# NITROGEN OXIDE ($NO_x$) EMISSION RATES FROM WASTE-TO-ENERGY PLANTS USING WESTINGHOUSE O'CONNOR (ROTARY) COMBUSTORS

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## INTRODUCTION

In waste-to-energy (WTE) facilities, air pollution emissions are a significant environmental concern. When municipal solid waste (MSW) is combusted, air emissions including CO, $NO_x$, $SO_2$, HCl, particulate matter, trace metals, and trace organic compounds are generated. Resource recovery vendors design facilities to achieve low emissions by using good combustion design and practices and by using effective add-on air pollution control equipment. Many of the air pollutants of concern are currently regulated by federal and state environmental agencies. However, most recently, these agencies are beginning to require resource recovery vendors to consider various technologies to reduce nitrogen oxide emissions from WTE facilities.

In the permitting process, vendors of WTE facilities propose Best Available Control Technology (BACT) as part of the Prevention of Significant Deterioration (PSD) permit application. In almost every PSD permit determination issued by EPA or the designated state agency, BACT for $NO_x$ emissions has not required add-on control equipment for $NO_x$ emissions. Three WTE facilities have installed ammonia injection processes to reduce $NO_x$ emissions to meet lowest achievable emission rate (LAER) requirements. All three of these facilities are in California where the plants are located in nonattainment areas for $NO_x$ and/or ozone.

Only two PSD permits issued during the past two years designated BACT for $NO_x$ have required add-on controls, specifically Selective Noncatalytic Reduction (SNCR) technology. The SNCR technology utilizes the injection of an ammonia/air or ammonia/steam mixture into the radiant section of the boiler. The injected ammonia promotes a gas-phase homogeneous reaction of $NH_3$ and the $NO_x$ in the flue gas to produce nitrogen and water. The two PSD permits were issued in late 1988 and early 1989 (Pennsauken, New Jersey and Huntington, New York). Two other PSD permits have been issued after the Pennsauken permit, namely Pasco County, Florida (early 1989) and San Juan, Puerto Rico (September 1989) and have not required ammonia injection as BACT for $NO_x$.

The U.S. EPA is currently developing new source performance standards (NSPS) for municipal waste combustion facilities. The NSPS was proposed in the Federal Register on December 20, 1989. EPA stated that the $NO_x$ limit will be set in a range from 120–200 ppmdv corrected to 7% $O_2$, and averaged over a 24 hr period.

EPA has stated that MSW combustion facilities can achieve these $NO_x$ emission levels using various control techniques including two-stage combustion, low excess air, flue gas recirculation, gas reburning, urea injection and ammonia injection. EPA also stated that vendors of WTE plants can decide on the appropriate tech-

nology to meet the $NO_x$ emission level. The remainder of this paper discusses the formation of $NO_x$ emissions and the emission data collected from WTE facilities using Westinghouse O'Connor combustors.

## NITROGEN OXIDE EMISSIONS FORMATION

Nitrogen oxides ($NO_x$) are products of all conventional combustion processes. Nitric oxide (NO) is the predominant form of $NO_x$ produced along with lesser amounts of nitrogen dioxide ($NO_2$). However, once emitted, NO converts to $NO_2$ in the atmosphere. Hence, NO and $NO_2$ are referred to collectively as $NO_x$. The generation of $NO_x$ from solid waste combustion is a result of two formation mechanisms, namely thermal $NO_x$ formation and fuel $NO_x$ formation. The $NO_x$ produced by exposing the nitrogen contained in the combustion air supply (ambient air contains 79% nitrogen by volume) to the high temperatures of combustion is referred to as thermal $NO_x$. Fuel $NO_x$ is formed when the nitrogen in the fuel is oxidized to $NO_x$.

Because of the abundance of available nitrogen, thermal $NO_x$ formation is primarily a function of temperature and excess air (oxygen availability). Fuel $NO_x$ formation is strongly affected by the local oxygen concentration present in the flame and also by the mixing rate of the fuel (MSW) and combustion air. Thus, like thermal $NO_x$, formation of fuel $NO_x$ is dominated by the local combustion conditions. Combustion modification techniques typically used on combustion sources include using low excess air firing, optimum burner designs, and staged combustion. These techniques have been shown to be effective in reducing $NO_x$ levels (Beachler, 1984).

The fuel/air mixing process in the rotary combustor is completely different from that found in a traditional MWC system. The rotary combustor uses a staged-combustion technique along with low excess air to control both CO and $NO_x$ emissions. The overfire air in the rotary combustor enters with very low radial velocity and slowly mixes with hot fuel gases coming up from the burning bed. The volatile fuel fragments, including volatile fuel nitrogen components, are driven from the bed early—near the entrance to the barrel—and then must flow down the barrel toward the radiant chamber. Not only does the overfire air slowly mix but the more slowly evolving fuel fragments are constantly being added to the gases, giving an excellent opportunity for the fuel-bound nitrogen to be converted to $N_2$.

The control of both fuel and thermal $NO_x$ is accomplished by the water-cooled rotary combustor. Heat generated by the burning solid waste is transferred to the water circulating inside the tubes which along with the perforated webs make up the combustor barrel. This heat removal mechanism moderates peak combustion temperatures, alleviating the need for large amounts of excess air. Since less excess air is required for rotary combustors, (50% versus 80–100%) than other mass-burn systems, less oxygen is available for $NO_x$ production. Therefore, maintaining lower peak temperatures in the combustor without supplying large amounts of excess air provides for the control of $NO_x$ emissions. Higher instantaneous local temperatures may exist within the combustor, but $NO_x$ formation rates are relatively slow requiring a certain residence time. The rotary combustor design includes a forced draft fan and dampers to control the amount and distribution of excess air delivered to the combustor.

## BAY COUNTY, FLORIDA WTE FACILITY TESTING

The Bay Resource Management Center (BRMC) is a 510 ton per day (TPD), or 464 metric ton per day (tpd), waste-to-energy facility located in Panama City, Florida. The BRMC uses two Westinghouse-O'Connor combustors each designed to burn 255 TPD (232 tpd) of MSW having a higher heating value of 4500 Btu/lb (2500 cal/g). A number of test programs have been conducted at the BMRC. In March of 1988, testing was conducted as part of a comprehensive research program to characterize the thermal performance and emission levels of the combustor/boiler system at a number of varying operating conditions, including burning at high and low feed rates, burning a small amount of sewage sludge, burning high- and low-Btu value waste, and burning waste containing alkali compounds (CaO, CaOH, and $CaCO_3$). Figures 1–3 show $NO_x$, CO, and $O_2$ concentration levels as measured during the MSW-only set-points. Measurements were made using continuous emission monitors (CEMS) that were calibrated before and after each day of sampling. Emission concentration levels were measured every minute and reported as hourly averages. As can be seen in Figs. 1–3, $NO_x$ emission levels averaged in the range of 100–140 ppm corrected to 7% $O_2$ (hourly averages). The CO emissions were typically between 100 and 200 ppm corrected to 7% $O_2$ while the excess air was approximately 50%. The permit limit for CO at the BRMC is 800 ppm. The graphs show a direct correlation between $NO_x$ emission levels and excess air levels. The graphs also indicate that the $NO_x$ emission levels were fairly steady despite corresponding low and high levels of CO emissions.

