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Emission Regulations Study, Deriving Engine Emission Targets Need for Trem-V Engine Development by Using Cal-G Hardware

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In an attempt to reduce pollution brought on by growing pollution levels and declining air quality, some countries have established emission standards based on their own pollution levels. For on-road vehicles, new emission standards have been developed and are currently in force. Every country has defined specific emission standards for off-road vehicles, such as generator sets, excavators, tractors, and construction equipment. April 1st, 2024 is when these restrictions will go into force. Every country has focused its regulations on nitrogen oxides (NOx) and particulate matter (PM), the two primary pollutants from cars. The revised standards will result in an 87% reduction in NOx and a 40% reduction in PM when compared to the current limits. It is possible to control the production of NOx and PM by adjusting a number of engine parameters, including main injection timing, fuel pressure, intake manifold pressure, fresh mass airflow, and air fuel ratio. A number of factors, including little combustion time and high temperatures within the cylinder, create NOx and PM. The pollutants can be reduced by modifying these factors under the selected emission standards.

Through parameter optimization, the tractor engine in this project is created to meet Stage-V European norms for PM and NOx emissions. Engine testing data from both the steady state and transient states is taken into account when optimizing an engine using the CalG software. The settings are tuned and the NOx and PM are minimized by varying the Power and Torque.

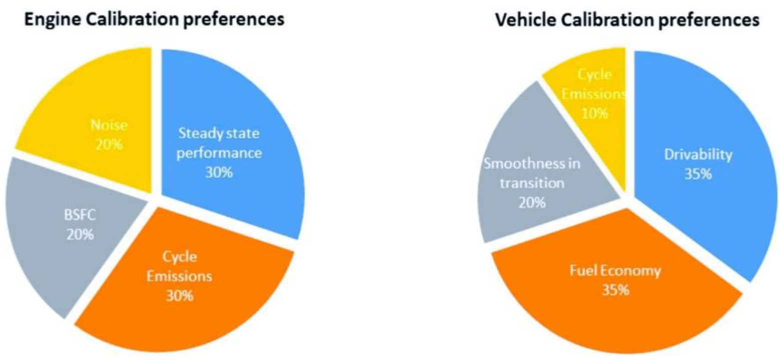
Keywords: Tractor emission regulation standards, Cal-g hardware, after treatment techniques.

1. Introduction

Off highway vehicles:

Typically used for industrial, recreational, or agricultural reasons, off-highway vehicles (OHVs) are vehicles intended for usage away from public roads and highways. Excavators, skid-steer loaders, bulldozers, tractors, and all-terrain vehicles (ATVs) are a few examples of OHVs.Numerous sectors, such as forestry, mining, construction, and landscaping, heavily rely on OHVs for their operations. Off-road driving, fishing, and hunting are some of the leisure activities that they are utilized for. But off-highway vehicles (OHVs) may contribute significantly to air pollution and climate change since they are frequently driven by diesel engines and do not have to follow the same emissions standards as on-road cars. Many nations, including China, have imposed emissions rules for off-highway vehicles (OHVs) in order to solve this problem. These laws place restrictions on the number of pollutants that OHVs are allowed to emit, including carbon monoxide (CO), nitrogen oxides (NOx), particulate matter (PM), and hydrocarbons (HC). In order to assure compliance, emissions testing of OHVs is required, and OHV manufacturers are required to develop and construct engines that fulfil these specifications.

One significant step in lowering air pollution and preserving public health is the establishment of emissions restrictions for off-highway vehicles (OHVs). We can lessen the detrimental impacts of air pollution on human health and the environment caused by OHVs by restricting the emissions from these vehicles.



Purpose of calibration:

Maintaining measurement accuracy, consistency, and repeatability through calibration is the main advantage; it guarantees reliable standards and results. If calibration is not done on a regular basis, equipment might malfunction, produce inaccurate data, and jeopardize durability, quality, and safety. The internal combustion engine turned the production of electricity on its head, made it possible to create the airplane and other forms of mobility, and helped free men from the most taxing physical labour. Thank you to the combustion engine, we can now move people and goods farther and faster than ever. More industries and employment have been created as a result of our ability to generate electricity and run manufacturing.

There are enormous societal costs associated with the combustion engine. In order to provide trustworthy standards and outcomes, calibration is primarily important since it preserves measurement accuracy, uniformity, and repeatability. Equipment may malfunction, give erroneous readings, and endanger durability, quality, and safety if it is not calibrated on a regular basis.

