International experience of wood waste use for heat and electricity production. Technologies and equipment for biomass combustion

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Presentation – overview

- Key information about the company
- Domestic combustion technologies
  - Wood stoves, wood log boilers
  - Wood chip fired units
  - Wood pellets burners
- Industrial combustion technologies
  - Fixed-bed furnaces
  - Fluidised bed combustion
  - Dust combustion
- Summary

Key information about BIOS BIOENRGIESYSTEME GmbH

- **BIOS BIOENERGIESYSTEME is an internationally active engineering company. The main markets are Austria, Italy, Germany, the Netherlands and recently also the USA.**
- **BIOS is active in research, development, engineering, realisation and optimisation of biomass combustion and biomass combined heat and power (CHP) plants.**
- **BIOS has comprehensive experience in the design and operation of plants for thermal biomass utilisation and can refer to many references of realised plants and successful developments.**

Working Fields (I)

- Design of plants for heat generation as well as for combined heat and power (CHP) generation from biomass fuels
- Design of plants for thermal waste wood utilisation
- Design of plants for exhaust heat utilisation
- Design and optimisation of district heating networks
- Design of special units for biomass combustion plants
- Optimisation of existing biomass combustion and CHP plants

Working Fields (II)

- **CFD based design of furnaces and boilers**
- **Measurements**
  (flue gas and efficiency measurements needed for plant commissioning and evaluation)
- **Analyses**
  (biomass fuels, ashes and aerosols, waste water)
- **Expertises**
  Concerning various aspects of thermal biomass utilisation and environmental assessment issues
- **Management of and participation in national and international R&D and demonstration projects**
- **Development of new biomass combustion, emission reduction (NO_x, dust) and CHP technologies**

European biomass combustion is mainly applied to the following processes:

- Heat generation in small domestic applications for space heating and cooking
- Heat production in medium and large scale applications for district and process heat supply
- Steam production for driving steam engines or turbines as well as for combined heat and power (CHP) applications
- Heat production for power or combined heat and power supply using heat carriers (e.g. thermal oil or air)

Selection and design of a biomass combustion system is mainly determined by

- size of the plant (heat only or CHP application)
- costs and performance of the equipment
- the local environmental legislation
- characteristics of the fuel to be used
  - moisture content 10 wt% w.b. (dry wood processing residues, pellets) up to 60 wt% w.b. (bark, sawmill by-products)
  - particle shapes and sizes
  - ash content, ash sintering temperatures

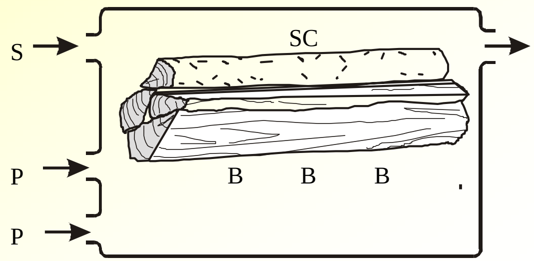
Small scale (domestic) combustion:

- Units used for heating (or cooking) up to a capacity of about 500 kW.

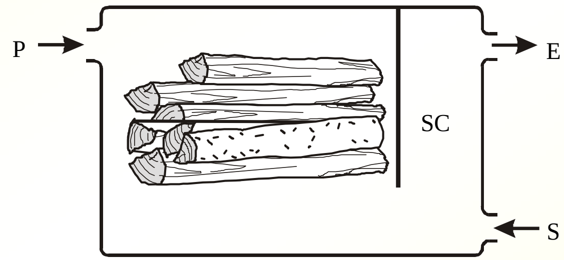
Domestic combustion technologies:

- Wood stoves and fireplaces inserts
- Wood log boilers
- Wood pellets burners
- Wood chip fired units

Classification of wood stoves depending on primary air flow paths:



Underfire air or updraft

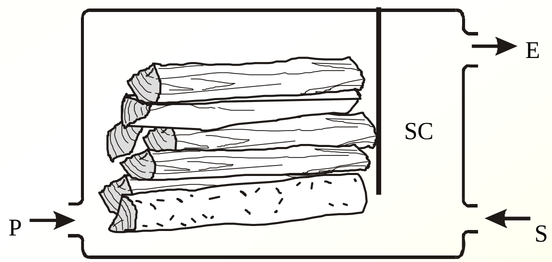


Down draft

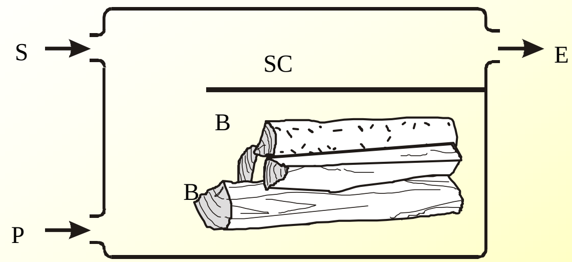
P = Primary air supply
S = Secondary air supply

