

WLTC Validation test 1

~ Progress report by JARI ~

Prepared by JARI

DHC group
under GRPE/WLTP informal group
12-14 September 2011
Bern, Switzerland

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4. Tentative Summary

Validate the WLTC ver.2 from the following view points

(1) Drivability

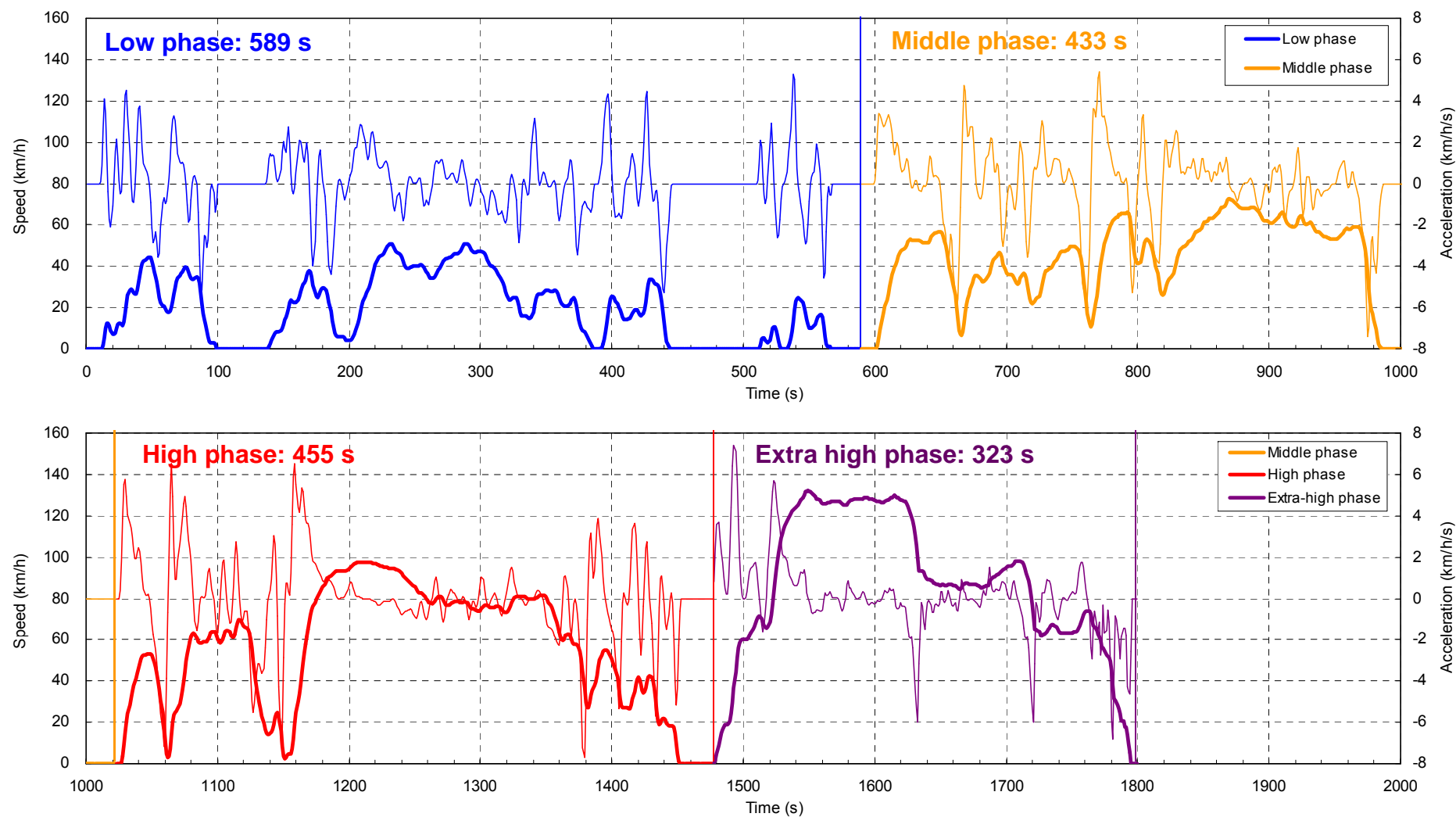
- Smooth throttle operation
- appropriate shift points
 - Option A: Fixed gear shift (Japan proposal)
 - Option B: Unique shift point (Mr. Steven's proposal)
- Clutch off points
- Mode traceability
- Slip

(2) Reproducibility

Based on validation test results, the WLTC may be modified with DHC member agreement.

2.1. Test cycle

[WLTC ver.2]



2.2.1. Test vehicles

Vehicle A: DAIHATSU MOVE

Passenger car, 660 cc, CVT, 46.3 kW/t*



Vehicle B: TOYOTA DYNA (GVW: 3.3 t)

Light duty vehicle, 1998 cc, 5MT, 55.7 kW/t*



Vehicle C: HONDA S2000 (under analysis)

Passenger car, 2200 cc, 6MT, 141.3 kW/t*



Vehicle D: SUZUKI CARRY (under analysis)

Light duty vehicle, 660 cc, 5MT, 45.5 kW/t*



2.2.3. Test vehicles

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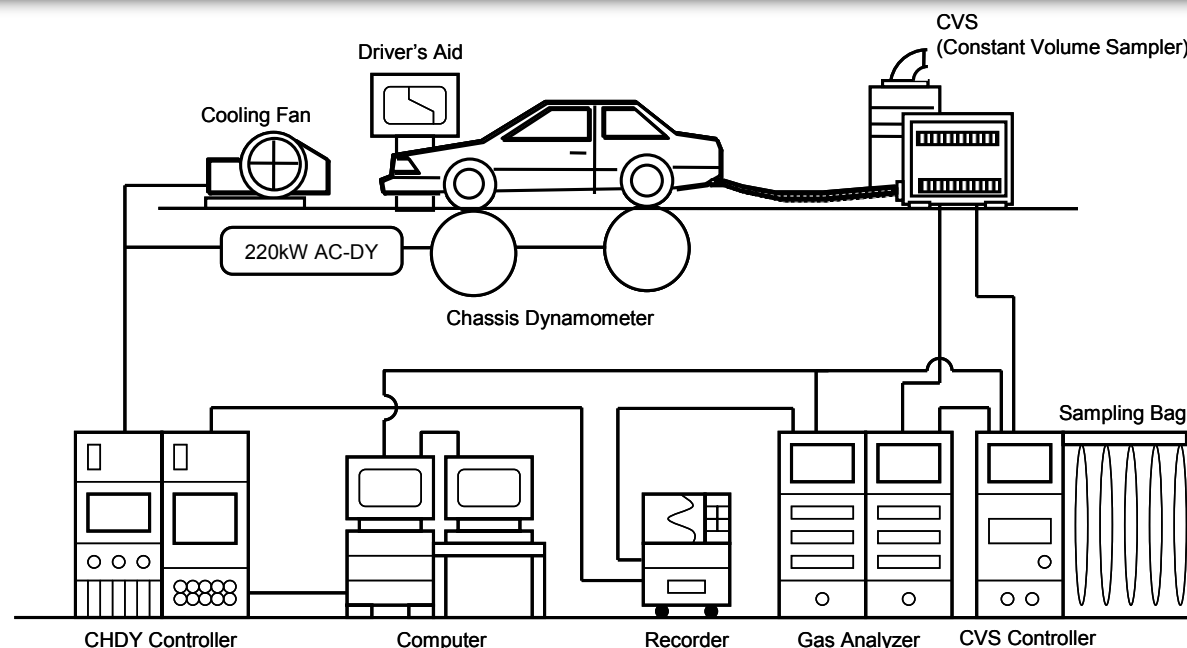
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Vehicle ID		Vehicle A	Vehicle B	Vehicle C	Vehicle D
Vehicle category		Passenger car	LDCV	Passenger car	LDCV
Manufacture		DAIHATSU	TOYOTA	HONDA	SUZUKI
Model name		MOVE	DYNA	S2000 TypeS	CARRY
Vehicle model		DBA-LA100S	ABF-TRY230	ABA-AP2	EBD-DA63T
Body	Curb weight	kg	820	1,760	1,260
	Riding capacity	persons	4	6	2
	Maximum load	kg	-	1,250	-
	Gross vehicle weight	kg	1,040	3,340	1,370
Engine	Engine type		KF	1TR	F22C
	Fuel type (Diesel/Gasoline/LPG)		Gasoline	Gasoline	Gasoline
	Engine features		3 cylinders	4 cylinders	4 cylinders
	Engine displacement	cc	658	1,998	2,156
	Maximum rated power	kW	38	98	178
	Engine speed @ Max. power	1/min-1	7200	5600	7800
	Maximum torque	Nm	60	182	221
	Engine speed @ Max. torque	1/min-1	4000	4000	6500-7500
	Engine speed @ Idling	1/min-1	800	700	900
	Exhaust-gas after treatment device (TWC, DPF, Urea SCR, etc)		TWC	TWC	TWC
Transmission	Drive system		2D-2	2-4D	2-2D
	Transmission type		CVT	5MT	6MT
	Transmission gear ratio	1st	3.327 ~ 0.628	5.146	3.133
		2nd		2.780	2.045
		3rd		1.509	1.481
		4th		1.000	1.161
		5th		0.830	0.942
		6th		-	0.763
		7th		-	-
	Final drive ratio		5.444	4.100	1st: 1.208 2nd: 4.100
Tiers	Front tire size	m	155/65R14 75S	175/75R15	215/45R17
	Rear tire size	m	155/65R14 75S	145R13	245/40R17
	Dynamic radius of driving tire	m	0.273	0.313	0.305
Performance	Maximum speed	km/h	130	135	180
	Power to mass ratio on curb mass	KW/t	46.3	55.7	141.3
	Drive train coefficient	-	-	0.354	0.266
Instruments and Controls	Gear shift indicator	Y/N	N	N	N
	Idling stop system	Y/N	N	N	N
	Cruise control	Y/N	N	N	N
Odometer		km	4,500	1,000	20,000

2.3. Test facility

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Item		Specification
Laboratory		Japan Automobile Research Institute (JARI)
Drive system		FF, FR, 4WD
CHDY	Type	Oil floated cradle AD-DY
	Rated power	220 kW (absorption), 200 kW (drive)
Rollar	Size	φ1219.2 mm x 800 mm
	Material & surface	Iron & sprayed surface (Tungsten carbide)
Inertia system		Electric inertia compensation
Inertia range	2WD	455 ~ 3500 kg
	4WD	800 ~ 3500 kg
Wheelbase		2100 ~ 4100 mm
Max. vehicle speed		200 km/h
Engine cooling fan		4 ~ 160 km/h, 1867 m ³ /min
Manufacture		MEIDEN

2.4. Test matrix

Vehicle	Driver	Cycle	Condition	Gear	No. of Test
Veh. A Passenger car 660 cc CVT	Driver 1	L-M	Cold	-	3
		L-M	Hot		3
		H-ExH			3
	Driver 2	L-M	Hot	-	1
		H-ExH			1
	Veh. B LDCV 2000 cc 5MT	Driver 1	L-M	Cold	Option A (Fixed)
L-M			Hot	3	
H-ExH				3	
L-M			Cold	Option B (Unique)	1
L-M			Hot		1
H-ExH					1
Veh. C Passenger car 2200 cc 6MT	Driver 1	L-M	Cold	Option A (Fixed)	3
		L-M	Hot		3
		H-ExH			3
		L-M	Cold	Option B (Unique)	1
		L-M	Hot		1
		H-ExH			1
	Driver 2	L-M	Hot	Option A (Fixed)	1
		H-ExH			1
Veh. D LDCV 660 cc 5MT	Driver 1	L-M	Cold	Option A (Fixed)	3
		L-M	Hot		3
		H-ExH			3
		L-M	Cold	Option B (Unique)	1
		L-M	Hot		1
		H-ExH			1
	Driver 2	L-M	Hot	Option A (Fixed)	1
		H-ExH			1

under analysis

under
analysis

2.5. Evaluation Items and Test Criteria

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Measurement Items	Methods	Criteria / Remarks
Driving Trace * (each ST)	Driving index by SAE J2951 Driven roller counter(10Hz or more) Acceleration ratio	+/- 3%
Tire Speed	Rotary encoder Difference between roller speed and tire speed	No slip
Gear Shift Points	Appropriate shift point Clutch off point	+/- 3kph within +/-1sec
Accel Pedal Angle	Positional Sensor	TBD
Engine Coolant Temperature	Thermostat surface temperature	Check necessity of Middle phase when hot start
Pollutants (CO, THC, NOx)	Bag sampling	NA
Difference of Test Drivers	Drive Trace Questionnaire	TBD

3.1. Test result – Vehicle A (DAIHATSU MOVE)^{WLTP-DTP-Current Status 12092011}

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Vehicle	Load	Gear	Driver	Condition	Test No.	Driving Index (Energy rating %)										Coolant Temperature (C) ^(*)		
						Low ST1	Low ST2	Low ST3	Low ST4	Low ST5	Low Total	Middle	High	Ex-High	Initial	End of Low phase	End of Middle phase	
Veh. A DAIHATSU MOVE PC 660cc CVT	2 persons (110kg)	-	Driver 1	Cold	1	2.00	1.96	3.68	12.20	4.68	2.37	0.52	-	-	26.5	88.4	90.1	
					2	2.37	2.11	9.01	10.28	6.62	3.19	0.79	-	-	25.2	89.5	90.8	
					3	1.60	1.01	1.43	2.19	0.81	1.20	-0.17	-	-	26.6	89.0	90.2	
				Hot	1	0.96	2.82	5.40	22.41	5.40	2.93	0.18	-0.02	-2.62	88.3	92.7	89.8	
					2	3.49	3.78	2.73	0.88	5.10	3.64	0.45	0.27	-2.43	89.1	93.2	90.8	
					3	3.56	2.07	0.29	14.43	4.62	2.47	0.57	0.35	-1.52	88.7	94.0	90.1	
			Driver 2	Hot	1	1.85	0.76	0.72	3.30	3.45	1.17	-0.01	0.37	-3.08	88.1	92.7	90.1	

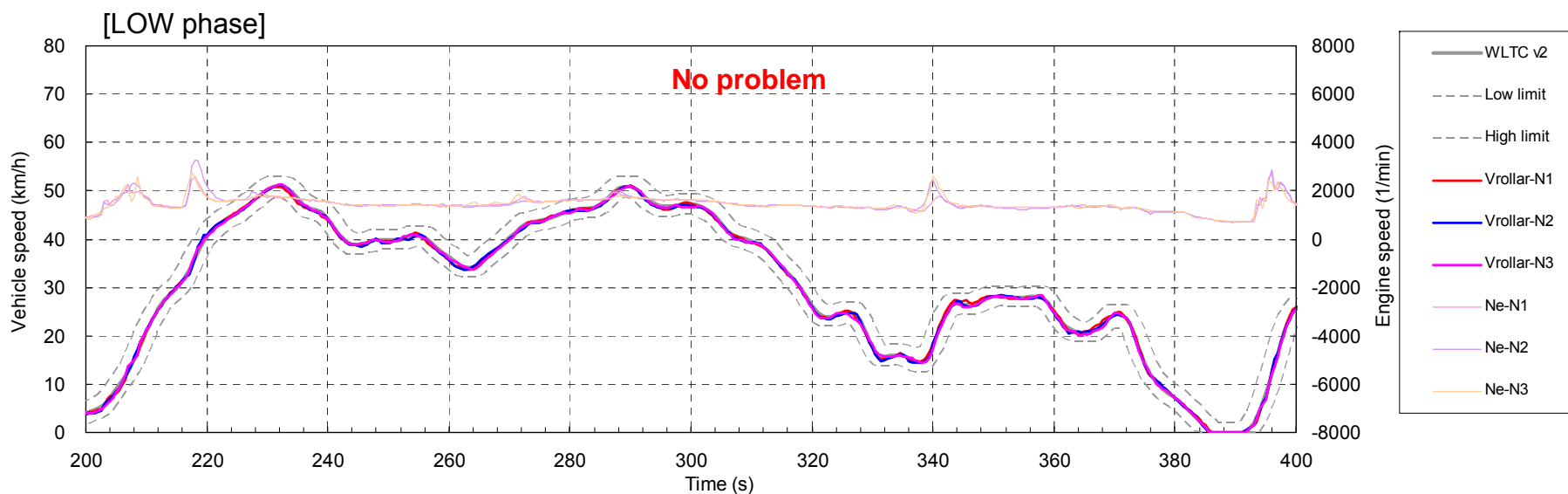
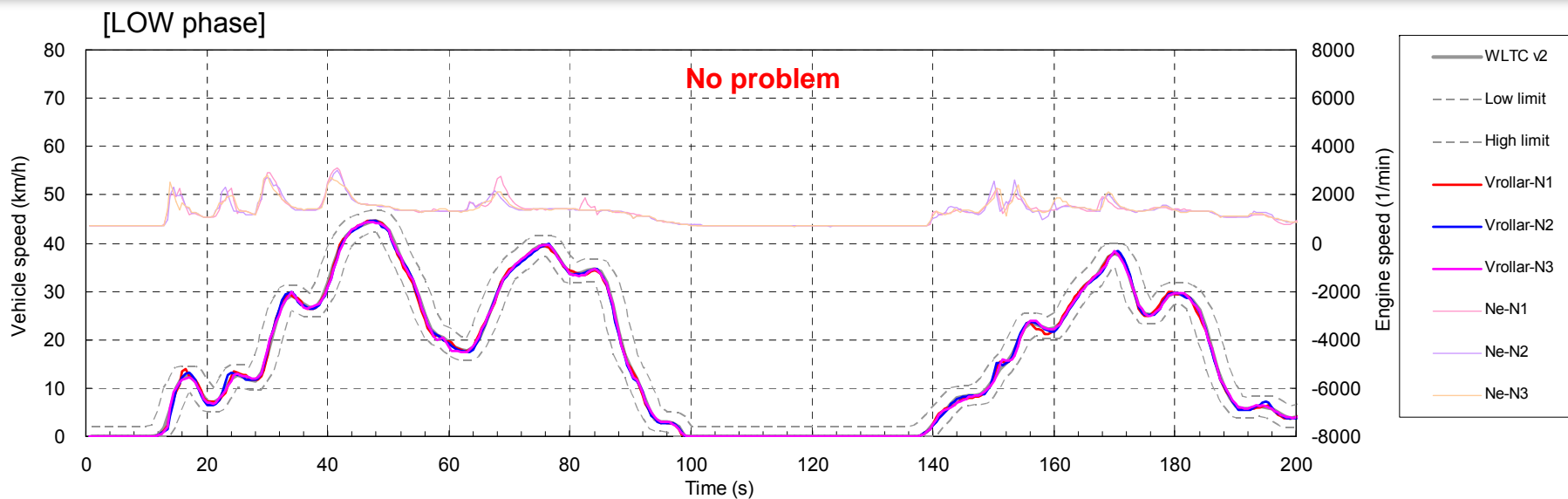
(*) Thermostat surface temperature

- LOW total: In 2 tests, Energy rating exceeded +/- 3%
- MIDDLE: Energy rating of all tests are within +/-3%
- HIGH: Energy rating of all tests are within +/-3%
- Ex-HIGH: It could not follow the target speed
- Coolant temp.: Coolant temperatures of end of low phase are difference between cold and hot condition.

Traceability – LM phase, Vehicle A (PC, 0.66L, CVT)

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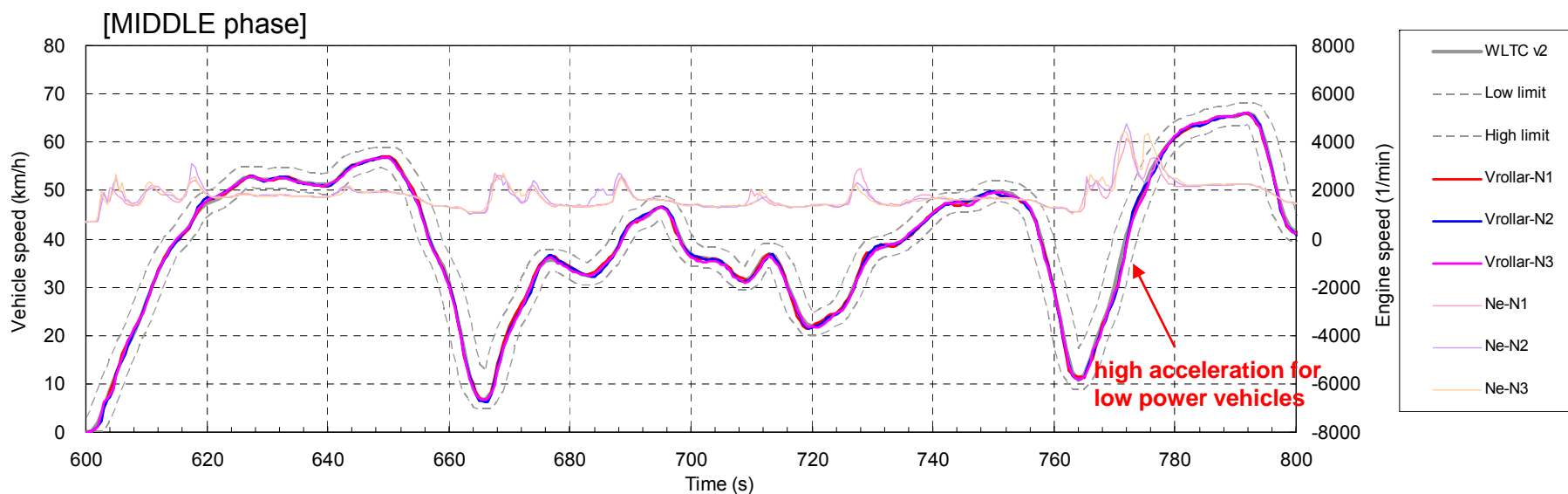
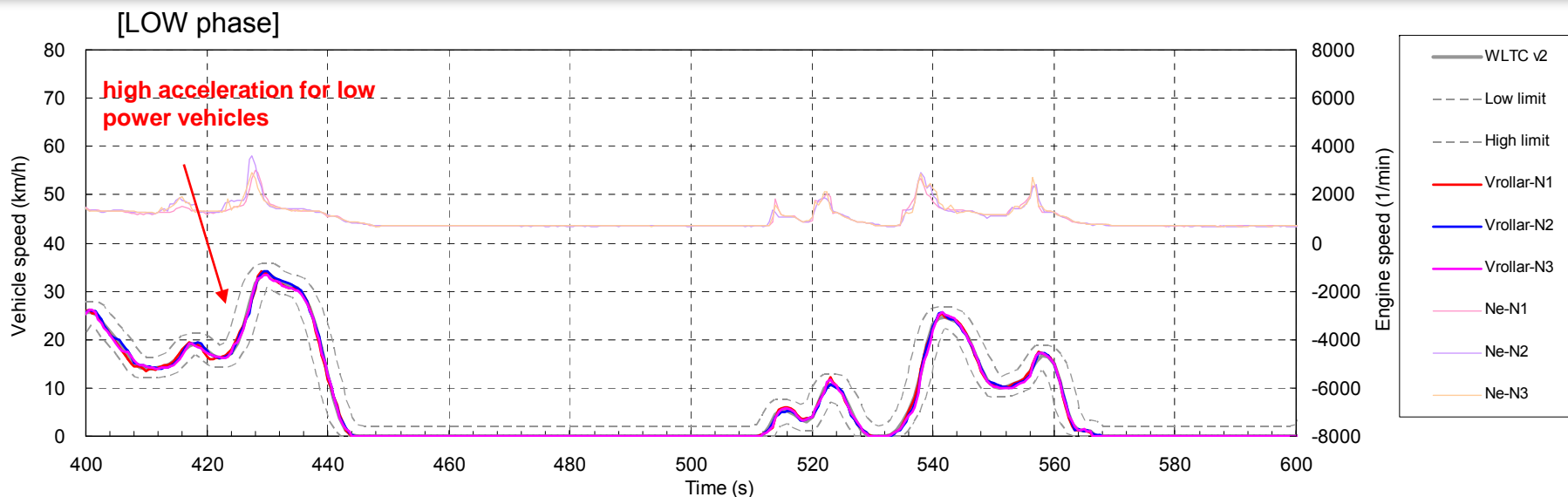


(*) Tolerance: ± 2 km/h and ± 1 s, follow the same tolerance as TRIAS

Traceability – LM phase, Vehicle A (PC, 0.66L, CVT)

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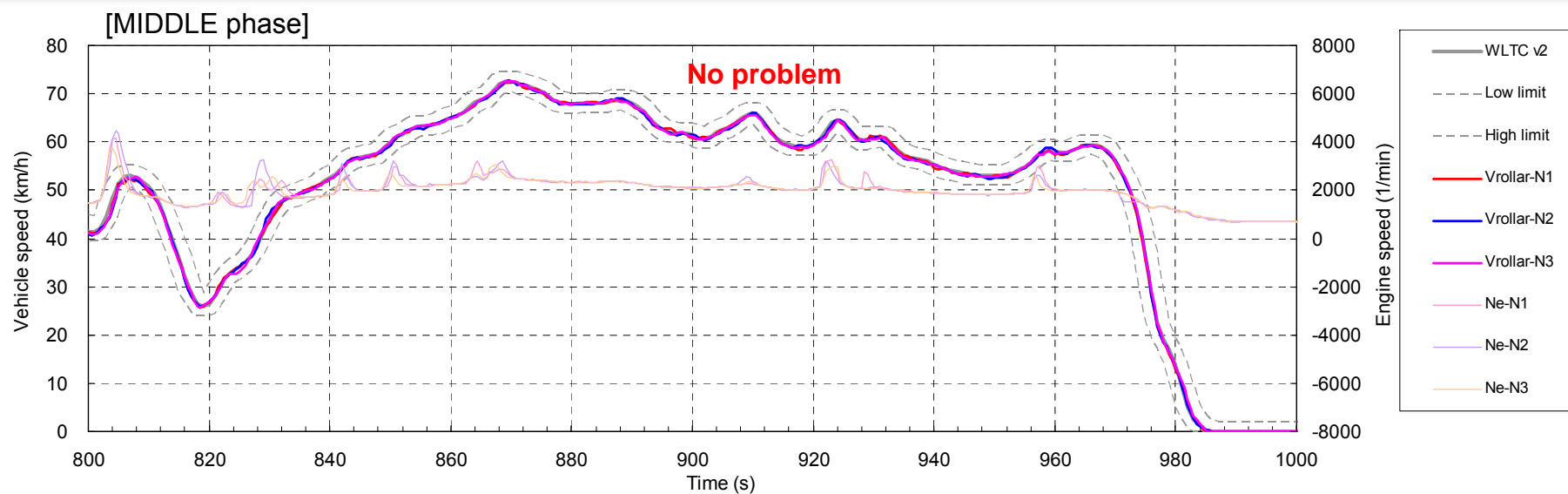


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Traceability – LM phase, Vehicle A (PC, 0.66L, CVT)

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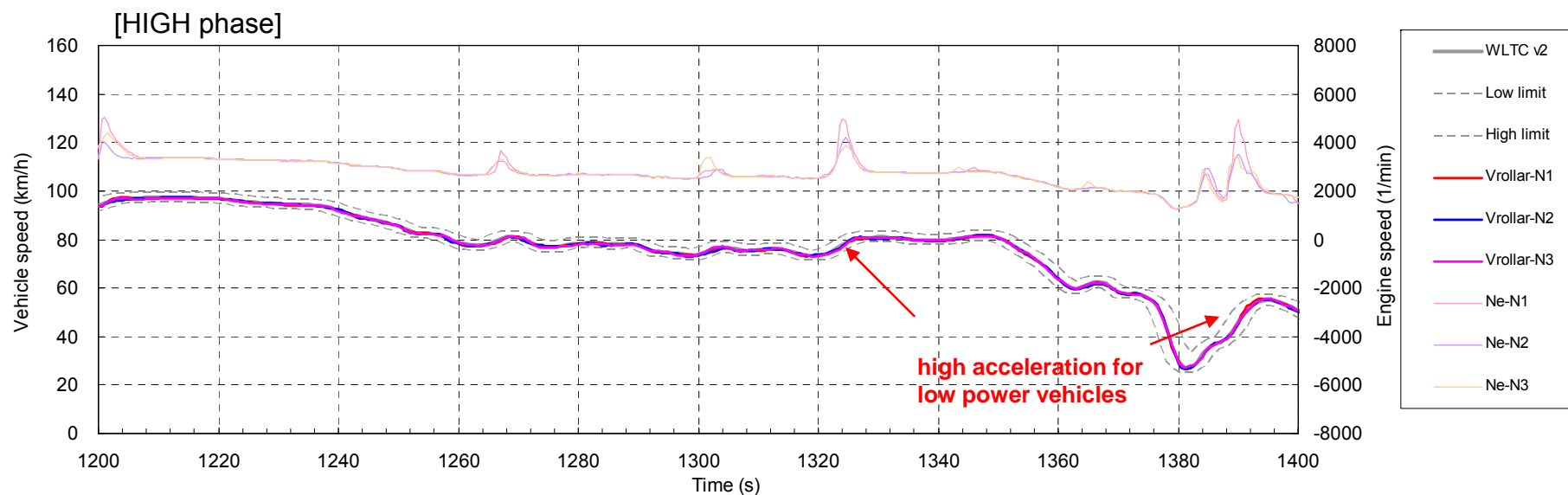
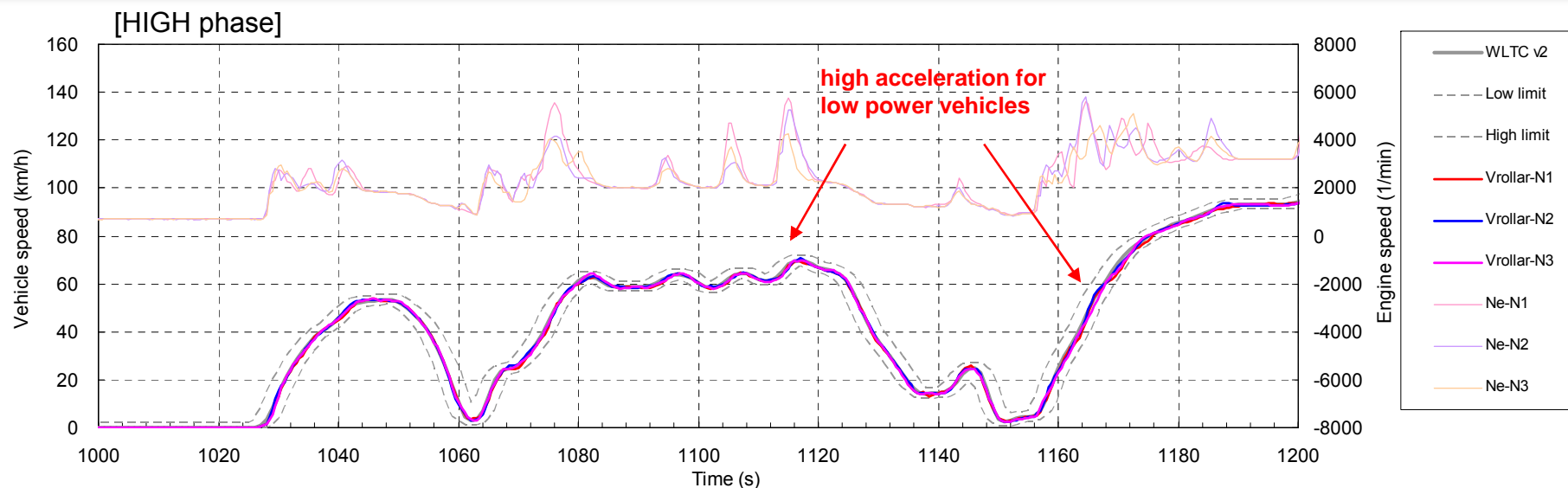


(*) Tolerance: ± 2 km/h and ± 1 s, follow the same tolerance as TRIAS

Traceability – HxH phase, Vehicle A (PC, 0.66L, CVT)

