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Heat flux method: experimental problems and some solutions

2nd Heat Flux Workshop, Warsaw, July 29, 2012

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Outline

Problems with MFCs

Problems with Cori-flow

Problems with thermocouples

Problems with Kinetic Modeling

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Problems with MFCs

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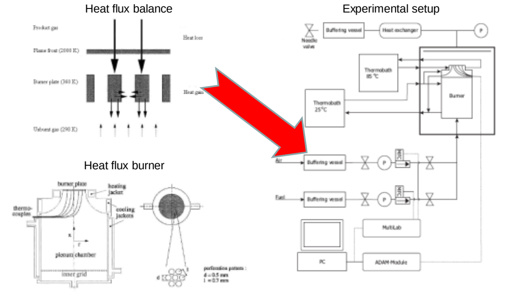
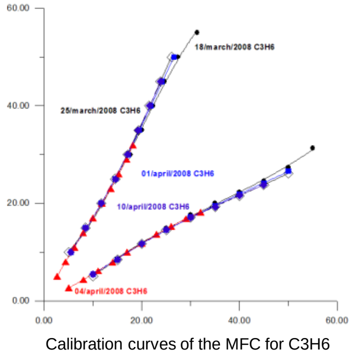
Buffering vessel



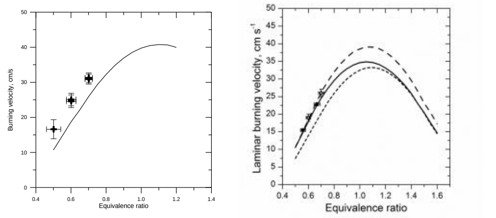
Remember to preheat MFCs !

Calibration



Calibration curves of the MFC for C3H6

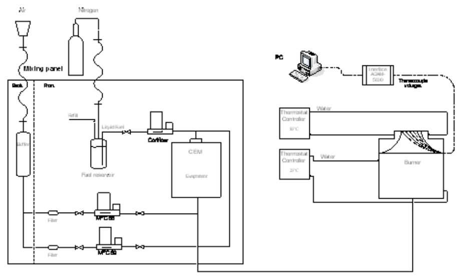
MFC calibration vs. fluidat



Laminar burning velocity vs. equivalence ratio for ethanol + O_2 + CO_2 at 298 K. Symbols: Open diamonds represent first set of experimental data, filled diamonds second set of experimental data. Lines represent modeling; solid line (-): Marinov's model, long dash line (--): the San Diego model; short dash line (..): the LDTV model.

Problems with Cori-flow

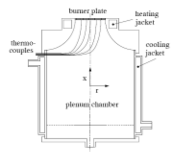
Experimental setup
Overview



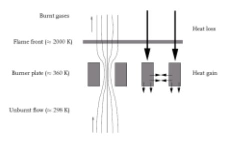
Problems with thermocouples

Experimental setup
Perforated plate burner

Schematic overview



Principle



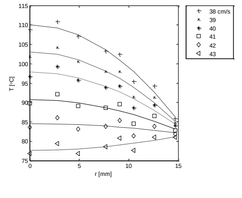
- **Perforated plate burner**
  - **Flow uniformity**
  - **Water circuits**
  - **Thermocouples**

Adiabatic state

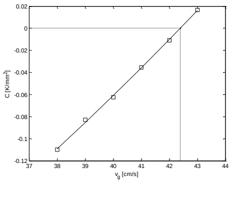
heat loss = heat gain

Experimental setup
Typical measurement

Ethanol / air flame; φ = 1.1, T_u = 298K



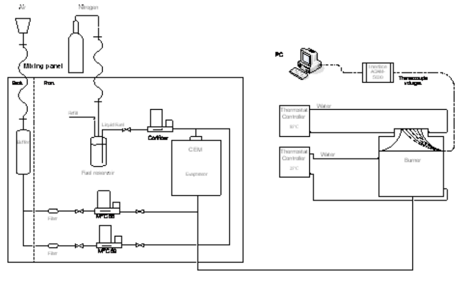
Temperature profile



Parabolic coefficient

$T = T_0 + Cr^2$

Experimental setup
Overview



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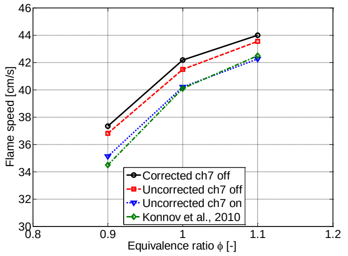
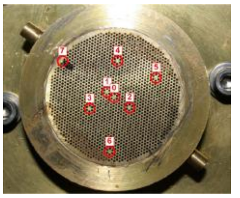
Ethanol flames

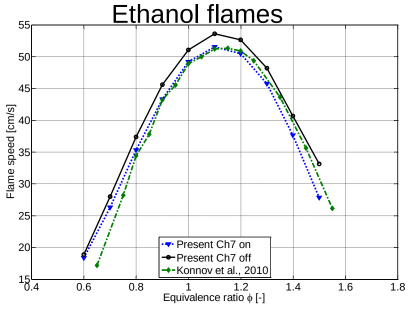


- Laminar burning velocities of ethanol + air flames at atmospheric pressure and initial temperature of 298 K.



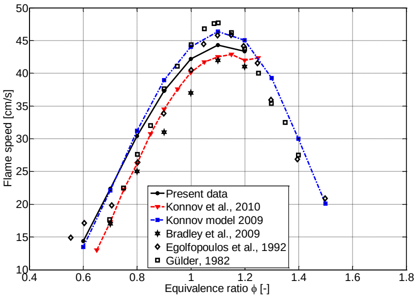
Top view of the perforated plate burner

Ethanol flames

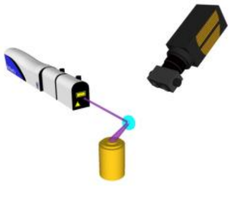


Laminar burning velocities of ethanol + air flames at atmospheric pressure and initial temperature of 338 K.

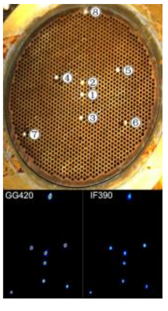
Ethanol flames



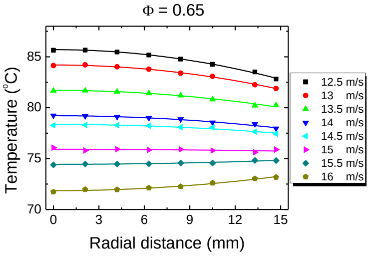
- Laminar burning velocities of ethanol + air flames at atmospheric pressure and initial temperature of 298 K.



setup



Photograph of the perforated burner disc coated with eight thermographic phosphor dots on top of the installed thermocouples installed. Showing beneath are a typical twin laser-induced phosphorescence images collected through two different filters as marked in the corresponding images.



Temperatures measured with thermographic phosphors at different radial distance on top of the burner disc (symbol) at different gas supply speeds and fitting curves (solid lines) for methane/air (Φ=0.65) flame speed evaluation.

Problems with Kinetic Modeling

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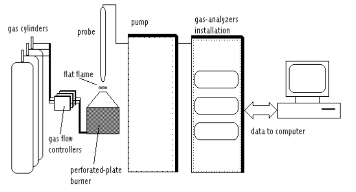
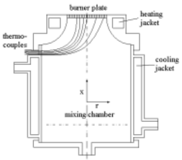
Experimental measurements of [NOx]





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Simple yet efficient

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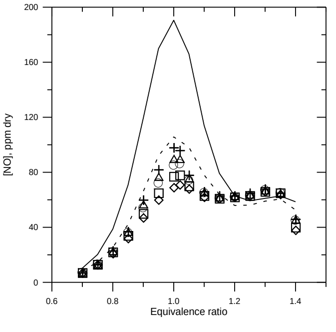
Experimental measurements of [NOx]

Fuel	oxidizer	$O_2/(O_2+Inert)$
CH4	O2+N2	0.209, 0.16, 0.17, 0.18
CH4+NO (100ppm)	O2+N2	0.209
CH4	O2+CO2	0.26, 0.29, 0.3155, 0.35
CH4	O2+Ar	0.17, 0.16, 0.15
CH4+N2O (100ppm)	O2+Ar	0.17, 0.16, 0.15
CO(45%)+H2(5%)+CO2	air	
CO(50%)+H2(50%)	O2+N2	0.09, 0.08, 0.07
CH4(99.5%)+NH3(0.5%)	O2+N2	0.209, 0.16, 0.17, 0.18
CH4(99.5%)+NH3(0.5%)	O2+CO2	0.26, 0.29, 0.3155, 0.35
C2H6	O2+N2	0.209, 0.18, 0.17, 0.16, 0.15
C2H6+NO (100ppm)	O2+N2	0.23, 0.209, 0.19
C2H6	O2+Ar	0.16, 0.15, 0.14
C2H6	O2+CO2	0.26, 0.29, 0.3155, 0.35
C2H4	O2+N2	0.18, 0.17, 0.16, 0.15, 0.14
C2H4+NO (100ppm)	O2+N2	0.18
C3H8	O2+N2	0.23 0.209, 0.18
C3H8+NO (100ppm)	O2+N2	0.23 0.209, 0.18
C3H8	O2+CO2	0.35

NO formation in flames of hydrocarbons

Concentrations of NO in CH4 – air flames at different distances from the burner. Points: measurements, lines: calculations. Diamonds: 10 mm from the burner; squares: 12 mm; circles: 15 mm; triangles: 17 mm; crosses: 20 mm. Solid line: [NO] in the adiabatic flame at 20 mm; dashed line: [NO] in the flame with downstream heat losses at 20 mm.



Gas purity

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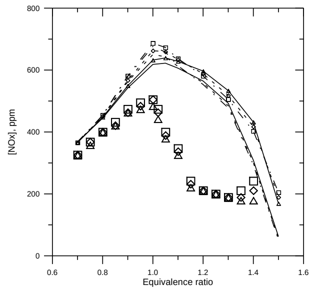
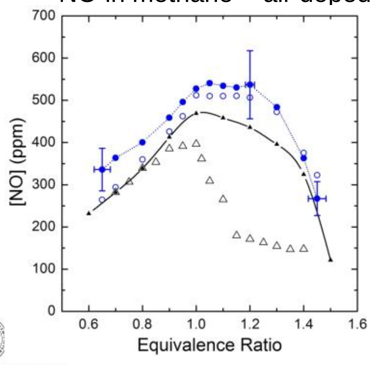
$(CH_4+NH_3) + O_2 + N_2$ flames



- Concentrations of NOx in $(CH_4+NH_3) + O_2 + N_2$ flames at different distances from the burner. Dilution ratio D = 0.209. Points: measurements, lines with small symbols: calculations employing Konnov (2000) mechanism, lines without symbols: calculations employing mechanism of Skreiberg et al. (2004). Solid lines and triangles: [NOx] at 10 mm from the burner; dashed lines and diamonds: [NOx] at 15 mm; dash-dot lines and squares: [NOx] at 20 mm.

NO in methane + air doped with NH3



NO concentrations in NH_3-doped CH_4 + air flames.

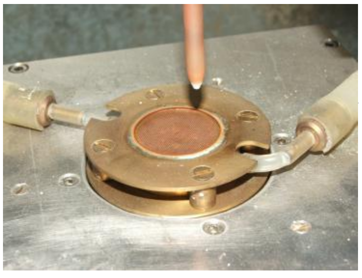
Solid circles: LSF measurements,

open circles: probe sampling measurements,

open triangles: previous data,

line with solid triangles: modeling.

$(CH_4+CO)+O_2+N_2$ flames



Direct photograph of the burner head and quartz sampling probe after 2-days exposure to $(CH_4+CO)+O_2+N_2$ flames with α=0.15.

Outlook

Suggestions

- Web-site + database : Liselotte Verhoeven and Stefan Voss presentation today
- Student exchange
- Information on plans / unpublished achievements
- Steam as inert