Fuel Consumption and Emission Tests of the KiTech Hydrogen Fuel Systems Technology

KiTech Knox-40™ Hydrogen Fuel System on Mahindra Blazo X 28– 7.2 Liter Diesel Engine

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About KiTech Hydrogen Systems

KiTech Hydrogen Systems Pte Limited, based in Singapore, is a company devoted to minimizing fossil fuel emissions and fuel consumption through their innovative hybrid fuel technology, which employs patented HHO (Brown Hydrogen) generation systems. Established in 2022, KiTech is a joint venture between Hydrogen Fuel Systems Pty Limited of Australia and Kuber Ventures Global Pte. Limited of Singapore.

For over a decade, our researchers have been actively engaged in designing, developing, and implementing hydrogen fuel systems for various vehicles. The team's primary goal is to reduce emissions and carbon footprints, conserve fuel, and accelerate the transition towards cleaner energy. To achieve this, they consistently create and refine systems that can enhance fuel efficiency and lower emissions for vehicles of various sizes, including earthmovers, without compromising safety or the driving experience.

KiTech's manufacturing facility and laboratory in Pune, India, collaborate with certified research and testing labs to ensure that their work remains relevant and aligned with the rapidly evolving automotive industry.

Our mission & Goal

Our goal is to be a pioneering, top-tier engineering team dedicated to promoting the creation and rapid adoption of secure, eco-friendly, and high-performance technologies and strategies that aid in decreasing emissions and fuel consumption in fossil fuel-powered vehicles and engines around the world.

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Context

KiTech Hydrogen Systems team relies in providing tested and proven technologies to its clients. The team ensured that the testing of the units should less in lab and more in practical conditions that give results that are closer to the real scenario.

While it is a proven through several research across the world, that HHO can help reduce emissions and help reduce fuel consumption, it is critical that KiTech tests its own models and comes out with the true data of emission and fuel reduction.

Vehicle for testing – Mahindra Dumper: Blazo X 28, with Engine of 7200 cc. The engine runs on latest BS6 emission standards as per the regulations of Government of India. The year of manufacturing of the dumper truck is 2022 and age of vehicle when tested is little less than 8 months. Fuel used by the Dumper truck is Diesel.

Vehicle Class: The dumper truck is CLASS 8 vehicle with 28000 Kg as gross vehicle weight (GVW).

Technology

KiTech-HFS™ technology is designed for on-road, off-road and static applications with Class 1 - 9 vehicles, Earthmovers, Static engine applications like Gen Sets and also marine engines. KiTech-HFS™ is a portable, safe and reliable aftermarket unit that produces hydrogen and oxygen (HHO) on demand, from the electrolysis of distilled water. The addition of hydrogen and oxygen gases through the air intake would improve the combustion resulting in a more complete fuel burn which would deliver increased fuel economy, increased torque, lower emissions, and extend engine oil life. The systemruns directly from the vehicles power system providing for high electrical efficiency and shuts off when thetruck key is off.

KiTech produces three versions of KiTech-HFS systems that produce varying level of HHO suitable for different engine sizes. The models Knox-20, 30 and 40 produce upto 2.5 to 8 Liters of HHO per minute even with power consumption of less than 600 watts, while running on a 12V battery system of a vehicle. This is the highest in the industry and opens up potential for higher savings even in very big engines as compared to any other systems tested so far.

1. Knox-20 systems are designed for Class 1 to 3 Vehicles & equivalent engine sizes.
2. Knox-30 systems are designed for Class 4 to 6 vehicles and equivalent engine sizes.
3. Knox-40 systems are designed for Class 7 to 8 vehicles and equivalent engine sizes.
4. For Earthmovers and very big sized engines, 2 Knox-30 or 2 Knox-40 systems should be sufficient* *(Pending field validations)*

Getting Emission & Fuel Savings with HHO

KiTech researchers have reasons to believe that 1:0.5 to 1:1 ratio of HHO against the engine CC is best to give optimal emission & fuel savings. This means a 2.5 Liters engine can get best savings with 1.25 to 2.5 liters of HHO per minute. Any more HHO than that may not bring any further difference to the outcome. KiTech-HFS produce highest HHO with small size and low energy making them stand out as a technology innovation in the field of hybrid hydrogen-based fuel system technologies.

Our research reveals four stages of fuel and emission reduction for any on-road vehicle. If all these stages are followed, it will lead to optimal savings of any vehicle.

1. Using HHO from KiTech-HFS unit – The first and highest savings are achieved with this stage. Our test results done for Class 1-3 vehicle (GM – Chevrolet Tavera 2499cc Diesel Engine) has shown average 40% of fuel savings in a real-life conditions on the roads of Pune.

2. Decarbonizing the engine – Engines typically are carbonized as they run. While most engine manufacturers do not specifically ask for this, it is advisable to decarbonize the engines after every 30,000 km to restore the milage and driving comfort. With KiTech-HFS the engines automatically decarbonize within 30 to 60 days of vehicle running and remains decarbonized thereafter. It is expected to get more savings on fuel and emission after 60 days of KiTech-HFS in operation on the vehicle.

3. Nozzle cleaning – With Diesel engines, nozzle cleaning can give another small savings as decarbonization does not cover the fuel nozzles. While there are fuel additives to aid this outcome, the same can be done while engine maintenance in any garage. For petrol engines, this part is not applicable.

4. Using Electronic Fuel Enhancer – This electronic component alters the fuel injection pattern based on HHO usage and can further give fuel and emission reduction of 2 to 7%. Careful and better driving style after HHO unit installation can also give similar savings as HHO improves the power of the engine. KiTech is in the process of making the Fuel Enhancer and does not supply that yet.

Understanding Greenhouse Emission, impact, and measurements

Greenhouse gas emissions in 2019 totalled 51.8 $GtCO_2e$, comprised primarily of CO_2 (72%), with substantial contributions from methane (19%), nitrous oxide (6%), and fluorinated gases (3%). These emissions originated from various sources, including coal (39%), oil (34%), gas (21%), cement (4%), and others (1.5%).
CO_2, the most dominant greenhouse gas, is significantly emitted by fossil fuel consumption (89%) and cement production (4%). Deforestation, wildfires, and non-energy uses of fuel also contribute.
Methane (Hydrocarbon), with a high short-term global warming potential, is largely emitted from fossil fuels (32%) and livestock (28%). Similarly, NO_x (Nitrous oxide), having a global warming potential 265 times greater than CO_2, is emitted mostly by agriculture (56%) and fossil fuel combustion (18%).
Fluorinated gases, used in industries like semiconductor manufacture and aluminium production, and hydrogen leakages, also contribute to global warming. On the other hand, green hydrogen can mitigate emissions by replacing fossil-based fuels.
Black carbon (Particulate matter), a by-product of incomplete combustion, isn't a greenhouse gas but influences climate by absorbing sunlight and reducing albedo. Measures to mitigate these emissions are critical for achieving climate goals.

Atmosphere consists of 78.08 percent nitrogen, 20.95 percent oxygen, and 0.93 percent argon. A brew of trace gases accounts for the other approximately 0.05 percent, including the greenhouse gases carbon dioxide (0.04%), and 0.01% constituting of methane, nitrous oxide and ozone. With increase of CO_2, Nitrous Oxide and methane, the impact on climate change can be significant affecting the delicate balance of the earth impacting health, wellbeing, food security, water levels and even endangering the existence of life on earth.

The emission test conducted checks the difference between the gases that were emitted while testing the baseline and the gases when K40 was installed and running on the vehicle. In case of Carbon dioxide the real method of measurement has to be done by eliminating the carbon dioxide that is already present in the atmosphere.

As per the scientific data, CO2 is a trace gas in Earth's atmosphere at 421 parts per million (ppm), or about 0.04% by volume (as of May 2022), having risen from pre-industrial levels of 280 ppm. Therefore while assessing the results of the emission, we need to check the net addition of CO2 in the process of running engine and burning fossil fuel before and after K40 system on the vehicle to get accurate CO2 reduction in percentage.

Methodology

Test site

KiTech testing team decided to conduct the milage test on real time traffic in the Indian City of Pune. This was done to ensure that realistic outcomes on fuel savings are achieved as static lab tests might give better results and may not reflect real driving conditions.

City of Pune with a population of more than 7 million is one of the large cities in India and good traffic conditions in city allows average driving speed of 20 km per hour for a dumper truck while on surrounding highways average speed can be average of 20 km per hour. On intercity highways the speed can be more than 40 km/hr. The load condition of the vehicle will determine the speed of the vehicle.

