

## I. IDENTIFICATION DATA

<b>Thesis title:</b>	<b>Detection of excess NO<sub>x</sub> emissions of Heavy-Duty vehicles during ordinary operation</b>
<b>Author's name:</b>	<b>Alden Fred Arul Raj</b>
<b>Type of thesis :</b>	Master's
<b>Faculty/Institute:</b>	Faculty of Mechanical Engineering
<b>Department:</b>	Institute of Automobiles, Combustion Engines and Rail Vehicles
<b>Thesis reviewer:</b>	Michal Vojtíšek
<b>Reviewer's department:</b>	Institute of Automobiles, Combustion Engines and Rail Vehicles

## II. EVALUATION OF INDIVIDUAL CRITERIA

<b>Assignment</b>	<b>Challenging</b>
<i>How demanding was the assigned project?</i>	
The student participated in an experimental research project aiming at assessing the prevalence of trucks with excess emissions of NO <sub>x</sub> on Czech roads and was asked to assess and compare several ways of computation of emissions factor and to summarize and interpret the data. The interdisciplinary nature of the work made the assignment challenging.	

<b>Fulfillment of assignment</b>	<b>C – Good</b>
<i>How well does the thesis fulfill the assigned task? Have the primary goals been achieved? Which assigned tasks have been incompletely covered, and which parts of the thesis are overextended? Justify your answer.</i>	
The primary assignment was, in general, fulfilled, but the overall technical level diminishes the usefulness of the results. There are no overextended parts – everything that is in the thesis is useful and has its place there. Additional analysis of the results would be beneficial.	

<b>Activity and independence when creating final thesis</b>	<b>A - Excellent</b>
<i>Assess whether the student had a positive approach, whether the time limits were met, whether the conception was regularly consulted and whether the student was well prepared for the consultations. Assess the student's ability to work independently.</i>	
The student has shown a great interest in the subject. He has worked diligently, discussed work in progress frequently, was well prepared for consultations, communicated well. He has worked independently within the limits of his comfort, and either completed the task we have agreed on or asked for clarification.	

<b>Technical level</b>	<b>C – Good</b>
<i>Is the thesis technically sound? How well did the student employ expertise in his/her field of study? Does the student explain clearly what he/she has done?</i>	
<p>The fairly broad introduction suggests that the student has gained reasonable knowledge of the underlying topics. The first assignment, to assess three methods of calculating the background concentration and the emissions factors, was addressed. It appears that not much rigorous analysis, and virtually no statistical calculations, are included. The background is calculated as the 20<sup>th</sup> percentile of the measured concentrations, which was recommended as the first estimate subject to revisions, but no additional evaluation has been done. The assessment of the three methods of calculations is limited to several cases, concluding that they yield comparable results when NO<sub>x</sub> emissions are high and consistent, without saying much about the other cases. At the same time, such analysis was, by far, not an easy task, due to considerable uncertainty in the measured data. Previously published work and common statistical approaches were of limited use.</p> <p>The second assignment was to assess the measured emissions factors. Due to the rather complex nature of the SCR systems, there is no generally accepted threshold applicable to a relatively short measurement, beyond which the vehicle is considered a high emitter. Further, the on-road emissions limits specified in the EU legislation are applicable to the 90<sup>th</sup> percentile of emissions measured over a period of time during which certain criteria need to be met. Therefore, some occurrence of high emissions is viewed as acceptable. Nonetheless, very little analysis is done on the measured data, not even basic statistics like mean or median emissions factor of each Euro category.</p>	

**Formal level and language level, scope of thesis****C - Good**

*Are formalisms and notations used properly? Is the thesis organized in a logical way? Is the thesis sufficiently extensive? Is the thesis well-presented? Is the language clear and understandable? Is the English satisfactory?*

The thesis is logically organized and provides a wealth of information which is reasonably well presented. The language is generally sufficiently clear to convey the message. However, not in all cases, the description is exact and specific as expected in an engineering text. For example, the statement "European Union has Euro 6d currently which gives the concentration in parts per million (ppm) or grams per km (g/km) or grams per kWh (g/kWh)" combines aspects of emissions limits for light-duty (in g/km) and heavy-duty (in g/kWh) vehicles.

**Selection of sources, citation correctness****B – Very good**

*Does the thesis make adequate reference to earlier work on the topic? Was the selection of sources adequate? Is the student's original work clearly distinguished from earlier work in the field? Do the bibliographic citations meet the standards?*

A total of 42 references are cited in the thesis. These constitute a reasonable and well selected set, covering the background topics of motor vehicle emissions, their risks, and their measurement, signal processing, and miscellaneous specific issues. The citations in the text are correct. The cited work can be readily identified from the reference list, albeit with some additional work (e.g. ref 2,6,16), however, the formatting of the reference list, notably of the authors names, is inconsistent.

**Additional commentary and evaluation (optional)**

*Comment on the overall quality of the thesis, its novelty and its impact on the field, its strengths and weaknesses, the utility of the solution that is presented, the theoretical/formal level, the student's skillfulness, etc.*

In parallel with the student's efforts, the assigned analysis was independently performed by experienced researchers, with the results reported to the Czech Ministry of Environment in October 2019, and with additional analysis being subject of a manuscript under preparation.

The work is of high relevance to the society. Vehicle emissions are one of the key contributors to the outdoor air pollution, which is one of the most pressing public health issues. Realistic assessment of emissions, including excess emissions, is of great importance to science-based policy on transportation and air quality.

### III. OVERALL EVALUATION, QUESTIONS FOR THE PRESENTATION AND DEFENSE OF THE THESIS, SUGGESTED GRADE

Alden has shown a keen interest in the subject matter, worked diligently on the assignment, and was a responsible and valuable member of the research group. I have enjoyed his positive approach and sense of responsibility. The assignment, which was part of an interdisciplinary research project, was challenging, and Alden has worked on it to the best of his ability. On a professional level, he has grown considerably during the course. The thesis judged on its own is fairly good, corresponding to a "better side" of the "C" grade, which is an overall result of Alden's diligent approach while here and a relatively weak prior background in general, including statistics and technical writing. Taking into the account the very commendable approach shown here, and thinking about how Alden would tackle the next engineering problem given to him, I assign the grade "B" – Very good.

The grade that I award for the thesis is **B – Very Good**

#### Questions:

1. Please assess the benefits of the technology used on Euro VI trucks relative to older trucks in terms of real-world NO<sub>x</sub> emissions.
2. Based on the measurements, please make a rough estimate of the reduction of NO<sub>x</sub> emissions from the Euro VI trucks if the current in-service conformity legislation (Euro VI standard of 0.46 g/kWh, 90<sup>th</sup> percentile of conformity factor no more than 1.5) would be met.
3. Assuming average NO<sub>x</sub> emissions from light duty (< 3.5 t gross weight) vans of 1 g/km, please offer advice to the City of Prague whether the exclusion of heavy trucks for delivery of goods into Prague is expected to have a positive effect on NO<sub>x</sub> emissions.

Date: January 29, 2020

Signature: