BOSCH

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MS/EEB-PJ1-PS	Sumanth Chatakonda / Rudresh Wanve	6309639731/ 7420901147	31 July 2024

Report Number

R&D Report: **Summer Trials**

Security Class: Confidential Export control relevant: No

Title: TML_CEV5_497_NA_41KW@2200RPM_THCM_BHL_Summer trials_Report

THCM 41kW Backhoe-Loader Summer Trials

- *Jaisalmer, Rajasthan*

BOSCH

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Document approval			
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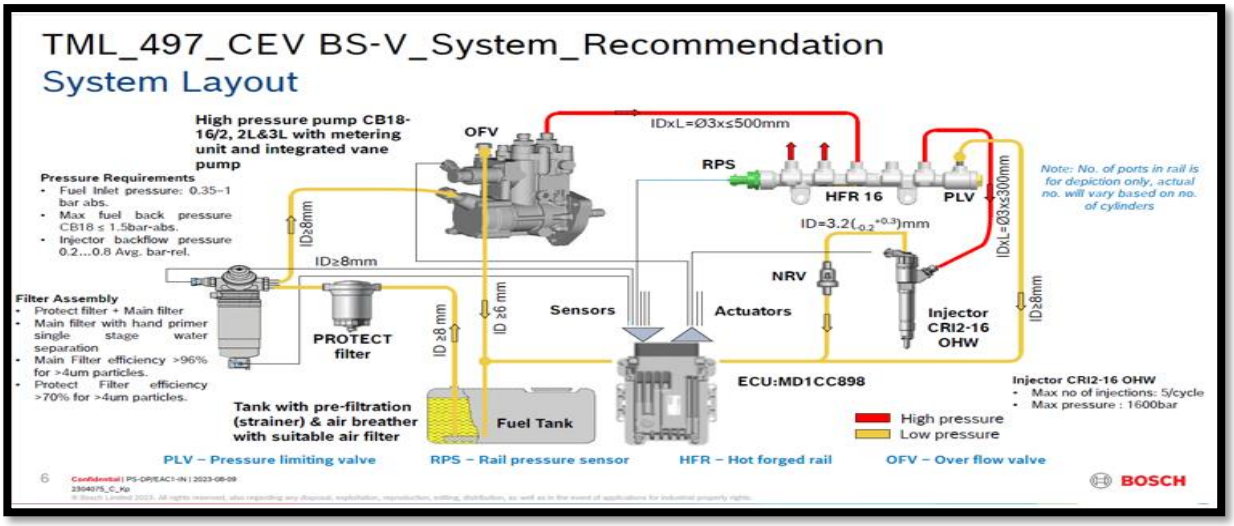
1. Objective

TML has developed 497NA engine with 41 kW @2200 RPM power rating for Backhoe Loader application. Representatives from BOSCH, TML, and THCM were present in Jaisalmer to attend the summer trials and ensure the effectiveness of the calibration under extreme conditions. The scope of this report is to summarize the activity along with the analysis and results.

2. Engine Configuration

Engine Details	
Engine configuration	**4 Cyl, 2V/Cyl, NA**
Displacement	**3.785ltr**
Power rating	**41kW @2200RPM**
Torque	**225Nm @1400RPM**
Sp. Power	**20.8 kW/L**
Drive ratio	**1:2**
Max Cylinder Pressure	**124 Bar**
Emission target	**CEV**
Application	**Backhoe-Loader**
Emission norm	**CEV5**

3. Hydraulic system Layout



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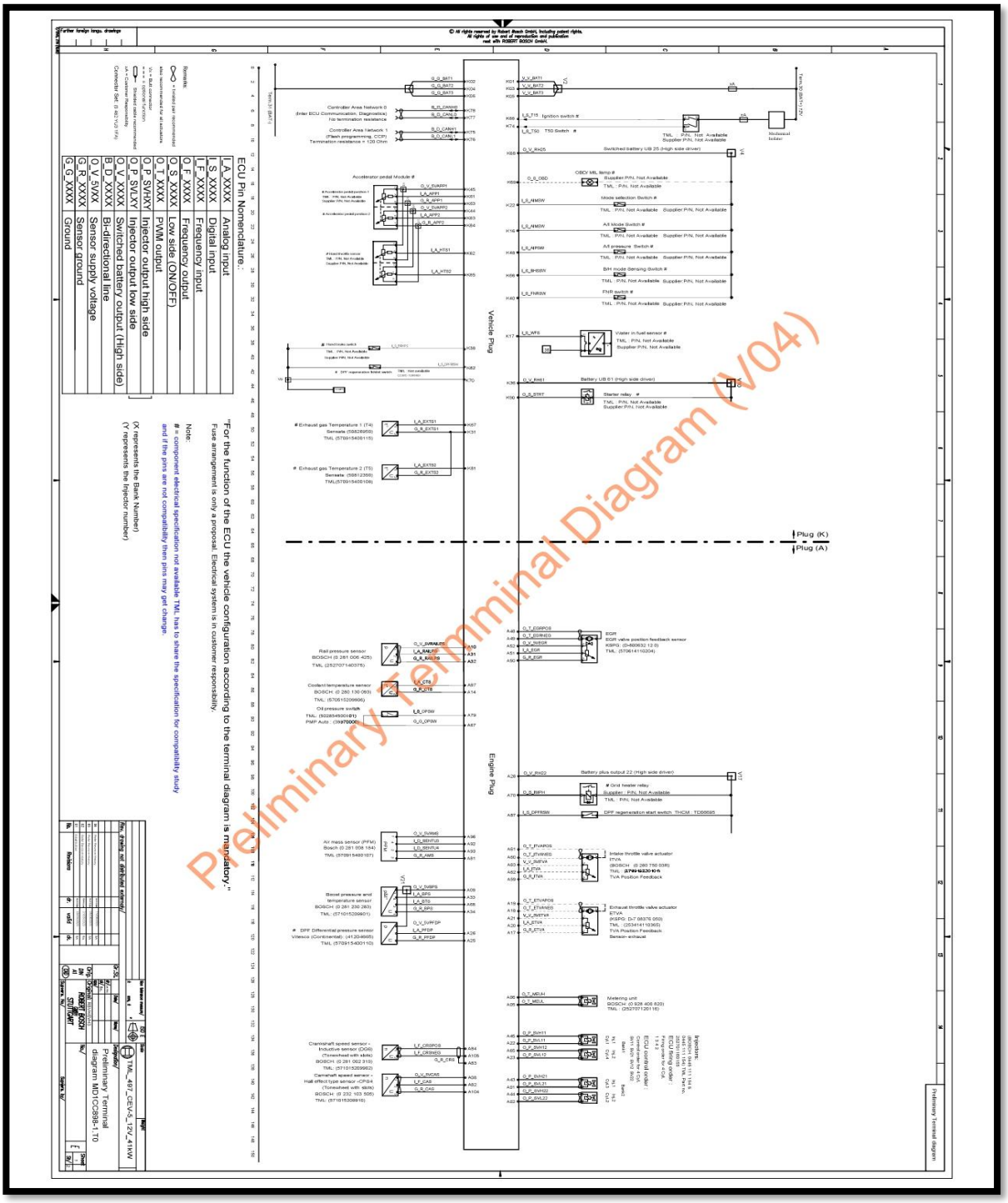
4. Terminal Diagram



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5. Sensors and Actuators plausibility check

Sl.No	Power train sensors	Plausibility status	Remark
1	Crank Shaft speed sensor	OK	-
2	Camshaft speed sensor.	OK	-
3	Accelerator Pedal Sensor	OK	-
4	Coolant temperature sensor	OK	-
5	TMAP Sensor	OK	-
6	T4	OK	-
7	T5	OK	-
8	Delta P sensor	OK	-
9	Oil Pressor sensor	OK	-
10	Rail Pressor sensor	OK	-
11	Remote accelerator pedal	OK	-
Sl.No	**Actuators**	**Plausibility status**	**Remark**
1	ITV Vlv	OK	-
2	EGR Vlv	OK	-
3	Metering Unit	OK	-
4	Injectors	OK	-
Sl.No	**Switch**	**Plausibility status**	**Remark**
1	Hand Brake Switch	OK	
2	Neutral Switch	OK	-
3	Ignition Switch	OK	-
4	DPF Regen Inhibit Switch	TBC	Will be checked by DPF team.
5	Regeneration Start Switch	TBC	Will be checked9 by DPF team.

