Off-road vehicle and bench calibration capability

Content

❑Regulatory progress

04.2016	2017	2018	2019	2020	2021	2022	2023	2024	2025

Non-road Stage 3 Compliance Timeline:

Engines: October 2015

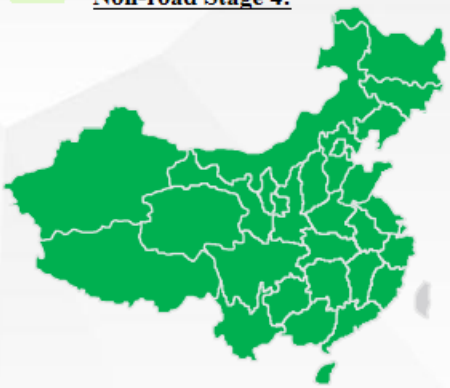
Mobile Machinery: April 2016

Agricultural Machinery: December 2026

* Beijing implemented its Phase 4 emission standards for non-road machinery and engines effective January 1, 2015."

2020.12?

Non-road Stage 4:



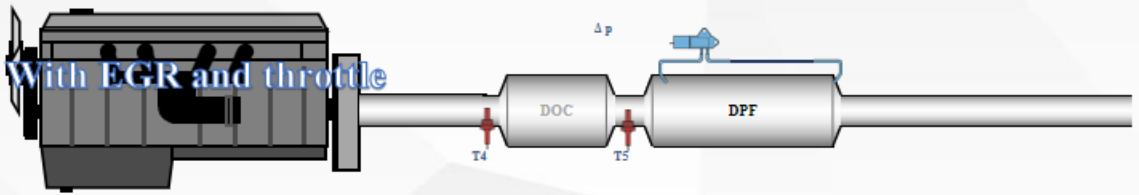
Power [kW]	NOx / PM [g/kWh]	NOx / PM [g/kWh]	Add on requirement
<37	7,5 1) /0,6	7,5 1) /0,6	+ NTE limit = 2*NRTC + PEMS limit = 2.5*NRTC (> 37 kW) + PN limit = 5*10 12 (>37kW)
37~56	4,7 1) /0,4	4,7 1) /0,025	
56~75		3,3/0,025	
75~130	4,0 1) /0,3		
130~560	4,0 1) /0,2	2.0/0,025	
>560	6,4 1) /0,2	3,5(0,67 2))/0,1	
Cycles	**Phase 3 NRSC**	**Phase 4 NRSC & NRTC & NTE & PEMS**	

1) NOx+HC in g/kWh 2) Apply to mobile generators with P>900kw

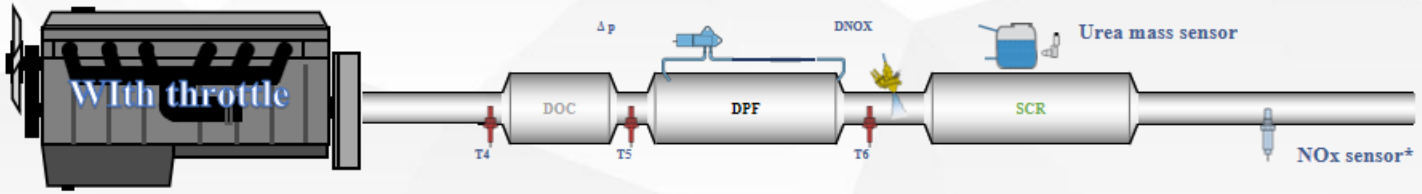
❑Technology roadmap

Power (kw)	System solution
>130	1600bar DOC + DPF + SCR
56~130	1600bar DOC + DPF + SCR
37~56	1600bar EGR + DOC + DPF
<37	1400bar (CRS14 S2) no ATS

System layout
（EGR scheme ）

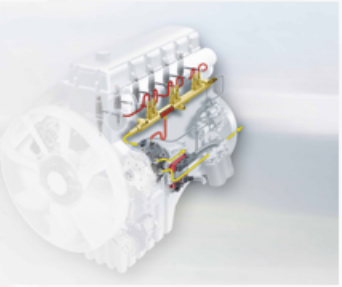


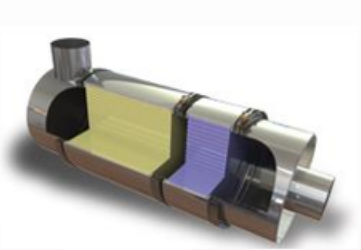
System layout
（SCR scheme ）

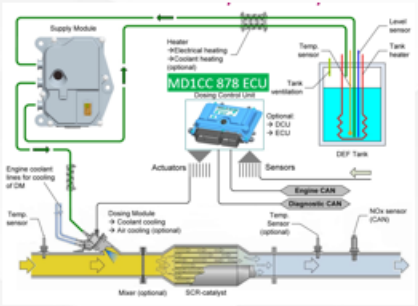


❑Calibration process

- Engine performance and emission test (fuel injection system section)
- Post-processing calibration
- Vehicle functional calibration and emission monitoring
- Triage trials

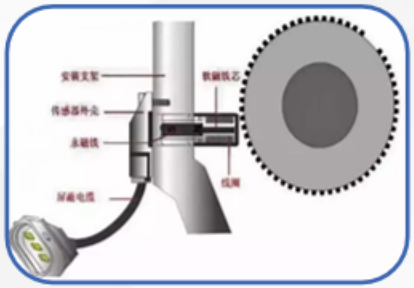




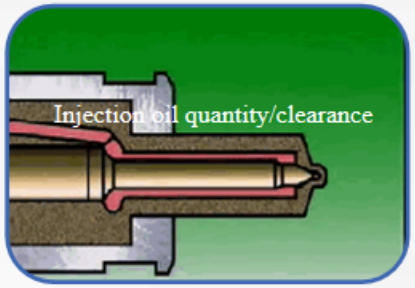


❑Fuel injection system section · Engine ignition

Component calibration

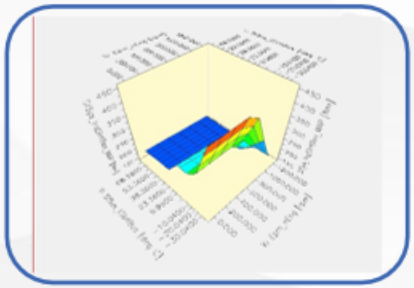


Synchronous signal calibration

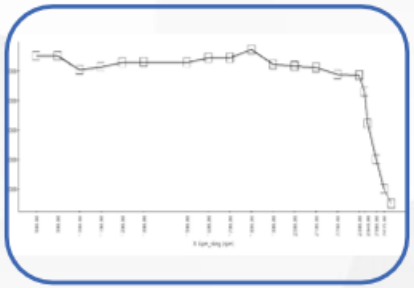


Off-line calibration

Fuel system: track pressure / Meun



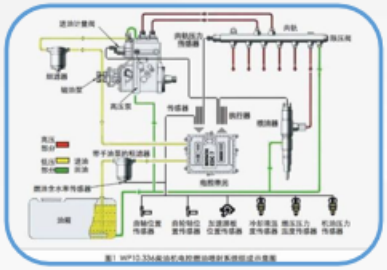
Starting torque



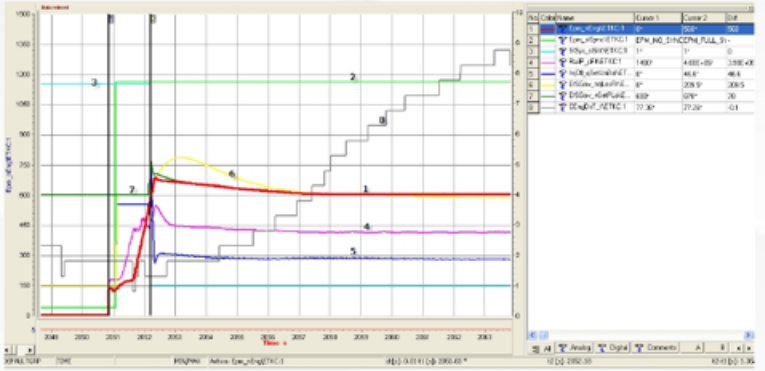
Engine protection

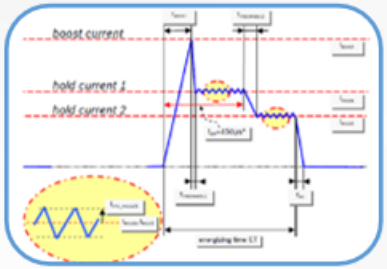
❑Fuel injection system section · Engine ignition