E = Exhaust to stack

B = Primary combustion
SC = Secondary combustion



Side cross draft



S-flow

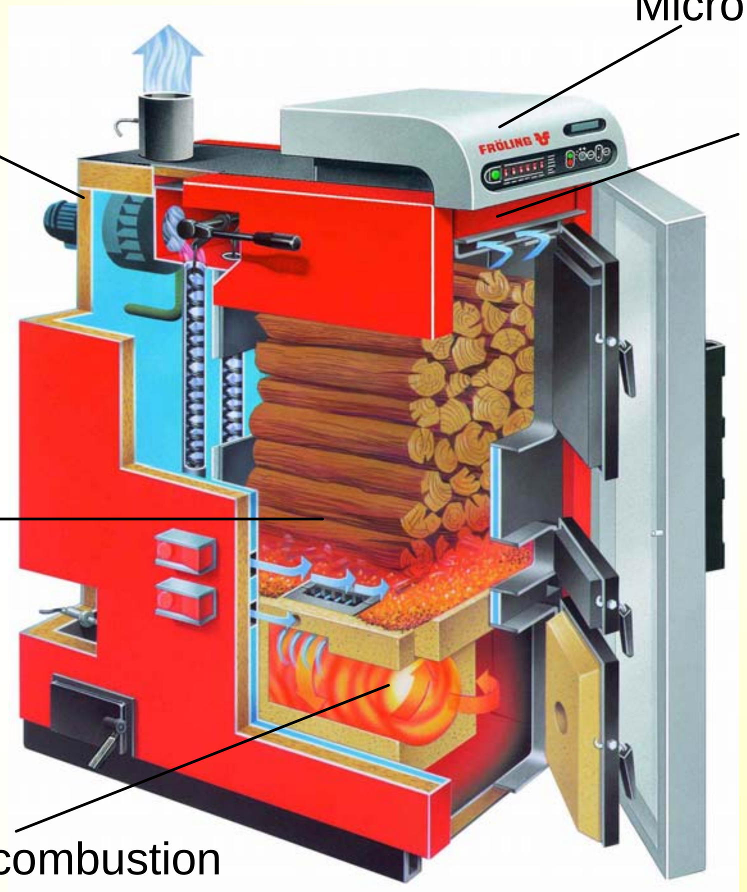
In stoves the heat from combustion is directly transferred by radiation an convection to the surroundings.

Wood log boilers (I)

Downdraft boilers:

- Flue gases are forced to flow down through holes in a ceramic grate
- Secondary combustion air is introduced directly below the grate (secondary combustion chamber)
- In the secondary combustion chamber the final combustion takes place at high temperatures
- Combustion air fan or flue gas fan is needed
- Include modern combustion control devices (lambda control probes, combustion air control, staged air combustion)

Microprocessor controlled downdraft boiler for wood logs [2]

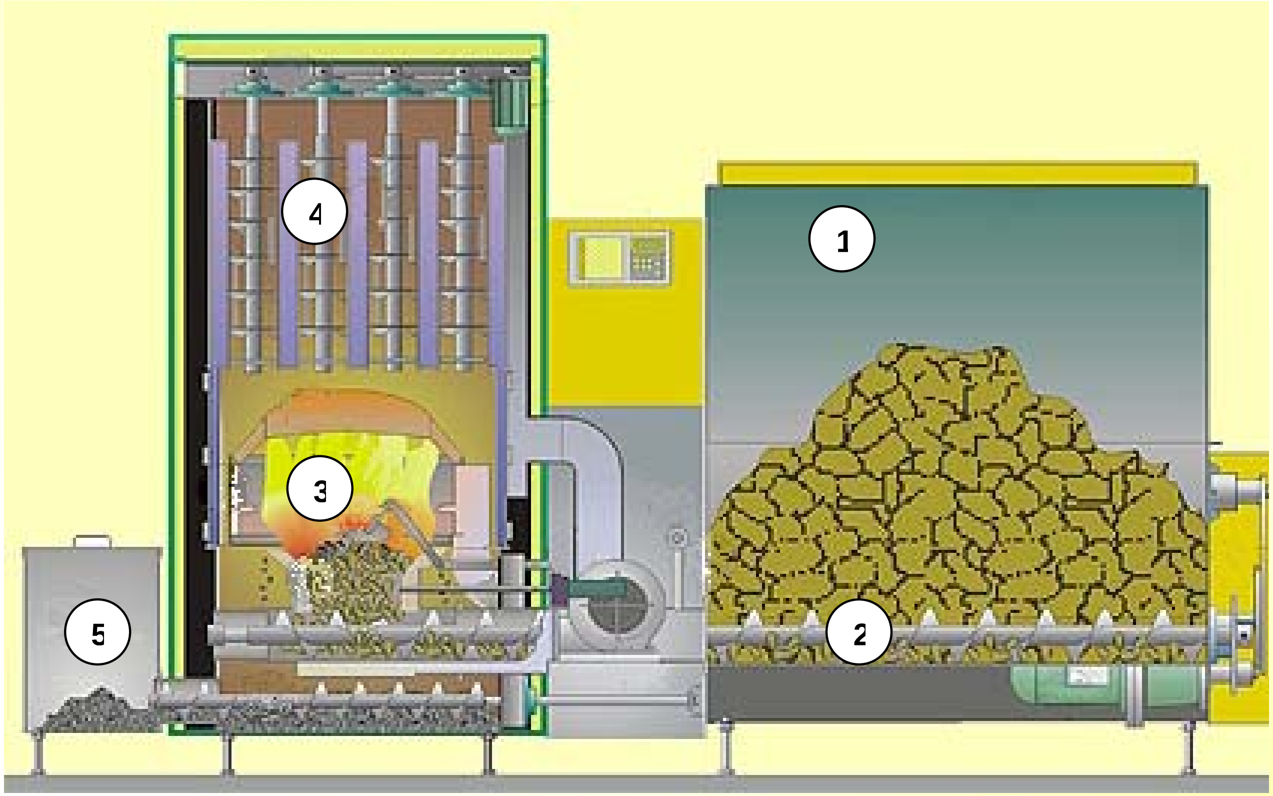


Wood chip fired units (I)

- The advantages of using wood chips instead of firewood are the automatic operation and much lower emissions because of the continuous combustion principle.
- But making and storing them requires a higher investment in machinery an storage space.
- Small scale wood chip combustion is often performed in underfeed or horizontally fed stoker burners.
- Designed for a heat output range of 10-200 kW.
- More common in the countryside heating detached houses and farms.

