REVIEW - WASTE HEAT HARVESTING SYSTEM ANALYSIS BY TEG USED AUTOMOBILE PARTS

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Abstract

The Automobile program review employ in the Thermo-electric energy conversion is one of the technologies with the capability to play a role in future energy technology. It incorporates direct energy conversion from heat sources to energy conservation and the physical into rapid effect has been well recovered in these centuries. The thermo-electric result is that the use of temperature differences to voltage creation and vice versa. This effect can be utilized to make electricity, to measure temperature and for cooling and of additives such as Phase change materials, use for heating system. Since Phase change material is mode of cooling or heating system is decided by the conducting of this voltage devices make temperature controllers. The major benefit of thermoelectric devices is ease; there are not any moving parts or chemical responses, which means that there are fewer maintenance requirements due to wearing out or corrode.

Keywords: Review, Automobile applications, TEG consumption, Analysis, Energy Techniques,

1. Introduction

1.1AUTOMOBILE ENERGY AND ITS APPLICATIONS

[1-2]All kinds of energy in the world are known to be originally switched from Automobile energy. Oil, coal, gasoline, and wood proved to be

made by photosynthetic procedures and then followed by sophisticated chemical reactions in which sterile plant was exposed to very significant temperatures and pressures over a long period of time.[3-6] Even the energies of this wind and tide possess their vehicle origin because they are due to variations in temperatures in various places across the world. Automobile vitality has been used by both humans and nature, it has been deliberately harnessed to carry out quite a few labor occupations.

[7-10]Automobile vitality is also utilized to restrain building temperatures, heating water to domestic and industrial applications, keep swimming pool temperature, power jets, function pumps, and engines, desalinate water for drinking reasons, create electricity, implement chemistry applications, etc. As outlined in the previous chapter, mankind is up against a predicament in which the buying price tag on fuels will quicken as natural reserves are reduced. Considering that the price of oil has gotten firmly established as the major selling price for all gas costs, the energy cost will constantly increase in the forthcoming many years.

[11]A catalytic converter is a vehicle emissions control device that converts toxic by-products of combustion in the exhaust of an internal combustion engine to less toxic substances by way of catalyzed chemical reactions. The specific reactions vary with the type of catalyst installed.[12-14] Most present-day vehicles that run on gasoline are fitted with a “three-way” converter, so named because it converts the three main pollutants in automobile exhaust: carbon monoxide, unburned hydrocarbon, and oxides of nitrogen. The first two undergo catalytic combustion and the last is reduced back to nitrogen.

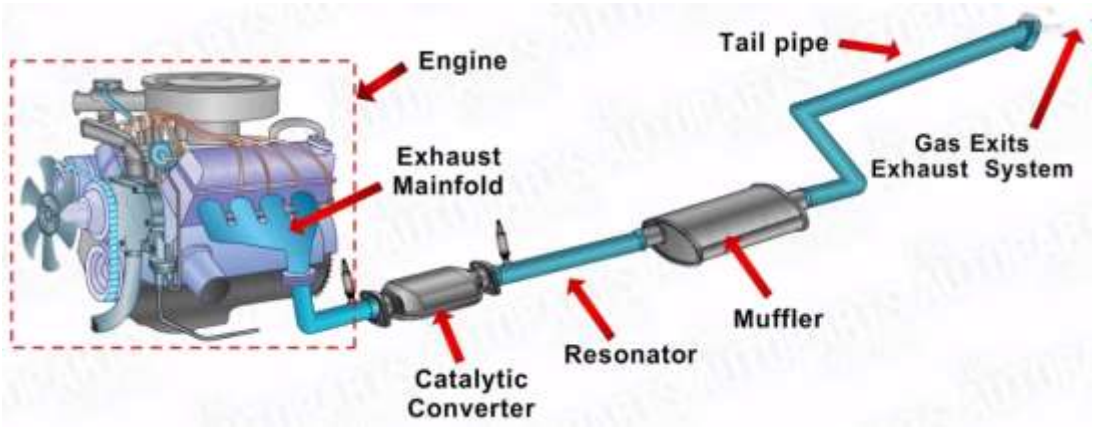
[18-19]The first widespread introduction of catalytic converters was in the United States market, where 1975 model year gasoline-powered automobiles were equipped to comply with tightening U.S. Environmental Protection Agency regulations on automobile exhaust emissions. These were “two-way” converters which combined carbon monoxide (CO) and unburned hydrocarbons (HC) to produce carbon dioxide (CO_2) and water (H_2O). Two-way catalytic converters of

this type are now considered obsolete, having been supplanted except on lean burn engines by “three-way” converters which also reduce oxides of nitrogen (NOx).

[20-22]Catalytic converters are still most commonly used in exhaust systems in automobiles but are also used on generator sets, forklifts, mining equipment, trucks, buses, locomotives, motorcycles, airplanes, and other engine-fitted devices. They are also used on some wood stoves to control emissions. This is usually in response to government regulation, either through direct environmental regulation or through health and safety regulations[23]

Catalytic oxidization is also used, but for the purpose of safe, flameless generation of heat rather than the destruction of pollutants, in catalytic heaters [24]

Catalytic converters were first widely introduced in cars produced in America during 1975 due to EPA regulations on toxic reductions. The United States Clean Air Act required a 70% decrease in emissions in all-new model vehicles after 1975. This reduction has to be carried out with the use of catalytic converters. Without catalytic converters, vehicles would release hydrocarbons, carbon monoxide, and nitrogen oxide. These gases are the largest source of ground-level ozone, which causes smog and is harmful to plant life. Catalytic converters can also be found in generators, buses, trucks, and trains. Almost everything with an internal combustion engine will have some sort of catalytic converter attached to its exhaust system.



