Study on Low~High temperature test

Prepared by Japan

18th WLTP-IWG

18-20 April 2017

Overview of the study

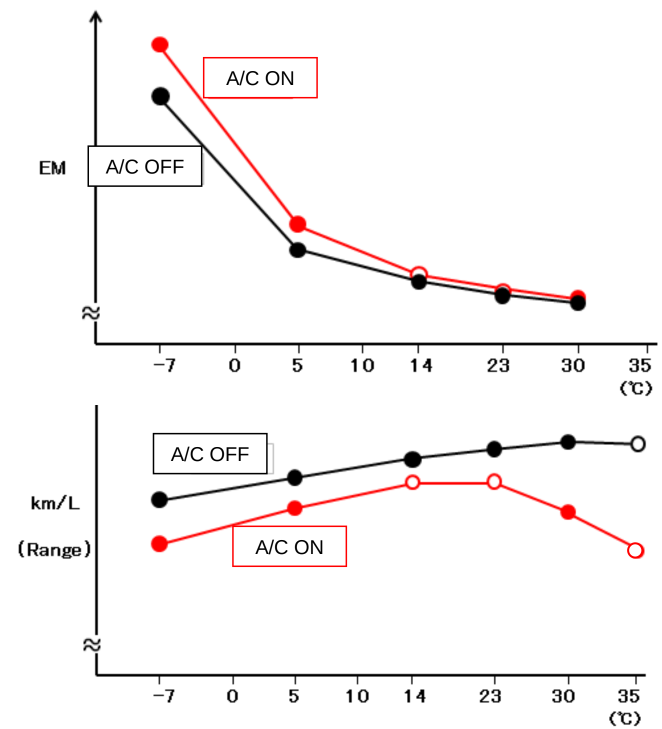
- Purpose: Evaluate the impact of temperature on Emissions and F.E.
- Test vehicles: ICE vehicle and NOVC-HEV
- Test cycle: WLTC-3 phase (LMH)
- Temperature: 5 conditions, (-7℃, only ICE), +5℃, +14℃, 23℃, 30℃
- A/C setting: A/C OFF, 25-AUTO

◆Test matrix

Vehicle type	A/C operation	Environmental condition				
		-7℃	5℃	14℃	23℃	30℃
ICE	A/C OFF	1	2	2	1	1
	25-AUTO	2	2	-	-	2
NOVC-HEV	A/C OFF	-	1	1	2	1
	25-AUTO	-	1	-	-	-

*) RCB correction factor in each temp. were measured for NOVC-HEV
*) Dynamometer set value was compensated both F0 and F2.

