COMMERCIAL INTRODUCTION OF THE ADVANCED NOxTECH SYSTEM

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INTRODUCTION

NOxTECH, Inc. is commercializing emissions control systems for combustion equipment. The first commercial product is the Advanced NOxTECH system for diesel engine exhaust. This system reduces NO_x emissions more than 90% and controls emissions rates below 0.25 g NO_2/hp-hr. These emissions reductions are achieved without NH_3 slip which is characteristic of other chemical aftertreatments such as selective catalytic reduction (SCR).

The Advanced NOxTECH system replaces the exhaust silencer for diesel engines. This simple, compact design was developed as an improvement to the commercial NOxTECH systems which are Best Available Control Technology (BACT) for diesel electric generators. Advanced NOxTECH uses a liquid chemical which reduces equivalent to powdered cyanuric acid. Like cyanuric acid powder, the liquid chemical is non-hazardous and innocuous, but it is handled more simply and conveniently than powder.

Southern California Edison Company (Edison) is using a NOxTECH system daily to operate a 2.8 MW diesel generator in compliance with their operating permit for a new major NO_x emissions source in the Los Angeles Air Basin. Also, a 150 kW Advanced NOxTECH system is operating at the NOxTECH test facility in Irvine, CA. Based on this successful development plan (Sudduth, et. al. 1995), NOxTECH, Inc. is introducing commercial systems as described below.

NOxTECH ESTABLISHED AS BACT

A first commercial NOxTECH system was installed on a 1.5 MW generator at the Edison Pebbly Beach Generating Station. This system demonstrated compliance with Rule 1110.2 of the South Coast Air Quality Management District (AQMD). Based on these results, the AQMD permitted Edison to construct a new 2.8 MW generating unit using the NOxTECH system for exhaust aftertreatment. The NOxTECH system was supplied to Edison with a guarantee for 95% NO_x reduction meeting the BACT requirement for major emissions sources.

This NOxTECH system (Picture 1) started operating in October 1995. By December 1995, the system was reliably reducing NO_x as much as 98% at 1400° F. During this period, the reactor startup procedure was modified for unexpectedly low engine exhaust temperatures of only 500-600°F. The modified procedure enabled the NOx-TECH system to startup within about 45 minutes while the engine exhaust slowly warmed up to normal operating temperatures in the range of 500-600° F.

The NOxTECH control system was upgraded in early January 1996 to implement the modified startup procedure automatically. As soon as the 4,000 hp engine switches from idle to run status, the burner firing rate is controlled to maintain an exhaust gas temperature of 1400° F in the NOxTECH reactor. This hot gas discharges into the NOxTECH heat exchanger for preheating the engine exhaust. After the engine warms up, the burner shuts down and the temperature is controlled by injecting diesel fuel directly into the preheated exhaust. The heat recovery and exhaust preheating minimize the consumption of diesel fuel to control the reactor temperature at 1400° F.

The final emissions source tests were conducted in late January 1996 following the successful automation of the modified start-up procedure. In addition to verifying compliance with the operating permit, the source tests also confirmed that the NOx-TECH system decreased particulate emissions by about 60% with negligible reaction by-products. Using powdered cyanuric acid to reduce NO_x, the system maintained CO below 50 ppm and NH_3 slip never exceeded 2 ppm. Extensive third-party testing detected no toxic reaction by-products.

These source test results established NOx-TECH as BACT for diesel electric generators. Since January 1996, continuous emissions monitoring has verified compliance with the new source operating permit for the 2.8 MW generator. These successful emissions controls have enabled Edison to expand their diesel electric power generating capacity on Catalina Island. Without this BACT performance, the emissions regulations would have required Edison to install combustion turbine generators at much greater expense.

ADVANCED NOxTECH SYSTEM

The Advanced NOxTECH system was developed to decrease the size, weight, and cost of equipment for BACT emissions reductions. In this system, the reactor and heat exchanger are integrated compactly together. Resembling an exhaust silencer, this configuration greatly improves heat recovery and accommodates thermal cycling to temperatures in the range of 1400-1550° F. At these conditions, the gas-phase NO_x reduction is completed in only 0.2-0.3 seconds, and less fuel is added to maintain the temperature.

