Hans Hartmann, Paul Roßmann, Heiner Link and Alexander Marks, Straubing

Flue Gas Condensation for Domestic Wood Chip Boilers

Through utilising supplementary heat exchangers, new or existing domestic wood boilers can be transformed into highly efficient condensing boilers. The additional cooling and condensing flue gas moisture can increase the power output by 18% on the average; thus raising boiler efficiency to above 100% (related to the lower caloric value). As a side effect, dust in the flue gas is also separated by 20 to 37%. Depending on wood moisture, a specific condensate volume of 0.05 to 0.2 l/kWh boiler heat output is produced. With wood combustion the pH-values of the condensate are between 2.9 and 6.4. Regional regulations are the determining factor in sewage disposal.

Dr. Hans Hartmann is the head of the department "Technology of Renewable Raw Materials" at the Technology and Support Centre in the Centre of Competence for Renewable Raw Materials; the other authors belong to this department, too; Schulgasse 18, 94315 Straubing; e-mail: *hans.hartmann@tfz.bayern.de*

Keywords

Flue gas condensation, wood furnace, dust separation, condensate

The use of a supplementary heat exchanger reduces the flue gas temperature of a wood chip furnace below the dew point, thus increasing the heat use of the fuel tremendously. This process, which is already well known for natural gas or heating oil furnaces, results in system efficiencies of more than 100% (related to the lower calorific value). This can be achieved in domestic wood combustion, too, particularly because the always existent moisture content in the fuel provides helpful conditions for the reclamation of latent heat from the flue gas.

Equipment testing

A secondary heat exchanger (BOMAT AWR 532) was combined as a supplementary component of a conventional wood chip boiler (HDG Compact C100) at the combustion test stand of the TFZ. Various biofuel types, boiler power levels and circulation return flow temperatures were investigated. Heat releases from the boiler and the condensation unit were recorded separately, this also applies for the flue gas composition (CO, VOC, NO_X, dust), which was monitored separately before and after the secondary heat exchanger (*Fig. 1*).

Power and efficiency increases

An average power output increase of 18% was determined in the trials. As this effect is exclusively due to an improved utilisation of the fuel input, the boiler efficiency consequently rises to over 100% (*Fig. 2*). This effect is particularly significant for high moisture fuels, e.g. a 106% efficiency was gained at 40% fuel moisture). Efficiency is reduced by about 2 percentage points, when the circulation return flow temperature is elevated from 20 °C to 30 °C.

Reduced pollutant emissions

A significant reduction of dust emissions by using the secondary heat exchanger was determined consistently in all trials. With wood chips the degree of dust separation was in a magnitude of 20 to 37% (*Fig. 3*). A high fuel moisture did not cause any further improvement, but a reduction of the return flow temperature by 10 Kelvin (from 30 to 20 °C) proved beneficial, causing a 4 to 14 percentage points higher dust separation rate.

For the non-wood fuels (grain straw, miscanthus pellets and triticale kernels) also investigated, the dust emission level was large-

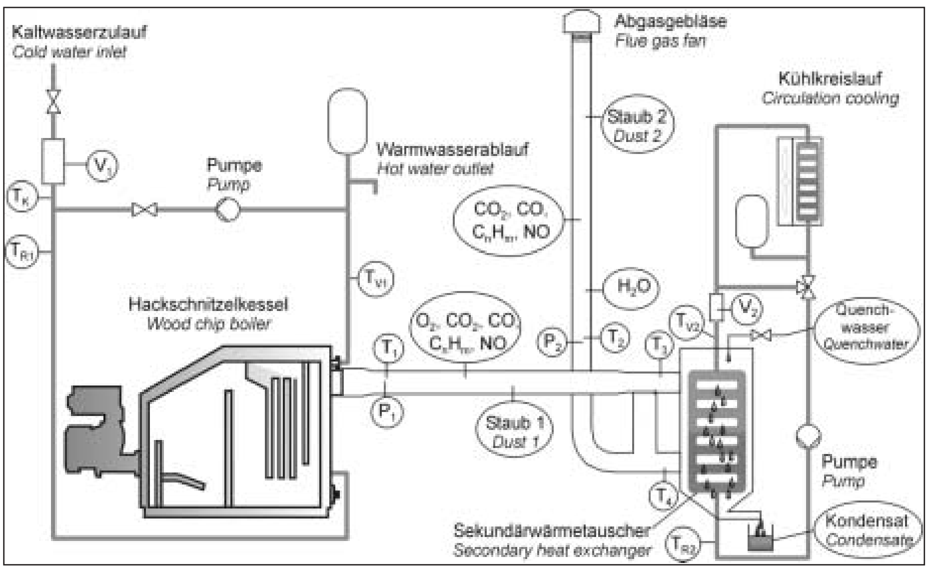

Fig. 1: Schematic description of the experimental set-up and arrangement of measuring points