Milage tests were done by driving the vehicle from Industrial town to Chakan to the center of the city, 30KM approximately. The dumper tested had modern fuel tracking system in place that gave us realistic data on fuel savings and milage. The baseline milage of the vehicle was taken with multiple averages over the days of the vehicle in operation and ensuring that the same matches with the average given by the vehicle under no load condition. We got milage report for the day from which we could calculate the real milage without K40 system.

Emission testing was done as per lab recommendations in the workshop for 4 different RPM. Higher than 1750 RPM was cut down by the intelligent system of the vehicle and therefore more than 1750 rpm was not possible to be taken in idle condition for the vehicle.

Test vehicles

Vehicle configurations are presented in Table 1. Figures 2 and 3 present photos of the test vehicle.

Table 1. Vehicle data

Parameters	***Test vehicle***
Vehicle Class	Class 8
Vehicle ID	MH 12 UM 2349 (Indian registration)
Make and model	Mahindra – Blazo X 28
Build year (model year)	2022 (2022)
Engine make and model	mPower 7.2 litre FuelSmart Eaton
Emission label info	BS 6
Rated power	206 kW @ 2200 r/min
Peak torque	1050 Nm @ 1200-1700 r/min
Transmission	Automatic - 6 Speed Gear Box
Tires	Tubeless
Tire pressure (cold)	35 psi
Test Weight	28000 Kg.
Battery Rating	24 V (2 12v Batteries)

Kitech - Knox 40 Hydrogen Fuel systems

Kitech has complete prototype of the systems in place that were put for the purpose of testing. The products are part of the lab setup where Kitech develops its new products. The same system will be manufactured at a later date and the system installation will be more presentable. The system generated HHO was pushed into the engine by inserting the HHO tube into Air Intake immediately after the Air Filter.

Figure 1. Test vehicle - Front

Figure 2. Test Vehicle - Side.

Fuel consumption test procedure

The test procedure was based on actual service conditions: this applies to real traffic and road conditions, load, weather, wind, etc.

Milage tests were done by driving the vehicle from within city to the industrial town of Chakan in Pune (India) for baseline and with K40 HHO testing was on return journey. Vehicle automated fuel and milage tracking system was used to track the distance travelled and milage. The data was taken from the vehicle service center where entire vehicle history is tracked and stored. Conditions of test were real life with no variation from the real-life driving conditions of a vehicle within the city with moderate traffic. Vehicle was test driven by one driver who normally drove that vehicle and were familiar with the vehicle functioning and could authentically tell the difference in driving experience before and after the tests.

Vehicle Driver – Mayur Shinde. The driver was accompanied with KiTech expert, Mangesh Bhalekar.

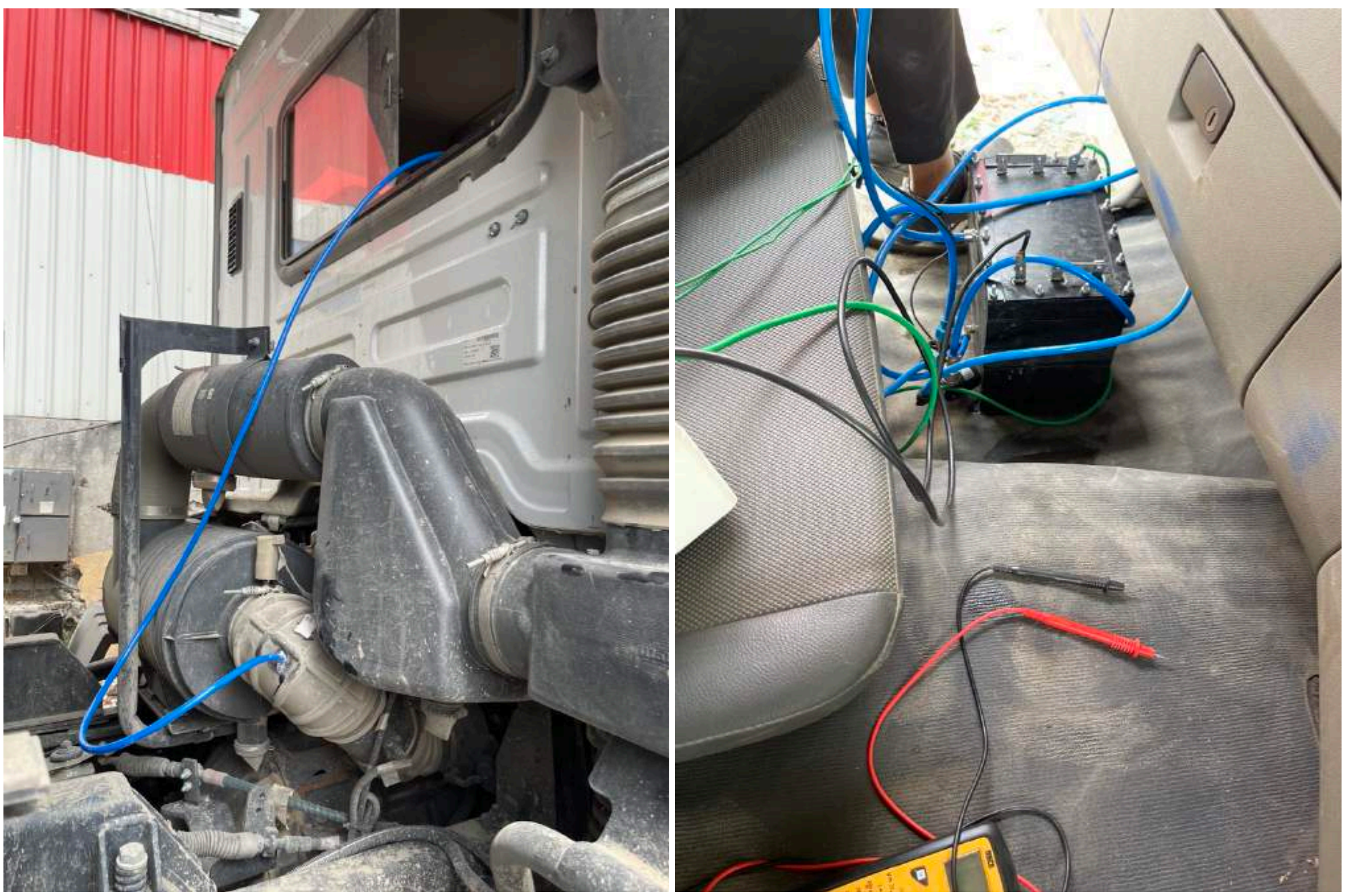


Figure 3. Installation of the test setup – K40 on the vehicle.

Emissions measurement procedure

Emission test on the vehicle was conducted with one unit of KiTech Hydrogen Fuel Systems. The K40 system that is designed for Class 8 & 9 commercial vehicles.

K40 system tested Hydrogen generation range varies from 3.5 liters to 6 Liters per minute. On running vehicle, we can safely assume the average Hydrogen generation to be 4.5 Liters per minutes.

Emission Testing collection partner "**Tulsi Environmental Services & Consultant**" and Test Lab Partner – "**Neetal Laboratories and Environmental Services Private Limited**" ***(Certifications part of Annexure)*** based out of Pune was chosen to do emission testing of the vehicle under different RPM as well as by running the vehicle without any HHO, running without K40 installed and running with K40 installed. The company, Tulsi collects the test samples from the sites and the samples are tested and report released from Neetal labs are certified by Central Pollution Control Board to conduct emission tests and release reports. They are also ISO/IEC 17025:2017 certified that refers to 'General requirements for the competence of testing and calibration laboratories'.

The purpose of this emission test is to check on the following two objectives:

1. Will there be emission reduction on the vehicle by using K40 system?
2. Does increasing the HHO level by almost two times using the K30 model will bring further positive change in overall emission over K20?

Figure 4. Emissions measurement preparation

Test equipment

The following equipment was used during the tests:

07) Instrument Details	**Make/ Model No.**	**Shree Scientfic and Calibration /SEM-150,220508**
	Lab ID	**NLES/Lab/Inst/01**
	Calibration Date	**Calibration on:11/05/2022, Due On:10/05/2023**

Figure 5. Emission testing equipment in operation

K40 Installation on vehicle remained same as that of the time fuel testing setup with Tank, Bubbler, power supply and electrolyser in the driver’s cabin.

Test results – Fuel Consumption

Fuel consumption test results

Fuel efficiency tests were conducted with K40 model on the 7.2 Liter diesel engine. K40 is designed for Class 8 vehicles.