NOxTECH, Inc. is operating a full-scale commercial prototype (Picture 3) of the advanced system at its test facility in Irvine, CA. This system replaces the silencer on a 150 kW generator. The engine exhaust discharges directly from the turbocharger to the Advanced NOxTECH system. The temperature and liquid chemical injection are controlled automatically as illustrated in Figure 1. NO_x reduction is monitored using stack gas emissions measurements.

In the Advanced NOxTECH prototype, the engine exhaust is first preheated within 120-150° F of the reaction temperature for NO_x reduction. After this heat recovery, the temperature is controlled by adding diesel fuel to the preheated exhaust, and the liquid chemical is injected to reduce NO_x. The gas-phase reactions require no solid catalytic surfaces. After NO_x removal, heat is recovered to preheat the engine exhaust and cool the treated stack gas.

The Advanced NOxTECH heat exchanger operates effectively throughout the normal load range for the diesel engine. The steady-state temperature measurements in Figure 2 show this performance in the range of 20-160 kW. The engine exhaust is consistently preheated to 1230-1370° F even though the turbocharger discharge varies between 600° F and 1080° F with generator load. No fuel is consumed for this exhaust preheating.

Diesel fuel is added only to control the reactor exit temperature. The preheated exhaust temperature increases by only 120-150° F. After NO_x reduction, the hot exhaust exits the reactor and enters the heat exchanger. The incremental heating enables countercurrent heat exchange between the hot treated gas and the engine exhaust. The stack gas temperature increases less than 120-150° F due to heat losses.

Heating the exhaust gas by 120-150° F increases fuel consumption less than 8% at full load. With Advanced NOxTECH, this small fuel penalty enables more than 90% NO_x reduction. Engine modifications cannot reduce NO_x equivalently, and they penalize fuel consumption more severely. The Advanced NOxTECH system reduces NO_x emissions more efficiently and cost-effectively than any engine modifications.

COST-EFFECTIVE EMISSIONS COMPLIANCE

The Advanced NOxTECH system enables diesel engines to operate most efficiently and cost-effectively. Higher baseline NO_x levels and lower exhaust temperatures do not increase the fuel consumption. BACT emissions levels are maintained while engines operate at maximum fuel efficiency, power production, and service reliability. This optimization of engine operations conserves fuel and offsets the small fuel penalty for Advanced NOxTECH which removes NO_x more selectively and less expensively than engine modifications.

The Advanced NOxTECH system reduces high NO_x levels in proportion to the liquid chemical injection. In Figure 3, this NO_x reduction is expressed stoichiometrically on a basis comparable to cyanuric acid which decomposes and forms HNCO. Emissions of about 6.0 g NO_2/hp-hr are reduced proportionately as much as 90%.

Chemical consumption increases more than stoichiometrically only when NO_x levels are reduced below 1.0 g NO_2/hp-hr. The NO_x emissions are reduced 95% or more to levels below 0.25 g NO_2/hp-hr by injecting liquid chemical in excess of stoichiometric amounts. The Advanced NOxTECH system maintains NH_3 slip below 2 ppm despite 50% excess chemical injection.

With the low-cost liquid chemical and the high-efficiency heat exchanger, NO_x removal costs are generally lower than $700/ton (basis NO_2 removed). This operating cost for fuel and chemical corresponds to a baseline NO_x level of 6.0 g NO_2/hp-hr. Since the gas-phase NO_x reactions do not deteriorate like catalysts, emissions are always reduced reliably using the same fuel and chemical injection.

NOxTECH, Inc. is quoting costs of about $100/kW for the Advanced NOxTECH system in prime power applications. These costs for introductory units depend on the performance guarantees in specific applications. Production units with standard performance guarantees are expected to cost $30-60/kW after about one-year of introductory unit operations.

In standby applications, the Advanced NOxTECH system costs about half as much as for prime power units. The heat exchanger is not needed when the startup burner is operated continuously to preheat the engine exhaust. If units are operated infrequently, the exhaust is preheated less expensively using the burner rather than the heat exchanger.