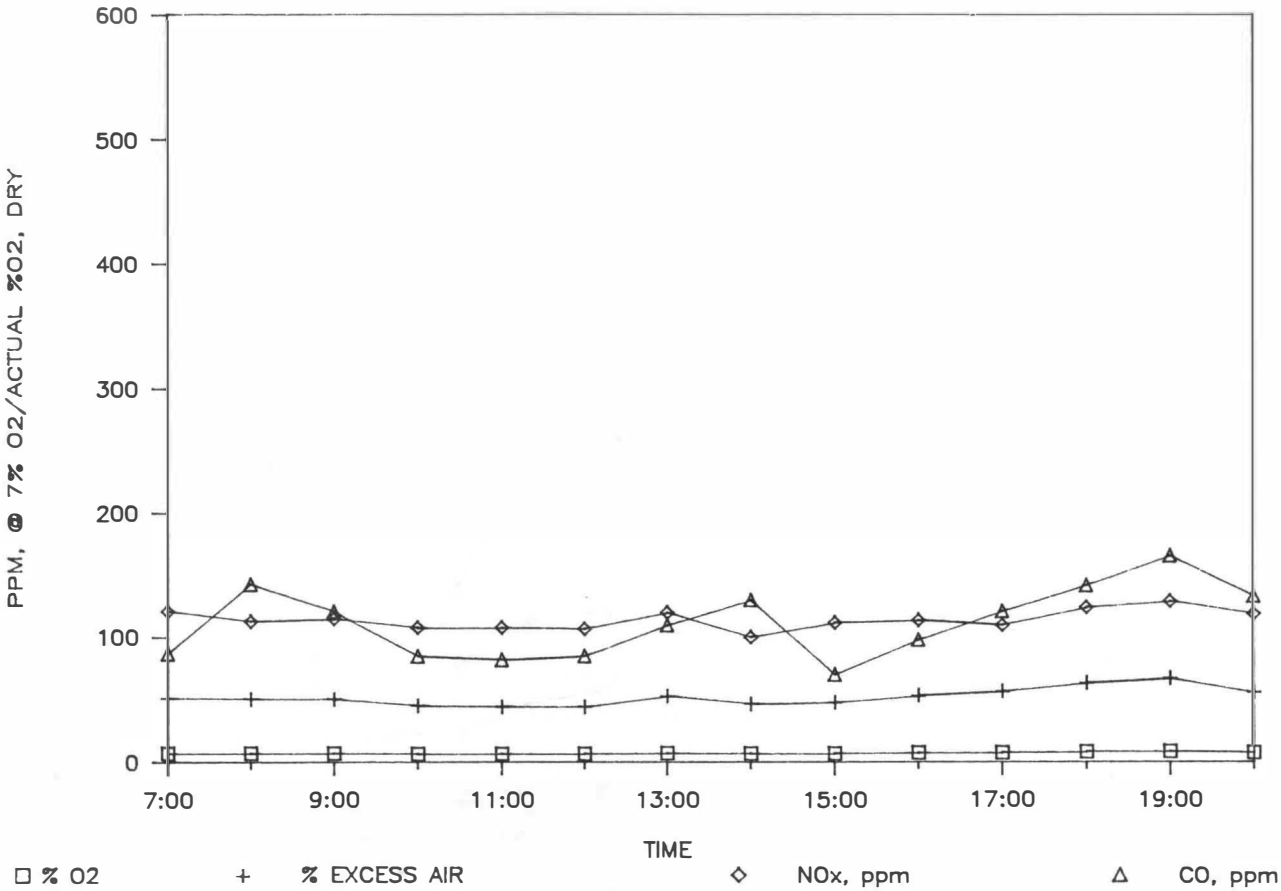


FIG. 1 BAY COUNTY DATA — UNIT 2
(3/9/88)

A CEM was installed to continuously measure $NO_x$ emissions during the summer of 1989. CEM certification tests (relative accuracy) were conducted in early September 1989. The $NO_x$ monitor passed the relative accuracy test and a final report will be issued shortly (See Table 1). Data from the facility-installed $NO_x$ monitor during August through October 1989 show that the $NO_x$ levels are in the range of 60–140 ppm, as shown in Fig. 4. These data were corrected to 7% $O_2$ by assuming an average oxygen concentration of 9% at the point of measurement which is typical for this unit. These data are similar to the levels reported from the March 1988 test program.

## DUTCHESS COUNTY, NEW YORK WTE FACILITY TESTING

The Dutchess County Resource Recovery Facility (DCRRF) was designed and constructed by Pennsylvania Resource Systems, Inc. The facility was designed to use two Westinghouse O'Connor RC-120 combustors (the same design as those used at the Bay County Facility.) Westinghouse was awarded a contract by the Dutchess County Resource Recovery Agency in August 1988 to complete the construction of the DCRRF and to conduct the acceptance tests. As part of the acceptance test conducted in early 1989, a number of emission parameters were measured including $NO_x$, CO and oxygen. Tables 2, 3 and 4 show the summary of the $NO_x$ and CO emission levels at the DCRRF. The $NO_x$ levels typically averaged between 90 and 110 ppm corrected to 7% $0_2$. The CO hourly average emission levels (actual readings) were typically between 50 and 200 ppm. After the initial test program conducted in late January/early February 1989, a number of changes were made to improve combustion conditions. First, the axial seals, used to seal the individual windbox sections on the combustor were replaced with an improved-design seal. Second, a deflector plate to cause ash to spread more evenly across the after-burning grate was installed. Since these changes have been