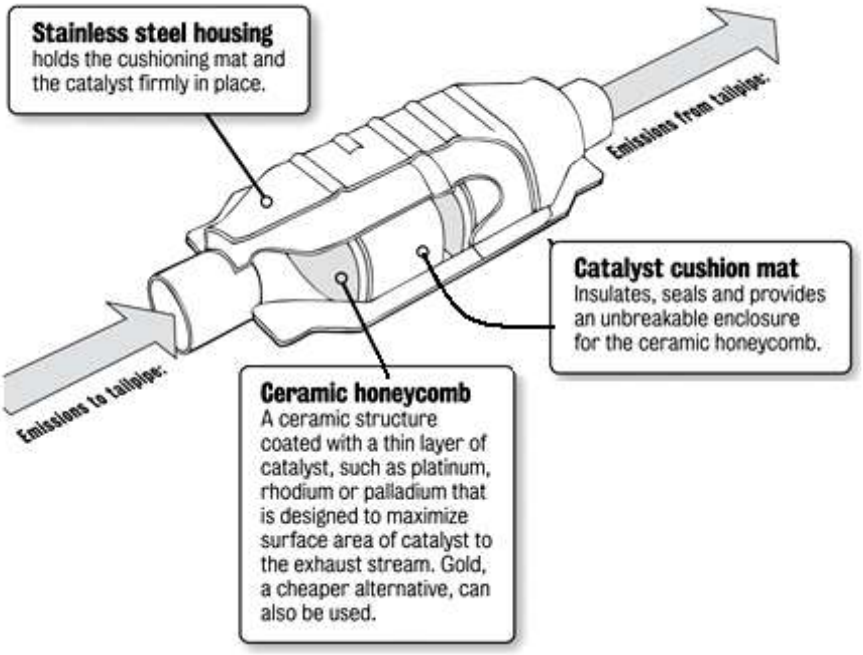
(Meng *et al.* 2016)

Figure 1 Position of the catalytic converter

1.2 BASIC COMPONENTS

The catalytic converter assembly will consist mostly of these components, inlet/outlet pipes/flanges, steel housing, insulation material, seals, inlet/outlet cones, substrate(s), coating and sensor boss.

- **Steel Housing** provides protection and structural support for substrate; insulation material (mat or wire mesh) provides heat insulation and support between steel housing and substrate; seals are there to protect mat material from being burned by the exhaust gas.
- The **Substrate** is often called as "catalyst support". It is a ceramic honeycomb or a stainless steel foil honeycomb in modern catalytic converters. The ceramic substrate was invented by Rodney Bagley, Irwin Lachman, and Ronald Lewis at Corning, as a means of increases the amount of surface area available to support the catalyst.
- The **washcoat** is used to make converters more efficient, it is often a mixture of silica and alumina. When a washcoat is added to the substrate, it forms a rough, irregular surface, which has a far greater surface area than the flat core surfaces do, which then gives the substrate a larger surface area, providing more sites for active precious metal – the catalytic which is added to the washcoat (in suspension) before being applied to the substrate.
- The **Catalyst** itself is most often a precious metal. Platinum is the most active catalyst and is widely used. However, because of unwanted additional reactions and/or cost, Palladium and rhodium are two other precious metals that are used. Platinum and rhodium are used as a reduction catalyst, while platinum and palladium are used as an oxidization catalyst. Cerium, iron, manganese, and nickel are also used, with their own limitations.



(Source: Kašpar *et al.* 2003)

Figure 2 Basic components

2. TYPES OF CATALYTIC CONVERTER

The two main types of catalytic converter used are

i. Two- way or oxidation catalytic converter

ii. Three-way catalytic converter

2.1 Two- Way or Oxidation Catalytic Converter

[25-26] presented Early converters, called “Two-Way” (or oxidation) catalytic converter that converts the harmful Carbon Monoxide (CO) and hydrocarbons (HC) produced by the relatively inefficient, low compression engines of the day to harmless carbon dioxide (CO_2) and water with the assistance of a precious- metallic catalyst. This process “converts” these harmful gasses with heat dissipated higher than three-way catalytic converter converting the high amount of heat into water vapor and harmless carbon dioxide (CO_2). But these converters have little effect on nitrogen oxides (NO_X) and particulate matter. It is

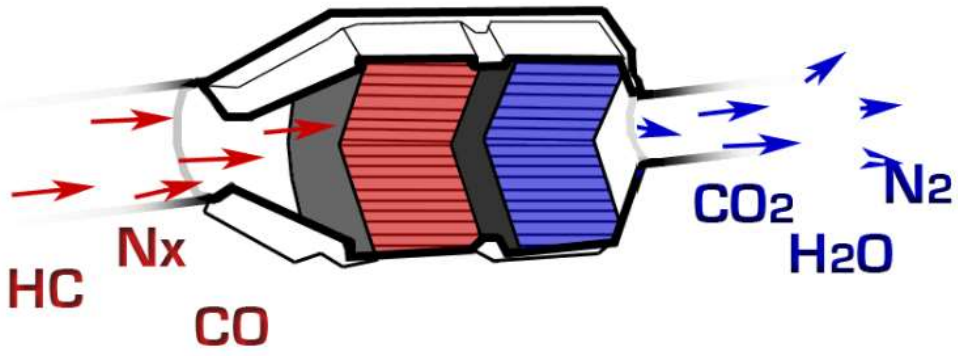
important to understand that Two-way converters are most effective when used with engines that have a lean air/fuel mix because this condition provides ample oxygen to "burn" the pollutants.

