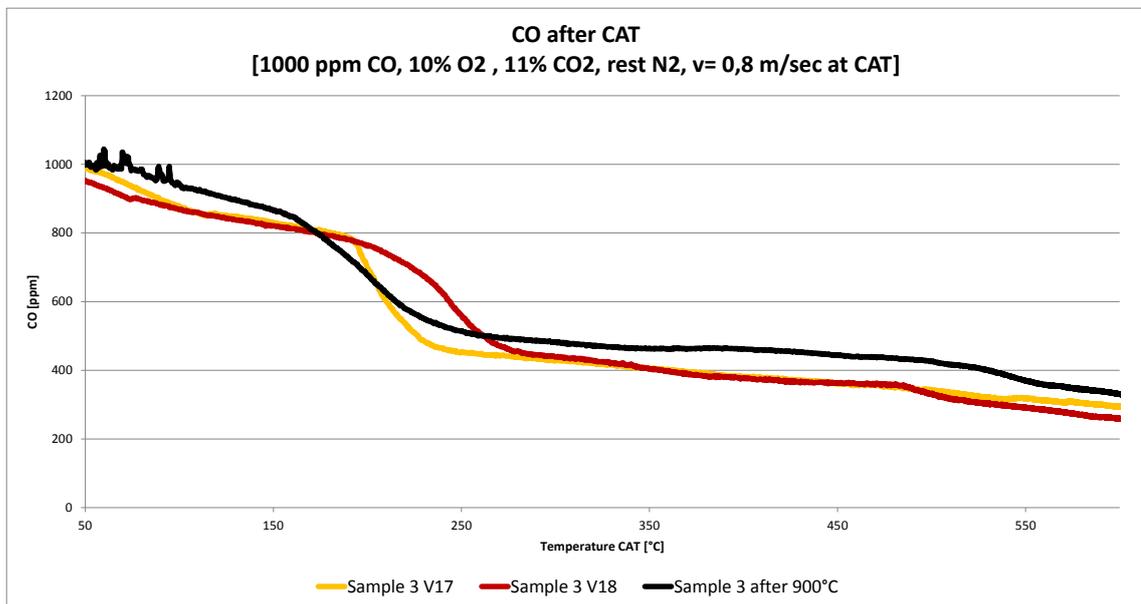Figure 1: Test stand for combustion catalysts



