Additional Sound Emission Provisions

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Additional Sound Emission Provisions

This proposal for additional sound emission provisions is based on the Off cycle emission provisons proposal from 15.08.2004. This proposal was modified with respect to the discussions in the previous ASEP group meeting. The limit curve is now related to the wot test result of annex 3 instead of Lurban. Aim and rationale are almost the same as in the previous proposal.

Aim

- **Additional sound emission provisions are preventive requirements intended to cover driving conditions of the vehicle in real traffic, which can be environmentally relevant concerning their sound emission and which differ from those during type approval.**
- **The sound emission of the vehicle under driving conditions different from the conditions of the type approval test in Annex 3 shall not differ significantly from what can be expected from the type approval test result for this specific vehicle.**

Rationale

- **The driving conditions of Annex 3 are intended to represent peak acceleration conditions (a_90) at 50 km/h and average engine speed values (n_50) in dense urban traffic under typical partial load operation of the engine. The corresponding sound level is quite well correlated with the Leq-contribution of the particular vehicle under test.**
- **Since partial load acceleration cannot be practised in a reproducible way it is simulated by a combination of a WOT tests and a constant speed tests.**
- **This leads to engine speeds during the test that are lower than the peak values (n_95) used in urban traffic under normal conditions and significantly lower than the peak values under conditions requiring a high acceleration potential like filtering into a main street with dense, fast going traffic stream (n_95_high), see figures 1 and 2.**

Approach and Database

- In order to develop requirements and a test method for additional sound emission provisions sound emission measurement results, obtained within two different research projects by order of the German federal environmental agency (UBA), were analysed. The technical data of the M1 and N1 vehicles are shown in Table 1 and Table 2. Double vehicle numbers indicate that these vehicles have been measured in two versions.
- In both projects measurements were carried out for the ECE R 51 in its current version (sometimes referred to as “old” or “ISO_old”) and for the new proposal developed by the GRB informal group (sometimes referred to as “new” or “ISO_new”). In /1/ additional measurements were carried out at lower vehicle speeds (around 30 km/h) in different gears in order to be able to calculate noise maps for the tested vehicles.