2.2 Three-Way Catalytic Converter

[27] studied most of today's cars that are equipped with a three-way catalytic converter. The term 3-way refers to the three emissions it helps to reduce, carbon monoxide, hydrocarbons or Volatile Organic Compounds (VOCs) and NO_X molecules. 3-way converters use two different types of catalysts, a reduction catalyst, an oxidization catalyst. Both types consist of a base structure coated with a catalyst such as platinum, rhodium and/or palladium. The scheme is to create a structure that exposes the maximum surface area of the catalyst to the exhaust flow with heat transferred in the range of 167^{o}C to 213^{o}C, concurrently minimizing the amount of catalyst required.

3. WORKING PRINCIPLE

A catalytic converter is a very simple device using the basic redox reactions in chemistry to help the car manufacturers to reduce the pollutants. It converts around 98% of the harmful fumes produced by a car engine into less harmful gases. It is composed of a metal housing that has a ceramic honeycomb-type interior with insulating layers. This honeycomb interior has thin wall channels that are coated with a washcoat of aluminum oxide [28]. This is very porous and increases the surface area, which allows for more reactions to take place. This is where the precious metals are located. These metals include platinum, rhodium, and palladium. Not more than 4to9 grams of these precious metals are used in a single converter. The converter utilizes simple oxidation and reduction reactions to convert toxic fumes into gases that are not really harmful to the environment. Recall that oxidation is the loss of electrons and reduction is the gaining of electrons. These precious metals listed earlier promote the transfer of electrons and in turn the conversion of toxic fumes.



(Source: Epling *et al.* 2004)

Figure 3 Basic conversion of the catalytic converter

3-Way converters working as two catalyst process:

1. Reduction and

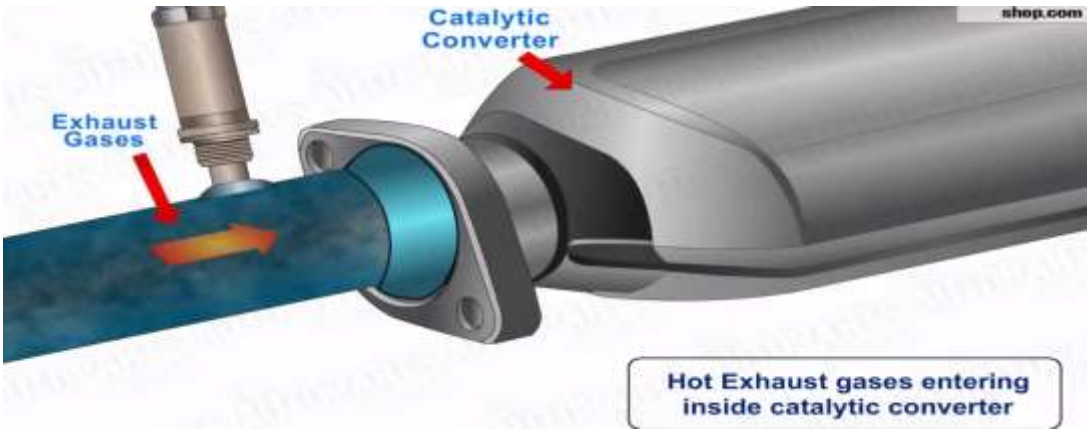
2. Oxidation- and a sophisticated oxygen storage/engine control system to convert three harmful gasses- HC, CO, and NO_X.

This is not an easy task: the catalyst chemistry required to clean up NO_X is most effective with a rich air/ fuel bias. To operate properly, a three-way converter first must convert NO_X (with a rich air/ fuel bias), then HC and CO (with a lean bias).