Figure 2: Reactivity of catalyst after thermal treatment
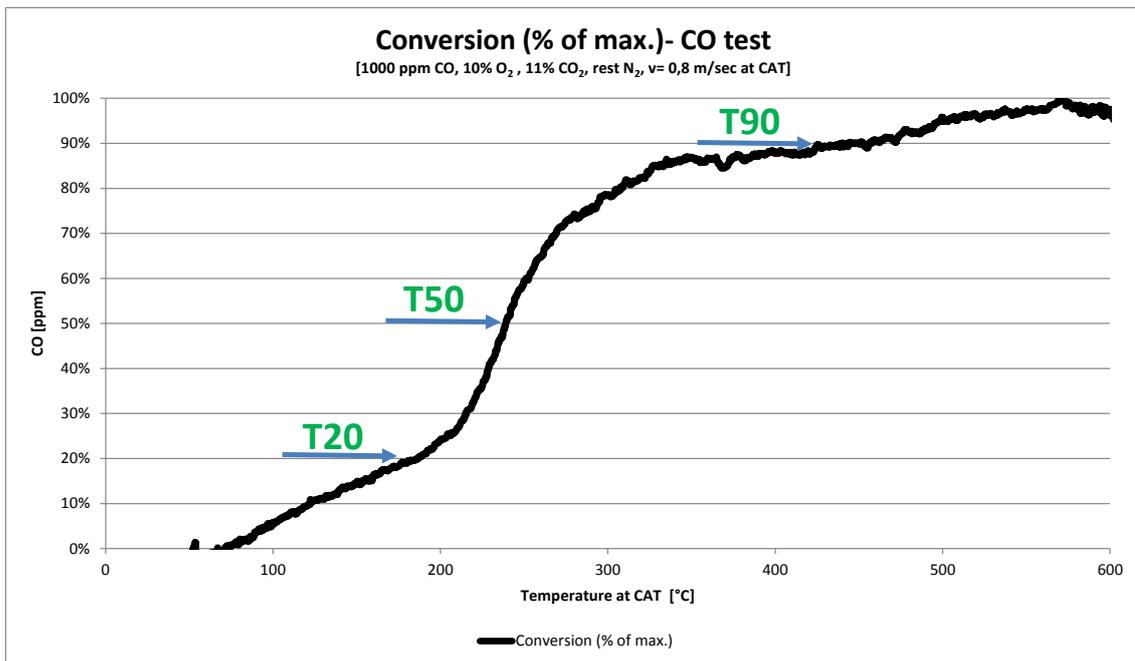
Figure 3: Conversion rate of CO on the catalyst
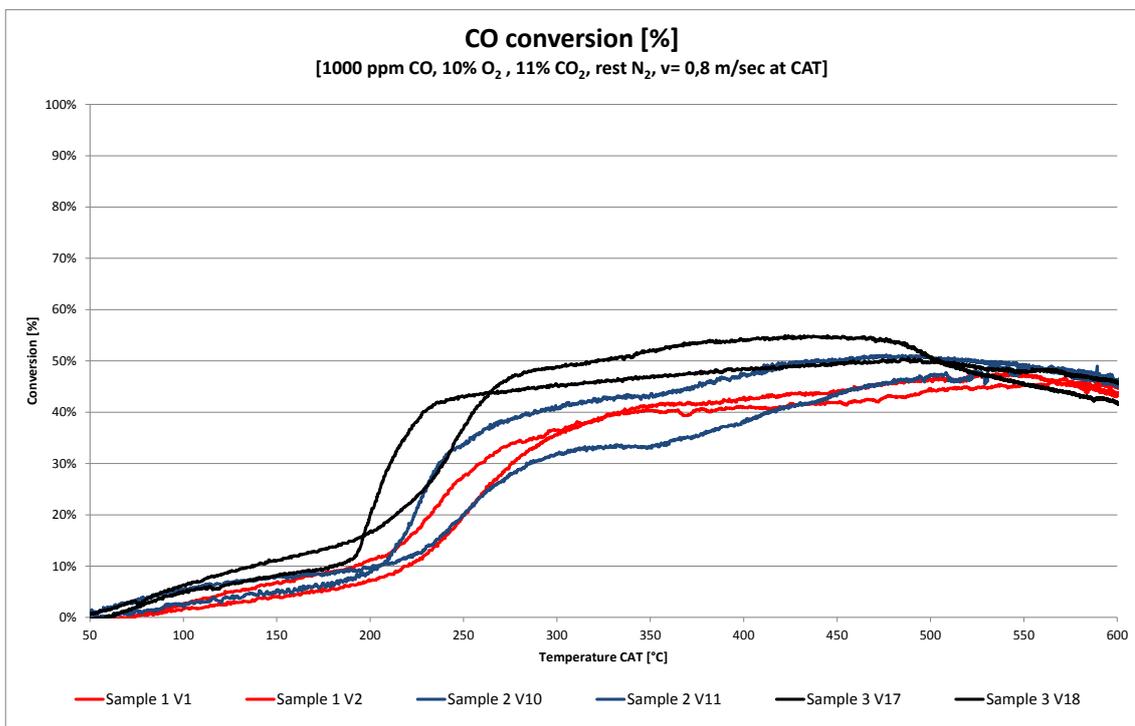


Figure 4: CO conversion rate.

Table 1: Characteristic temperatures for CO conversion

| | Sample 1 average (n=3) | Sample 2 average (n=2) | Sample 3 average (n=2) | Total average (n=7) |
|---|---|---|---|---|
| T20 | 201°C | 205°C | 165°C | 190°C |
| T50 | 249°C | 246°C | 220°C | 238°C |
| T90 | 421°C | 418°C | 305°C | 381°C |