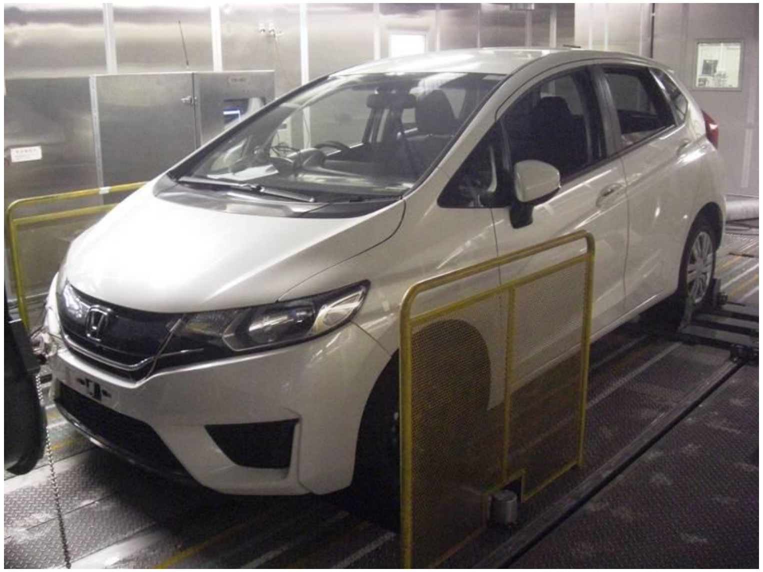
◆Image of test results



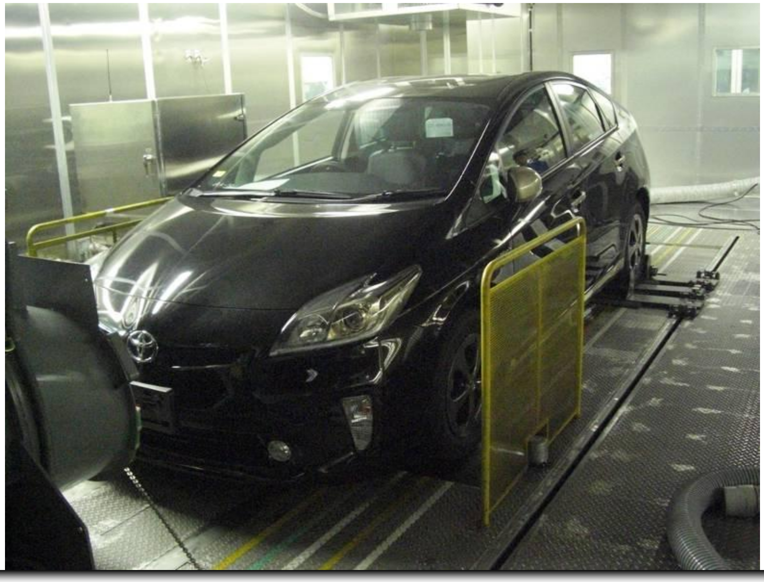
Test vehicles

Vehicle ID			ICE	NOVC-HEV
Vehicle category: M1/N1		-	M1	M1
Vehicle Model		-	DBA-GK5	DAA-ZVW30-AHXEB
Body	Length	mm	3,955	4,480
	width	mm	1,695	1,745
	height	mm	1,525	1,490
	Wheelbase	mm	2,530	2,700
	Curb mass under JP regulation - individual	kg	1,070	1,350
	Weight for Tire and tool	kg	8	10
	Curb(Unladen) mass under EU regulation (UM)	kg	1075	1357
	Mass in Running order	kg	1150	1432
	Riding capacity	persons	5	5
	Maximum pay load	kg	0	0
	Gross vehicle weight	kg	1,345	1,625
	Technically permissible maximum laden mass (LM)	kg	1,602	1,695
	Mass of the optional equipment of vehicle H	kg	10	70
	Test mass HIGH	kg	1,248	1,552
	Inertia weight under WLTP - Heaviest-Worst for 2WD-CHDY	kg	1,265	1,574
	Volume of Fuel tank	L	40	45
Engine	Engine type	-	L15B	2ZR-FXE
	Fuel type (Diesel/Gasoline/LPG)	-	Gasoline-Regular	Gasoline - Regular
	Engine features Technology for FE improvement	-	Inline-four cylinder engine, Electronic fuel injection, Idle stop, Variable valve timing control device, Electric power steering system	Inline-four cylinder engine, electronic fuel injection, Idle stop, Variable valve timing control device, , electric power steering system, Hybrid system, Electronically controlled Continuously Variable Transmission
	Engine displacement	cc	1,496	1,797
	Compression ratio	-	11.5	13.0
	Maximum rated power	kW	97	73
	Engine speed at Max. power	min-1	6600	5200
	Maximum torque	Nm	155	142
	Engine speed at Max. torque	min-1	4600	4000
	Engine speed at Idling	min-1	700	1000 @ Maintenance mode
	Exhaust-gas after treatment device (TWC, DPF, Urea SCR, etc), Exhause-gas countermeasure device (EGR, etc)	-	TWC	TWC
Motor	Motor type	-	-	3JM
	Kind of motor	-	–	Permanent magnet AC synchronous motor
	Rated power	kW	-	18
	Maximum power	kW	-	60
	Motor speed at Max. power	min-1	-	2768～4000
	Maximum torque	Nm	-	207
	Motor speed at Max. torque	min-1	-	0～2768
Propulsion battery for HEV/EV	Type	-	-	NiMH
	Voltage in each battery	V	-	7.2
	Capacity	Ah	-	6.5
	Number of battery	-	-	28
	Total voltage (Nominal voltage)	V	-	201.6
	Circuit type	-	-	Series
Transmission	Drive system	-	2D-2	2D-2
	Transmission type	-	CVT	CVT
	Gear ratio	1st	-	-
		2nd	-	-
		3rd	-	-
		4th	-	-
		5th	-	-
		6th	-	-
		7th	-	-
	Final drive ratio		4.992	3.267
	gear ratio (Reverse)		2.706～1.382	-
Tires	Front tire size	m	185/60R/15	195/65R15
	Rear tire size	m	185/60R/15	195/65R15
	Dynamic radius of drive tire	m	0.288	
	Pressure	kpa	Fr:220 Rr:210	Fr230/Rr220
Instruments and Controls	Gear shift indicator	Y/N	Y	N
	Idling stop system	Y/N	Y	Y
	Cruise control	Y/N	N	N
Odometer		km	12,000	101,500

◆ICE vehicle



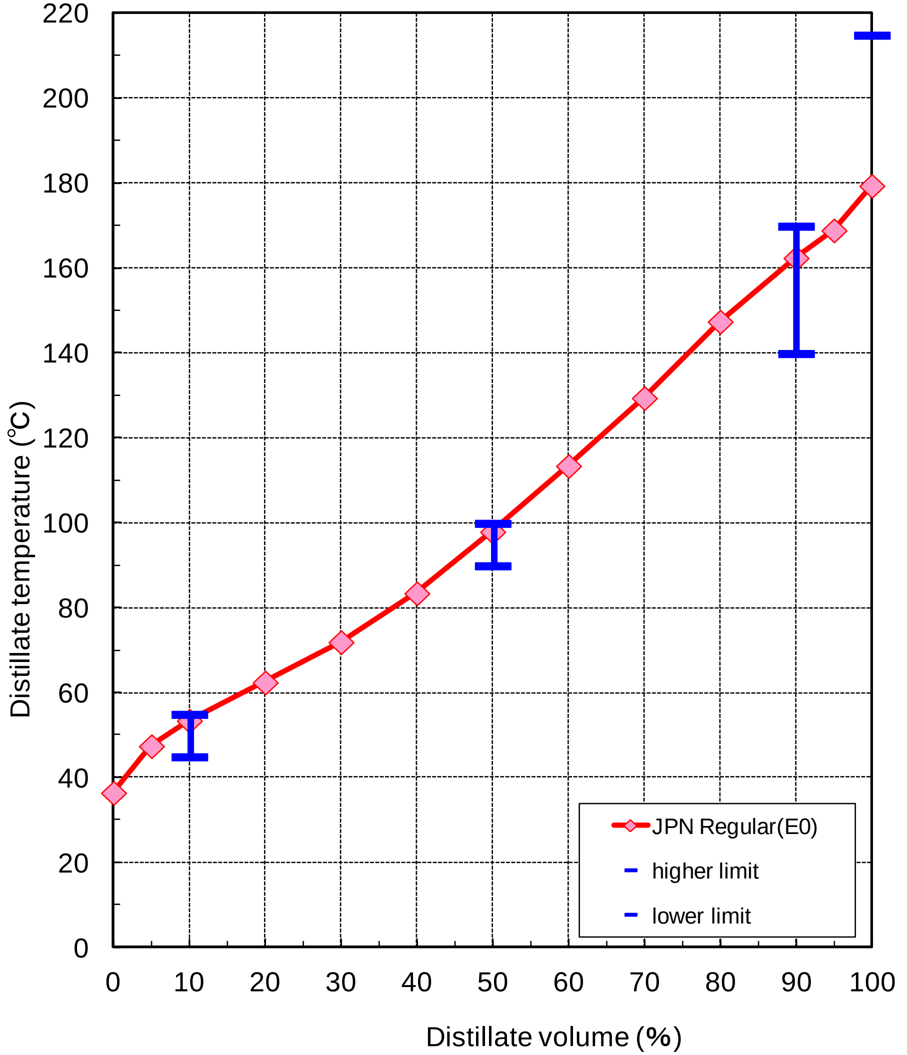
◆NOVC-HEV



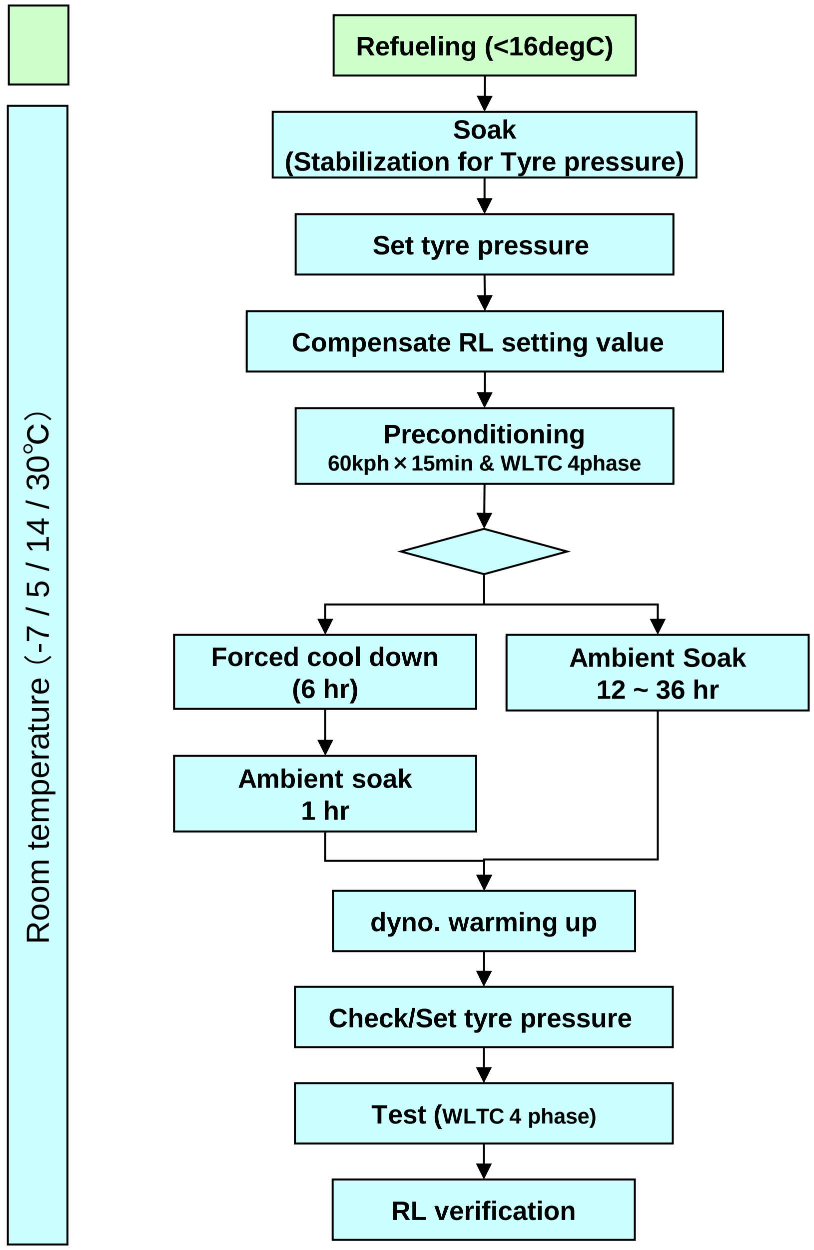
Fuel property

Reference fuel for Japan type approval test was used (not winter grade fuel)

Property		Unit	Value	Method
Type of fuel		-	Gasoline Regulaer	-
Density at 15 °C		g/cm3	0.7320	JIS K2249
Octane number	RON	-	90.5	JIS K2280
Distillation:	10% point	℃	53.5	JIS K2254
	50% point	℃	98.0	JIS K2254
	90% point	℃	162.5	JIS K2254
	Final boiling point	℃	179.5	JIS K2254
	Residue	vol%	1.0	JIS K2254
Vapour pressure (RVP) 37.8℃		kPa	58.1	JIS K2258
Lead content		g/l	0.001(-)	JIS K2255
Sulphur content		mass%	0.0007	JIS K2541
benzene		vol%	0.4	JIS K2536
Oxygen content		vol%	0.1(-)	JIS K2536
MTBE		vol%	0.1(-)	JIS K2536
Methanol		vol%	0.1(-)	JIS K2536
Ethanol		vol%	0.1(-)	JIS K2536
Kerosene		vol%	0.7(-)	JIS K2536
Solvent washed gum (Exsistant gum content)		mg/100ml	0	JIS K2261



Test procedure



- JPN fuel for TA

- **Compensate dyno. RL set value**
  (Both F0 and F2)

- Average of 1hr：±3℃
- Maximum：±6℃
- 3 minutes ：±3℃

- At start：±2℃
- Average：±3℃
- Maximum：±6℃
- 3 minutes.：±3℃
- A/C operation：25-AUTO@-7℃，5℃，30℃
- Defroster：OFF
- Cooling fan：speed proportional
- Bonnet：Close

RL Compensation

- Target RL in each temperature was calculated by the equation in the GTR15 annex4.

$$F_{0\_t} = \frac{F_{0\_20}}{\left(1 + 8.6 \times 10^{-3} \times (t - 20)\right)}$$

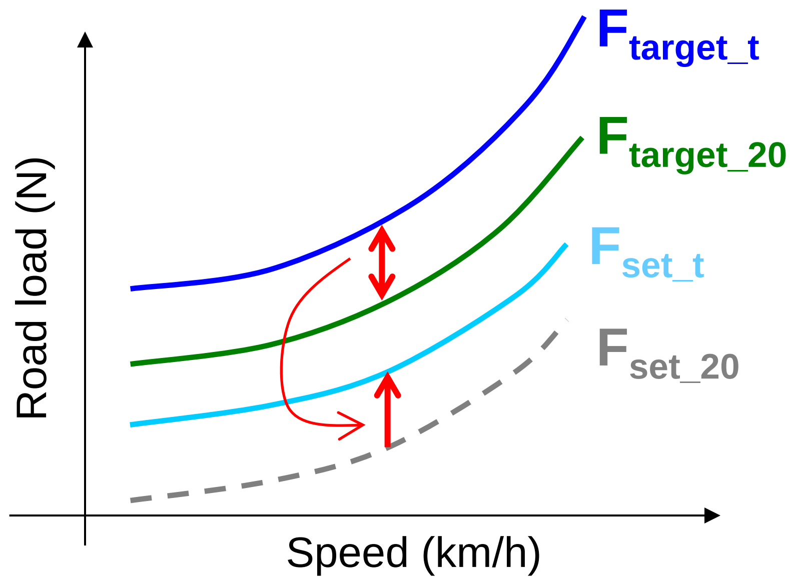
$$F_{2\_t} = \frac{F_{2\_20}}{\left((273 + t)/293\right)}$$

- Dyno. set value was compensated. (Coast down wasn't performed)

$$F_{set\_t} = F_{set\_20} + \left(F_{target\_t} - F_{target\_20}\right)$$

$$F_{target\_t} = F_{0\_t} + F_{1\_t} \cdot v + F_{2\_t} \cdot v^2$$

t: test temperature (degC)