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6. Machine Details

Application	**THCM Backhoe Loader**
Vehicle Name	Shinrai Pro
Maximum load which can be lifted	Loader capacity = 2T
Accessories (additional load on the engine)	Cabin fan, air pump (brake), headlights

7. Cluster Checks

Sl. No	Cluster Components	Bosch SW status	Vehicle Cluster status
1	Parking Brake	HndBrk_stDebVal =1	P
		HndBrk_stDebVal =0	Indicator off
2	Low Engine oil pressure/Engine oil pressure switch(OilPLmp_st)	1	Low oil P indication
		0	Indicator off
3	Water in Fuel	**Planned in next visit with the spare WIF sensor**	
4	Neutral	Gbx_stNPosRaw =1	N
		Gbx_stNPosRaw =0	F
		Gbx_stNPosRaw =0	R
5	DPF lamp	**Planned during DPF team visit**	
6	Exhaust High Temperature lamp: HEST		
7	DPF Inhibit		
8	POP up messages of Regeneration		
9	MIL check (checked for DFC_DevLibBat-tUHi)	ErrLmP_stMIL - 64	MIL Lamp ON
10	Coolant Temperature gauge	CEngDsT_t =40	C
		CEngDsT_t =80	Middle
		CEngDsT_t =120	H
11	SVS lamp/ check engine (checked for DFC_CEnDsTPhysRngHi)	-ErrLmP_stSVS - 65	SVS Lamp ON

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8. Summer trials

8.1. Boundary conditions

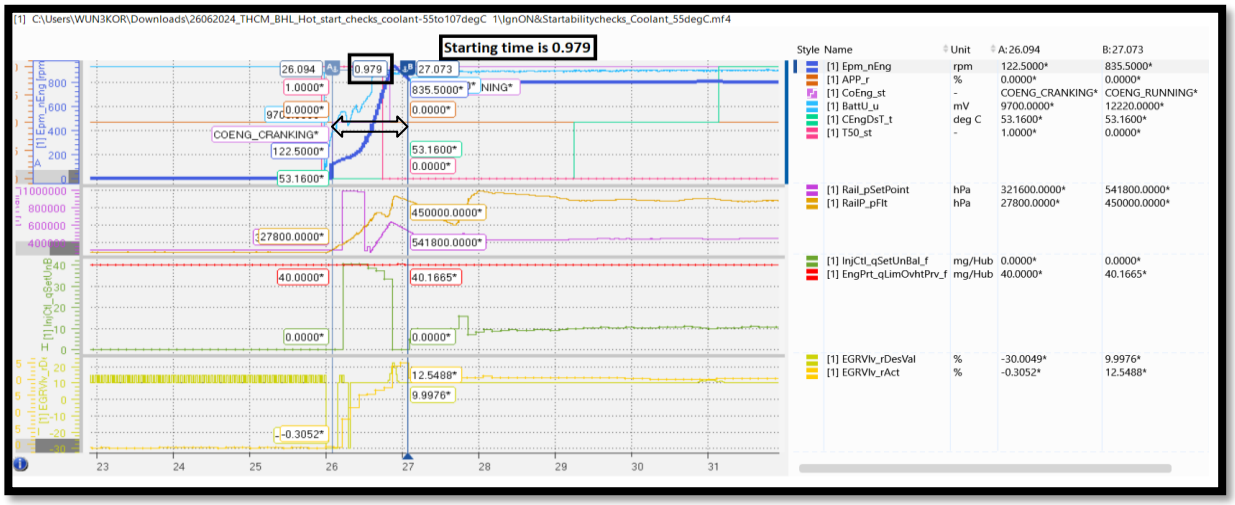
a) Location: Jaisalmer, Rajasthan
b) Altitude: 225mtr
c) Peak Ambient temperature recorded: 43℃.
d) Ambient pressure: 1001hPa
e) Initial dataset used for trials:

A2L: P2101_CEVST5_V312_TSW4.A2L
Hex: 0024625_TML_497_41kW_CEV_stage5_V312TSW4_THCM_BHL_M2_V09_summertrial.hex

8.2. Hot start trials

The engine coolant temperature remained below 85°C during operation. To increase the coolant temperature and test the starting capability, the radiator (blow-out type) was obstructed from the outside with 2-3 paperboards. This blockage caused the coolant temperature to exceed 95°C while the vehicle was in a stationary condition.

8.2.1. Start check at ~55℃ coolant temperature and 40℃ Ambient temperature.



➢ **Observation: Starting time is 0.979s, No visible smoke & stable start.**

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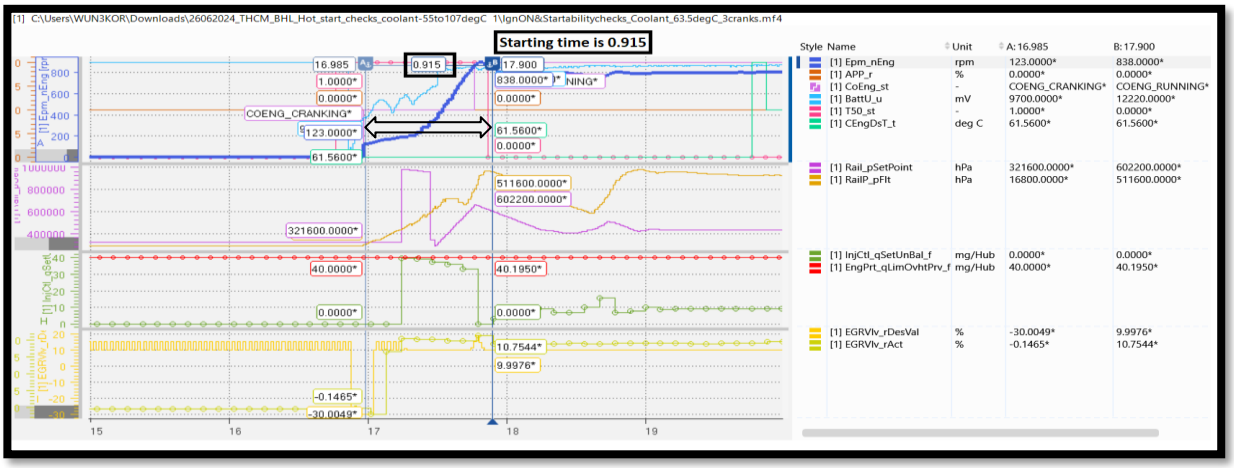
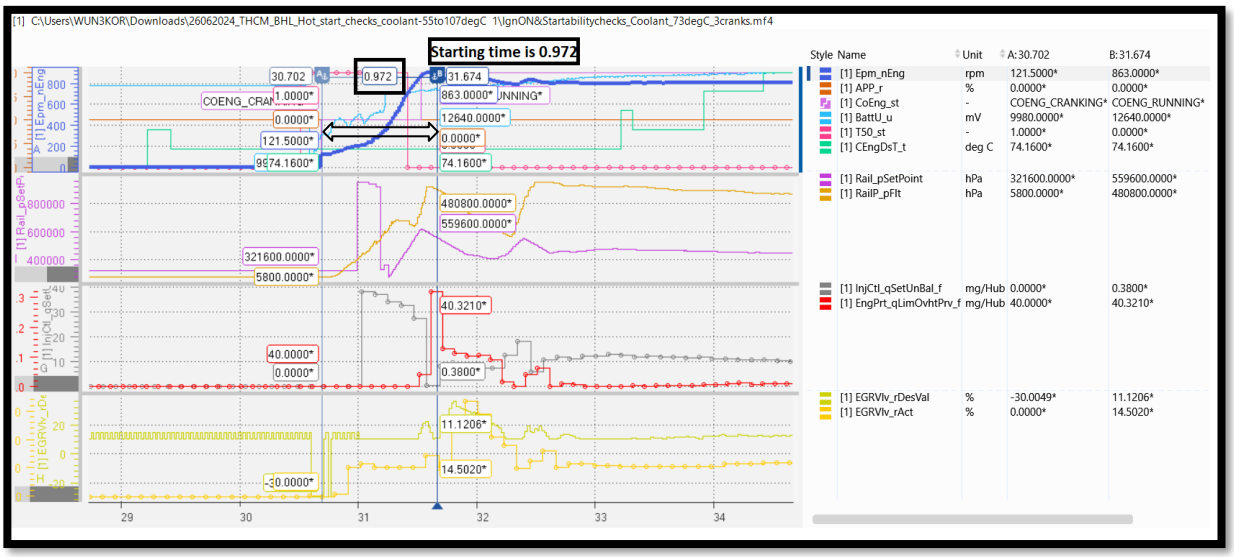
8.2.2. Start check at ~63℃ coolant temperature and 40℃ Ambient temperature.