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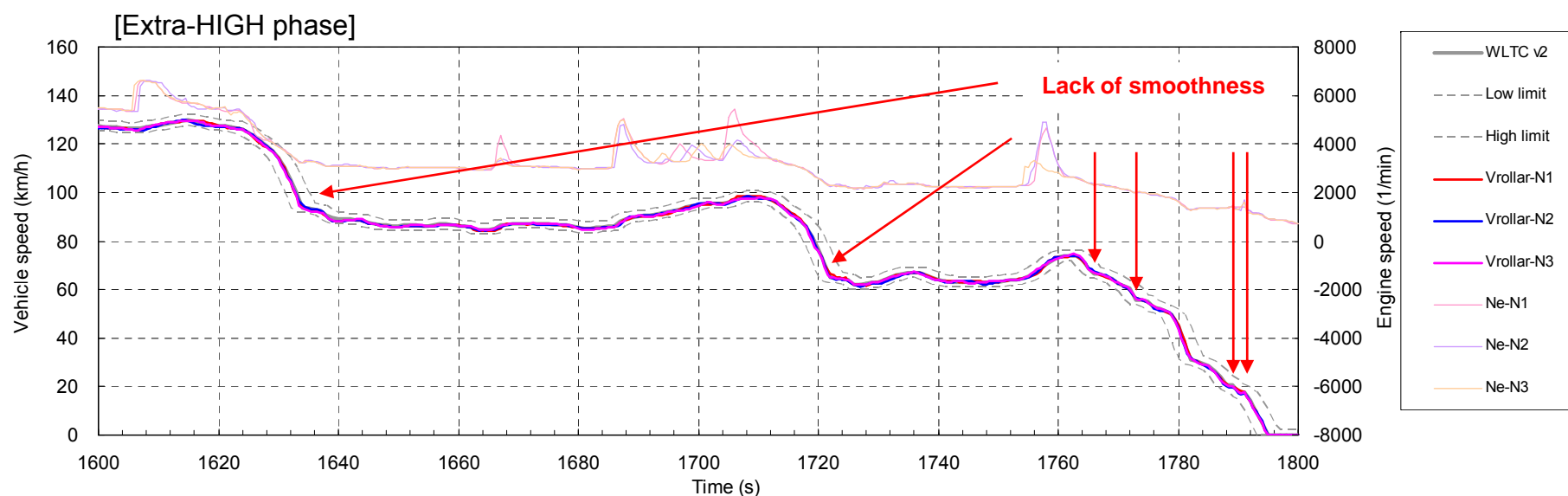
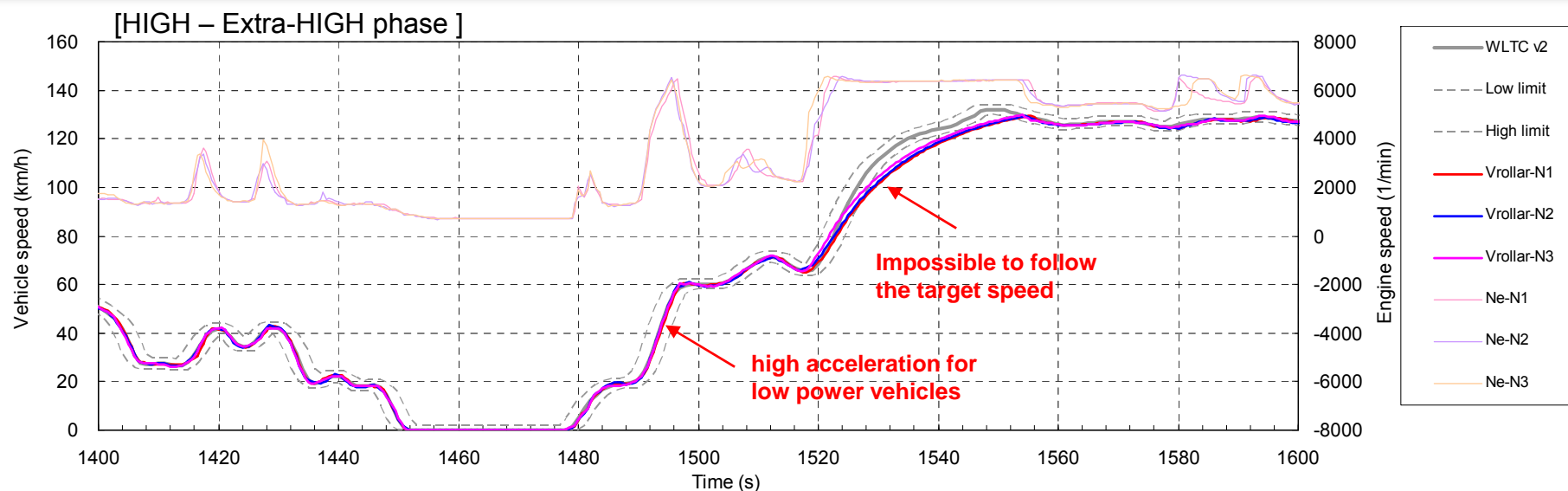


(*) Tolerance: +/- 2 km/h and +/- 1 s, follow the same tolerance as TRIAS

Traceability – HxH phase, Vehicle A (PC, 0.66L, CVT)

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(*) Tolerance: ± 2 km/h and ± 1 s, follow the same tolerance as TRIAS

Traceability – Vehicle A

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	Time	Comments
1	L/M/H	There are some area where are higher acceleration for low power vehicle
2	ExH	It is impossible to follow the target from 1520 s to 1560 s
3	L/M/H/ExH	It was not observed “slip” and/or “lock”
4	ExH: 1635, 1723, 1774, 1777, 1789, 1791	Lack of smoothness during deceleration → cruise portions
5		
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3.2.1. Test result – Vehicle B (TOYOTA DYNA) ^{WLTP-DTP-Current Status 12092011}

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Vehicle	Load	Gear	Driver	Condition	Test No.	Driving Index (Energy rating %)									Coolant Temperature (C ^(*))		
						Low ST1	Low ST2	Low ST3	Low ST4	Low ST5	Low Total	Middle	High	Ex-High	Initial	End of Low phase	End of Middle phase
Veh. B TOYOTA DYNA LDCV 2000cc 5MT	2 persons	JP	Driver 1	Hot	1	3.40	3.45	3.52	-5.08	5.11	3.46	0.81	-1.77	-10.14	54.7	58.3	54.9
	2 persons (110kg) + load 500kg with rear deck	JP	Driver 1	Cold	1	1.80	3.51	1.70	-8.99	3.72	2.83	1.04	-	-	26.9	50.7	54.3
					2	4.31	3.38	2.24	1.17	7.58	3.66	0.72	-	-	25.2	49.9	53.3
					3	0.29	2.76	2.45	5.50	3.07	2.18	0.72	-	-	26.2	50.3	54.2
				Hot	1	0.88	1.87	2.94	2.00	4.35	1.86	0.37	-1.11	-10.18	55.7	58.8	55.1
					2	3.12	2.79	2.47	-2.25	1.74	2.75	0.69	-1.29	-9.04	54.6	57.7	54.9
					3	1.11	2.59	4.05	7.12	3.60	2.47	0.29	-1.15	-9.53	54.6	58.3	54.5
		HS	Driver 1	Cold	1	0.69	3.67	5.93	1.29	11.50	3.54	0.98	-	-	25.1	51.3	54.0
				Hot	1	0.69	3.52	3.97	1.53	9.87	3.17	0.47	-0.24	-8.60	54.4	59.0	54.8

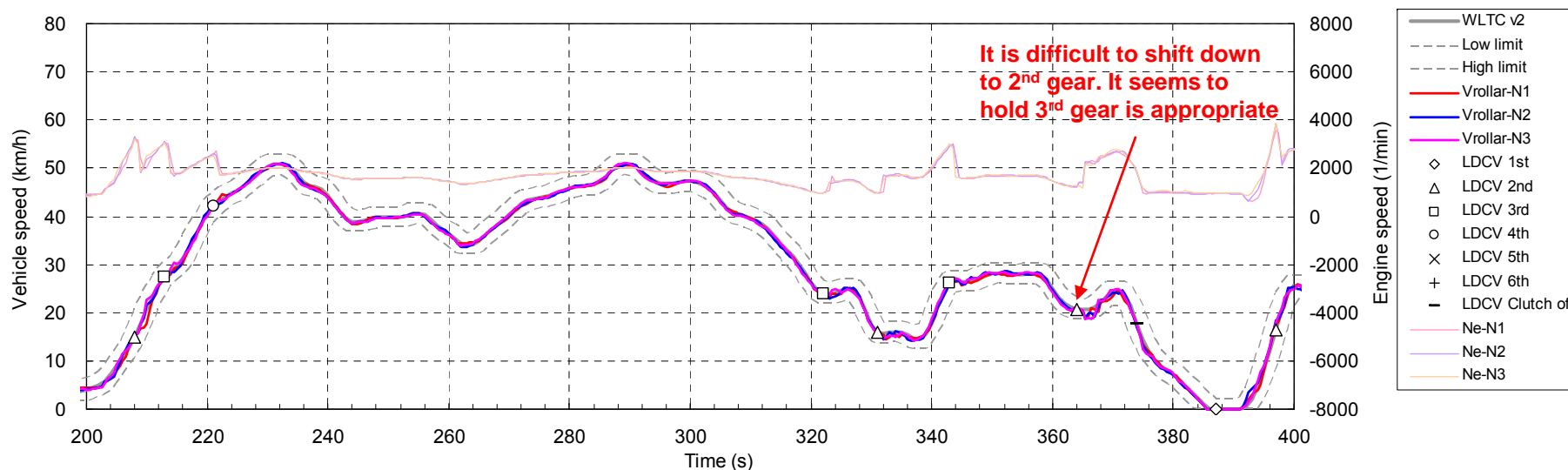
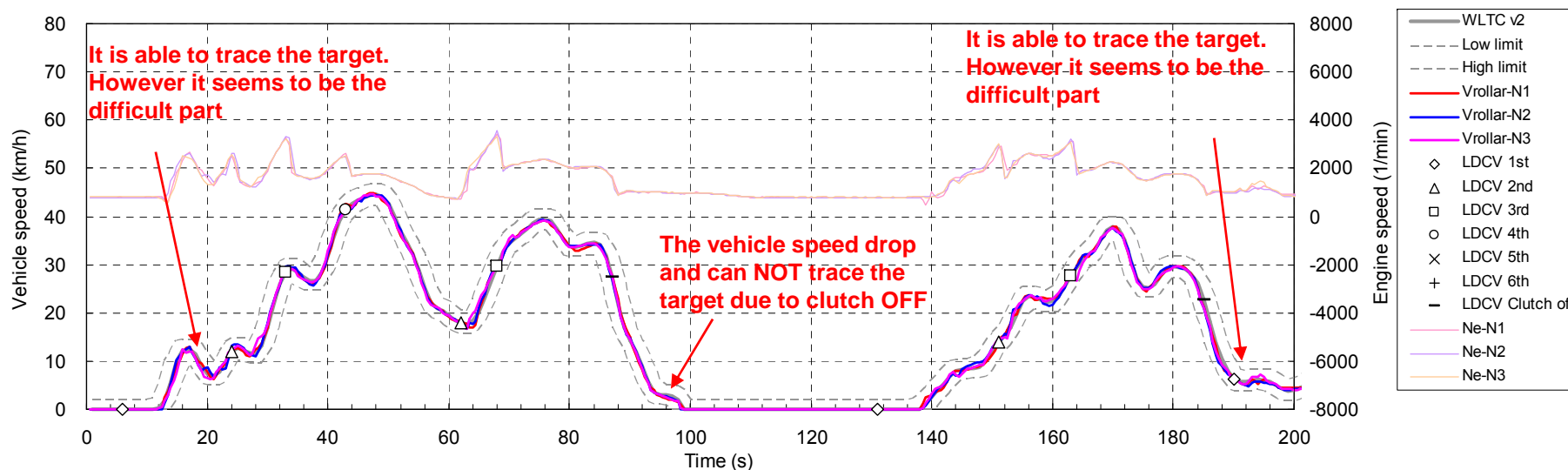
(*) Thermostat surface temperature