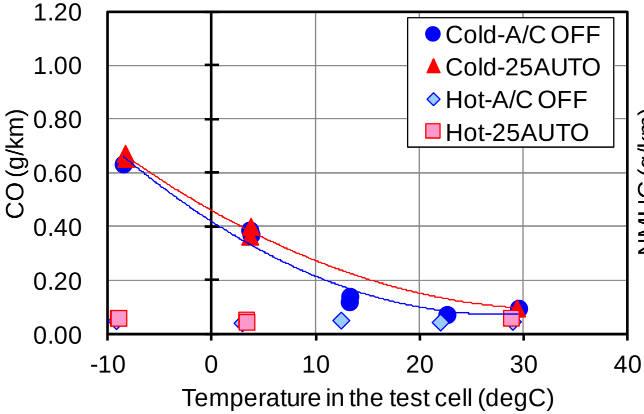


Add the difference between target RLs to RL set value at 20 degC

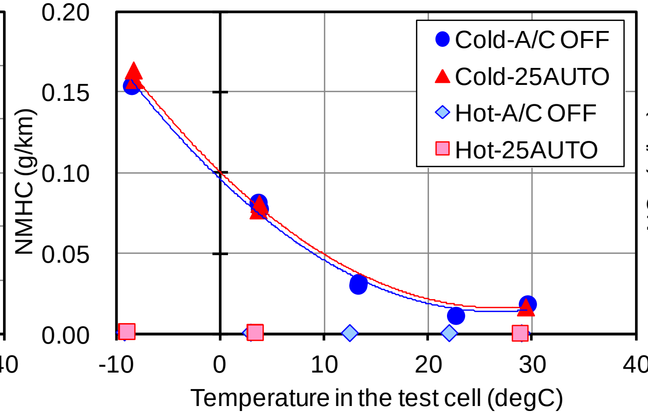
Test results of ICE vehicle

<WLTC-LMH>

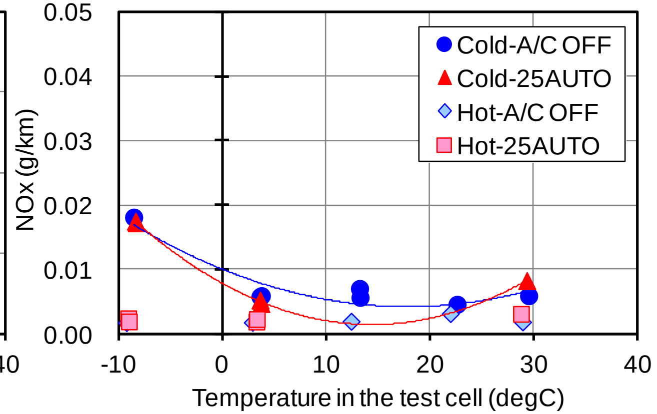
◆CO



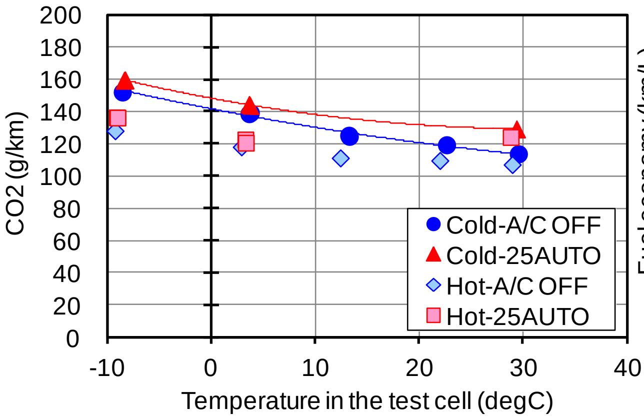
◆NMHC



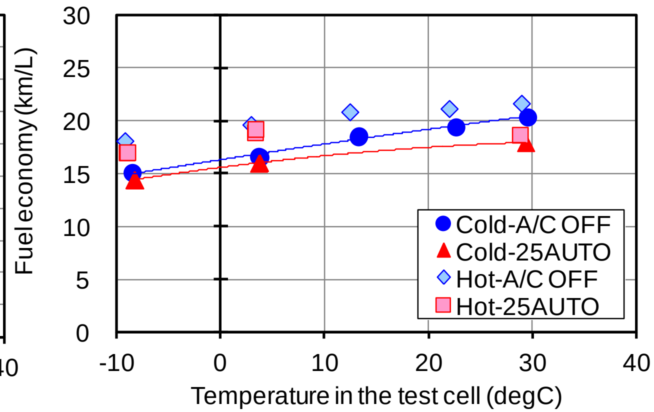
◆NOx



◆CO2



◆Fuel economy



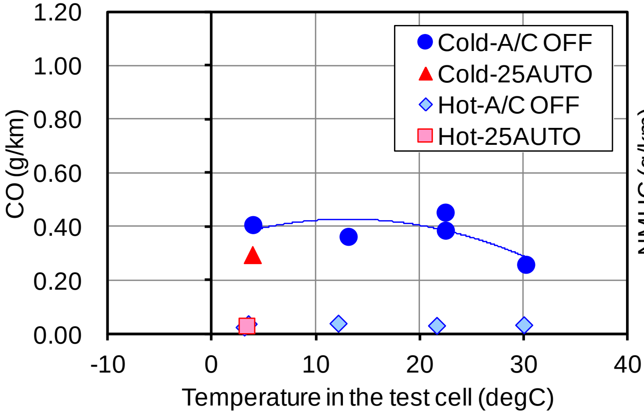
- CO, NMHC, NOx and CO2 were increased with decrease of the temperature.
- The changes are approximated by a quadratic curve. (Not linear)

[NOTE] Emission and F.E were measured during preconditioning and then the results are consider as the hot condition