➢ **Observation: Starting time is 0.915s, No visible smoke, stable start**

8.2.3. Start check at ~73℃ coolant temperature and 40℃ Ambient temperature.



➢ **Observation: Starting time is 0.972s, No visible smoke, stable start**

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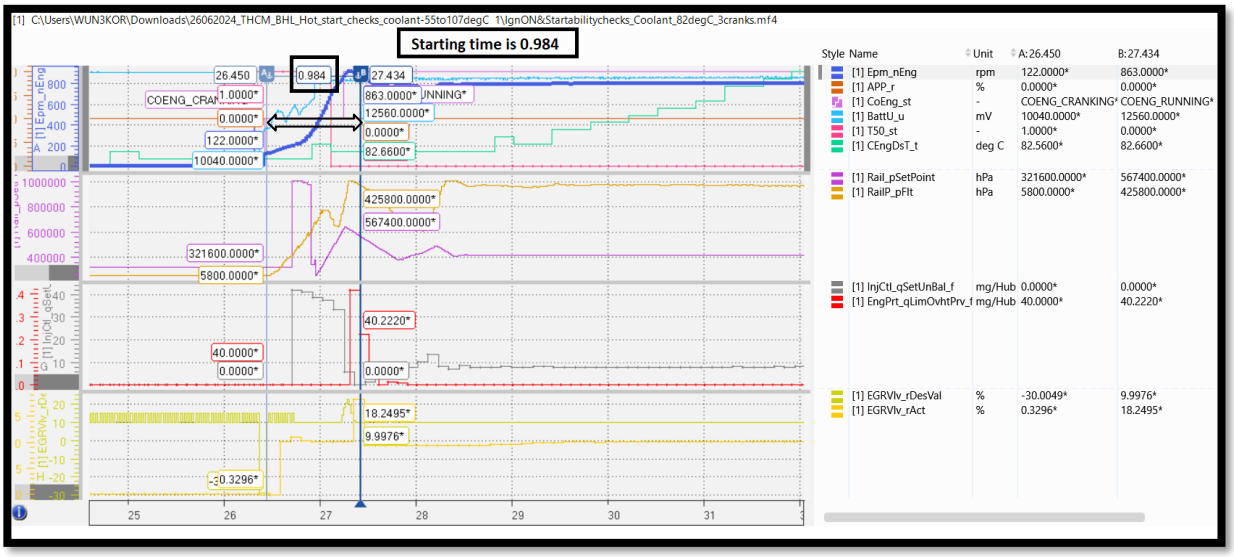
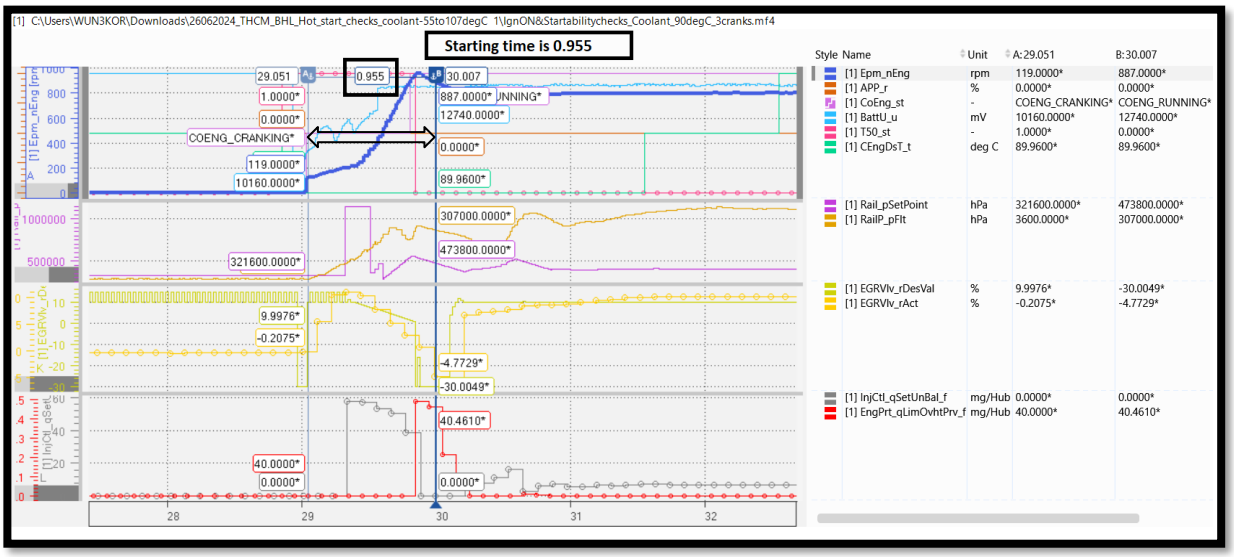
8.2.4. Start check at ~82℃ coolant temperature and 40℃ Ambient temperature.