Fuel savings with KiTech Systems depend on various factors. The key 4 factors that bring optimal savings are

1. Supply of HHO gas in the engine (Key factor)
2. Engine decarbonization (over sustained running for 30 to 60 days on Kitech Systems)
3. Electronic Fuel Enhancer (Optional item)
4. Diesel spay nozzle cleaning (Done while servicing the engine)

This test was done with the Key factor of supply of HHO in the engine in optimal quantity.

The following results were obtained for K40 Models of KiTech on Mahindra Blazo X 28:

- On Highway with average speed of 23 Km/ Hour (see Evidence below):
    - Fuel savings With K40: **32%**

Fuel savings obtained were based on the system generated data of the truck which was monitored by the service centre. Key data points that went into the calculation of the fuel consumption and savings were as follows:

Table 2. Summary of test results: On mid traffic drive in city of Pune – India

(Average speed 27km/hr for with K40 and without K40)

Calculation Parameter	Readings	Evidence
Total Distance travelled	84 km @ 2.5 km/lit	Fig E 1
Total Fuel Consumed	33.6 Lit	
Total fuel spent in Idling during Test	1.24 Lit	Table 3
Total Fuel consumed while running	33.6 - 1.24 ie. 32.36 Lit	
With K40 - Total Travel	30 Km @ 3.13 Km/ Lit	Fig E 2
Total fuel consumed	9.59 Lit	
Balance travel without K40	54 km *(84-30)*	
54 Km without K40 travelled in	22.77 Lit *(33.6 - 9.59 - 1.24)*	
Average fuel efficiency without K40	2.37 km/ lit. *(54/22.77)*	
Additional Milage - K40 vs Without K40	0.759 km/ Lit *(3.13-2.37)*	
Fuel Saving efficiency	32% *(0.759/2.37)*	
Savings on fuel in real driving conditions with K40	**32%**	

Evidences

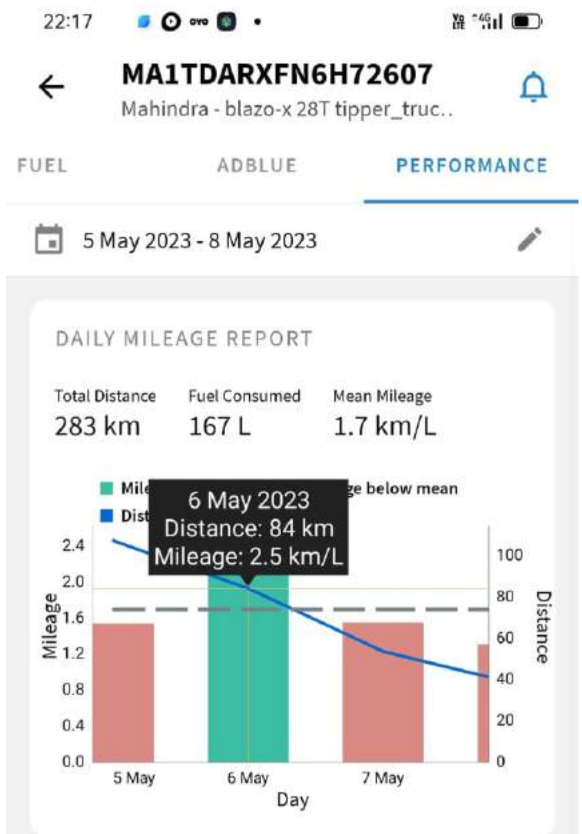


Fig: E 1 Full day Data from the vehicle on test date of 6th May 2023 (Note above average milage on this date vs. other dates)

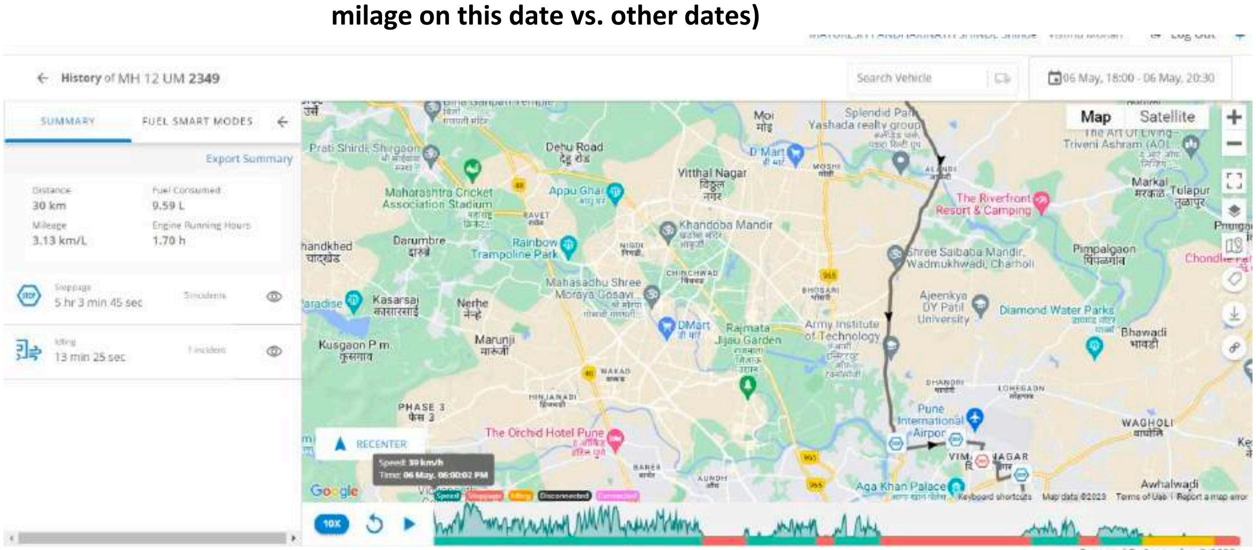


Figure E 2 - With K40 – Journey travel data on 6th May 2023

Table 3 - Idling Data while emission testing on 6th May 2023

Sr. No.	Violation Type	Vehicle	Idling Time (min)	Fuel Consumed (Lt)	From Date	To Date
1	Idling	MH12UM2349	16	0.86	May 06 2023 11:41 am	May 06 2023 11:57 am
2	Idling	MH12UM2349	7	0.38	May 06 2023 11:18 am	May 06 2023 11:25 am

Fuel efficiency of any heavy vehicle will vary with several factors like average speed, load, driving style and terrain. The test conducted tried to keep conditions of the truck and driving conditions similar. The truck was empty for the entire duration of the testing and operated with its base load of 28000 KG. These tests have been performed without using a DC power supply and Fuel Enhancer that could have given better average theoretically. Engine decarbonization takes place within 30 to 60 days of the vehicle regular running on HHO system will further improve the fuel average of the engine.
The ARAI Tests on claim to get 4 to 5 km per liter for this vehicle in empty condition running on a test track, but the historical data of this vehicle that was tested, has given an average of 1.71 km/ lit in last six months of its operation. Thereby having access to real data overrides the data of ARAI that is done on ideal testing setup of a new vehicle.

The outcome proves that use of Knox-40* on Class 8 vehicle can give about 32% additional milage on trucks operating in similar conditions of 7.2 Lit engine capacity.

Note: *The actual production of Hydrogen in this test was significantly below its capacity as the vehicle operated on a 24 volt system and taking direct power from battery reduced the required voltage from 12.7 to 11.4 volts. This resulted in about 25% less Hydrogen generation to approximately 3 to 4 lit/ min for most part of the milage test. Even with this reduced capacity, the savings were significant. Test team is confident of getting better results in fully ready system.*

**(Prototype Knox-40 produces 3.5 to 6 Liters/ min of Hydrogen under real-life conditions.)*

Test Results - Emissions

Process of engine emission

When fuel burns in a diesel engine, both carbon monoxide (CO) and carbon dioxide (CO_2) are produced as by-products. The combustion process in a diesel engine involves the reaction between the hydrocarbon fuel and oxygen in the air, which leads to the formation of water (H_2O), CO, CO_2, and other compounds, including nitrogen oxides (NO_x) and particulate matter (PM). Ideally, complete combustion of the fuel would result in only CO_2 and water as by-products. However, real-world combustion processes are not perfect, and several factors can lead to the formation of CO and other emissions:

1. Incomplete combustion: Insufficient oxygen, poor fuel atomization, or inadequate mixing of air and fuel can result in incomplete combustion. This can cause some of the carbon in the fuel to combine with a smaller amount of oxygen, forming CO instead of CO_2.
2. Cold-start conditions: When a diesel engine is cold, the combustion process may not be as efficient, leading to the production of more CO and other pollutants.
3. Engine operating conditions: Different engine operating conditions, such as idling or high-load situations, can affect the combustion process and the balance of CO and CO_2 emissions.