Less stringent emissions reductions lower both the equipment and operating costs for Advanced NOxTECH. For example, a 1.8 g NO_2/hp-hr engine is controlled below 1.0 g NO_2/hp-hr by treating 50% of the exhaust with 90% NO_x reduction. Then, Advanced NOxTECH costs only half as much as a standard application requiring 90% NO_x reduction overall, and the fuel consumption is increased no more than 4% because only half of the exhaust is heated to reaction temperatures. The liquid chemical consumption remains proportional to the NO_x removed when NO_x reduction does not exceed about 90%.

EMISSIONS CONTROL ADVANTAGES

The Advanced NOxTECH system uniquely controls exhaust temperature. The burner quickly establishes the reactor temperature after engine startup. As the engine warms up, the burner modulates to maintain the reactor temperature. After the engine is warmed up, the burner or a heat exchanger can preheat the engine exhaust. In either case, the exhaust is heated continuously to an optimum temperature for NO_x reduction.

This unique temperature control enhances emissions control in comparison with other exhaust aftertreatments. In standby applications, the Advanced NOxTECH system operates effectively before the engine exhaust is warm enough for catalytic NO_x removal. Soon after startup, the Advanced

NOxTECH system is removing CO, particulates, and ROG's.

Advanced NOxTECH does not trade off one pollutant for another. The NOxTECH temperature control reliably maintains NH_3 slip below 2 ppm even when NO_x is reduced by 95% or more. In SCR systems, NO_x emissions are reduced more than 90% only by greatly increasing NH_3 slip or catalyst volume. The catalyst accumulates poisonous contaminants and represents a hazardous waste similar to excess NH_3 slip.

Even engine modifications cannot generally remove NO_x concurrently with CO, particulates, and ROG's. Engine modifications typically result in tradeoffs between the different pollutants which can damage SCR catalysts by plugging their pores with soot or poisonous contaminants. Only Advanced NOxTECH removes all criteria pollutants concurrently, and no exhaust contaminants are detrimental to the gas-phase thermal reactions.

These inherent advantages enable NOxTECH systems to control emissions reliably without continuous emissions monitoring. Advanced NOxTECH can maintain emissions compliance using feedforward control of the liquid chemical injection. Only a feedback temperature control is needed to ensure effective reduction of all criteria pollutants. NOxTECH, Inc. is testing various methods for verifying NO_x reduction without measuring NO_x specifically.

OTHER NOXTECH APPLICATIONS

With its inherent advantages, NOxTECH is suited to a wide range of commercial and industrial applications. The Advanced NOxTECH system can compactly replace the exhaust silencers for mobile diesel engines, especially in fleet applications including trucks, buses, and locomotives. NOxTECH, Inc. is also planning to test equipment for applying the technology to industrial and utility boilers.

The Advanced NOxTECH system is especially well-suited for coal-fired utility boilers. A boiler retrofit requires only the installation of an injection grid and control system. The boiler operations already preheat the exhaust gas and recover waste heat. Such boiler retrofits are projected to cost less than half as much as SCR systems. Advanced NOxTECH is expected to enhance flyash properties substantially, decreasing unburned carbon. In this case, flyash is upgraded from a hazardous waste to a valuable cement component.

SUMMARY AND CONCLUSIONS

NOxTECH is BACT for diesel electric generators. Emissions of NO_x are reduced 95% or more with substantial concurrent reductions in CO, particulates, and ROG's. No engine modifications or other exhaust aftertreatments can remove all criteria pollutants as effectively as NOxTECH. The NOxTECH system reliably maintains NH_3 slip below 2 ppm. Unlike other emissions controls, NOxTECH does not generate hazardous by-products.

The Advanced NOxTECH system reduces the size, weight, and cost for BACT emissions reductions. Based on the operation of a 150 kW prototype, NOxTECH, Inc. is quoting commercial units for diesel electric generators. Advanced NOxTECH equipment costs about half as much as SCR systems, and NOx reduction can exceed 95% with guarantees for emissions compliance.

REFERENCES

Sudduth, B.C., M. Addy, M. Ramavajjala, V. Palekar, S. Ren, and R. Slone, "Advanced NOxTECH System for Exhaust Aftertreatment", Proceedings of the 1995 Diesel Engine Emissions Reduction Workshop, July 24-27 (1995).

