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Applications of Non-Thermal Plasmas for Control of NOx and VOCs from U.S. Air Force Operations

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The Environics Directorate (AL/EQ) of the U.S. Air Force Armstrong Laboratory is developing and demonstrating new technologies for environmental risk reduction in hazardous waste treatment, air pollution control, and site cleanup. The control of air pollution from dilute, large volume sources is a challenging problem encountered at Department of Defense installations. AL/EQ is exploring novel low-temperature (ambient to ~125°C) approaches for reduction or oxidation of gaseous effluents, including nitrogen oxides (NOx), volatile organic compounds (VOCs) and other hazardous air pollutants (HAPs), from Air Force maintenance and training operations. AL/EQ is currently in various stages of conducting programs investigating the nonthermal plasma treatment of VOC and HAP emissions from paint spray facilities, and NOx , VOC, and HAP emissions from jet engine test facilities and aerospace ground equipment. Nonthermal plasmas can be generated through various processes by excitation of electrons in a gas flow to create radical species which initiate primarily oxidation reactions. Pulsed corona, dielectric barrier discharge, and electron beam irradiation are well-established processes for generation of nonthermal plasmas. We will present experimental results using a small electron beam reactor, pulsed corona reactor, and dielectric-barrier discharge. We have used these reactors to study the removal of NOx and a wide variety of VOCs. We have studied the effects of background gas composition and gas temperature on the decomposition chemistry. The decomposition mechanisms will be discussed to illustrate how the chemistry could strongly affect the economics of the process. Computer modeling of the plasma chemical kinetics serves as an important design tool for minimizing the energy consumption of the process and identifying all possible byproducts.

Current activities include the following: 1) A large pulsed corona reactor has been constructed for treatment of NOx , VOCs, and HAPs from stationary jet engine testing, 2) a proposal is being prepared for a program to demonstrate an electron beam for treatment of VOCs from spray painting. Design has also begun on a pulsed corona reactor for treatment of paint spray VOCs, and 3) a system to demonstrate a barrier discharge reactor for exhaust gas treatment of air pollutant emissions from aerospace ground equipment (AGE) is under design.

Stationary testing of jet engines was considered for new source regulation pursuant to the 1990 Clean Air Act Amendments. A joint Department of Transportation and Environmental Protection Agency Report to Congress estimated total NOx emissions from commercial and military jet engine testing at approximately 3 percent of stationary source and 0.7 percent of combined stationary and mobile source NOx emissions nationwide. AL/EQ had previously investigated catalytic oxidation and reduction utilizing metal catalysts and selective catalytic reduction using ammonia injection and determined both incapable of handling the nonsteady state flow conditions of jet turbine exhaust in the proper operating temperature windows. Exhaust flow rates during jet engine testing range from 5500 to 115,000 cubic meters per minute, with NOx concentrations less than 100 ppm. One of two processes identified with potential for down-stream control of NOx emissions was pulsed corona-induced nonthermal plasma. A 30-cm diameter pulsed corona reactor with 2.5 m of active corona length has been constructed in the laboratory and is being optimized for control of NOx, VOCs, and HAPs present in jet turbine exhaust.

Aircraft painting and depainting facilities in the U.S. Air Force, from paint spray booths for parts to full aircraft hangars, have exhaust flow rates ranging from 500 to 6000 cubic meters per minute, with VOC concentrations of around 100 ppm. Multiple commercial technologies are available to reduce the total volume of exhaust air to be treated, including split-flow recirculation and rotary concentrators. A pulsed corona reactor system is being designed to treat approximately 25 cubic meters per minute of exhaust flow from a paint spray facility. A proposal has been submitted for a program to demonstrate a similar system using an electron beam for treatment of paint spray VOCs. When both programs are complete, the performance results and economics will provide comparisons of the practical applicability of the technologies. The proposed system design, construction, installation, and testing schedule will be presented in this paper.

Stringent regulations of emissions from aerospace ground equipment (AGE) are causing logistics problems that could impair flight-line operations at several Air Force bases. Of immediate concern are the NOx emissions from AGE at March AFB near Los Angeles, California. In response to this concern the Logistics Research Division of Armstrong Laboratory (AL/HRG) is managing the "Green AGE" effort to develop and demonstrate technologies to control AGE NOx emissions. As part of the Green AGE program, the Armament Directorate of Wright Laboratory (WL/MNMW) and AL/EQ are constructing a nonthermal plasma discharge (NTPD) system to treat a portion of the exhaust from the worst AGE NOx emitter, the A/M32A-86 diesel-powered generator. The reactor tube of the NTPD system will be 45 enamel-coated electrodes (double dielectric barrier) spaced 1 to 3 millimeters apart, and will be capable of treating flow rates up to 1 cubic meter per minute. The reactor tube will be followed by an air-to-air heat exchanger and wet scrubber. The system design, status, schedule, and initial results will be presented in this paper.

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