Wood chip fired units (II)

Automatically underfed wood chip stoker burner (50-100 kW)



Explanations: 1…storage container, 2…feeding screw, 3…combustion plate, 4…heat exchanger with turbolators and cleaning system, 5…ash container [3]

Wood pellet burners

- A pellet burner is a unit for continuous automatic combustion of a refined and well defined fuel.
- Pellet burners for domestic use are usually constructed for a nominal thermal output of less than 25 kW.
- Some burners are quipped with a smaller storage unit (enough for one or a few days) that can be refilled manually or by an automatic system from a larger storage unit.
- Modern automatic pellet burners comprise air staging with separate primary and secondary combustion zones and microprocessor-controlled combustion systems.

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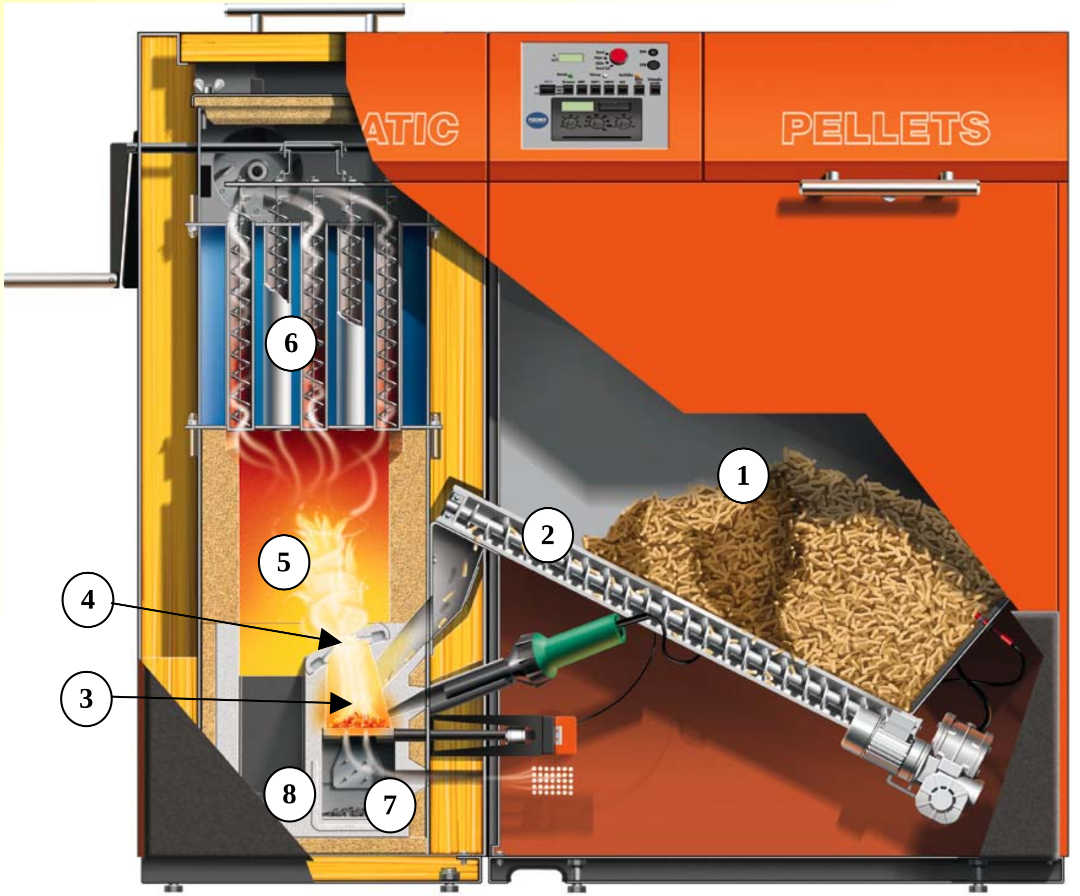
Automatically overfed pellet boiler (3.5-15 kW)



Explanations: 1…fuel container; 2…stoker screw; 3..primary combustion chamber with primary air addition; 4..secondary air addition; 5…secondary combustion chamber; 6…heat exchanger with cleaning device; 7…bottom ash container; 8…fly ash container [4]

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Industrial combustion technologies overview

Industrial combustion:

- Medium or large scale combustion systems with a nominal thermal capacity exceeding 500 kW

Industrial combustion technologies:

- Fixed-bed combustion
  - Underfeed stokers
  - Moving grate furnaces
- Fluidised bed combustion
- Dust combustion