ACKNOWLEDGEMENT

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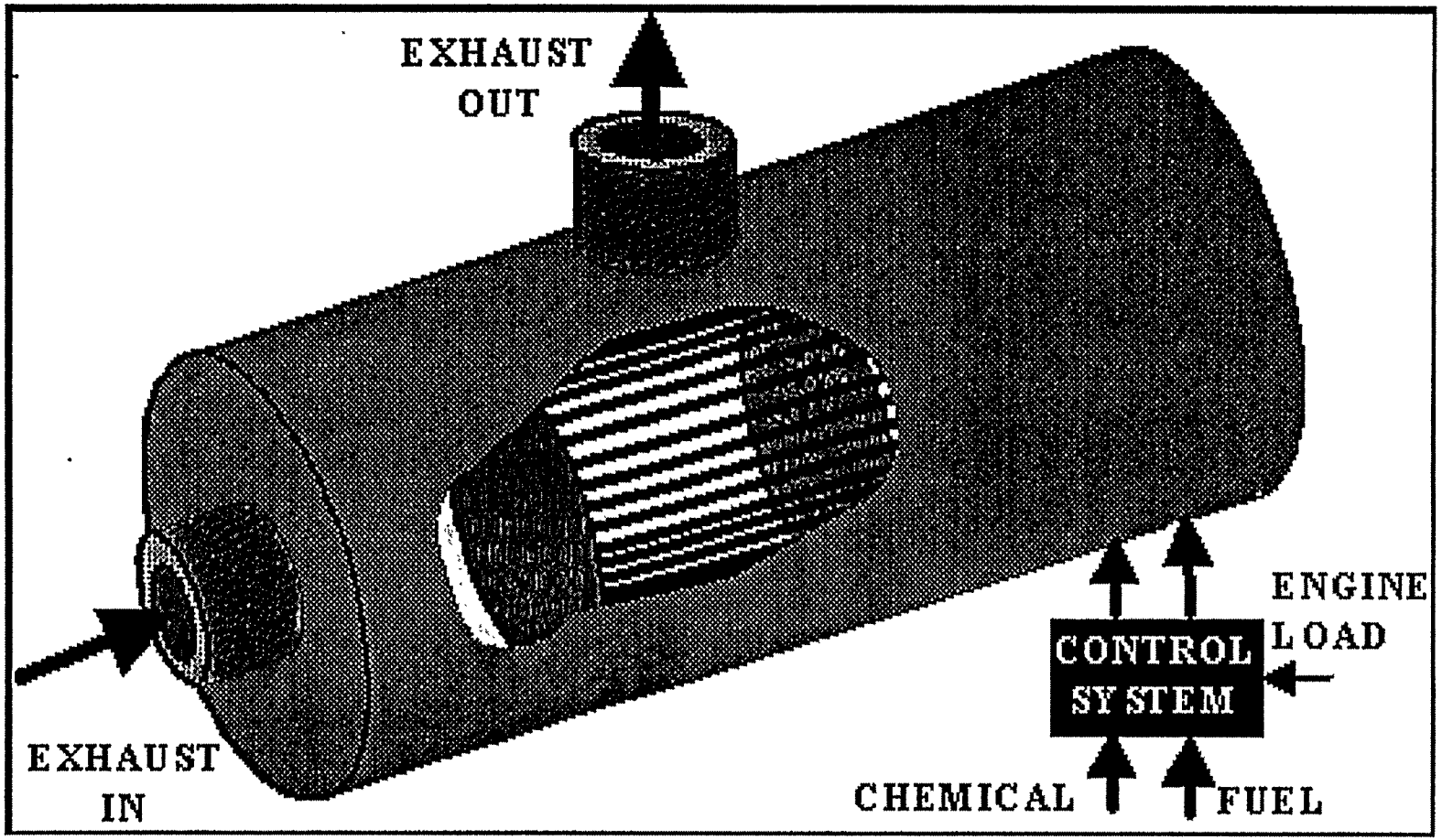