- LOW total: In 4 tests, Energy rating exceeded +/- 3%
- MIDDLE: Energy rating of all tests are within +/-3%
- HIGH: Energy rating of all tests are within +/-3%
- Ex-HIGH: Energy ratings are lower than -3%, because it was impossible to follow the target speed
- Coolant temp.: Coolant temperatures of end of low phase are difference between cold and hot condition.

Traceability – LM phase, Op-A, Vehicle B (LDCV, 2.0L, 5MT)

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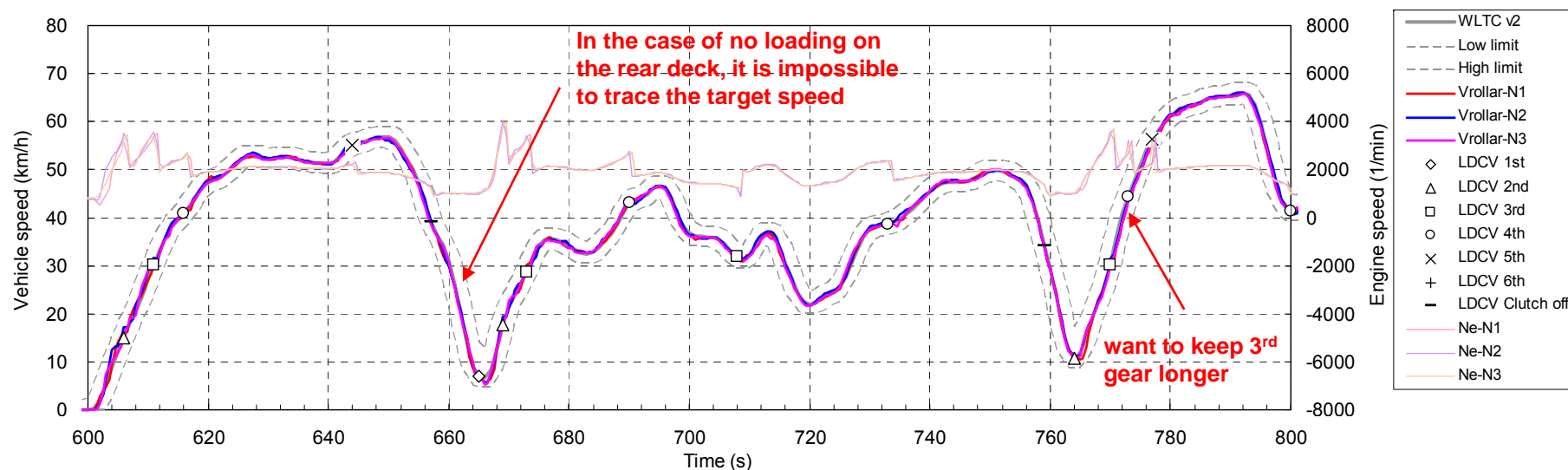
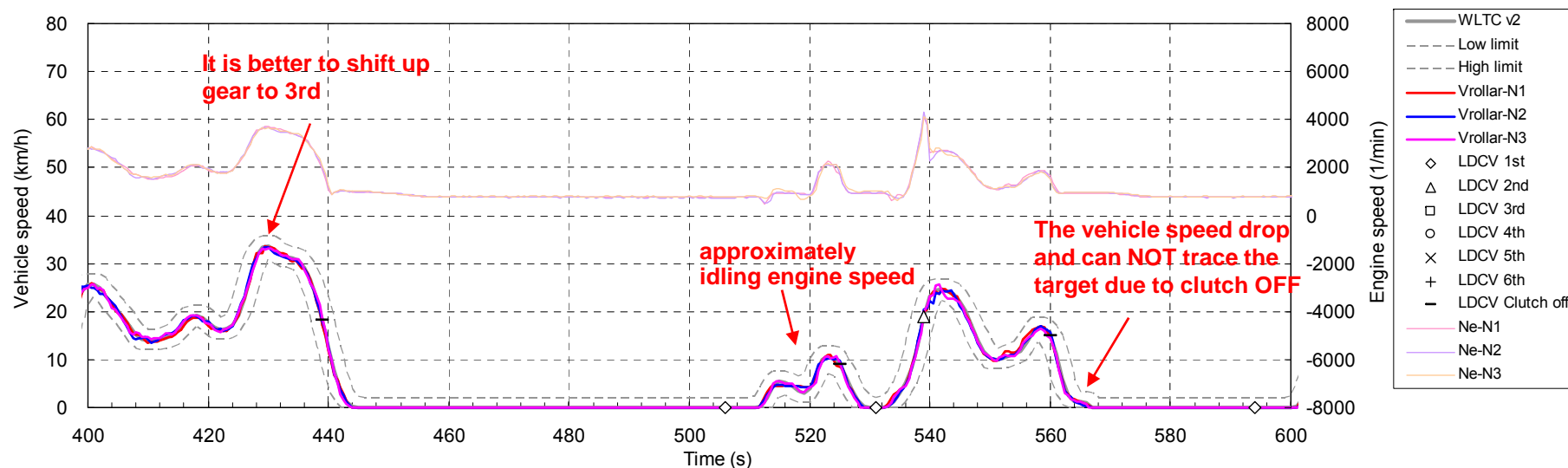


(*) Tolerance: +/- 2 km/h and +/- 1 s, follow the same tolerance as TRIAS

Traceability – LM phase, Op-A, Vehicle B (LDCV, 2.0L 5MT)

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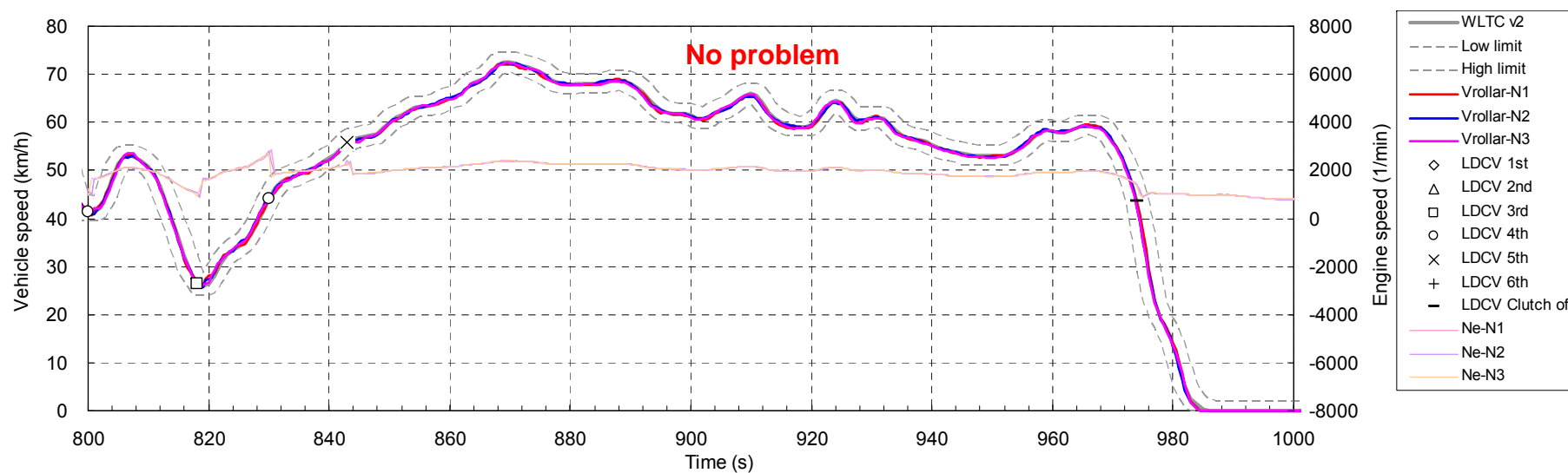


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Traceability – LM phase, Op-A, Vehicle B (LDCV, 2.0L, 5MT)

