Evaluating the Accuracy of a Portable NO_x Sensor for Measuring Emissions from a Biomass Gasifier-Generator System

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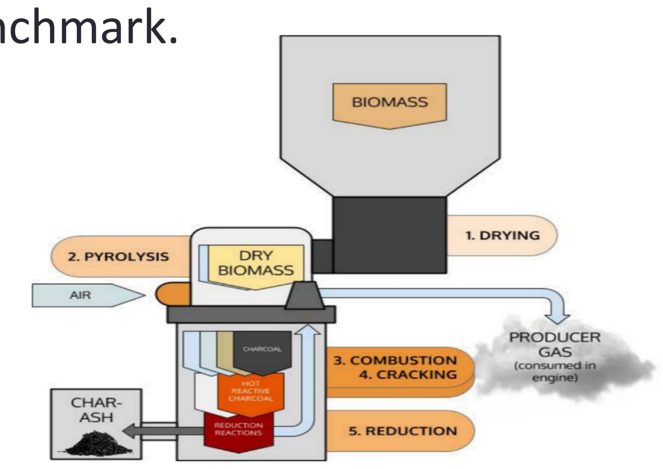
INTRODUCTION

Biomass gasification is the process of partially oxidizing organic matter into gaseous hydrogen, carbon monoxide, and other hydrocarbons through the application of high temperature and the addition of low amounts of oxygen (Hamilton). Due to growing concerns about the negative impacts of burning fossil fuels, researchers hope to harness these gases by combusting them in engines to generate electricity. Doing so emits small amounts of gaseous hydrocarbons, carbon monoxide, and nitrogen oxides (NO_x gases) (Akagi et al.) Dr. William Northrop is supervising a project to characterize biomass gasification's NO_x emissions.

The project uses the ALL Power Labs 20 kW Power Pallet, an integrated gasifier, engine, and electrical generator that will be operated at a testing site in New Ulm, Minnesota in the fall. This transportation requirement necessitates the use of a self-contained, portable NO_x sensor capable of being directly mounted to the exhaust of the Power Pallet. This UROP study evaluated the accuracy of one such sensor, the Continental Smart NO_x Sensor, by comparing its readings to those of California Analytical Instruments (CAI) Inc.'s NO_x analyzer, an external laboratory grade unit that served as a benchmark.