Wire harness and engine component inspection

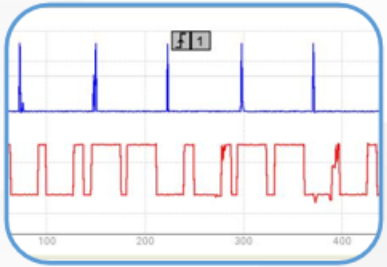


Tablet layout and low pressure oil circuit





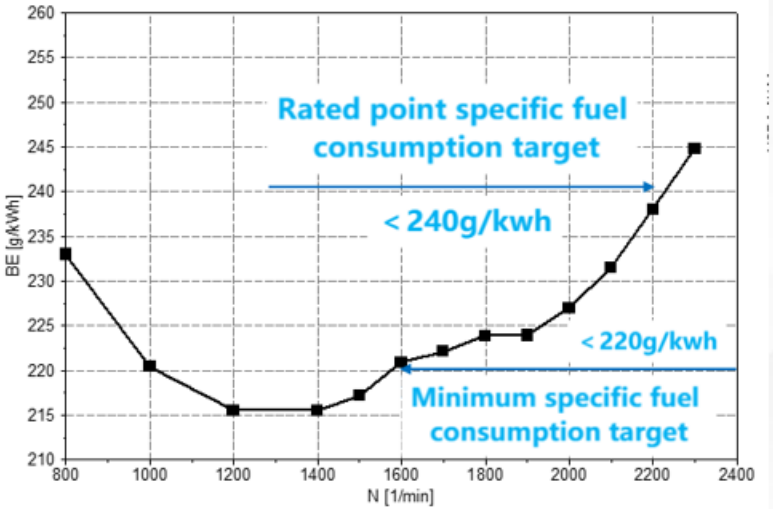
Injector current waveform inspection



Check the crankshaft and camshaft synchronization signal

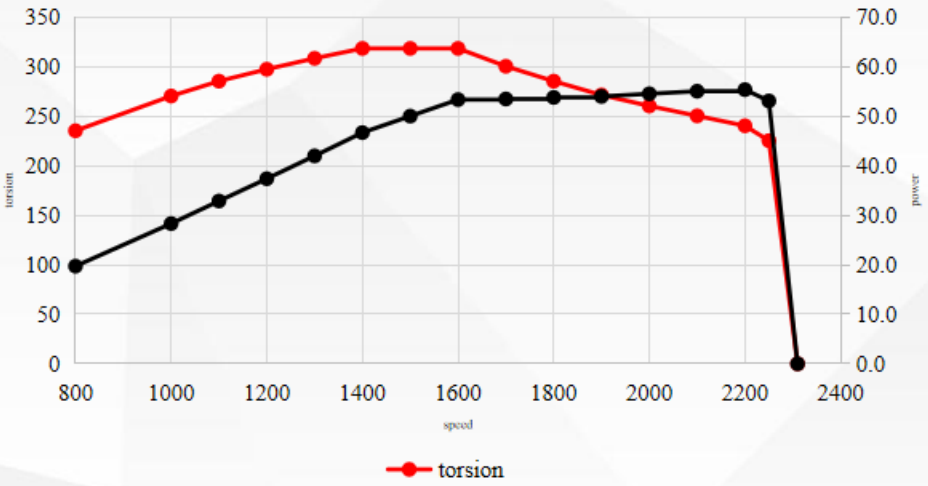
❑Fuel injection system section · External characteristic calibration

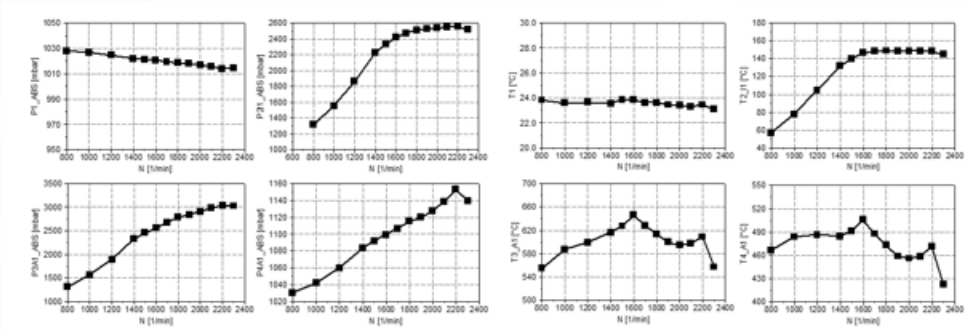
In order to achieve the performance of the engines external characteristics, and optimize fuel injection to meet torque targets at 100% throttle.



The fuel consumption, smoke, air volume and NOx emissions of the external characteristics should be considered.

External characteristic curve

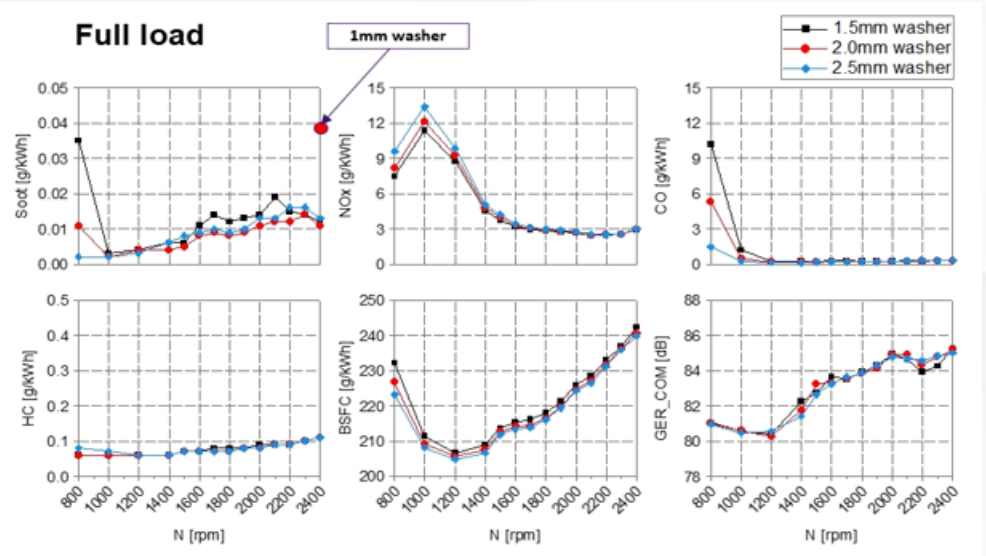


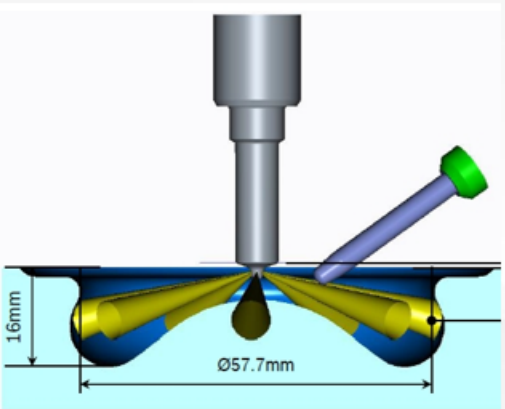


❑Fuel system injection system · Nozzle injection timing change test

Engine performance and emission tests are carried out based different injection landing points (add/subtract pad test).

It is recommended to add/subtract 0.5mm and test the shim.

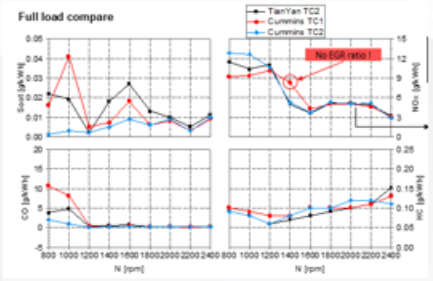




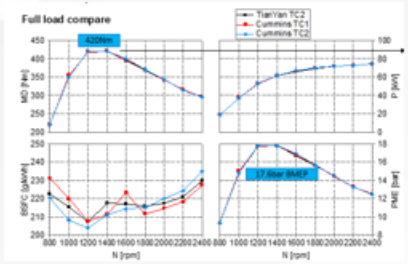
NRSC	Nox [g/kWh]	Soot [g/kWh]	HC [g/kWh]	CO [g/kWh]	Be [g/kWh]	PM [g/kWh]
1.5mm	3.09	0.010	0.123	0.359	248.2	0.0323
2.0mm	3.14	0.0104	0.122	0.363	247.5	0.0288
2.5mm	3.19	0.012	0.114	0.379	246.8	0.0297

❑Fuel injection system section · Turbocharger selection

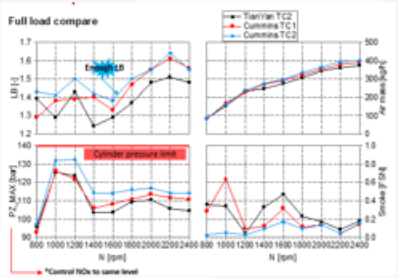
Consider the options and choose the most suitable turbocharger.



The same Nox, compared with Soot Nox CO HC

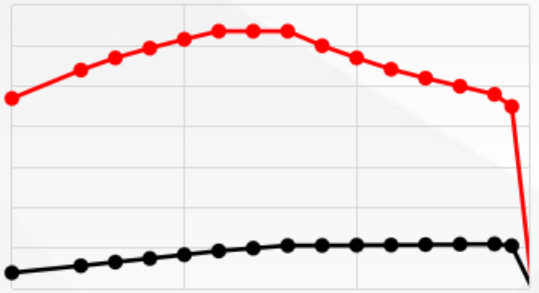


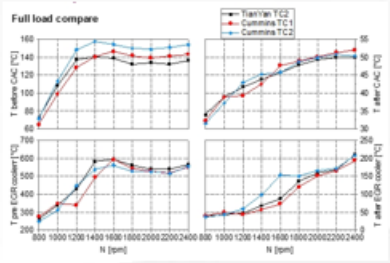
Same power, torque, average effective pressure, compare fuel consumption



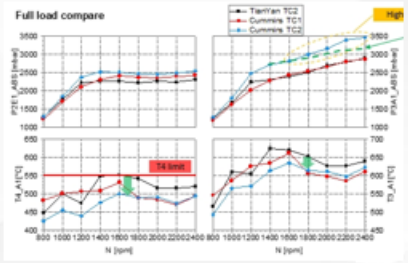
Same Nox, compare intake volume, combustion pressure, FSN

Full load

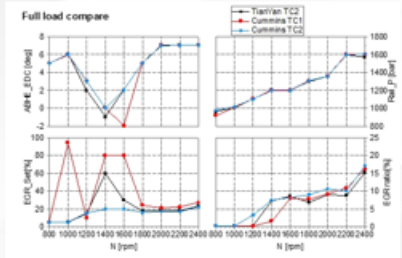




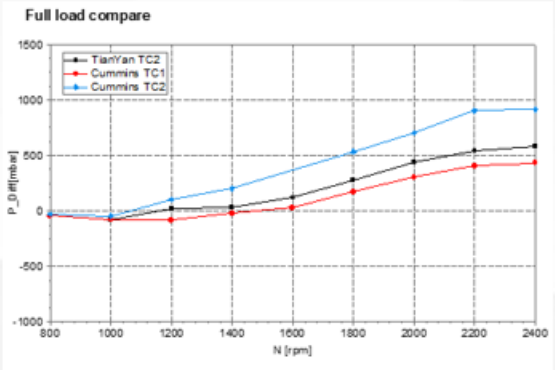
Compare the P2, P3 pressure, T3 and T4 temperature, and the pressure increase efficiency



Compare the temperature before and after cooling with the temperature before and after the EGR cooler