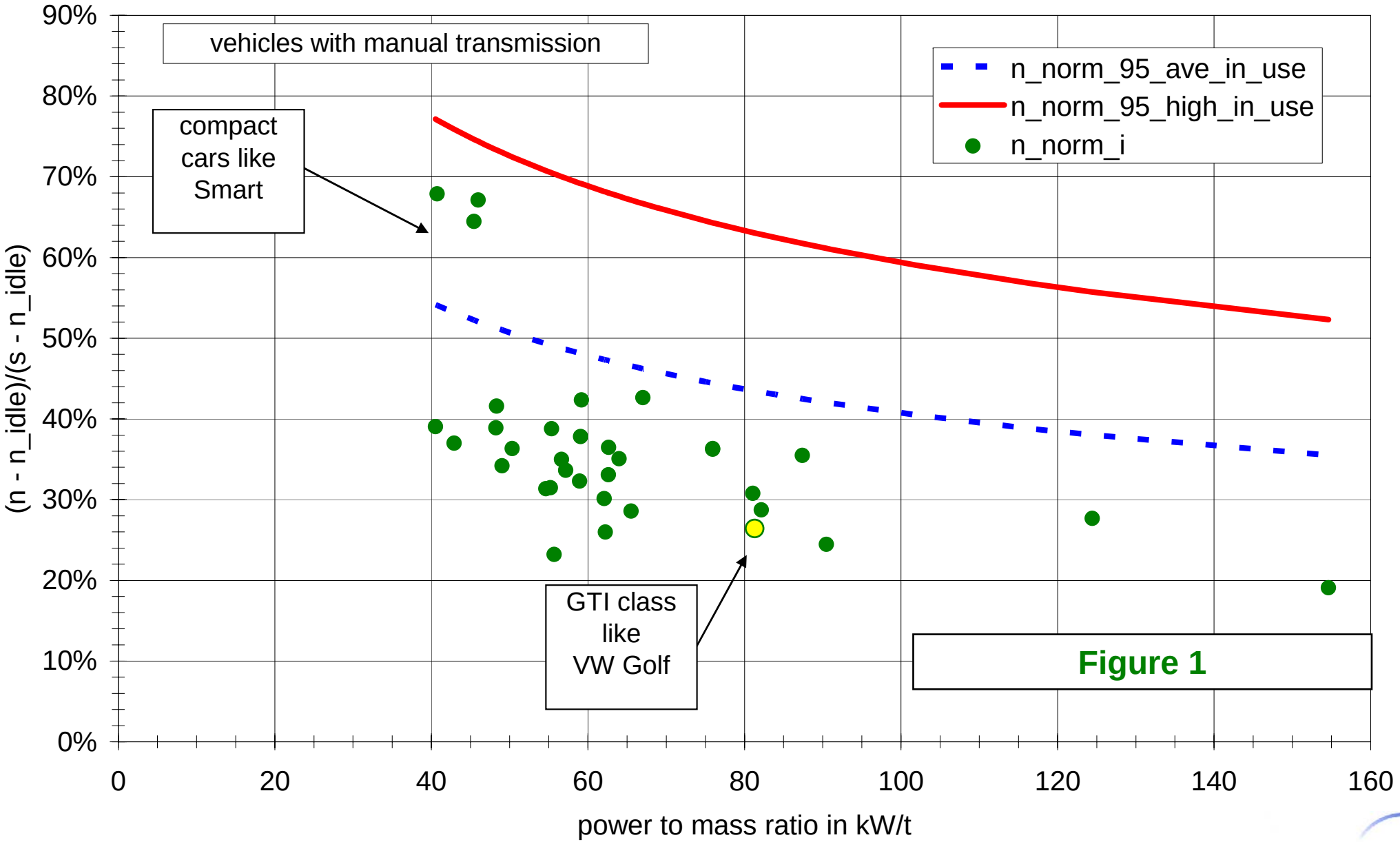
Vehicle Sample

veh no	registration year	veh_cat	engine type	Length in m	rated power in kW	rated speed in min^{-1}	engine capacity in cm^3	vmax in km/h	idling speed in min^{-1}	registered type approval level in dB(A)	transmission type	no of gears	kerb mass in kg	max. mass in kg	power to mass ratio index
1	1997	N1	Diesel	5107	75	3500	2461	157	750	74	manual	5	1754	2700	41.01
2	1997	M1	Diesel	4149	81	4150	1896	193	900	72	manual	5	1296	1750	59.08
3	2002	M1	Diesel	3821	55	4000	1422	173	950	72	manual	5	1065	1505	48.25
4	2002	M1	petrol	3817	43	5600	973	155	850	71	manual	5	980	1405	40.76
5	2002	M1	Diesel	4804	96	3800	1998	200	750	71	manual	5	1547	2165	59.19
6	2002	M1	petrol	4164	79	5750	1598	195	750	73	manual	5	1160	1600	63.97
7	2001	M1	petrol	3835	44	5000	1242	155	800	72	manual	5	950	1385	42.93
8	2002	M1	petrol	4288	74	6000	1598	183	750	72	manual	5	1265	1740	55.22
9	2002	M1	Diesel	4528	105	4200	2148	215	700	68	automatic	5	1545	2000	64.81
10	2002	M1	petrol	4797	125	6000	2393	220	750	73	automatic	6	1590	2065	75.08
11	2002	M1	Diesel	4634	85	4000	1896	181	900	74	manual	6	1683	2470	48.35
12	2002	M1	petrol	4710	103	4500	2435	205	750	73	manual	5	1569	2100	62.65
13	2002	M1	petrol	4775	141	6000	2494	232	750	71	automatic	5	1605	2040	83.93
14	2002	M1	petrol	4617	152	6000	2946	232	800	74	automatic	4	1595	2020	91.02
15	2002	M1	petrol	2500	40	5250	599	135	850	73	manual	6	805	990	45.45
16	2002	M1	petrol	4860	120	5000	1998	210	800	71	manual	6	1715	2190	67.04
17	2000	M1	petrol	5034	191	6000	3697	250	700	73	automatic	5	1800	2325	101.87
18	2000	M1	petrol	4528	125	5500	2597	232	700	70	automatic	5	1565	2015	76.22
19	2002	M1	petrol	4454	74	6000	1596	185	650	69	manual	5	1180	1635	58.96
20	2002	M1	petrol	4507	75	5600	1595	190	650	72	manual	5	1280	1790	55.35
21	2002	M1	petrol	4920	147	6400	2988	230	650	70	manual	5	1550	2035	90.46
22	2002	M1	Diesel	4861	110	4000	2188	188	950	71	manual	6	1900	2605	55.7
23	2003	M1	Diesel	5065	116	3600	2953	160	850	72	automatic	5	2400	3000	46.87
24	2002	M1	Diesel	4202	79	4000	1997	188	900	74	manual	5	1371	1796	54.63
25	2002	M1	petrol	3615	50	6000	998	155	750	69	manual	5	945	1350	49.02
26	2003	M1	petrol	4754	162	6400	3189	203	700	75	automatic	5	2275	2945	68.94
27	2002	N1	Diesel	5645	80	3800	2148	145	800	75	manual	5	2105	2800	36.7
28	2002	N1	Diesel	5645	80	3800	2148	145	800	75	manual	5	2105	2800	36.7
29/30	2002	M1	petrol	4731	107	6000	1998		700	72	manual	5	1334		75.94
31/33	2202	N1	Diesel	6936	92	3600	2800	154	800	78	manual	6	2420	3500	36.87
32/34	2002	N1	Diesel	5621	92	3800	2402	150	800	75	manual	5	1940	3500	45.66
35/37	2001	N1	Diesel	5388	66	3650	2188	130	800	75	manual	5	1895	3300	33.5
36	2003	M1	petrol	4050	125	6100	2171	224	700	74	manual	5	1355	1550	87.41
38/39	2000	N1	Diesel	4655	63	4350	2446	130	800	74	manual	5	1910	3250	31.74
42	2002	M1	petrol	4600	122	6500	2261	211	650	73	manual	5	1430	1890	81.06
43	2002	M1	petrol	4430	235	6800	3596	285	700	75	manual	6	1445	1790	154.61
46/47	2000	N1	Diesel	5505	63	4350	2446	127	850	73	manual	5	1940	3250	31.27
48	2003	M1	petrol	4596	90	6000	1796	205	700	72	manual	5	1375	1870	62.07