**Conversion CH$_4$ [%]**
**[200 ppm CH$_4$, 10% O$_2$ , 11% CO$_2$, rest N$_2$, v= 0,8 m/sec at CAT]**
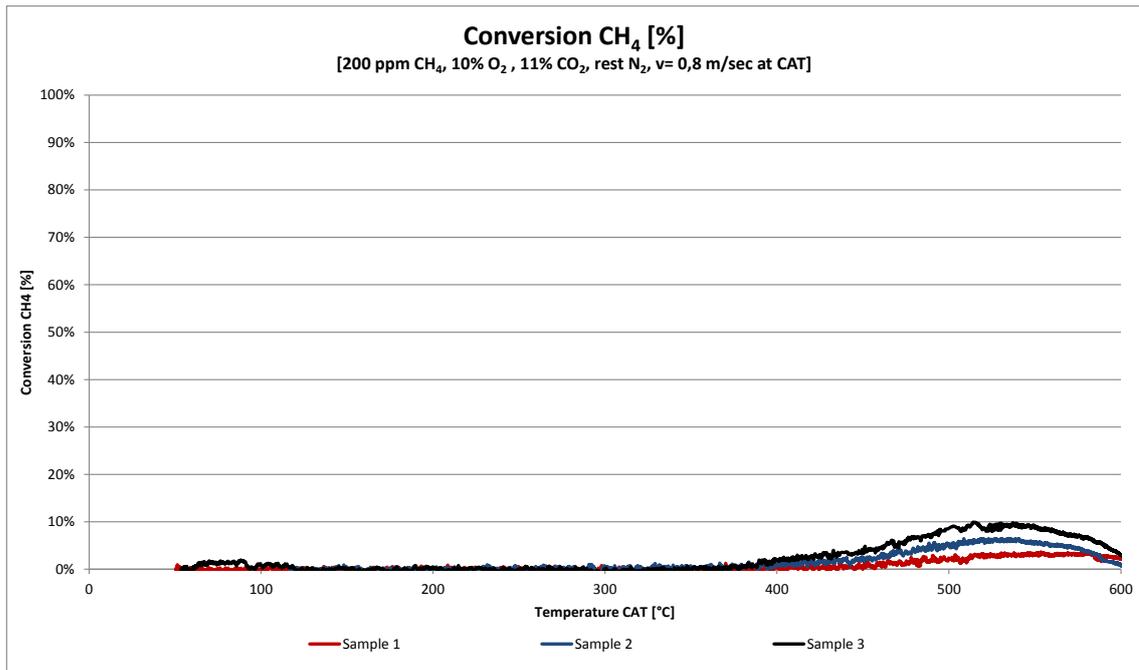
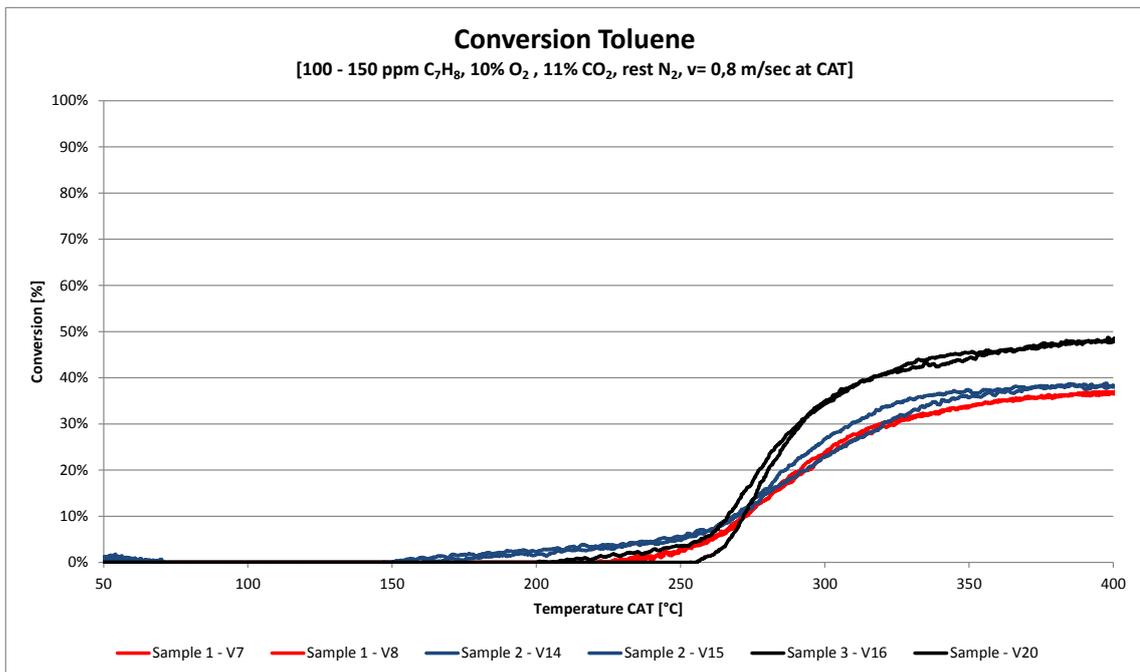Figure 5: Conversion of methane depending on catalyst temperature