Figure 1 Controlled Fuel and Chemical Injection for Exhaust Aftertreatment

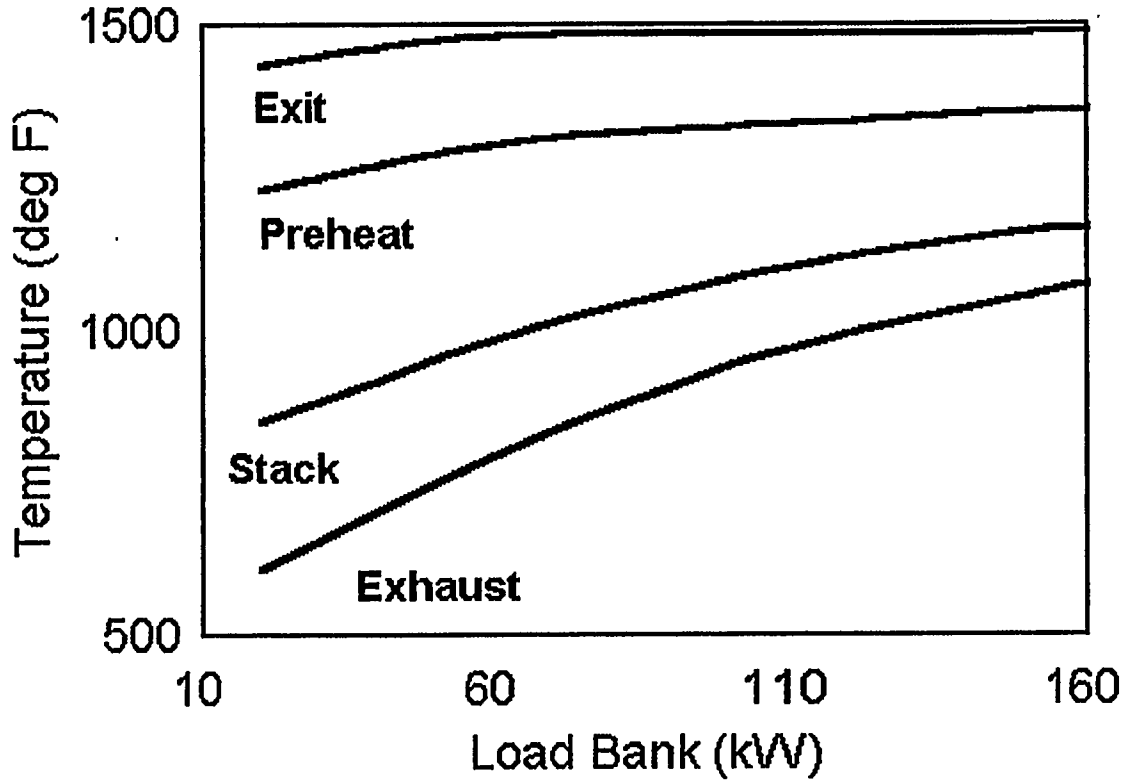


Figure 2 Uniform Exhaust