➢ **Observation: Starting time is 0.98s, No visible smoke, stable start**

8.2.5. Start check at ~90℃ coolant temperature and 40℃ Ambient temperature.



➢ **Observation: Starting time is 0.95s, No visible smoke, stable start**

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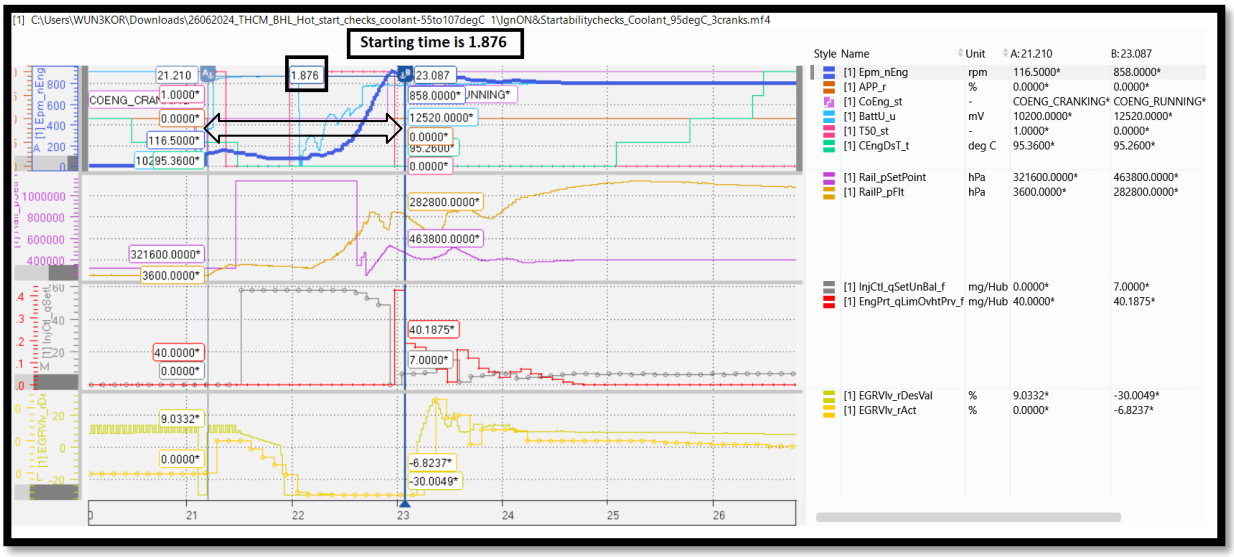
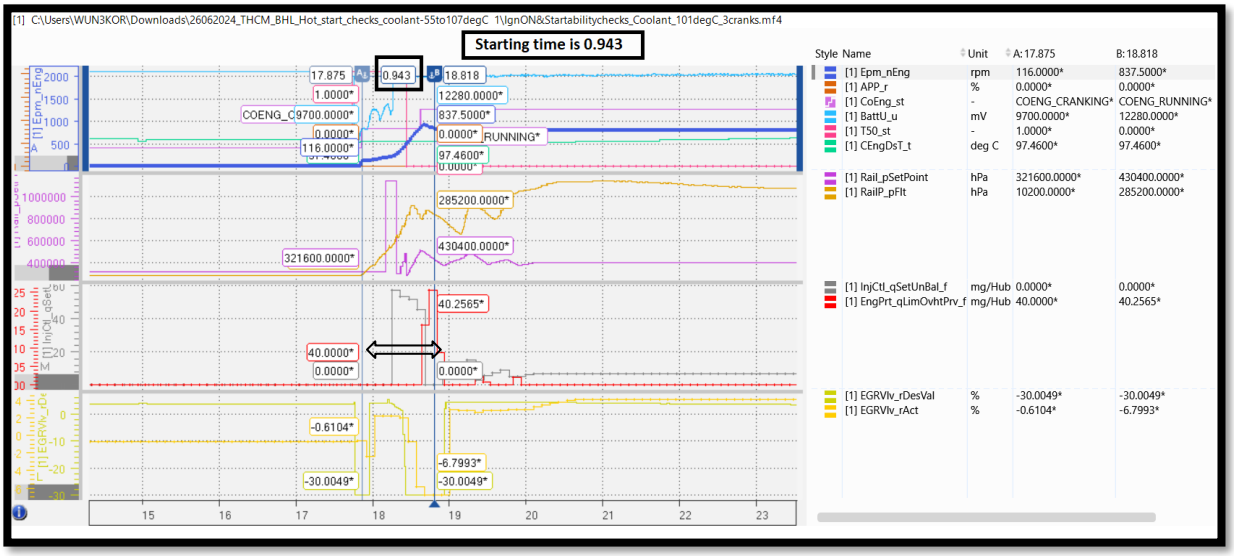
8.2.6. Start check at ~95℃ coolant temperature and 40℃ Ambient temperature.



➢ **Observation: Rail pressure builds in 0.99 seconds, causing a delayed start time of 1.87 seconds. There's no visible smoke, and the start is stable.**

8.2.7. Start check at ~101℃ coolant temperature and 40℃ Ambient temperature.



➢ **Observation: Rail pressure builds in 1.4 seconds, causing a delayed start time of 2.57 seconds. There's no visible smoke, and the start is stable.**

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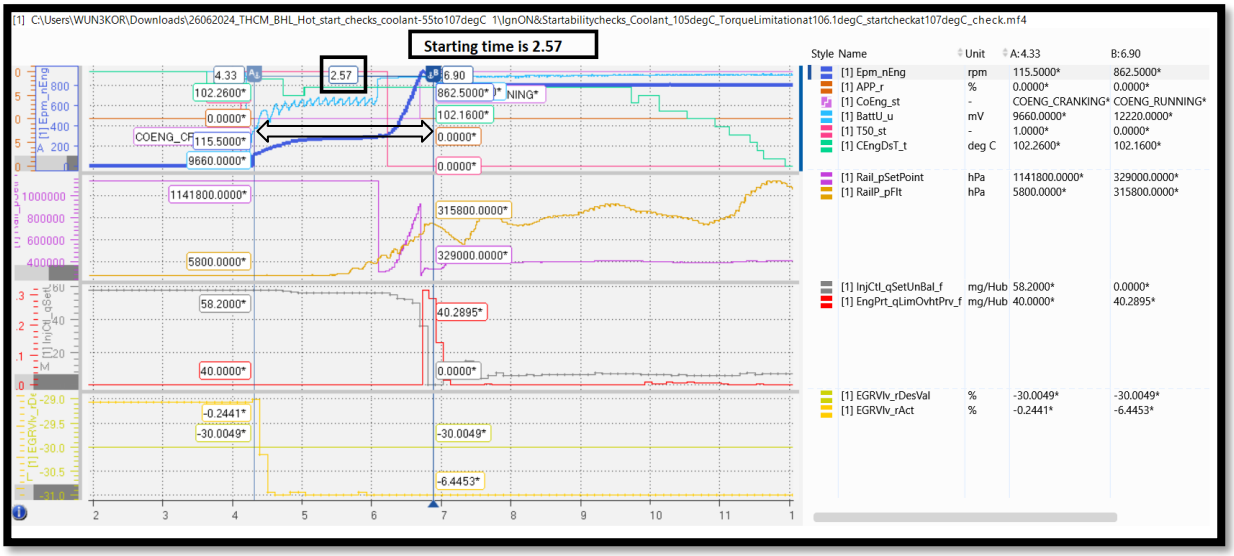
8.2.8. Start check at ~105℃ coolant temperature and 40℃ Ambient temperature.



➢ **Observation: Rail pressure builds in 1.4 seconds, causing a delayed start time of 2.57 seconds. There's no visible smoke, and the start is stable.**

➢ **<u>Summary of hot start trials:</u>**

a. During start, battery voltage dropped to 8.46V (at 43℃ ambient and 55℃ coolant temperature) which is within ECU working threshold. Battery voltage is regained subsequently, and engine starts with repeatability.
b. The rail pressure builds up adequately to release ET and consistently follows the set point without any lag.
c. The starter engages for less than 0.8 seconds, and the engine starts within 1 second on the first crank, which is acceptable to TML.
d. No visible smoke was observed during startup or low idle conditions at the test location.

8.3. Performance check at hot condition

We conducted comprehensive performance checks to evaluate engine effectiveness under high-temperature conditions. The operator constructed a water storage tank, utilizing leveling, travel, and operations with the Backhoe and Front Loader. These tests aimed to ensure that the calibration performed reliably and efficiently despite the extreme heat. Detailed analysis and results of these performance checks are presented in the following sections of this report.

