx in the low ambient temperature NEDC, in %, compared to limit values and normal NEDC test values

	CO		HC	NOx		HC+NOx	
	Per cent of NEDC limit value +24	Per cent of NEDC +24 test value	Per cent of NEDC +24 test value	Per cent of NEDC limit value +24	Per cent of NEDC +24 test value	Per cent of NEDC limit value +24	Per cent of NEDC +24 test value
BMW	198%	1320%	485%	511%	601%	430%	588%
Skoda	-33%	108%	35%	239%	425%	190%	319%
Peugeot	-13%	55%	0%	199%	308%	159%	241%
Mini	272%	812%	1443%	370%	363%	347%	429%
Toyota	0%	279%	59%	45%	119%	24%	112%
Volvo	160%	424%	356%	563%	480%	493%	461%

Table 15 Change of PM, Fc and CO₂ in the low ambient temperature NEDC, in %, compared to limit values, when applicable, and normal NEDC test values

	PM		Fc	CO ₂
	Per cent of NEDC limit value +24	Per cent of NEDC +24 test value	Per cent of NEDC +24 test value	Per cent of NEDC +24 test value
BMW	-88%	54%	25%	24%
Skoda	-98%	20%	16%	16%
Peugeot	-94%	-51%	37%	39%
Mini	-87%	70%	25%	22%
Toyota	-99%	-50%	23%	22%
Volvo	-100%	-96%	23%	22%

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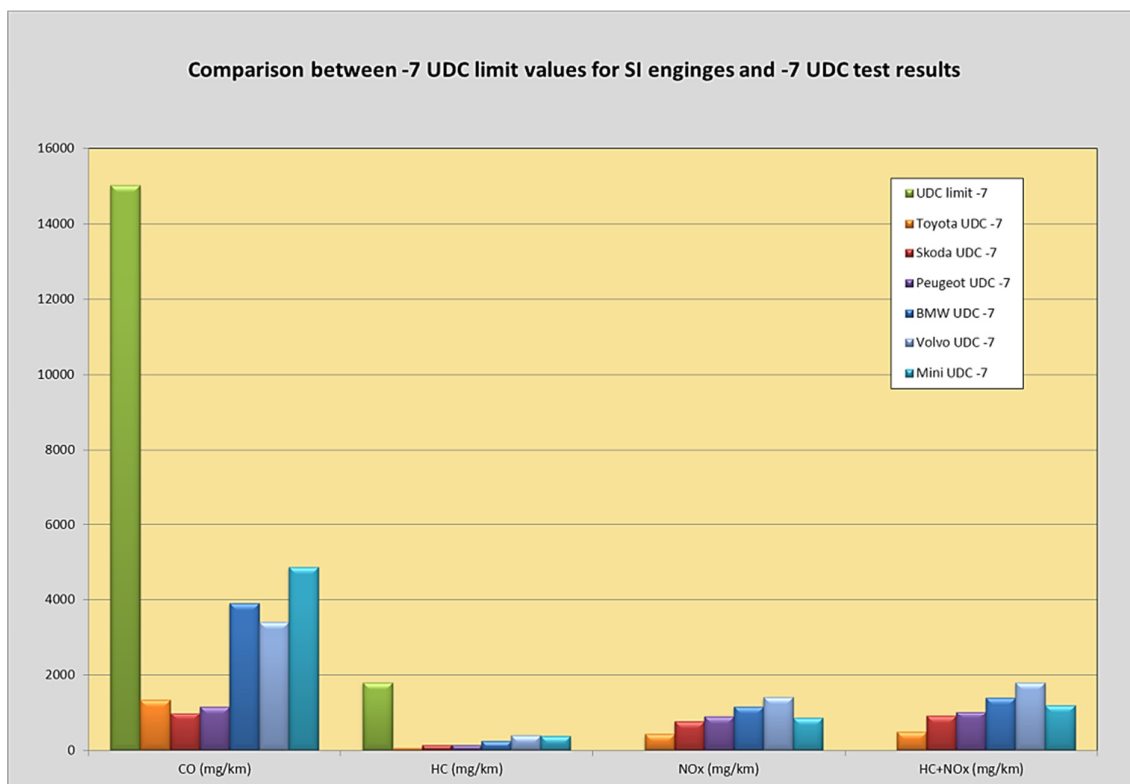


Figure 4 Type VI test results in comparison to emission limit valid for SI engine vehicles

In the Type VI test, none of the vehicles exceeded the SI engine emission limits regarding CO and HC. However, all vehicles showed increases of all emissions in comparison to the emissions in the UDC at ambient temperature +24°C.