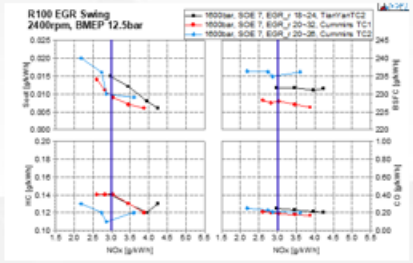


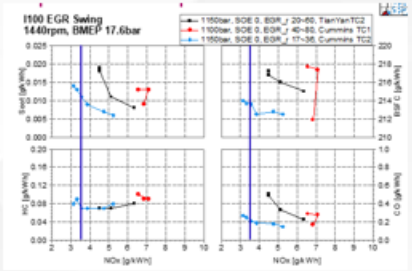
Under the same combustion state, the EGR opening degree is calibrated and the EGR rate is compared

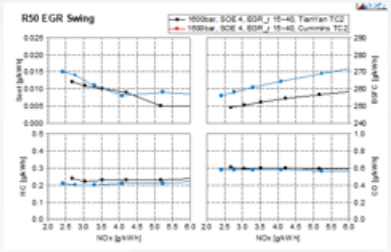


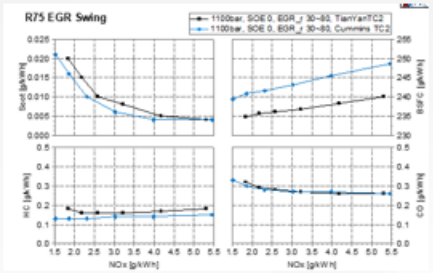
boost pressure

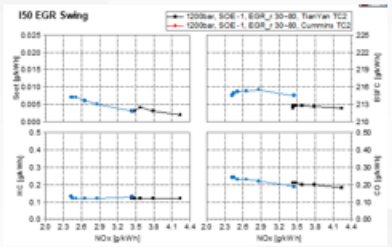
❑Fuel injection system section · Turbocharger selection

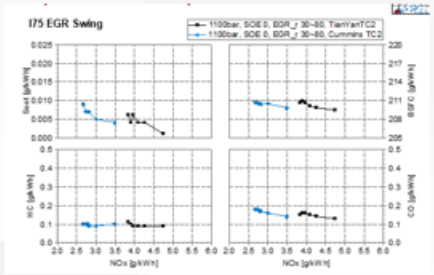


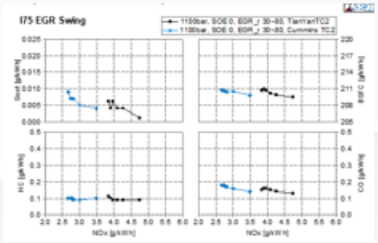


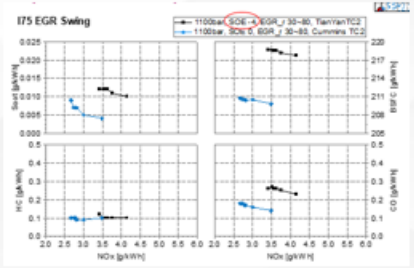


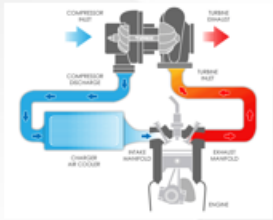




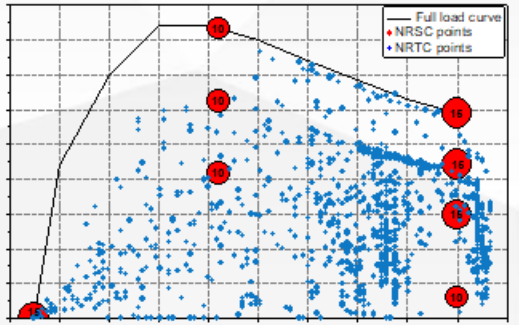




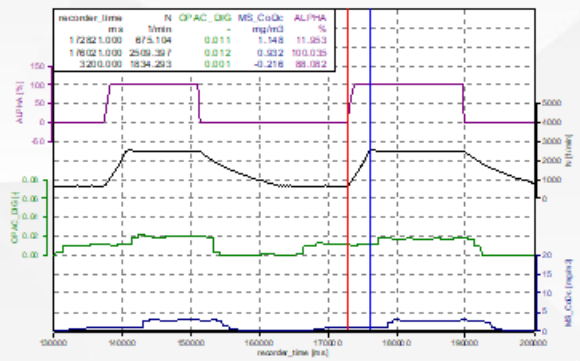




Emission point



❑Fuel injection system section · Turbocharger selection



dynamic response

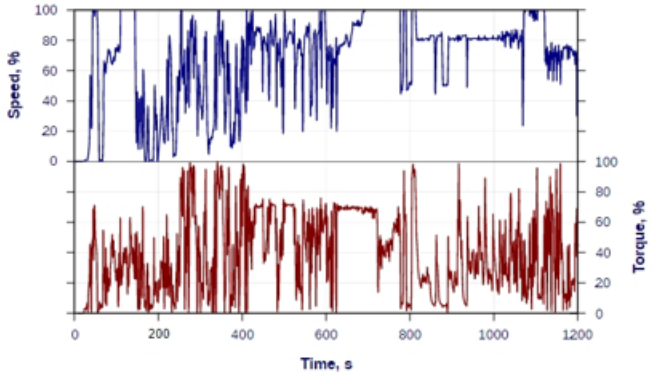
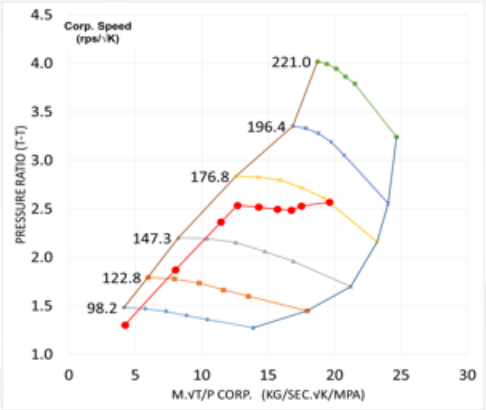
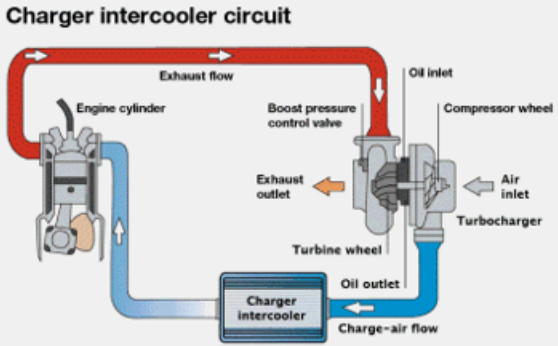


Figure 1. Normalized speed and torque over NRTC cycle

NRTC



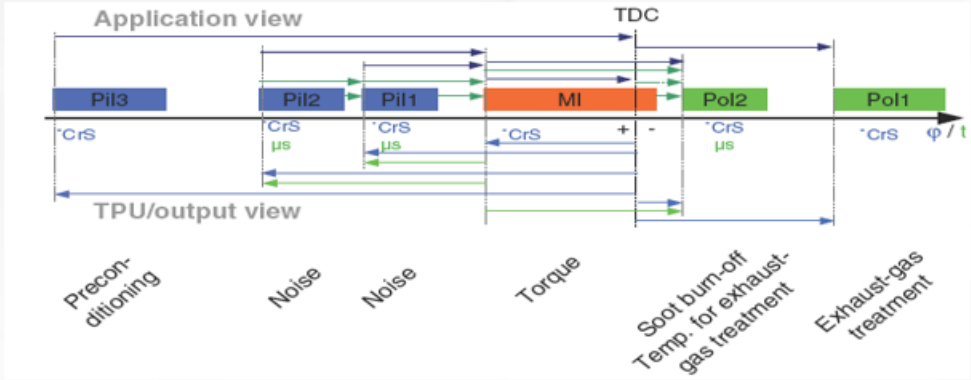
Safe work area

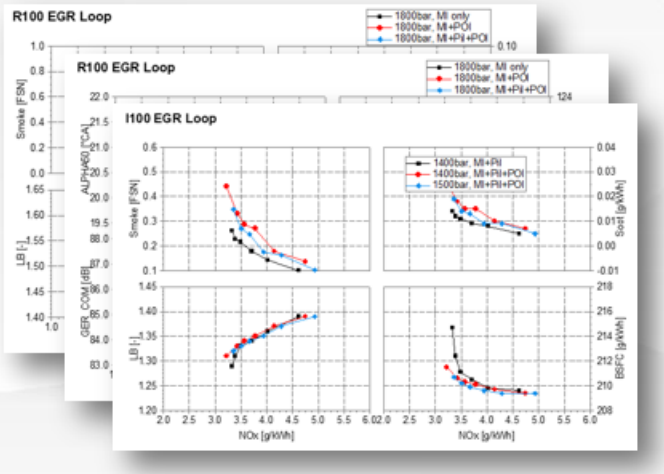


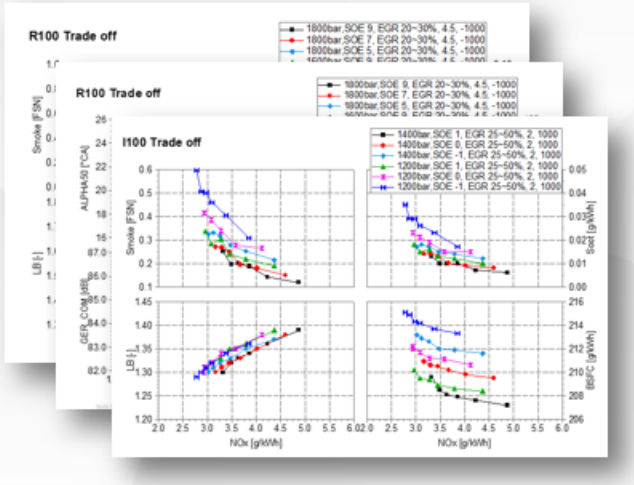
❑Fuel injection system section · Emission point calibration

Combustion parameter :

- Injection mode and release
- Main injection advance Angle and track pressure setting
- Pre-injection amount and pre-injection clearance
- Late injection amount and late injection clearance

