Austrian pellet boiler technologies – state-of-the-art, ecological evaluation and future developments

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Introduction

- Austrian pellet market
- Standards for pellet furnaces
- Pellet combustion technology
  - Feeding
  - Storage
  - Burn-back protection
  - Basic burner principles
  - Technical details
    (furnace geometry, materials, control systems, boiler technology, de-ashing)
- Emissions
- Future developments
Development of small-scale pellet furnaces in Austria

Source: [Lower Austrian Chamber for Agriculture and Forestry, 2005]

Number of newly installed pellet central heating units

- Year 1997: 425
- Year 1998: 1,323
- Year 1999: 2,128
- Year 2000: 3,466
- Year 2001: 4,932
- Year 2002: 4,492
- Year 2003: 5,193
- Year 2004: 6,077

Legend:
- Red: feed from storage tank
- Blue: feed from storage room
Pellet production in Austria – present state and outlook

Pellet production [1,000 t/a]

Source: [Geisslhofer, 2000: Wood pellets in Europe; own enquiries]

* estimate
Pellet consumption in Austria (year 2004)

- About 28,000 pellet central heating systems already installed in Austria
- Total nominal boiler capacity installed: about 520 MW
- Annual utilisation rate: about 74%
- Boiler full load operation hours: 1,500 h p.a.
- Net calorific value of pellets: 4.9 kWh/kg (w.b.)

Pellet consumption in Austria approximately 216,000 t/a (related to pellet central heating systems)

Additional amounts related to pellet stoves and medium-scale pellet furnaces (100 to 1,000 kWth)

Difference to production: mainly export
Investment subsidies granted in Austria on average 25% (depending on the Austrian provinces)

Currently 18 pellet producers active or near start-up in Austria

Pellet quality, transport and storage regulated by ÖNORM M 7135, M 7136 and M 7137

Quality of pellet furnaces regulated by ÖNORM EN 303-5

Supply of pellets in Austria assured throughout the country by a well organised distribution network

About 30 manufacturers of small-scale pellet furnaces in Austria
### ÖNORM EN 303-5

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valid for heating boilers with a nominal boiler capacity up to</td>
<td>300 kW</td>
</tr>
<tr>
<td>Testing required by law</td>
<td>yes</td>
</tr>
<tr>
<td>All solid fuels (biomass and fossil fuels) are permitted</td>
<td>yes</td>
</tr>
<tr>
<td>Maximum organic carbon (OGC) emission [mg/MJ\textsubscript{NCV}]</td>
<td>40</td>
</tr>
<tr>
<td>Maximum CO emission [mg/MJ\textsubscript{NCV}]</td>
<td>500</td>
</tr>
<tr>
<td>Maximum NO\textsubscript{x} emissions [mg/MJ\textsubscript{NCV}]</td>
<td>150</td>
</tr>
<tr>
<td>Maximum dust emissions [mg/MJ\textsubscript{NCV}]</td>
<td>60</td>
</tr>
<tr>
<td>Minimum combustion efficiency</td>
<td>*</td>
</tr>
</tbody>
</table>

*depending on the nominal boiler capacity (see following slide)
Minimum combustion efficiency according to ÖNORM EN 303-5

\[
\text{combustion efficiency} [\%] = \frac{\text{boiler heat produced}}{\text{fuel heat input (NCV)}}
\]
Pellet combustion systems

Pellet stoves

Pellet central heating systems

Grate fired pellet boilers for medium-scale applications (150 to 300 kWth)

Source: [RIKA Metallwaren-ges.m.b.H. & Co KG, Austria]

Source: [Gilles Energie und Umwelttechnik GmbH, Austria]

Source: [GUNTAMATIC Heiztechnik GmbH, Austria]

Source: [KWB Kraft und Wärme aus Biomasse GmbH, Austria]
Feeding and storage systems used

Feeding systems

- Screw conveyor (inflexible)
- Screw conveyor (flexible)
- Pneumatic system
- Pneumatic system / screw conveyor combination
- Agitator / screw conveyor combination