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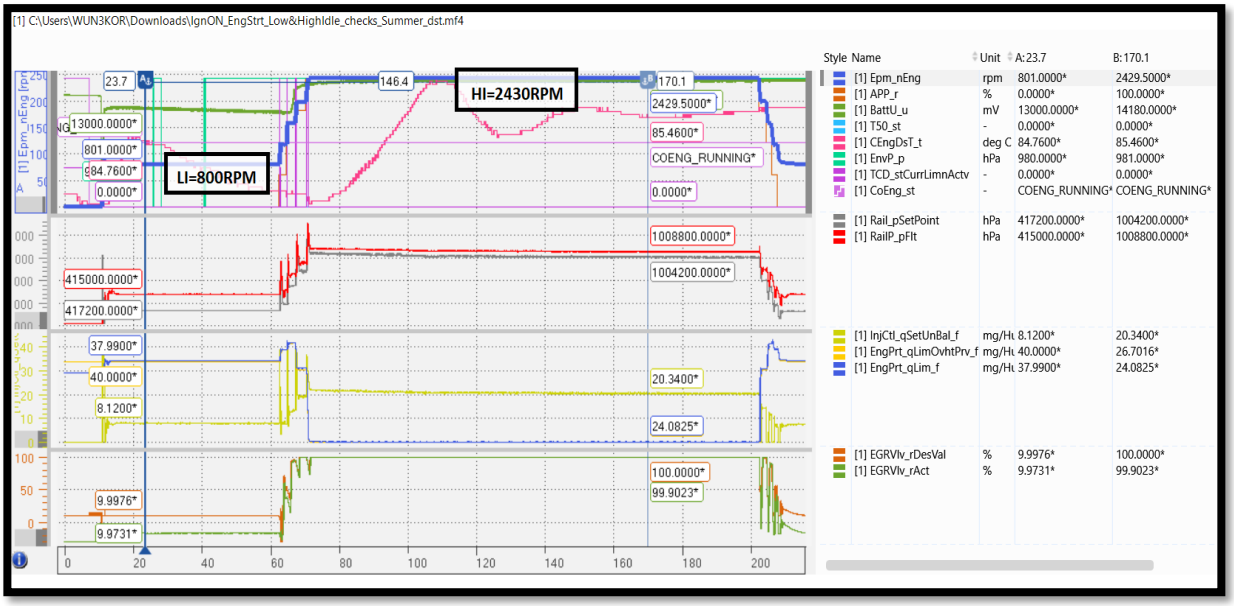
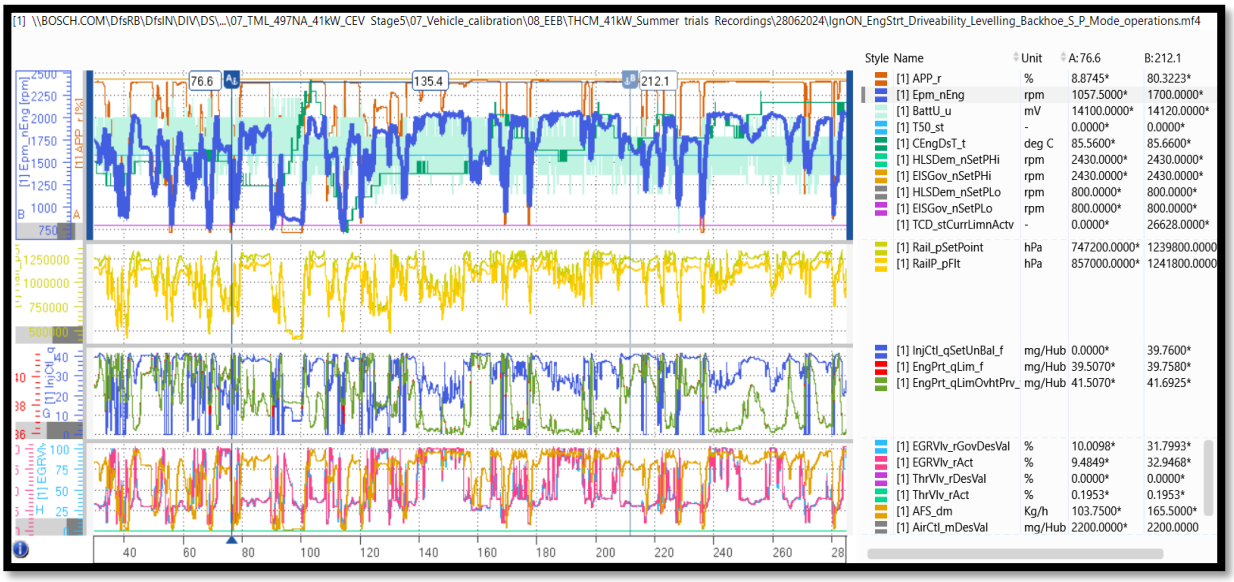
- **<u>Low idle and High idle check</u>:** Low idle and high idle was observed to be 800RPM and 2430RPM respectively. Both the idles were stable as shown in the below snap.



- **<u>Drivability check</u>**: A drivability test was conducted at an ambient temperature of 43°C. To ensure an accurate assessment, travel and leveling operations were performed. These measures ensured a thorough evaluation of drivability under high temperatures.



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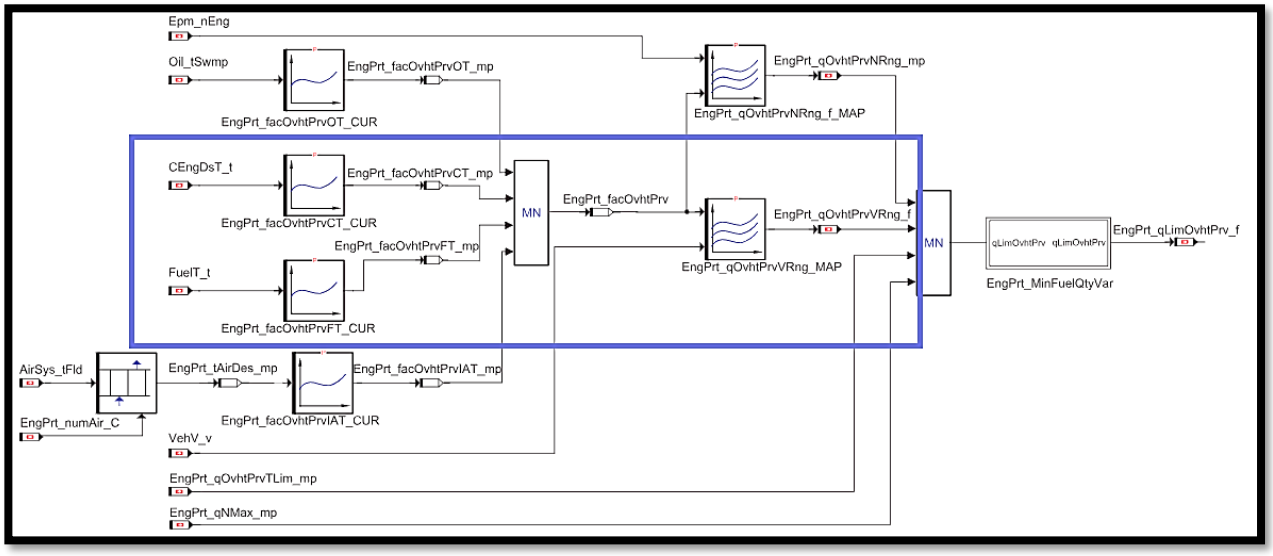
8.4. Overheat Prevention Calibration

The engine coolant temperature remained below 85°C during operation. To increase the coolant temperature and test the starting capability, the radiator (blow-out type) was obstructed from the outside with 2-3 paperboards. This blockage caused the coolant temperature to exceed 95°C while the vehicle was in a stationary condition.

