

## DEVELOPMENT OF NITRIC OXIDE SYNTHESIS IN A D.C. PLASMA CHEMICAL REACTOR

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### ABSTRACT

Investigations on nitric oxides synthesis from nitrogen-oxygen mixtures of varying composition in plasma stream have been carried out. The system was quenched by water injection. Maximum NO concentration and minimum energy consumption were found for mixtures of lower than 50% oxygen content. NO concentration approaching 6% has been obtained.

### 1. INTRODUCTION

Although production of nitric oxides directly from elements involves the necessity of heating up the substrate mixture to high temperature requiring considerable energy consumption, the process is still investigated both theoretically and in its perspective applications /1-4/. Plasma of direct as well as of alternating current discharge is applied as the high temperature source.

The results of our research concerning the subject were reported on 3-rd International Symposium on Plasma Chemistry in Limoges /8/, with view to their practical application. The research data were obtained from different types of plasma chemical reactors. They differed both in their geometry and in the way of quenching the reaction products. In our experiments we quench the total mass of gases, at which high effectiveness of water injection quenching has been stated. The theretofore reported results concerned the stream of air plasma. Thermodynamic calculations indicate that the increase of oxygen content in the system should promote both the increase of nitric oxide concentration in the post-reaction gas and lowering the unit energy consumption /9-12/. However, the calculations may be taken only as an indication as the quenched plasma stream constitutes a non-isothermal system,

what causes the effects of kinetic factors. Attempts at modelling systems considering the kinetic factors are known /13/, however, the number of interfering factors being high the experimental part cannot be neglected.

The presently reported results concern the course of nitric oxide synthesis in the stream of low temperature plasma of 20-25 kW d.c. with the especially constructed by us element of water quenching. As the substrate gas, nitrogen-oxygen mixtures of variable constitution have been applied to check, among others, whether the theoretical assumptions indicating maximum NO concentration at 55 % of  $O_2$  and minimum energy consumption at 45 % of  $O_2$  are valid under specific conditions of the processes.

## 2. EXPERIMENTAL

In the reactor used for our experiments /Fig.1/, a cooled copper cathode with a circonium insert has been applied. A copper nozzle insulated electrically from the anode, constituted the intermediate element. Like the anode, it has been cooled diaphragmatically by water. The quenching system constitutes a roll formed channel prolonging the anode and having an injection gap.

It may be assumed that the applied system ensures the quenching rate not lower than  $10^7$  K/s. In the course of the experiment the rate of the substrate gas flow ranged from 2-5  $m^3/h$ . The nitric oxide concentration in the post-reaction gas and in the condensate have been determined by means of potentiometric titration. Also, measurements of thermal and electric quantities have been carried out to make possible power balancing of the process each time.

## 3. RESULTS

Curves of the dependence of nitric oxide concentration and the unit energy consumption on the oxygen fraction in the substrate gas have been drawn /Figs. 2,3/. Particular curves correspond to different values of the effective energy density.

Maximum nitric oxide concentrations have been obtained at 0.38-0.42 oxygen fraction. Curves  $r_{NO} = f/r_{O_2}$  corresponding to higher values of energy density, have their maximums shifted towards lower oxygen fractions in the substrate gas. Nitric oxide concentrations approaching 6 % of the volume have been obtained.

Curves  $Z = f/r_{O_2}$  are also of extreme character, reaching their minimum at 0.35 - 0.38 oxygen fraction.

Analysis of the condensate and the post-reaction gases proves, that with the increasing oxygen quantity in the mixture, the relative nitric oxide fraction in the post-reaction gas decreases in favour of water absorbed oxides used for the non-diaphragmal quenching of the reaction products /Fig.4/.

Simultaneously to the increase of the effective density /obtained by the decrease of the mass intensity of the gas flow at the constant reactor power/ the nitric oxides absorption in the condensate increases. It is due to the lengthening of the contact period between the gas and the quenching water.

#### 4. CONCLUSIONS

It has been observed that during the synthesis of nitric oxides from elements in the low temperature plasma stream under the described conditions, the highest NO concentrations and the lowest unit energy consumption are obtained at oxygen fraction lower than calculated theoretically.

It has been also stated that the increase of oxygen content in the substrate gas and the decrease of gas flow intensity promote, at non-diafragmal quenching of the products, the shift of higher NO quantities to the quenching water.

The highest concentration of ca 5.81 % of NO volume in post-reaction gases has been obtained at ca 40 % of O<sub>2</sub>, corresponding to 7.26 % of the degree of oxygen conversion into NO.

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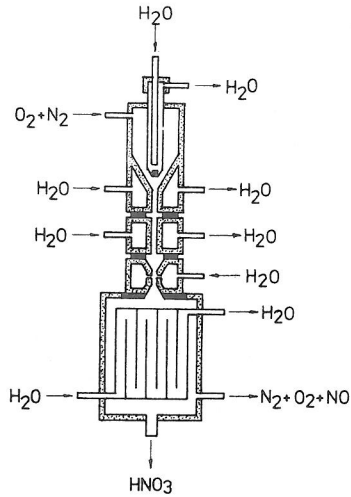


Fig. 1 D.C. Plasma Chemical Reactor

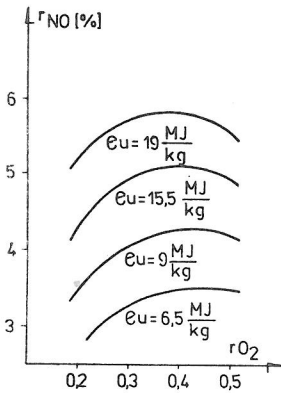


Fig. 2 Effect of oxygen contain in gas on NO concentration

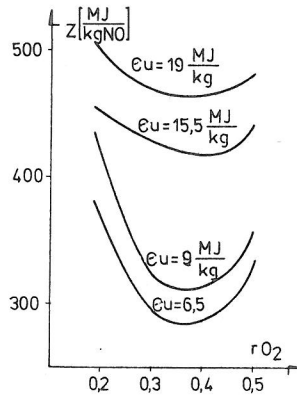


Fig. 3 Effect of oxygen contain on energy consumption

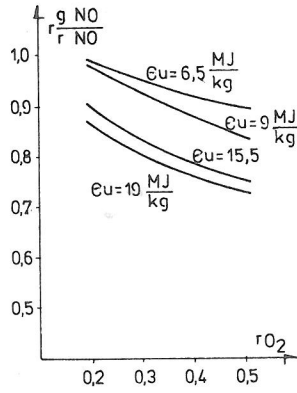


Fig.4 Effect of oxygen contain on relative concentration of NO in gas and condensate