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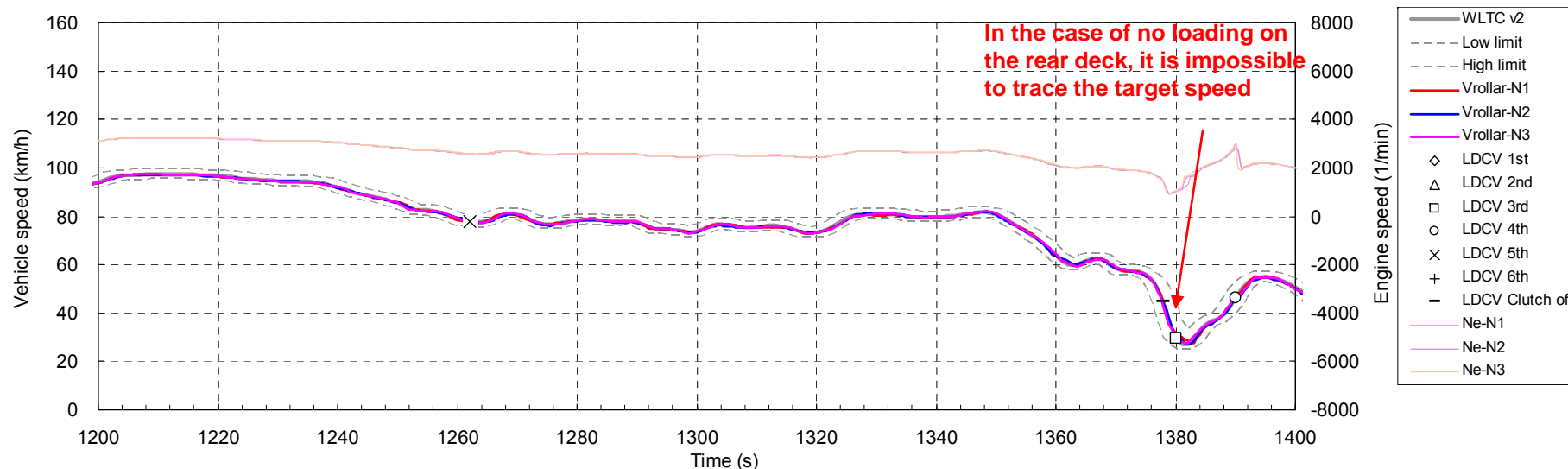
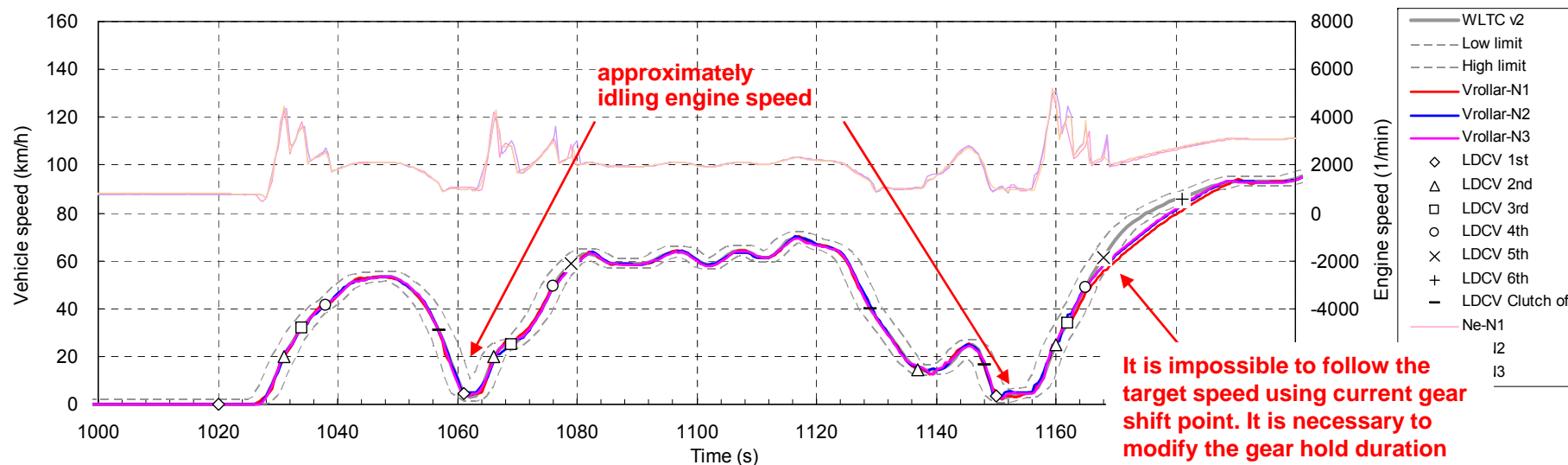


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Traceability – HxH phase, Op-A, Vehicle B (LDCV, 2.0L, 5MT)

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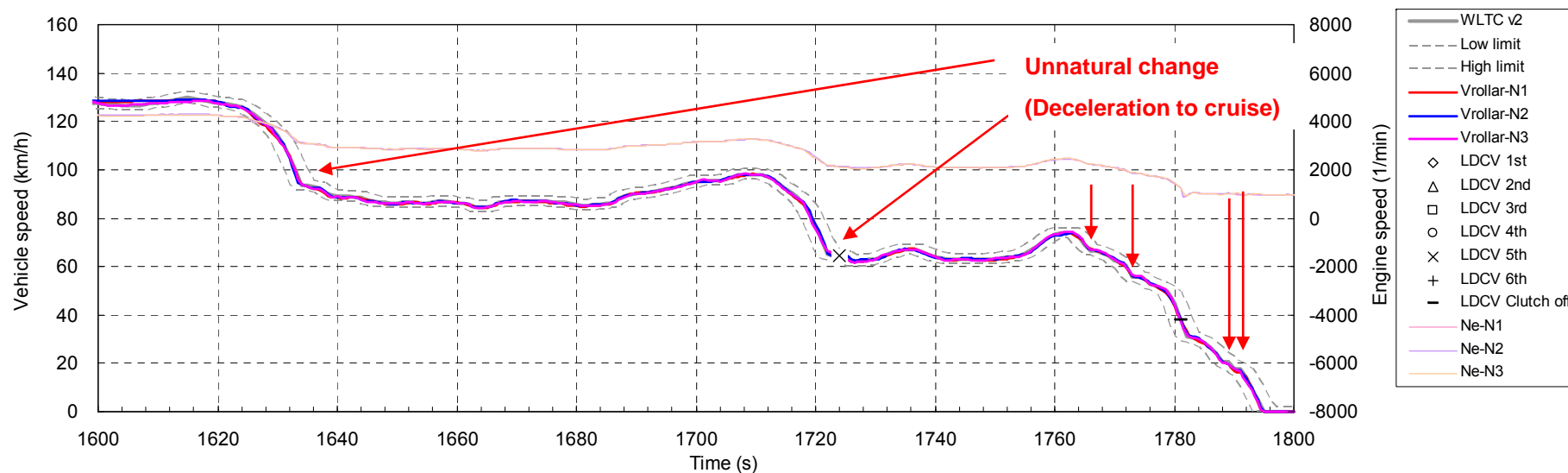
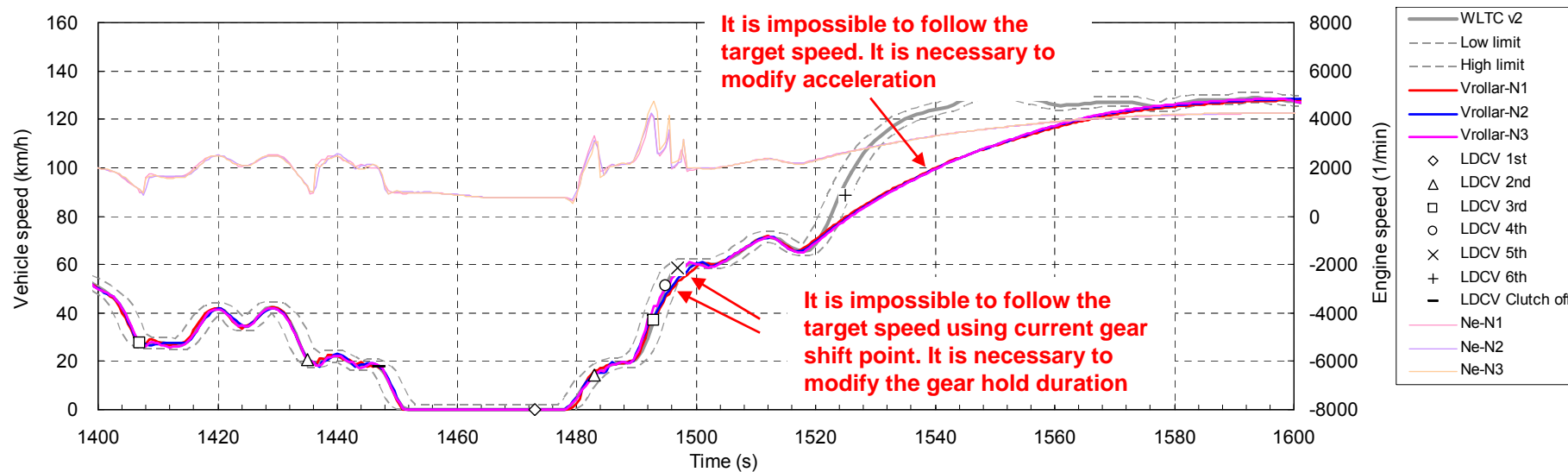


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Traceability – HxH phase, Op-A, Vehicle B (LDCV, 2.0L, 5MT)

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Traceability – Vehicle B, Op-A

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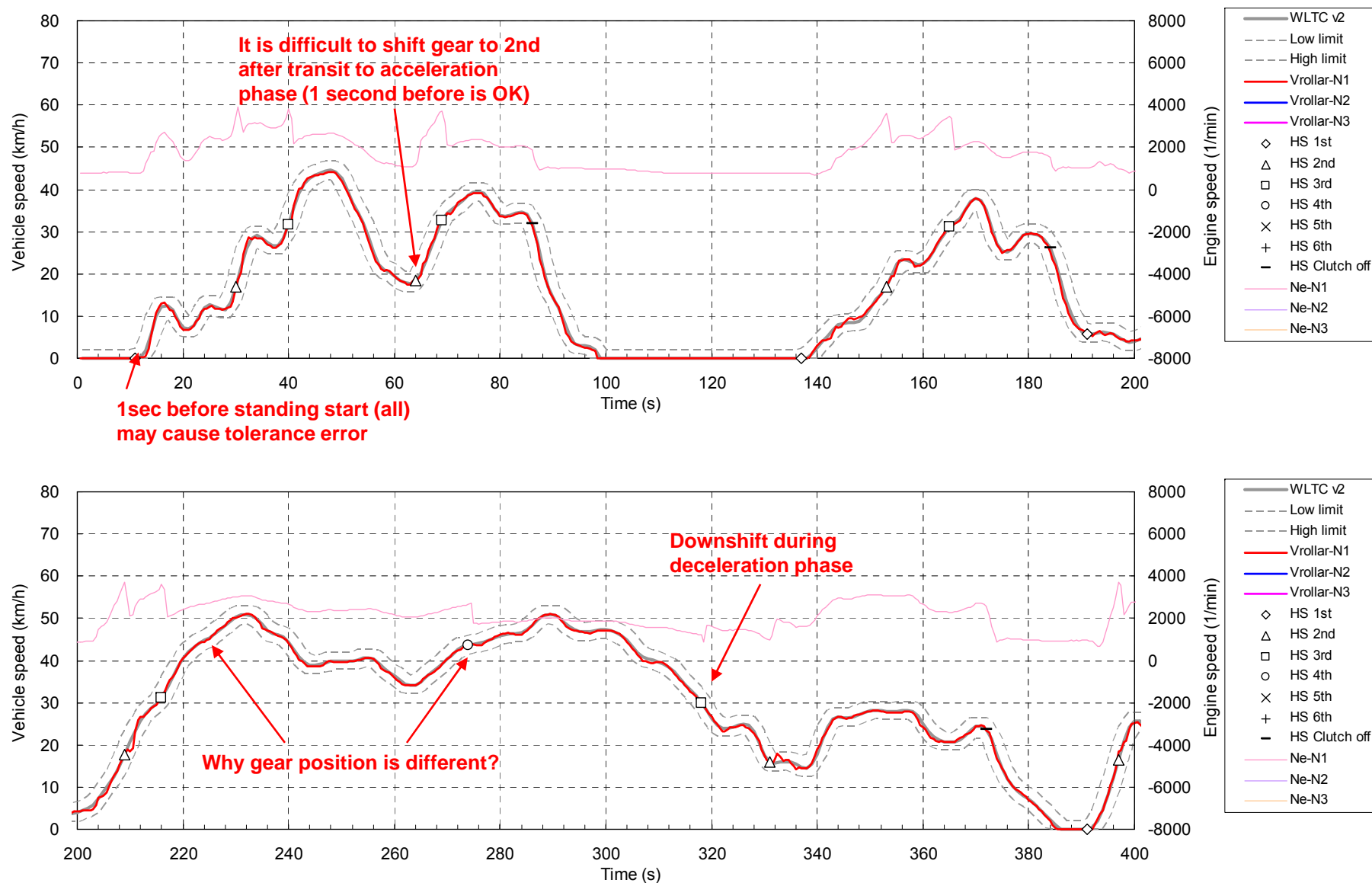
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	Time	Comments
1	L/M/H/ExH	In the case of no loading on the rear deck, it is impossible to trace the target speed during high deceleration portions.
2		In the case of load weight of 500 kg on the rear deck, it was not observed “slip” and/or “lock”
3	364	It is difficult to shift down to 2 nd
4	512~	ST4: Approximately idling engine speed
5	1070 ~ 1080	It is impossible to follow the target speed
6	1160~1182	It is necessary to revise gear position
7	1490 ~ 1580	It is impossible to follow the target speed
8	1490 ~ 1530	It is necessary to revise gear position
9		
10		