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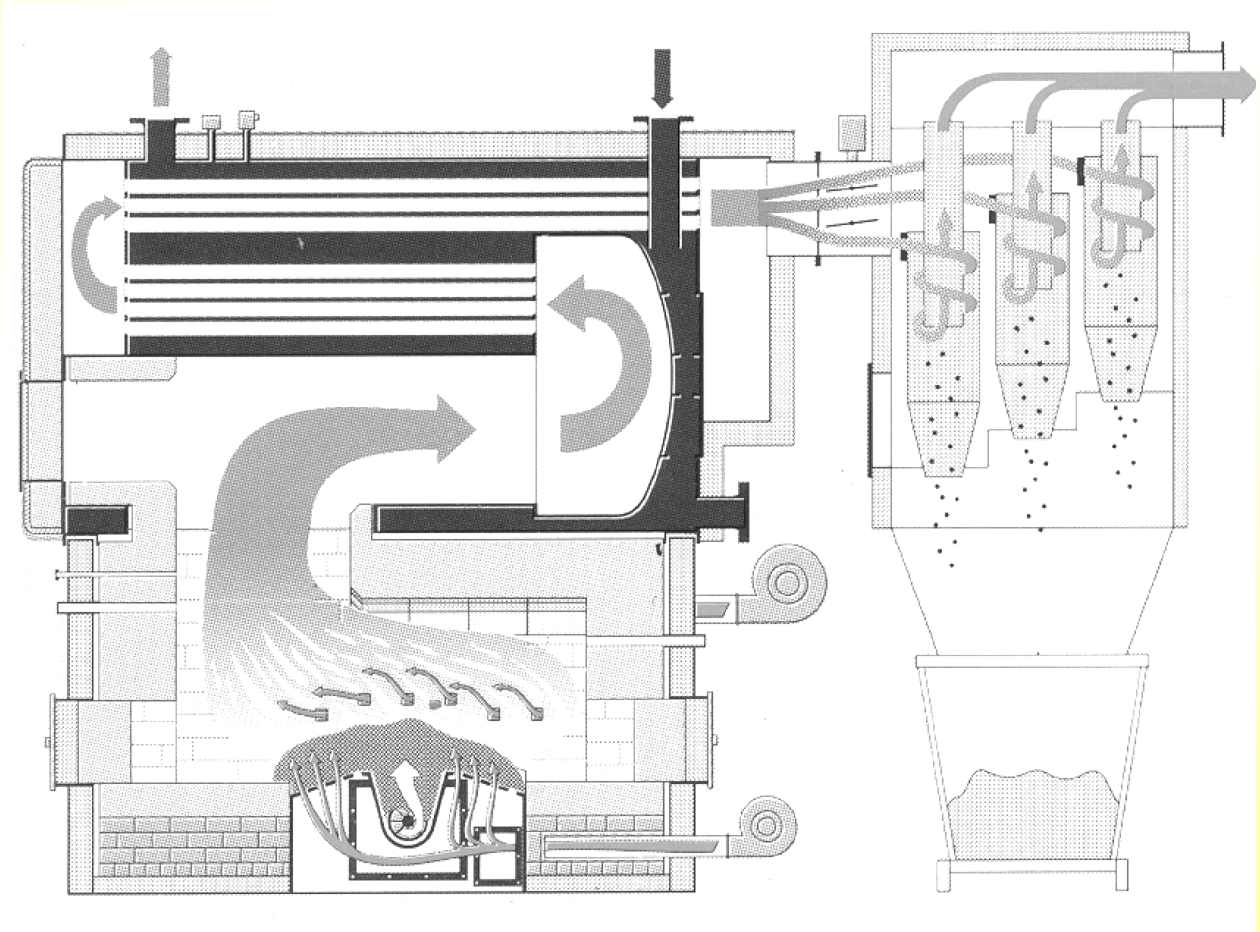
Underfeed stokers (I)

- Fuel is feed into the combustion chamber by screw conveyors
- For fine-grained biomass fuels (<50mm) with low ash content
  - Wood shavings
  - Pellets
  - Sawdust
- Nominal boiler capacity up to 6 MW
- In this performance range the investment costs are lower than for other technologies (e.g. grate fired combustion units)

Underfeed stoker furnace [5]

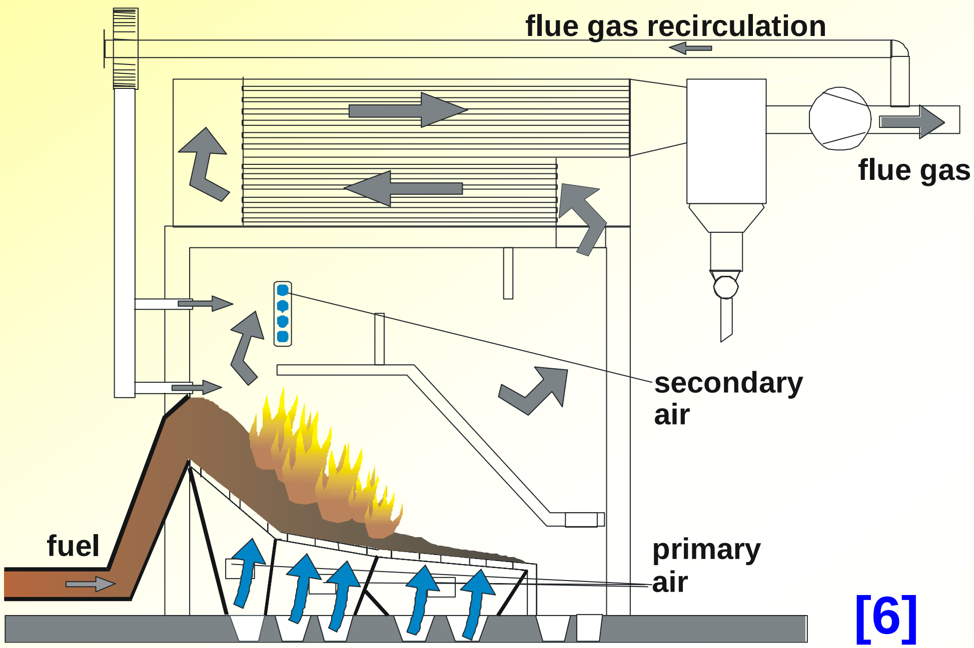


Moving grate furnaces overview

Moving grate furnaces are generally distinguished by the way the grate is moving:

- Inclined moving grates
- Horizontally moving grates
- Travelling grates
- Vibrating grates
- Rotating grates