While CO_2 is a significant greenhouse gas and contributes to global warming, CO is a toxic gas that can be harmful to human health. Diesel engines are designed to minimize the production of CO and other harmful emissions by optimizing combustion, fuel injection, and exhaust after-treatment systems. Modern diesel engines are equipped with advanced emission control systems, such as diesel particulate filters (DPFs) and selective catalytic reduction (SCR) systems, to further reduce CO, NO_x, and PM emissions.

Impact of HHO on Emission

Introducing HHO (hydrogen-oxygen gas mixture, also known as oxyhydrogen or Brown's Gas) into an internal combustion engine like that with KiTech Hydrogen Fuel Systems, can improve fuel efficiency and reduce emissions. This is due to the following reasons:

1. Improved combustion efficiency: HHO has a higher flame speed and lower ignition energy than conventional fuels, such as gasoline or diesel. When HHO is mixed with the air-fuel mixture in the engine, it can enhance the combustion process, leading to a more complete burning of the fuel. As a result, the engine can extract more energy from the same amount of fuel, improving its efficiency.

2. Reduction in harmful emissions: Since the combustion process becomes more complete with the introduction of HHO, fewer unburned hydrocarbons and partially oxidized compounds, such as carbon monoxide (CO), are produced. Furthermore, the hydrogen in HHO reacts with oxygen during combustion to produce water (H_2O) as its primary byproduct instead of carbon dioxide (CO_2). This can lead to a reduction in CO_2 and CO emissions.

3. Lower combustion temperature: The addition of HHO can result in a lower overall combustion temperature. This can help to reduce the formation of nitrogen oxides (NO_x), which are harmful pollutants that form at high temperatures.

4. Reduction in particulate matter: In diesel engines, HHO can help to improve the atomization of the fuel, leading to smaller fuel droplets and better mixing with air. This can lead to more complete combustion, reducing the amount of particulate matter (PM) produced during the combustion process.

It is important to note that while introducing HHO into an engine can potentially improve fuel efficiency and reduce emissions. HHO as an efficiency and emission reduction strategy can vary depending on the specific engine type, setup, and operating conditions.

Table 4 presents the results of emissions measurement.

Tests were done with one model of KiTech Hydrogen Fuel Systems. The K40 model which delivers hydrogen between 3.5 to 6 Liters per minute and is designed for Class 8 commercial vehicles.

On an engine capacity of 7200cc the hydrogen input of about 3.5 liters/ min What happens to emission if Hydrogen supply is 1:0.5. The following table shows the impact of emission reduction.

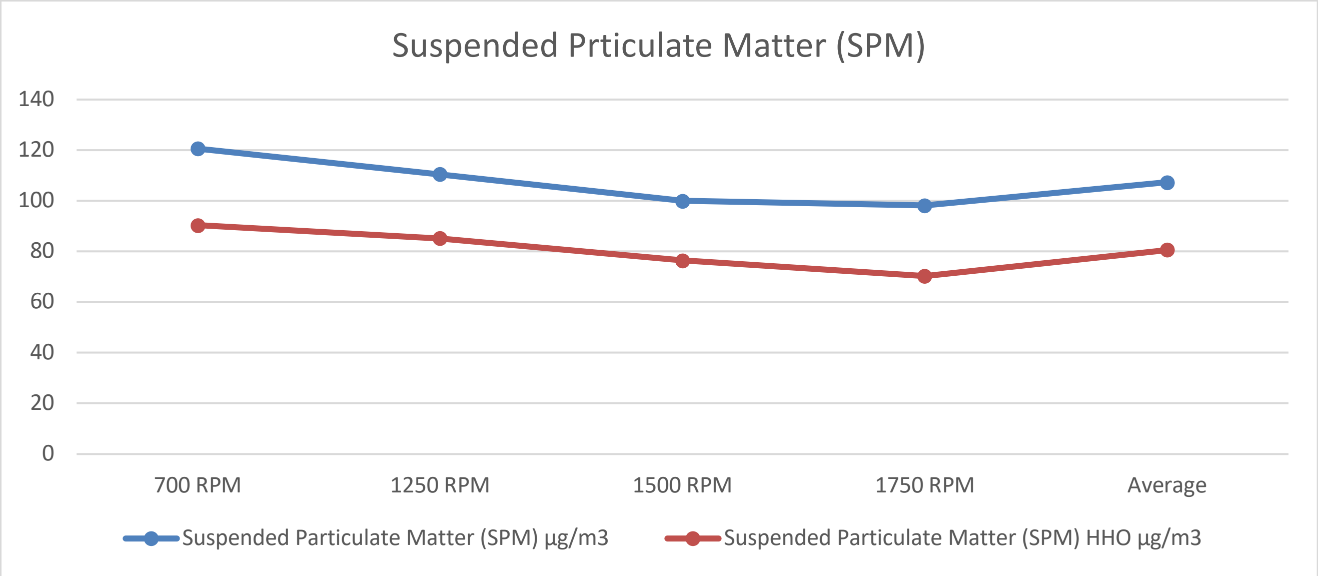
The results are showing significant decreases in emission levels between baseline and final measurements. K40 system in optimal operation can give better savings than what is achieved.

Summary of emissions measurement results for test vehicle on 6th May-2023

Table 4 - Emission test results – Baseline Operation on Diesel without K40							
Sl. No.	Parameter	UOM	Results				
			700 RPM	1250 RPM	1500 RPM	1750 RPM	Average
1	Suspended Particulate Matter (SPM)	µg/m3	120.6	110.4	100.02	98.2	107.305
2	Hydrocarbons (HC)	µg/m3	0.45	0.4	0.38	0.34	0.3925
3	Oxides of Nitrogen (Nox)	mg/m3	0.26	0.254	0.246	0.24	0.25
4	Carbon Dioxide (CO2)	mg/m3	680.63	674.54	670.5	668.43	673.525
5	Carbon Monoxide (CO)	µg/m3	0.812	0.789	0.772	0.769	0.7855

Table 5 - Emission test results - 7200 cc Diesel Engine Operation with K40								
Sl. No.	Parameter	UOM	Results					
			700 RPM	1250 RPM	1500 RPM	1750 RPM	Average	Average % Reduction
1	Suspended Particulate Matter (SPM)	µg/m3	90.4	85.2	76.5	70.3	80.6	25%
2	Hydrocarbons (HC)	µg/m3	0.25	0.2	0.17	0.12	0.185	53%
3	Oxides of Nitrogen (NOx)	mg/m3	0.234	0.229	0.223	0.219	0.22625	10%
4	Carbon Dioxide (CO2)	mg/m3	556.6	542.3	528.4	514.6	535.475	20%
5	Carbon Monoxide (CO)	µg/m3	0.43	0.39	0.368	0.349	0.38425	51%

Table 6- Suspended Particulate Matter (SPM) comparison - 7200 cc Diesel Engine without & with K40							
Sl. No.	Parameter	UOM	Results				
			700 RPM	1250 RPM	1500 RPM	1750 RPM	Average
1	Suspended Particulate Matter (SPM) without K40 (Baseline)	µg/m3	120.6	110.4	100.02	98.2	107.305
2	Suspended Particulate Matter (SPM) with K40	µg/m3	90.4	85.2	76.5	70.3	80.6
3	% Reduction		25%	23%	24%	28%	25%



Induction of HHO (hydrogen-oxygen gas mixture) into an internal combustion engine can lead to a significant reduction in Suspended Particulate Matter (SPM) emissions. This is due to the following reasons:

1. Improved combustion efficiency: Introducing HHO into the engine can enhance the combustion process, leading to more complete burning of the fuel. With a more efficient combustion, the amount of unburned or partially burned fuel particles that form SPM is reduced.
2. Better fuel atomization: In diesel engines, HHO can help to improve the atomization of the fuel, leading to smaller fuel droplets and better mixing with air. Smaller fuel droplets have a higher surface area to volume ratio, which allows for more efficient and complete combustion. As a result, the formation of SPM is reduced.
3. Hydrogen as a combustion enhancer: When HHO is introduced into the engine, the hydrogen in the mixture reacts with oxygen during combustion. This reaction produces water (H2O) as its primary by-product, which can help to reduce the peak combustion temperature. Lower combustion temperatures can lead to a reduction in the formation of particulate matter.
4. Reduction of soot formation: The presence of hydrogen in HHO can help to reduce soot formation during combustion. Hydrogen can react with soot particles or their precursors, promoting their oxidation to less harmful gaseous compounds, which can result in a reduction of SPM emissions.

