FABRICATION AND ANALYSIS OF 3 WAY CATALYTIC CONVERTER USING SCR

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ABSTRACT

A catalytic converter is an exhaust emission control device that converts toxic gases and pollutants in exhaust gas from an internal combustion engine into less-toxic pollutants by catalyzing a redox reaction (an oxidation and a reduction reaction). Selective catalytic reduction (SCR) is a means of converting nitrogen oxides, also referred to as NO_x with the aid of a catalyst into diatomic nitrogen (N_2) , and water (H_2O). A gaseous reductant, typically anhydrous ammonia, aqueous ammonia or urea, is added to a stream of flue or exhaust gas and is adsorbed onto a catalyst. Carbon dioxide, CO_2 is a reaction product when urea is used as the reductant. We have further developed this system by deploying a new redox agent which has greater reduction of NO_x and CO_2. We have used reduction agent like Ammonium chloride and Zinc to convert NOx into Ammonia, Ammonia is further oxidized by Manganese Dioxide to form Ammonium hydroxide. After the Ammonium hydroxide is converted a dilute HCL is sprayed to make Ammonium hydroxide into Ammonium chloride. A small-scale Ammonium chloride is formed inside the muffler which must be maintained and cleaned for an interval period of time.

Keyword: *SCR TECHNOLOGY, 3-WAY CATALYTIC CONVERTER, NOx REDUCTION.*

1. INTRODUCTION ON CATALYTIC CONVERTER

A catalytic converter is an exhaust emission control device that converts toxic gases and pollutants in exhaust gas from an internal combustion engine to less toxic pollutants by catalyzing a redox reaction (an oxidation and a reduction reaction). Catalytic converters are usually used with internal combustion engines fueled by either petrol (gasoline) or diesel—including lean-burn engines as well as kerosene heaters and stoves.

1.1 THREE-WAY CATALYTIC CONVERTERS

Three-way catalytic converters (TWC) have the additional advantage of controlling the emission of nitric oxide (NO) and nitrogen dioxide (NO_2) (both together abbreviated with NO_x and not to be confused with nitrous oxide (N_2O)), which are precursors to acid rain and smog.

Since 1981, "three-way" (oxidation-reduction) catalytic converters have been used in vehicle emission control systems in the United States and Canada; many other countries have also adopted stringent vehicle emission regulations that in effect require three-way converters on gasoline-powered vehicles. The reduction and oxidation catalysts are typically contained in a common housing; however, in some instances, they may be housed separately. A three-way catalytic converter has three simultaneous tasks:

Reduction of nitrogen oxides to nitrogen (N_2)

- $2\,CO + 2\,NO \rightarrow 2\,CO_2 + N_2$
- hydrocarbon + NO → $CO_2 + H_2O + N_2$
- $2\,H_2 + 2\,NO \rightarrow 2\,H_2O + N_2$

Oxidation of carbon monoxide to carbon dioxide

- $2\,CO + O_2 \rightarrow 2\,CO_2$

Oxidation of unburnt hydrocarbons (HC) to carbon dioxide and water, in addition to the above NO reaction

- hydrocarbon + $O_2 \rightarrow H_2O + CO_2$

These three reactions occur most efficiently when the catalytic converter receives exhaust from an engine running slightly above the stoichiometric point. For gasoline combustion, this ratio is between 14.6 and 14.8 parts air to one-part fuel, by weight. The ratio for Auto gas, natural gas and ethanol fuels is slightly different for each, requiring modified fuel system settings when using those fuels. In general, engines fitted with 3-way catalytic converters are equipped with a computerized closed-loop feedback fuel injection system using one or more oxygen sensors, though early in the deployment of three-way converters, carburetors equipped with feedback mixture control were used. Three-way converters are effective when the engine is operated within a narrow band of air-fuel ratios near the stoichiometric point, such that the exhaust gas composition oscillates between rich (excess fuel) and lean (excess oxygen). Conversion efficiency falls very rapidly when the engine is operated outside of this band. Under lean engine operation, the exhaust contains excess oxygen, and the reduction of NO_x is not favored. Under rich conditions, the excess fuel consumes all of the available oxygen prior to the catalyst, leaving only oxygen stored in the catalyst available for the oxidation function. Closed-loop engine control systems are necessary for effective operation of three-way catalytic converters because of the continuous balancing required for effective NO_x reduction and HC oxidation. The control system must prevent the NO_x reduction catalyst from becoming fully oxidized yet replenish the oxygen storage material so that its function as an oxidation catalyst is maintained. Three-way catalytic converters can store oxygen from the exhaust gas stream, usually when the air–fuel ratio goes lean.[19] When sufficient oxygen is not available from the exhaust stream, the stored oxygen is released and consumed (see cerium(IV) oxide). A lack of sufficient oxygen occurs either when oxygen derived from NO_x reduction is unavailable or when certain maneuvers such as hard acceleration enrich the mixture beyond the ability of the converter to supply oxygen.