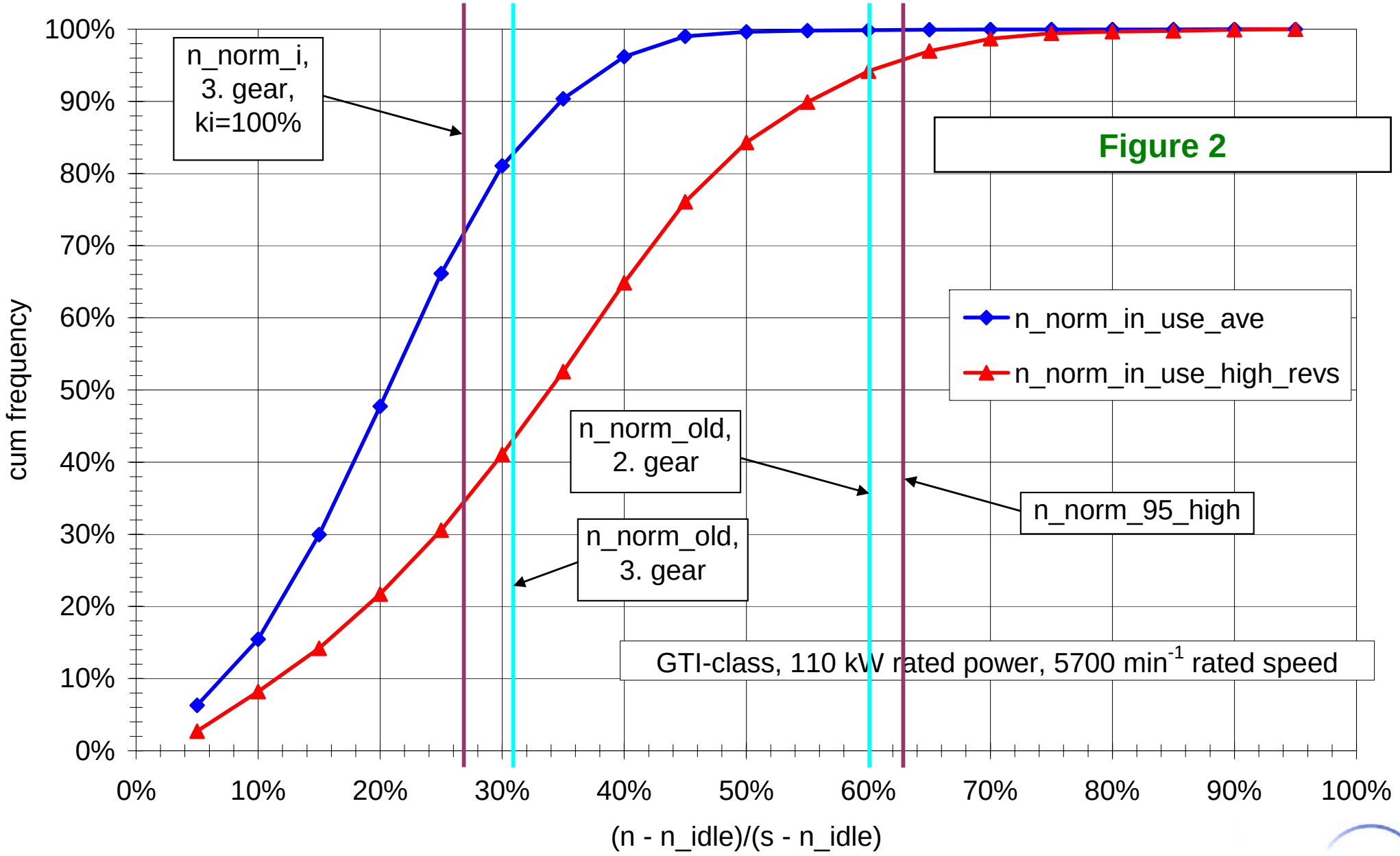
Vehicle Sample

veh no	registration year	veh_cat	engine type	Length in m	rated power in kW	rated speed in min^{-1}	engine capacity in cm^3	vmax in km/h	idling speed in min^{-1}	registered type approval level in dB(A)	transmission type	no of gears	kerb mass in kg	max. mass in kg	power to mass ratio index
101	2004	M1	Diesel	4797	132	4000	2496	217	800	72	automatic	5	1840	2315	68.93
102	2003	M1	petrol	4149	110	5700	1781	216	800	71	manual	5	1278	1730	81.3
103	2004	M1	petrol	4091	170	5900	2979	244	800	72	automatic	5	1385	1610	116.44
104	2004	M1	Diesel	4253	59	4000	1910	170	800	72	manual	5	1380	1815	40.55
105	2003	M1	Diesel	4818	120	4200	2685	222	800	71	automatic	5	1665	2200	68.97
106	2003	M1	Diesel	4317	92	4000	2172	187	800	74	manual	5	1550	2095	56.62
107	2003	M1	petrol	4441	122	6400	1970	220	800	73	manual	5	1410	1850	82.15
108	2003	M1	petrol	4528	105	5200	1796	203	800	74	automatic	5	1505	1955	66.46
109	2003	M1	petrol	3916	59	5700	1388	167	800	71	manual	5	1097	1530	50.34
110	2003	M1	Diesel	4317	92	4000	2172	187	750	74	manual	5	1550	2095	56.62
111	2004	M1	petrol	4183	77	5700	1598	192	800	71	manual	5	1272	1717	57.16
112/114	2004	N1_D	Diesel	6735	95	3800	2148	155	750	77	manual	5	2160	3500	33.57
113	2000	M1	petrol	2500	40	5250	599	135	850	73	manual	6	795	980	45.98
115/116	2004	N1_D	Diesel	5399	84	3500	2463	143	750	77	manual	6	1960	3500	41.28
117	2004	M1	petrol	4209	83	6000	1598	192	800	71	manual	5	1250	1725	62.64
118	2004	M1	petrol	4058	160	5700	3199	250	700	71	automatic	5	1460	1665	104.23
119	2004	M1	petrol	4349	100	6000	1997	207	800	73	manual	5	1532	1830	62.23
120/121	2004	N1_D	Diesel	5099	74	4000	2179	140	800	75	manual	5	1870	3300	28.63
122	2004	M1	petrol	4320	168	6300	2687	253	700	75	manual	5	1275	1600	124.44
123/124	2004	N1_D	Diesel	4834	55	3300	1998	130	700	73	manual	5	1736	2640	25.14
125	2004	M1	petrol	4460	77	6200	1590	190	750	71	manual	5	1100	1550	65.53

Norm. engine test speeds vs. in-use peak values



In-use norm. engine speeds vs test speeds



Conclusions (1/2)

- From this example can be concluded that there is a need for sound limiting requirements in the engine speed range above n_norm_i.
- It is proposed to choose nnorm_95_high, in-use as the upper speed limit for sound limiting requirements. This curve is related to the engine speed where the maximum sound level occurs. It can be translated into a curve for engine speeds at BB‘.
- For WOT acceleration tests with a sample of 64 vehicles the ratio between the engine speed at BB‘ and at the location where the maximum sound level occurred was found to be 1.15 on average.
- Consequently, the upper limit of the control range results from multiplying the nnorm,95,high,in-use curve by 1.15. This upper limit of the control range is called n_norm_max_BB‘ and is also shown in Figure 1. It shall be limited to 90% for very low power to mass ratios (which corresponds rather well to 95% of the rated engine speed).

Conclusions (2/2)

- Since the concern with the sound emission for engine speeds higher than n_norm_i is related to “sporty sound emissions” and thus to exhaust and intake silencers, the additional sound emission provisions can be focussed on WOT tests.
- In this context higher engine speeds require the use of lower gears than in Annex 3, in order to avoid too high vehicle speeds and thus too high contributions of tyre/road noise. Since the 1. gear cannot be used for lack of reproducibility, the 2. gear shall be used for vehicles with manual transmission.
- To be consistent with Annex 3, the D-range shall be used for vehicles with automatic transmission. The manufacturer may electronically prevent automatic downshifting to first gear or electronically limit the engine speed to the upper limit of the control range (n_norm_max_BB’).
- As a consequence the wide open throttle acceleration test results of vehicles with manual transmissions in 2. gear were analysed in more detail in order to determine a reference curve for the dependence of the vehicles’ sound emission on the vehicle speed.
- Figure 3 shows approximation functions for the sound emission at WOT in 2. gear for a series of M1 vehicles. The highest curve belongs to a high performance sports car and was not included in the calculation of the average curve. The average curve was approximated by a polynomial function of 3. degree, but since the correlation coefficient for a linear approximation was not significantly worse, the linear approximation can be used for reasons of simplicity.