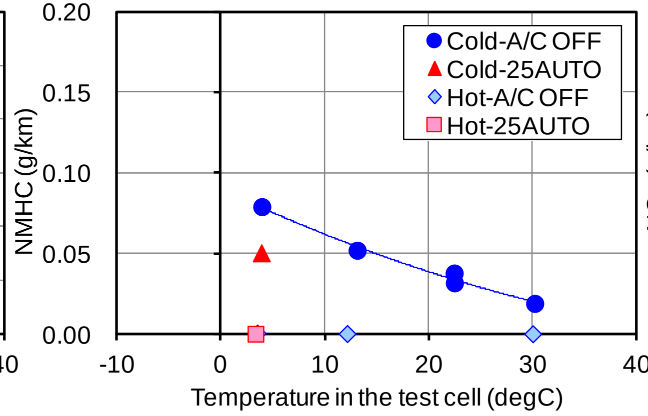
Test results of NOVC-HEV

<WLTC-LMH>

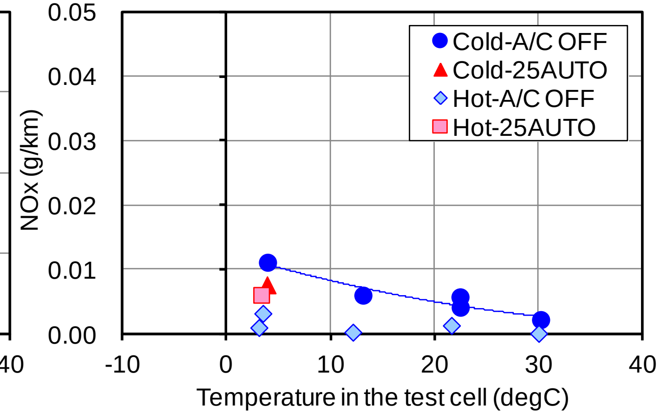
◆CO



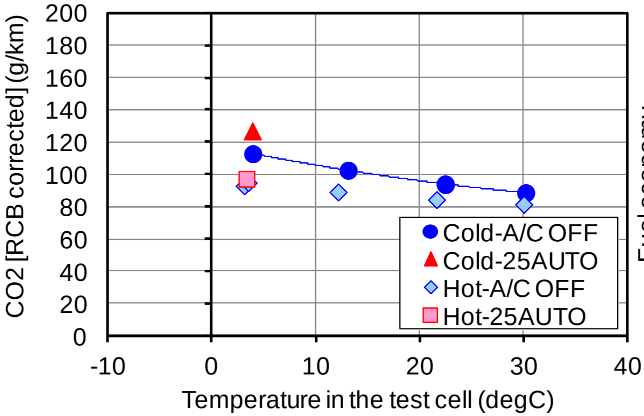
◆NMHC



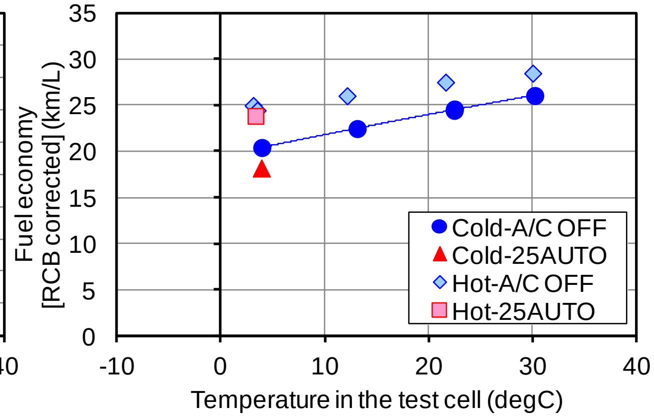
◆NOx



◆CO2



◆Fuel economy

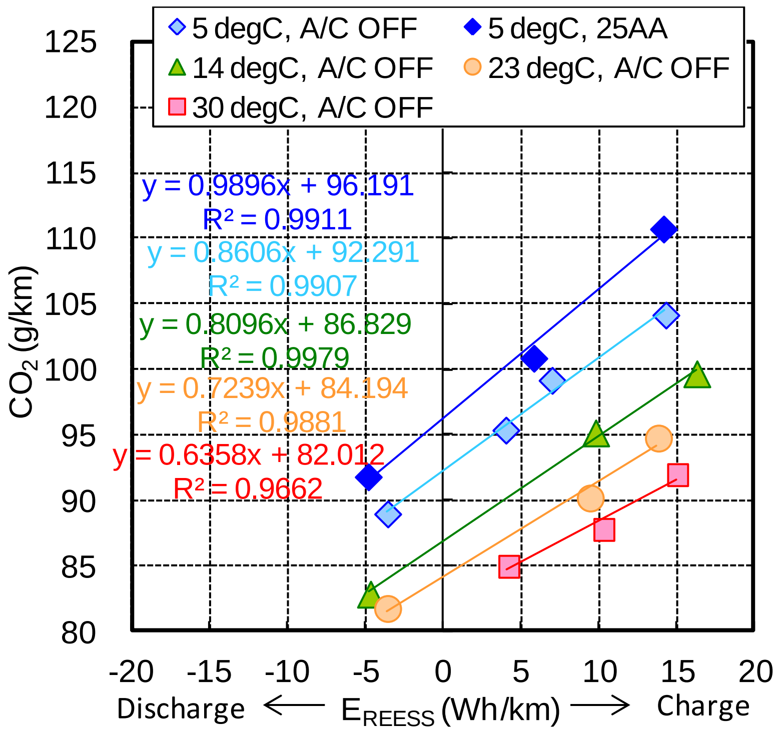


- NMHC, NOx and CO2 were increased with decrease of the temperature.
- The changes are approximated by a quadratic curve. (Not linear)

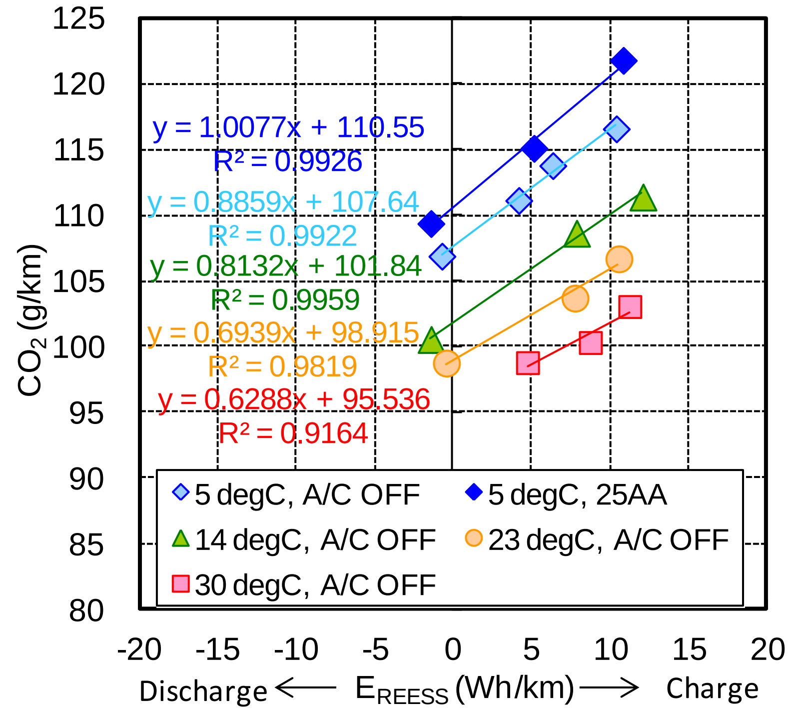
[NOTE] Emission and F.E were measured during preconditioning and then the results are consider as the hot condition

CO2 correction coefficient (measured under Hot condition)

◆3 phase



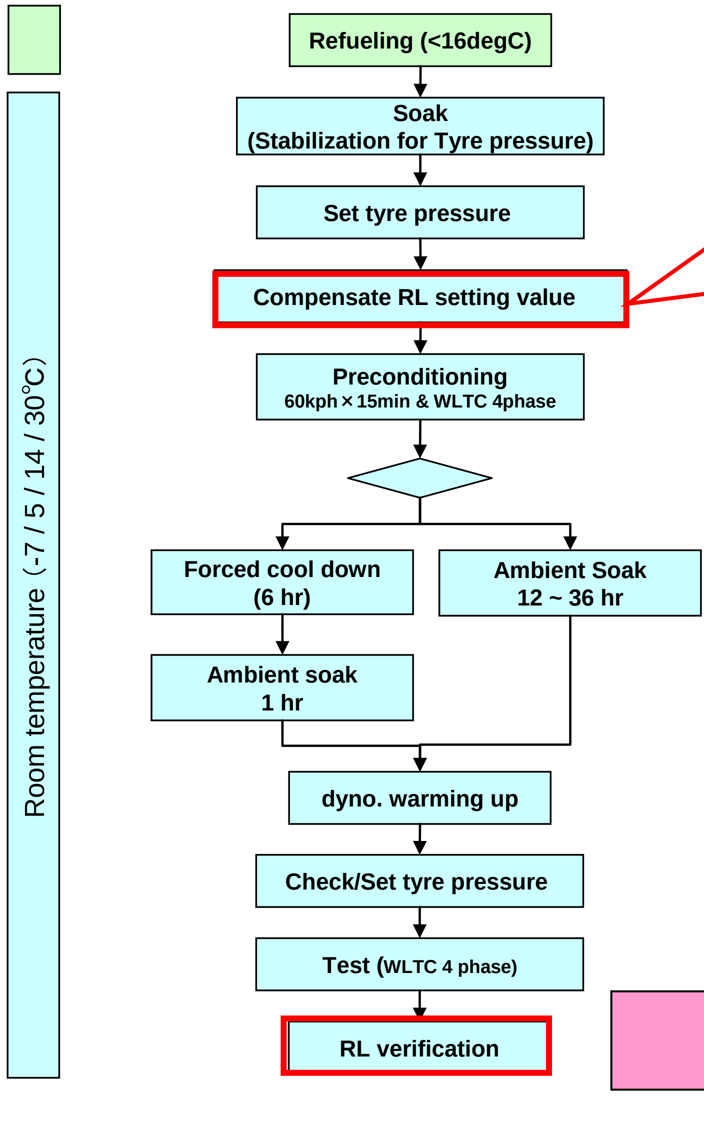
◆4 phase



CO2 correction coefficients in each temperature with&without MAC are slightly different.

