NOx Emissions Intrinsic to Water/Gas hybrid DC Arc Plasma Torch at Different Power Levels and Plasma Gas Flow Rates

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UNIVERSITY OF CHEMISTRY AND TECHNOLOGY PRAGUE

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Introduction

Plasma Torches

Over the years it has been established that an arc plasma jet, a beam of huge concentrated thermal energy at very high temperature consisting of electrons, ions and neutrals, can meet the high temperature requirement of many high temperature based processes like

- Plasma spraying
- Spheroidization
- Plasma Cutting
- Pyrolytic treatment of waste materials

Devices for producing such plasma jets are called Plasma Torches.

Applications

➢When such applications require water/gas hybrid plasma torches to be operated at temperatures above 2500 K, significant quantities of nitrogen oxides (NOx) are produced.

➢NOx production in heated air is of interest both in industrial applications and environmental studies.

➢Due to increasingly strict emission regulations and standards set by European Commission, researchers are developing new strategies and technologies to reduce pollutants from any combustion system or process.

Objective

- ✓ Remote monitoring of NOx emissions from the external plasma jet of a water/gas hybrid plasma torch at different power levels (400,500A) were investigated.
- ✓ NOx concentrations at each point in the plasma jet were analyzed by a calibrated thermochemical NOx analyzer (Horiba PG-300).
- ✓ Together with additional thermochemical and CFD simulations, the obtained results will lead to a number of conclusions concerning the control of NOx emissions.
- ✓ Results can be used to ensure that the final NOx gases released into the atmosphere remain within regulatory limits.

NOx Mechanisms

Thermal NOx is formed by the high-temperature reaction of nitrogen with oxygen, by the well-known zeldovich mechanism:

$N_2 + O_2 \rightarrow NO, NO_2$

It increases exponentially with temperature above about 2,000°F (1,100°C).

Prompt NOx is formed by the relatively fast reaction between nitrogen, oxygen, and hydrocarbon radicals:

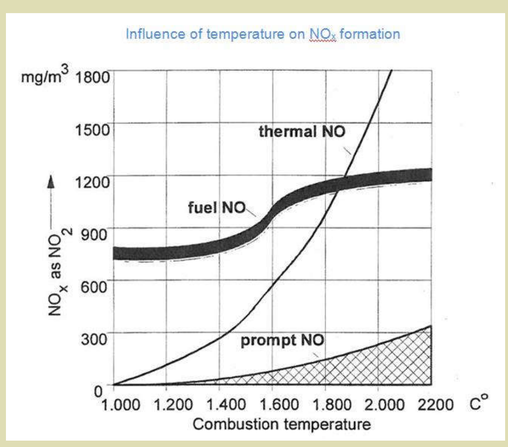
$CH_4 + O_2 + N_2 \rightarrow NO, NO_2, CO_2, H_2O$, trace species

It is generally an important mechanism in lower- temperature combustion processes that's why less important than Thermal NOx.

Fuel NOx is formed by the direct oxidation of organo-nitrogen compounds contained in the fuel.

$R_XN + O_2 \rightarrow NO, NO_2, CO_2, H_2O$, trace species

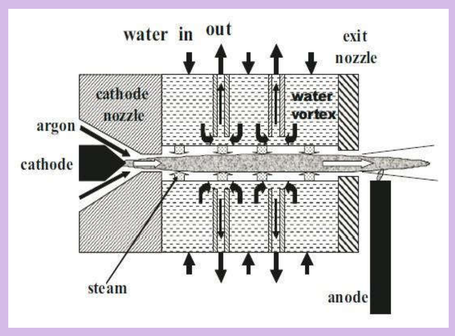
It is not a concern for high-quality gaseous fuels like natural gas or propane, which normally have no organically-bound nitrogen.



Source:TFTEI

Water argon Plasma Torch

- Plasma is formed by electric arc from water steam and gas (argon).
- Arc stabilization is characterized by extremely high plasma enthalpy, temperature, and very low plasma flow rate.
- Argon plasma flows through the nozzle to the second part of the arc chamber, where an arc column is surrounded by a water vortex.
- Steam evaporation is the main mechanism of plasma gas production.
- An anode is created by a rotating copper disc with internal water cooling.



Methodology

Remote monitoring of NOx carried out using a calibrated thermo- chemical NOx sensor (Horiba PG-300).

Using precise linear movement system, axial and radial movement of the torch were carried out from a well-defined zone of plasma jet.

