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The formation of NO_x and soot in oxygen-enriched suspension flames

1 – Introduction

Experiments in the Chalmers 100 kW unit (Figure 1a) with oxygen-enriched air show a continuous, but moderate increase in NO_x and soot formation when the feed gas oxygen content is increased from 21% up to a specific value (around 30%). Above this feed gas oxygen content, the soot formation increases by magnitudes, in a step-change, and the NO_x emission decreases significantly (Figure 2). Three theories are suggested for the sudden change in NO_x formation:

- Homogeneous interactions between NO_x and soot precursors cause an increase in NO reduction
- The increased soot formation lowers the flame temperature and decreases the amount of thermal NO_x formed
- Heterogeneous reduction of NO_x by soot particle

The work presented here is another attempt to examine the above mentioned mechanisms. Focus is put on explaining the increase in soot formation and the method is to use a detailed reaction modeling combined with in-flame measurements.

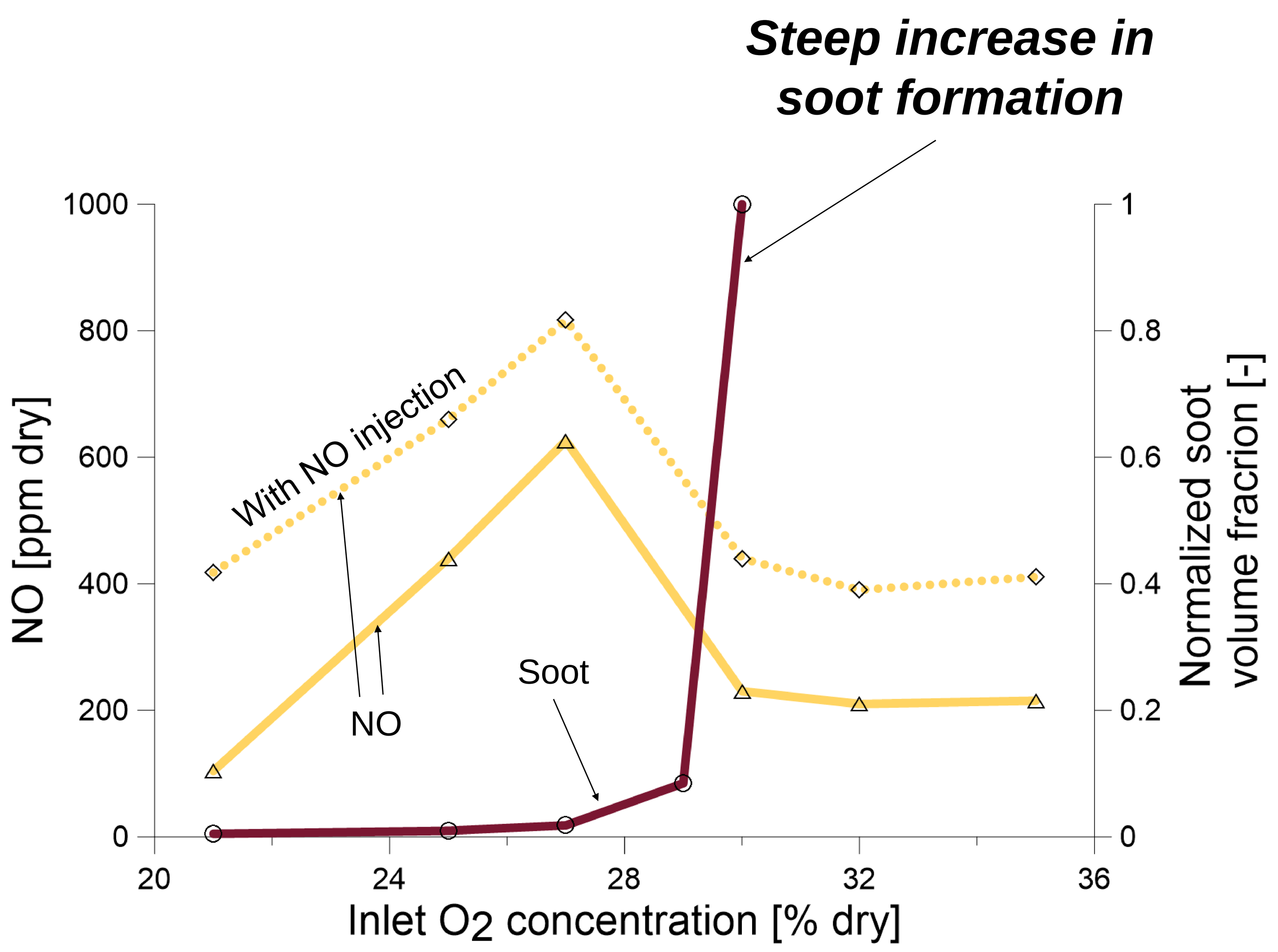

Figure 2. Previous experimental results for different oxygen content in the oxidizer. The NO levels were measured at the outlet with conventional measurement techniques while the soot measurements were performed in M3 using laser induced incandescence (LII)