→ need to consider the balance between test accuracy and testing burden

Confirmation on the set RL



Both F0 and F2 were compensated

RL Compensation

WLTP-18-11e

- Target RL in each temperature was calculated by the equation in the GTR15 annex4.

$$F_{0\_t} = \frac{F_{0\_20}}{\left(1 + 8.6\times10^{-3}\times(t-20)\right)}$$

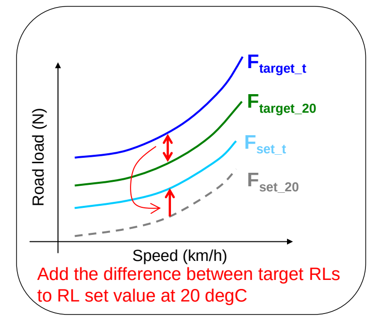
$$F_{2\_t} = \frac{F_{2\_20}}{\left((273+t)/293\right)}$$

- Dyno. set value was compensated. (Coast down wasn't performed)

$$F_{set\_t} = F_{set\_20} + \left(F_{target\_t} - F_{target\_20}\right)$$

$$F_{target\_t} = F_{0\_t} + F_{1\_t}\cdot v + F_{2\_t}\cdot v^2$$

t: test temperature (degC)



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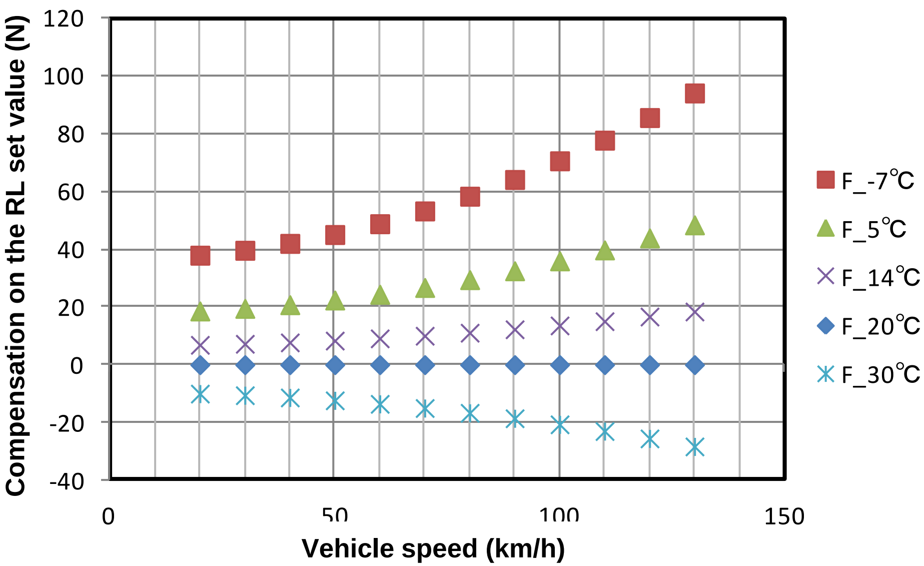
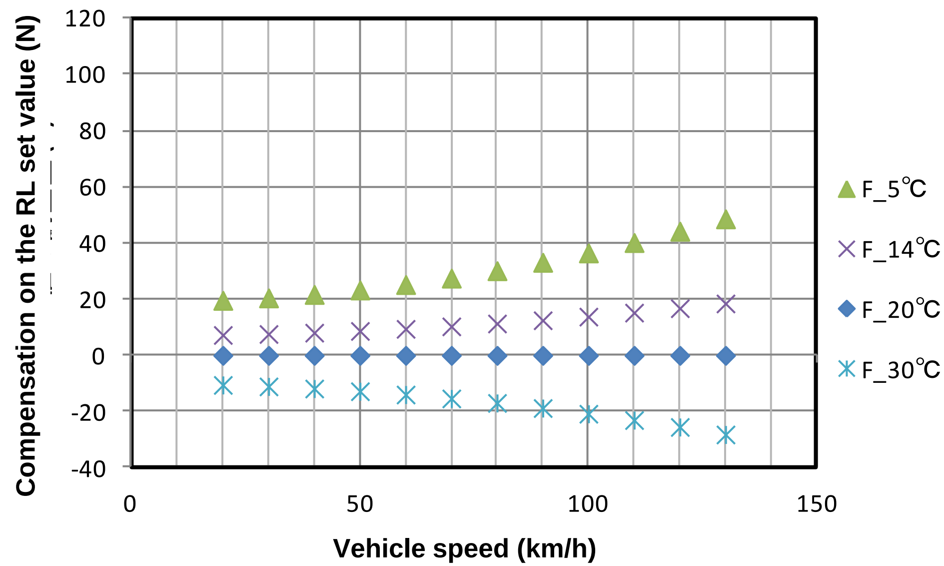
Check the verified RL just after the WLTC test. Then it was compared to the target RL.

Compensation for RL setting value

◆ICE



◆HEV



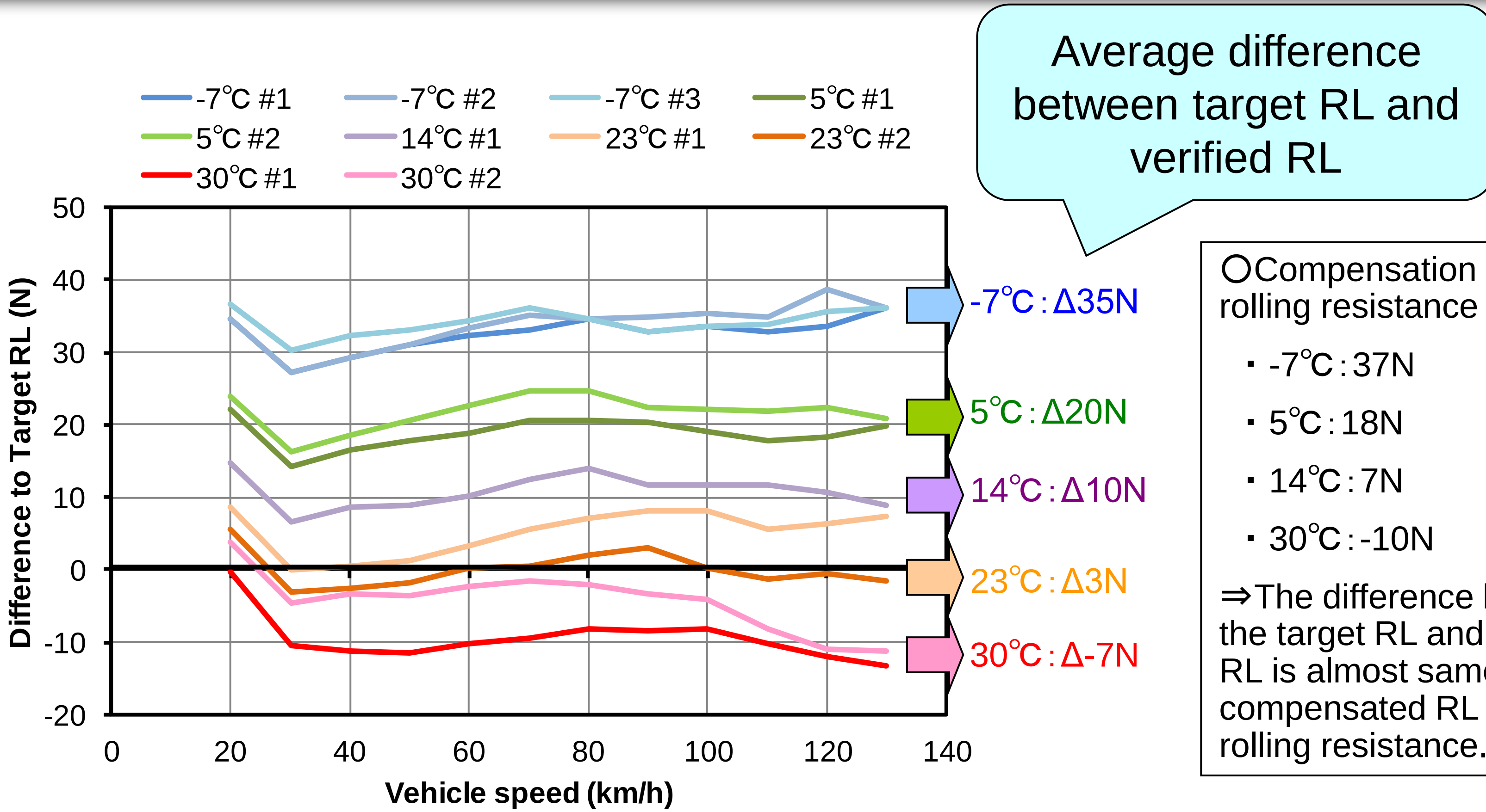
○Detail of compensation
(Rolling resistance and air resistance component)