Typical temperature and NOx distribution field inside the plasma jet plus the temperature along the plume were obtained through CFD simulation and thermo-couple respectively.

The experiments were carried out for two power levels i.e. 400,500A.

Argon gas flow rate was 12 slpm.

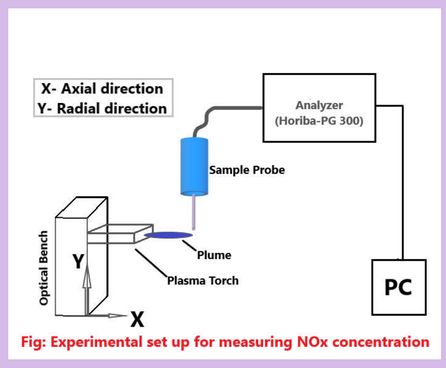
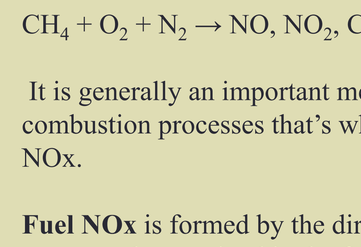
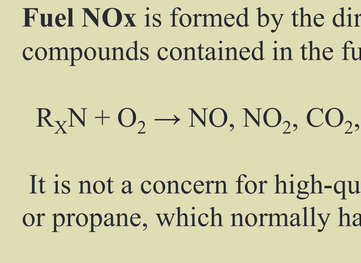


Fig: Experimental set up for measuring NOx concentration

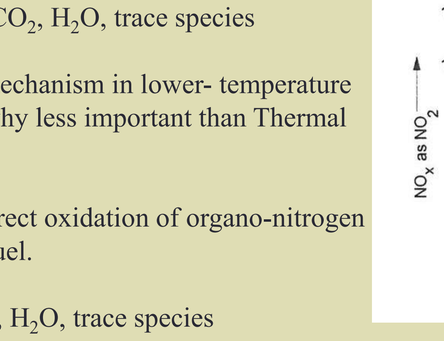
Results: Data and Discussion

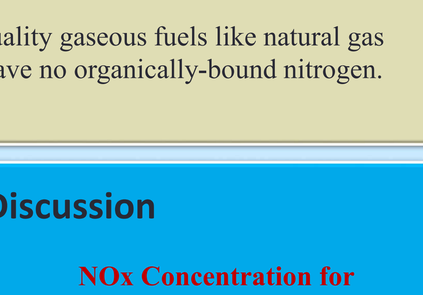
Temperature along the Plasma Plume





NOx Concentration for 400A



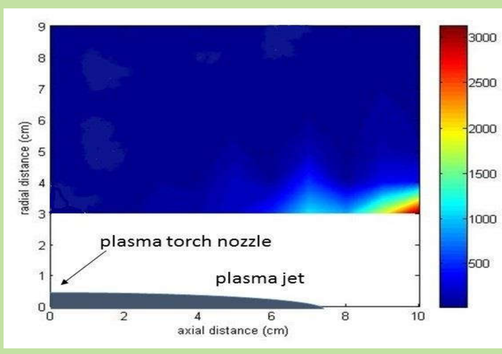


NOx Concentration for 500A

Discussion

✓The rate of NOx formation generally increases significantly above 2,000°F flame temperature.
✓To break the strong $N \equiv N$ molecules, a high temperature is required.
✓As long as N_2 and O_2 are available in the combustion air and the temperature is high enough, NO is produced.
✓The total amount of NOx is positively correlated with the flame temperature and the retention time.
✓Therefore, we get less concentration of NOx in the flame front(near the nozzle) and much higher in the end, where plasma starts expanding.

NOx concentration Through CFD Modelling for 400 A



Conclusion

- NOx is a regulated pollutant formed in nearly all industrial combustion processes.
- Controlling and minimizing pollutant emissions is critical for meeting air quality regulations.
- It can generally be easily controlled using a variety of proven strategies.
- Suitable instrumentation, such as gas analysers for measuring O_2 and NOx in the exhaust products, is recommended to ensure the equipment is operating according to specifications.
- Our experiment will help plasma processors continue to be environmentally friendly and within compliance of their air permits.
- The results will be helpful in designing off-gas process system so that the final gas, released to the atmosphere, remains well within the acceptable limit.

Acknowledgement:

This research was supported by financial support from specific university research (MSMT No 21-SVV/2019) and ORLEN UniCRE.