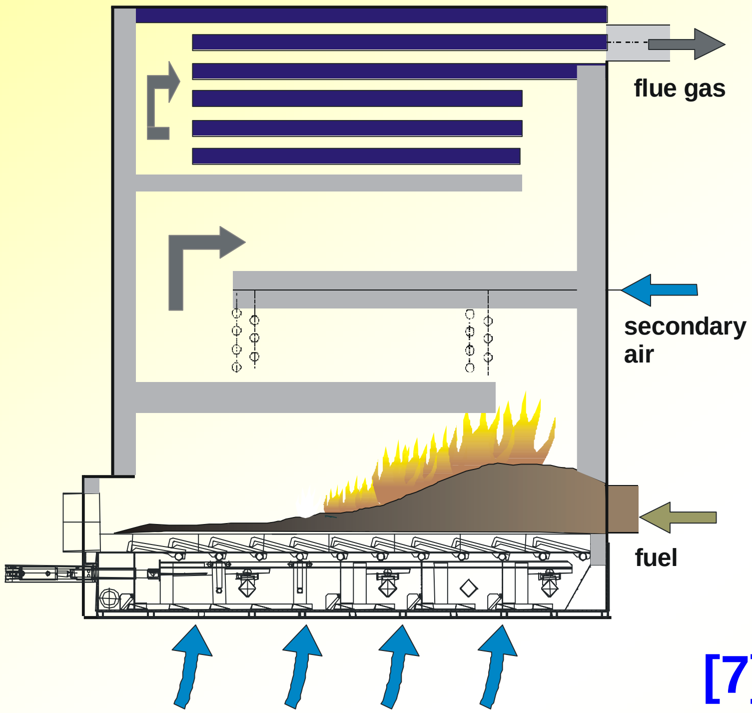
Inclined moving grates



[6]

- Inclined grate consisting of fixed and moveable rows of grate bars.
- By alternating forward and backward movements of the moveable sections, the fuel is transported along the grate.
- The movement is achieved by hydraulic cylinders.
- The whole grate is divided into several grate sections, which can be moved at different speeds according to different stages of combustion.
- The grate bars themselves are made of heat-resistant steel alloys and can be air-cooled or water-cooled.

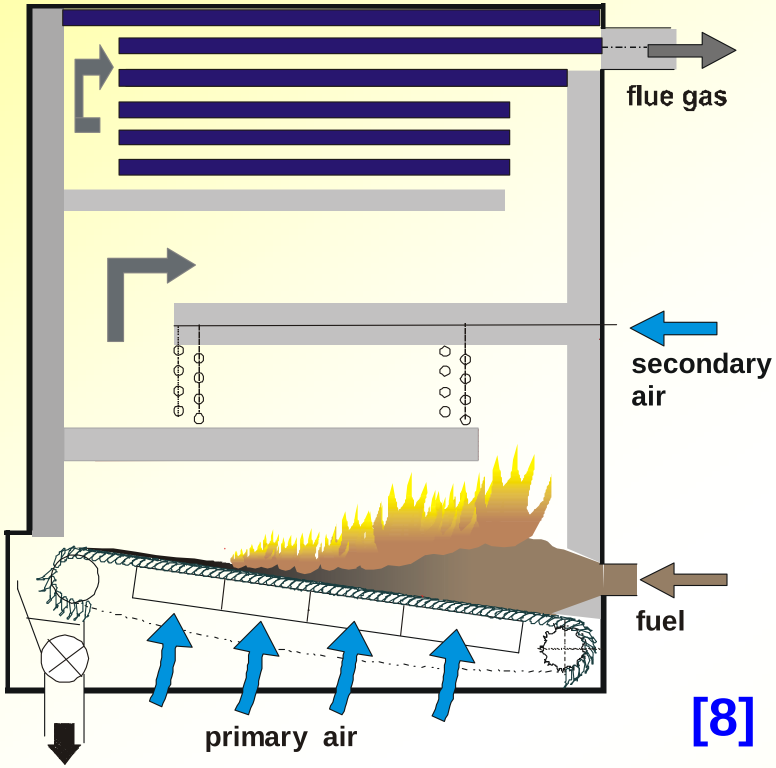
Horizontally moving grates



[7]

- The completely horizontal fuel bed is achieved by the diagonal positioning of the grate bars.
- This technology impedes uncontrolled gravity induced fuel movements.
- Increases stoking effect of the grate movements.
- Leading to a very homogenous distribution of material on the grate surface.
- A further advantage is that the overall height can be reduced.

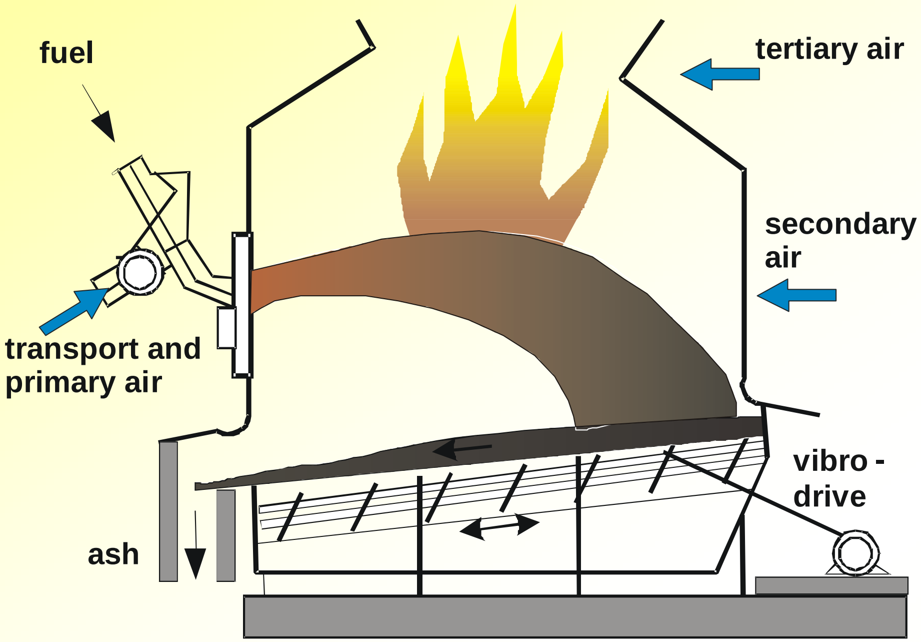
Travelling grates



[8]