Figure 6: Conversion of toluene depending on catalyst temperature
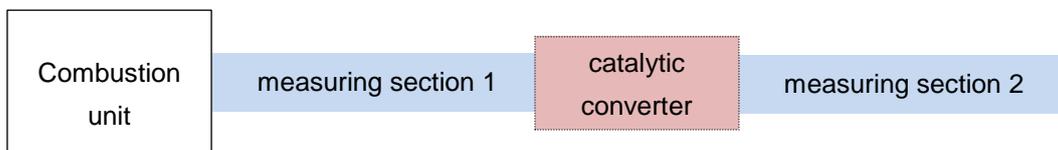


Figure 7: Parallel measuring up- and downstream of the catalytic converter

Equation 1: Conversion rate calculation

$$conversion\ rate\ (\%) = \frac{m_{upstream\ CAT} - m_{downstream\ CAT}}{m_{upstream\ CAT}} \ x\ 100$$
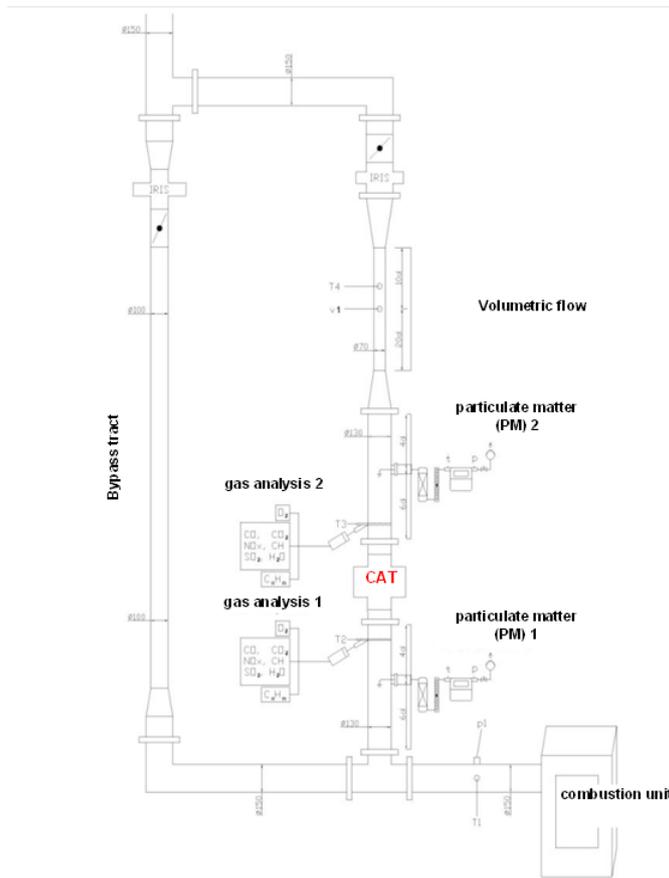