3.1 Reduction Catalyst

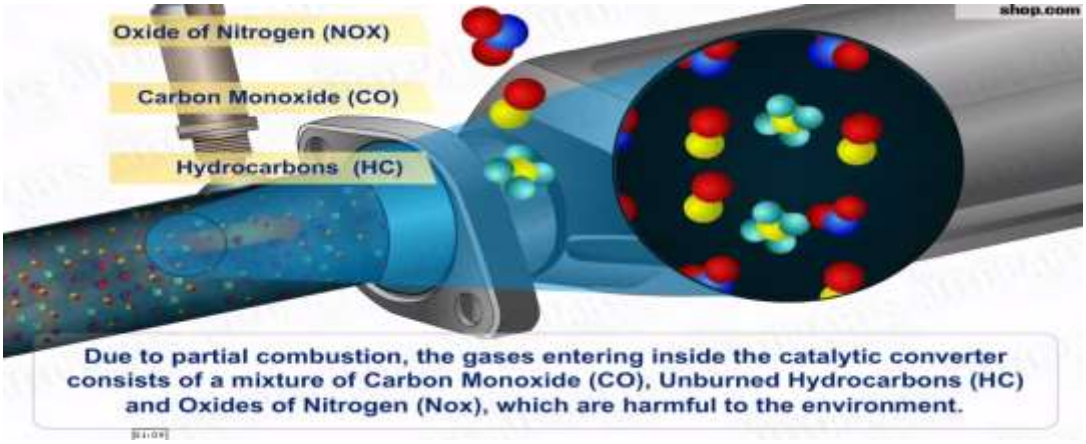
[29] the reduction catalyst is the first stage of the catalytic converter. It uses platinum and rhodium to help reduce NO_X emissions. When a NO or NO_2 molecule contacts the catalyst, the catalyst rips the nitrogen atom out of the molecule and holds on to it, freeing the oxygen in the form of O_2. The nitrogen atoms bond with other nitrogen atoms that are also stuck to the catalyst, forming N_2.

For example: $\mathbf{2NO \rightarrow N_2 + O_2}$ **(Or)** $\mathbf{2NO_2 \rightarrow N_2 + 2O_2}$



(Source: Matsumoto 2000)

Figure 4 Inside flow process



(Source: Liu & Ihl Woo 2006)