	-7℃		5℃		14℃		30℃	
	$\Delta\mu_r$	$\Delta\mu_a \cdot V^2$	$\Delta\mu_r$	$\Delta\mu_a \cdot V^2$	$\Delta\mu_r$	$\Delta\mu_a \cdot V^2$	$\Delta\mu_r$	$\Delta\mu_a \cdot V^2$
20	37	1	18	1	7	0	-10	0
30	37	3	18	2	7	1	-10	-1
40	37	5	18	3	7	1	-10	-2
50	37	9	18	5	7	2	-10	-3
60	37	12	18	7	7	3	-10	-4
70	37	17	18	9	7	3	-10	-5
80	37	22	18	12	7	4	-10	-7
90	37	28	18	15	7	6	-10	-9
100	37	34	18	18	7	7	-10	-11
110	37	41	18	22	7	8	-10	-13
120	37	49	18	26	7	10	-10	-16
130	37	58	18	31	7	12	-10	-19
	37N		**18N**		**7N**		**-10N**	

○Detail of compensation
(Rolling resistance and air resistance component)

	-7℃		5℃		14℃		30℃	
	$\Delta\mu_r$	$\Delta\mu_a \cdot V^2$	$\Delta\mu_r$	$\Delta\mu_a \cdot V^2$	$\Delta\mu_r$	$\Delta\mu_a \cdot V^2$	$\Delta\mu_r$	$\Delta\mu_a \cdot V^2$
20	39	1	19	1	7	0	-10	0
30	39	3	19	2	7	1	-10	-1
40	39	5	19	3	7	1	-10	-2
50	39	8	19	4	7	2	-10	-3
60	39	12	19	6	7	2	-10	-4
70	39	16	19	9	7	3	-10	-5
80	39	21	19	11	7	4	-10	-7
90	39	27	19	14	7	6	-10	-9
100	39	33	19	18	7	7	-10	-11
110	39	40	19	21	7	8	-10	-13
120	39	48	19	25	7	10	-10	-15
130	39	56	19	30	7	11	-10	-18
	39N		**19N**		**7N**		**-10N**	

The result of RL verification (ICE vehicle)



〇Compensation on rolling resistance

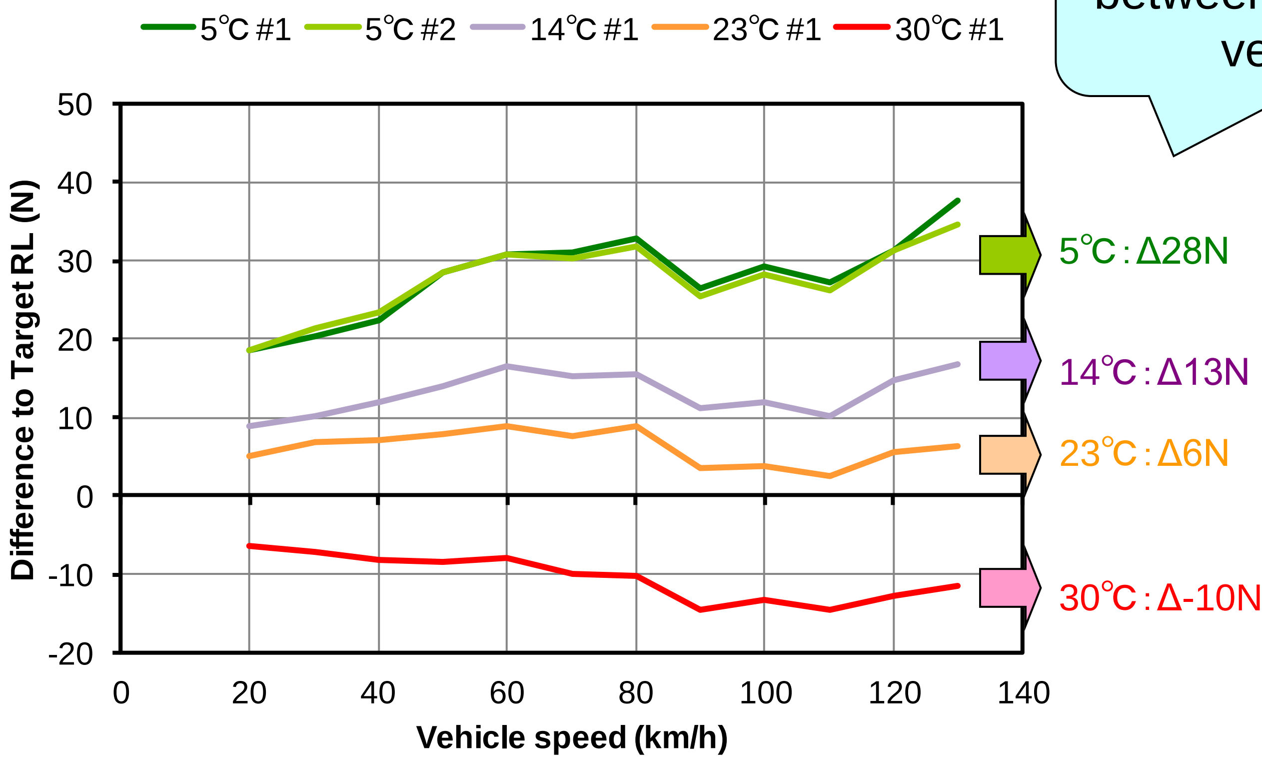
- -7℃ : 37N
- 5℃ : 18N
- 14℃ : 7N
- 30℃ : -10N

⇒The difference between the target RL and verified RL is almost same as the compensated RL of rolling resistance.