Traceability – LM phase, Op-B, Vehicle B (LDCV, 2.0L, 5MT)

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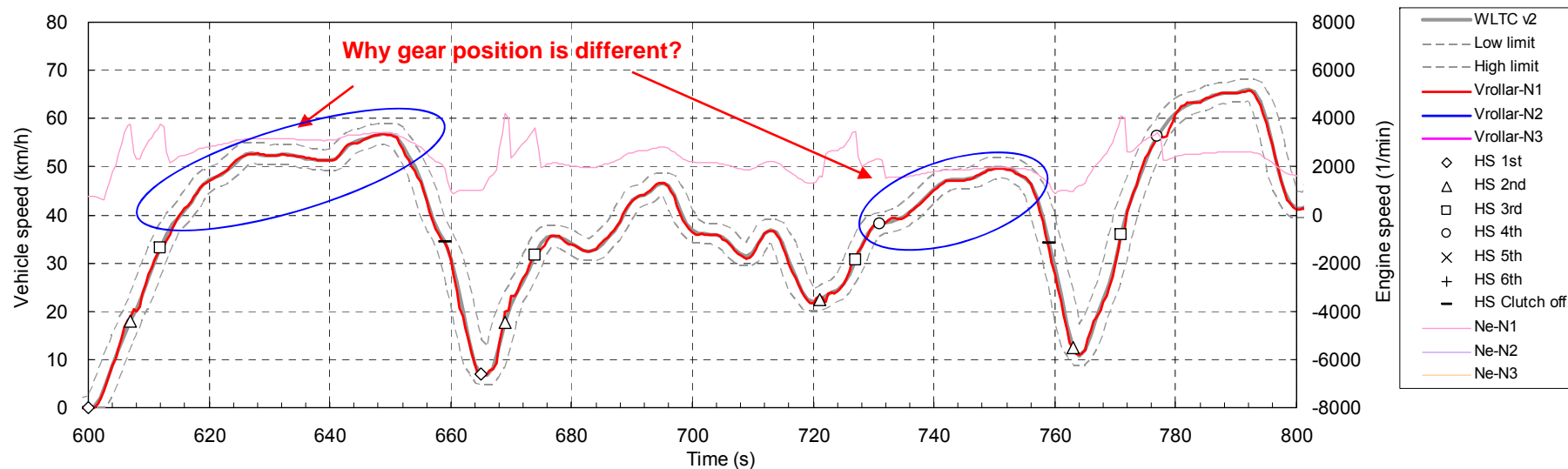
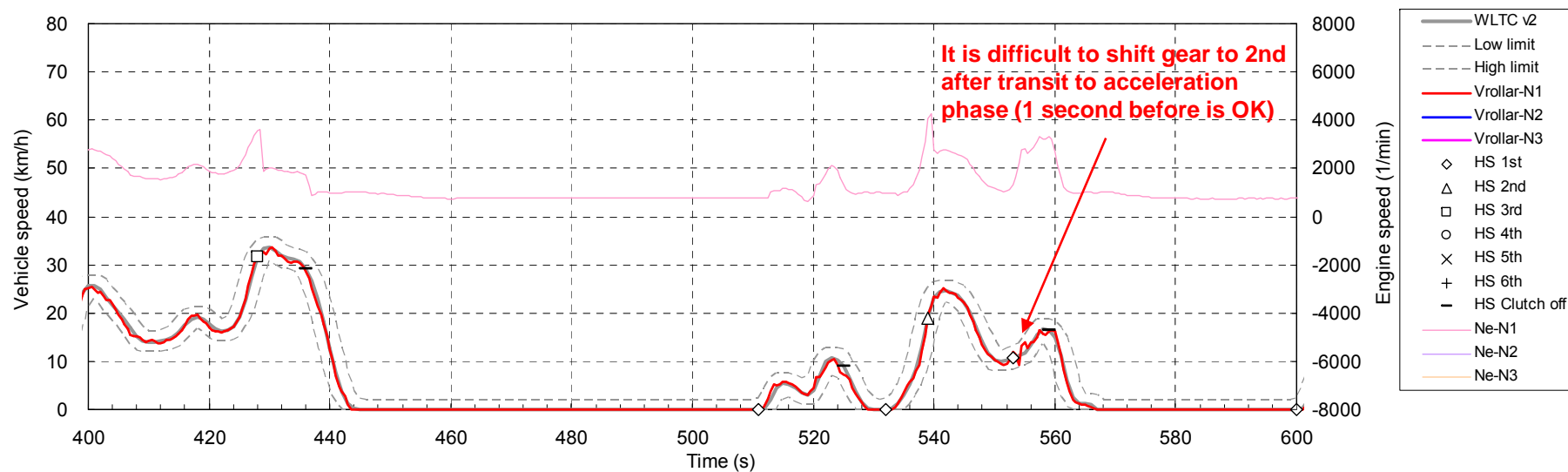


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Traceability – LM phase, Op-B, Vehicle B (LDCV, 2.0L, 5MT)

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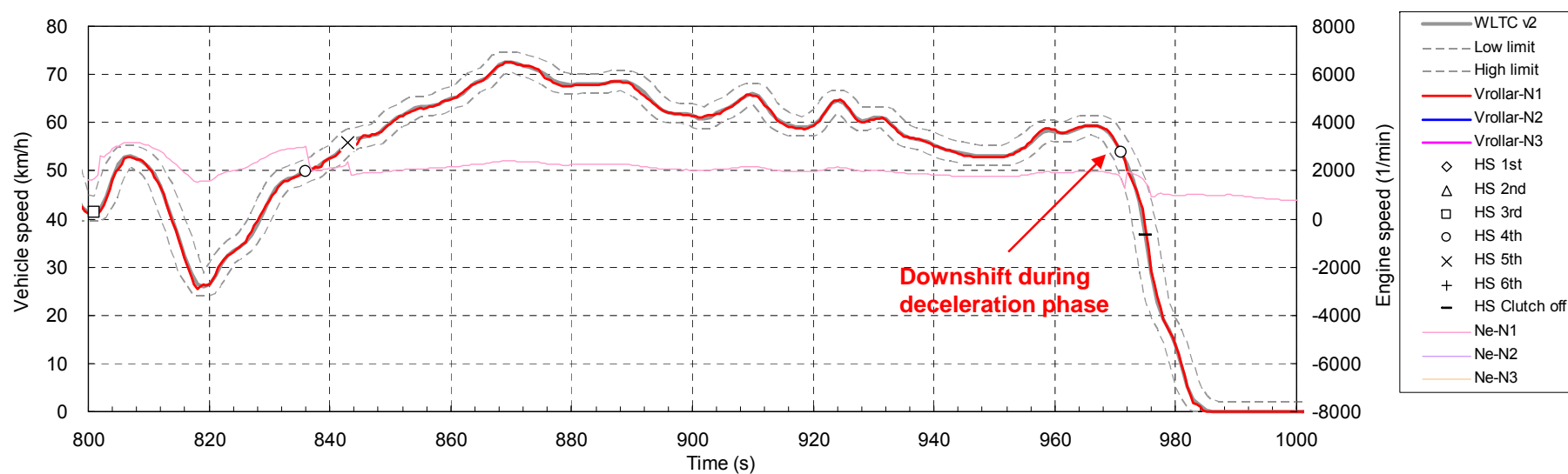


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Traceability – LM phase, Op-B, Vehicle B (LDCV, 2.0L, 5MT)

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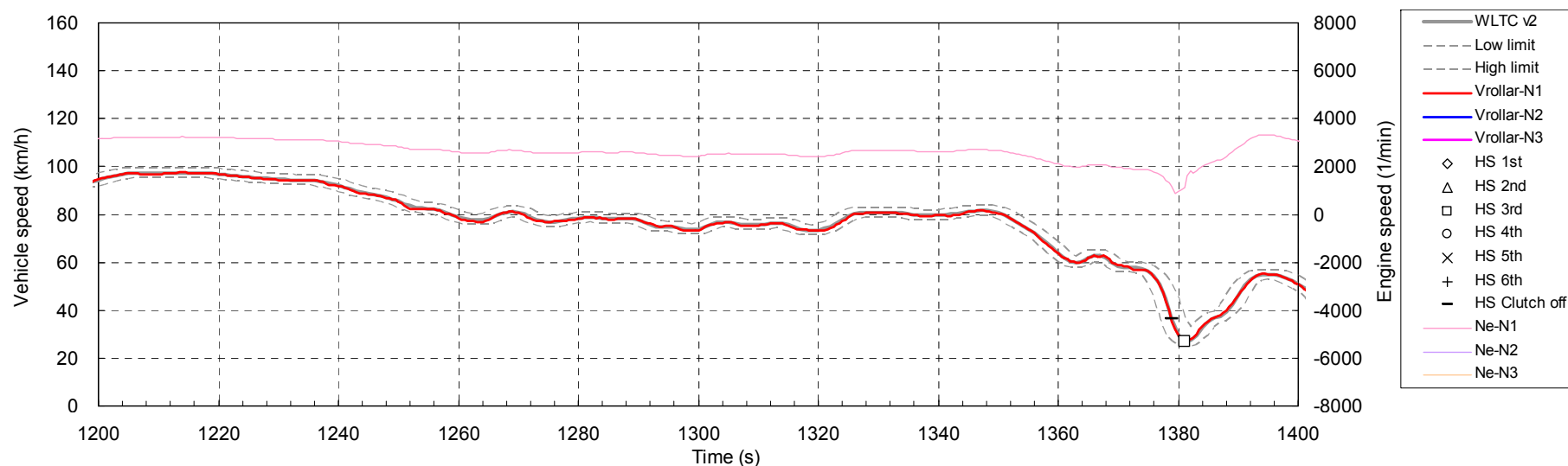
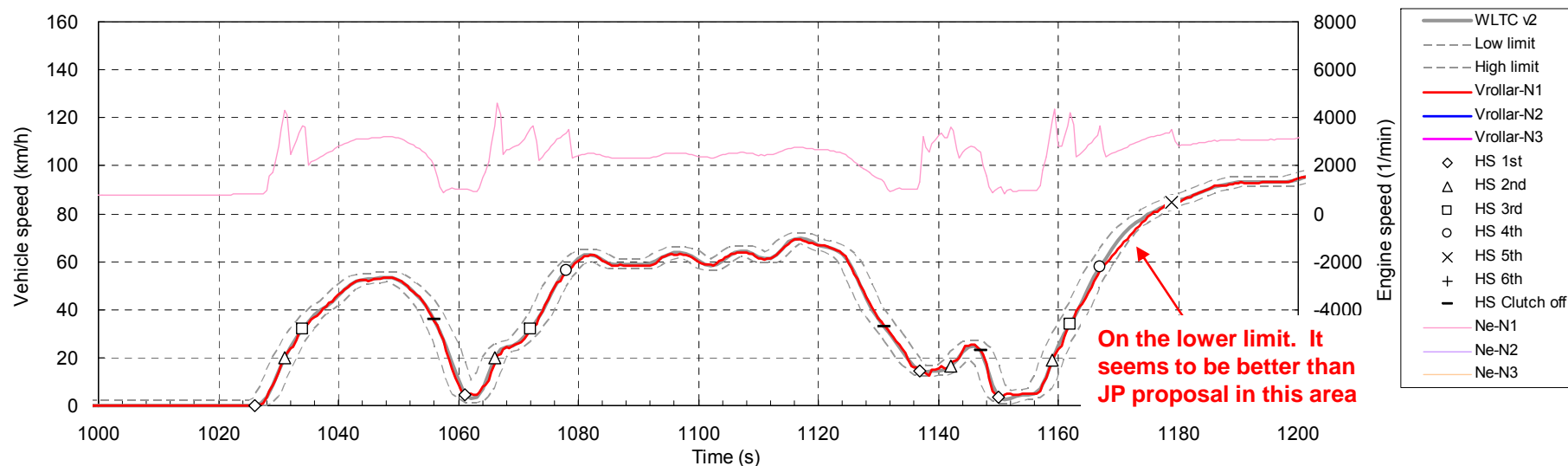


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Traceability – HxH phase, Op-B, Vehicle B (LDCV, 2.0L, 5MT)

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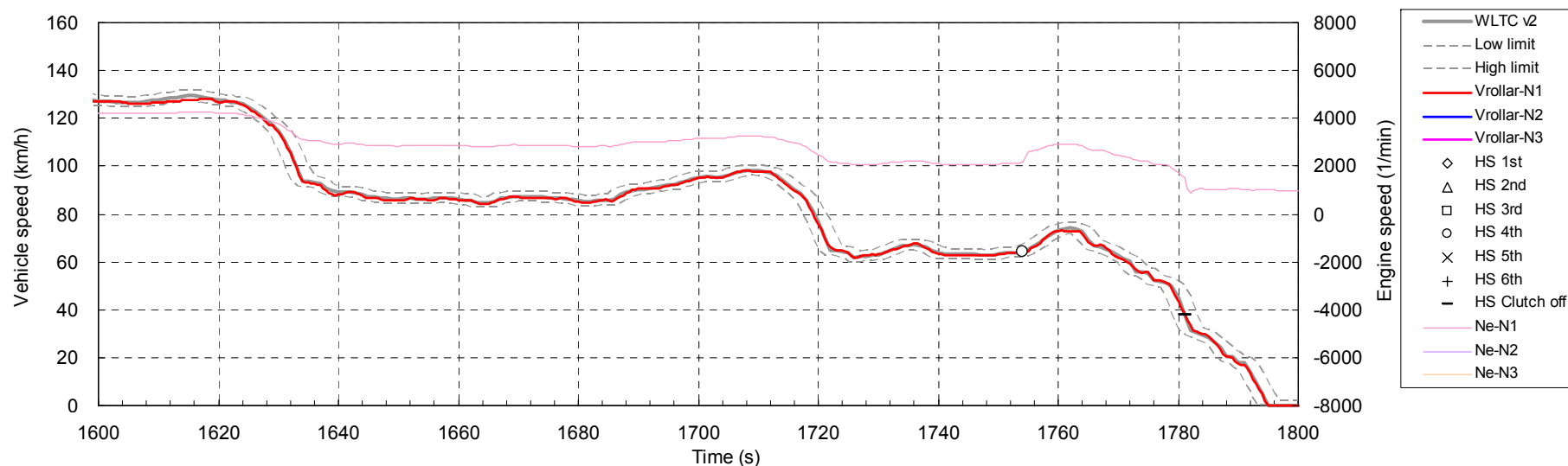
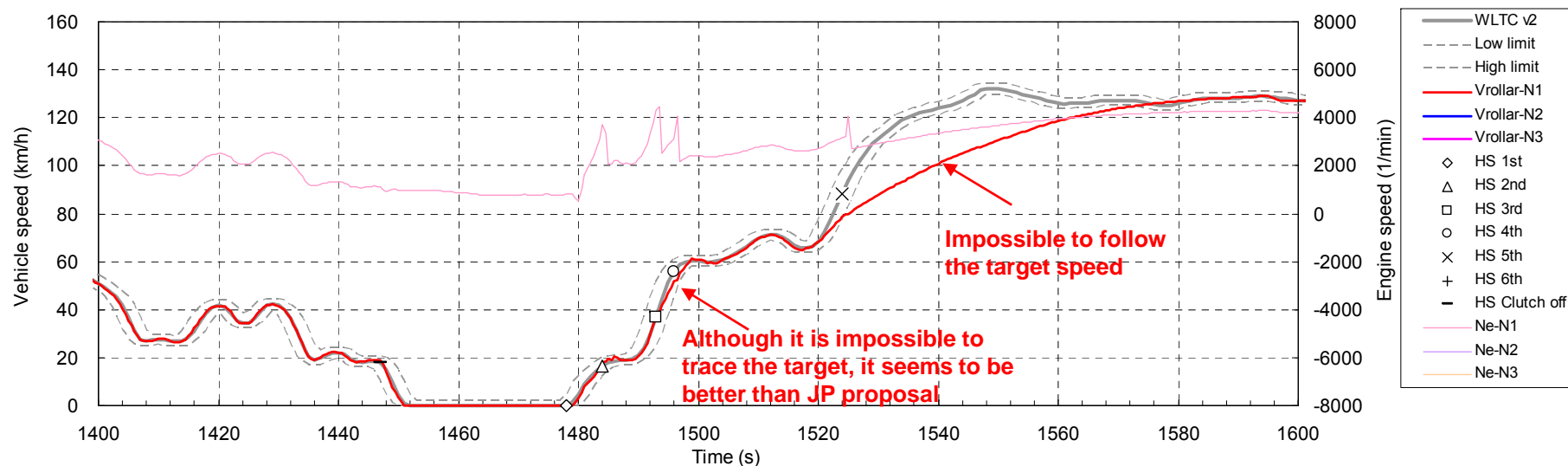


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Traceability – HxH phase, Op-B, Vehicle B (LDCV, 2.0L, 5MT)

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(*) Tolerance: +/- 2 km/h and +/- 1 s, follow the same tolerance as TRIAS

Traceability – Vehicle B, Op-B

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	Time	Comments
1	64	It is difficult to shift gear to 2nd after transit to acceleration phase
2	316	Downshift during deceleration phase
3	553	It is difficult to shift gear to 2nd after transit to acceleration phase
4	971	Downshift during deceleration phase
5	1070 ~ 1080	It is impossible to follow the target speed
6	1490 ~ 1580	It is impossible to follow the target speed
7		
8		
9		
10		

4. Summary (Tentative)

➤ TEST CYCLE

➤ LOW

- ✓ Although following the target speed, Energy rating error indicate more than 3%.
- ✓ In low speed area (<10 km/h), test vehicles with manual transmission have difficulty to follow the cycle

➤ MIDDLE

- ✓ Energy ratings are within +/- 3% in all tests
- ✓ Low powered vehicles may use WOT (Wide Open Throttle) operation

➤ HIGH

- ✓ Low powered vehicle may use WOT operation
- ✓ Some of low powered vehicles was not able to follow the target speed.

➤ Ex-HIGH

- ✓ Both vehicle A and vehicle B could not follow the target speed.

➤ OVERALL

- Higher acceleration/deceleration area in each phase may cause difficulty on reproducibility / repeatability of trace.

➤ GEAR SHIFT

➤ Option A (Fixed):

- Modifications in several area are necessary. (such as gear hold duration etc)

➤ Option B (Unique):

- Mismatch gear positions were observed between gear shift logic and calculation sheet.

➤ NEXT STEP

- Validation 1 tests on another LDCV and PC vehicle are under the way at JARI
- Plan to propose the modification on test cycle/gear shift point based on validation test results from all around the world

- Engine force
 - $F_{ENG} = [F_0 + F_1 * V + F_2 * V^2 + 1.015 * ETW * a]^+$
- Engine work increment
 - $W_i = F_{ENGi} * d_i$
- Cycle energy (CE)
 - $CE = \sum W_i = \sum [(F_0 + F_1 * V_i + F_2 * V_i^2 + 1.015 * ETW * a_i) * d_i]^+$
- Energy rating (ER)
 - $ER = (CE_D - CE_T) / CE_T * 100$
- Distance rating (DR)
 - $DR = (D_D - D_T) / D_T * 100$
- Energy economy rating (EER)
 - $EER = [1 - (DR / 100 + 1) / (ER / 100 + 1)] * 100$
- Absolute speed change rating (ASCR)
 - $ASCR = (ASC_D - ASC_T) / ASC_T * 100$
 - $ASC = \Delta t * \sum |a_i|$
- Root mean squared speed error (RMSSE)
 - $RMSSE = 2.237 * \sqrt{(\sum (V_{Di} - V_{Ti})^2) / N}$

(*)Subscript

T: Target, D: Driven (= roller)

(*) $D = \sum d_i$