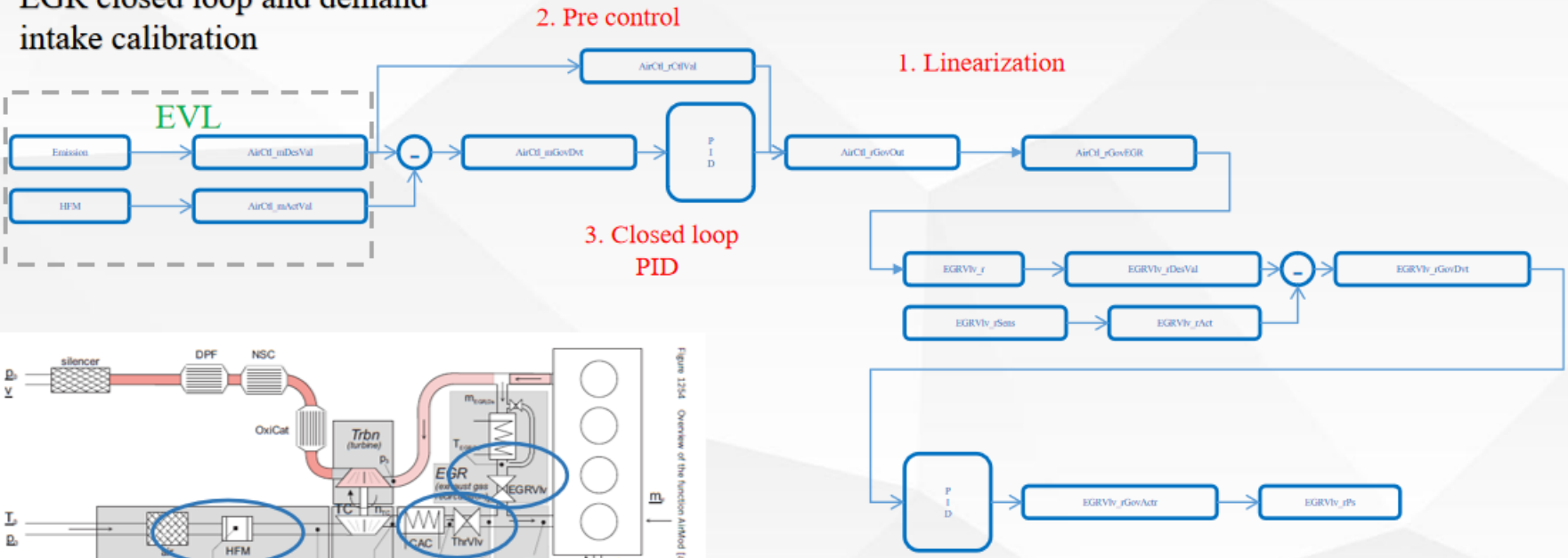






❑Fuel injection system section · Emission point calibration

EGR closed loop and demand intake calibration



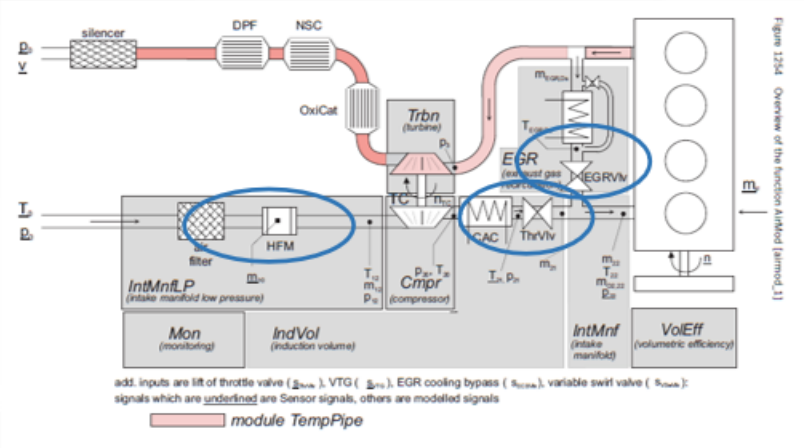
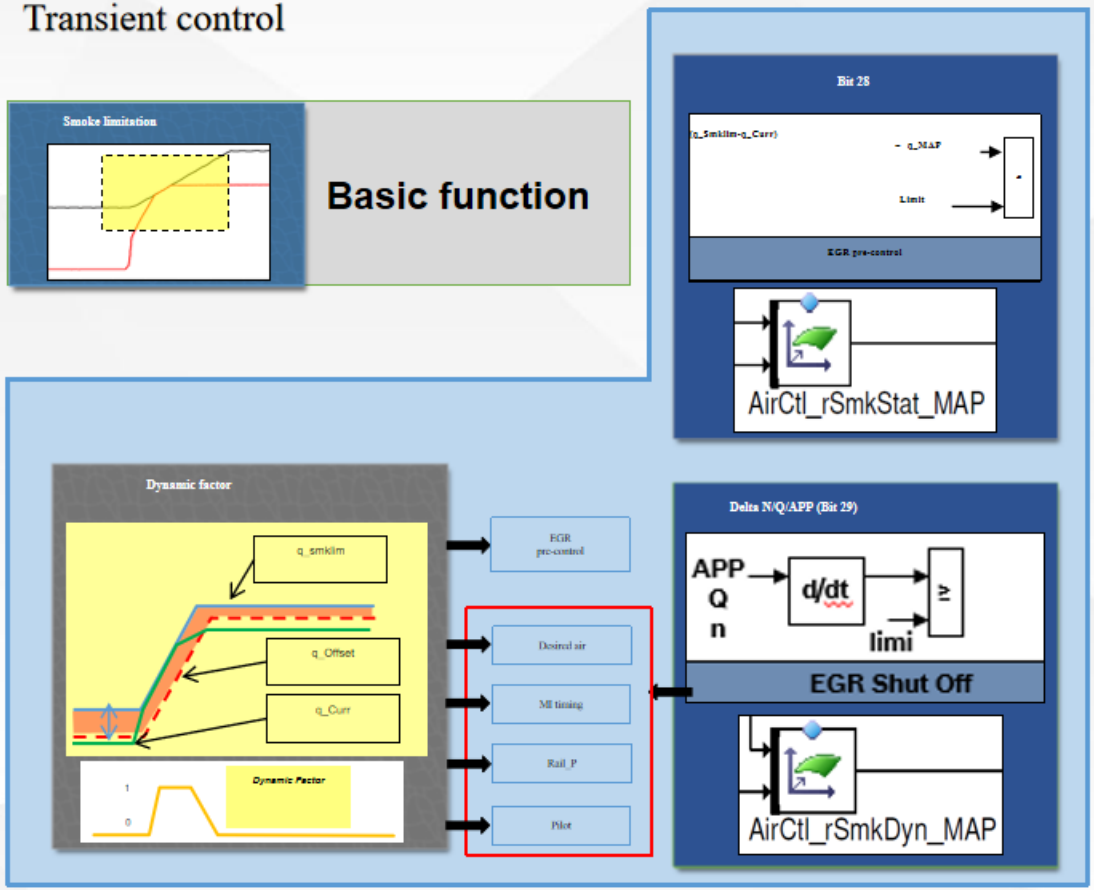
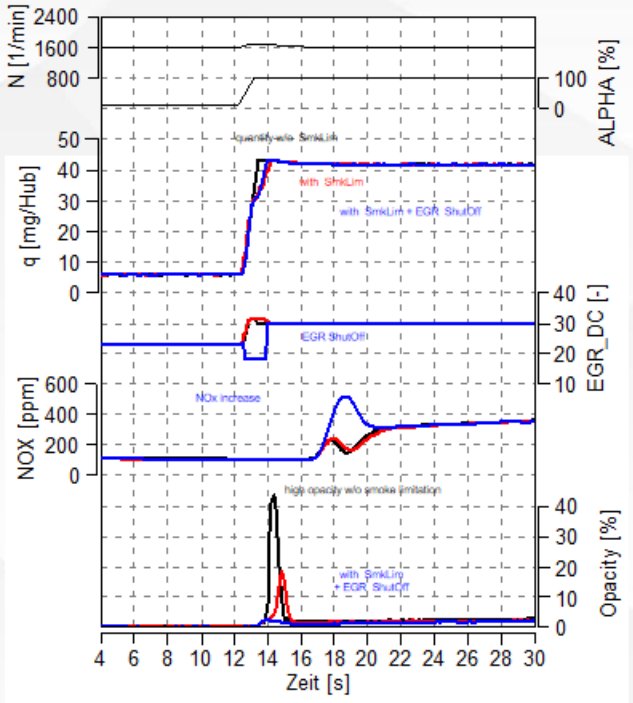


Figure 1254 Overview of the function AirMod (airmod_1)