1.2 SCR- SELECTIVE CATALYTIC REDUCTION

Selective catalytic reduction (SCR) is a means of converting nitrogen oxides, also referred to as NO*x* with the aid of a catalyst into diatomic nitrogen (N_2) , and water (H_2O). A gaseous reductant, typically anhydrous ammonia, aqueous ammonia or urea, is added to a stream of flue or exhaust gas and is adsorbed onto a catalyst. Carbondioxide,CO_2 is a reaction product when urea is used as the reductant. Selective catalytic reduction of NO*x* using ammonia as the reducing agent was patented in the United States by the Engelhard Corporation in 1957. Development of SCR technology continued in Japan and the US in the early 1960s with research focusing on less expensive and more durable catalyst agents. The first large-scale SCR was installed by the IHI Corporation in 1978. Commercial selective catalytic reduction systems are typically found on large utility boilers, industrial boilers, and municipal solid waste boilers and have been shown to reduce NO*x* by 70-95%.[1] More recent applications include diesel engines, such as those found on large ships, diesel locomotives, gas turbines, and even automobiles. The NO*x* reduction reaction takes place as the gases pass through the catalyst chamber. Before entering the catalyst chamber the ammonia, or other reductant (such as urea), is injected and mixed with the gases. The chemical equation for a stoichiometric reaction using either anhydrous or aqueous ammonia for a selective catalytic reduction process is:

$4NO + 4NH_3 + O_2 \rightarrow 4N_2 + 6H_2O$

$2NO_2 + 4NH_3 + O_2 \rightarrow 3N_2 + 6H_2O$

$NO + NO_2 + 2NH_3 \rightarrow 2N_2 + 3H_2O$

- With several secondary reactions:
  $2SO_2 + O_2 \rightarrow 2SO_3$

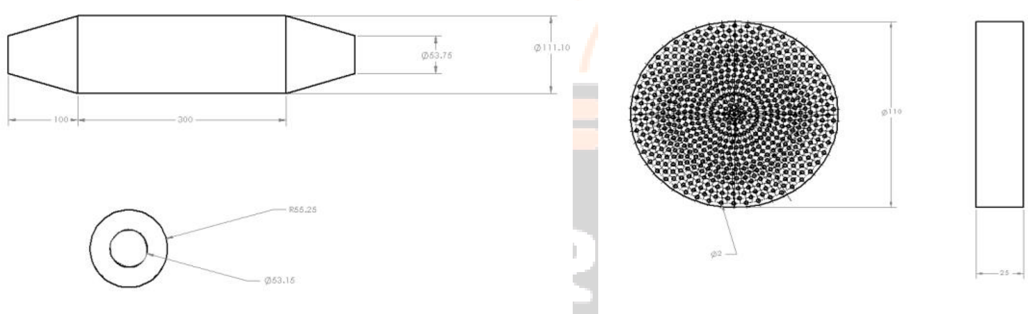
  $2NH_3 + SO_3 + H_2O \rightarrow (NH_4)_2SO_4$

  $NH_3 + SO_3 + H_2O \rightarrow NH_4HSO_4$

- The reaction for urea instead of either anhydrous or aqueous ammonia is:
  $4NO + 2(NH_2)_2CO + O_2 \rightarrow 4N_2 + 4H_2O + 2CO_2$

- The ideal reaction has an optimal temperature range between 630 and 720 K but can operate from 500 to 720 K with longer residence times. The minimum effective temperature depends on the various fuels, gas constituents, and catalyst geometry. Other possible reductants include cyanuric acid and ammonium sulfate.

