United States
Environmental Protection
Agency

Industrial Environmental Research
Laboratory
Research Triangle Park NC 27711

Research and Development

EPA-600/S7-81-151 Oct. 1981

EPA

Project Summary

Fuel NO_x Control by Catalytic Combustion

E. K. Chu, K. D. Seifert, R. M. Kendall, and J. P. Kesselring

This report describes the results of an experimental study to define operating conditions for catalytic combustors that give low levels of NO_x emissions for fuel-bound nitrogen compounds, and to quantitatively determine the fate of fuel nitrogen during catalytic combustion. Tests were conducted with platinum and nickel oxide catalysts over a range of test conditions, using ammonia and methylamine as model fuel nitrogen compounds. Fuel NO_x emissions were found to be strongly dependent on catalyst type, but varying mass throughput, bed temperature, fuel, and fuel nitrogen type had virtually no effect on fuel NO_x. The dominant nitrogenous products resulting from the catalytic combustion of a nitrogen-containing fuel were NO, N_2, NH_3, and HCN.

This Project Summary was developed by EPA's Industrial Environmental Research Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

As a result of this experimental study, an improved understanding of fuel NO_x formation during catalytic combustion has been gained. Knowledge gained in this report may lead to further development of catalytic burners which control both thermal and fuel NO_x. One feasible concept which was demonstrated in previous work and further verified by the present study is the two-stage catalytic combustion system. Also, data obtained under the present study indicate that the design of a lean low NO_x combustor may be possible. This summarizes the conclusions reached and the concepts formulated under this study, and makes recommendations for further study.

Based on results of screening tests, the bed operating temperature was shown to have only a slight effect on fuel NO_x emissions. Under fuel-lean conditions, the bed operating temperature affected fuel NO_x emissions indirectly, depending on the CO emissions and the stoichiometry. High CO emissions tended to suppress fuel NO_x emissions, and this effect became less significant as the test condition became leaner. Under fuel-rich conditions, an increase in the bed operating temperature tended to shift the fuel NO_x minimum slightly toward stoichiometric conditions.

The mass throughput was found to have no significant effect on fuel NO_x emissions under fuel-lean conditions. Under fuel-rich conditions, however, an increase in the mass throughput appeared to broaden the fuel NO_x minimum. In addition, a second fuel NO_x minimum was observed for cases where both the mass throughput and the bed operating temperature were low.

No significant effects on fuel NO_x emissions due to the difference in fuel type were observed. Under fuel-lean conditions with natural gas, fuel NO_x emissions maximized at 130 percent theoretical air and declined slightly as theoretical air was further increased. With propane, fuel NO_x emissions also maximized at the same stoichiometry but remained relatively constant as

theoretical air was further increased. Under fuel-rich conditions, the fuel NO_x minimum for propane appeared to be somewhat broader and slightly deeper than that for natural gas.

Fuel NO_x emissions were found to be strongly dependent on the catalyst type—a more active catalyst results in higher fuel NO_x emissions with other operating parameters held constant. Under fuel-rich conditions, the less active NiO/Pt catalyst achieved a conversion of NH_3 of only 25 percent, while the more active Pt catalyst had a conversion of 80 percent.

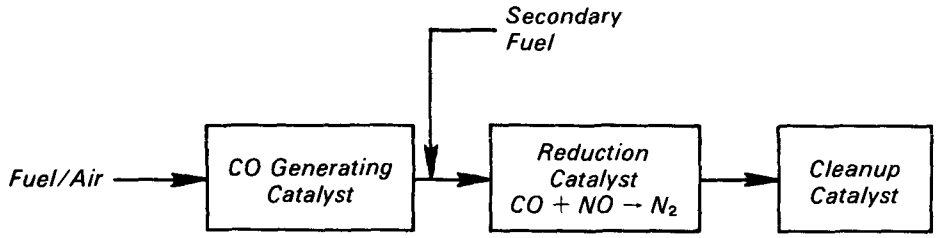
Fuel NO_x formation was found to be insensitive to the molecular structure of the chemically bound nitrogen compounds tested. This indicates that the pyrolysis process was not the controlling step for fuel NO_x formation, if the chemically bound nitrogen content is highly volatile.

The percentage of NH_3 conversion to fuel NO_x was found to be inversely proportional to the chemically bound nitrogen content. This phenomenon was probably due to the destruction reaction prompted by the excess NH_3.

Based on results of detailed tests, it was verified that NO, N_2, NH_3, and HCN are the dominant products of the chemically bound nitrogen conversion process. N_2O was not detected for any condition tested. With the addition of H_2S to the reactive mixture, NO emissions were slightly increased under fuel-rich conditions and inhibited at stoichiometric conditions. A nitrogen balance within reasonable accuracy was not obtained with H_2S addition. The error may be due to the interference of sulfide with the specific ion electrode measurements for HCN and NH_3.

To obtain further understanding of fuel NO_x formation during catalytic combusiton, as well as to develop low NO_x combustors, the following studies are recommended:

- A study of CO-NO-catalyst reactions under fuel-lean conditions.
- Test of fuels which contain chemically bound nitrogen—especially those which contain refractory chemically bound nitrogen.
- A study of NO_x-SO_x interactions during catalytic combustion for both fuel-rich and fuel-lean conditions.
- Development of a fuel-lean low NO_x combustor; e.g.,



E. K. Chu, K. D. Seifert, R. M. Kendall, and J. P. Kesselring are with Acurex Corporation, 485 Clyde Avenue, Mountain View, CA 94042.
***G. Blair Martin** is the EPA Project Officer (see below).*
The complete report, entitled "Fuel NO_x Control by Catalytic Combustion," (Order No. PB 82-102 351; Cost: $11.00, subject to change) will be available only from:
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650
The EPA Project Officer can be contacted at:
Industrial Environmental Research Laboratory
U.S. Environmental Protection Agency
Research Triangle Park, NC 27711

United States
Environmental Protection
Agency

Center for Environmental Research
Information
Cincinnati OH 45268

Postage and
Fees Paid
Environmental
Protection
Agency
EPA 335

Official Business
Penalty for Private Use $300