8.4.1. TML target for overheat prevention:

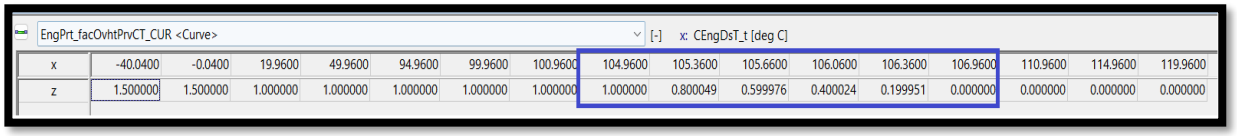
Coolant Temperature (°C)	Action
Up to 105°C	No overheating prevention needed
105°C to 107°C	Gradually limit engine torque
Above 107°C	Engine shuts off to prevent overheating

The above target can be achieved using the software logic shown below:



8.4.2. Final calibration used to achieve overheat prevention targets:

EngPrt_facOvhtPrvCT_CUR – This curve was calibrated to achieve the target based on CT, as previously discussed. When the factors fall below 1, there is a restriction on torque, and when the factor reaches 0, the engine should shut off.



x	-40.0400	-0.0400	19.9600	49.9600	94.9600	99.9600	100.9600	104.9600	105.3600	105.6600	106.0600	106.3600	106.9600	110.9600	114.9600	119.9600
z	1.500000	1.500000	1.000000	1.000000	1.000000	1.000000	1.000000	1.000000	0.800049	0.599976	0.400024	0.199951	0.000000	0.000000	0.000000	0.000000

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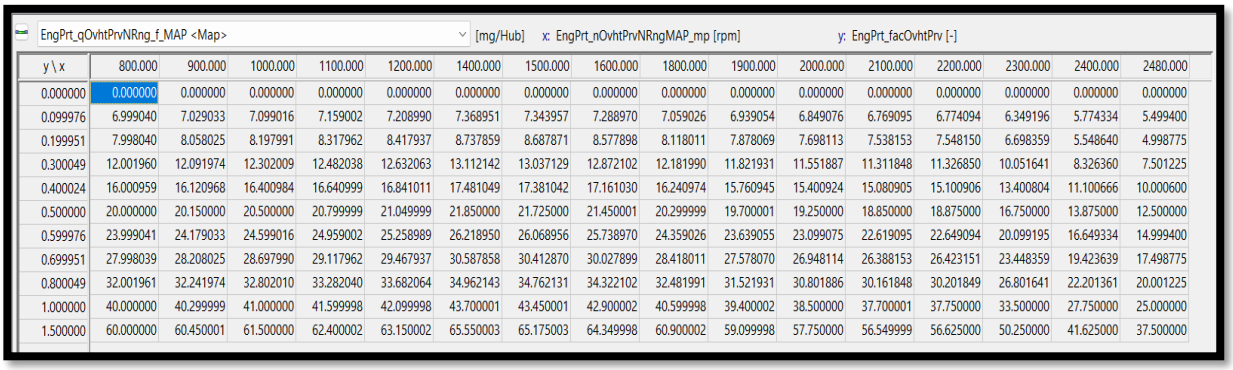
EngPrt_qOvhtPrvNRng_f_MAP – The fuel quantity is determined based on coolant-dependent factors, as detailed in this section. The calibrated coolant-based factor will be applied to the map, and the torque limitation will be enforced accordingly.



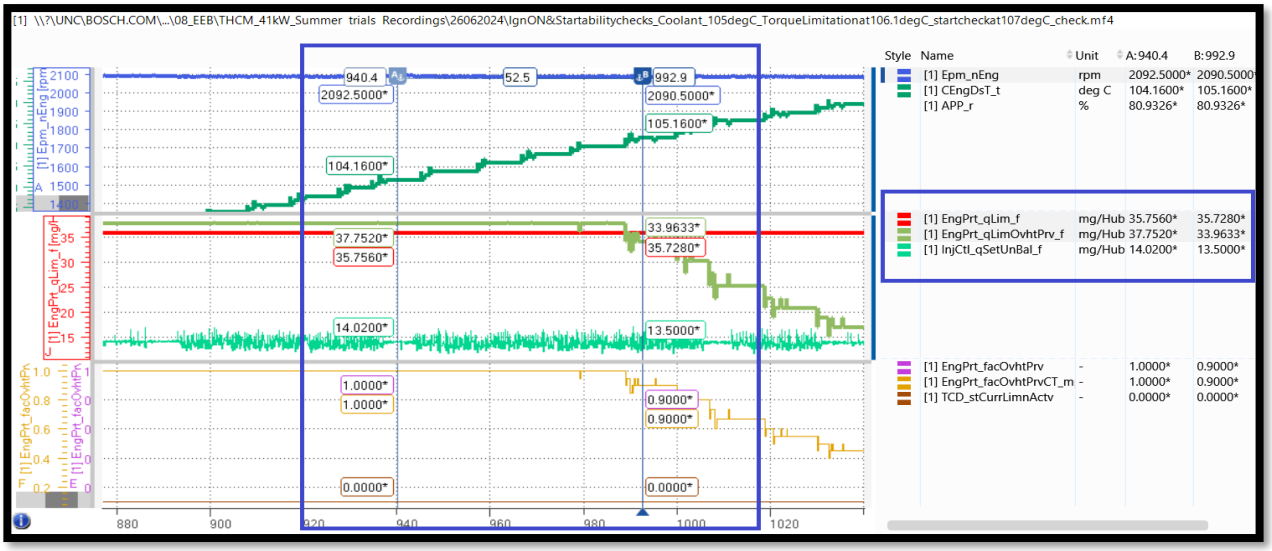
EngPrt_qOvhtPrvNRng_f_MAP <Map> [mg/Hub] x: EngPrt_nOvhtPrvNRngMAP_mp [rpm] y: EngPrt_facOvhtPrv [-]

y \ x	800.000	900.000	1000.000	1100.000	1200.000	1400.000	1500.000	1600.000	1800.000	1900.000	2000.000	2100.000	2200.000	2300.000	2400.000	2480.000
0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
0.099976	6.999040	7.029033	7.099016	7.159002	7.208990	7.368951	7.343957	7.288970	7.059026	6.939054	6.849076	6.769095	6.774094	6.349196	5.774334	5.499400
0.199951	7.998040	8.058025	8.197991	8.317962	8.417937	8.737859	8.687871	8.577898	8.118011	7.878069	7.698113	7.538153	7.548150	6.698359	5.548640	4.998775
0.300049	12.001960	12.091974	12.302009	12.482038	12.632063	13.112142	13.037129	12.872102	12.181990	11.821931	11.551887	11.311848	11.326850	10.051641	8.326360	7.501225
0.400024	16.000959	16.120968	16.400984	16.640999	16.841011	17.481049	17.381042	17.161030	16.240974	15.760945	15.400924	15.080905	15.100906	13.400804	11.100666	10.000600
0.500000	20.000000	20.150000	20.500000	20.799999	21.049999	21.850000	21.725000	21.450001	20.299999	19.700001	19.250000	18.850000	18.875000	16.750000	13.875000	12.500000
0.599976	23.999041	24.179033	24.599016	24.959002	25.258989	26.218950	26.068956	25.738970	24.359026	23.639055	23.099075	22.619095	22.649094	20.099195	16.649334	14.999400
0.699951	27.998039	28.208025	28.697990	29.117962	29.467937	30.587858	30.412870	30.027899	28.418011	27.578070	26.948114	26.388153	26.423151	23.448359	19.423639	17.498775
0.800049	32.001961	32.241974	32.802010	33.282040	33.682064	34.962143	34.762131	34.322102	32.481991	31.521931	30.801886	30.161848	30.201849	26.801641	22.201361	20.001225
1.000000	40.000000	40.299999	41.000000	41.599998	42.099998	43.700001	43.450001	42.900002	40.599998	39.400002	38.500000	37.700001	37.750000	33.500000	27.750000	25.000000
1.500000	60.000000	60.450001	61.500000	62.400002	63.150002	65.550003	65.175003	64.349998	60.900002	59.099998	57.750000	56.549999	56.625000	50.250000	41.625000	37.500000

8.4.3. Overheat Prevention Checking Trials

During overheat prevention checks, we conducted trials in a standstill condition to thoroughly evaluate the performance and reliability of the overheat protection system.

a. Overheat Prevention Checking Trials at 105℃ In Standstill Condition



- **Observation:** At 104°C, the overheat protection is not activated. When the coolant temperature reaches 105°C, the overheat protection logic activates, causing the overheat protection quantity curve to decrease and set the limit for the actual fuel quantity.

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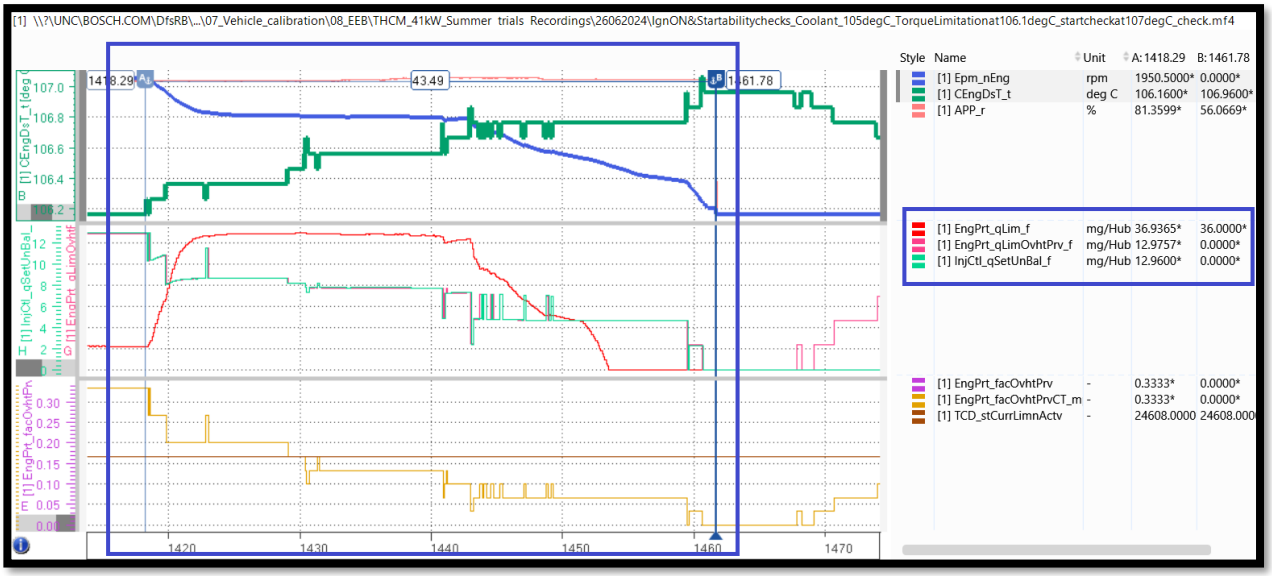
b. Overheat Prevention Checks From 105 ℃ to 107℃ In a Standstill Condition



- **Observation:** At 105°C, the overheat prevention activates. By 106°C, the overheat prevention quantity curve and the actual fuel quantity curve intersect, with the overheat prevention curve setting the limit for the actual fuel quantity, and both curves decreasing together thus leading the system to shut-off at 107 °C.

8.4.4. Overheat Prevention validation and results:

The machine was run to validate overheat prevention measures in both Travel and Backhoe modes. During this comprehensive test, we aimed to ensure the effectiveness of the overheat prevention system under various operational conditions.

8.4.4.1. Overheat Prevention validation and results for Travel Mode

The machine was run in travel mode to validate overheat prevention measures. During this test, the overheat prevention system started to activate when the coolant temperature exceeded 105°C. As the coolant temperature continued to rise and exceeded 107°C, the engine RPM dropped to zero, causing the vehicle to shut down.

From
MS/EEB-PJ1-PS

Our Reference
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Phone
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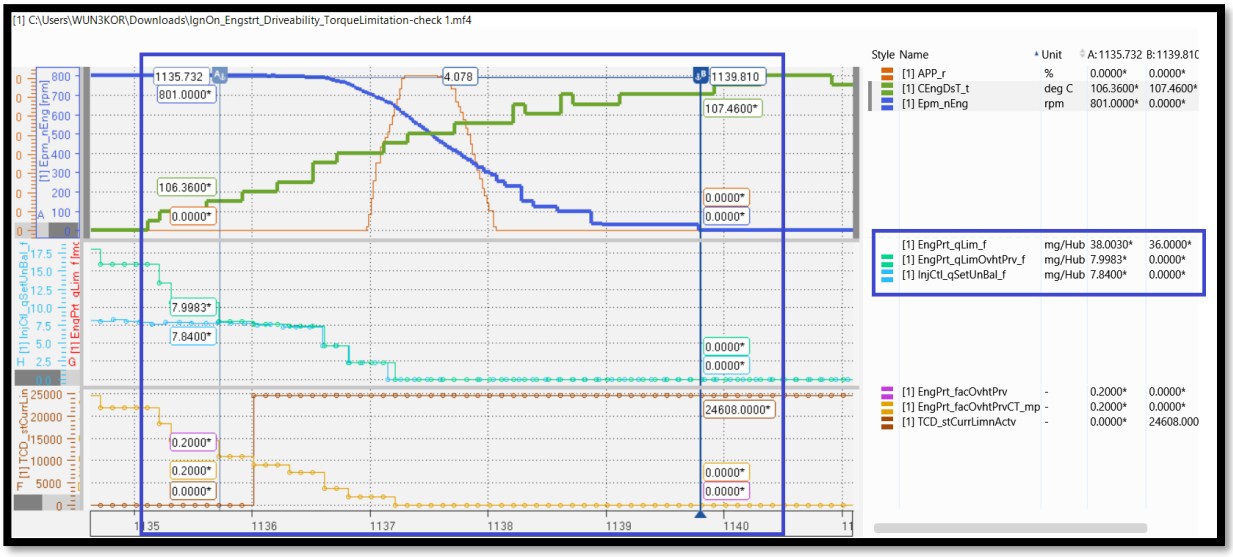
Pune
31 July 2024
Report Number

R&D Report: **Summer Trials**

Security Class: Confidential Export control relevant: No

Title: TML_CEV5_497_NA_41KW@2200RPM_THCM_BHL_Summer trials_Report

a. *Overheat prevention check in* Travel Mode.

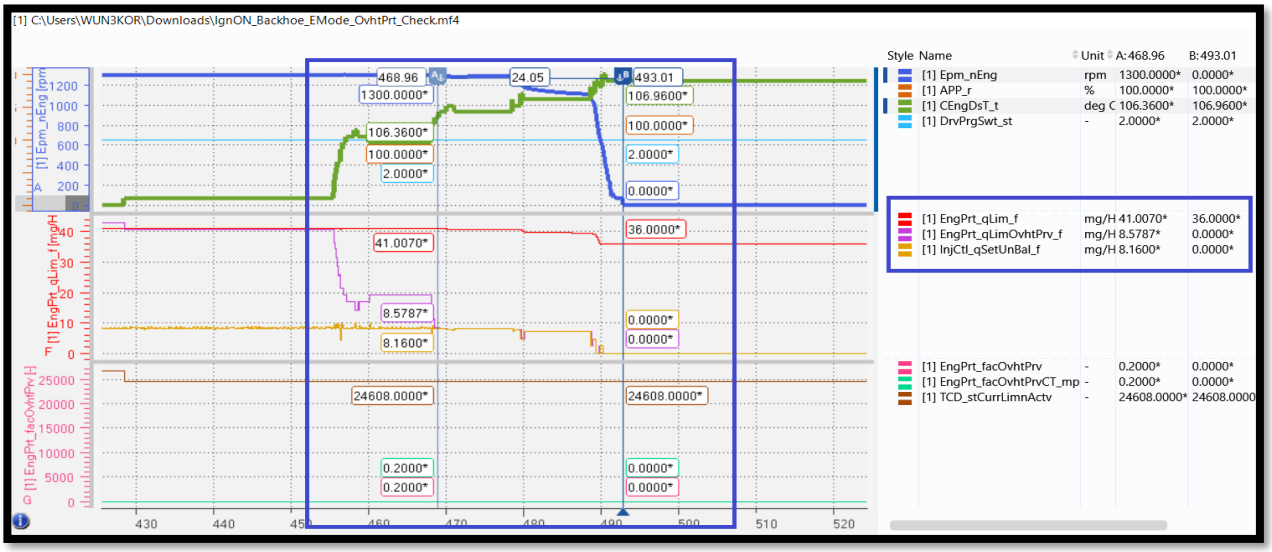


➢ **Observation: Over-heat prevention logic is working as intended.**

8.4.4.2. Overheat Prevention validation and results for Backhoe Mode

The machine was tested in Backhoe mode with E, S and P Mode to validate the overheat prevention system. The protection system kicks in when the coolant temperature exceeds 105°C, and the engine shuts down at 107°C Coolant temp.

a. Overheat prevention check in Backhoe E mode(DrvPrgSwt=2).