❑Fuel injection system section · Emission point calibration

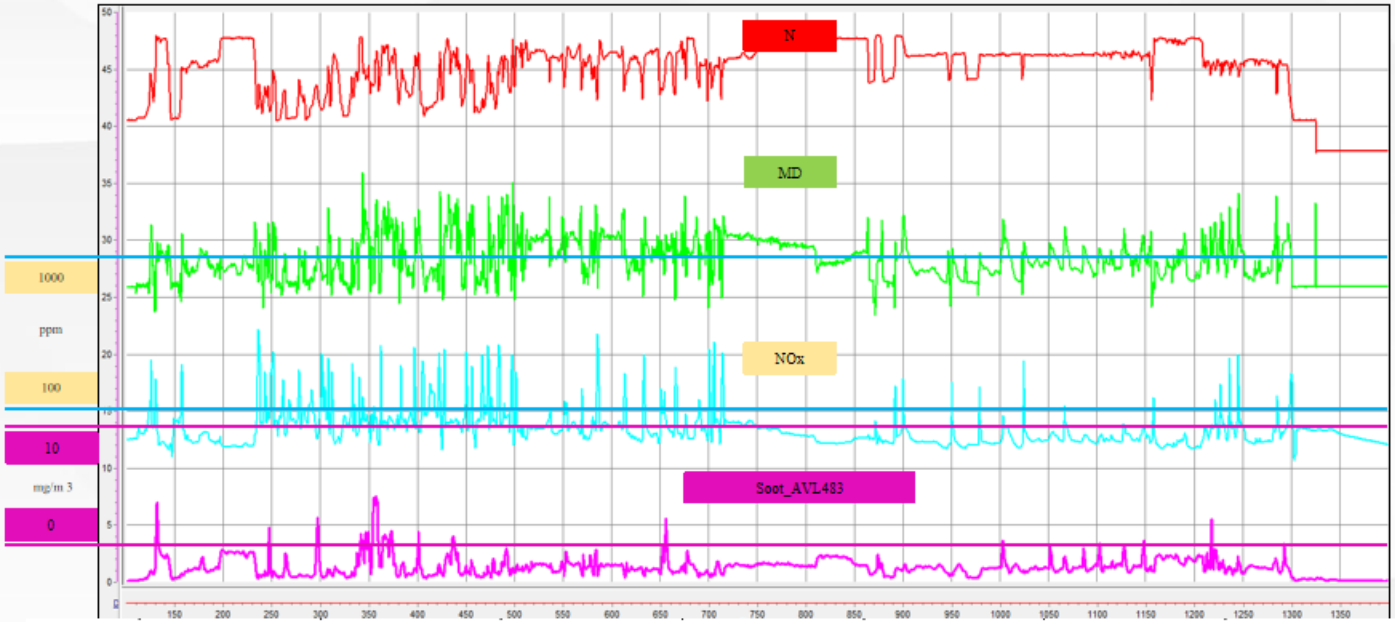
Transient control

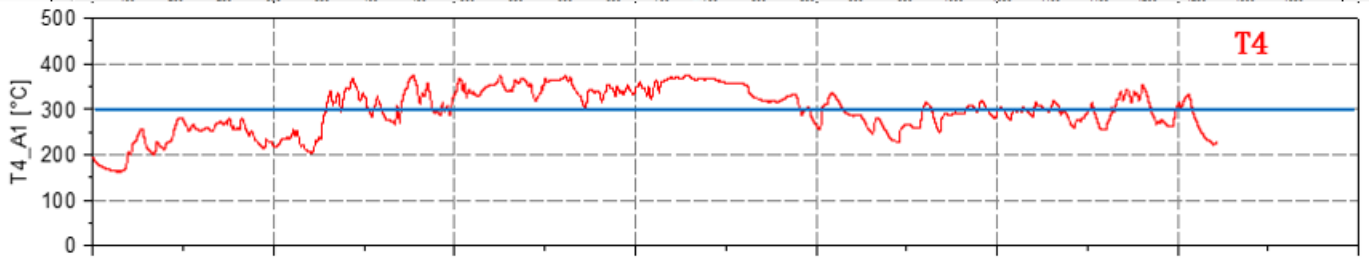




❑Fuel injection system section · Emission point calibration

Non-Road Transient Cycle



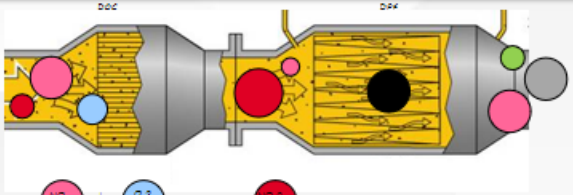


Average 297℃

@Hot NRTC

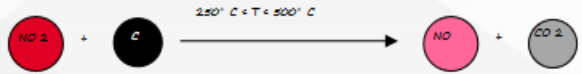
❑Post-processing system section · DPF

Passive regeneration: NO 2 Regeneration (continuous regeneration ®)*



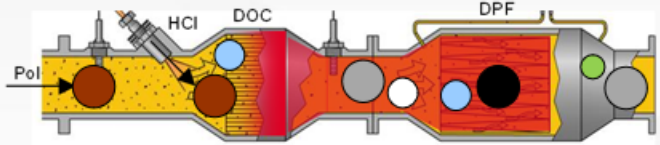
Requirements：

- Temperature range: 250... 350...450 °C
- NO 2 / PM ratio > 12
- DOC is in effect throughout the life cycle



→Low regeneration speed

Active regeneration: Thermal regeneration by O_2 (post injection 1)

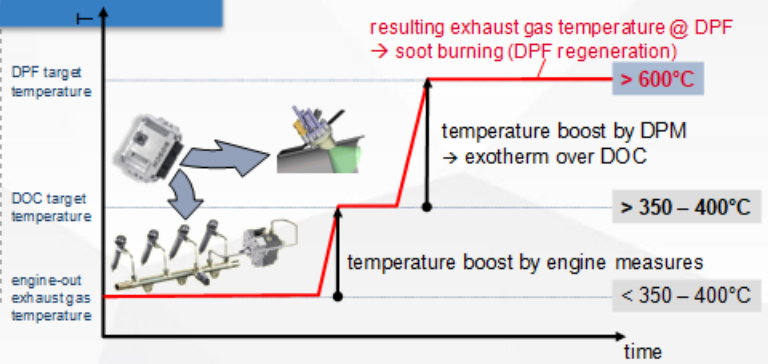


Thermal energy

Requirements：

- Temperature range: 550...650 °C
- O The content of 2 is> 5 Vol%
- DOC is in effect (aged) throughout its life cycle

→Fast regeneration



❑Post-processing system section · DPF

Parking regeneration and driving regeneration

	Car regeneration	Park and regroup
Vehicle status	Regular service	Rarking
Safety	○	++
DPF overtemperature risk	Secondary	Lower
Driveability (regenerative mode)	Secondary	No driving
Measurement difficulty and workload	Big	Small
Software requirements	Complicated	Simple
Application type	Passenger vehicles, commercial vehicles	**Off-road, commercial vehicles**

❑Post-processing system section · DPF

DPF engine bench calibration:

Precondition: Engine bare discharge calibration is completed to confirm the engine state and bare machine discharge

DPF regeneration temperature calibration

- oT4 temperature (DOC inlet)
- oT5 temperature (DPF inlet)

Regeneration interval calibration

- oSOF mode automatically triggers time
- oParking and regeneration interval time and cumulative fuel consumption
- oPressure differential protection calibration

DPF vehicle verification and calibration:

Precondition: DPF engine bench calibration is completed

DPF regeneration temperature verification and correction

- o Recovery temperature verification
- o Calibration based on environmental pressure and engine temperature correction

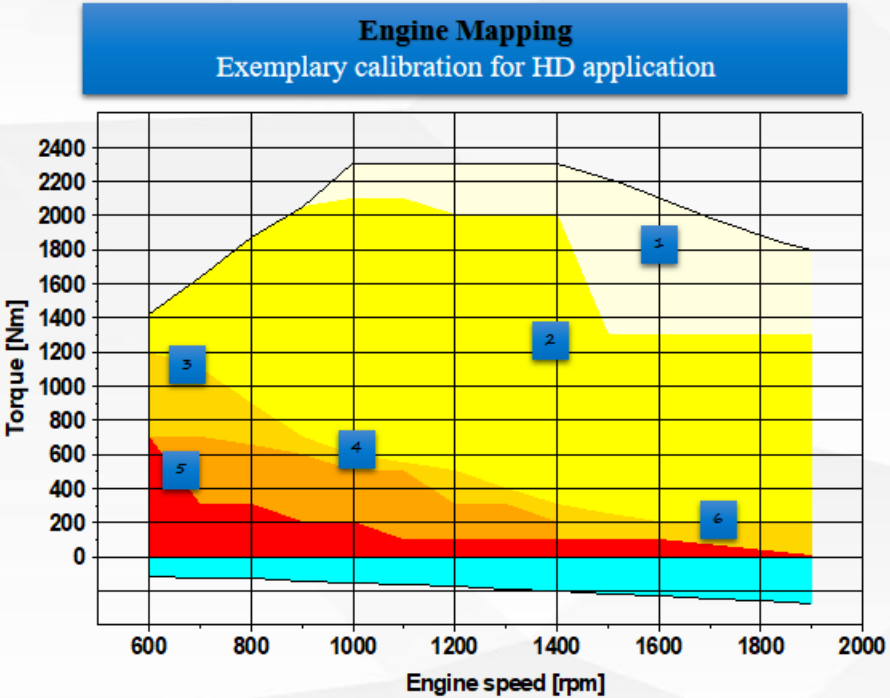
Regeneration interval verification and correction

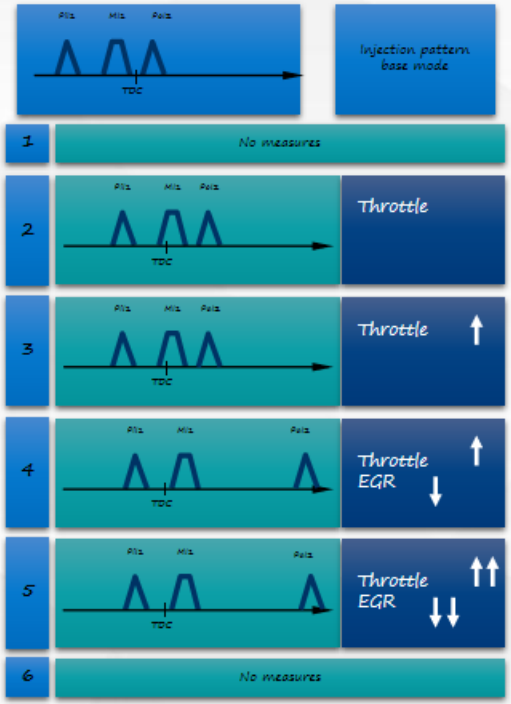
- o The SOF mode automatically triggers time correction
- o Correction of parking and regeneration interval time and cumulative fuel consumption

High altitude test (high temperature, high cold, plateau)