Approach

In order to define what can be expected from the type approval test result for a specific vehicle with regard to driving conditions of the vehicle in real traffic, which can be environmentally relevant concerning their sound emission and which differ from those during type approval, the following technical side conditions have to be considered:

- **The additional sound emission provisions can be focussed on wide open throttle (wot) tests,**
- **An upper limit for the engine speed range environmentally relevant should be derived from in-use data as function of power to mass ratio to reflect real world driving,**
- **A specification of gear ratios for wot tests,**
- **A slope for the vehicle speed dependence of the sound emission at wot.**

Approach

- **The engine speed range up to n_95_high includes higher speeds than those tested in annex 3. In order to minimise the tyre/road contribution and to avoid too high vehicle speeds, lower gears than in annex 3 shall be used. Since the 1. gear cannot be used for reproducibility reasons, the 2. gear shall be used for vehicles with manual transmission. To be consistent with Annex 3, the D-range shall be used for vehicles with automatic transmission.**
- **In order to find a representative limit curve for the wot sound emission between 25 and 70 km/h, the measurement results of 36 M1 vehicles and more than 10 N1 vehicles were approximated as functions of vehicle speed.**

Limit curve for engine speeds

- The n_95_high curve of figure 1 can be used to specify the upper engine speed limit. This curve is defined by the following formula:

  $n\_norm\_95\_high = 2.26 * pmr^{-0.29}$,

  pmr is the ratio between rated power and kerb mass + 75 kg, expressed in kW/t

- This curve is related to the engine speed where the max. sound level occurs. For wot tests it is better to specify an engine speed at BB‘. For a sample of 64 vehicles the ratio between the engine speed at BB‘ and at max sound level occurance was analysed for wot acceleration tests. The rounded average value was 1.15.
- Consequently, the n_norm_95_high curve was multiplied by 1.15, in order to specify a curve for n_norm_max_BB‘. n_norm_max_BB‘ shall be limited to 90%.

Limit curve for wot emissions

- It would be not sufficient to specify one limit curve for each category, because it would allow vehicles with a low test result for annex 3 to be much louder in the additional sound emission provision area than one would expect from the annex 3 result.
- Therefore it is proposed to link the upper limit curve to the test result of annex 3. Since annex 10 deals with wot results, it would be consequent to use the wot result of annex 3.
- In order to find an appropriate link between the limit curve of annex 10 and the test result of annex 3, the latter were compared with the wot results in different gears or gear ranges between 25 km/h and 70 km/h for 36 vehicles.
- A limit curve was then derived from the analysis complying with the following side conditions:
  - ✓ The wot sound level at 50 km/h should not be more than 5 dB(A) higher than L_wot_ref of annex 3,
  - ✓ The slope of the limit curve should be an average slope for the 2. gear,
  - ✓ The difference between the limit curve and L_wot_ref of annex 3 should not exceed 7 dB(A) at any speed up to 70 km/h.

Limit curve for wot emissions

This leads to the following formula for the limit curve:

$L_{\_limit}$ = 0,3 * (v – 50 km/h) + $L_{\_wot\_ref}$ + 5 dB(A), if 25 km/h <= v < 56,7 km/h

= $L_{\_wot\_ref}$ + 7 dB(A), if 56,7 km/h <= v <= 70 km/h

With v at PP'

and $n_{\_norm\_BB}$' <= 2.6*$pmr^{-0.29}$, but not more than 90%

pmr is the ratio between rated power and kerb mass + 75 kg, expressed in kW/t,

$n_{\_norm}$ = (n – $n_{\_idle}$)/(s – $n_{\_idle}$),

n is the engine speed, s is rated engine speed, n_idle is idling speed, all in min^{-1}

Steps for the measurements

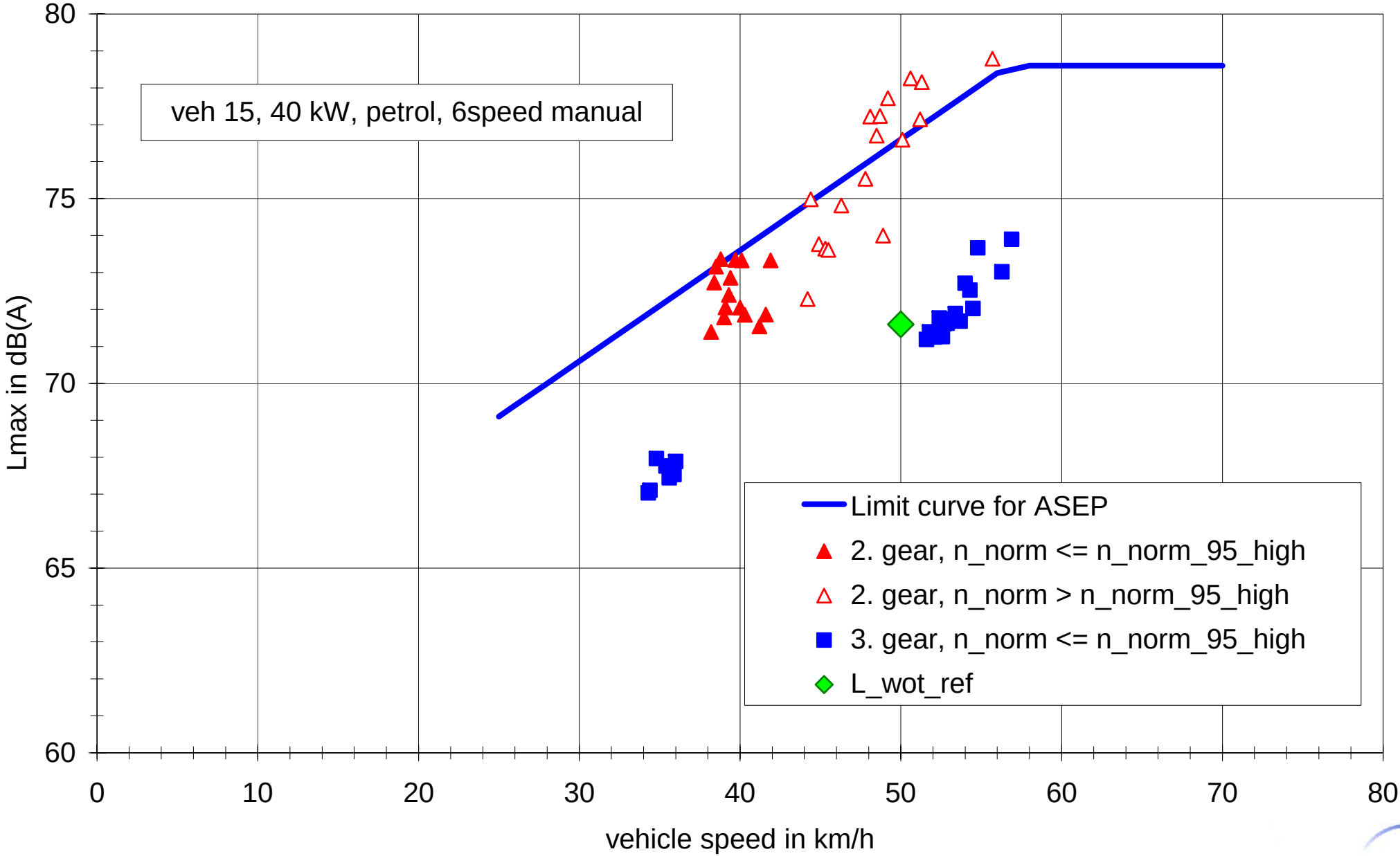
Steps to be carried out:

1. If it is ensured that the contributions of sources other than tyre road noise is always below the tyre contribution, no test at all.
2. Choose 2. gear (or 3. gear) for manual transmissions, D-range for automatic transmissions (if different options are provided, choose that one which is equivalent to “sporty”).
3. Choose entry speed so that 25 km/h <= v_PP’ <=70 km/h.
4. Perform wot acceleration test, check the acceleration rate.
5. Make sure that n_BB’ is below limit curve, otherwise reduce entry speed.
6. Average the results of 4 valid wot tests to get L_asep.
7. Check whether L_asep <= 0.3*(v_PP’ in km/h – 50) + L_wot_ref + 5 dB(A)

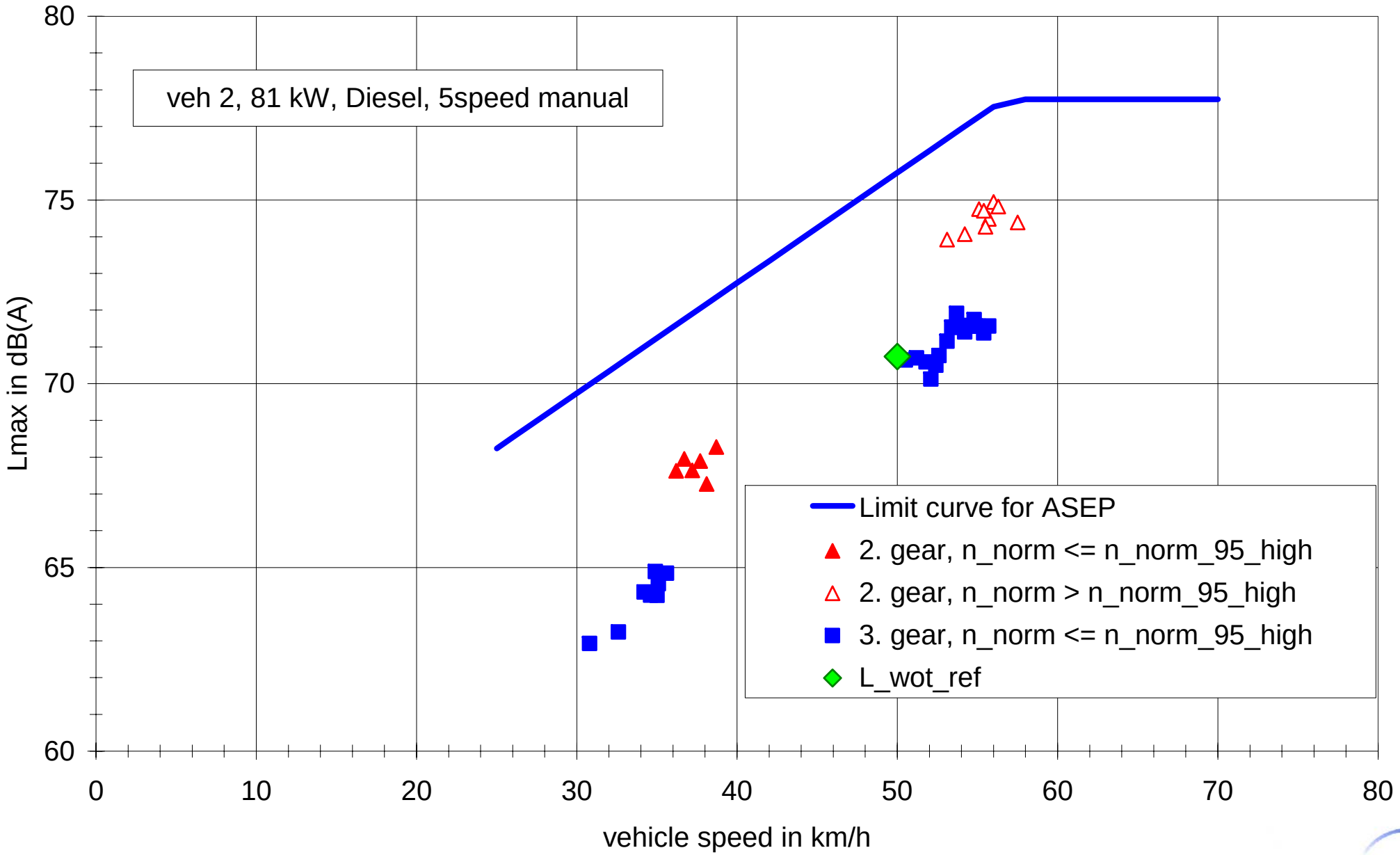
No engine speed limitation for hybrids, electrical powered or fuel cell vehicles.

The following figures show some measurement results together with the above defined limit curve.