Table 7 - Hydrocarbons (HC) comparison - 7200 cc Diesel Engine without & with K40

Sl.No.	Parameter	UOM	Results				
			700 RPM	1250 RPM	1500 RPM	1750 RPM	Average
1	Hydrocarbons (HC) without K40 (Baseline)	µg/m3	0.45	0.4	0.38	0.34	0.3925
2	Hydrocarbons (HC) - With K40	µg/m3	0.25	0.2	0.17	0.12	0.185
3	% Reduction		44%	50%	55%	65%	53%

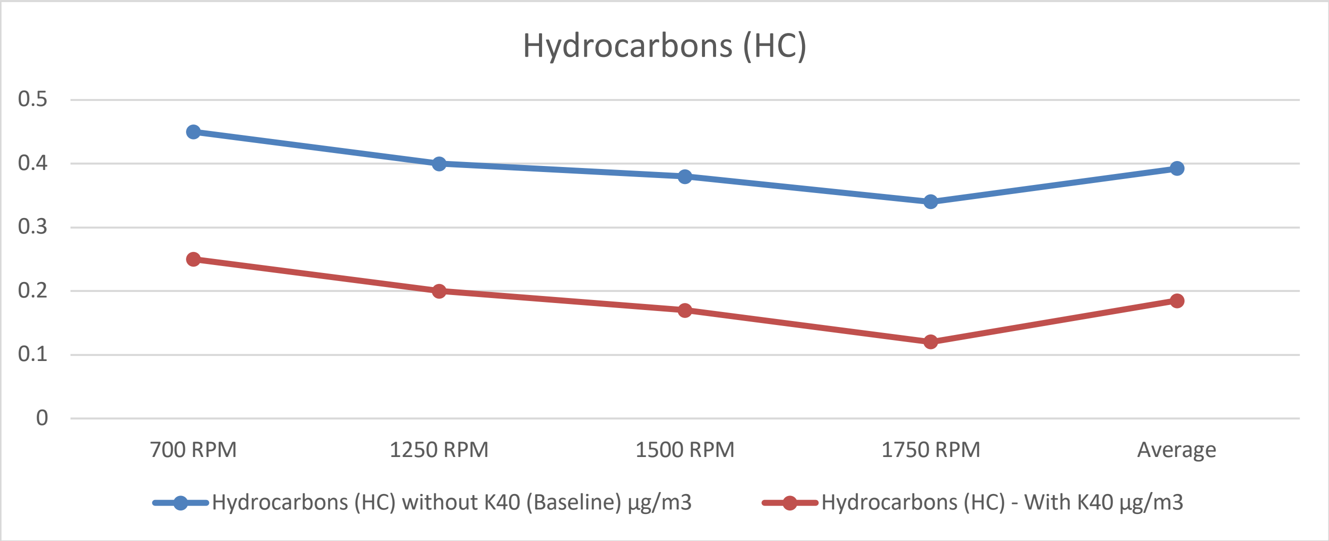
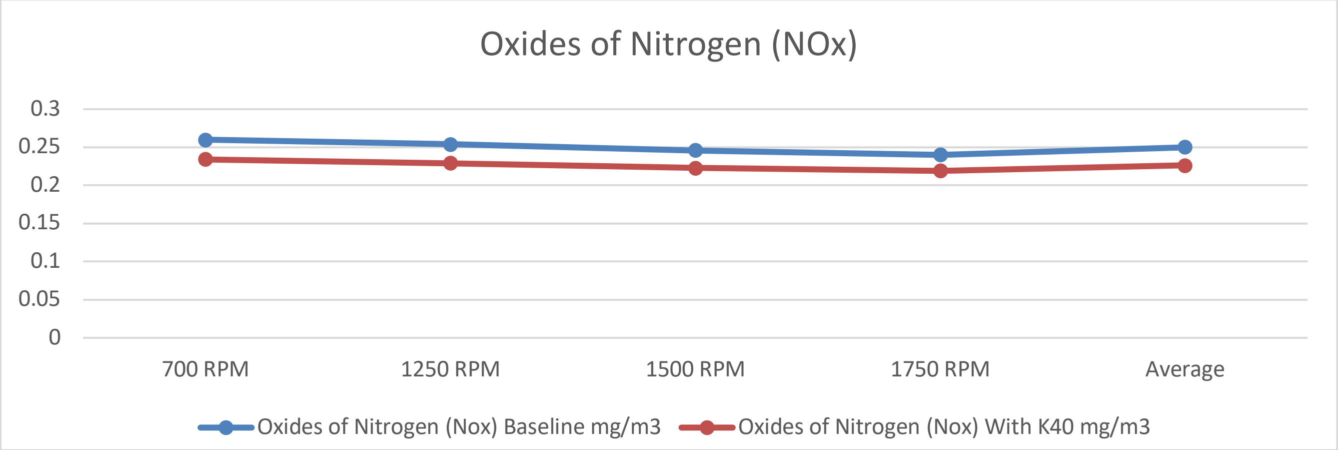


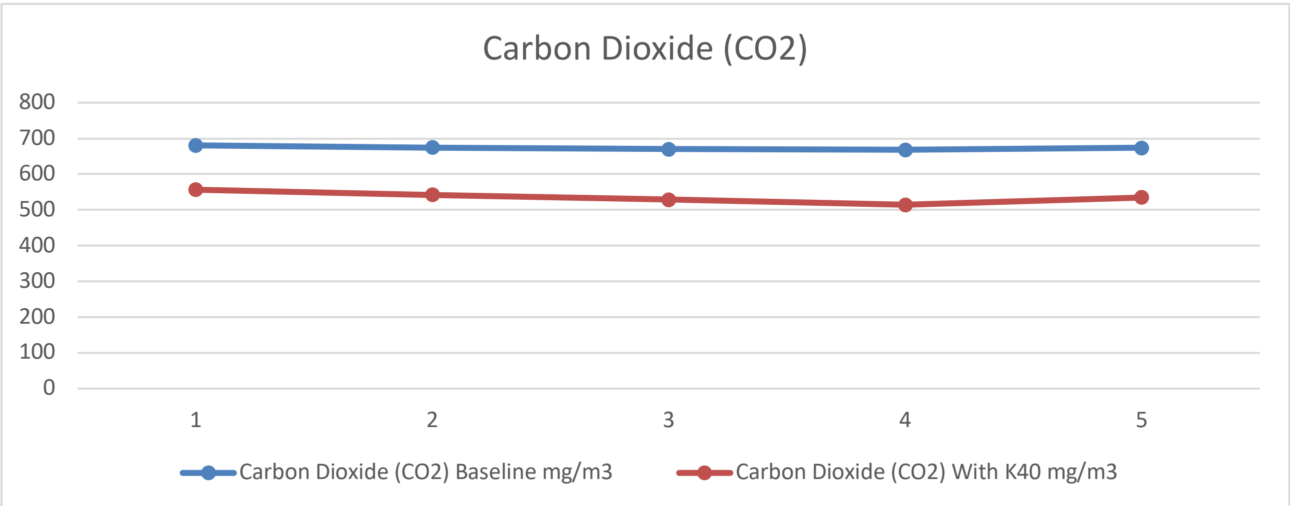
Table 8 - Oxides of Nitrogen (NOx) comparison - 7200 cc Diesel Engine without & with K40							
Sl. No.	Parameter	UOM	Results				
			700 RPM	1250 RPM	1500 RPM	1750 RPM	Average
1	Oxides of Nitrogen (Nox) Baseline	mg/m3	0.26	0.254	0.246	0.24	0.25
2	Oxides of Nitrogen (Nox) with K40	mg/m3	0.234	0.229	0.223	0.219	0.22625
3	% Reduction		10%	10%	9%	9%	10%



Induction of HHO (hydrogen-oxygen gas mixture) into an internal combustion engine can lead to a significant reduction in Oxides of Nitrogen (NOx) emissions. This is due to the following reasons:

1. Lower combustion temperatures: The presence of hydrogen in the HHO mixture can help reduce the peak combustion temperature. The formation of NOx is highly temperature-dependent, as it occurs when nitrogen and oxygen in the air react at high temperatures. By reducing the peak combustion temperature, the rate of NOx formation is decreased.
2. Hydrogen as a combustion enhancer: The hydrogen in HHO improves combustion efficiency by increasing the flame speed and promoting a more complete burning of the fuel. This results in a more uniform and controlled combustion process, which can contribute to a reduction in NOx emissions.
3. Exhaust gas recirculation (EGR) effect: When HHO is introduced into the engine, the water produced during combustion can have a similar effect to exhaust gas recirculation (EGR). The water vapor dilutes the combustion mixture, absorbs heat, and lowers the combustion temperature. This helps to reduce the formation of NOx emissions.
4. Better fuel atomization: In diesel engines, the introduction of HHO can improve fuel atomization, leading to smaller fuel droplets and better mixing with air. This allows for a more controlled and efficient combustion process, which can contribute to a reduction in NOx emissions.
5. Reduction in oxygen concentration: The hydrogen in HHO reacts with oxygen during combustion, which can lead to a reduction in the local oxygen concentration within the combustion chamber. This can help to decrease the rate of NOx formation.