- Consist of grate bars mounted on an endless belt.
- The fuel bed itself does not move but is transported by the grate.
- At the end of the combustion chamber the grate is cleaned of ash while the belt turns around.
- Advantages are the uniform combustion conditions due the uniform bed and the easy maintenance or replacement of grate bars.
- In comparison to moving grate furnaces there is a longer burn-out time and a higher primary air input.

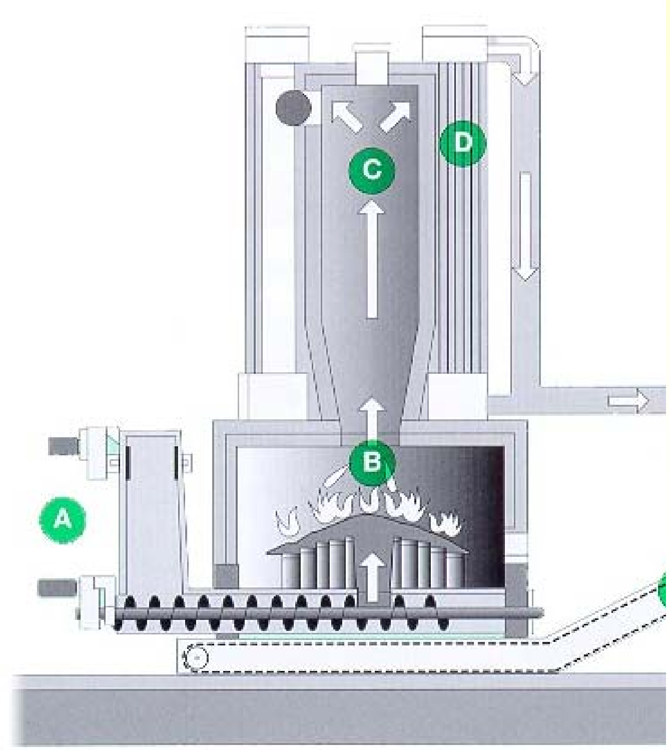
Vibrating grates



[9]

- Furnaces consist of a declined finned tube wall placed on springs.
- Two ore more vibrators transport fuel and ash towards the ash removal unit.
- Primary air is fed through holes located in the ribs of finned tube walls.
- The formation of slag is inhibited due the vibrating movement. Thus this technology is especially applied with fuels showing sintering or slagging tendencies (e.g. waste wood).
- Disadvantages are the high fly-ash emissions cause by the vibrations and the higher CO emissions.

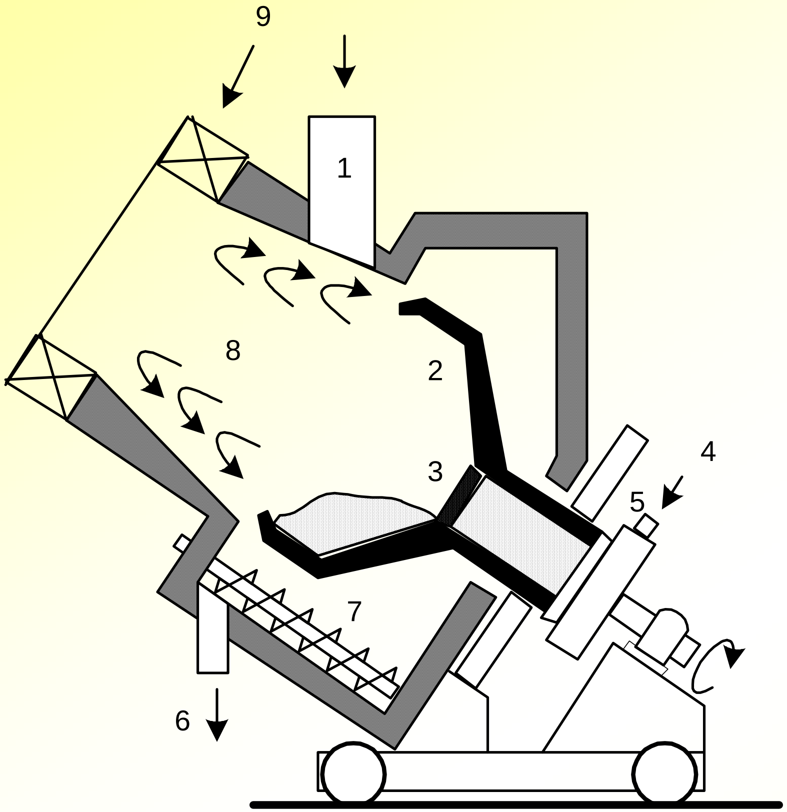
Underfeed rotating grate



[10]

- Makes use of conical grate sections that rotate in opposite directions and are supplied with primary air from below.
- As a result wet burning fuels are well mixed, which makes the system adequate for burning very wet fuels.
- Capable of burning mixtures of solid wood fuels and biological sludge.
- The fuel is feed to the grate from below by screw conveyors.
- The combustible gases formed are burned out with secondary air in a separate horizontal or vertical combustion chamber .