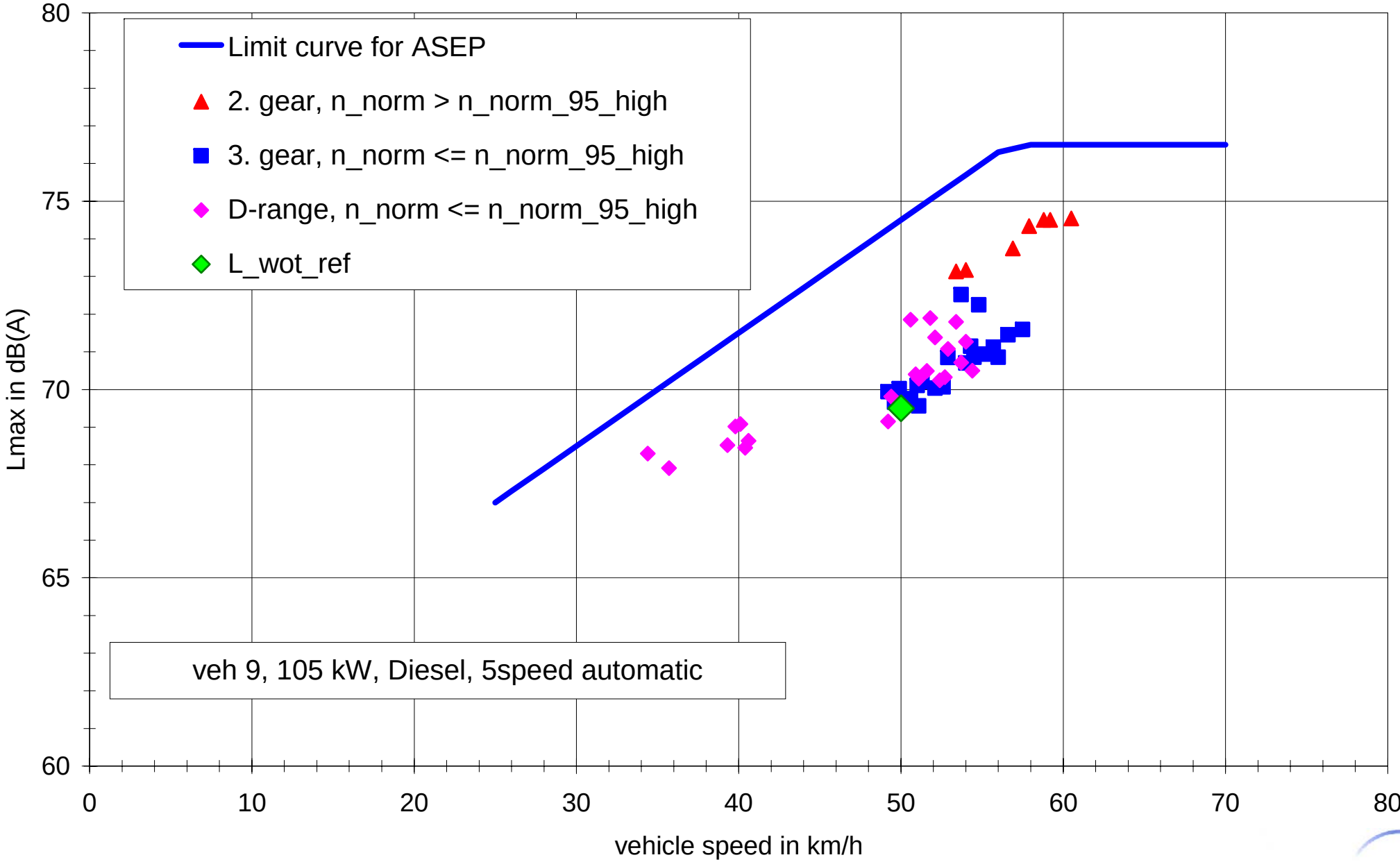
measurement results and ASEP limit curve



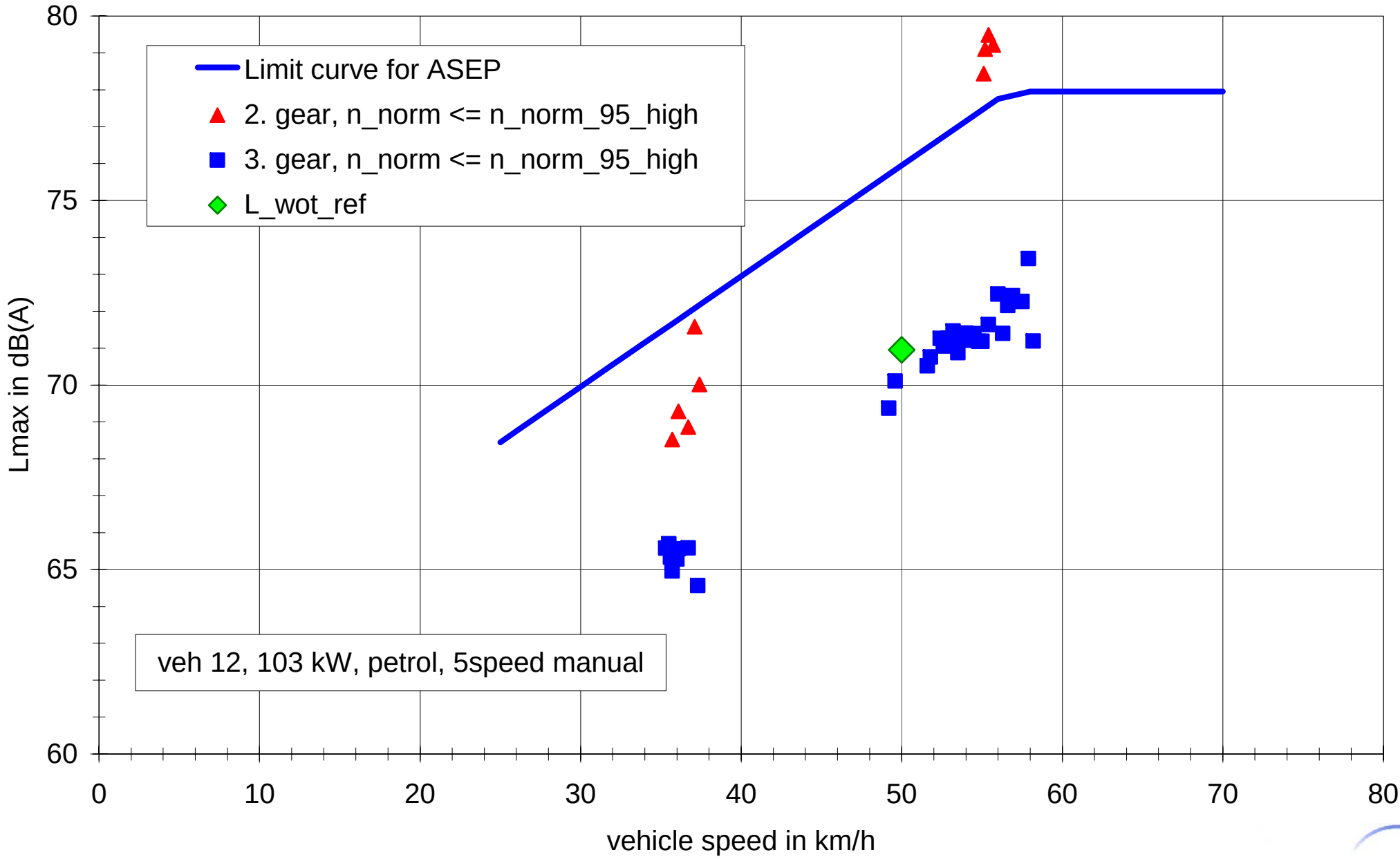
measurement results and ASEP limit curve