2. CONSTRUCTION OF SCR CATALYTIC CONVERTER



(fig.3.1 dimension of catalytic converter)

2.1 SPECIFICATION

Length = 100mm

Sheet thickness = 1.5 mm

Funnel diameter, d_1 = 53.75 mm

Funnel diameter, d_2 =111.1mm

Die diameter = 110mm

No. of dies placed = 4

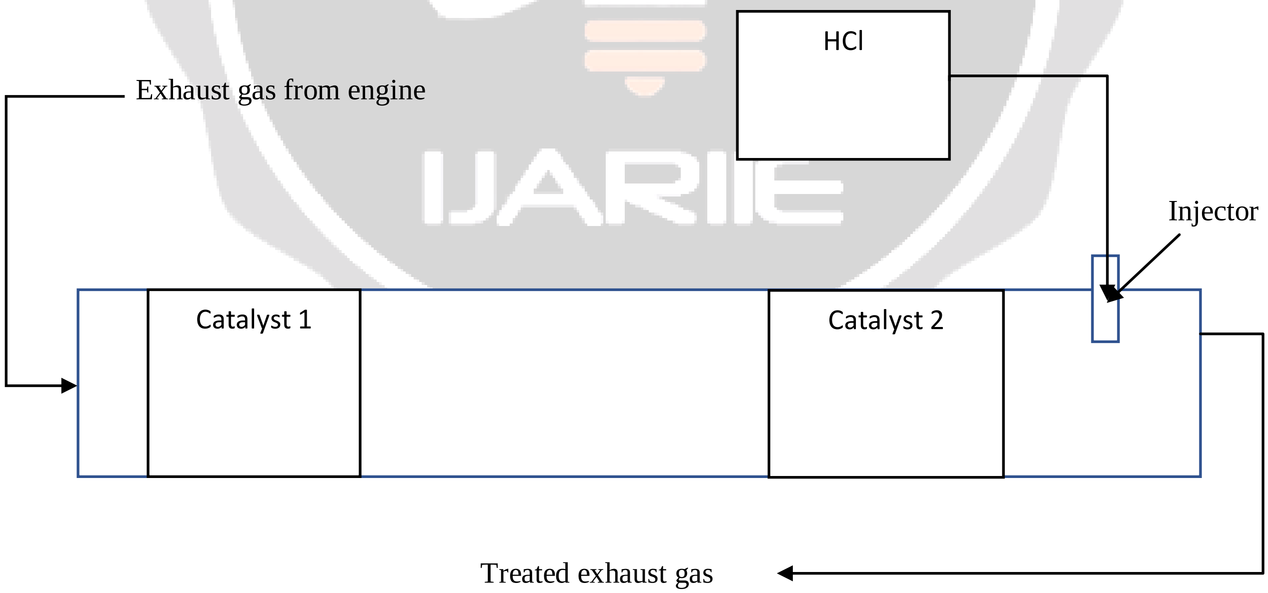
2.2 PREPARATION OF CATALYST

(fig.3.8 die covered with Manganese Dioxide) (fig.3.9 covered with Ammonium chloride and zinc)

2.3 STEPS IN PREPARATION OF THE CATALYST

- A one liter of distilled water poured in to bucket.
- a composition of NH_4Cl + Zn is added to the distilled water.
- After a 15 minute of Stirling the die is dipped to the chemical composition of NH_4Cl +Zn.
- The dipped die is left for an hour for complete absorption of chemical
- After this process the die is dried in atmospheric temperature of about 5 to 6 hours.
- The same process is carried out for next composition of MnO_2.
- After the completion the dipped and dried die is inserted in muffler.

3. 0 LAYOUT



Catalyst 1- Ammonium chloride and Zinc

Catalyst 2- Manganese Di-oxide

3.1 WORKING OF THE CATALYTIC CONVERTER

It is based on the 3-way catalytic reduction and SCR technology. The main aim is to reduce the NOx emission from the exhaust gases. The first stage of process is reduction by using Ammonium chloride and Zinc as a catalyst which is reacted with NOx to form ammonia. Ammonia is future processed in oxidation by using Manganese Di-oxide. The final stage is SCR by using Dilute Hydrochloric Acid which is sprayed on the Ammonium Hydroxide to form Ammonium chloride and water. These are the step by step reaction of the process of our catalytic converter.