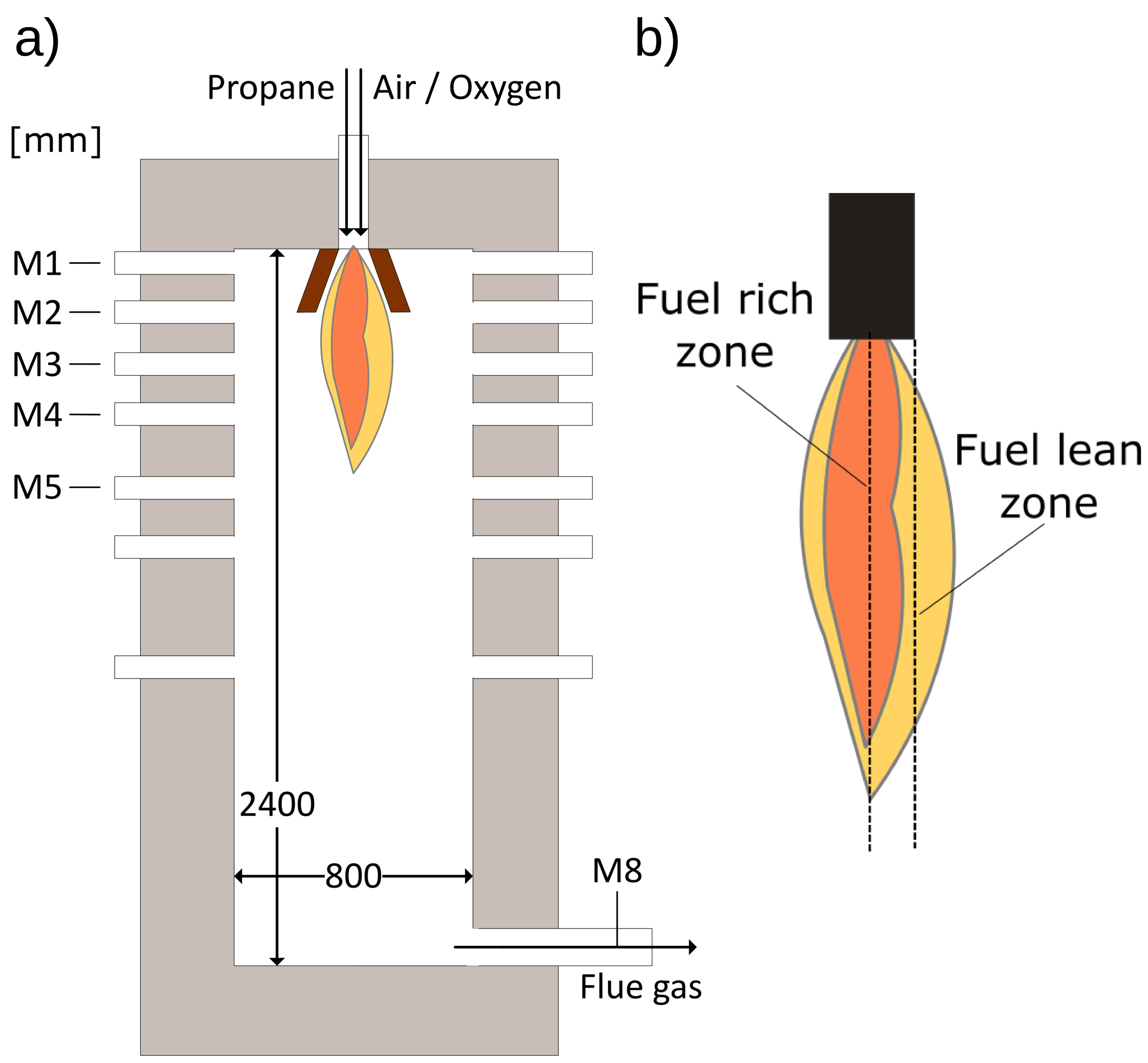

Figure 1. a) the Chalmers 100 kW unit
b) two regions of the flame that are modelled

2 – Method

A detailed reaction mechanism, including a nitrogen subset, describes the soot formation. A plug-flow reactor model with injection of oxidizer (to simulate mixing) represents the combustion process. Two cases are modeled, applying air (21% O_2) and oxygen enriched air (32% O_2). A fuel rich zone and a fuel lean zone is modelled to investigate the chemistry in different parts of the flame (Figure 1b). The in-flame temperature and concentration of CO and O_2 are fitted to available experimental data.