Table 16 Change of emissions in the -7°C UDC, in %, compared to the SI engine limit values and +24°C UDC test values

	CO		HC		NOx	HC+NOx	Fc	CO ₂
	Per cent of UDC SI engine limit value -7°C	Per cent of UDC +24°C test value	Per cent of UDC SI engine limit value -7°C	Per cent of UDC +24°C test value	Per cent of UDC +24°C test value	Per cent of UDC +24°C test value	Per cent of UDC +24°C test value	Per cent of UDC +24°C test value
BMW	-74%	1280%	-87%	441%	556%	533%	36%	33%
Skoda	-93%	103%	-92%	43%	321%	221%	25%	25%
Peugeot	-92%	210%	-92%	308%	270%	274%	27%	26%
Mini	-68%	1614%	-80%	725%	367%	438%	-3%	-4%
Toyota	-91%	284%	-97%	89%	187%	170%	35%	34%
Volvo	-77%	416%	-79%	357%	412%	399%	39%	36%

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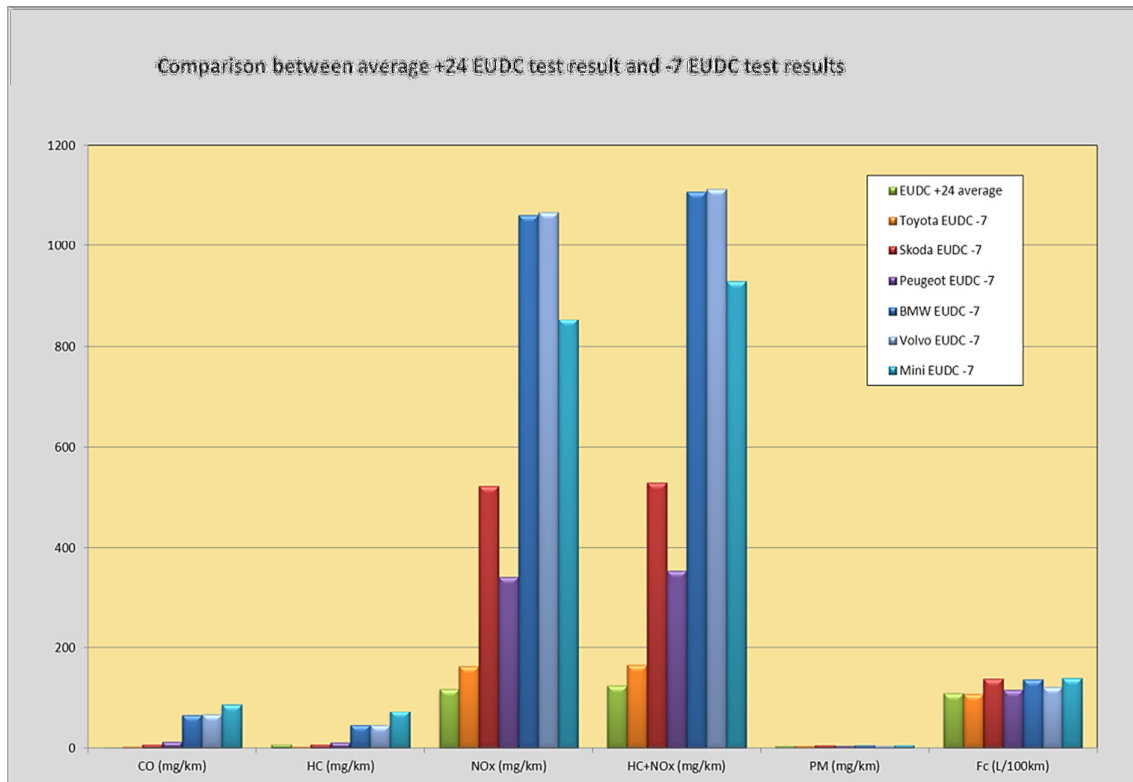


Figure 5 Test results from highway part of the NEDC when tested at ambient temperature -7 °C in comparison to average test results when tested at +24°C

Also in the EUDC are, for most tested vehicles, the NOx values considerable higher when tested in low ambient temperature than in the corresponding “warm” test.