Preheating Over Load Range

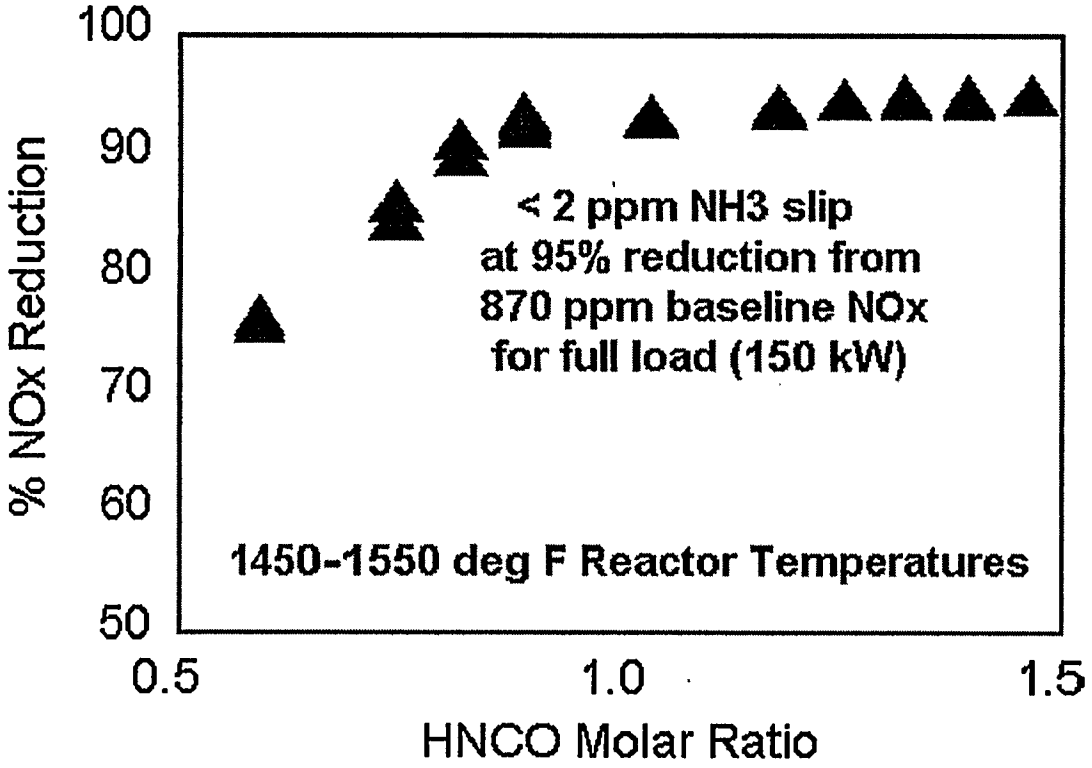
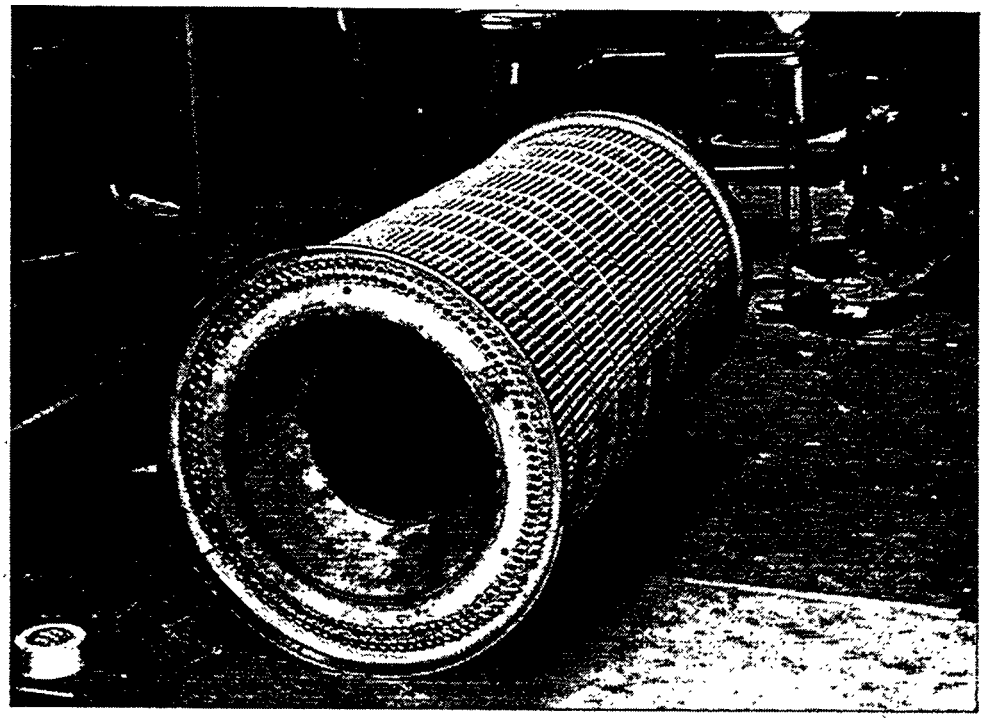
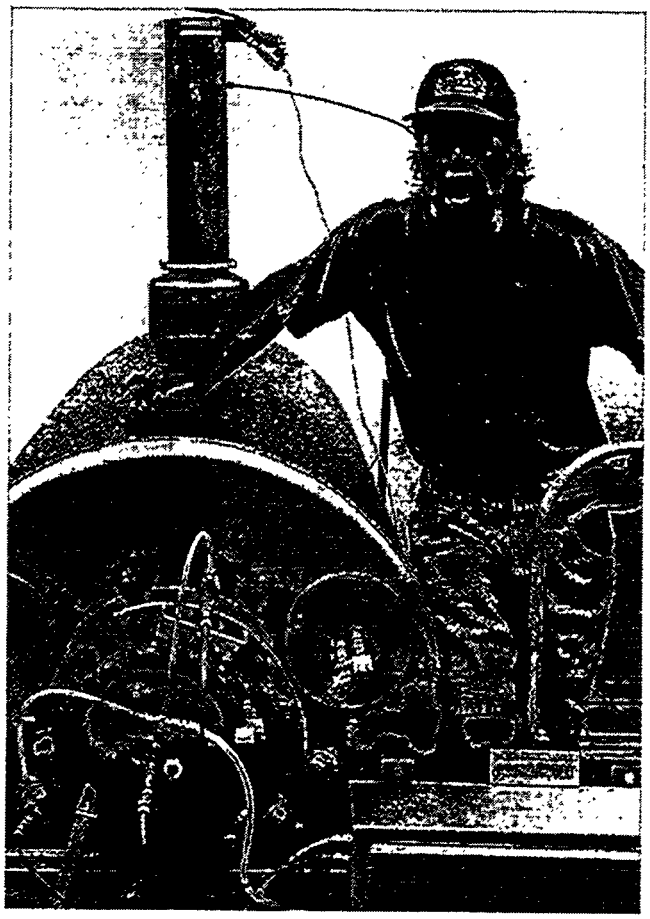