EMISSION NORMS/STANDARDS:

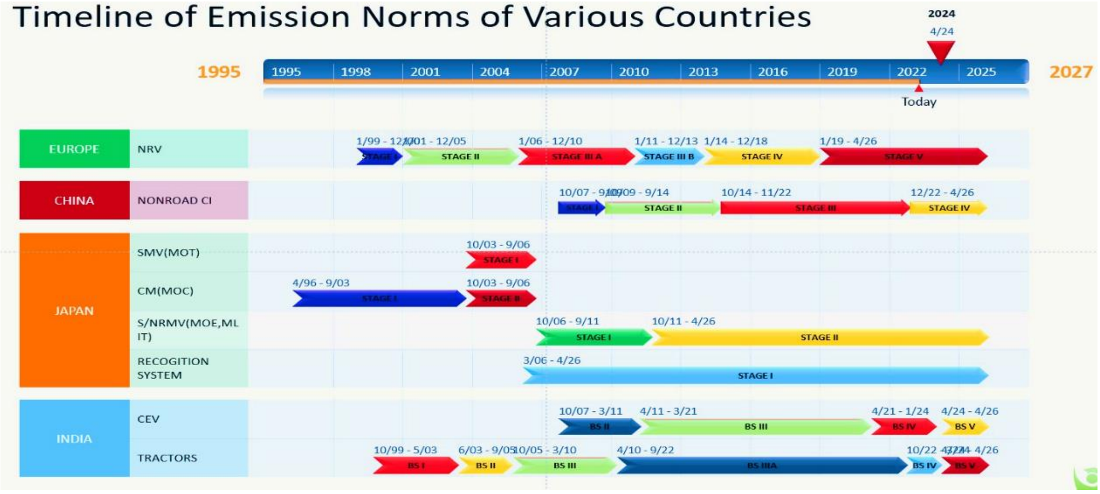
Emission standards, which are also referred to as emission norms or regulations, are the legal restrictions imposed by governments or regulatory bodies to limit the quantity of pollutants and harmful substances released into the environment from a variety of sources, including cars, factories, power plants, and other sources of emissions. These regulations seek to lessen environmental harm caused by human activity, safeguard public health, and limit air and water pollution. The maximum permissible levels of particular pollutants that can be released from a particular source are normally specified by emission regulations, which can change depending on the area, nation, or industry. The following contaminants are frequently included by emission standards:

Engine Categories (From Apr 2024)							
Country	0 to 8 kW	8 to 19 Kw	19 to 37	37 to 56	56 to 130	130 to 560	Above 560
INDIA – BS V	✓	✓	✓	✓	✓	✓	✓
EUROPE	✓	✓	✓	✓	✓	✓	✓
CHINA	✓	✓	✓	✓	✓	✓	✓
JAPAN SMRV			✓	✓	✓	✓	✓
JAPAN REC SYSTEM		✓	✓	✓	✓	✓	✓

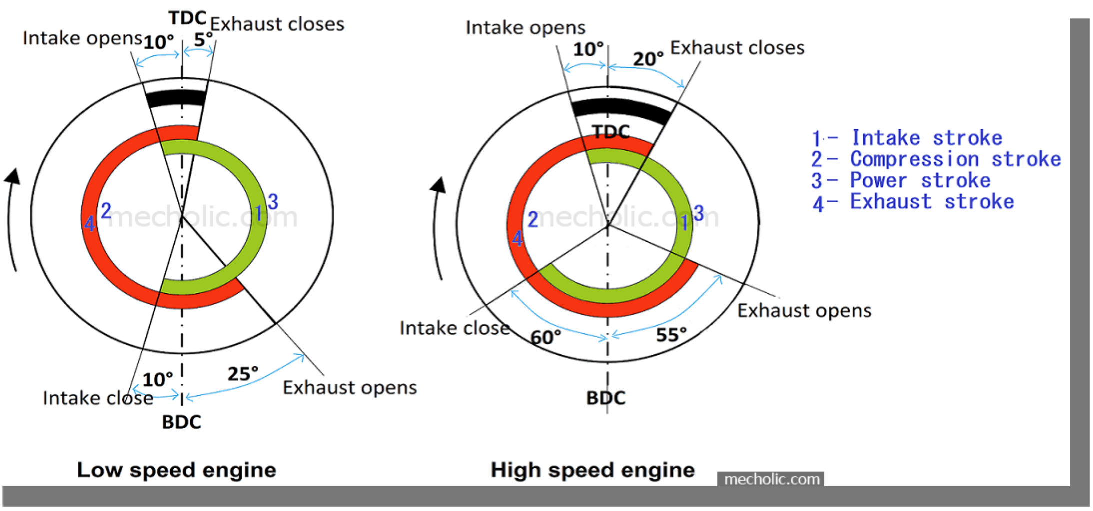
VARIOUS COUNTRIES TREM/CEV STAGE IV-V

2. METHODOLOGY

India Bharat Stage (BS) Standards: Bharat Stage (BS) standards are the name given to emission requirements in India. They specify the highest amounts of pollutants that cars are allowed to produce, much as the Euro standards. The European laws that form the basis of the BS requirements have been modified to comply with the driving conditions of India. For both gasoline and diesel automobiles, the most recent standard is BS VI.For nonroad diesel engines used in agricultural equipment and construction trucks, Trem and CEV Stage IV - V emission criteria apply. While the BS V standards apply to all power ratings, the BS IV/V nonroad regulations do not contain BS IV emission criteria for diesel engines with rated power below 37 kW (a group that covers around 90% of agricultural tractors in India) or for engines above 560 kW. The rule contains a six-month grace period during which equipment that complies with the prior set of emission criteria may be registered. From April 2026, all BS V authorized engines produced must undergo an in-service conformity inspection.



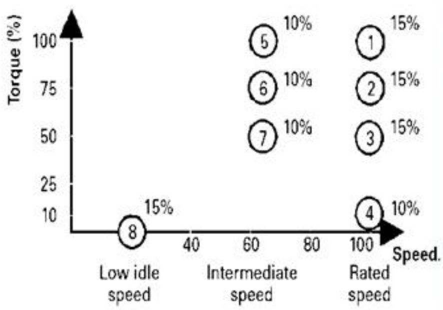
VVT-Often used to improve power, fuel efficiency, or pollution reduction, variable valve timing (VVT) alters the timing of a valve lift event in internal combustion engines. Systems with variable valve lift are increasingly being integrated with it. Numerous methods, including as electro-hydraulic systems, mechanical devices, and calmness systems, can be used to accomplish this. Because of the stricter pollution regulations, a lot of automakers are using VVT systems. Two-stroke engines employ power valve systems to get results similar to VVT.

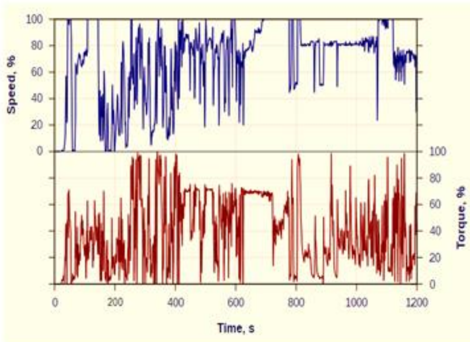


NRSC and NTRC CYCLES:

NRTC-Developed by the US EPA in collaboration with EU authorities, the NRTC test is a transient driving cycle for transportable nonroad diesel engines. Worldwide usage of the test is required for nonroad engine type approval and emission certification. Many emission requirements for nonroad engines, such as the US EPA Tier 4 rule, the EU Stage III/IV regulation, and the Japanese 2011/13 rules, require NRTC testing. The cycle, which lasts for a total of 1238 seconds, is an engine dynamometer transient drive program. NRTC test results for the normalized engine speed and torque

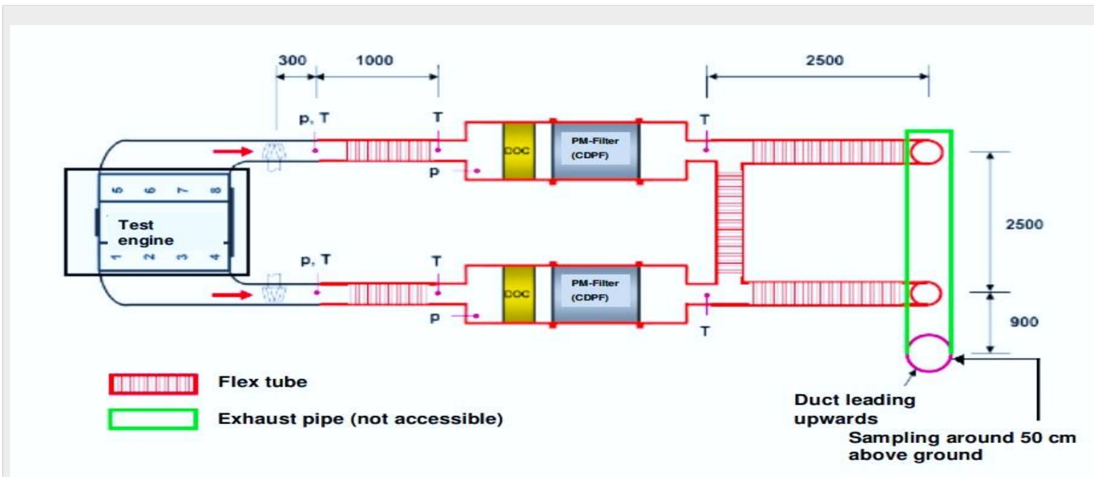
NRSC-The European Union, the United States, Japan, and other nations employ ISO 8178, a set of steady state test cycles, to determine emission limits for non-road engines. "Non-Road Steady Cycle" is another name for test cycle ISO 8178 C1, which is widely used.





NRSC NRTC

The cycle, which has a total duration of 1238 seconds, is a temporary driving program for an engine dynamometer. The normalized engine speed and torque during the NRTC test are shown in the accompanying chart. With a 20-minute soak break in between, the NRTC is run twice—once with a cold start and once with a hot start. The cold start weighting factors are 5% in the US and 10% in the EU. The average power of the engine is around 37% of its maximum power. The NRTC test, which is used for highway engines, reaches the working temperatures for exhaust aftertreatment more quickly than the WHTC test.



ENGINE TEST RIG UNIT

3. CAL-G HARDWARE

CalG means gannet acceleration calibration data analytical platform. CalG is a custom tool for performance to solve the problem in a systematic way paying the path per standards of optimization routine or flows and finally helping organisation to save lot of time by reducing the dependency of high court infrastructure and also assisting in avoiding iteration due to human errors. Engine and vehicle calibration is classified into 8 features. They are:

1. Operating zone identification

2. Engine emissions output optimisation

3. Not to exit threshold [NTE]zone identification

4. SCR aftertreatment emissions optimization

5. Engine out NOx estimator

6. Engine out soot estimator

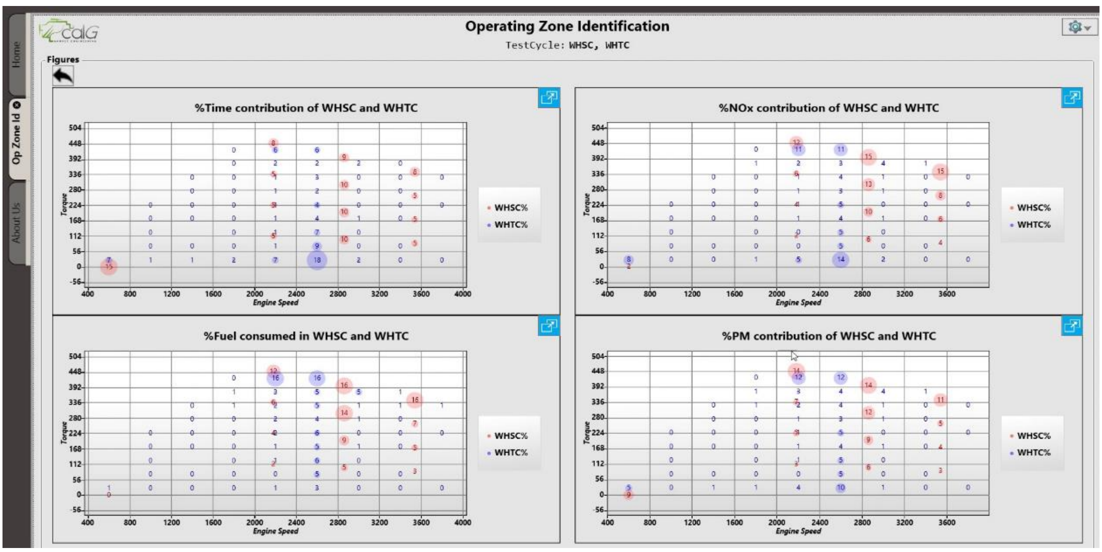
7. Mass air flow estimator

8. 3D Map interpolator to draw ECU outputs.

Emission reduction technique/process using Cal-G:

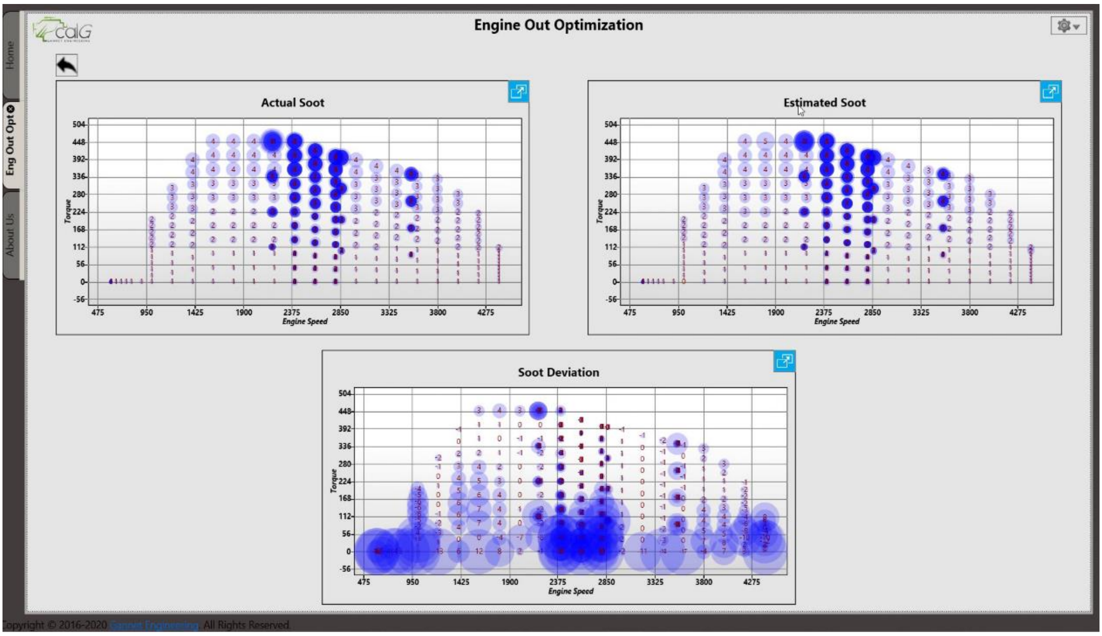
Operating zone identification:

Internal combustion engines use a method called operating zone identification to ascertain their present mode or operating state based on a variety of inputs and sensor readings. For the purposes of optimizing and controlling engines, this information is essential. The engine control unit (ECU) may modify the fuel injection, ignition timing, and other variables by determining the operating zone to guarantee effective performance and emissions compliance.



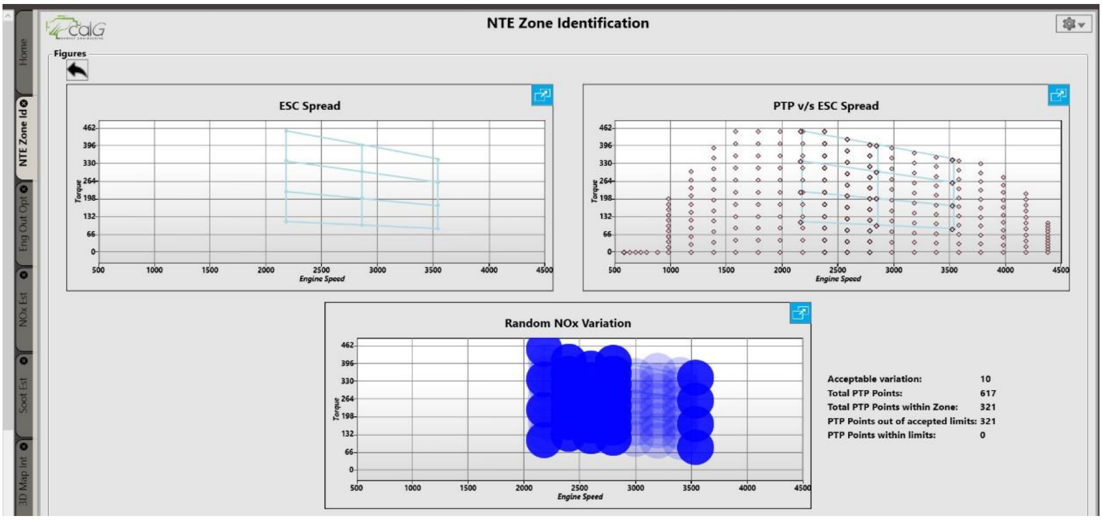
ENGINE OUT IDENTIFICATION:

Engine emissions optimization refers to the technique of reducing harmful pollutants and greenhouse gases emitted by internal combustion engines. In order to maximize the positive environmental benefits of transportation and industry, maintain emission regulations, and improve air quality, it is imperative. Some strategies to improve engine emissions are as follows: Optimizing the emissions production of engines: These comprise the engine test results for the following parameters: air fuel ratio, NOx, PM, main injection timing pressure, fuel pressure, mean effective pressure, power, torque, and speed of the engine. where the results from the CalG data differ in terms of NOx and PM.



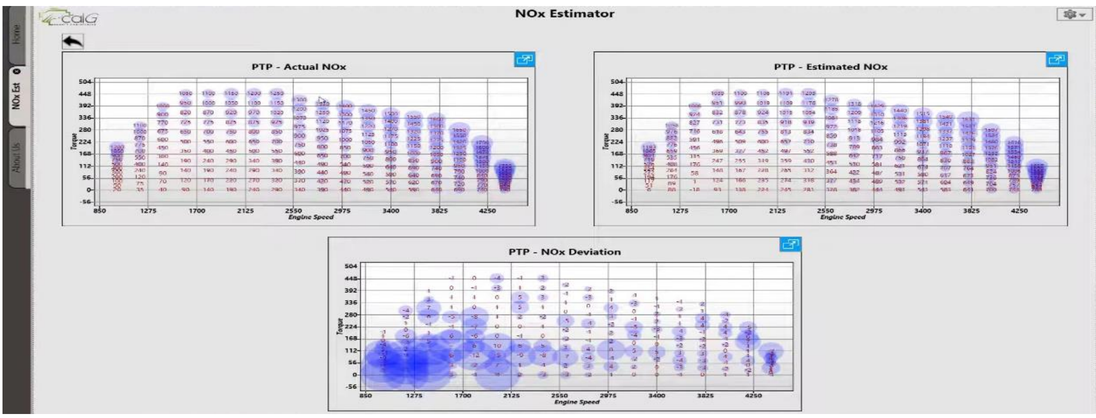
NTE ZONE IDENTIFICATION:

Internal combustion engine NTE (Not-To-Exceed) zone identification is the process of identifying and monitoring the engine's operating circumstances to make sure that it stays within the established emission limits. In the control of emissions from heavy-duty diesel engines, particularly for on-road vehicles, the NTE concept is frequently utilized. In the context of NTE, the "Family Emission Limit" (FEL) curve is used to specify the emission limits for certain pollutants, such as nitrogen oxides (NOx). The FEL curve, which is often written as a function of engine power or torque and engine speed, reflects the maximum allowed emissions for a certain engine family at various operating conditions.



ENGINES OUT NOx ESTIMATOR:

An "engine-out NOx estimator" is a model or algorithm used to predict the amount of nitrogen oxides (NOx) emissions produced by an internal combustion engine before they undergo any aftertreatment processes. It estimates the level of NOx emissions directly from the engine's combustion process, without considering the effects of any emission control devices like selective catalytic reduction (SCR) or exhaust gas recirculation (EGR). The engine-out NOx estimator typically takes into account various engine operating parameters and sensor inputs to make its predictions.

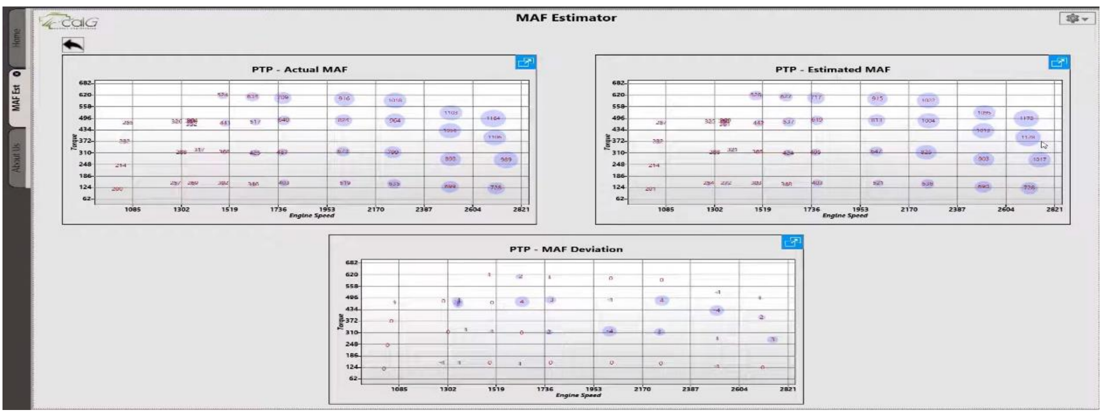


ENGINE OUT SOOT ESTIMATOR:

The amount of soot or particulate matter (PM) emissions produced by an internal combustion engine is estimated using a model or algorithm called a "engine soot out estimator" prior to the use of any aftertreatment techniques. It computes the quantity of soot emissions that come directly from the engine's combustion process, ignoring the effects of any emission control devices, such as diesel particulate filters (DPF) or other exhaust aftertreatment systems.

MASS AIR FLOW METER ESTIMATOR:

The amount of air that will actually reach the engine's intake manifold is predicted in real time using a model or algorithm called a mass air flow (MAF) estimate. It determines the mass flow rate of the incoming air based on many engines operating parameters and sensor inputs. The MAF estimator plays a vital role in the effective functioning of the engine management system by providing essential data for calculating the ideal air-fuel ratio and optimizing engine performance. Under these conditions, the engine control system may not have a separate MAF estimator and the MAF sensor provides a direct measurement. In engines where air flow information is obtained from other sensors (speed-density-based systems), a MAF estimator is required to provide the appropriate air flow input for fuel management.

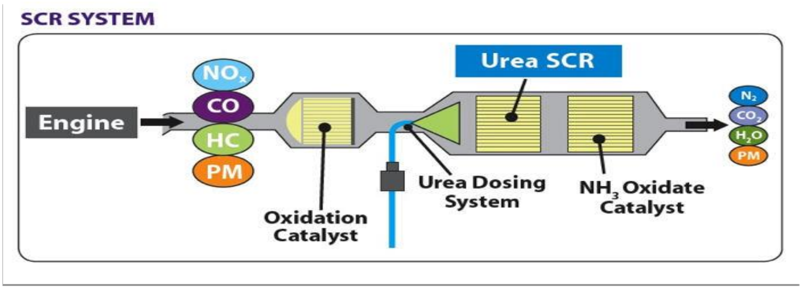


4. AFTER TREATMENT TECHNIQUES:

1.Diesel Oxidation Catalyst (DOC) System The exhaust from the engine initially passes through the DOC, where the exhaust gases are oxidised to reduce carbon monoxide and hydrocarbon emissions. An aftertreatment component called a diesel oxidation catalyst (DOC) is made to change hydrocarbons and carbon monoxide (CO) into carbon dioxide (CO2) and water.

2. Diesel particulate filter is the process designed to capture diesel PM or soot physically produced from diesel engine. It has become one of the most effective technologies for control emissions of diesel soot with the filtration efficiency of exceeding 90%, and it shows good thermal and mechanical durability.

3.Diesel Exhaust Fluid (DEF) Injection The subsequent procedure is known as DEF injection. Nitrous oxide (NOx) is first transformed by injecting DEF, a urea and water mixture, into the exhaust stream. It breaks down into ammonia, water, and carbon dioxide in the hot exhaust. 4.Selective catalytic reduction these standards call for nitrogen oxides (NOx) and particulate matter (PM) to be reduced to almost zero levels. SCR has the ability to cut NOx emissions by up to 90% while also cutting HC and CO emissions by 50% to 90% and PM emissions by 30% to 50%. SCR systems can also be used in conjunction with a diesel particulate filter to reduce PM emissions even more.



5. RESULTS & CONCLUSION

		Emission Standards				
		Current Values	India -Trem V	Europe-V	China-IV	Japan
Steady State	Cycle Nox	2.96	0.4	0.4	3.3	0.4
	Cycle Soot	0.055	0.015	0.015	0.025	0.02
Transient State	Cycle Nox	2.68	0.4	0.4	3.3	0.4
	Cycle Soot	0.054	0.015	0.015	0.025	0.02
		Engine out Values	Engine+After Treatment	Engine+After Treatment	Engine+After Treatment	Engine+After Treatment
	PM		DPF -	DPF -	DPF -	DPF -
	NOx		SCR -	SCR -	SCR -	SCR -
	NOx		LNT -	LNT -	LNT -	LNT -
	CO, HC		CC,DOC	CC,DOC	CC,DOC	CC,DOC

1. A decrease in emissions
2. Adherence to
3. Energy efficiency
4. Advances in technology
5. Long-term viability
6. Performance of the engine
7. Reduced turbo lag
8. Improved torque & power
9. Potential for downsizings
10. Emission controls

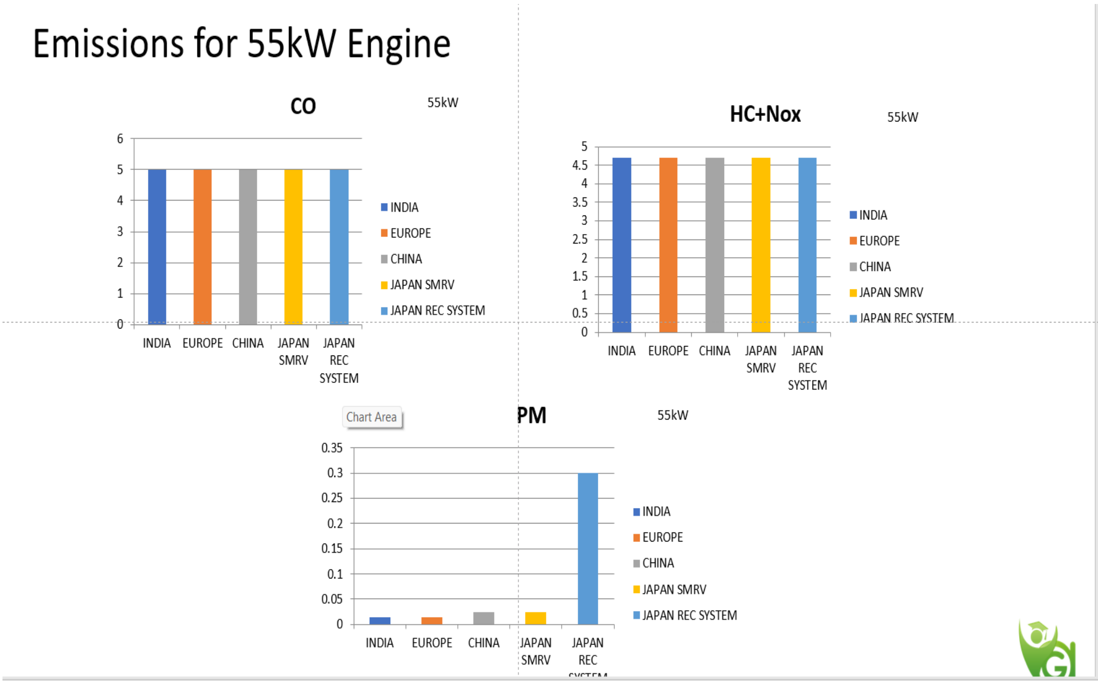
		Emission Standards					
		Current Values	India -Trem V	% reduction required	DPF	SCR	Engine Targets
Steady State	Cycle Nox	2.96	0.4	87%		75%	1.6
	Cycle Soot	0.055	0.015	73%	80%		
Transient State	Cycle Nox	2.68	0.4	85%		75%	1.6
	Cycle Soot	0.054	0.015	72%	80%		
		Engine out Values	Engine+After Treatment	Engine+After Treatment	Engine+After Treatment	Engine+After Treatment	
	PM		DPF -	DPF -	DPF -	DPF -	
	NOx		SCR -	SCR -	SCR -	SCR -	
	NOx		LNT -	LNT -	LNT -	LNT -	
	CO, HC		CC,DOC	CC,DOC	CC,DOC	CC,DOC	

		India -Trem V	DPF	SCR	Engine Targets
Steady State	Cycle Nox	0.4		75%	1.6
	Cycle Soot	0.015	80%		0.075
Transient State	Cycle Nox	0.4		75%	1.6
	Cycle Soot	0.015	80%		0.075
		Engine+After Treatment	Engine+After Treatment	Engine+After Treatment	
	PM	DPF -	DPF -	DPF -	
	NOx	SCR -	SCR -	SCR -	
	NOx	LNT -	LNT -	LNT -	
	CO, HC	CC,DOC	CC,DOC	CC,DOC	

1.The changes will limit particulate matter produced by engines, reducing air pollution. This is important for the environment and our health. A specific status and consideration should be given to agricultural tractors when creating an emission control plan.

2.April 2026 is when Bharat (TREM) V will be adopted, after a 2020 assessment of the EU Stage-V reduction in Europe that is slated to be implemented in 2019.

3.AIS 137 for Agricultural Tractor for TREM IV/TMR V must also be developed. AIS has to address this as soon as possible.



FUTURE SCOPE

These results will be affected from April 1st 2024.The two main pollutants from automobiles, nitrogen oxides (NOx) and particulate matter (PM), have been the focus of regulation in every nation. Comparing the new criteria to the existing norms, the NOx will be reduced by 87% and the PM by 40%. Various factors, such as fuel pressure, intake manifold pressure, fresh mass airflow, main injection timing, and little combustion time and high temperatures within the cylinder create NOx and PM, which may be controlled by adjusting several engine parameters such as Main Injection Timing, Fuel Pressure, Intake Manifold Pressure, Fresh Mass Airflow, and Air Fuel Ratio. Under the chosen emission criteria, the pollutants can be decreased by adjusting these factor.

References

[1] web-based Department of Agricultural and Environmental Sciences, Production, Landscape, Agroenergy, University Deglin Studi di Milano, Via G. Celoria 2, 20133 Milan, Italy

[2] J. Bacenetti et al. (2018) developed a website which is helpful to clarify the significance of these statutory constraints from an environmental perspective. The two tractors under analysis are distinguished by varying engine efficiency and by the production and consumption of urea solution. They are outfitted with the most contemporary emissions savings technology (European Stage IIIA with EGR and European Stage IIIB with SCR). At a test bench, two distinct tractor models—one with SCR and the other with EGR—were used to imitate a ploughing activity.

[3] Parks. et al. (2017) developed the dependability and predictability of an engine model, as well as engine control factors, were assessed for the study's objectives. These findings allowed for a DOE-based analysis and clarification of the diesel engine's intake air and fuel control plan optimization. It was determined which nine engine control settings had an impact on exhaust emissions and fuel consumption. The primary and secondary DOE were divided, and experiments were conducted in

order of effect.
[4] G. Larsson (2011) his research examined three choices for the post-treatment process: a diesel particulate filter (DPF)/diesel oxidation catalyst (DOC) system; a selective catalytic reduction (SCR) catalytic converter; and no retrofit. Two vehicle usage patterns were taken into account: one that matched the average usage of agricultural tractors and the other that followed the legal test cycle, which is utilized for all off-road vehicles.
[5] Cory Walters (2023) in this paper we study fuel economy that results from the EPA's exhaust pollution rules is examined in this article. By statistically analysing field data from a range of tractor drivetrains, sizes, policy tiers, and horsepower, we determine how the emissions standards affect fuel efficiency while accounting for improvements in fuel efficiency made possible by the introduction of the standards.
[6] W. S. Kim et al., (2022) Utilizing an agricultural tractor of the 78-kW class, the study's goal was to determine the engine load factor of significant agricultural operations in order to estimate greenhouse gas emissions and air pollution. CAN (controller area network) connectivity was used to gather engine load statistics. It was RT that had the greatest engine load factor. Ultimately, an integrated engine load factor of 0.63 was determined as a consequence of applying the weight factor for the utilization ratio of agricultural operations.