Storage systems

- Storage room (88 %)
- Integrated store (12 %)
- Underground storage tank
Screw conveyor (inflexible)

Motor for conveying screw
Conveying screw
Screw channel

Source: [KWB – Kraft und Wärme aus Biomasse GmbH, Austria, 2002]
1 Pellet storage
2 Manhole pit
3 Filling connections

4 Discharge
5 Duct
6 Earthing

7 Sucker
8 Dust separator
9 Burner

Source: [Stefan Nau GmbH & Co. KG, Germany, 2002]
Burn-back protection systems (1)

Cellular wheel sluice

Source: [COMPACT Heiz- und Energie-systeme GesmbH, Austria]

Fireproof valve

Source: [KWB – Kraft und Wärme aus Biomasse GmbH]
Burn-back protection systems (2)

Extinguisher system

- Motor
- Water level switch
- Water tank
- Thermal burn-back protection storage
- Valves
- Motor
- Thermal burn-back protection burner
- Conveying screw from storage
- Level switch
- Thermocouple fall shaft
- Conveying screw to burner

Source: [Anton Eder GmbH, Austria]
Basic principles of wood pellet burners

- Underfed burners
- Horizontally fed burners
- Overfed burners

Source: [Handbook of Biomass Combustion and Co-Firing, IEA, 2002]
Underfed burner

Boiler with spiral scrapers

Flue gas

Secondary air

Retort

Primary air

Ash box

Intermediate storage

Fuel supply (stoker screw)

Conveying screw

Fan

Source: [KWB – Kraft und Wärme aus Biomasse GmbH, Austria, 2002]
Geometry of the combustion chamber – important parameters

- Air staging
- Mixing of secondary air and flue gas (position and design of the secondary air nozzles)
- Appropriate dimensioning of primary and secondary combustion zone (residence time)
- Good utilisation of the furnace volume (flow distribution)
- Even temperature distribution (furnace temperature control)
Air staging and optimised mixing between flue gas and secondary air

Source: [GUNTAMATIC Heiztechnik GmbH, Austria]
Design and optimisation of the nozzles for the injection of secondary air

Vectors of the flue gas velocity [m/s] in the horizontal cross-section right over the secondary air nozzles

Basic nozzle design

Improved nozzle design

→ CFD-based furnace and nozzle design of great relevance

Source: [BIOS BIOENERGIESYSTEME GmbH, Austria, 2002]
Control systems

Load control
- Guiding value: feed water temperature
- Variables: fuel and primary air feed

Combustion control
- Guiding value: $O_2$, CO or $O_2$ and CO concentration in the flue gas (lambda, CO or CO/lambda control)
- Variable: secondary air supply

Temperature control
- Guiding value: temperature in the combustion chamber
- Variables: flue gas recirculation or water-cooled furnace walls

Pressure control
- Guiding value: pressure in the combustion chamber
- Variable: induced draught fan (frequency)
Relevance of automatic control systems

- Importance of automatic control systems to guarantee low CO, TOC and particulate emissions at all load conditions (start-up, shut-down, load changes, full and part load operation)

Notes:
- Data related to the current operating conditions
- Change of load from 40% part load to nominal load
Geometry

- Usually vertical fire tube boilers (one or three-pass boilers)

Boiler cleaning

- Fully automatic by spiral scrapers in the fire tubes
- Semi-automatic by spiral scrapers in the fire tubes with a lever from the outside
- Manually

Automatic boiler cleaning systems increase the efficiency and reduce dust emissions
Fully automatic boiler cleaning system

Source: [BIOS BIOENERGIESYSTEME GmbH, Austria, 2002; furnace of KWB - Kraft und Wärme aus Biomasse GmbH]
De-ashing systems

- Usually ash collection in an ash box
  - ash box must be emptied periodically

- Ash compaction systems partly applied
  - ash box must be emptied periodically in longer periods of time

- Fully automatic de-ashing system by a screw conveyor in an external container
  - ash box must be emptied only about once a year
Ash compaction system