- According to the RL verification (quick check) after the WLTC test, the verified RL was higher than the target RL in low temperature test.
- The difference between the target RL and verified RL are almost identical to the compensated value of rolling resistance component.
- There is a possibility that it is not need to compensate rolling resistance component. (need to further analysis of non-driven wheels component)

The result of RL verification (NOVC-HEV)

Average difference between target RL and verified RL



〇Compensation on rolling resistance

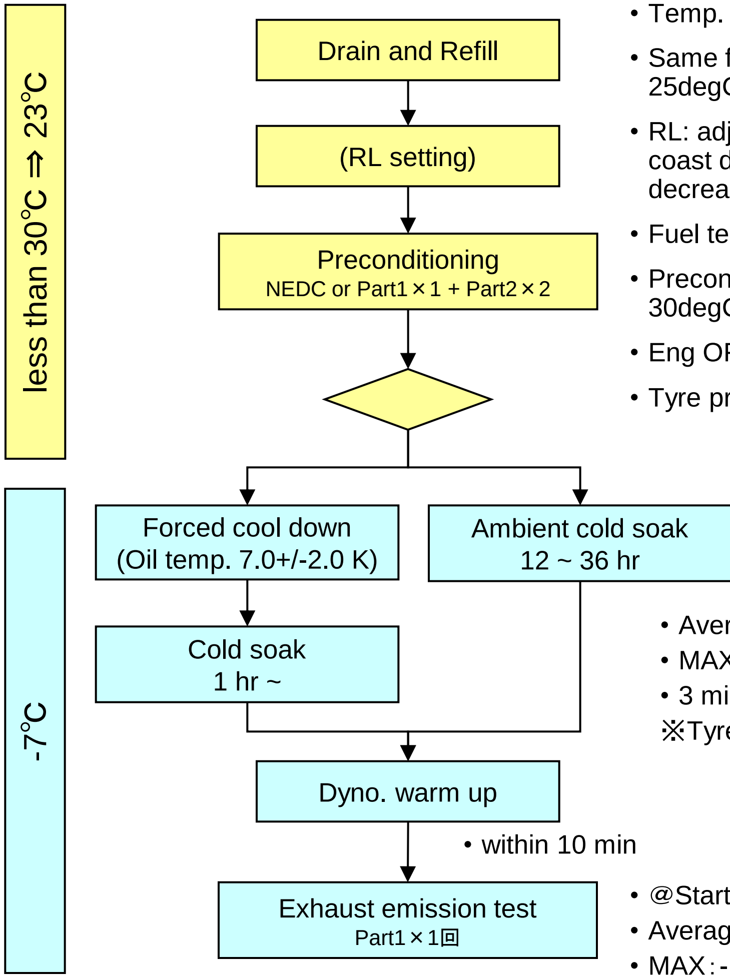
- 5℃ : 19N
- 14℃ : 7N
- 30℃ : -10N

⇒The difference between the target RL and verified RL is almost same as the compensated RL of rolling resistance.

- According to the RL verification (quick check) after the WLTC test, the verified RL is higher than the target RL in this test condition.
- The difference between the target RL and verified RL are nearly identical to the compensated value of rolling resistance component.
- There is a possibility that it is not need to compensate rolling resistance component. (need to further analysis of non-driven wheels component)

(Ref.) Comparison of -7 degC test

UN R83 Annex8



- Temp. of fuel : ≦ 16℃
- Same fuel property as 25degC test
- RL: adjust at -7 degC or coast down time 10% decrease
- Fuel temp. : ?
- Preconditioning: < 30degC
- Eng OFF: within 10 min
- Tyre pressure : @ ? ℃

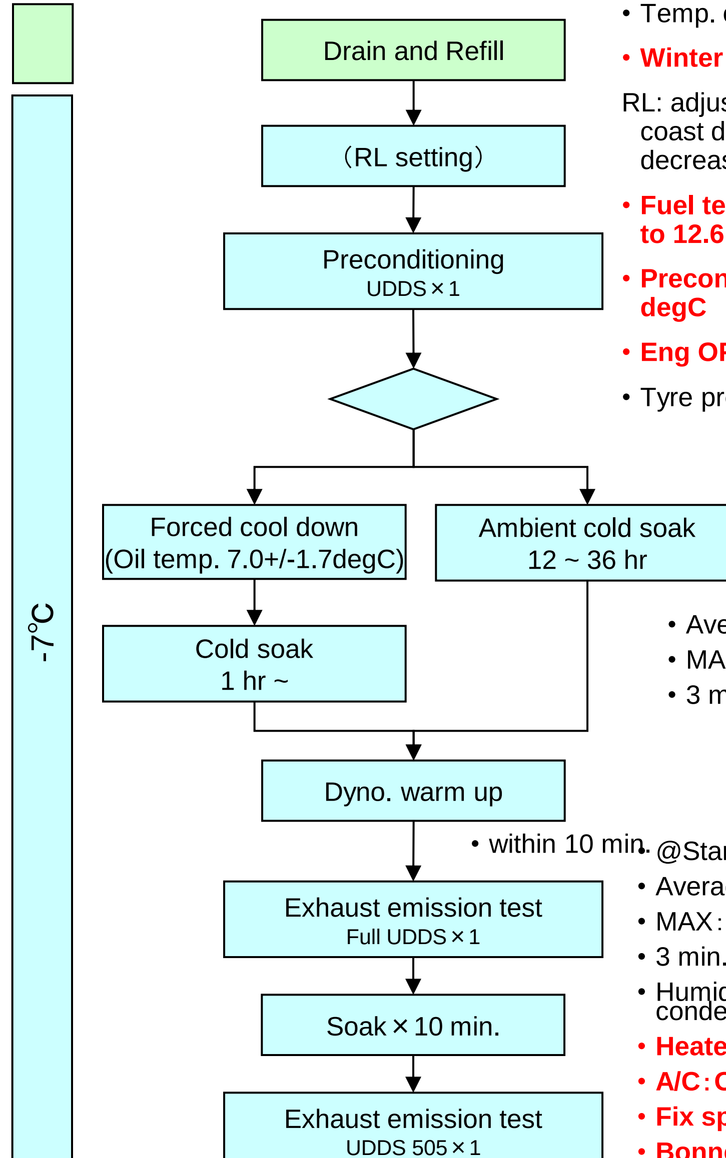
- Average : -7±3℃
- MAX : -13～-1℃
- 3 min. : -10～-4℃

※Tyre pressure: ?

- within 10 min

- @Start : -7±2℃
- Average : -10～-4℃
- MAX : -13～-1℃
- 3 min. : -10～-4℃
- Humidity : prevent condensation
- Heater/Defroster : OFF
- Cooling fan: Speed proportional type

US 40CFR 1066 subpart H



- Temp. of fuel : **≦15.5℃**
- **Winter grade fuel**

RL: adjust at -7 degC or coast down time 10% decrease

- **Fuel temp. : stabilized to 12.6 to -1.4 ℃**
- **Preconditioning: at -7 degC**
- **Eng OFF: within 5 min**
- Tyre pressure : **@-7℃**

- Average : -7±**2.8**℃
- MAX : **-12**～-1℃
- 3 min : **-9**～-4℃

- within 10 min.

- @Start : -7±**1.7**℃
- Average : -10～-4℃
- MAX : -13～-1℃
- 3 min. : -10～-4℃
- Humidity : prevent condensation
- **Heater/Defroster : ON**
- **A/C : OFF**
- **Fix speed fan**
- **Bonnet: Open**