ENOx, AN ELECTRONIC PROCESS FOR NOx ABATEMENT

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Recent revisions of the Clean Air Act have mandated increasingly stringent controls on NOx emissions. Combustion of fuel in engines for transportation and in boilers for electric utility and industrial power generation produce over 90 percent of all NOx emissions. ENOx, a recently discovered electronic process, shows significant promise for reducing NOx emissions from mobile sources such as cars and trucks in the near term and large stationary sources such as boilers in the long term.

The key to PlasMachines ENOx emission control process is the use of a **plasma,** that is an **electronically excited gas**, to cause the decomposition of NO and NO_2. A simplified process diagram is shown in Figure 1. Electrical power feeds a proprietary electronics package which provides the excitation to the process duct. The duct is basically an open chamber with special electrodes and operates at atmospheric pressure or the combustion exhaust stream pressure. The process plasma is an alternating current, discontinuous, multifrequency, non-equilibrium discharge. During operation,

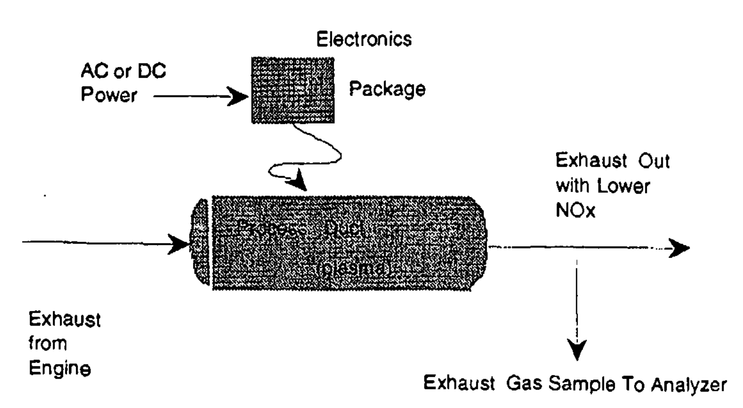

Figure 1 . Simplified Process Flow Diagram

exhaust gas flows through the process duct and constituents of the exhaust stream are activated by collision or ionization with plasma electrons under the influence of the electronic excitation. Molecules of NO and NO_2 are thermodynamically unstable with respect to decomposition back to the elements, nitrogen and oxygen . Hence, after activation by plasma processes, NO and NO_2 undergo decomposition and their concentrations in the exhaust are reduced.

Three engines have been tested using this exhaust treatment process: a 5 hp Briggs and Stratton gasoline engine, an 8 hp Kubota diesel electrical generator set, and a 40 hp Ford multi-fuel industrial engine. The Ford Model VSG-411 is a multi-fuel four cylinder, four stroke, 1.1 liter engine. The engine will accept either gasoline or methanol as liquid fuels and with an IMPCO carburetor will also burn natural gas. Natural gas was used as the fuel for the testing during this experimental work.

PlasMachines current facilities include a complete test facility for dynamometer and emissions testing of engines of all types up to 1000 hp. A Superflow 901 Dynamometer utilizes a water brake to load and measure the output torque of engines, including the Ford engine used in this development work, operating on a test stand under computer control. A photograph of the Ford engine mounted on the dynamometer is shown in Figure 2

Samples of exhaust gas are drawn continuously by vacuum pumps from the engine exhaust line, through a teflon transfer line, and into the emissions analyzers. A small refrigerator with collection trap was used to prevent condensation from the exhaust sample line from entering and interfering with the analyzers.

Emissions monitoring equipment utilized include a Thermo Electron Model 10S NO/NOx Chemiluminescent Analyzer capable of measuring either NO or total NOx concentrations from 1 to 10,000 ppm. An Horiba Model MEXA-554GE NDIR automotive emission analyzer provides capability of continuous or spot monitoring of O_2, CO_2, CO, unburned hydrocarbons (UHC), and calculated air to fuel (A/F) ratio.

The four parallel reactors were each assembled from two stainless steel tees and a single straight length of 1.5 inch tube which were clamped together and clamped to the inlet and outlet manifold. Adapters clamped to each end of the reactor tube served to coaxially locate and support a one inch diameter electrode. Each reactor was connected electrically to a PlasMachines electronic source with two leads - the ground lead was connected to the stainless steel reactor shell while the electronic signal was connected to the electrode. A front view of the parallel reactor array are shown photographically in Figure 3.

The engine and reactors were tested using the following protocol. The Ford natural gas engine was started and run for approximately twenty minutes to ensure that all operating components and fluids including engine oil, cooling and dynamometer water were up to normal operating temperatures. The surface temperatures on the exhaust lines and reactor exterior surfaces were measured. The reactor exterior surfaces were found to be between 250 and 280 F. The engine was operated at 830 and 1600 rpm with a torque load of 7 ft-lbs. With the PlasMachines electronic sources turned off, the uncontrolled levels of NO and NOx *were measured* as 300 *and* 320 respectively. When the electronic sources were turned on, the resulting ENOx process plasma reduced the NO and NOx levels to 60 and 180 respectively. **This demonstrates an 80% reduction in NO and a 44% reduction in NOx.** Power consumption by the electronic unit was 200 W.

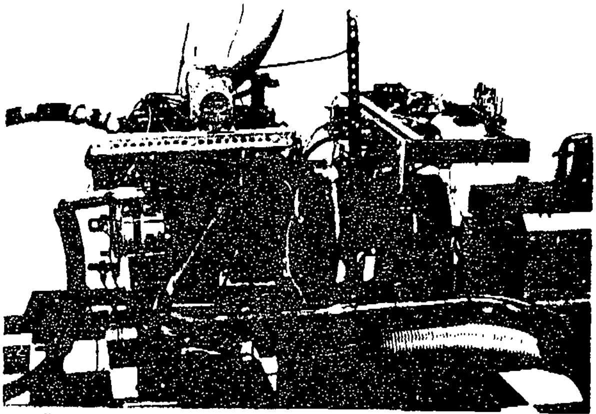

Figure 2. Ford industrial engine mounted on Superflow 901 Dynamometer

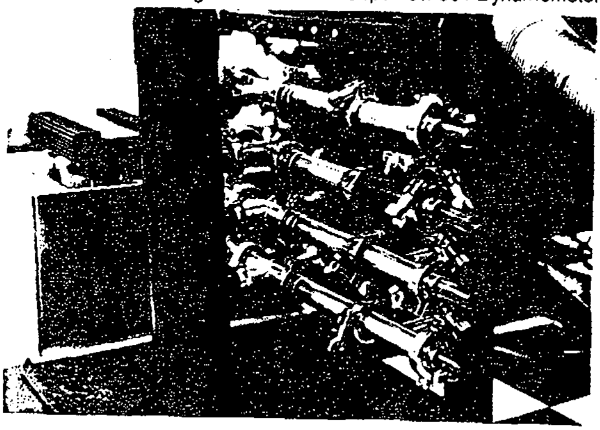

Figure 3. Front view of four parallel reactor units