# EEN-E2002 Combustion Technology / 2019

# Learning Exercise 4

The exercise is meant to be completed as pair work. However, it can also be completed individually or in a group of three students.

The solution is to be returned as a single pdf file. Only one solution is needed from a pair or team. On the first page of the solution you have to write your name and student number and, if you worked in pairs or groups, the names and student numbers of everyone in your pair/group.

The solution must be clear and readable, and it may be hand-written or created with a computer. The equations and input data that you are using must be clearly specified, as well as any sources you have used. Include tables and diagrams to illustrate your results as requested in the problem. Please note that all students are expected to follow the Aalto University Code of Academic Integrity (see https://into.aalto.fi/display/ensaannot/Aalto+University+Code+of+Academic+Integrity+and+Handling+Violations+Thereof ).

Name the uploaded pdf-file so that it tells the name of the course, learning exercise number, and your name, like Combustion_Technology_LE4_Lastname.pdf.

No single question/problem is compulsory, but a minimum of 50 % of points is required in order to pass the exercise. A proper length of an answer for the whole learning exercise would be maximum 8 pages. The time for answering this exercise is estimated not to exceed 8 hours, provided that you have attended lectures.

Return deadline of LE4: Monday, 4$^{th}$ March, 2019 at 16:00 pm.

Please read the problem statement carefully! Note that there are two pages.

## Task 1 (12 x 3 p. = 36 p.)

You are working for an engineering company. Your customer is using LPG (propane) as a fuel in an industrial furnace. In normal operating conditions, the firing rate is 3.5 MW (based on the lower heating value) and the oxygen content (mole fraction) in dry flue gas is 2.0 %. As the propane is coming from fossil sources, you are asked to analyze the possibility of substituting the propane with bio-ethanol.

a) Present the chemical formula, molar mass and lower heating value for propane. Specify your source(s).
b) Compute the fuel flow rates (kg/s and mol/s) for propane.

c) Present the reaction equation for the following cases:
   - stoichiometric combustion of propane in pure oxygen
   - stoichiometric combustion of propane in air
   - combustion of propane in air with an air factor λ.

   Show that you have checked that the reaction equations are balanced, i.e., the amounts of each element are the same on both sides of the reaction equation.
d) Calculate the equation for the oxygen mole fraction in dry flue gas as a function of the air factor. Present a plot of your results. Which air factor corresponds to the normally observed oxygen mole fraction 2.0 %?
e) Calculate the flow rates of combustion air and flue gas (kmol/s and kg/s; here we wish to know the flow rates of wet flue gas, i.e., the flue gas which still contains the water vapor originating from the oxidation of hydrogen in the fuel).
f) Same as a) but for ethanol.
g) Same as b) but for ethanol.
h) Same as c) but for ethanol.
i) Same as d) but for ethanol.
j) Same as e) but for ethanol. Assume that also for ethanol firing, the oxygen content in dry flue gas will be 2.0 %.
k) How much do the fuel flow rates, combustion air flow rates and flue gas flow rates change if the conversion to bioethanol is carried out? What is your opinion on the feasibility of the conversion based on the results you have obtained?
l) What do you think, are the conclusions you reached in part k) valid in general, i.e., in the conversion for any fuel? If so, why? If not, why not?

Attach a list of your sources (a reference list) in your solution. When you present your findings, specify the sources using the normal conventions of scientific writing (see, e.g., http://libguides.aalto.fi/citation_guide . Please include also the page number containing the information.

Tips:

For the sake of simplicity, you may assume that air is a mixture of oxygen and nitrogen, the mole fraction of oxygen being 0.21 and the mole fraction of nitrogen being 0.79.

Dry flue gas means flue gas from which all water vapor has been removed. It is a common practice to remove water vapor from flue gas before flue gas samples are directed to gas analyzer for determining the composition of the flue gas.

For advice on writing the reaction equations, please see slides of Lecture 2 (10 Jan 2019) by Ossi Kaario, especially slides 19–22. https://mycourses.aalto.fi/pluginfile.php/893652/mod_resource/content/2/Lecture2_20190110.pdf .

## **Task 2** (this does not affect the grading)

Your free feedback on the first weeks of part II of the course and time spent on this learning exercise.