Table 9 - Carbon Dioxide (CO2) comparison - 7200 cc Diesel Engine without & with K40							
Sl. No.	Parameter	UOM	Results				
			700 RPM	1250 RPM	1500 RPM	1750 RPM	Average
1	Carbon Dioxide (CO2) Baseline	mg/m3	680.63	674.54	670.5	668.43	673.525
2	Carbon Dioxide (CO2) with K40	mg/m3	556.6	542.3	528.4	514.6	535.475
3	% Reduction		18%	20%	21%	23%	20%
4	% Net addition Reduction (421 mg/m3 CO2 in atmosphere goes in the engine)		48%	52%	57%	62%	55%



Reduction of Carbon Dioxide getting added in the atmosphere is average of 51% when K40 is used on the vehicle. This percentage reduction comes from the assumption that 421mg/m3 is the CO2 already present in the atmosphere and it simply gets sucked in along with air when engine is running. For a net zero carbon dioxide addition, the amount of CO2 should remain at 421mg/m3. Therefore only the incremental addon in baseline and with K40 is taken to come to 51% of average savings which is more meaningful for emission control targets.
K40 cuts Carbon dioxide addition in the atmosphere by 51% as per this test result.

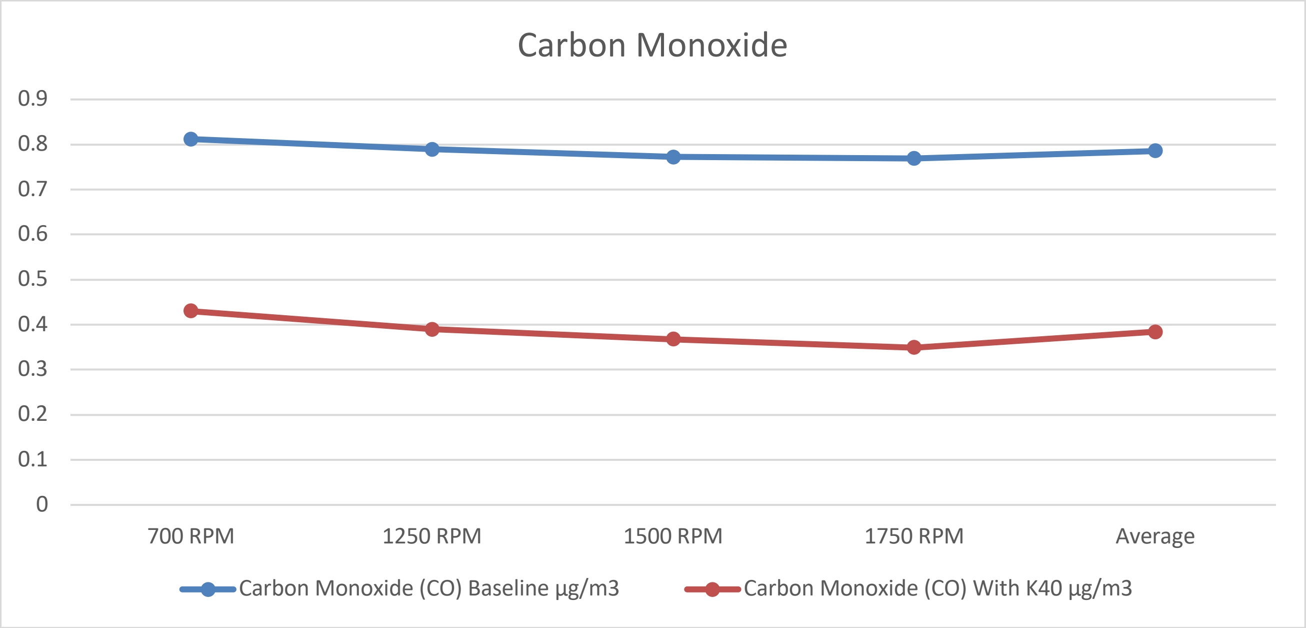
Induction of HHO (hydrogen-oxygen gas mixture) into an internal combustion engine can lead to a reduction in Carbon Dioxide (CO2) emissions. This is due to the following reasons:

1. Improved combustion efficiency: Introducing HHO into the engine can enhance the combustion process, leading to more complete burning of the fuel. More efficient combustion means that less fuel is needed to produce the same amount of power, which in turn results in reduced CO2 emissions.
2. Hydrogen as a combustion enhancer: The hydrogen in HHO reacts with oxygen during combustion, producing water (H2O) as its primary byproduct instead of CO2. Since a portion of the fuel is replaced by hydrogen, the overall production of CO2 is reduced.

3. Better fuel atomization: In diesel engines, HHO can help to improve the atomization of the fuel, leading to smaller fuel droplets and better mixing with air. Smaller fuel droplets have a higher surface area to volume ratio, which allows for more efficient and complete combustion. This can lead to a reduction in the amount of fuel consumed and, consequently, a decrease in CO_2 emissions.
4. Reduction in engine load: The introduction of HHO can result in a more efficient combustion process, providing additional power and torque to the engine. This can help reduce the engine load, enabling it to operate at a more efficient point in its operating range and thereby reducing CO_2 emissions.

Table 10 - Carbon Monoxide (CO) comparison - 7200 cc Diesel Engine without & with K40

Sl. No.	Parameter	UOM	Results				
			700 RPM	1250 RPM	1500 RPM	1750 RPM	Average
1	Carbon Monoxide (CO) Baseline	µg/m3	0.812	0.789	0.772	0.769	0.7855
2	Carbon Monoxide (CO) with K40	µg/m3	0.43	0.39	0.368	0.349	0.38425
3	% Reduction		47%	51%	52%	55%	51%



Induction of HHO (hydrogen-oxygen gas mixture) in a controlled manner into an internal combustion engine can lead to a significant reduction in Carbon Monoxide (CO) emissions. This is due to the following reasons:

1. Improved combustion efficiency: Introducing HHO into the engine enhances the combustion process, leading to more complete burning of the fuel. Carbon Monoxide is primarily formed due to incomplete combustion of the fuel. When combustion efficiency is improved with HHO, more fuel is converted into carbon dioxide (CO_2) and water (H_2O), leaving less unburned fuel that could form CO.
2. Hydrogen, acting as a combustion enhancer in HHO, increases flame speed and promotes more complete, uniform fuel burning while having a lower ignition energy and a wider flammability range compared to hydrocarbon fuels, which enables it to ignite more easily and burn more quickly, thereby ensuring a more efficient combustion process that reduces CO emissions as more of the fuel is fully oxidized to CO_2.
3. Better fuel atomization: In diesel engines, the introduction of HHO can improve fuel atomization, leading to smaller fuel droplets and better mixing with air. Smaller fuel droplets have a higher surface area to volume ratio, which allows for more efficient and complete combustion, leading to reduced CO emissions.
4. Leaner air-fuel mixture: The addition of hydrogen and oxygen from HHO can lead to a leaner air-fuel mixture in the combustion chamber. Leaner mixtures tend to have more available oxygen, which promotes more complete combustion and reduces the likelihood of CO formation and eventually CO_2 formation also.

Mr. Mayur Shinde (Driver) and Mr. Mangesh Bhalekar (Testing expert from KiTech)

Driving Experience

Mayur Shinde (Driver) supported by Mr. Mangesh Bhalekar from KiTech drove the vehicle most of the time during the test procedure. Mr. Mayur Shinde reported the following improvement in the driving experience:

1. Engine sound was lower than normal. Engine was quieter.
2. General vibration caused by engine in baseline testing was lower while the vehicle was tested with K40.
3. Engine power appeared better and the pickup and climbing gradients appeared easier than in baseline.
4. There was no negative driving experience during driving to report.
5. The fuel measurement dial clearly showed significantly better fuel efficiency that is not generally seen in normal day to day driving.