Figure 5 Inside flow fluid

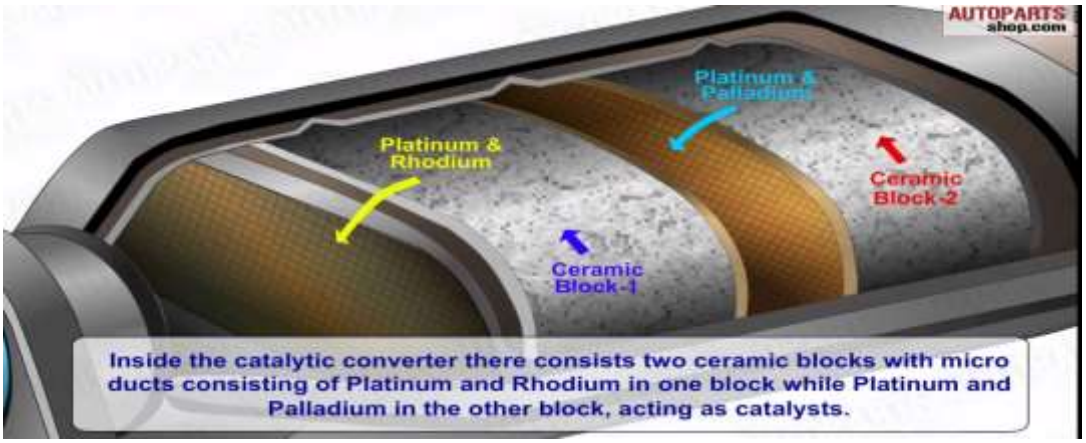


Figure 6 Internal Catalytic Parts

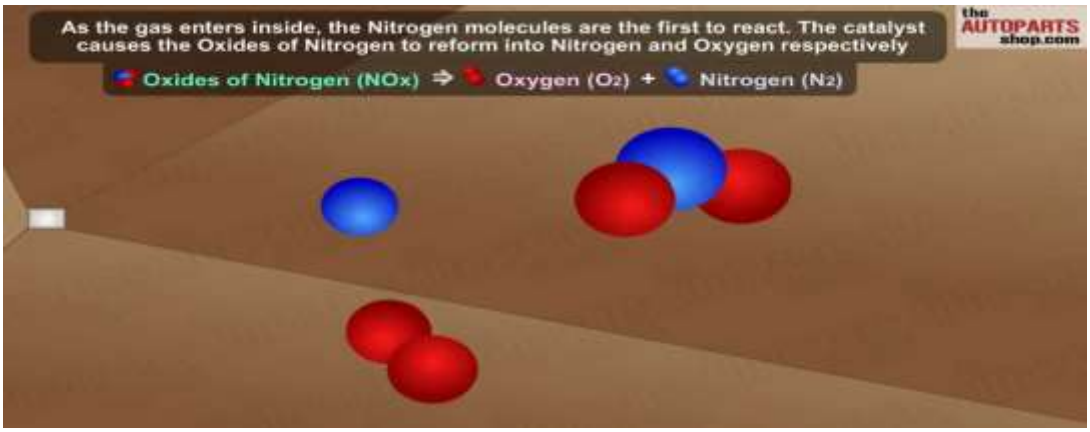


Figure 7 Internal fluid consideration in oxygen and nitrogen

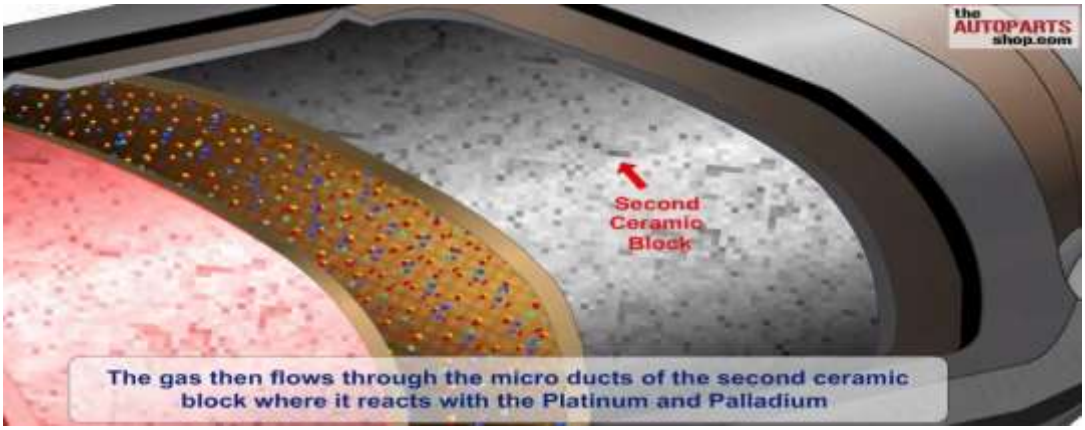


Figure 8 External gas mixtures

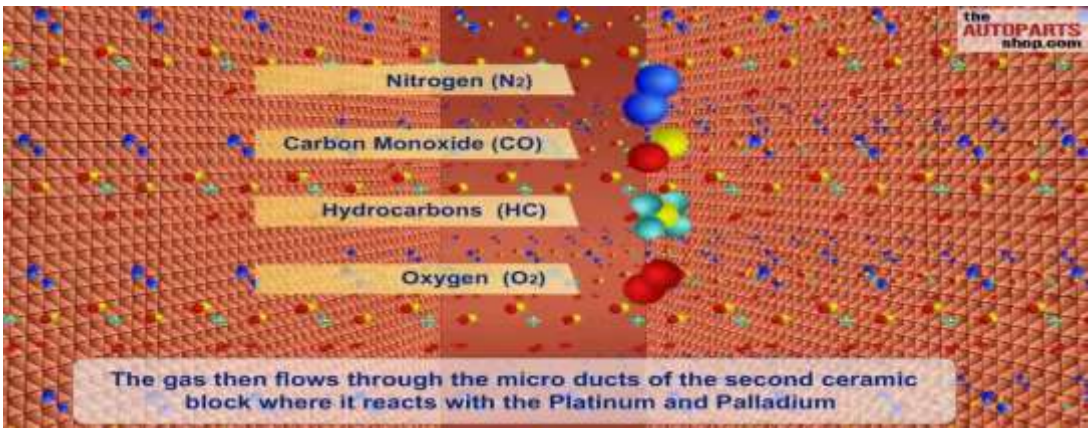


Figure 9 Transformation of Gases from one phase to another phase

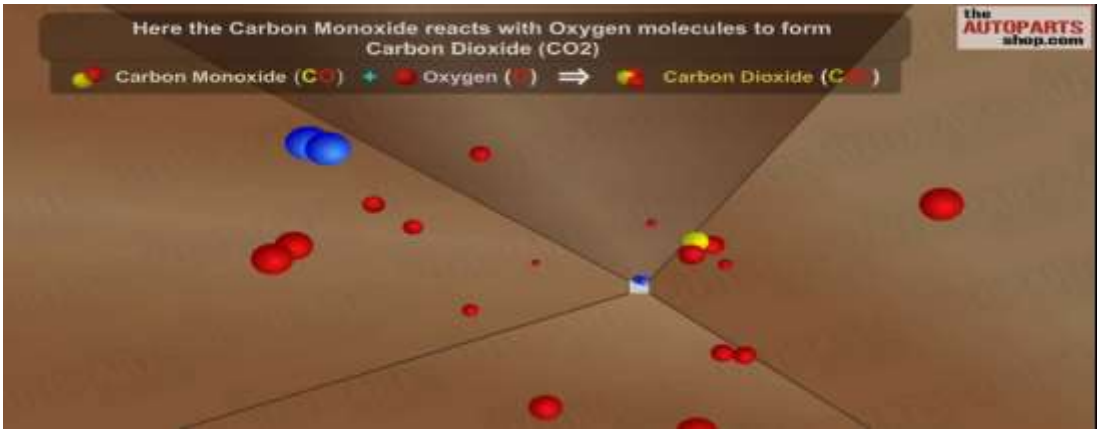


Figure 10 Formation of Carbon dioxide

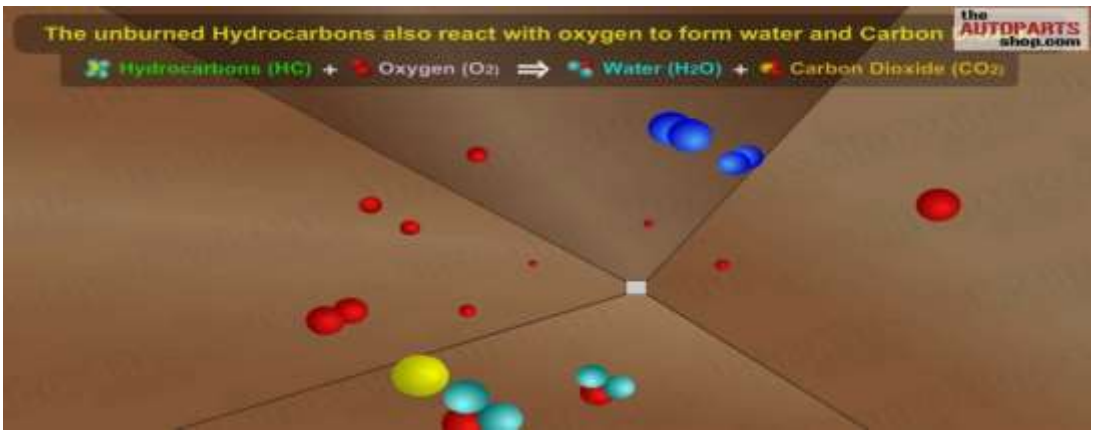


Figure 11 Reaction of Oxygen with unburnt Hydrocarbons

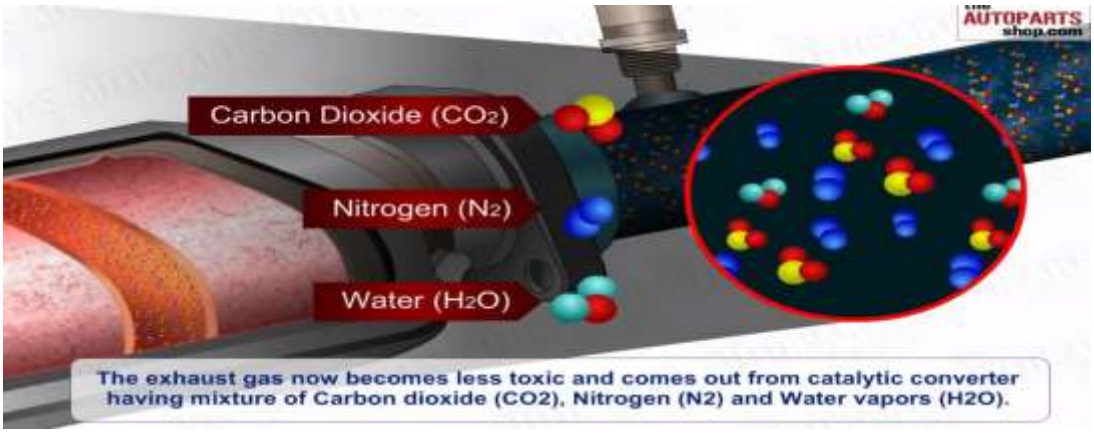


Figure 12 Step by Step working procedure

3.2 Oxidation Catalyst

[30] The oxidation catalyst is the second stage of the catalytic converter. It reduces the unburned hydrocarbons and carbon monoxide by burning (oxidizing) them over a platinum and palladium catalyst. This catalyst aids the reaction of the CO and hydrocarbons with the remaining oxygen in the exhaust gas. For example:

$$\mathbf{2CO + O_2 \rightarrow 2CO_2}$$

The diesel engine catalytic converter is a pure oxidation catalytic converter. It oxidizes HC and CO into water and CO_2. It cannot reduce NO_2.

4. FUNCTIONS

A three-way catalytic converter has three simultaneous functions:

1. Reduction of nitrogen oxides into elemental nitrogen and oxygen. ($NO_x \rightarrow N_x + O_x$)
2. Oxidation of carbon monoxide to carbon dioxide. ($CO + O_2 \rightarrow CO_2$)
3. Oxidation of hydrocarbons into carbon dioxide and water. ($C_xH_{4x} + 2xO_2 \rightarrow xCO_2 + 2_xH_2O$)

Shelef & McCabe (2000) there are two types of "systems" that run in the catalytic converter- "lean" and "rich". When the system is running "lean", it means there is more oxygen than required, thus the reactions favor the oxidation of carbon monoxide and hydrocarbons (at the expense of the reduction of nitrogen oxides). On the contrary, when the system is running "rich", it means there is more fuel than needed, the reactions favor the reduction of nitrogen oxides into elemental nitrogen and oxygen (at the expense of the two oxidation reactions). With a constant imbalance of the reactions, the system is never running at 100% efficiency.

Converters can store "extra" oxygen in the exhaust stream for later use. This storage usually occurs when the system is running lean; the gas is released when there is not enough oxygen in the exhaust stream. The released oxygen compensates for the lack of oxygen-derived from the reduction of NO_x, or when there are hard acceleration and the air-to-fuel ratio system runs rich suddenly, faster than the catalytic converter can adapt to it. Also, the release of the stored oxygen helps in the oxidation process of CO and HC.