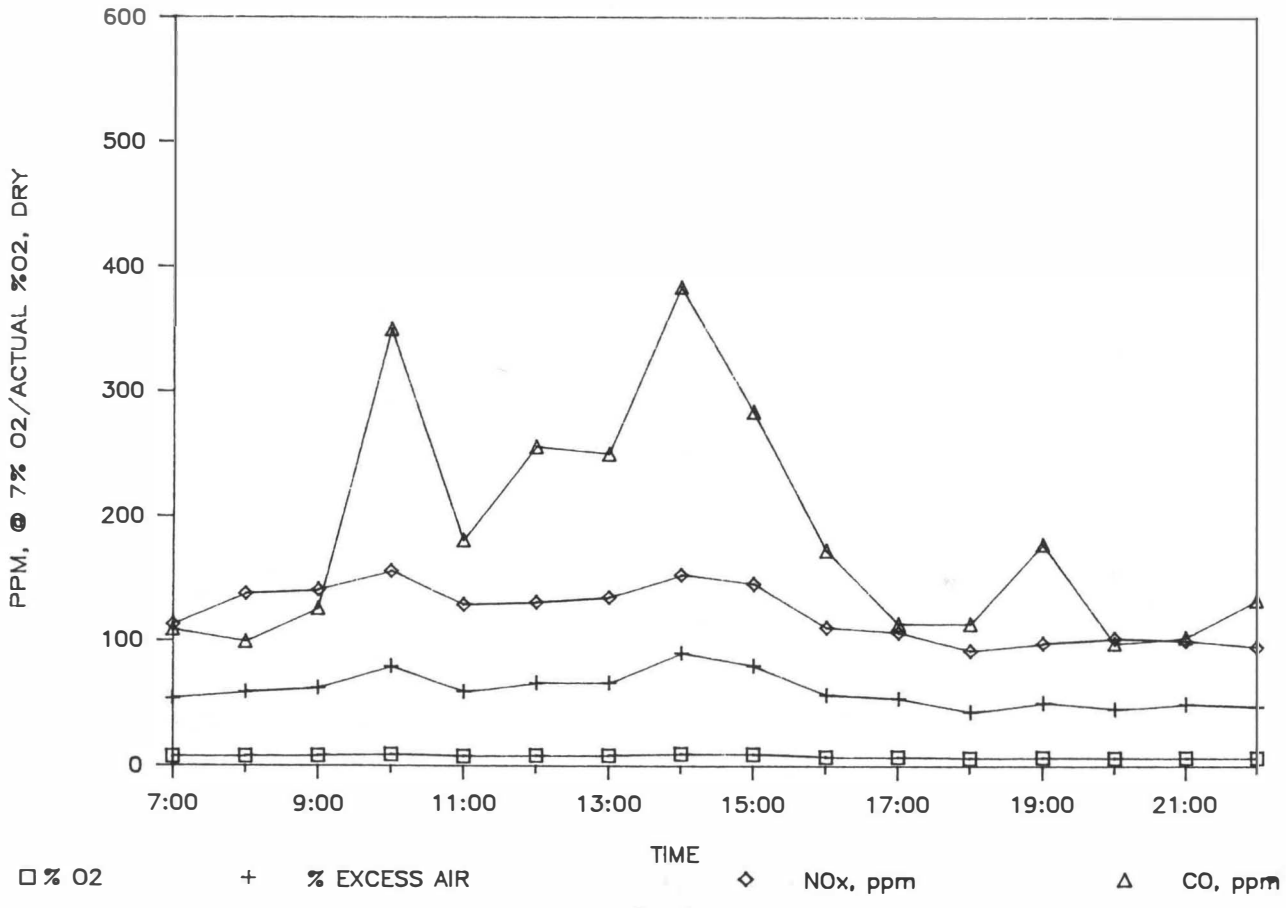


FIG. 2 BAY COUNTY DATA — UNIT 2
(3/11/88)

made, CO emission levels have consistently been less than the permit level of 170 ppm.

In the summer of 1989, a $NO_x$ CEM was installed to continuously measure $NO_x$ emissions from both units. Figures 5 and 6 show CO and $NO_x$ emission levels (daily averages) during January and February 1990. The $NO_x$ emission levels are similar to the values that were measured during the January/February 1989 test program. Relative accuracy tests on the $NO_x$ monitor are planned to be conducted in February 1990.

## YORK COUNTY, PENNSYLVANIA WTE FACILITY TESTING

The York County Resource Recovery Facility (YCRRF), a 1344 TPD (1222 tpd) plant using three 448 TPD (407 tpd) rotary water-cooled combustors, began start-up operations in November, 1989. Figures 7–10 show $NO_x$ emission levels as measured by the plant's installed CEM system for Units 2 and 3 ranging between 60 and 120 ppm corrected to 7% $0_2$ while the CO emission levels were less than 100 ppm corrected to 7% $O_2$. The $NO_x$ levels correlate closely to the excess air levels as was shown at the Bay facility. Additional data from the York facility will be available in the very near future as the plant moves closer to conducting the acceptance test, scheduled for early 1990.

## VARIATIONS IN $NO_x$ EMISSIONS

The $NO_x$ emissions from the Bay facility are generally higher than those from the Dutchess facility. The waste composition burned at the Bay facility contains more wood, tree branches, and grass clippings than the waste burned at the Dutchess facility. Similar results were reported by Radian (1989) and Hahn (1989). These reports indicated higher $NO_x$ emissions

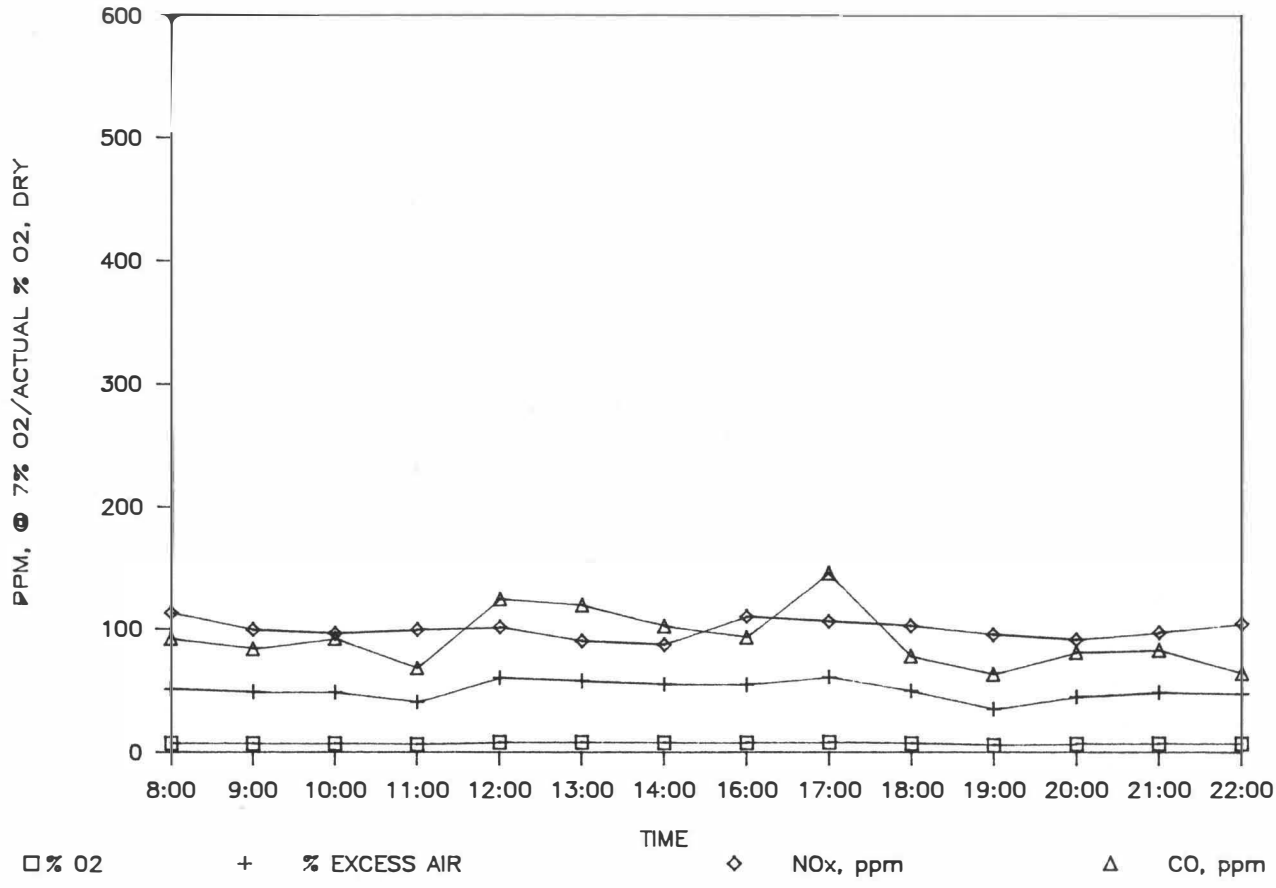


FIG. 3 BAY COUNTY DATA — UNIT 2
(3/17/88)