Rotating cone furnaces



[10]

Explanations: 1...fuel feed, 2...rotating grate, 3...bottom of the cone, 4...primary air, 5...air control, 6...ash disposal, 7...ash screw conveyor, 8...burn out zone, 9...secondary air

- Basically consist of a slowly rotating inverted conical grate.
- Primary air enters the grate through the bars in the fuel covered bottom part of the cone shaped grate.
- Secondary air is fed tangentially and at high speed into the cylindrical secondary combustion chamber.
- One weak point is the limited experience with the utilisation off different biomass fuels.

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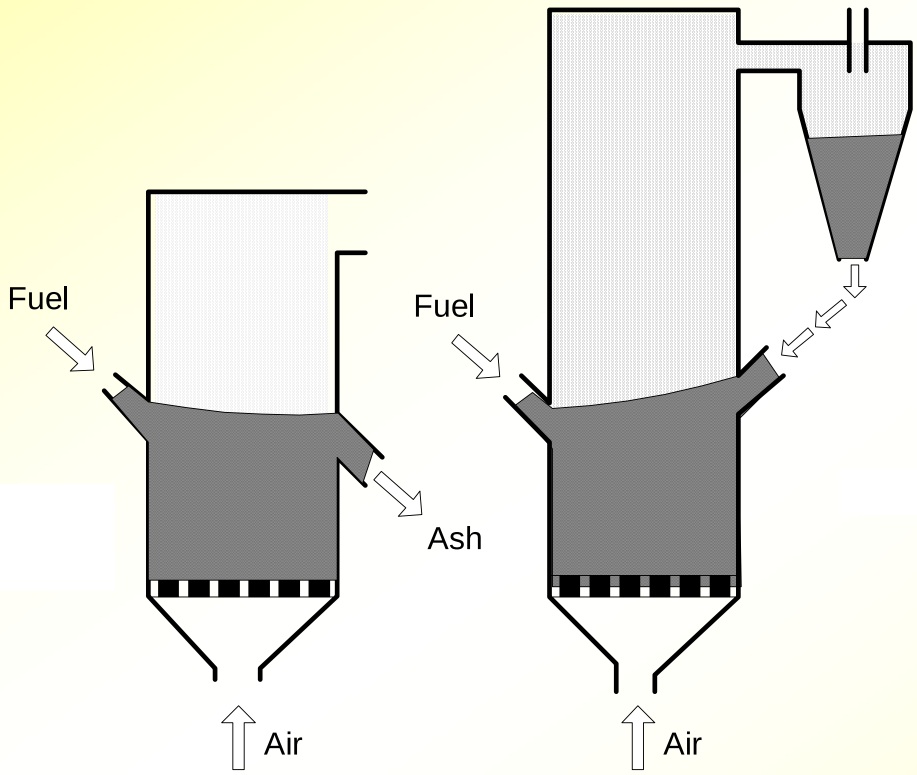
Fluidised bed combustion (I)

Bubbling fluidised beds (BFB) and circulating fluidised beds (CFB) have to be distinguished.



bubbling fluidised bed furnace

circulating fluidised bed furnace [9]

- Cylindrical vessel with a perforated bottom plate filled with a suspension bed of hot, inert and granular material.
- Common bed materials are silica sand and dolomite.
- Primary air enters the furnace from below an fluidises the bed .
- fluidisation velocity of the air:
  - BFB: 1.0 to 2.5 m/s
  - CFB: 5.0 to 10.0 m/s

Fluidised bed combustion (II)

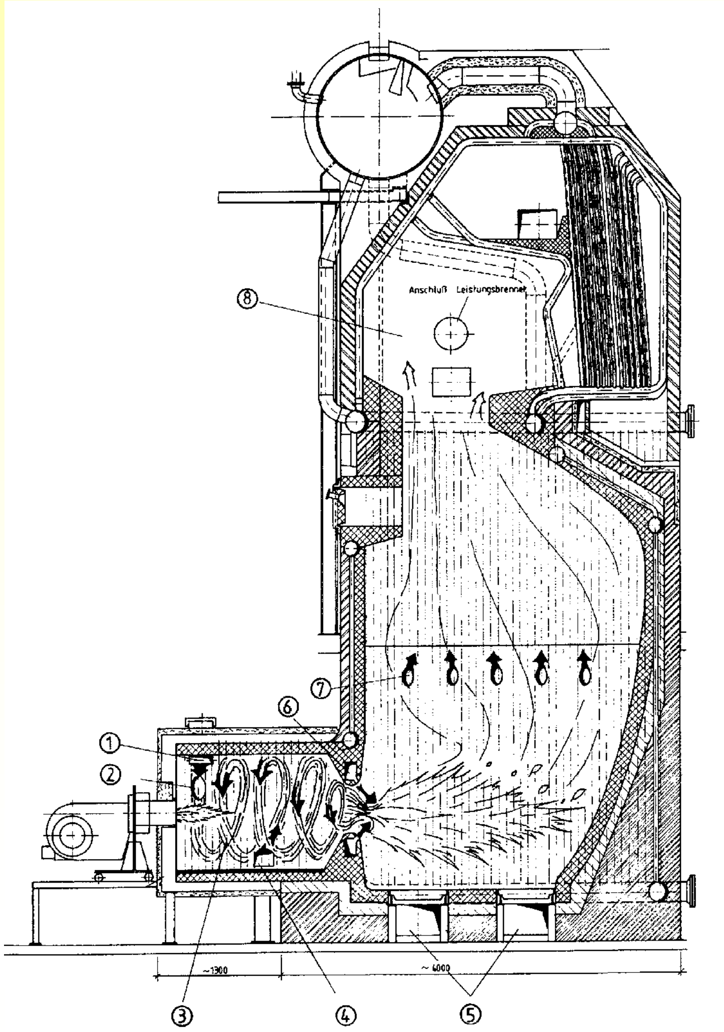
- The intense heat transfer and mixing provide good conditions for a complete combustion with low excess air demand.
- The combustion temperature must be kept low (usually 800-900°C) in order to prevent ash sintering in the bed.
  - Internal heat exchanger surfaces
  - Flue gas recirculation
  - Water injection
- Flexibly with different fuel mixtures but limited when it comes to fuel particle size and impurities contained in the fuel.
- An appropriate fuel pre-treatment system covering particle size and separation of metals is necessary.