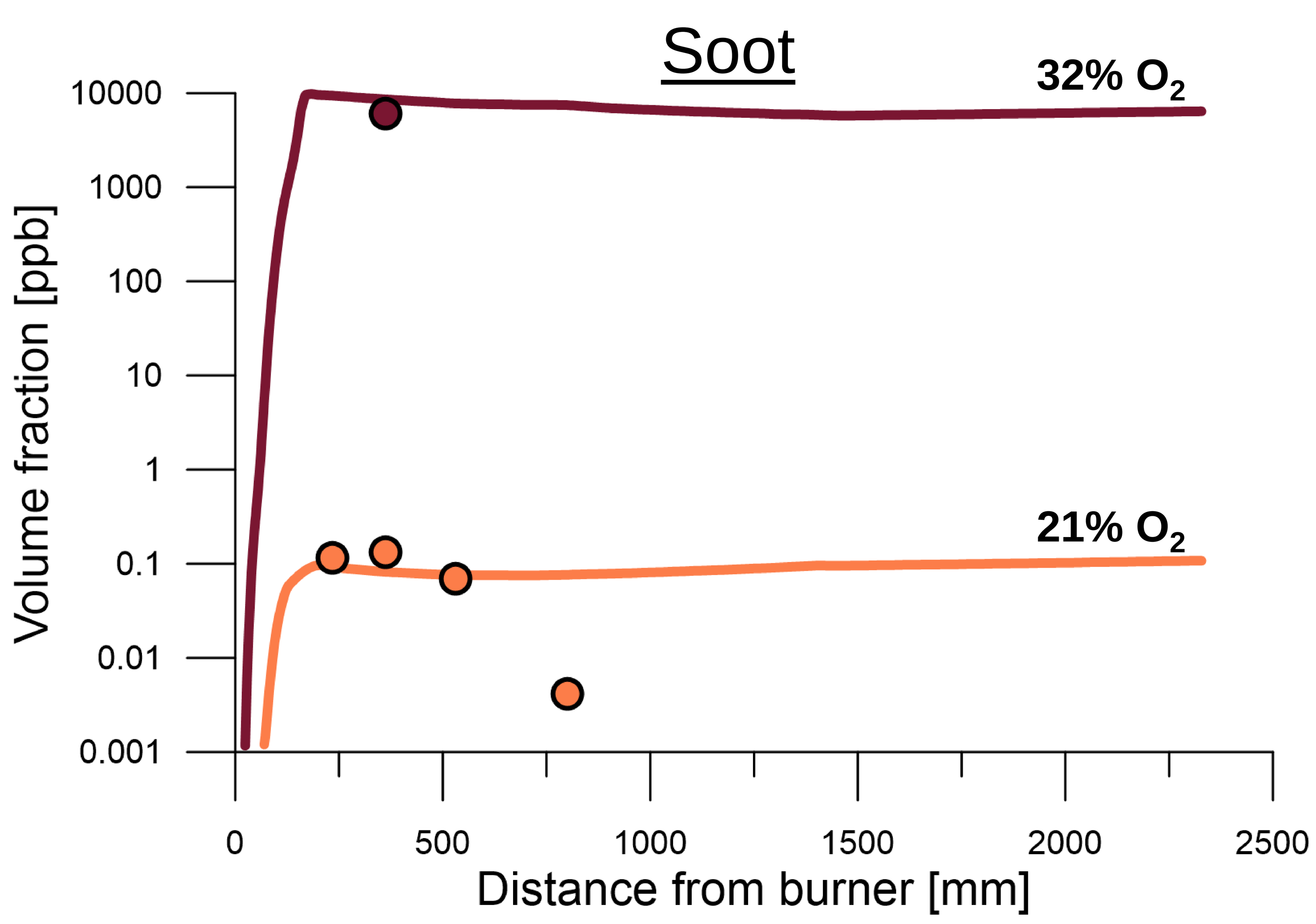

Figure 3. Soot concentration profiles in the fuel rich zone for propane combustion applying 21% O_2 and 32% O_2. The measured soot concentrations in the case with 21% O_2 were obtained with probe measurements and a scanning mobility particle sizer (SMPS)

3 – Results and future work

The results shows that:

- The reaction mechanism captures the shift in soot formation observed in the experiments (Figure 3)
- The soot formation is sensitive to the temperatures in the initial/ignition zone of the flame
- The soot oxidation is underestimated in the model due to an overestimation of large soot particle formation.

The next step in this work is to perform a reaction analysis to map the connections between NO_x and soot formation discussed in the introduction.