3.2 CHEMICAL REACTION

REDUCTION

$$NO_x \xrightarrow[Zn]{NH_4Cl} NH_3$$

EXPECTED: NH_2, $ZnNH_2$

OXIDATION

$$NH_3 \xrightarrow{MnO_2} NH_4OH$$

EXPECTED: H_2O, NO_2

NEUTRALSATION

$$NH_4OH + HCl \rightarrow NH_4Cl + H_2O$$

4. EMISSION CONTROL RESULT

The catalytic converter is tested under emission analyzer with various loads at different time. The results of the test are failed because it is calibrated under standard reading as per the emission norms. The various compounds from the exhaust gases are listed as below.

4.1 LOAD 3.5 Kg

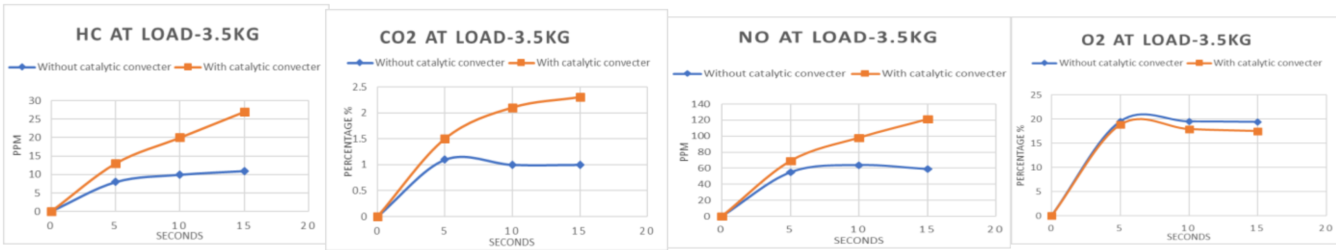
Test Date: 14-Mar-2018 VIN: DIESEL-3.5
Model: Default Engine Speed (RPM): 1600 RPM

TestTime	CO %	HC PPM	CO2 %	O2 %	NO PPM	Lambda	Result	Remarks
3:50:41 pm	0.02	8	1.10	19.5	55	-----	Fail	CO and HC Low in Range
3:50:50 pm	0.02	10	1.00	19.5	64	-----	Fail	CO and HC Low in Range
3:51:00 pm	0.02	11	1.00	19.4	59	-----	Fail	CO and HC Low in Range

Test Date: 14-Mar-2018 VIN: D&CC-3.5
Model: Default Engine Speed (RPM): 1600 RPM

TestTime	CO %	HC PPM	CO2 %	O2 %	NO PPM	Lambda	Result	Remarks
4:06:43 pm	0.04	13	1.50	18.8	69	-----	Fail	CO and HC Low in Range
4:06:54 pm	0.05	20	2.10	17.9	98	9.807	Fail	CO and HC Low in Range
4:07:04 pm	0.05	27	2.30	17.5	121	8.412	Fail	CO and HC Low in Range

(TABLE 5.5 Emission test result with and without catalytic converter under 3.5 Kg load)



(GRAPH 5.4 Emission test under 3.5 kg with and without catalytic converter)

After the application of diluted hydrochloric acid, the emission in various compounds obtained without catalytic converter is very less than the emission obtained with catalytic converter at 3.5 kg load. The first two readings are taken without the application of diluted hydrochloric acid and the final reading is taken after the application of diluted hydrochloric acid. The readings are tabulated at different intervals of time and are plotted as graph as shown above.

4.2 LOAD 6 Kg

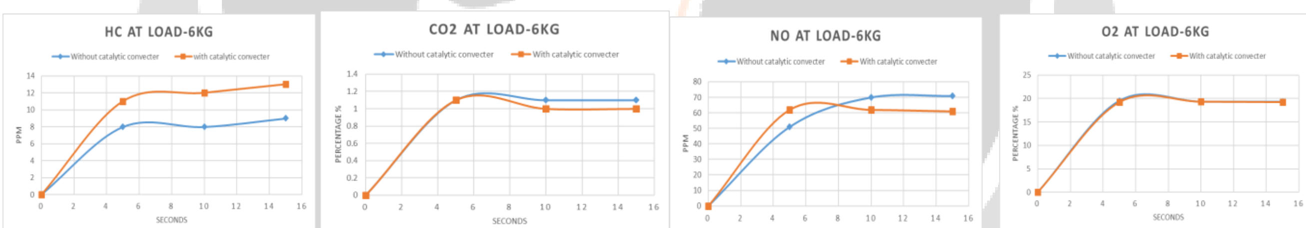
Test Date 14-Mar-2018 VIN DIESEL-6
Model Default Engine Speed (RPM) 1600 RPM