Above: Continental Smart NO_x Sensor
Left: Gasification process overview

OBJECTIVE

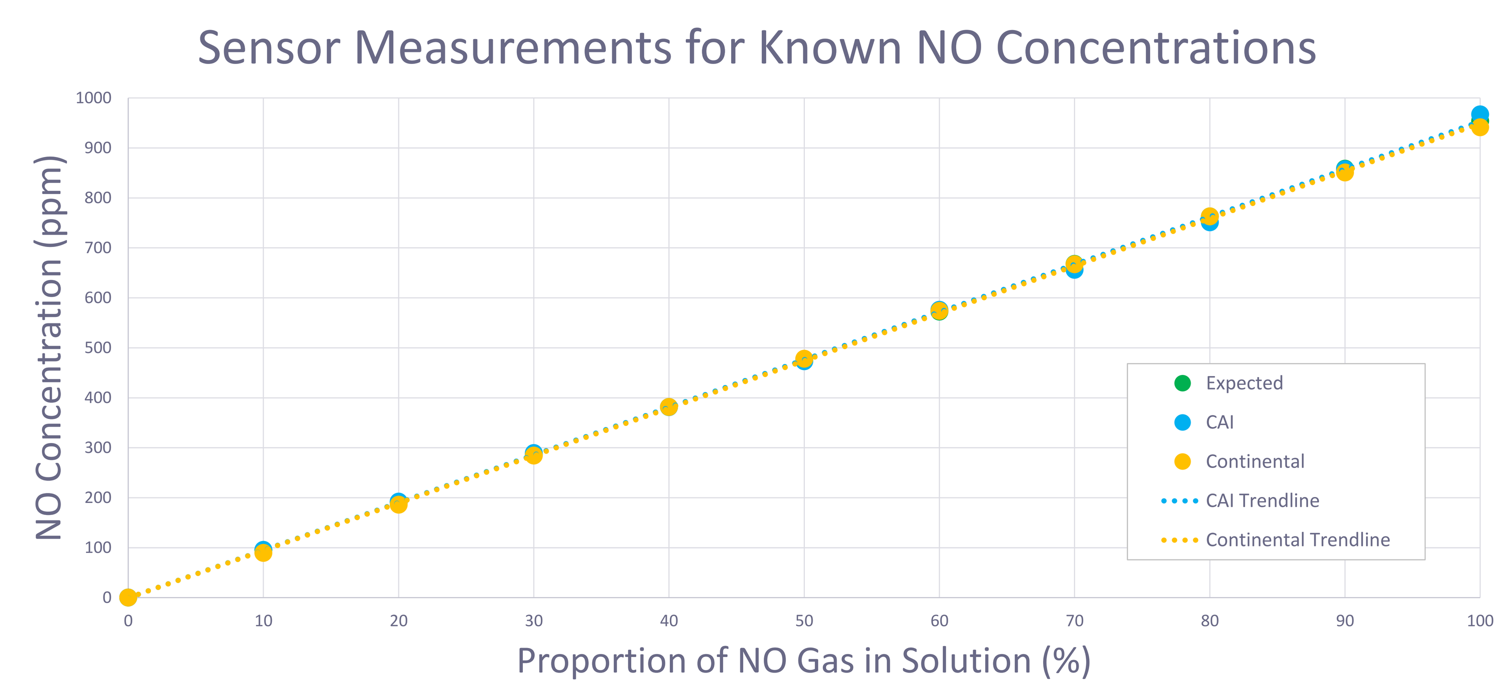
To determine whether the onboard Continental Smart NO_x Sensor can replace the external, laboratory grade CAI NO_x analyzer when measuring NO_x emissions from the exhaust of the Power Pallet biomass gasifier-generator.