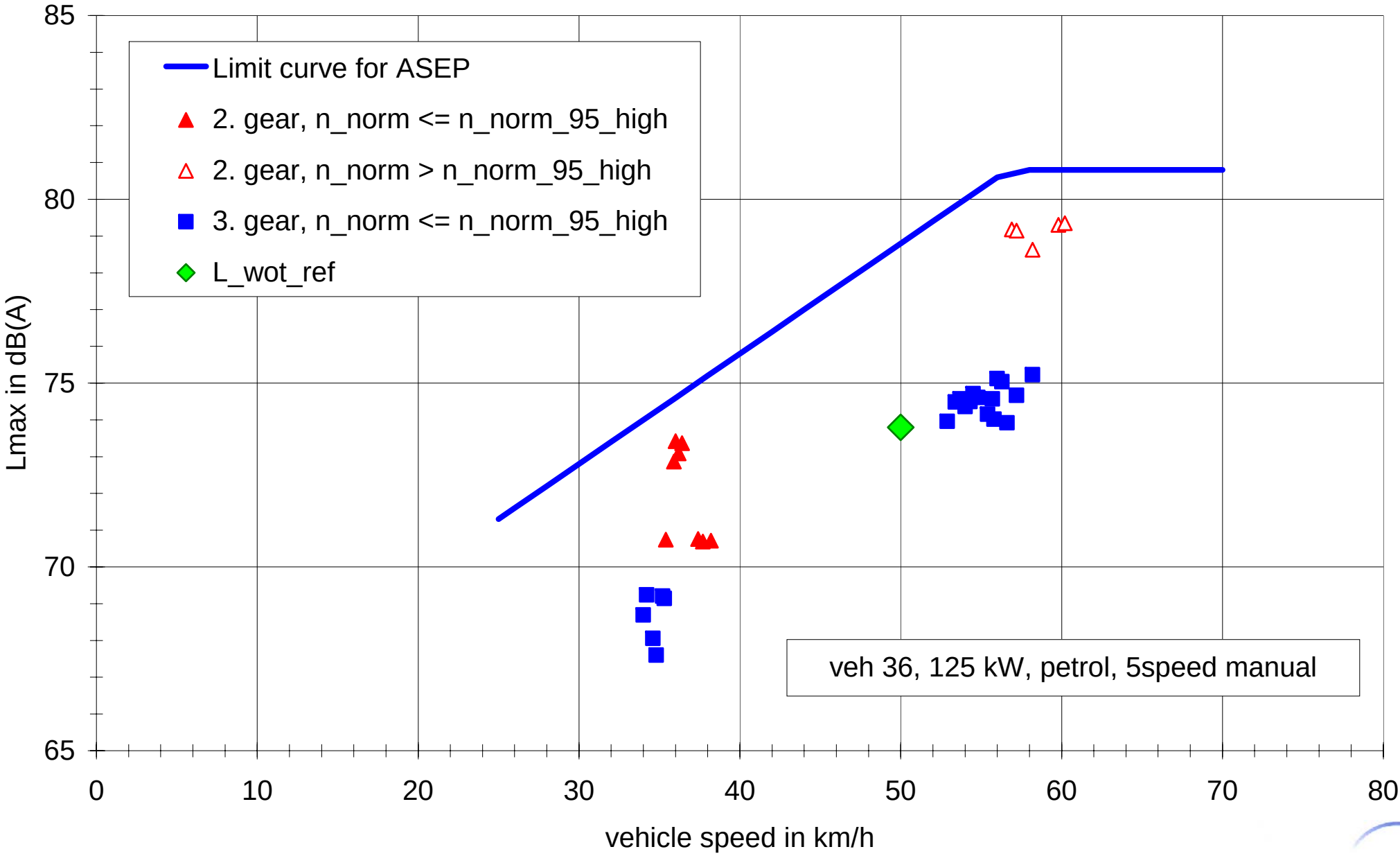
measurement results and ASEP limit curve