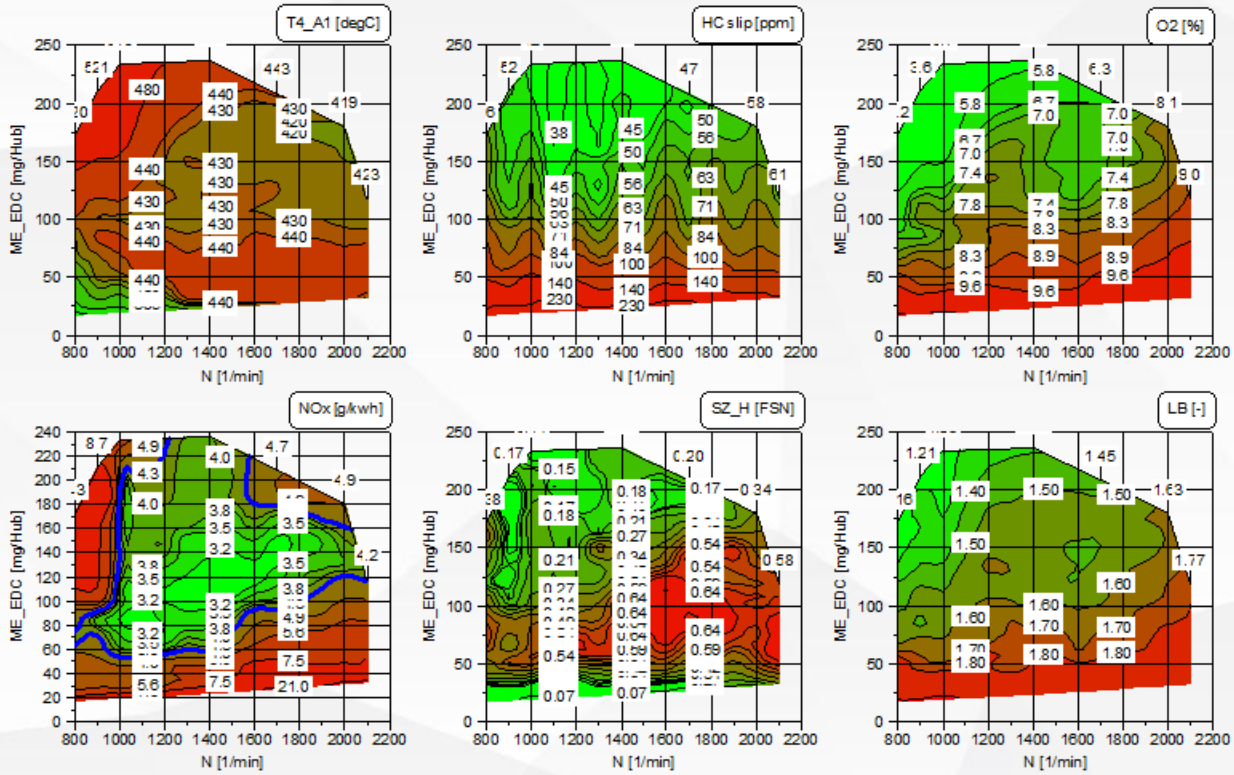
- o T4&T5 validation
- o Renewable efficiency correction
- o Regeneration interval correction

❑DPF engine bench calibration · T4 calibration

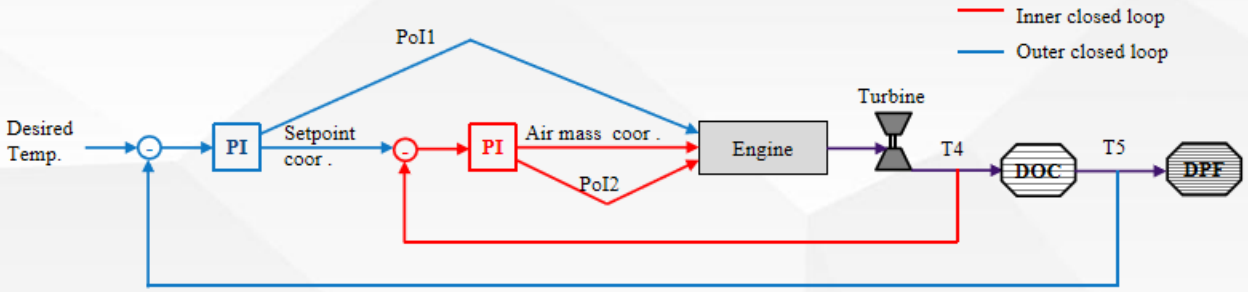




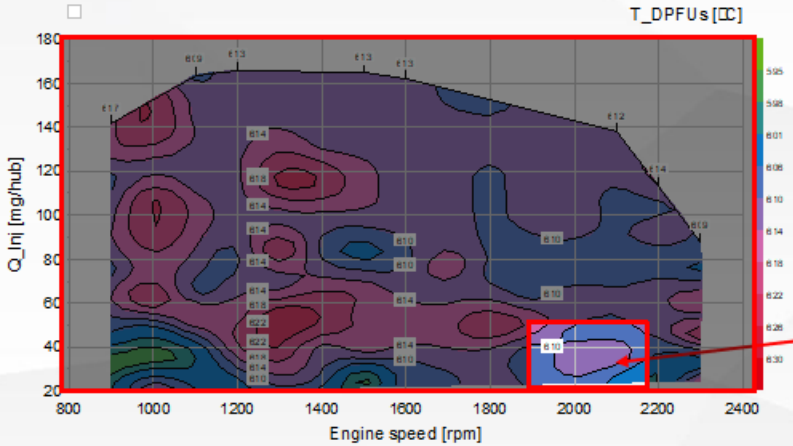
❑DPF engine bench calibration · T4 calibration



❑DPF engine bench calibration · T5 calibration



T5 engine map



Park and regeneration:
Only one working point needs to be calibrated.

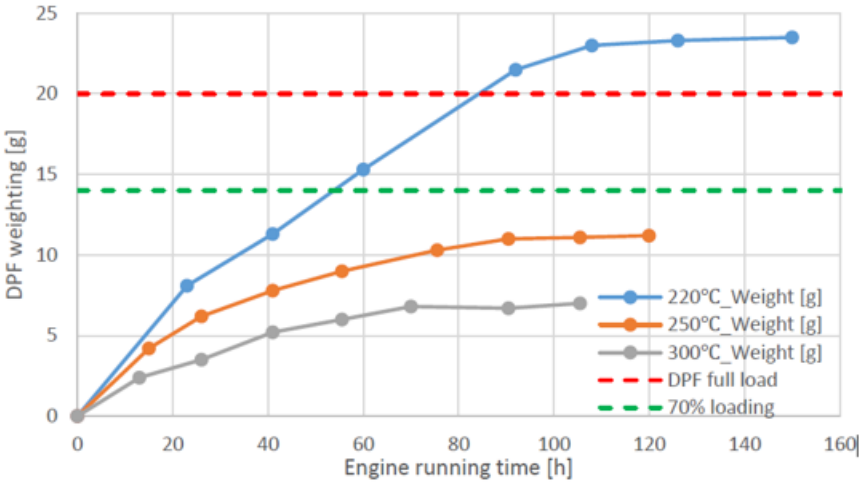
❑DPF engine bench calibration · Regeneration interval and T5 correction

Calibration of regeneration time

(1) Basic trigger time: Use the matched vehicle to collect typical application road spectrum, and conduct loading test on the engine bench until the DPF is full load or balance. This time is used to evaluate the regeneration interval of the machine under normal use conditions.

(2) Trigger time correction calibration: The purpose is to reflect the differences in passive regeneration effects under different working conditions and environmental conditions of the engine. It mainly considers the influence of DPF inlet temperature (T5), ambient pressure (EnvP) and engine water temperature (EngT).

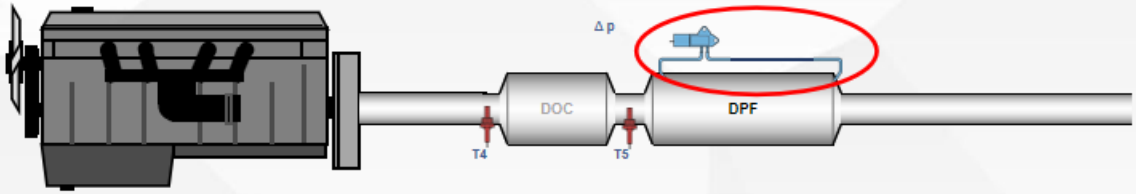
The correction of T5 on the engine bench, ambient pressure (EnvP) and engine water temperature (EngT) are calibrated during vehicle and three high experiments.

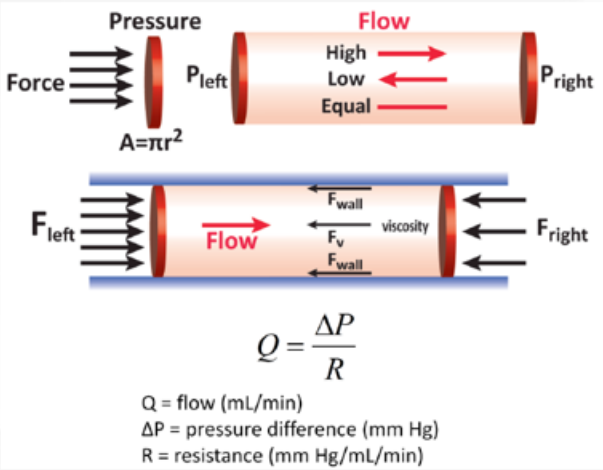


- The selection of the exhaust temperature range can be selected from NRTC, WHTC, C-WTVC and other cycles according to different temperature ranges
- Run load test in selected temperature range to determine the running time/accumulated fuel consumption at full load

❑DPF engine bench calibration · Flow resistance protection

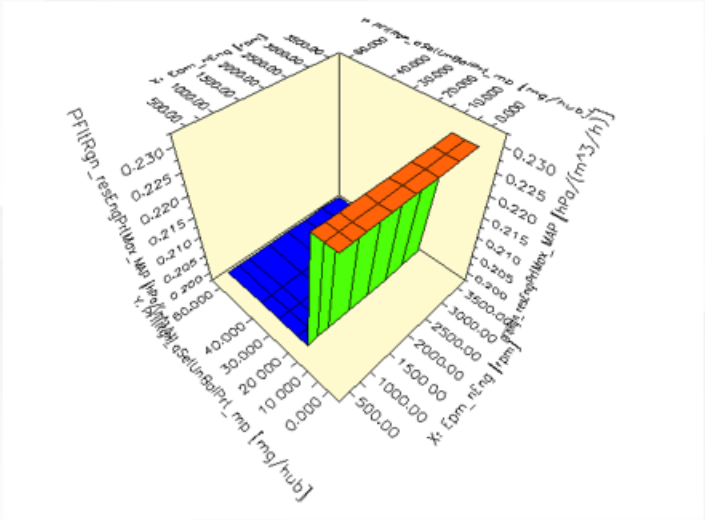
Regeneration based on flow resistance trigger is mainly used as a backup scheme. When the flow resistance reaches the upper limit value, it will directly remind the driver to regenerate.