TestTime	CO %	HC PPM	CO2 %	O2 %	NO PPM	Lambda	Result	Remarks
3:52:40 pm	0.01	8	1.10	19.5	51	-----	Fail	CO and HC Low in Range
3:52:51 pm	0.02	8	1.10	19.3	70	-----	Fail	CO and HC Low in Range
3:53:02 pm	0.02	9	1.10	19.3	71	-----	Fail	CO and HC Low in Range

Test Date 14-Mar-2018 VIN D&CC-6
Model Default Engine Speed (RPM) 1600 RPM

TestTime	CO %	HC PPM	CO2 %	O2 %	NO PPM	Lambda	Result	Remarks
4:08:51 pm	0.03	11	1.10	19.2	62	-----	Fail	CO and HC Low in Range
4:09:02 pm	0.03	12	1.00	19.3	62	-----	Fail	CO and HC Low in Range
4:09:12 pm	0.03	13	1.00	19.2	61	-----	Fail	CO and HC Low in Range

(TABLE 5.7 Emission test result without catalytic converter under 6 kg load)



(GRAPH 5.5 Emission test under 6 kg with and without catalytic converter)

After the application of diluted hydrochloric acid, the emission in various compounds obtained without catalytic converter is very less than the emission obtained with catalytic converter at 6 kg load. The first two readings are taken without the application of diluted hydrochloric acid and the final reading is taken after the application of diluted hydrochloric acid. The readings are tabulated at different intervals of time and are plotted as graph as shown above.

4.3 LOAD 8.5 Kg

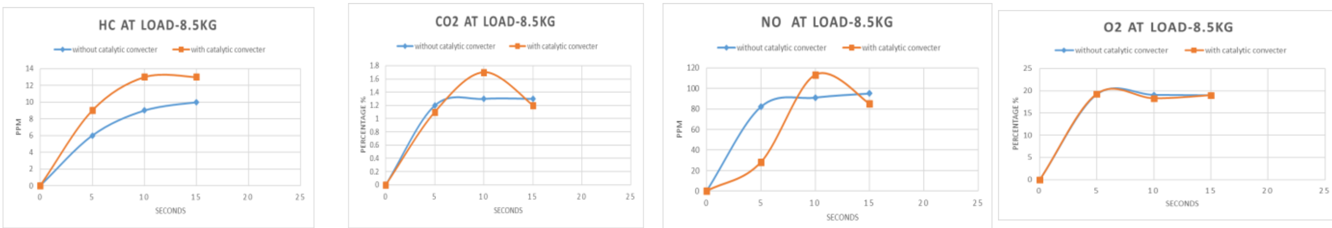
Test Date 14-Mar-2018 VIN DIESEL-8.5
Model Default Engine Speed (RPM) 1600 RPM

TestTime	CO %	HC PPM	CO2 %	O2 %	NO PPM	Lambda	Result	Remarks
3:54:31 pm	0.01	6	1.20	19.2	82	-----	Fail	CO and HC Low in Range
3:54:41 pm	0.02	9	1.30	19.1	91	-----	Fail	CO and HC Low in Range
3:54:51 pm	0.02	10	1.30	19.0	95	-----	Fail	CO and HC Low in Range

Test Date 14-Mar-2018 VIN D&CC-8.5
Model Default Engine Speed (RPM) 1600 RPM

TestTime	CO %	HC PPM	CO2 %	O2 %	NO PPM	Lambda	Result	Remarks
4:11:42 pm	0.02	9	1.10	19.3	75	-----	Fail	CO and HC Low in Range
4:11:54 pm	0.02	9	1.10	19.2	80	-----	Fail	CO and HC Low in Range
4:12:04 pm	0.02	10	1.10	19.2	77	-----	Fail	CO and HC Low in Range
4:12:14 pm	0.03	12	1.20	18.9	91	-----	Fail	CO and HC Low in Range

(TABLE 5.9 Emission test result with and without catalytic converter under 8.5 Kg load)



(TABLE 5.10 Emission result test with catalytic converter under 8.5 kg load)

After the application of diluted hydrochloric acid, the emission in various compounds obtained without catalytic converter is very less than the emission obtained with catalytic converter at 8.5 kg load. The first two readings are taken without the application of diluted hydrochloric acid and the final reading is taken after the application of diluted hydrochloric acid. The readings are tabulated at different intervals of time and are plotted as graph as shown above.

