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EXAM IN SUBJECT TEP4170 HEAT AND COMBUSTION TECHNOLOGY
(Varme- og forbrenningsteknikk)
8 August 2017 Time: 9:00 – 13:00

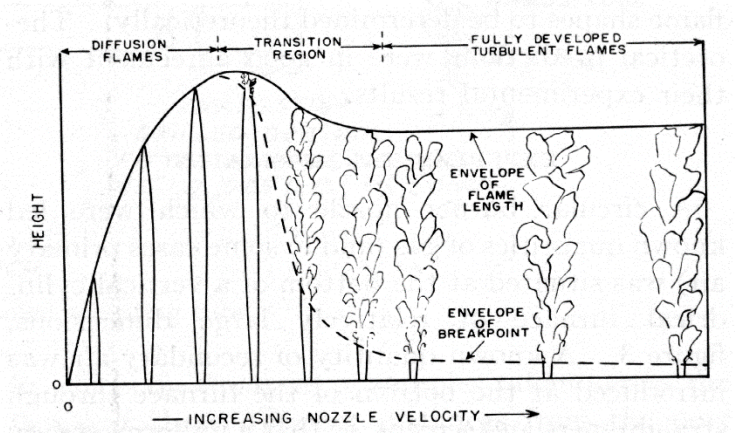
The exam is only available in English. The answers can be written in Norwegian or English.

Permitted aids: D – No printed or handwritten aids. Certain simple calculator.

- Please do not use red pencil/pen, as this is reserved for the censors.
- Read through the problems first. Begin with the problem where you feel that you have the best insight. If possible, do not leave any problems blank. Formulate clearly, it pays off!
- Some information is given at the end.

Problems:

1)
The figure is taken from a paper by Hottel and Hawthorne, 1949, and shows a sketch of an experiment with a jet flame.
--Explain what the sketch shows.



2)
-- Make a sketch that illustrates/defines the flame speed, the flame thickness and the chemical time scale of a one-dimensional laminar premixed flame.

-- How can the flame speed, the flame thickness and the chemical time scale be defined/determined for a non-premixed flame?

3)
The laminar flame speed can be determined experimentally from a Bunsen burner.
--Describe the experiment; including which quantities that are measured and the mathematical relation(s) between the flame speed and the measured quantities.

4)
-- List and discuss the four steps involved in soot formation and destruction in laminar diffusion (non-premixed) flames.
-- Sketch a typical radial temperature profile and soot concentration profile in a vertical jet of non-premixed hydrocarbon laminar flames. (Both profiles in one graph; make care in the relative position of the two profiles.)

5)
From a chemical mechanisms, the following is extracted:

$CO + O_2 \rightarrow CO_2 + O,$ (CO.1)
$O + H_2O \rightarrow OH + OH,$ (CO.2)
$CO + OH \rightarrow CO_2 + H,$ (CO.3)
$H + O_2 \rightarrow OH + O,$ (CO.4)
$O + H_2 \rightarrow OH + H,$ (CO.5)
$OH + H_2 \rightarrow H_2O + H,$ (CO.6)
$CO + HO_2 \rightarrow CO_2 + OH,$ (CO.7)

-- Explain the terms chain reaction, chain-initiation reaction, chain-propagating reaction, and chain-termination reaction.
-- To which of these categories does each of the 7 CO-reactions above belong?

6)
A cylinder containing methane leaks its content of 1,1 kg into a (4,0m x 4,0m x 2,5m) room at 21 °C and 1 bar. After a long time, the methane is well mixed with the air. Methane-air mixtures are flammable for $0,50 < \Phi < 1,68$.
($\Phi = \lambda^{-1}$ is the equivalence ratio, λ is the excess air ratio (Norw: "luftoverskotstal"))
Air can be assumed as 21% O_2 and 79% N_2 (molar based).
Universal gas constant: R_u = 8,314 kJ/(kmol K). Molar mass of methane: 16 kg/kmol
-- Is the mixture in the room flammable? Discuss the result.

7)
The "exact" equation for the turbulence energy can be written as

$$\frac{\partial}{\partial t}(\rho k) + \frac{\partial}{\partial x_j}(\rho k \bar{u}_j) = \frac{\partial}{\partial x_j}\left(\mu \frac{\partial k}{\partial x_j}\right) + \frac{\partial}{\partial x_j}\left(-\tfrac{1}{2}\rho \overline{u_i' u_i' u_j'} - \overline{p' u_j'}\right) - \rho \overline{u_i' u_j'} \frac{\partial \bar{u}_i}{\partial x_j} - \mu \overline{\frac{\partial u_i'}{\partial x_j} \frac{\partial u_i'}{\partial x_j}}$$

--Show how to develop this equation. (You should demonstrate the the principle, not every detail for all terms.)

--Describe the physical significance of each term of the equation.
--Which terms have to be modeled and which can be retained? Explain why.

8)
Put up the modelled partial differential equations ("transport equations") of the k - ε model.

9)
The mixing length (Norw.: "blandingsvegen") was introduced as part of Prandt's Mixing Length Model (Norw.: "Blandingsveg-modellen"). This length can be useful to determine from other models as well.
--Express the mixing length from quantities that are available when using the k - ε model.

10)
Describe the main parts of Magnussen's Eddy Dissipation Concept (EDC).