TABLE 1 BAY RESOURCE MANAGEMENT CENTER
$NO_x$ LEVELS
(Unit 1 — 9/14/89)

| Run # | TIME | Plant CEM Average NOx Conc. ppm @ 7% O2 | Test Team CEM Average NOx Conc. ppm @ 7% O2 | %O2 |
|---|---|---|---|---|
| 1 | 14:56 - 15:20 | 74.3 | 73.48 | 7.61 |
| 2 | 15:48 - 16:17 | 65.0 | 65.36 | 8.59 |
| 3 | 18:45 - 19:10 | 112.1 | 111.60 | 10.42 |
| 4 | 20:17 - 20:38 | 67.8 | 68.39 | 7.27 |
| 5 | 21:22 - 21:42 | 67.8 | 68.41 | 9.13 |
| 6 | 22:30 - 22:51 | 82.1 | 83.21 | 8.49 |
| 7 | 23:35 - 00:00 | 73.6 | 73.26 | 7.57 |
| 8 | 00:38 - 01:01 | 61.6 | 61.79 | 9.00 |
| 9 | 01:36 - 01:56 | 72.6 | 72.76 | 8.67 |

in the spring and summer months when the waste contains a larger proportion of yard wastes, which generally have a high nitrogen content. Hahn reported a $NO_x$ emission increase of approximately 23% during summer months versus winter months. The Bay facility data shows an increase in $NO_x$ emissions of approximately 10–15% during the summer months versus the winter months. For the Dutchess facility, the summer time data are too limited to draw any conclusions.

## SUMMARY

The data reported from rotary combustors have shown $NO_x$ levels typically in the range of 60–140 ppm corrected to 7% $O_2$. These low levels are achieved by using low levels of excess air generally around 50%. In addition, heat generated by the burning of solid waste is transferred to water inside the tubes of the water-cooled rotary combustor. This heat removal mechanism moderates peak flame temperatures during the combustion process. Because less excess air is required than other mass-burn systems, less oxygen is available to form $NO_x$ emissions.

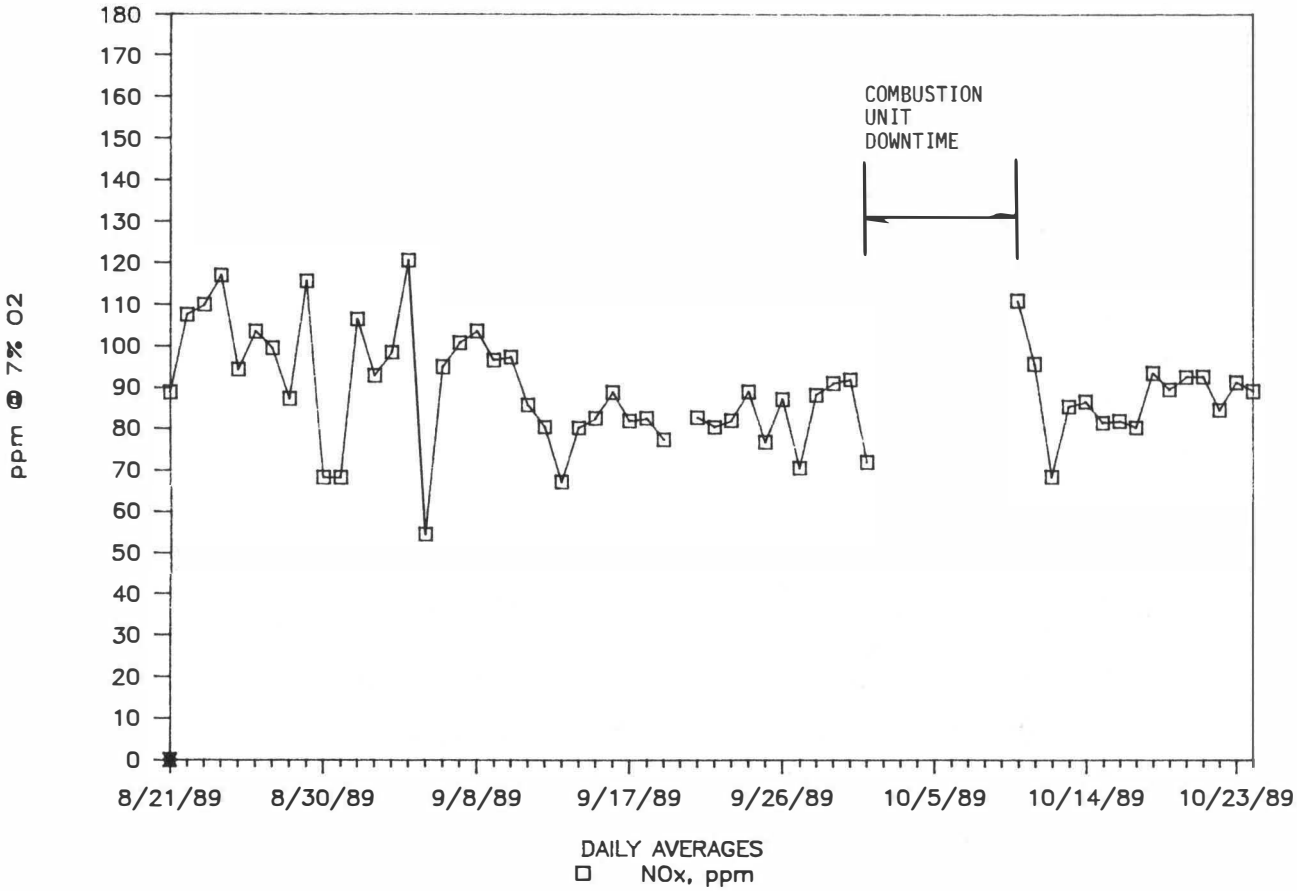


**FIG. 4 BAY RESOURCE MANAGEMENT CENTER — UNIT 1 ($NO_x$ Emission Data)**

As can be seen from the figures presented in this paper, $NO_x$ emission levels are a direct function of the amount of excess air used in the rotary combustor and do not directly correlate with the levels of CO leaving the combustor/boiler as is observed in other MWC systems. Emission data measured at the Bay, Dutchess and York County facilities show low $NO_x$ and CO emission levels. The design of the water-cooled rotary combustor provides for very good combustion, while simultaneously keeping $NO_x$ emissions extremely low.

## REFERENCES

Beachler, D. S. "APTI Course SI:428A Introduction to Boiler Operation." EPA 450/2-84-010, 1984.

Hahn, J. L., et al. "Recent Air Emission Data from Three New Ogden Martin Systems, Inc. Resource Recovery Facilities." Presented at the AWMA Conference, Atlantic City, New Jersey, October 4, 1989.

Radian Corporation. "Control of $NO_x$ Emissions from Municipal Waste Combustors." EPA Contract No. 68-02-4378., 1989.