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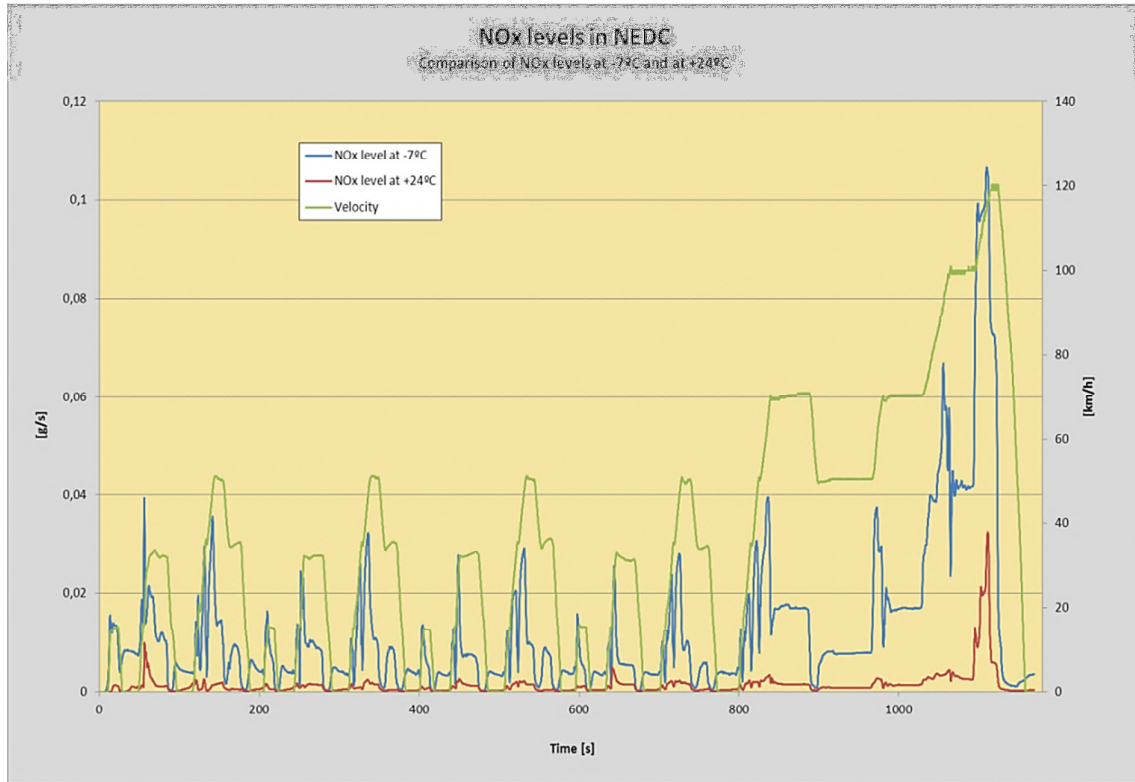


Figure 6 NOx levels during the NEDC at ambient temperatures -7 °C and +24 °C

The NOx level is at a high level throughout the entire NEDC cycle when tested at -7°C.

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Results from measurement of Fuel consumption and CO₂