➢ **Observation: Over-heat prevention logic is working as intended.**

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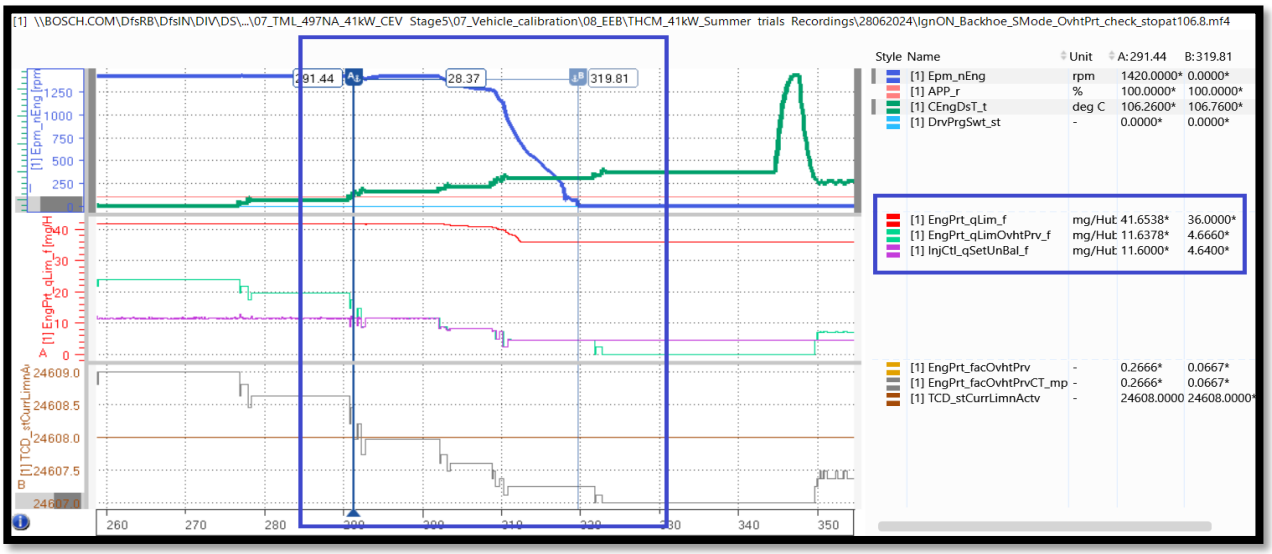
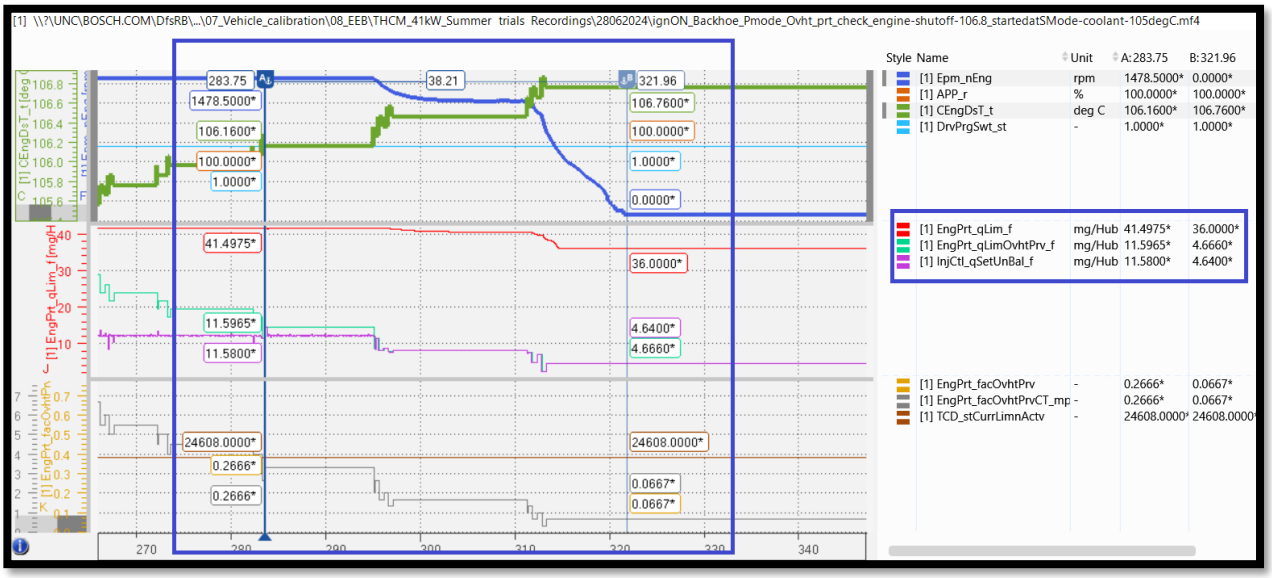
b. Overheat prevention check in Backhoe S mode(DrvPrgSwt=0).



➢ **Observation: Over-heat prevention logic is working as intended.**

c. Overheat prevention check in Backhoe P mode(DrvPrgSwt=1).



➢ **Observation: Over-heat prevention logic is working as intended.**

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8.5. Open Points list and further action

Sl.No	Open Points	Action Plan
1	Sometimes "DFC_OilPNpl" is popping up after starting the engine although oil pressure switch is properly connected	- No errors are observed in THCM with same dataset on Proto 1 - Kept disabled in current dataset to avoid misdetections. - Wiring Harness must be checked again and DSM team to revalidate the same during their visit
2	Sometimes "DFC_StDrvPrgSwtErr" is popping up after key ON	- Only observed on INCA but not on cluster as P code is not available for this DFC in current DSM sheet - DSM team to check this during their visit
3	High water coolant lamp is glowing when coolant temperature reaches 102 °C but THCM requirement is 105°C	- Label to calibrate this target temperature is enabled in new V401 SW. -V401 SW was not available during trials

8.6. Conclusion and results

All the tests detailed in the report were successfully conducted at the machine level. The summary of the completed activities is as follows:

A. Sensor-actuator plausibility checks were performed before starting the trials. Since there was no ambient temperature sensor available, the ambient temperature was obtained using a thermometer.
B. At an ambient temperature of approximately 43°C, start ability, low idle (LI) condition, engine ramp to high idle (HI), high idle conditions, and white smoke behavior were evaluated. Calibration and verification were conducted to ensure the observed behavior met the acceptability criteria defined by TML.
C. Basic checks on engine stability and performance were conducted at part and full acc. pedal positions under hot conditions (ambient temperature around 45°C). The performance was deemed acceptable by TML.
D. The overheat prevention calibration was checked and verified to ensure machine safety at higher coolant temperatures. The overheat prevention function operated as intended.

All the application-relevant functions tested and discussed in the report are performing as intended, and the results meet TML's acceptance criteria.

BOSCH

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Dataset finalized:
HEX:
20240628_TML_497_41kW_CEV_Stage5_V312TSW4_THCM_BHL_M2_V09_summer trial_OilPMin&OilPNpl&CEngDST_Phys_Rng-Hi_enabled_LIM_FID_changed_CEng-PhysRng_Max-105℃_2.hex
A2L:
P2101_CEVST5_V312_TSW4.A2L