**Keywords:** Combustion; Control(s); Emissions; MSW Insineration; Nitrogen Oxide; State of the Art

## TABLE 2 SUMMARY OF $NO_x$ EMISSIONS (1 hr AVERAGES) DUTCHESS COUNTY RESOURCE RECOVERY FACILITY

| Date | Unit | Gas Flow Rate dscfm | Concentration ppmdv @ 7% O2 | Mass Rate lb/hr | Permit Limit lb/hr |
|---|---|---|---|---|---|
| 1/31 | 1 | 22604 | 114 | 10.2 | 25 |
| 1/31 | 1 | 22604 | 127 | 11.5 | 25 |
| 1/31 | 1 | 20242 | 67 | 7.0 | 25 |
| 1/31 | 1 | 20153 | 87 | 7.1 | 25 |
| 1/31 | 1 | 20153 | 96 | 9.2 | 25 |
| 1/31 | 1 | 21700 | 92 | 9.4 | 25 |
| 1/31 | 1 | 21700 | 88 | 8.7 | 25 |
| 1/31 | 1 | 21700 | 101 | 9.8 | 25 |
| 1/31 | 1 | 21700 | 97 | 10.3 | 25 |
| 1/31 | 1 | 21700 | 58 | 6.8 | 25 |
| 2/1 | 1 | 22268 | 108 | 10.4 | 25 |
| 2/2 | 1 | 24032 | 105 | 14.1 | 25 |
| 2/2 | 1 | 24032 | 94 | 13.4 | 25 |
| 2/2 | 1 | 24215 | 97 | 14.2 | 25 |
| 2/3 | 1 | 22874 | 79 | 12.8 | 25 |
| | Average Unit 1 : | | 94 | 10.3 | 25 |
| 2/1 | 2 | 23032 | 88 | 13.7 | 25 |
| 2/1 | 2 | 23032 | 91 | 9.5 | 25 |
| 2/1 | 2 | 26550 | 100 | 15.6 | 25 |
| 2/1 | 2 | 26550 | 101 | 15.8 | 25 |
| 2/1 | 2 | 26550 | 101 | 15.1 | 25 |
| 2/2 | 2 | 24482 | 107 | 15.2 | 25 |
| 2/2 | 2 | 24482 | 109 | 15.5 | 25 |
| 2/5 | 2 | 23193 | 88 | 13.7 | 25 |
| 2/5 | 2 | 23193 | 90 | 14.0 | 25 |
| 2/5 | 2 | 23193 | 109 | 15.6 | 25 |
| 2/5 | 2 | 23757 | 107 | 16.0 | 25 |
| 2/5 | 2 | 23757 | 96 | 15.0 | 25 |
| 2/5 | 2 | 23757 | 91 | 13.8 | 25 |
| 2/6 | 2 | 24644 | 108 | 13.2 | 25 |
| 2/6 | 2 | 24644 | 113 | 14.1 | 25 |
| 2/6 | 2 | 24644 | 104 | 14.6 | 25 |
| 2/6 | 2 | 24644 | 90 | 12.8 | 25 |
| 2/7 | 2 | 22004 | 113 | 13.2 | 25 |
| 2/7 | 2 | 22004 | 112 | 15.2 | 25 |
| | Average Unit 2 : | | 101 | 14.3 | 25 |

## TABLE 3 SUMMARY OF CO EMISSIONS — UNIT 1 (1 hr AVERAGES) DUTCHESS COUNTY RESOURCE RECOVERY FACILITY

| Date | Gas Flow Rate dscfm | Actual Concentration ppmdv | Permit Limit ppmdv* |
|---|---|---|---|
| 1/31 | 22604 | 101 | 170 |
| 1/31 | 20242 | 100 | 170 |
| 1/31 | 20153 | 127 | 170 |
| 1/31 | 21700 | 46 | 170 |
| 1/31 | 21700 | 51 | 170 |
| 2/1 | 22268 | 93 | 170 |
| 2/2 | 24032 | 128 | 170 |
| 2/2 | 24032 | 144 | 170 |
| 2/2 | 24215 | 126 | 170 |
| 2/3 | 22874 | 309 | 170 |
| 2/16 | 23070 | 130 | 170 |
| 2/17 | 24286 | 131 | 170 |
| 3/16 | 25805 | 238 | 170 |
| 3/16 | 25805 | 51 | 170 |
| 3/16 | 25805 | 214 | 170 |
| 3/16 | 21535 | 67 | 170 |
| 5/24 | N/A | 74 | 170 |
| 5/24 | N/A | 48 | 170 |
| 5/24 | N/A | 138 | 170 |
| | Average Unit 1 : | 122 | 170 |

* Equals approximately 240 ppm corrected to 7% $O_2$.

N/A = Available

## TABLE 4 SUMMARY OF CO EMISSIONS — UNIT 2 (1 hr AVERAGES) DUTCHESS COUNTY RESOURCE RECOVERY FACILITY

| Date | Gas Flow Rate dscfm | Actual Concentration ppmdv | Permit Limit ppmdv* |
|---|---|---|---|
| 2/1 | 26550 | 157 | 170 |
| 2/1 | 26550 | 102 | 170 |
| 2/2 | 24481 | 150 | 170 |
| 2/2 | 24481 | 128 | 170 |
| 2/5 | 23193 | 278 | 170 |
| 2/16 | 20460 | 142 | 170 |
| 2/16 | 20460 | 153 | 170 |
| 2/17 | 27540 | 174 | 170 |
| 2/17 | 27540 | 259 | 170 |
| 2/17 | 27540 | 103 | 170 |
| 2/17 | 29590 | 228 | 170 |
| 3/15 | 20682 | 64 | 170 |
| 3/15 | 20682 | 52 | 170 |
| 3/15 | 20682 | 55 | 170 |
| 3/16 | 23174 | 51 | 170 |
| 3/16 | 23174 | 30 | 170 |
| 3/16 | 22953 | 45 | 170 |
| 5/24 | N/A | 170 | 170 |
| 5/25 | N/A | 106 | 170 |
| 5/25 | N/A | 73 | 170 |
| 5/25 | N/A | 103 | 170 |
| | Average Unit 2 : | 125 | 170 |

* Equals approximately 240 ppm corrected to 7% $O_2$.

