

# RETROFIT ELECTROSTATIC PRECIPITATOR FOR AUTOMOBILES

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**Abstract** - Electrostatic precipitators are used in the steel plants, thermal power plants and other such industries to remove harmful solid aerosols from flowing gases that are emitted into the atmosphere. The main objective of installing Electrostatic precipitators is to control the air pollution caused by the large industries. The industrial electrostatic precipitators are 3 to 6 meters in length and work on very high voltages. In this paper we brief about the scaling down the electrostatic precipitators into a retrofit device that can be used to capture the air pollution particulates from the exhaust gas of the automobile engines using the principle of electrostatic precipitation.

**Key Words:** Precipitation, Retrofit, Pollution, Particulate, ESP, Automobile, Engines, Exhaust.

## 1. INTRODUCTION

An electrostatic precipitator works on the electrostatic attraction of the unlike charges. An electrostatic precipitator uses a high voltage static electric field to separate the solid particulates from the flowing gas. The passage of the gas consist of vertical parallel plates that and the ground collector plate that act as electrodes. A high voltage source powers the electrodes to generate the static electric field between them. The vertical parallel plates and the ground collector plates are separated up to one meter to avoid short circuit. When the gas flows into the strong negative electric field within the vertical parallel plates it produces corona discharge that is the electrical breakdown of the gas transforming it into conducting state from insulating state. Corona discharge produces free electrons that gets adhere to the solid particulates present in the flowing gas and make them negatively charged. The strong negative electrical field repels the negatively charged solid particulates while the strong positive electrical field of the ground plate attracts the solid particulates towards them and form a dust layer on the plate.

To eliminate the solid particulates from the exhaust gas of the automobile engines electrostatic precipitation principle can be utilized. For this application the electrostatic precipitators should be scaled down into a retrofit device that can be fitted onto the exhaust pipe of the automobiles. The exhaust gas of the engine when passed through such a device undergoes electrostatic precipitation and the solid particulates can be eliminated from the exhaust gas of the automobile. Where the catalytic convertors oxidize harmful gas carbon monoxide to less harmful carbon dioxide gas, the addition of a retrofit electrostatic precipitator can make the emissions harmless by eliminating solid aerosols. The

working of this device resembles to that of industrial electrostatic precipitators the difference being operating voltage, operating temperature and working gas. The working gas here being emissions from both petrol, diesel engines.

### 1.1. Particulate matter in Working Gas

The particulate matter associate with both petrol and diesel engines. However they are most commonly associated with diesel engines. They are responsible for the black smoke emitted by the old diesel engines. The modern medical science suggests that the solid particulate matter emitted by the diesel engines is harmful to both human health and the environment. The size of the particles is directly linked to the potential for causing health and environmental problems. The smaller size particles are known to cause more damage, these particles are carried by the winds for long distances and settle on the water bodies making them less acidic and disturbing the aquatic ecosystem. Diesel particulate matter are the primary focus of the diesel emission control technology. The particulate matter primarily consist of soot particles of diameter less than 40 nm and polynuclear aromatic hydrocarbons (PAH). The emission rate of particulates for any engine is calculated by particulate matter (PM) mass (mg/km) and total particle number (1/km). The figure 1.1.1 gives the comparison of the emission rates of particulates from various engine technologies such as CNG, Gasoline, GDI and Diesel.

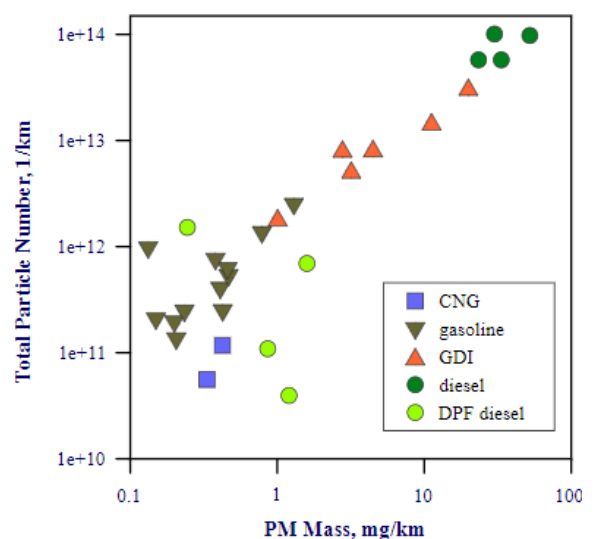


Figure 1.1.1 Comparison of the emission rates of particulates.