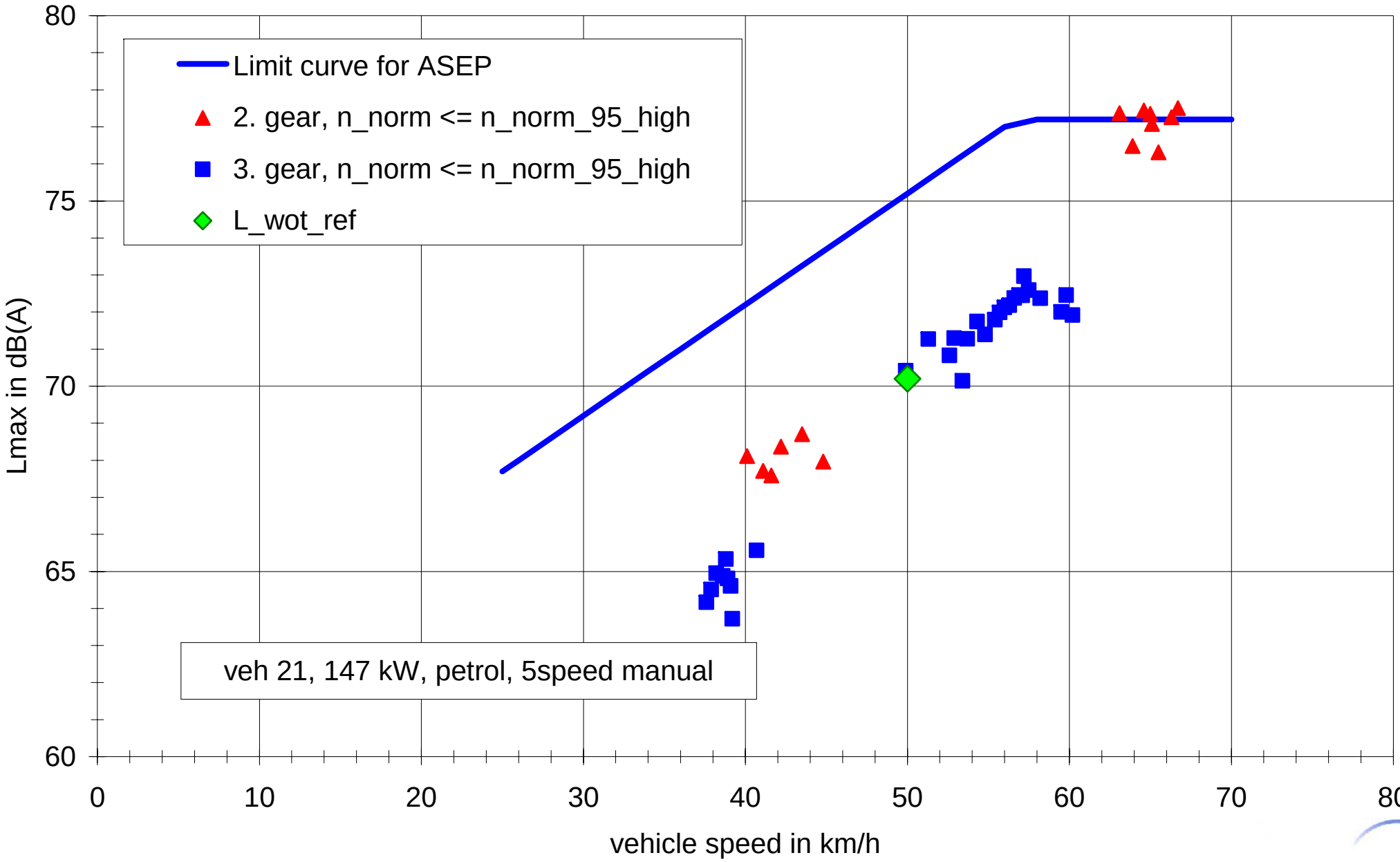
measurement results and ASEP limit curve



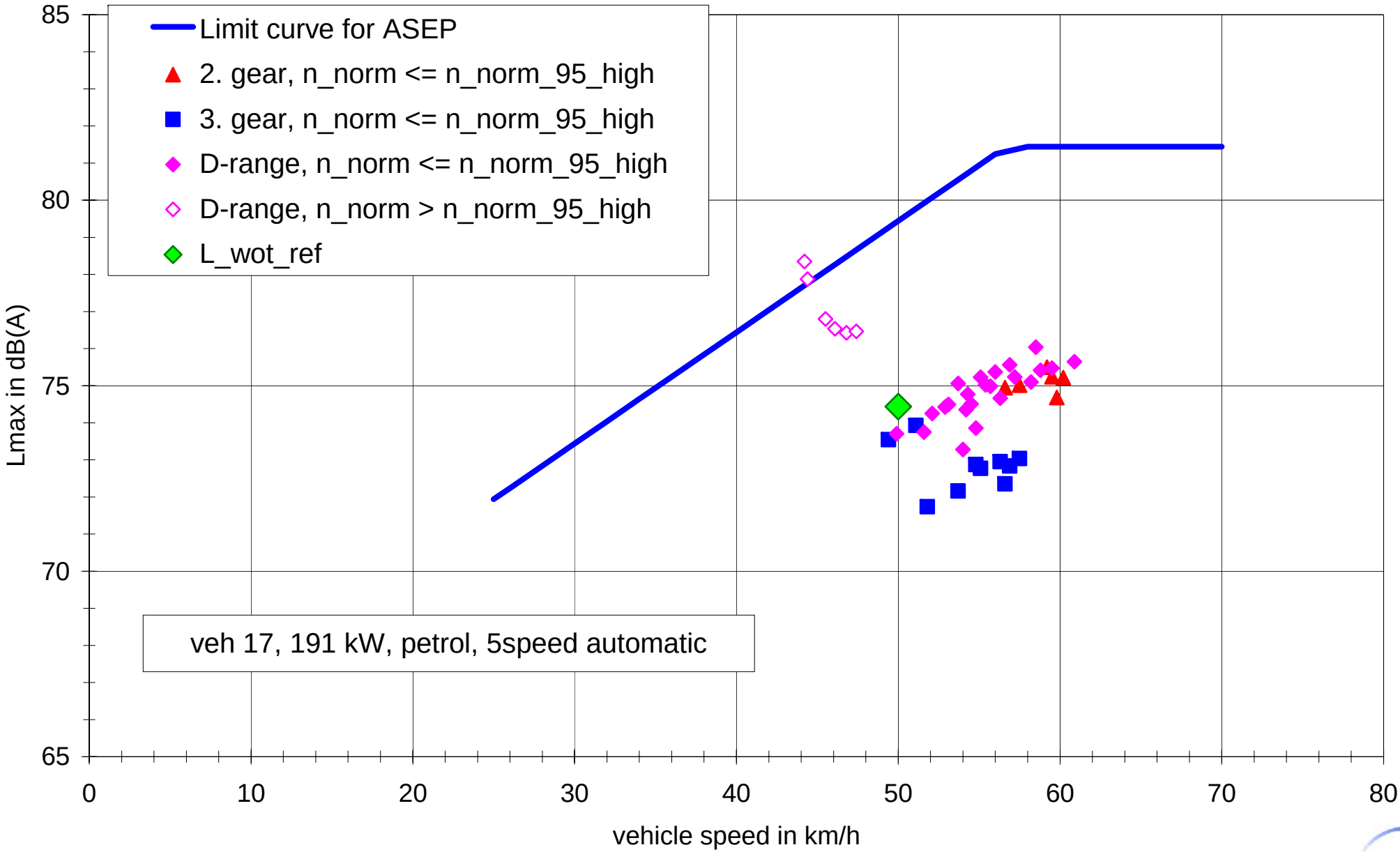
measurement results and ASEP limit curve



measurement results and ASEP limit curve



measurement results and ASEP limit curve



measurement results and ASEP limit curve