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Interactive comment on "Use of an Unmanned Aircraft System to Quantify NO_x Emissions from a Natural Gas Boiler" *by* Brian Gullett et al.

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RC2 General Comments: Gullett et al. describe the methods and results for a novel UASbased sampling approach for stack emissions relative to standard stack continuous emission monitoring system (CEMS). Results indicate good agreement (within 9 percent) for Run-Averaged NOx Emission Factor between UAS and CEMS systems. Error values for UAS-based measurements range from 3 times greater to more than an order of magnitude greater than for CEMS measurement. The paper would be strengthened by discussion of the implications of differences between methods and the greater error associated with UAS-based measurement. Such a discussion, in turn, may aided by addressing in the Introduction and Conclusions sections, the potential applications of UAS-based measurement for future research or regulatory purposes. The

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Discussion paper

paper could benefit from additional background and discussion of observed sensor performance in the context of known issues relating to sensor performance as affected by atmospheric conditions. The comment from Referee #2 asking for more detail on “extensive testing” is germane, and can be addressed by reference to other publications by the authors (if available) or through the inclusion of descriptions of such testing and data as supplemental materials. Suggestion for reconsideration after “major” revisions is based on author’s ability to address above issues.

RESPONSE to general comments: The authors believe that the standard deviation values don’t reflect “error” – our error measures are based on the test runs’ emission factor calculations, not the instantaneous variation of the measured concentrations. These run-specific variations in emission factors are quite modest: average of 5.6% (3.5% for carbon-weighted values) for the three boilers. The significant variation in concentrations observed by the sensors within the plume due to mixing of ambient air is compensated for by reliance on whole-run, integrated values of concentrations for determinations of emission factors. Thus, use of UAS for emission determination, much like annual compliance tests with CEMS, would require a series of measurements to arrive at a final value.

The authors are limited to speculate on regulatory prospects due to the policy implications. Additional information on sensor sensitivities is now included in the body.

Specific comments: 1. Suggestion to include closer imager of mounted Kolibri to illustrate location of intake ports

RESPONSE: We have added a labelled photo of the Kolibri.

2. Suggestion to include schematic of Kolibri as flown

RESPONSE: Labelled photo is added.

3. How did the authors treat data values where CO2 readings were at or above the limits of the detectors, and what assumptions were made about error for such readings.

RESPONSE: CO2 peaks exceeded the range of the sensor for 1,108 seconds out of the 16,500 seconds total sampling duration for the St. Charles location (not Midland), or a total of 6.7%. These are included in the average. Exclusion of the NOx and C data during those 1,108 seconds only affects the EFs by 3 %. When the sensors' ranges are exceeded, the UAS pilot is instructed to back off from the source toward a more dilute airstream.

4. Vertical axis scale adjustment for CO and NO2

RESPONSE: We scaled up the NO2 and CO concentrations by 10 times for improved visibility.

Technical comments: 1. In Table 3, flight 4 is excluded from the table entirely and an explanatory note provided; however, in Table 4, Flight 5 is excluded from calculations (for reasons that appear similar to flight 4's exclusion from the previous table), but its data is retained in the table. Recommendation to leave flight 4 data in table 3 and use common language (e.g. "excluded from calculations") between tables.

RESPONSE: We added the data for flight 4 in the revised table 5.

Authors' comments: Data had been erroneously been moved around in Table 5. We have corrected this in the updated table.

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