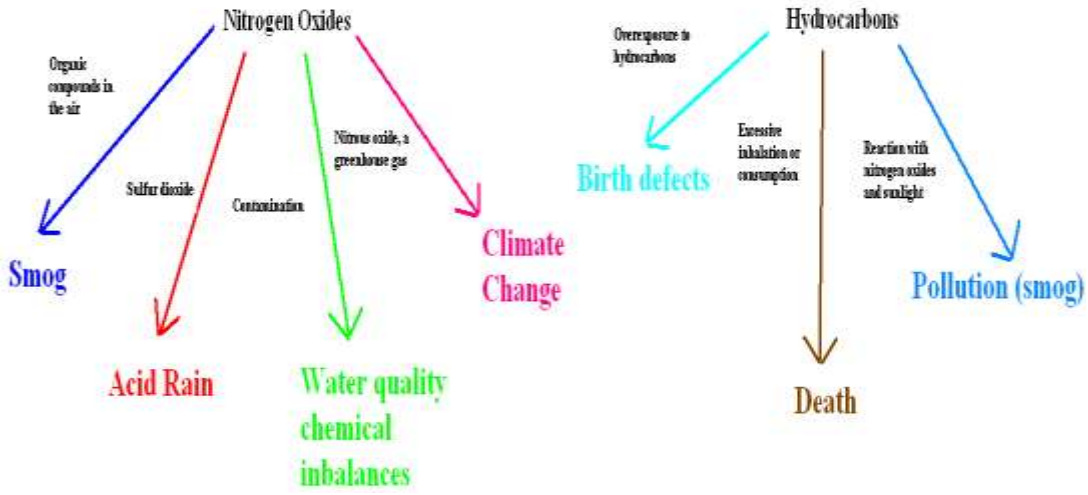
5.PROBLEM STATEMENT

Kuo Morgan *et al.* (1971) catalytic converters have proven to be reliable and effective in reducing noxious tailpipe emissions. However, they also have some shortcomings and adverse environmental impacts in production:

- Although catalytic converters are effective in removing hydrocarbons and other harmful emissions, they do not reduce the emission of carbon dioxide (CO_2), one of the greenhouse gases indicated by the Intergovernmental Panel on Climate Change (IPCC) as the leading cause of global warming.
- An engine equipped with a three-way catalyst must run at the stoichiometric point, which means more fuel is consumed than in a lean-burn engine. This means approximately 10% more CO_2 emissions from the vehicle.

Catalytic converter production requires palladium or platinum; part of the world supply of these precious metals is produced near Norilsk, Russia, where the industry (among others) has caused Norilsk to be added to Time magazine's list of most-polluted places.

5.1 Dangers of Pollutants



(Source: Dresselhaus & Thomas 2001)

Figure 13 Dangers of pollutants

Without the redox process to filter and change the nitrogen oxides, carbon monoxides, and hydrocarbons into less harmful chemicals, the air quality (especially in large cities) would reach a harmful level to the human being (Klimstra 1987).

Nitrogen oxides - these compounds are in the same family as nitrogen dioxide, nitric acid, nitrous oxide, nitrates, and nitric oxide. When NO_x is released into the air, it reacts with organic compounds in the air and sunlight, the result is smog. Smog is a pollutant and has adverse effects on children's lungs. NO_x reacting with sulfur dioxide produces acid rain, highly destructive to everything it lands on. Acid rain deteriorates cars, plants, buildings, national monuments and pollutes lakes and streams to such an acidity that is unsuitable for fish. NO_x can

also bind with ozone to create biological mutations and reduce the transmission of light (like smog).

Carbon monoxide - this form of CO_2 is a harmful variant of a naturally occurring gas. Odorless and colorless, this gas does not have many useful functions in everyday processes.

Hydrocarbons - inhaling hydrocarbons from gasoline, household cleaners, propellants, kerosene, and other fuels can cause death in children. Further complications can be central nervous system impairments and cardiovascular problems.

5.2 Global Warming into the Waste Heat Recovery System

Amatayakul & Ramnäs (2001) although catalytic converter has helped to reduce poisonous emissions from internal combustion motors, has also done its role in damaging the surroundings. Throughout the conversion of hydrocarbons and carbon monoxide carbon dioxide is made. CO_2 is just one of the absolute most usual greenhouse gases and contributes immensely to worldwide warming. Along with carbon dioxide, the human converters occasionally conjure the nitrogen-oxygen compounds to produce nitrous oxide. This really may be the very same substance used for laughing gas and in autos because of speed hike. Nitrous oxide is quite a bit more potent than carbon dioxide for greenhouse gas. It is 300 times more potent and therefore contributes to global warming that much more.

6.CONCLUSIONS

Varieties of the auto energy system have been grown and commercialized. The success of this technique will be striking and might result in a circumstance where the sort of dynamic power-plant or forthcoming Automobile waste heating inactive has been introduced. In this thesis, the dish machine has been selected to employ some promising field including thermo-electric. Factual statements regarding the testing and machine result, along with thermoelectric technology exhibited.

REFERENCES

1. Hosseini, M, Ranjbar, A, Sedighi, K & Rahimi, M 2012, 'A combined experimental and computational study on the melting behavior of a medium temperature phase change storage material inside shell and tube heat exchanger'. International Communications in Heat and Mass Transfer, vol. 39, no. 9, pp. 1416-1424.

2. Ikoma, K, Munekiyo, M, Furuya, K, Kobayashi, M, Izumi, T & Shinohara, K 1998, 'Thermoelectric module and generator for gasoline engine vehicles'. Thermoelectrics, Proceedings ICT 98. XVII International Conference on, IEEE.

3. Kaiser, A & Uher, C 1991, 'Thermoelectricity of high temperature superconductors. Studies of High Temperature Superconductors.

4. Kašpar, J, Fornasiero, P & Hickey, N 2003, 'Automotive catalytic converters: current status and some perspectives'. Catalysis Today, vol. 77, no. 4, pp. 419-449.

5. Khodadadi, J, Fan, L & Babaei, H 2013, 'Thermal conductivity enhancement of nanostructure-based colloidal suspensions utilized as phase change materials for thermal energy storage: a review'. Renewable and Sustainable Energy Reviews, vol. 24, pp. 418-444.