From Figure 1.1.1 it is observed that the emission rate of particulate matter is highest in diesel engine technology.

## 2. Design of the Retrofit Device

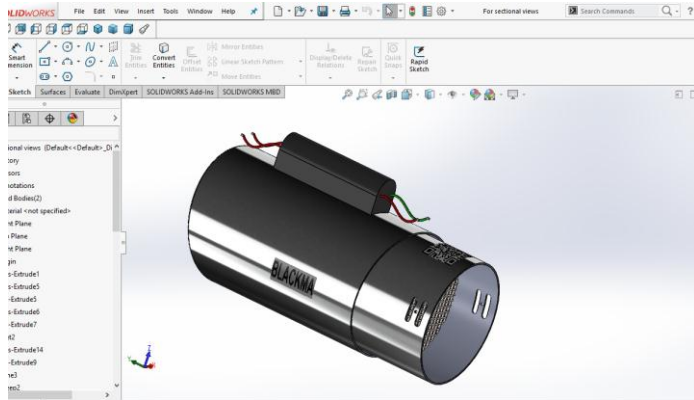


Figure 2.1 CAD Model of the Device



Figure 2.2 Physical model of the Device

The device mainly consist of metal casing, insulating tube, positive and negative electrodes, high voltage source. The device can be powered by both automobile battery as well as external power source. 1mm Galvanized iron plates are used as the positive electrode, a metal mesh is used as the negative electrode. A DC 12 V to 400 kV high voltage generator transformer inverter module 67 x 25 mm is used to generate strong static electric field in the path of flowing gas. The charge leakage in the system is eliminated by an insulating tube that avoids any short circuit due to high voltage. A removable rectangular storage unit inside the metal casing collects the solid particulate matter and soot particles.

### 2.1. Design of the Positive Electrodes

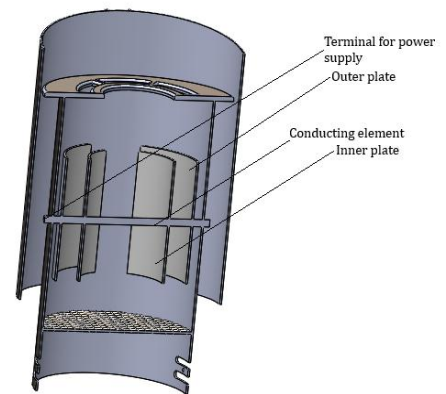


Figure 2.1.1 Isometric Sectional View to reveal vertical plates

The device consists of four vertical plates that act as positive electrode. Two outer plates and two inner plates. All the four plates are curved to match the curvature of the inner periphery of the metal casing. The curvature of the plates increases the contact area between the flowing gas and plates. Between all the four electrodes a conducting element passes through as shown in Figure 2.1.1 that holds the plates in place as well as provides the terminal for the power supply. The outer plates have less radius of curvature compared to that of the inner electrodes.

### 2.2. Design of the Negative Electrodes

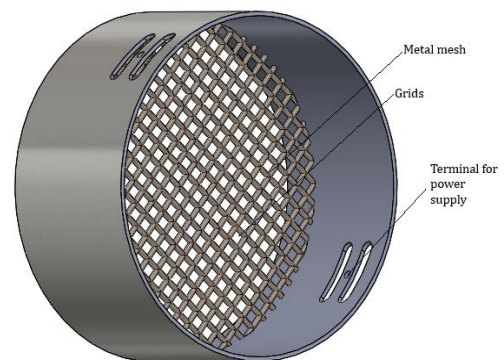


Figure 2.2.1 Isometric Sectional View revealing the Metal mesh

The device consists of a metal that act as the negative electrode. The electrode has a grid size of 2mm, to increase the contact area between the flowing gas and the metal mesh. The terminal for power supply is located above the metal mesh as shown in the Figure 2.2.1. As the whole electrode body is conductive, the metal mesh can be negatively charged by connecting the negative terminal of the high voltage source to the terminal of power supply provided in the negative electrode.