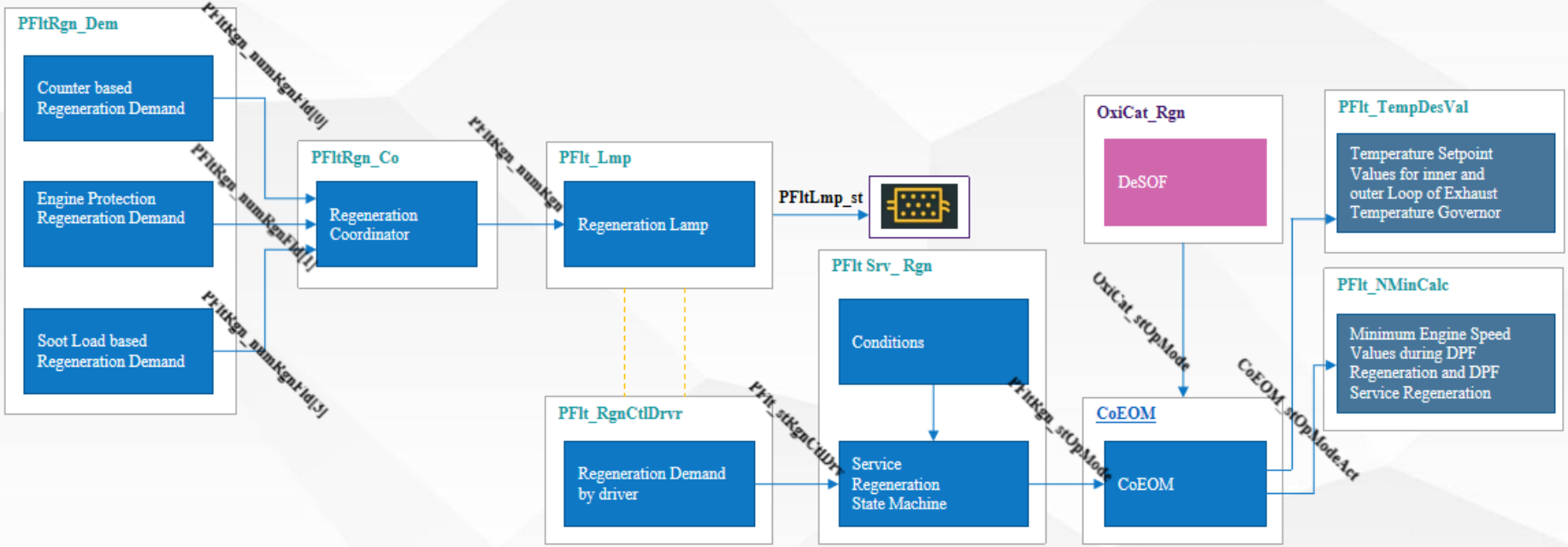


$$Q = \frac{\Delta P}{R}$$

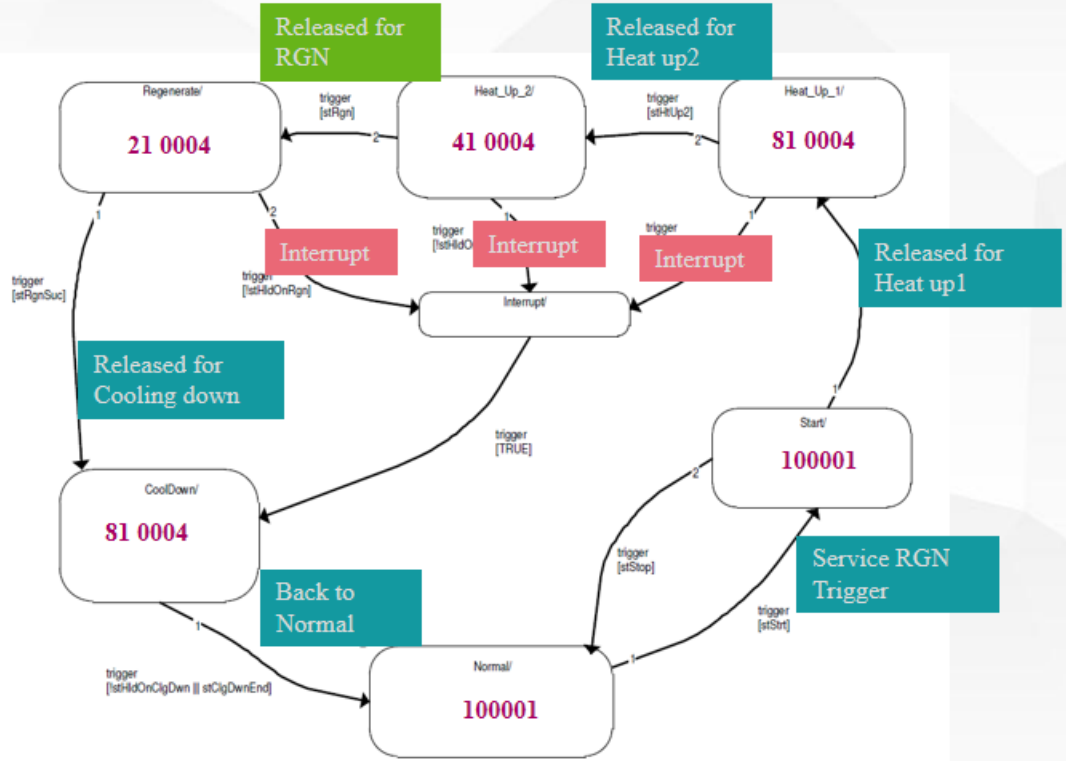
Q = flow (mL/min)
ΔP = pressure difference (mm Hg)
R = resistance (mm Hg/mL/min)

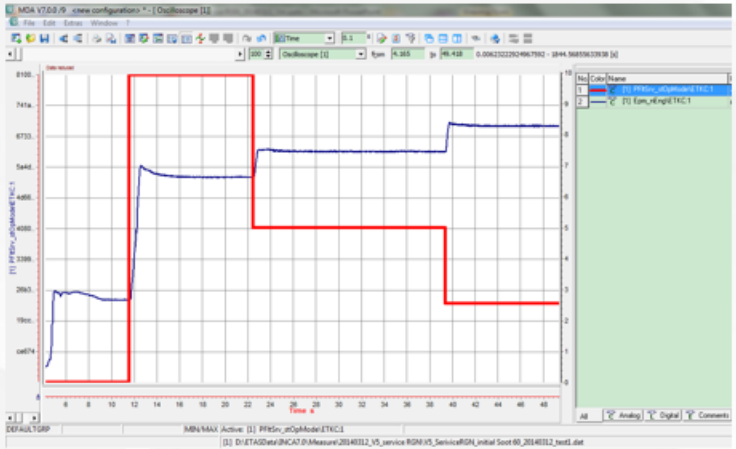


❑DPF calibration· Control strategy



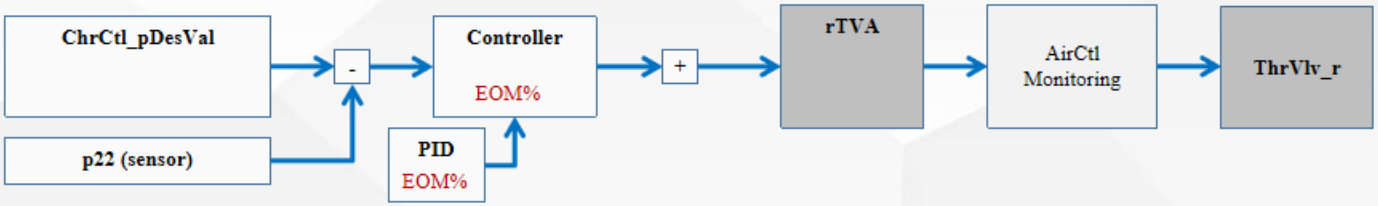
❑DPF calibration · Control strategy





❑DPF Calibration

TVA close loop control



Oil dilution

Desof

Car regeneration

❑Post-processing section · SCR

Pre-Calibration

Pre-Calibration:
1.Engine original discharge and thermal management calibration completed;
2.Determine SCR original emission model and NO2/NOx ratio;
3.Assess the installation position of T6&T7 sensors;
4.Determine the Load-Empty experimental working point;

1 st

Load-Empty Test:
1.The characteristic parameters of SCR catalyst are obtained;
2.Determine the coefficient SCRFFC Map for NOx to NH3;
3.Calibrate SCR conversion efficiency SCRMod Map;
4.Calibrate NH3 storage SCRLdG Map;

2 nd & 3 rd

Open-Loop Calibration&Validation:
1.SCRMod and SCRLdG are based on the dynamic calibration of SCRFFC based on the rack cycle (NRSC&NRTC);
2. Calibration of SCRT temperature model and original discharge model;
3.Under the condition of opening the loop, the urea injection verification based on Engine Map, the SCRT temperature model verification, and the exhaust pipe emission verification are carried out;

4 th & 5 th

Close-Loop Calibration:
1.Calibration of closed-loop release conditions;
2. SCRFBC feedback control calibration;
3.Turbulence control calibration;
4.NRSC&NRTC;

6 th

Close-Loop Validation:
1.Under the closed-loop condition, the urea injection verification and exhaust emission verification are based on Engine Map;