Figure 3 Liquid Injection Equivalent to Cyanuric Acid

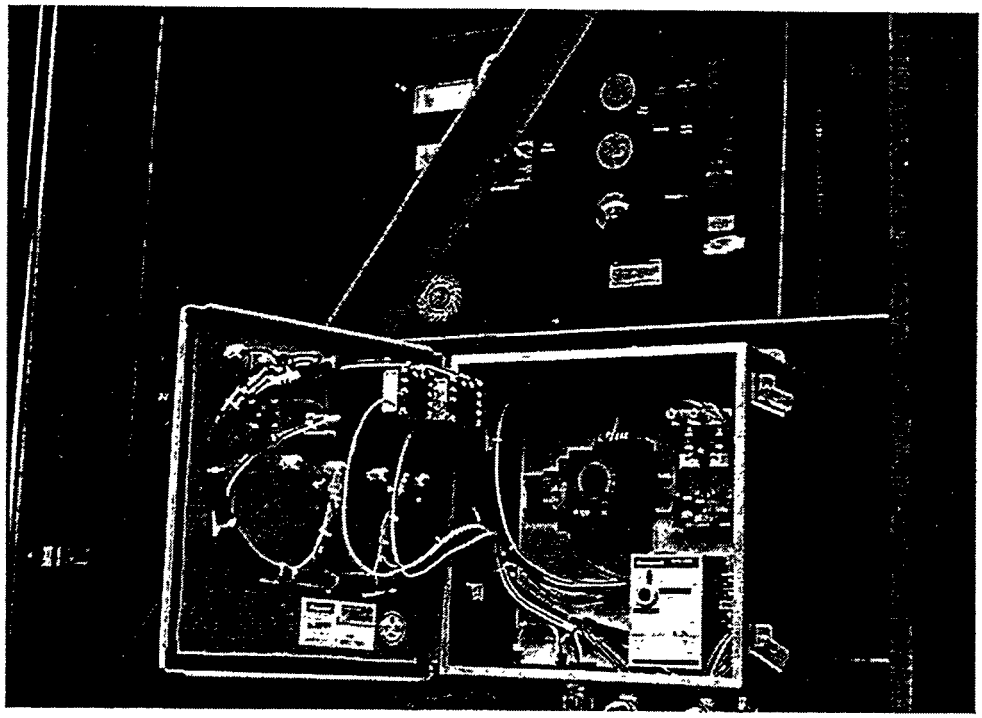
2.8 MW system established NOxTECH as BACT for diesel generators



Advanced NOxTECH heat exchanger surrounds open reaction chamber



. Commercial NOxTECH protoype resembles and replaces exhaust silencer



NOxTECH temperature control ensures removal of all criteria pollutants