### 2.3. Materials

The whole metal casing is made using stainless steel grade 202. The metal mesh is made using the mild steel 0.5mm metal wire. The vertical plates are made using Galvanized iron 1mm thick plates. The inner periphery of the metal casing is lined with a thin layer of varnish to avoid the charge leakage due to strong static electric fields created by the DC transformer inverting module. The conducting element is a 5mm mild steel rod with the open contacts at the extreme ends. The storage unit is also made of stainless steel grade 202 metal.

### 3. Working of the Device

The device works on the principle of electrostatic precipitation. Electrostatic precipitation uses high static electric field to capture the particulate matter. When the device is powered the vehicle exhaust gases first passes through the mesh which act as negative electrode as shown in the Figure 2.2.1. After which the precipitation of the gas occurs and the carbon particulate matter will accumulate on the curved plates which act as positive electrodes as shown in the Figure 3.1.

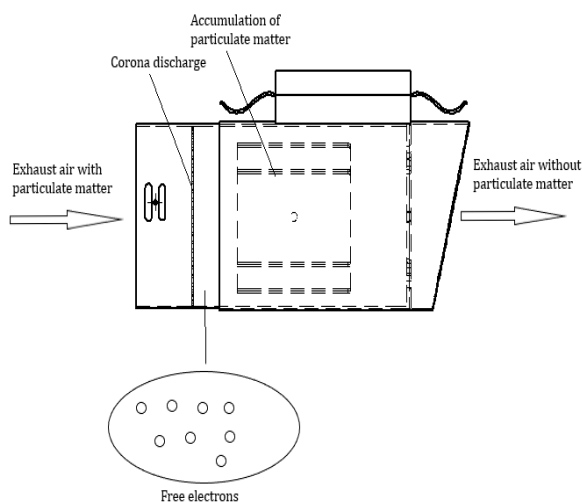


Figure 3.1 Working of the Device

#### 3.1. At Negative Electrode

The device is powered on and the voltage across electrodes is increased until the electrical breakdown of the gas occurs from insulating phase to conducting phase that is known as corona discharge. During corona discharge some free electrons get generated those free electrons move away from the negative electrode (because like charges repel) these electrons crash on to gas molecules bumping off electrons from those molecules. This chain continuous producing many electrons, when the exhaust gases pass through the negative electrode the free electrons generated during chain reaction will bombard on the solid particulate matter

present in the exhaust gas and adhere to them. This makes the particulate matter to charge negatively.

#### 3.2. At Positive Electrodes

The exhaust gas move further carrying negatively charged solid particulate matter towards the positively charged electrodes. As the negatively charged particulate matter come near the positive electrodes they attract negatively charged particulate matter towards them (because unlike charges attract). As a result of this the particulate matter get accumulated on the positive electrode plates. Some negative charge remain on those particulate matter which help them to stick on to positive electrode. This process result in exit of clean exhaust gas from the vehicle.

#### 4. Real time working of the Device



Figure 4 Device installed on a petrol engine car

Testing of the device was carried on a petrol engine car. The test was carried out for two hour. In the first hour the device was not powered on, while in the second hour the device was powered on and the reading were recorded as shown in the Table 4.1.



Figure 4.1 Collected particulate matter during second hour

**Table 4.1 Test Readings**

Weight of the positive electrode	
Before Powered	After Powered
41.280 gram	43.836 gram



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**Conclusion**

The paper dealt with effective scaling down of the industrial electrostatic precipitator to a retrofit electrostatic precipitator for automobile engines. It is observed the efficiency of the device is greater when the exhaust gas interacts with the negative electric field first. The device collected 2.556 gram/hr of solid particulate matter from the running petrol engine and the number is estimated to be greater in case of diesel engines. There is scope for further optimization of the device.

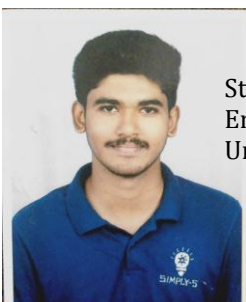
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