4.4 LOAD 11 Kg

Test Date 14-Mar-2018 VIN DIESEL-11

Model Default Engine Speed (RPM) 1600 RPM

TestTime	CO %	HC PPM	CO2 %	O2 %	NO PPM	Lambda	Result	Remarks
3:56:11 pm	0.02	1	0.70	20.0	4	-----	Fail	CO and HC Low in Range
3:56:20 pm	0.02	6	1.40	19.0	100	-----	Fail	CO and HC Low in Range
3:56:30 pm	0.02	9	1.40	18.9	103	-----	Fail	CO and HC Low in Range

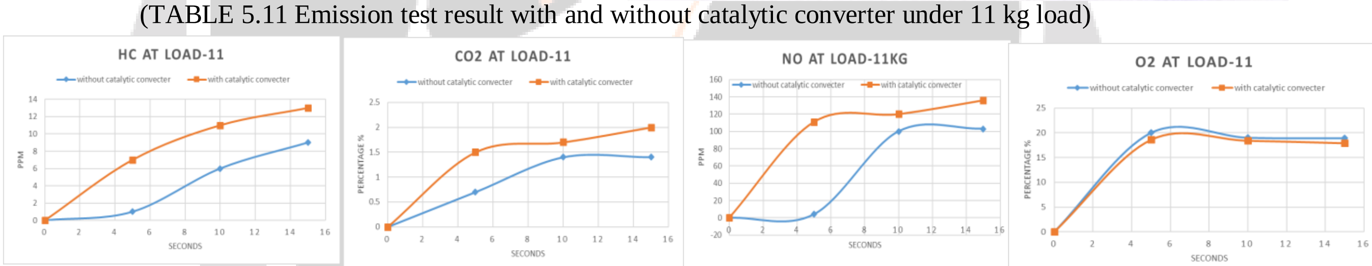
Serial No. 246 Engine No. NA

Test Date 14-Mar-2018 VIN D&CC-11

Model Default Engine Speed (RPM) 1600 RPM

TestTime	CO %	HC PPM	CO2 %	O2 %	NO PPM	Lambda	Result	Remarks
4:17:09 pm	0.03	7	1.50	18.6	111	-----	Fail	CO and HC Low in Range
4:17:20 pm	0.03	11	1.70	18.4	120	-----	Fail	CO and HC Low in Range
4:17:30 pm	0.03	13	2.00	17.9	136	9.866	Fail	CO and HC Low in Range

(TABLE 5.11 Emission test result with and without catalytic converter under 11 kg load)



(GRAPH 5.7 Emission test under 11 kg with and without catalytic converter)

After the application of diluted hydrochloric acid, the emission in various compounds obtained without catalytic converter is very less than the emission obtained with catalytic converter at 11 kg load. The first two readings are taken without the application of diluted hydrochloric acid and the final reading is taken after the application of diluted hydrochloric acid. The readings are tabulated at different intervals of time and are plotted as graph as shown above.

5. CONCLUSION

Our method's aim is to reduce the emission of NOx from Diesel engine using SCR technology. This method is less expensive as compared to other catalytic converter using SCR technology because the catalyst used in the catalytic converter is very expensive like platinum, palladium or rhodium, etc. Normally the catalytic converter requires frequent cleaning because of the wear of the material present in the catalytic converter. The same situation happens to our method too. Our method requires frequent cleaning because of the formation of ammonium chloride salt. This salt also corrodes the material, and this can be prevented by using stainless steel or polymer material. There is minimal scale formation of salt which does not affect the material up to drastic levels. The catalysts used in this method are easily available as compared to other catalysts and it does the same work as the other catalysts do. We chose the diluted hydrochloric acid because it reacts with compounds vigorously in nature and forms the desired product instantly. So, we chose the diluted hydrochloric acid as reducing agent. It is used for the reduction in catalytic converter. So, this method is more advantageous, if applied in conventional Diesel engines.

6. REFERENCE

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