Source: [KWB – Kraft und Wärme aus Biomasse GmbH, Austria, 2002]
Emissions

Source: Spitzer et al, 1998; BLT Wieselburg, 2002

<table>
<thead>
<tr>
<th>Particulate Matter</th>
<th>Emission Factor [mg/MJ (NCV)]</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO</td>
<td>163</td>
</tr>
<tr>
<td>TOC</td>
<td>43</td>
</tr>
<tr>
<td>NOx (NO2)</td>
<td>73</td>
</tr>
<tr>
<td>dust</td>
<td>29</td>
</tr>
</tbody>
</table>

- **Test stand measurements**
- **Field measurements**
- **Limiting value**

**Test stand measurements**:
- CO: 163 mg/MJ (NCV)
- TOC: 43 mg/MJ (NCV)
- NOx (NO2): 73 mg/MJ (NCV)
- Dust: 29 mg/MJ (NCV)

**Field measurements**:
- CO: 1 mg/MJ (NCV)
- TOC: 22 mg/MJ (NCV)
- NOx (NO2): 87 mg/MJ (NCV)
- Dust: 11 mg/MJ (NCV)

**Limiting value**:
- CO: 500 mg/MJ (NCV)
CO emissions – comparison between old and new pellet furnaces

Source: Jungmeier et al, 1999; BLT Wieselburg, 2005; results from test stand measurements
Dust emissions – comparison between old and new pellet furnaces

Source: Jungmeier et al, 1999; BLT Wieselburg, 2005; results from test stand measurements
Fine particulate emissions – new pellet furnaces

- About 90 to 95% of the total dust emissions are fine particles (< 1 µm)
- Fine particulate emissions from modern pellet furnaces usually have a mass mean diameter of about 0.15 µm
- If combustion is complete about $1.5 \times 10^7$ particles per cm$^3$ are formed
- A complete burnout of the flue gas is very important to minimise fine particulate emissions
- The chemical composition of the fuel strongly influences fine particulate emissions
Explanations: Emissions related to dry flue gas and 13 vol.% O₂; d.b. ... dry basis; results from measurements at grate furnaces with nominal capacities between 400 kWₜₜ and 50 MWₜₜ
Future developments

- CFD-aided furnace development and optimisation
- Medium-scale combustion systems
  (nominal boiler capacities between 100 and 1,000 kW\text{th})
- Reduction of particulate emissions (especially PM1)
- Small-scale dust burners
  (utilisation of pulverised pellets)
- Utilisation of herbaceous / non-woody biomass fuels
- Combination of pellets with solar systems
- Pellet furnaces with flue gas condensation
- Small-scale CHP systems
  (e.g. Stirling engines)
Pellet furnace with flue gas condensation

- First pellet boiler with flue gas condensation
- Market introduction: 2004
- Efficiency: 103%
  (according to type test by BLT Wieselburg)
- Nominal capacities: 8, 10, 15 and 20 kW

Source: [OkoFEN, Austria, 2004]
New small-scale CHP technology based on Stirling engines for wood chip and pellet furnaces

- 2 pilot plants in operation
  35 kW_{el} and 70 kW_{el}
- Start-up:
  End of 2002 (35 kW_{el}) and
  End of 2003 (70 kW_{el})
- Operating hours:
  > 12,000 (35 kW_{el})
  > 4,000 (70 kW_{el})
- Electric plant efficiency:
  approximately 11 to 12%
- Fuels:
  Pellets, wood chips, sawdust
- First small series production
  (7 plants with 35 kW_{el})
- Comprehensive field tests ongoing
  (2005/06)

Source: [BIOS BIOENERGIESYSTEME GmbH; MAWERA Holzfeuerungsanlagen GesmbH, Austria, 2005]
Rapidly expanding pellet market in Austria

Several actors, quality standards and subsidies supporting this development

Proven feeding and combustion technologies available from many furnace manufacturers which ensure a fully automatic operation

Low emissions with a decreasing tendency for new furnaces

Several research activities and promising developments focusing on new fields of application, new biomass fuels and emission reduction