N/A = Not Available

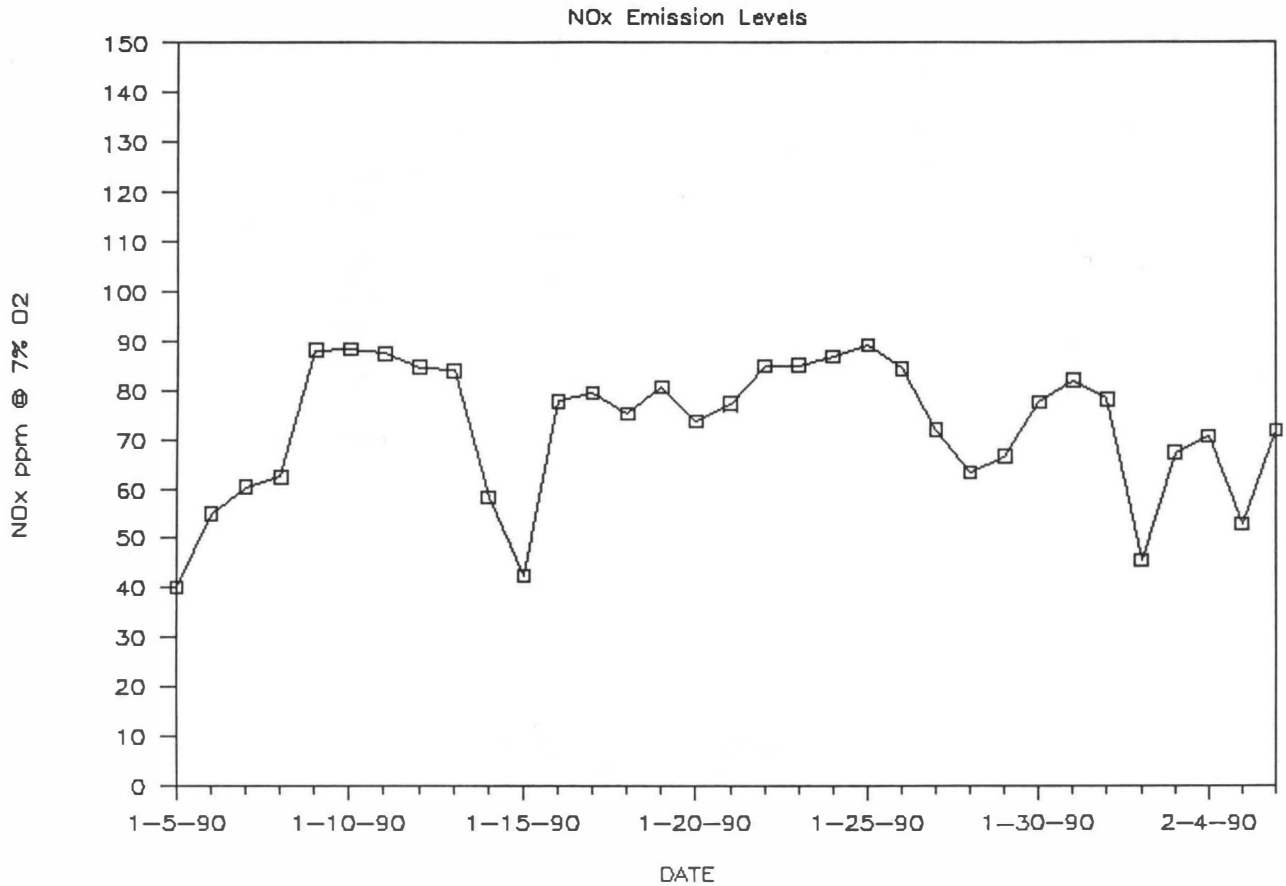


**FIG. 5 DUTCHESS COUNTY FACILITY — UNIT 1**
**($NO_x$ Emission Levels — July/August 1989)**

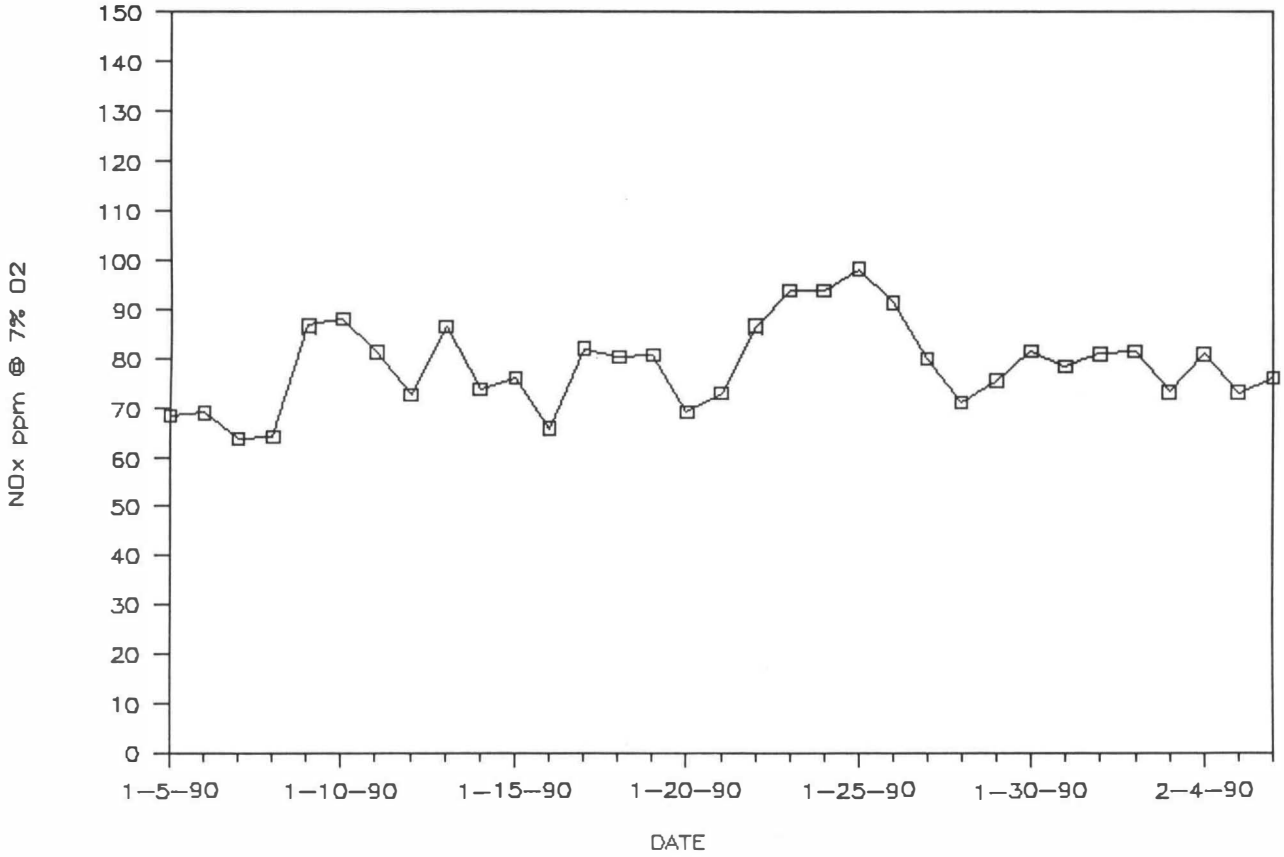