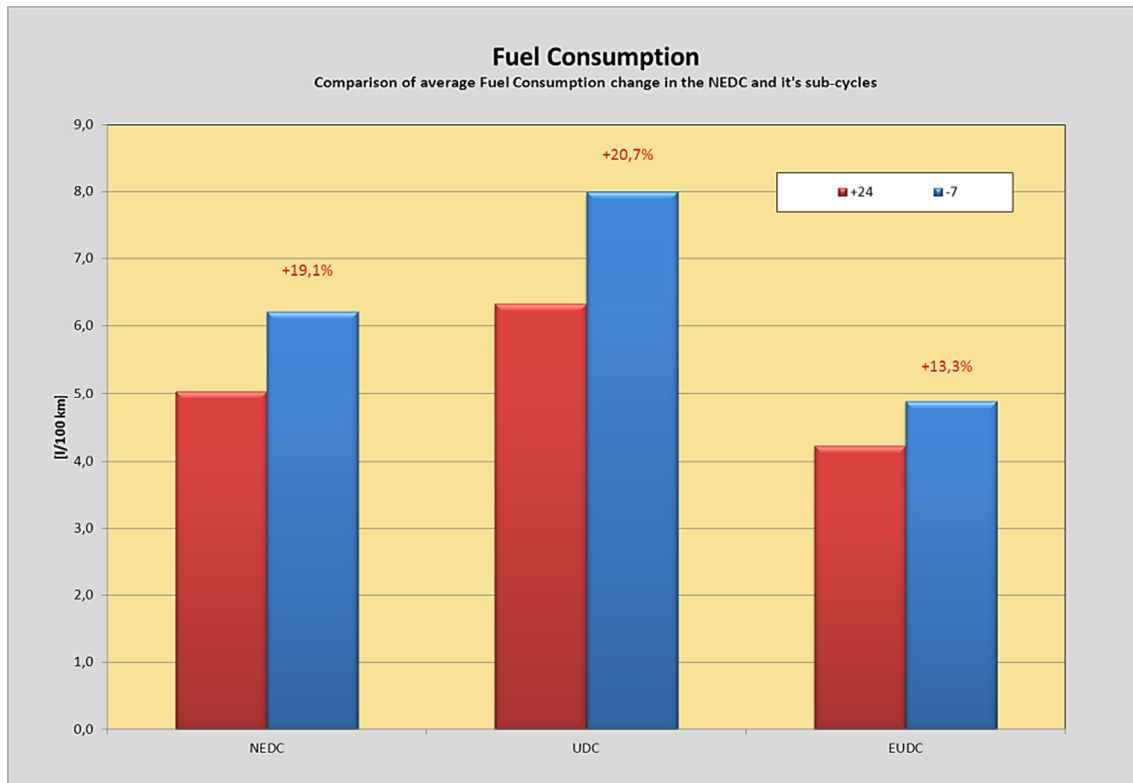


Figure 7 Fuel consumption during NEDC, UDC and EUDC during different ambient temperatures

The fuel consumption increases approximately 19% in the low ambient temperature test. The difference is larger in the UDC compared to the EUDC.

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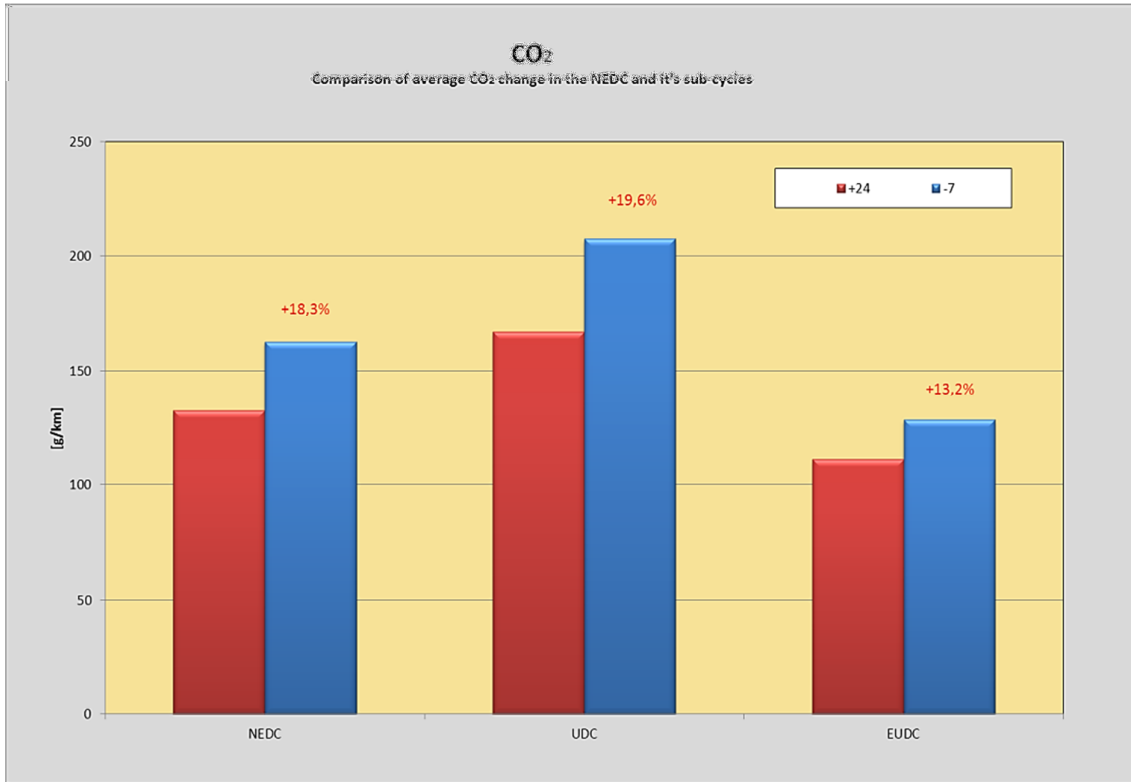


Figure 8 CO₂ during NEDC, UDC and EUDC during different ambient temperatures

The CO₂ increases approximately 18% in the low ambient temperature test. The difference is larger in the UDC compared to the EUDC.