Summary

Table 11 presents the fuel consumption and emission reduction test results obtained for the Hydrogen Fuel System, Knox-40 (K40) technology from KiTech Hydrogen Systems, expressed for the confidence level of 95%. Any variation to the fuel saving test result will be the result of changed conditions of traffic, load or vehicle condition. The test was conducted in real life traffic and highway condition while the emission test was done in the workshop as per the recommendations of the emission testing lab.

Table 11. Summary of test results

Fuel Improvement – Using K40 on Mahindra Blazo X 28 (7.2 Lit Diesel Engine) BS 6 Emission standard	
Test Segment	**Pune City drive (23 km/hr average speed)**
Test date	**May 6th 2023**
Fuel savings with K40	32.00%
Emission Improvement using K40	
Parameter	**K40 - % Improvement (Average between 750 to 1750 rpm)**
Suspended Particulate Matter (SPM)	24.89%
HC (Hydrocarbons)	52.87%
Oxides of Nitrogen (NOx)	9.50%
Carbon Dioxide (CO2) - Net added reduction	55.00%
Carbon Monoxides (CO)	51.08%

Significant emission reductions observed as per the recorded data.

Disclaimer

This outcome pertains exclusively to the vehicle and specific technology sample tested, following the procedures and conditions outlined in this report. KiTech cannot assure that these results will be reproducible under specific operating conditions.

Annexure

Neetal
An ISO 9001 & 45001 Certified Company

NEETAL LABORATORIES
And Environmental Services Pvt. Ltd.

SOURCE (STACK) EMISSION MONITORING REPORT

Client's Name & Address	Report No.	NLES/23-24/05/ST/RE/46
M/s KiTech Hydrogen System(India)Pvt Ltd Gat No-357/86, Plot no-14, Waghjai nagar, Kharabwadi, Chakan, Taluka khed, Dist-Pune 410501.	Date of Reporting	13-05-2023

SAMPLING DETAILS

01) Location of Sampling	MH-12 UM 2349 Mahindra Blazo X 28	
02) Sample Status (Sealed/Unsealed)	Sealed	
03) Sample Collected By	M/s. Tulsi Environmental Services & Consultant	
04) Date of Sampling	06-05-2023	
05) Time of Sampling & Sampling Duration	From 11:00 AM to 12.30 PM	
06) Date of Received in Lab	07-05-2023	
07)Fuel Used	Diesel Oil	
07) Instrument Details	Make/ Model No.	Shree Scientific and Calibration /SEM-150,220508
	Lab ID	NLES/Lab/Inst/01
	Calibration Date	Calibration on:11/05/2022, Due On:10/05/2023

RESULTS

Sr. No	Parameter	UOM	Results	Results	Results	Results	Limits as Per MPCB Consent
	Idle Engine Running		700 RPM 11.00 AM	1250 RPM 11.20 AM	1500 RPM 11.40 AM	1750 RPM 12.00 AM	
1	Suspended Particulate Matter (SPM)	$\mu g/m^3$	120.6	110.4	100.02	98.2	≤ 150
2	HC(Hydrocarbons)	$\mu g/m^3$	0.45	0.40	0.38	0.34	-
3	Oxides of Nitrogen (NOx)	mg/m^3	0.260	0.254	0.246	0.240	-
4	Carbon Dioxide (CO_2)	mg/m^3	680.63	674.54	670.50	668.43	-
5	Carbon Monoxides (CO)	$\mu g/m^3$	0.812	0.789	0.772	0.769	-

UOM: Unit of Measurement
Remarks: - All above results are within MPCB Limits.

Reviewed By

(Ms. Sadhana Kanase)
(Dy. Quality Manager)

Neetal Laboratories & Environmental Services Pvt. Ltd. ★ PUNE

Authorized Signatory

Kalyani
(Ms. Kalyani Gore)
(Technical Manager)

******************End of Report*****************

Terms and Conditions

- This Report is valid for tested sample only
- The results shown in this test report may differ based on various factors including temperature, humidity, pressure, retention time etc.
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Page 1 of 1

AN ENVIRONMENTAL LABORATORY RECOGNISED UNDER EPA, ENVIRONMENT (PROTECTION) ACT
BY (MoEF & CC) MINISTRY OF ENVIRONMENT FOREST & CLIMATE CHANGE

Address : H.NO. 43, SANTOSH NAGAR, WAKI BK., TAL. KHED, DIST. PUNE - 410 501
Website : www.neetalenvirolab.com, Email: sales@neetalenvirolab.com / neetalenviro@gmail.com, Mob. 8669699854 / 52

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NEETAL LABORATORIES
And Environmental Services Pvt. Ltd.

SOURCE (STACK) EMISSION MONITORING REPORT

Client's Name & Address	Report No.	NLES/23-24/05/ST/RE/47
M/s KiTech Hydrogen System(India)Pvt Ltd Gat No-357/86, Plot no-14, Waghjai nagar, Kharabwadi, Chakan, Taluka khed, Dist-Pune 410501.	Date of Reporting	13-05-2023

SAMPLING DETAILS

01) Location of Sampling	MH-12 UM 2349 Mahindra Blazo X 28	
02) Sample Status (Sealed/Unsealed)	Sealed	
03) Sample Collected By	M/s. Tulsi Environmental Services & Consultant	
04) Date of Sampling	06-05-2023	
05) Time of Sampling & Sampling Duration	From 12:35 PM to 13:50 PM	
06) Date of Received in Lab	07-05-2023	
07)Fuel Used	Diesel Oil	
07) Instrument Details	Make/ Model No.	Shree Scientific and Calibration /SEM-150,220508
	Lab ID	NLES/Lab/Inst/01
	Calibration Date	Calibration on:11/05/2022, Due On:10/05/2023

RESULTS

Sr. No	Parameter	UOM	Results	Results	Results	Results	Limits as Per MPCB Consent
	IdleEngine Running with K 40 Kit		700RPM K-40 12.25 PM	1250 RPM K-40 12.45 PM	1500 RPM K-40 13.05 PM	1750 RPM K-40 13.25 PM	
1	Suspended Particulate Matter (SPM)	$\mu g/m^3$	90.4	85.2	76.5	70.3	≤ 150 -
2	HC(Hydrocarbons)	$\mu g/m^3$	0.25	0.20	0.17	0.12	-
3	Oxides of Nitrogen (NOx)	mg/m^3	0.234	0.229	0.223	0.219	-
4	Carbon Dioxide (CO_2)	mg/m^3	556.6	542.3	528.4	514.6	
5	Carbon Monoxides (CO)	$\mu g/m^3$	0.430	0.390	0.368	0.349	-

UOM: Unit of Measurement

Remarks: - All above results are within MPCB Limits.

Reviewed By

(Ms. Sadhana Kanase)
(Dy. Quality Manager)

Neetal Laboratories & Environmental Services Pvt. Ltd. PUNE

Authorized Signatory

Kalyani

(Ms. Kalyani Gore)
(Technical Manager)

*****************End of Report**************

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AN ENVIRONMENTAL LABORATORY RECOGNISED UNDER EPA, ENVIRONMENT (PROTECTION) ACT BY (MoEF & CC) MINISTRY OF ENVIRONMENT FOREST & CLIMATE CHANGE

Address : H.NO. 43, SANTOSH NAGAR, WAKI BK., TAL. KHED, DIST. PUNE - 410 501
Website : www.neetalenvirolab.com, Email: sales@neetalenvirolab.com / neetalenviro@gmail.com, Mob. 8669699854 / 52

केन्द्रीय प्रदूषण नियंत्रण बोर्ड
CENTRAL POLLUTION CONTROL BOARD
पर्यावरण, वन एवं जलवायु परिवर्तन मंत्रालय भारत सरकार
MINISTRY OF ENVIRONMENT, FOREST & CLIMATE CHANGE GOVT. OF INDIA

F.No. LB/99/7/2021-INST LAB-HO-CPCB-HO/Pvt./ 9129

Dated: 28th January 2023

Provisional Certificate

To,

Head of Laboratory,
M/s Neetal laboratories and Environmental Services Private Limited,
H. No.-43, Santosh Nagar, Waki Budruk, Tal. Khed, Dist. Pune,
Maharashtra-410501.