Figure 8: Setup of test stand for catalyst testing under real combustion gas conditions
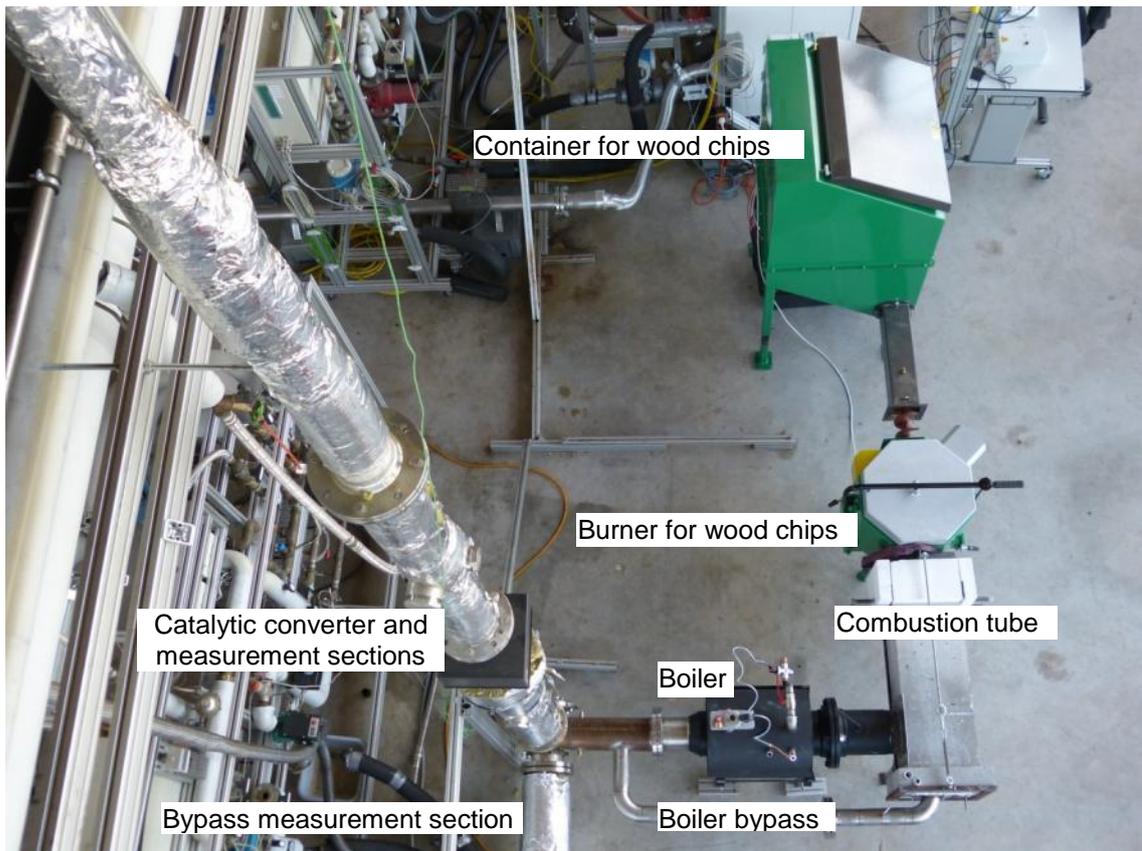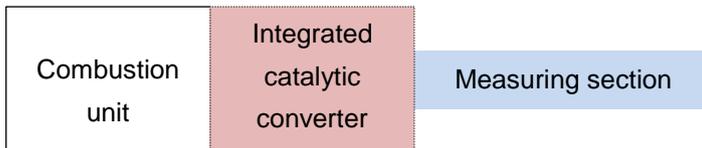
Figure 9: Setup of test stand



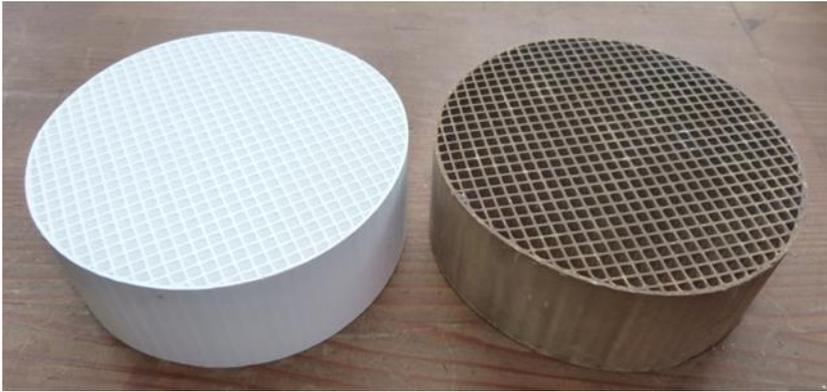Figure 10: Measuring downstream of the catalytic converter

Figure 11: Unused honeycomb mullite ceramic without (left) and with (right) catalytic coating.