**FIG. 6 DUTCHESS COUNTY FACILITY — UNIT 2**
**($NO_x$ Emission Levels — August 1989)**

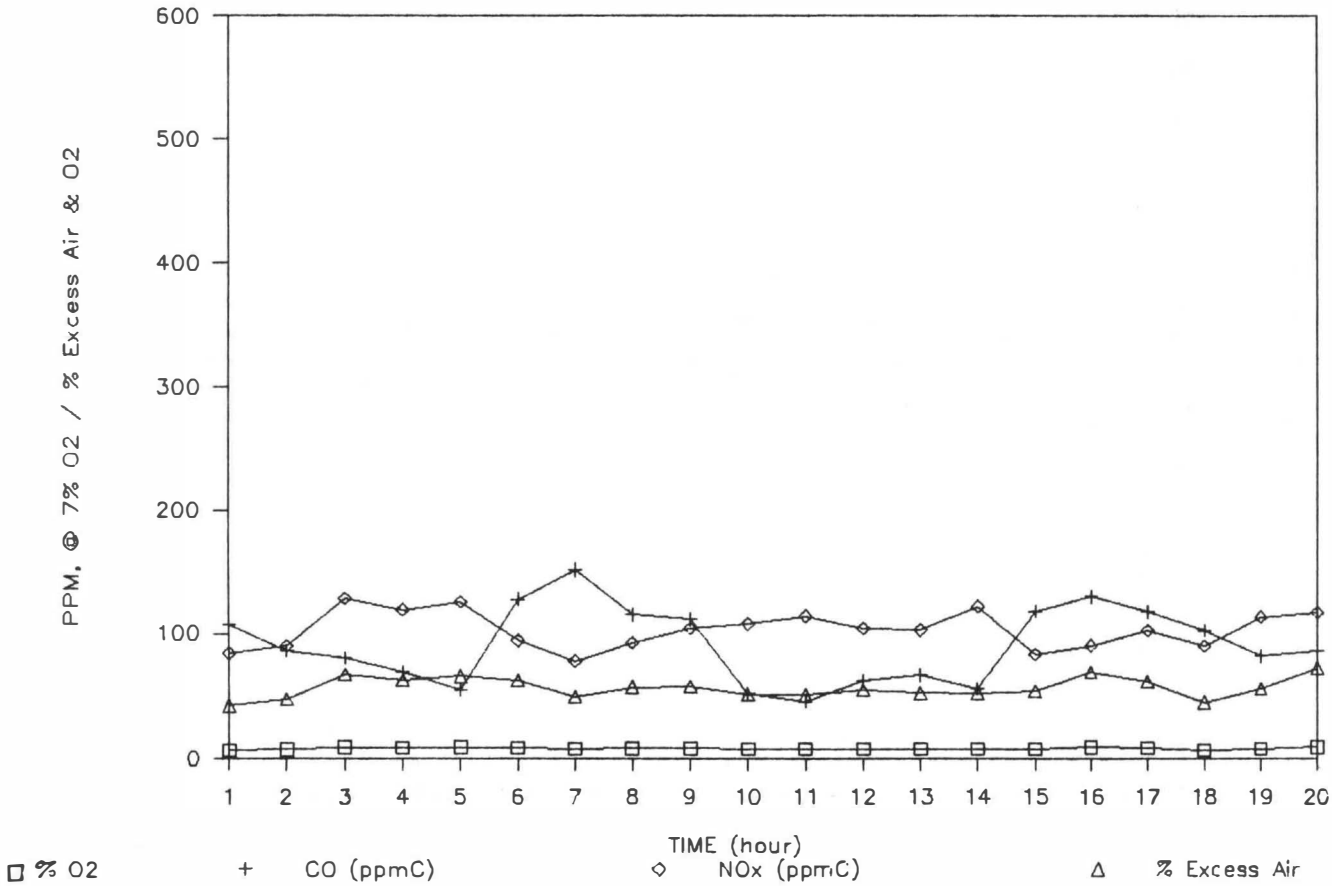


**FIG. 7 YORK COUNTY DATA — UNIT 3 (12/2/89)**

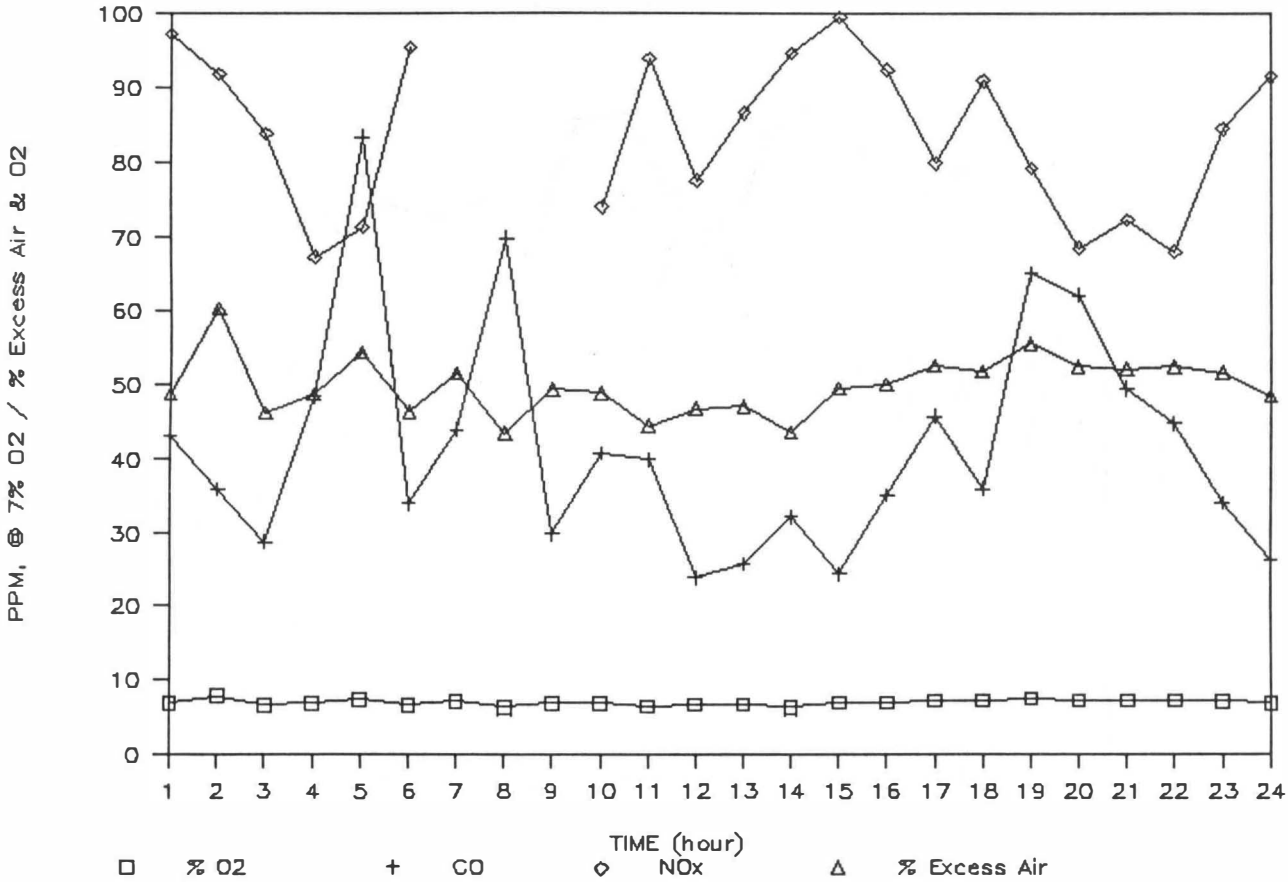


FIG. 8 YORK COUNTY DATA — UNIT 2
(12/23/89)

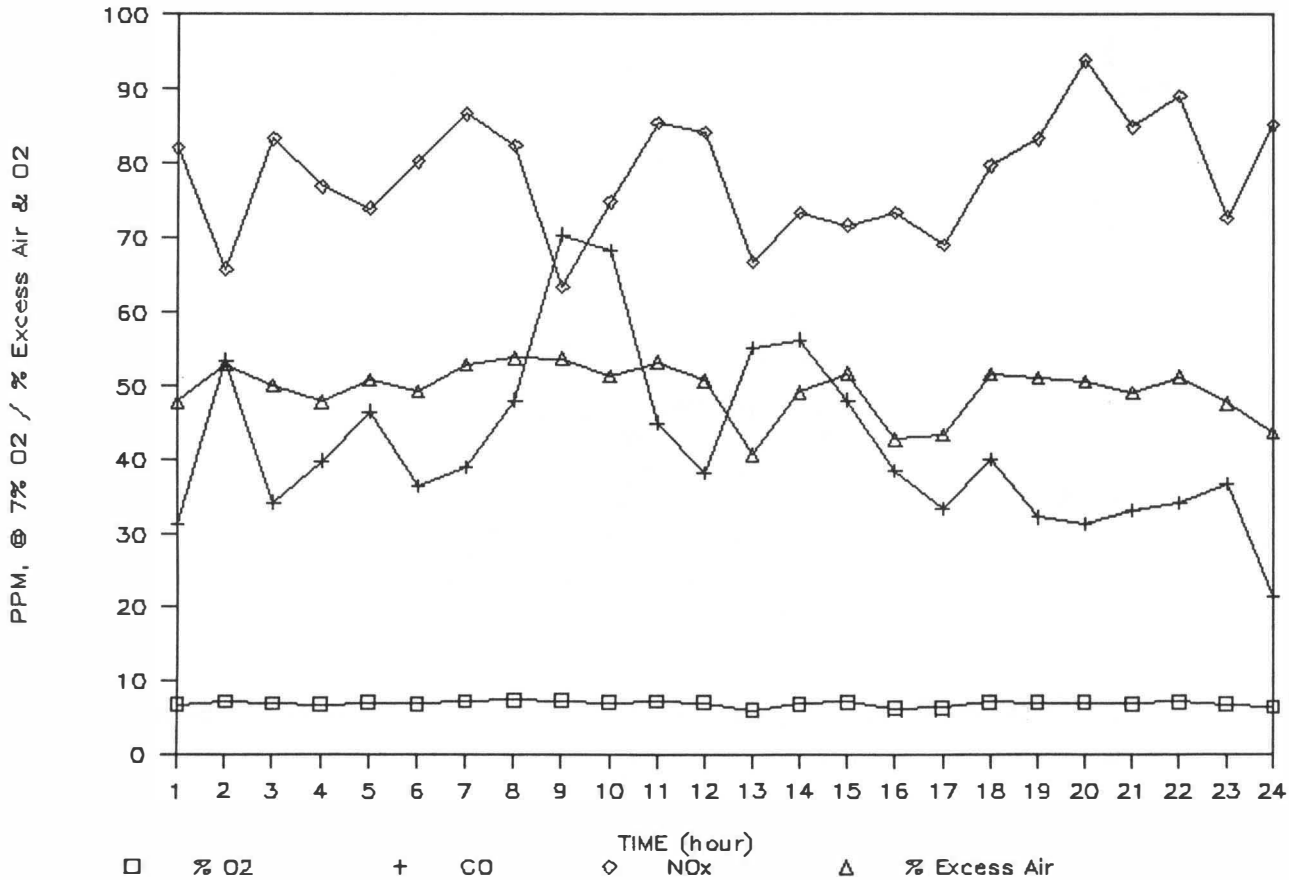


FIG. 9 YORK COUNTY DATA — UNIT 2
(12/24/89)

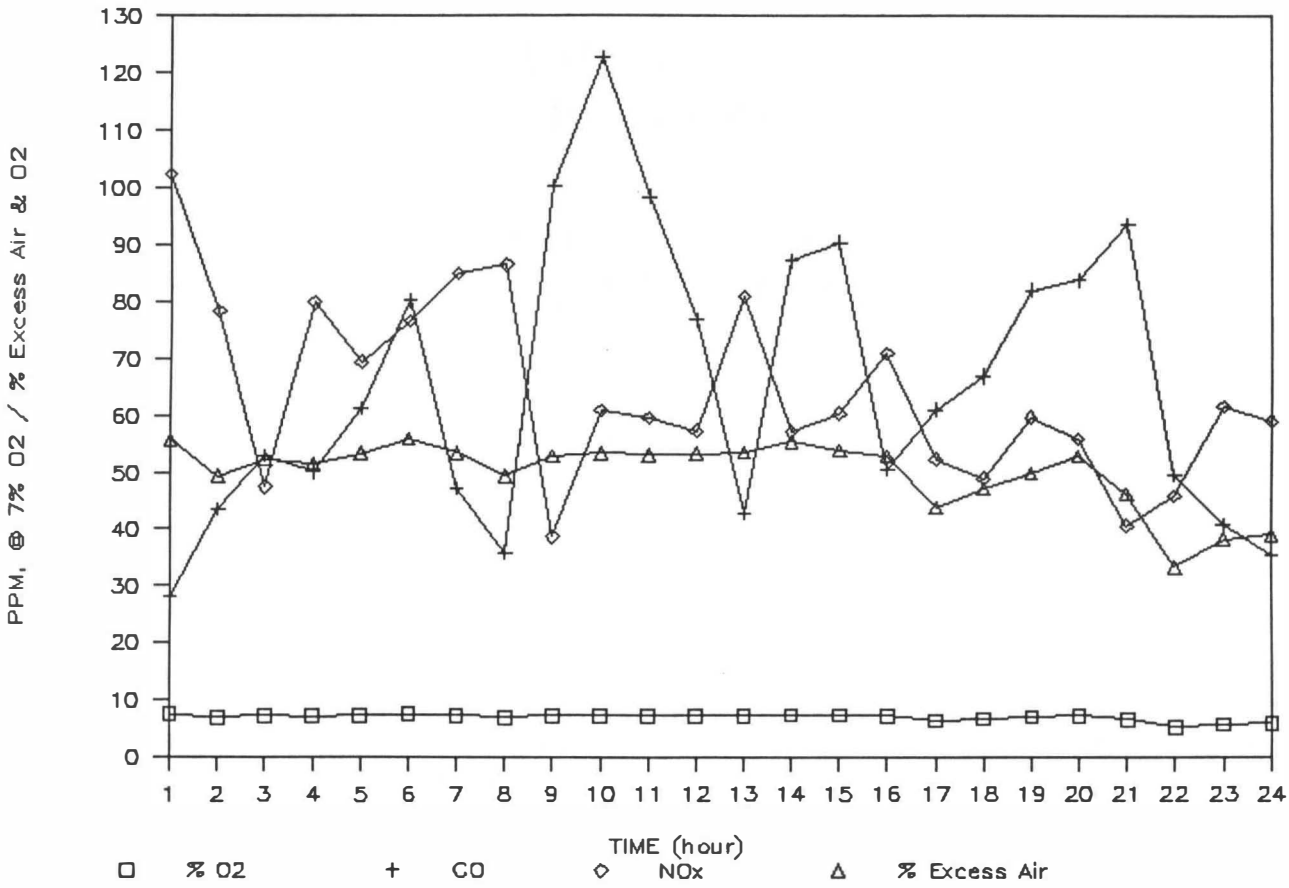


FIG. 10 YORK COUNTY DATA — UNIT 2
(12/25/89)