Dust Combustion systems (I)

- Fuels like saw dust and fine shavings are pneumatically (usually tangentially) injected into the furnace.
- Fuel quality needs to be constant (maximum particle size of 10-20 mm, fuel moisture content should not exceed 20 wt%)
- Start up of the furnace is achieved by an auxiliary burner.
- Fuel gasification and charcoal combustion take place at the same time because of small particle size.
- Therefore, quick load changes and efficient load control can be achieved.
- Beside muffle furnaces, cyclone burners for wood dust are also in use.

Dust Combustion systems (II)

Muffle furnace in combination with a water-tube steam boiler [9]



- A disadvantage is that insulation bricks wear out quickly due to thermal stress and erosion
- Thus also other dust combustion systems are built without rotational flow, where dust injection is conducted without a swirl.

Explanations; 1...primary air supply, 2...fuel feed, 3...gasification and partial combustion, 4...flue gas recirculation, 5...ash disposal, 6...secondary air supply, 7...tertiary air supply, 8...water tube boiler

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Summary of combustion technologies (I)

Technology	Typical size range	Fuels	Ash content	Moisture content
wood stoves	2 kW - 10 kW	dry wood logs	< 2%	5 - 20%
log wood boilers	5 kW - 100 kW	log wood, sticky wood residues	< 2%	5 - 30%
pellet stoves and boilers	2 kW - 200 kW	wood pellets	< 2%	8 - 10%
underfeed stoker furnaces	20 kW - 6.0 MW	wood chips, wood residues	< 2%	5 - 50%
moving grate furnaces	500 kW - 50 MW	all wood fuels and most biomass	< 10%	5 - 60%
underfeed stoker with rotating grate	2 MW - 5 MW	wood chips, high water content	< 10%	30 - 65%
dust combustor, or cyclone furnaces	1 MW - 10 MW	various biomass, (dP< 5 mm)	< 2%	< 20%
bubbling fluidised bed	20 MW - 50 MW	various biomass, (dP<80mm)	< 10%	5 - 60%
circulating fluidised bed	30 MW - 100 MW	various biomass, (dP<40mm)	< 10%	5 - 60%

Summary of combustion technologies (II)

Advantages	Disadvantages
underfeed stokers	
• low investment costs for plants < 6 MWth • simple and good load control due to continuous fuel feeding • low emissions at partial load operation due to good fuel dosing	• suitable only for biofuels with low ash content and high ash melting point (wood fuels) • low flexibility concerning particle size
moving grate furnaces	
• low investment costs for plants < 15 MWth • low operating costs • low dust load in the flue gas • less sensitive to slagging than fluidised bed furnaces • many options in terms of fuel particle size and moisture content	• no mixing of wood fuels and herbaceous fuels possible • efficient NOx reduction requires special technologies • high excess oxygen decreases efficiency • combustion conditions not as homogeneous as in fluidised bed furnaces • low emission level at partial load operation is difficult to achieve

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Summary of combustion technologies (III)

Advantages	Disadvantages

dust combustion

Advantages

- low excess oxygen (4 - 6 vol%) is possible which increases efficiency
- high NOx reduction by efficient air staging and mixing possible if cyclone or vortex burners are used
- very good load control and fast load changes possible

Disadvantages

- particle size of biofuel is limited (< 10-20 mm)
- high wear of the insulation brickwork if cyclone or vortex burners are used
- an extra start-up burner is necessary

BFB furnaces

Advantages

- no moving parts in the hot combustion chamber
- NOx reduction by air staging works well
- high flexibility concerning moisture content and type of biomass fuels used
- low excess oxygen (3 - 4 vol%) which raises efficiency and decreases flue gas volume

Disadvantages

- high investment costs, interesting only for plants > 20 MWth
- high operating costs
- low flexibility with regard to particle size (< 80 mm)
- high dust load in the flue gas
- operation at partial load requires special technology
- medium sensitivity concerning ash slagging
- loss of bed material with the ash
- medium erosion of heat exchanger tubes in the fluidised bed

Summary of combustion technologies (IV)

Advantages	Disadvantages

CFB furnaces

Advantages

- no moving parts in the hot combustion chamber
- NOx reduction by air staging works well
- high flexibility concerning moisture content and type of biomass fuels used
- homogeneous combustion conditions in the furnace if several fuel injectors are used
- high specific heat transfer capacity due to high turbulence
- use of additives easy
- very low excess oxygen (1 - 2 vol%) raises efficiency and decreases flue gas flow

Disadvantages

- high investment costs, interesting only for plants > 30 MW(th)
- high operating costs
- low flexibility with regard to particle size (< 40 mm)
- high dust load in the flue gas
- partial-load operation requires a second bed
- loss of bed material with the ash
- high sensitivity concerning ash slagging
- medium erosion of heat exchanger tubes in the furnace

Thank you
for your attention

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