Equation 2: Variance with catalyst-dummy

$$s_1^2 = \frac{\sum_{(1)}(x - \bar{x}_1)^2}{n_1 - 1}$$

$s_1^2:$ *estimated variance of the tests conducted with catalyst − dummy*
$\bar{x}_1:$ *arithmetic mean of the tests conducted with catalyst − dummy*
$n_1:$ *number of repetitions of the tests conducted with catalyst − dummy*


Equation 3: Variance with catalyst

$$s_2^2 = \frac{\sum_{(2)}(x - \bar{x}_2)^2}{n_2 - 1}$$

$s_2^2:$ *estimated variance of the tests conducted with catalyst*
$\bar{x}_2:$ *arithmetic mean of the tests conducted with catalyst*
$n_2:$ *number of repetitions of the tests conducted with catalyst*


Equation 4: Variance of the difference

assumption: Same variance for repetitions with catalyst-dummy and with catalyst

$$s^2 = \frac{\sum_{(1)}(x - \bar{x}_1)^2 + \sum_{(2)}(x - \bar{x}_2)^2}{n_2 + n_1 - 2}$$

$s^2:$ *estimated variance of the difference of the arithmetic means*


Equation 5: Standard error of the difference

$$SE_{(\bar{x}_1 - \bar{x}_2)} = \sqrt{s^2 \cdot \left(\frac{1}{n_1} + \frac{1}{n_2}\right)}$$

$SE_{(\bar{x}_1 - \bar{x}_2)}:$ *standard error of the difference of the arithmetic means*


Equation 6: Confidence limits

$$\bar{x}_1 - \bar{x}_2 \pm t_{v,\alpha} \cdot SE_{(\bar{x}_1 - \bar{x}_2)}$$

$t:$ *t distribution*
$v:$ *degree of freedom*
$\alpha:$ *level of significance, corresponding level of confidence = 1 − α*


Equation 7: Significant conversion

$$significant\ conversion = \bar{x}_1 - \bar{x}_2 - t_{v,\alpha} \cdot SE_{(\bar{x}_1 - \bar{x}_2)}$$


Equation 8: Significant conversion rate

$$significant\ conversion\ rate = \frac{significant\ conversion}{\bar{x}_1}$$

Table 2: Improvement in emissions and energy efficiency by primary measures

| Parameter | Appliance No | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 5 |
| | Relative improvement from initial state | | | |
| CO | - 74 % | - 63 % | - 44 % | - 56 % |
| VOC | - 72 % | - 40 % | - 47 % | - 78 % |
| η | + 59 % | + 7 % | ± 0 % | + 34 % |

| Round shape; ceramic | Rectangular shape; ceramic | Round shape; metallic |
|---|---|---|



Figure 12: Honey comb catalysts of different shape and carrier materials

Table 3: Overview on type testing results (emissions based on 13 % $O_2$)

| Combustion system | Hapero | Rika | Stuv 16-78 | Stuv 30.3-IN | Staffieri |
|---|---|---|---|---|---|
| Testing institute: | TU-Wien | TGM | SGS | SGS | TU-Wien |
| CO [mg/Nm$^3$] | 836 | 209 | 117 | 391 | n.a.[1] |
| OGC [mg/Nm$^3$] | 8 | 45 | 32 | 78 | n.a.[1] |
| PM [mg/Nm$^3$] | 63 | 19 | 27 | 29 | n.a.[1] |
| η [%] | 79 | 75 | 79 | 79 | n.a.[1] |

Table 4: Target values at the beginning of the project (emissions based on 13 % $O_2$)

| Combustion system | Hapero | Rika | Stuv 16-78 | Stuv 30.3-IN | Staffieri |
|---|---|---|---|---|---|
| CO [mg/Nm$^3$] | 200 | 200 | 500 | 400 | 1000 |
| PM [mg/Nm$^3$] | 25 | 20 | 30 | 25 | 40 |

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[1] Type testing results are coming up soon