TEST REPORT

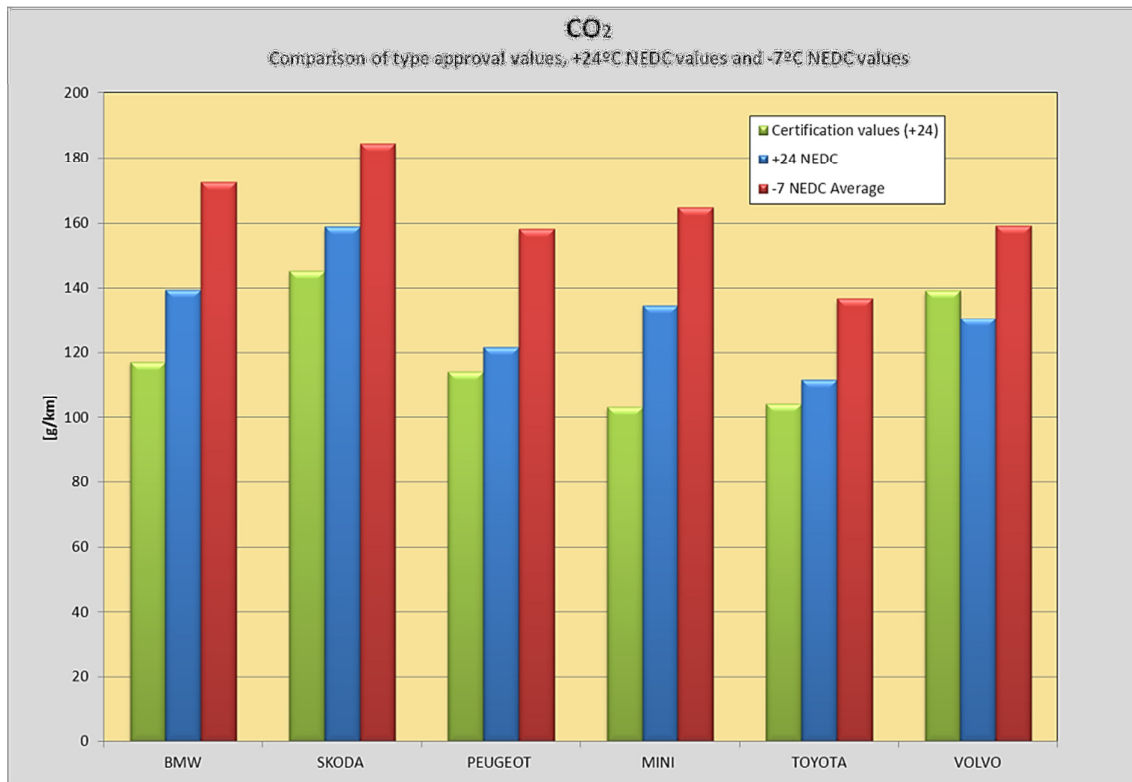


Figure 9 Illustration of CO₂ variations in tests at different temperatures and the type approval values.

TEST REPORT

8. Conclusions

At a low ambient temperature, the diesel fuelled vehicles included in this test had no problems fulfilling the emission limits set for vehicles with a SI engine. However, in comparison to the tests performed at starting temperature +24°C, all the vehicles showed increases of all emissions.

The emissions of CO increased between 55% and 1320% when tested in the NEDC cycle at -7°C compared to +24°C. Emissions of HC increased up to 1443%. NOx increased between 119% and 601%.

Also fuel consumption and CO₂ increased approximately 19% on average.

When looking at second to second traces of CO and HC, evident peaks are shown in the beginning of the cycle for both temperatures (higher peak in the -7°C test). During the rest of the UDC are the emission base levels for the -7°C test higher than for the +24°C test. When the EUDC starts, the emission levels drop to almost zero.

Regarding NOx it can be noted that for most cars, the NOx emissions are at a high level throughout the entire NEDC cycle when tested at -7°C.

The low ambient temperature NOx results are for all cars higher than the +24°C test results and the +24°C limits. Some of the cars are however considerable better than others which is most likely due to differences of engine management strategies regarding the EGR.

There are some disadvantages with EGR at lower temperatures such as decreased performance and fuel economy, risk of freezing or other malfunction. There is also no limit value for NOx at low ambient temperature.

The problems with EGR can easily be solved by turning the EGR off at cold temperatures. Different manufacturers may choose different temperatures when to do this, which may explain the variance of the NOx emissions between the different vehicle models.



TEST REPORT

9. Additional information

- 9.1. Technical service responsible for carrying out the test: AVL MTC AB
P.O. Box 223
SE-136 23 Haninge
SWEDEN
- 9.3. Project ID: AU 18/11
- 9.4. Remarks (if any):
- 9.5. Place: Stockholm
- 9.6. Date: 2012-03-02
- 9.7. Signature:

A handwritten signature in blue ink, appearing to read 'Gareth Taylor'.

Gareth Taylor
AVL MTC
Certification & Regulation Compliance