6. Khudhair, AM & Farid, MM 2004, 'A review on energy conservation in building applications with thermal storage by latent heat using phase change materials'. Energy conversion and management, vol. 45, no. 2, pp. 263-275.

7. Kim, H & Choi, B 2008, 'Effect of ethanol–diesel blend fuels on emission and particle size distribution in a common-rail direct injection diesel engine with warm-up catalytic converter'. Renewable Energy, vol. 33, no. 10, pp. 2222-2228.

8. Klimstra, J 1987, 'Catalytic Converters for Natural Gas Fueled Engines - A Measurement and Control Problem', SAE Technical Paper.

9. Koltsakis, G, Konstantinidis, P & Stamatelos, A 1997, 'Development and application range of mathematical models for 3-way catalytic converters'. Applied Catalysis B: Environmental, vol. 12, no. 2-3, pp. 161-191.

10. Kuo, J, Morgan, C & Lassen, H 1971, 'Mathematical modeling of CO and HC catalytic converter systems', SAE Technical Paper.

11. Laing, D, Steinmann, WD, Tamme, R & Richter, C 2006, 'Solid media thermal storage for parabolic trough power plants'. Solar energy, vol. 80, p. 10.

12. Lane, G A 1983, 'Solar heat storage: latent heat materials'.

13. Liu, M, Saman, W & Bruno, F 2012, 'Review on storage materials and thermal performance enhancement techniques for high temperature phase change thermal storage systems'. Renewable and Sustainable Energy Reviews, vol. 16, no. 4, pp. 2118-2132.

14. Liu, Z & Ihl Woo, S 2006, 'Recent advances in catalytic DeNOx science and technology'. Catalysis Reviews, vol. 48, no. 1, pp. 43-89.

15. Lu, H, Wu, T, Bai, S, Xu, K, Huang, Y, Gao, W, Yin, X & Chen, L 2013, 'Experiment on thermal uniformity and pressure drop of exhaust heat exchanger for automotive thermoelectric generator'. Energy, vol. 54, pp. 372-377.

16. MacDonald, DKC 2006, 'Thermoelectricity: an introduction to the principles, Courier Corporation.

17. Maiboom, A, Tauzia, X & Hetet, JF 2008. 'Influence of high rates of supplemental cooled EGR on NOx and PM emissions of an automotive

HSDI diesel engine using an LP EGR loop'. International Journal of Energy Research, vol. 32, no. 15, pp. 1383-1398.

18. Maiboom, A, Tauzia, X, Shah, SR & Hetet, JF 2010. 'Experimental Study of an LP EGR System on an Automotive Diesel Engine, compared to HP EGR with respect to PM and NOx Emissions and Specific Fuel Consumption'. SAE International journal of engines source, vol. 40, pp. 597-610.

19. Majumdar, A 2004, 'Thermoelectricity in semiconductor nanostructures'. Science ruby vol. 303, no. 5659, pp. 777-778.

20. Matsumoto, SI 2000, 'Catalytic reduction of nitrogen oxides in automotive exhaust containing excess oxygen by NOx storage-reduction catalyst'. Cattech, vol. 4, no. 2, pp. 102-109.

21. Meng, JH, Wang, XD & Chen, WH 2016, 'Performance investigation and design optimization of a thermoelectric generator applied in automobile exhaust waste heat recovery'. Energy Conversion and Management, vol. 120, pp. 71-80.

22. Mukadi, L & Hayes, R 2002, 'Modelling the three-way catalytic converter with mechanistic kinetics using the Newton–Krylov method on a parallel computer'. Computers & chemical engineering, vol. 26, no. 3, pp. 439-455.

23. Niu, X, Yu, J & Wang, S 2009, 'Experimental study on low-temperature waste heat thermoelectric generator'. Journal of Power Sources, vol. 188, no. 2, pp.621-626.

24. Pincemin, S, Olives, R, Py, X & Christ, M 2008, 'Highly conductive composites made of phase change materials and graphite for thermal storage'. Solar Energy Materials and Solar Cells, vol. 92, no. 6, pp. 603-613.

25. Py, X, Olives, R & Mauran, S 2001, 'Paraffin/porous-graphite-matrix composite as a high and constant power thermal storage material'. International Journal of heat and mass transfer, vol. 44, no. 14, pp. 2727-2737.

26. Rowe, DM 1999, 'Thermoelectrics, an environmentally-friendly source of electrical power'. Renewable energy, vol. 16, no. 1-4, pp. 1251-1256.

27. Salee, G 1995, 'Microwaved-activated thermal storage material; and method', Google Patents.

28. Saqr, KM, Mansour, MK & Musa, M 2008, 'Thermal design of automobile exhaust based thermoelectric generators: Objectives and challenges'. International Journal of Automotive Technology, vol. 9, no. 2, pp. 155-160.

29. Sarı, A & Karaipekli, A 2007, 'Thermal conductivity and latent heat thermal energy storage characteristics of paraffin/expanded graphite composite as phase change material'. Applied Thermal Engineering, vol. 278, no 9, pp. 1271-1277.

30. Schar, CM, Onder, CH & Geering, HP 2006, 'Control of an SCR catalytic converter system for a mobile heavy-duty application'. IEEE Transactions on Control Systems Technology, vol.14, no. 4, pp.641-653.