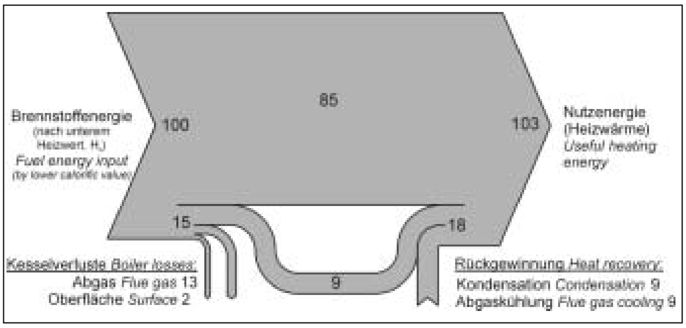

Fig. 2: Typical energy flow diagram of the tested condensation operation

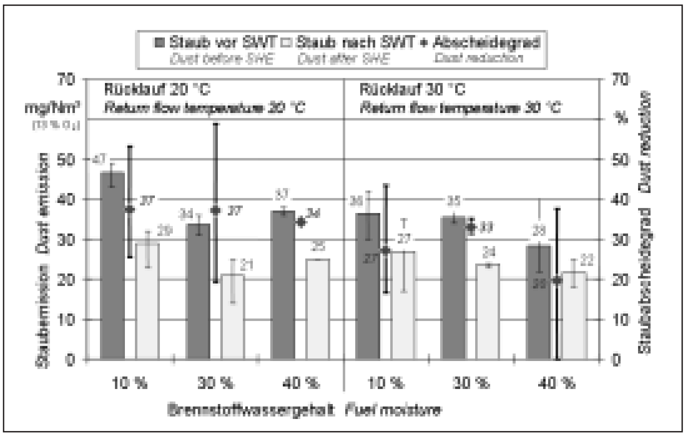

Fig. 3: Dust emission reduction for different fuel moistures and return flow temperatures using secondary heat exchanger (SHE) (measurements with forest wood chips at 60 kW boiler power, mean values and amplitudes with 3 replications per variable)

ly higher and the degree of dust separation was lower than for wood fuels. Also a 50% reduced heat power load caused lower dust separation degrees.

In contrast to the significant reductions for dust emissions the other unwanted flue gas components carbon monoxide (CO), volatile organic carbons (VOC) and nitrogen monoxide (NO) did not improve.

Condensate quantity and quality

Analogous to the above mentioned efficiency gain the condensate quantity is also strongly dependent on the fuel moisture content. In the usual range between 10 and 40%, the produced condensate volume is between 0,05 and 0,2 litres per kilowatt-hour boiler power output. A reduction of the return flow temperature by 10 degrees Celsius causes a condensate increase between 30 and 50% (*Fig. 4*). At a similar fuel moisture (around 10%) the grain kernel fuel (Triticale) applied also produced the highest specific condensate volumes compared to dry wood fuels.

The condensate quality depends mainly on the applied biofuel type. With wood chips (from forest residues) a more or less acidic condensate can be expected (pH 2,9 to 6,4). Herbaceous fuels, however, prove to be particularly disadvantageous in this respect; the pH-value of their condensates is always lower (pH 1,7 to 2,2). This can be explained by the higher chlorine content in the condensates. Also the heavy metal concentrations were consistently higher compared to wood fuel condensates.

Conclusion

The use of a secondary heat exchanger with condensate separation is an interesting option for improving the system efficiency and reducing dust emissions of a domestic wood boiler. This applies particularly for wood chips with their usually relatively high fuel moisture. During combustion, however, this fuel moisture leads to a relatively high flue gas volume which is already high for wood furnaces due to the larger air surplus compared to heating oil or natural gas furnaces. Therefore the secondary heat exchanger needs to be dimensioned significantly larger than for oil or gas boilers at a similar heating power output.

The beneficial side effect of dust emissions are believed to be in the lower range of the possibilities. Further development on improvements for this feature are desirable. But the application of a secondary heat exchanger implies that the low temperature heat can be used. At most locations for domestic wood chip furnaces such conditions are not given (e.g. in old buildings or on farms), additionally the costs for the provision of biofuels are there rather low. Chances for an economic application of secondary heat exchangers are therefore higher for new installations and for pellet furnaces. Here the relatively high fuel costs may be compensated by the achieved efficiency gains. The higher investment of today about 3000 to 5000 € per installation (at about 60 kW heat power) may then pay off.

Acknowledgements and References:

The research was funded by the Deutsche Bundesstiftung Umwelt. The authors would like to thank the company BOMAT (Überlingen), the company HDG (Massing) and the Bayerisches Landesamt für Umweltschutz (Augsburg) for good cooperation. A long version of the report (in German language) is available in the series "Berichte aus dem TFZ", Vol. 2 (download at *www.tfz.bayern.de*).

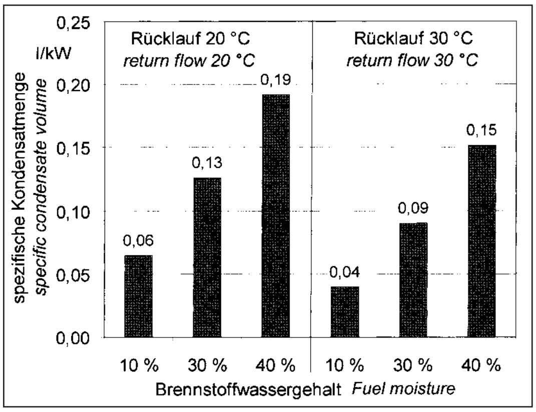

Fig. 4: Volume of condensate collected from the secondary heat exchanger during the condensation operation (Fuel: wood chips)