PROCEDURE

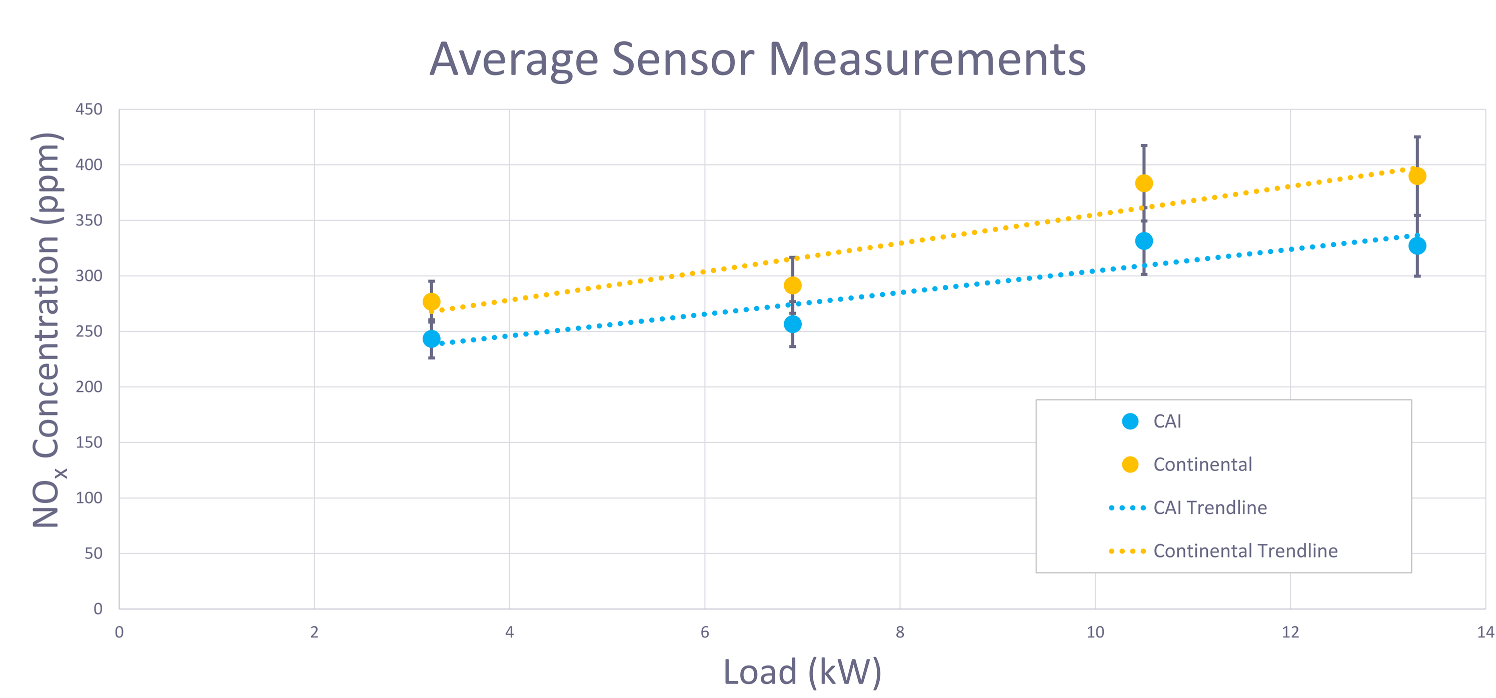
- The Continental sensor was mounted directly on the exhaust pipe of the gasifier, while a separate sampling line fed exhaust to the CAI analyzer
- With both instruments sampling emissions, the gasifier was run twice under the following loads: 3.2, 6.9, 10.5, and 13.3 kW
- The NO_x concentration measurements of the Continental sensor were compared to those of the CAI analyzer

RESULTS

First, the accuracy of both sensors in a controlled environment was determined. A gas with a known nitric oxide (NO) concentration of 953.9 ppm was diluted with nitrogen to ten different proportions, and both sensors sampled all ten solutions. Both the CAI analyzer and the Continental sensor provided extremely accurate measurements for each gas mix, as shown below.



Next, the Power Pallet gasifier-generator was run on two different days, using woodchips for biomass. Each of the four loads was tested for 45 minutes, with both sensors sampling emissions. A 15-minute portion of data from each load was averaged, and the two means for each load (one for each day) were averaged. The resulting 4 mean NO_x measurements from each sensor are plotted below.



All data samples taken had large standard deviations, as indicated by the intersecting error bars. Still, the two trend lines suggest that overall, both instruments reflected an expected increase in NO_x emissions with load. The Continental sensor consistently read higher NO_x concentrations than the CAI analyzer, with the average difference being 45.82 ppm. A systematic error in the Continental's measurements is possible, but less than likely given its accuracy when sampling known concentrations of NO. However, previous literature suggests the sensor can be cross-sensitive to ammonia (Chou et al.). The process of biomass gasification is known to produce ammonia that could escape combustion in an engine and

RESULTS (CONTINUED)

be present in the exhaust (Hongrapipat et al.). This experiment did not determine whether enough ammonia is produced when running the gasifier to account for the noted discrepancy between the two sensors, leaving the matter open for further investigation. It is also possible the CAI analyzer had been improperly calibrated and consequently read lower NO_x concentrations than existed, though no explicit evidence supports this explanation.

CONCLUSION

While both the external CAI analyzer and the onboard Continental sensor respond identically and accurately to controlled gas solutions, one of the two falters when sampling exhaust from the Power Pallet gasifier-generator. Which instrument incorrectly measures NO_x emissions is unclear, so ultimately it is unknown if the Continental sensor can replace the CAI analyzer. Future research to answer this question may involve measuring the ammonia content of the gasifier's exhaust, and acquiring more than two days of data.

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