Subject: Recognition of M/s Neetal laboratories and Environmental Services Private Limited, H. No.-43, Santosh Nagar, Waki Budruk Pune, Maharashtra- 410501 as Environmental laboratory under the Environmental (Protection) Act- 1986.

Sir,

I am directed to refer the online application, dated 12/12/2022 for the recognition of your laboratory under Environmental (Protection) Act, 1986. Based on the recommendations of the concerned Division, approval of Competent Authority for recognition of Environmental laboratories and your acceptance of the revised terms and conditions at Annexure-III & IV of the guidelines for recognition of environmental laboratories, CPCB approves the recognition of **M/s Neetal laboratories and Environmental Services Private Limited, H. No.-43, Santosh Nagar, Waki Budruk Pune, Maharashtra- 410501** and shall be notified in the Gazette of India. Considering the current requirement of mandatory accreditation/ certifications of the laboratory, **this recognition shall be valid up to 23/11/2024.**

2. As sought in the aforementioned application, **M/s Neetal laboratories and Environmental Services Private Limited, H. No.-43, Santosh Nagar, Waki Budruk, Pune, Maharashtra-410501** may undertake the following tests:

i. **Physical Tests-**Conductivity, Colour, pH, Fixed & Volatile Solids, Total Solids, Total Dissolved Solids, Total Suspended Solids, Turbidity, Temperature, Velocity & Discharge Measurement of Industrial Effluent Stream, Flocculation Test (Jar test), Odour, Salinity, Settleable Solids and Sludge Volume Index.

ii. **Inorganic (General and Non-metallic):** Acidity, Alkalinity, Ammonical Nitrogen, Chloride, Chlorine Residual, Dissolved Oxygen, Fluoride, Total Hardness, Total Kjeldahl Nitrogen (TKN), Nitrite Nitrogen, Nitrate Nitrogen, Phosphate, Sulphate, Bromide, Chlorine Demand, Iodine, Sulphite, Silica, Cyanide and Sulphide.

iii. **Inorganic (Trace Metals):** Boron, Cadmium, Calcium, Total Chromium, Chromium Hexavalent, Copper, Iron, Lead, Magnesium, Mercury, Nickel, Potassium, Sodium, Sodium Absorption Ratio, Zinc, Arsenic, Aluminium, Beryllium, Barium, Manganese, Selenium, Silver, and Cobalt.

iv. **Organics (General) and Trace Organics:** Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Oil and Grease, Phenolic Compounds, Pesticides (each) (Organo-Chlorine and Organo Nitrogen-Phosphorus), Surfactant, Poly-Chlorinated Biphenyl (PCB's) each, Poly-Nuclear Aromatic Hydrocarbon (PAH), Organic Carbon (in Solid) and Carbon/Nitrogen Ratio.

v. **Microbiological Test:** Total Coliform, Faecal Coliform, *E. coli, Faecal Streptococci* and Total Plate Count.

vi. **Toxicological Tests:** Bioassay Method for Evaluation of Toxicity Using Fish and Measurement of Toxicity Using Daphnia or Other Organism.

vii. **Biological Test:** Benthic Organism Identification and Count, Macrophytic Identification and Planktonic Identification Count.

viii. **Characterization of Hazardous Waste:** Corrosivity, Reactivity and Measurement of Heavy Metals/Pesticides in the Waste/Leachate.

Contd.

'परिवेश भवन' पूर्वी अर्जुन नगर, दिल्ली-110032
Parivesh Bhawan, East Arjun Nagar, Delhi-110032
दूरभाष/Tel : 43102030, 22305792, वेबसाईट/Website : www.cpcb.nic.in

ix. **Soil/Sludge/Sediment and Solid Waste:** Boron, Cation Exchange Capacity (CEC), Electrical Conductivity, Nitrogen (Available), Organic Carbon/Matter (Chemical Method), pH, Phosphorous (Available), Phosphate (Ortho), Phosphate (Total), Potassium, SAR in Soil Extract, Sodium, Soil moisture, TKN, Calorific Value, Ammonia, Bicarbonate, Calcium, Calcium Carbonate, Chloride, Colour, Gypsum Requirement, H.Acid, Heavy Metal, Magnesium, Nitrate, Nitrite, Potash (Available), Sulphate, Sulphur, Total Water Soluble Salt and Water Holding Capacity.

x. **Ambient Air/ Fugitive Emissions:** Nitrogen Dioxide (NO_2), Sulphur Dioxide (SO_2), Total Suspended Particulate Matter, Respirable Suspended Particulate Matter PM_{10}, Ammonia, Carbon Monoxide, Fluoride, Lead, Ozone, Benzene Toluene Xylene (BTX) and $PM_{2.5}$.

xi. **Stack Gases/ Source Emission:** Particulate Matter, Sulphur Dioxide, Velocity & Flow, Carbon Dioxide, Carbon Monoxide, Temperature, Oxygen, Oxides of Nitrogen, Acid Mist, Ammonia, Chlorine, Fluoride(Particulate) and Total Hydrocarbon.

xii. **Noise Level:** Noise Level Measurement (20-140 dBa) and Ambient Noise and Source Specific Noise.

xiii. **Meteorological:** Ambient Temperature, Wind Direction, Wind Speed, Relative Humidity, and Rainfall.

3. Further, the following analysts have been approved as Government Analysts.

    i. Mrs. Kalyani Yuvraj Gore
    ii. Sh. Abhishek Dattatray Tope
    iii. Mrs. Dipa Nilesh Mahajan

4. The laboratory shall compulsorily participate in the Analytical Quality Exercise conducted by the Central Pollution Control Board (CPCB) to ascertain the capability of the laboratory and analysis carried out and shall submit quarterly progress report to CPCB.

5. The surprise inspection/periodic surveillance of the recognized environment laboratory will be undertaken by CPCB to assess its proper functioning systematic operation and reliability of data generated at the laboratory.

6. It is also mandatory for the laboratory to have requisite accreditations of the ISO: 17025 and ISO:45001 and its renewal as per accreditation rules. This recognition is subject to such accreditations and renewals as applicable. The laboratory is required to apply online for further renewal of recognition through CPCB web portal after renewal of the mandatory accreditations / certifications concerned.

7. The laboratory should compulsorily follow the accepted terms and conditions. In case of serious non-compliance of any of the terms and conditions, the laboratory may be black listed for a minimum period of two years and civil/criminal proceedings, as applicable, may be initiated for performing functions on behalf of the Government in an unauthorized manner.

Yours faithfully,

K. R. 28/2/23

(Dr. K. Ranganathan)
Scientist-E & Divisional Head
Instrumentation laboratory

डॉ. के. रंगनाथन / Dr. K. Ranganathan
वैज्ञानिक 'ई' / Scientist 'E'
प्रभारी जल एवं उपकरणीय प्रयोगशाला
Div. Head-Water & Instrumentation Laboratory
केन्द्रीय प्रदूषण नियंत्रण बोर्ड
Central Pollution Control Board
पर्यावरण, वन एवं जलवायु परिवर्तन मंत्रालय, भारत सरकार
(M/o Environment, Forest & Climate Change, Govt. of India)
परिवेश भवन, पूर्वी अर्जुन नगर, दिल्ली-110032
Parivesh Bhawan, East Arjun Nagar, Delhi-110032

National Accreditation Board for
Testing and Calibration Laboratories

NABL

CERTIFICATE OF ACCREDITATION

NEETAL LABORATORIES AND ENVIRONMENTAL SERVICES PRIVATE LIMITED

has been assessed and accredited in accordance with the standard

ISO/IEC 17025:2017

"General Requirements for the Competence of Testing & Calibration Laboratories"

for its facilities at

HOUSE NO. 43, SANTOSH NAGAR, AT POST: WAKI BUDRUK, PUNE, MAHARASHTRA, INDIA

in the field of

TESTING

Certificate Number: TC-11184

Issue Date: 24/11/2022 **Valid Until:** 23/11/2024

This certificate remains valid for the Scope of Accreditation as specified in the annexure subject to continued satisfactory compliance to the above standard & the relevant requirements of NABL.
(To see the scope of accreditation of this laboratory, you may also visit NABL website www.nabl-india.org)

Name of Legal Identity : Neetal Laboratories and Environmental Services Private Limited

Signed for and on behalf of NABL

N. Venkateswaran
Chief Executive Officer

Further Inquiry:

Alok Kumar - alok@kihydrogen.com
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Shailesh Karande – shailesh@kihydrogen.com
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This report contains a total number of 29 pages including cover pages and empty pages