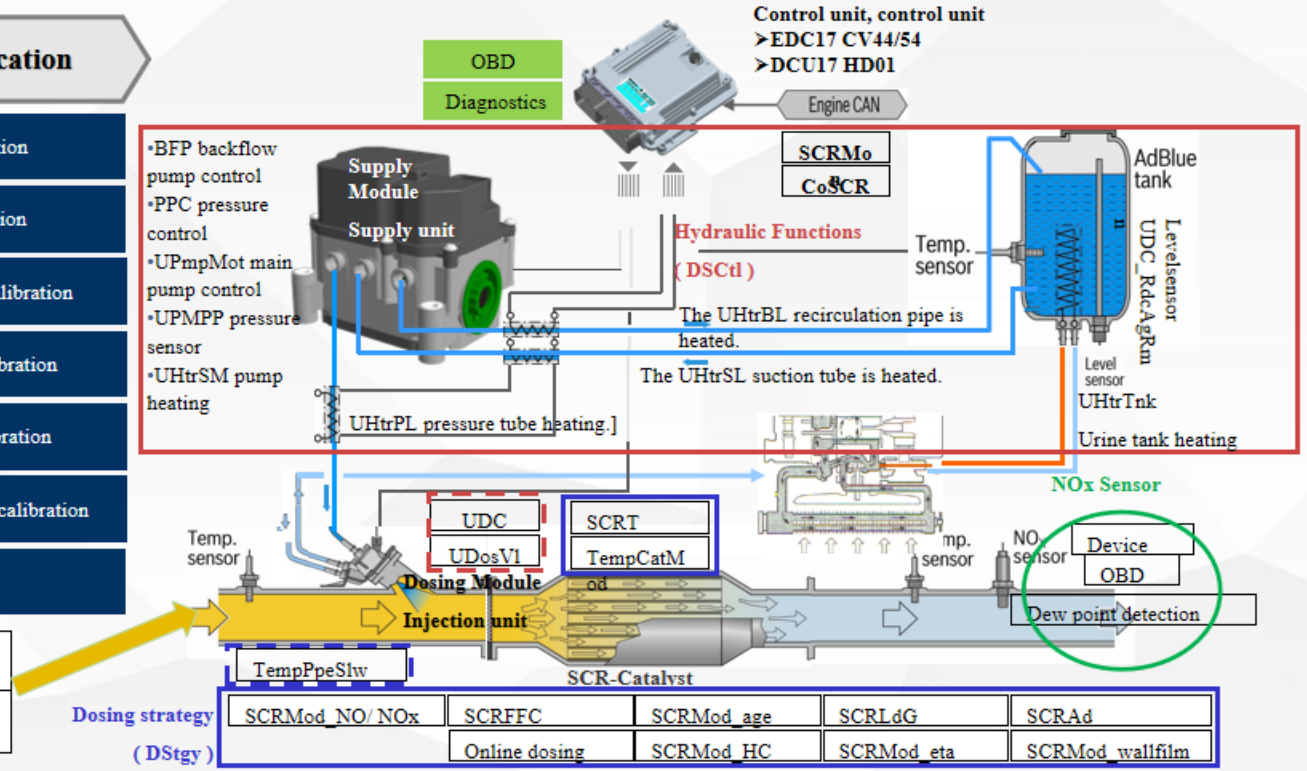
Post-Calibration

Post-Calibration:
1. Calibration and verification of emission from regeneration under DPF regeneration conditions;
2.Self-learning calibration of SCR variant vehicle based on nitrogen oxide sensor;

❑Post-processing section · SCR

Calibration and application

- SCR hydraulic system calibration
- SCR electrical system calibration
- NOX sensor dew point detection calibration
- NOX naked discharge model calibration
- Catalyst temperature model calibration
- SCR injection strategy (closed loop) calibration
- DSM and OBD calibration



Post-processing section · NCDPCD

There are no OBD limits specified for phase 4 off-road, but there are still diagnostic and torque limit requirements.
The fault diagnosis system monitors components and control functions related to NOx control and particulate matter control.

Monitoring items related to NOx control

- Urea level is low.
- Urea quality issues
- Ejection terminal
- Tampering: Sensor-related
- Non-heating system: Urea freezes
- EGR valve stuck

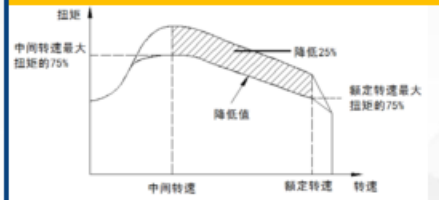
Monitoring items related to particle control

- The particle processor is removed.
- DPM system failure
- Distort

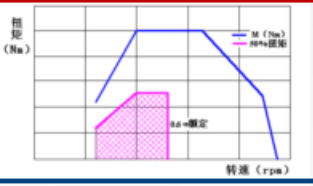
Incentive method

Alarm

Primary restraint system

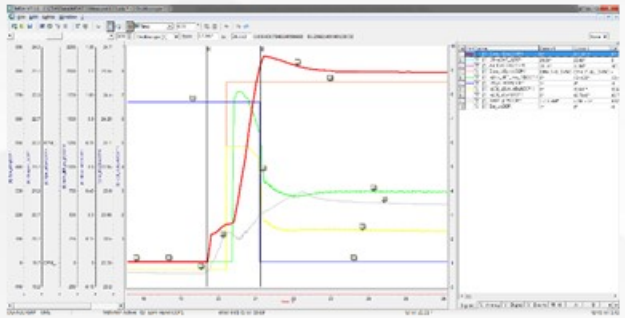


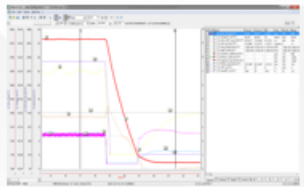
Severe restrictions on the system

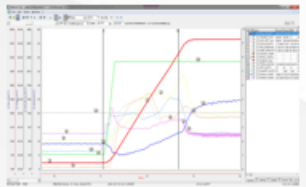


❑Vehicle functional calibration

Items	Tasks	Description
Start calibration	Water temperature starts at 20°C~70 degrees Celsius	Start time <1.6s and speed <100 rpm
Idle speed calibration	Low idle stability	The speed fluctuates at <±5 rpm (w/ full load) and the speed drops below <10 rpm
	Low idle start	The vehicle can start in high gear at low idle speed
	High idle performance	The speed fluctuates <±5 rpm and the speed rises <25 rpm
Free acceleration and smoke limit calibration	Balance acceleration and smoke	Acceleration and smoke level meet customer needs
Vehicle function calibration	Speed control mode	According to customer requirements, the throttle opening is controlled to control the engine speed, and the speed fluctuation is maintained within ±10rpm
Field test verification and calibration (for tractors)	Rotary tillage	Acceleration and smoke level meet customer needs
	deep ploughing	
	Deep pockets	
	Drive	

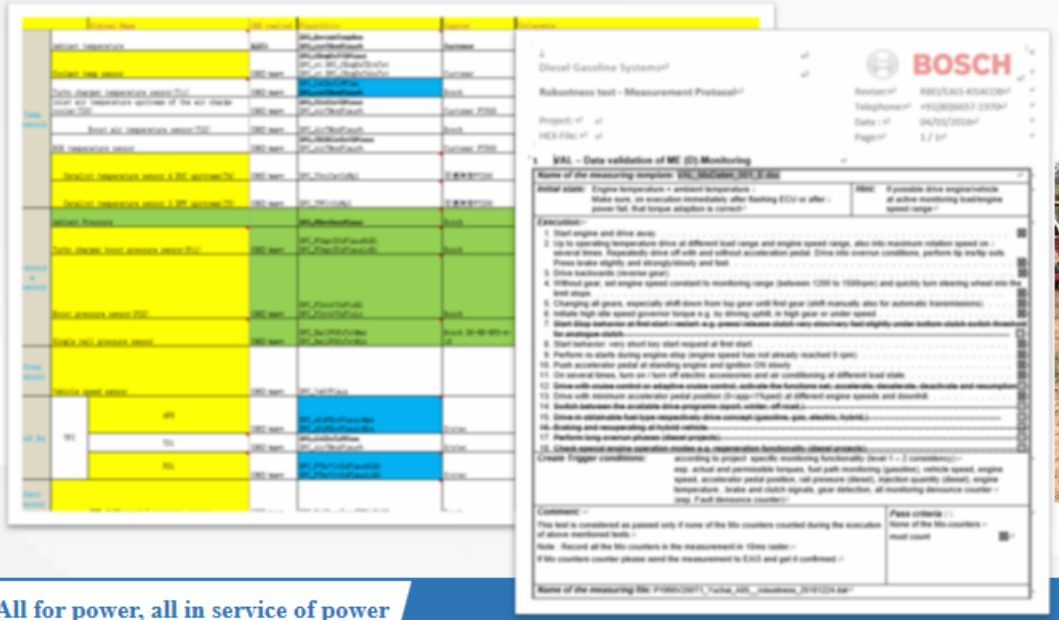






❑Vehicle functional calibration

Items	Tasks	Description
Fault simulation	Simulate all faults	According to the vehicle configuration file, all faults can be simulated to report errors according to the pre-configured configuration
DSM fault diagnosis	Complete all fault diagnosis calibration and submit to customer	Complete all DSM calibrations and resolve all errors
MST	Level 2 monitoring pole	Complete all MonCal rule calculations



❑Three-high calibration · Vehicle function correction

Trial	Functional verification
Winter trials	Cold start, preheat calibration, dynamic smoke limit, low idle stability of each gear, driving
Summer trials	Start, each gear idle stability, driving, turbocharger overheat protection
Highland trials	Start, idle stability at each gear, driving, turbocharger overspeed surge protection, dynamic smoke limit

❑Triage calibration and post-processing

Real 里尔汽车

Regenerative functional environment validation

DPF tool bag	Plain	Winter trial	Summer trial	High trial
T4&T5 validation	Scene • Steady state point check • Transient cycle check	Scene • Steady state point check • Transient cycle check • (T4 and T5 temperatures are insufficient)	Scene • Steady state point check • Transient cycle check • (T4 and T5 temperature overheat, DPF internal overheat)	Scene • Steady state point check • Transient cycle check (T4 and T5 temperature overheat, DPF internal overheat)
Renewable efficiency correction	Scene • Weigh after regeneration	Scene • Weigh after regeneration	Scene • Weigh after regeneration	Scene • Weigh after regeneration
Regeneration interval correction	Scene • On-site verification (weighing) is required	Scene • High emissions • On-site correction is required according to ambient temperature (weight, working condition to be determined, -20°C&-7°C)	Target • On-site correction is required according to ambient temperature	Scene • High soot/PM emissions • On-site corrections are required according to environmental pressures
Oil dilution verification	• Manual parking regeneration for 4h, take oil samples and measure oil dilution	• Manual parking regeneration for 4h, take oil samples and measure oil dilution	• Manual parking regeneration for 4h, take oil samples and measure oil dilution	• Manual parking regeneration for 4h, take oil samples and measure oil dilution

THANKS !

Address： Building E10-1, Lane 4, Lane 866, Jinghui Road, Juxian Street, Yinzhou District, Ningbo City, Zhejiang Province
Tel/WeChat： 13185992058
Postcode： 315000
Website： www.auto-real.cn
Jin Hong-General Manager
E-mail： hongjin@auto-real.cn

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