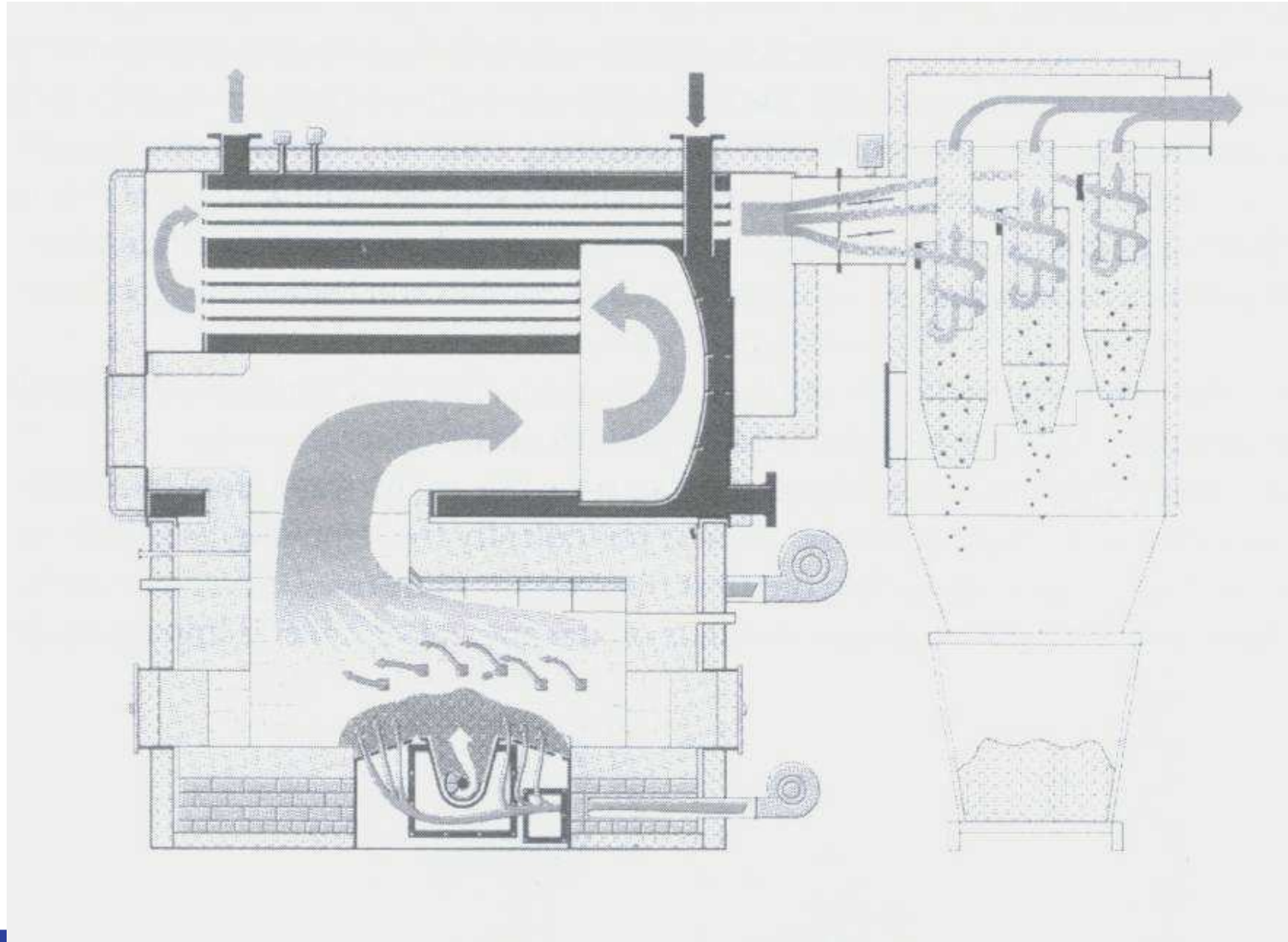
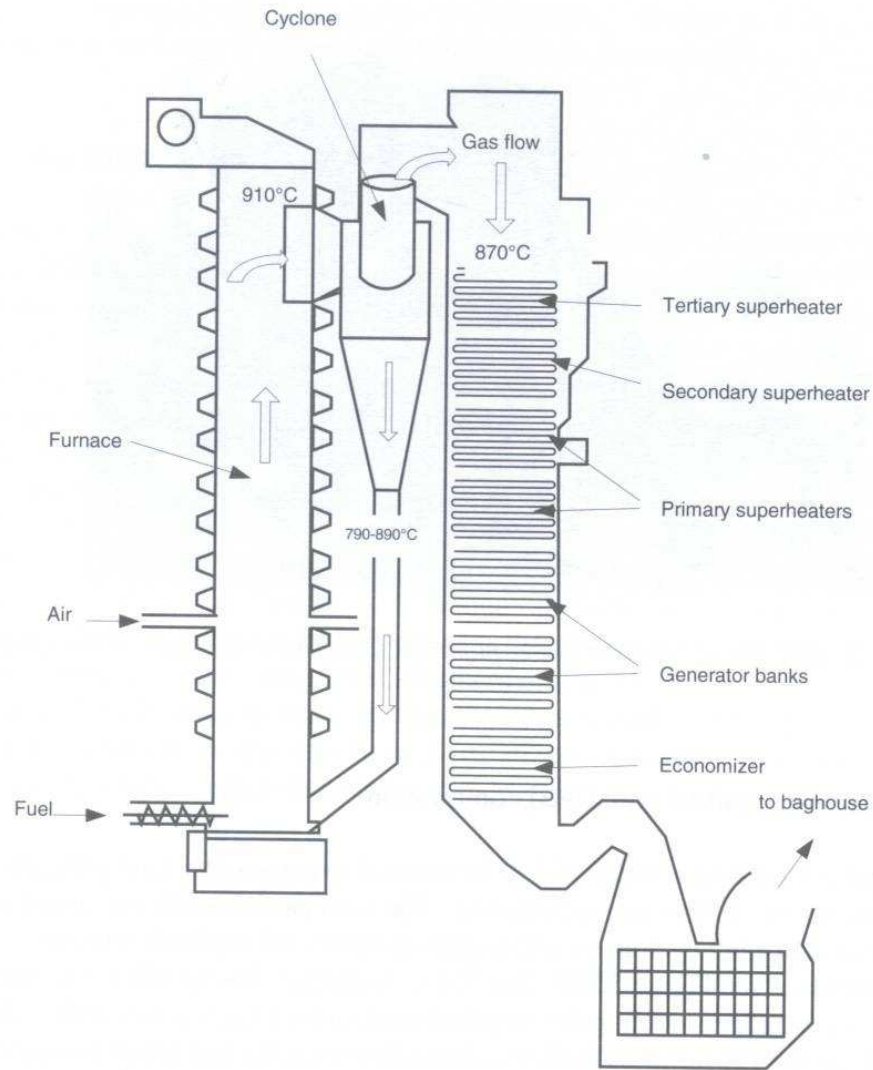

Biomass ash deposition, erosion and corrosion processes.

W R Livingston
IEA Task 32/Thermalnet Workshop
Glasgow
September 2006

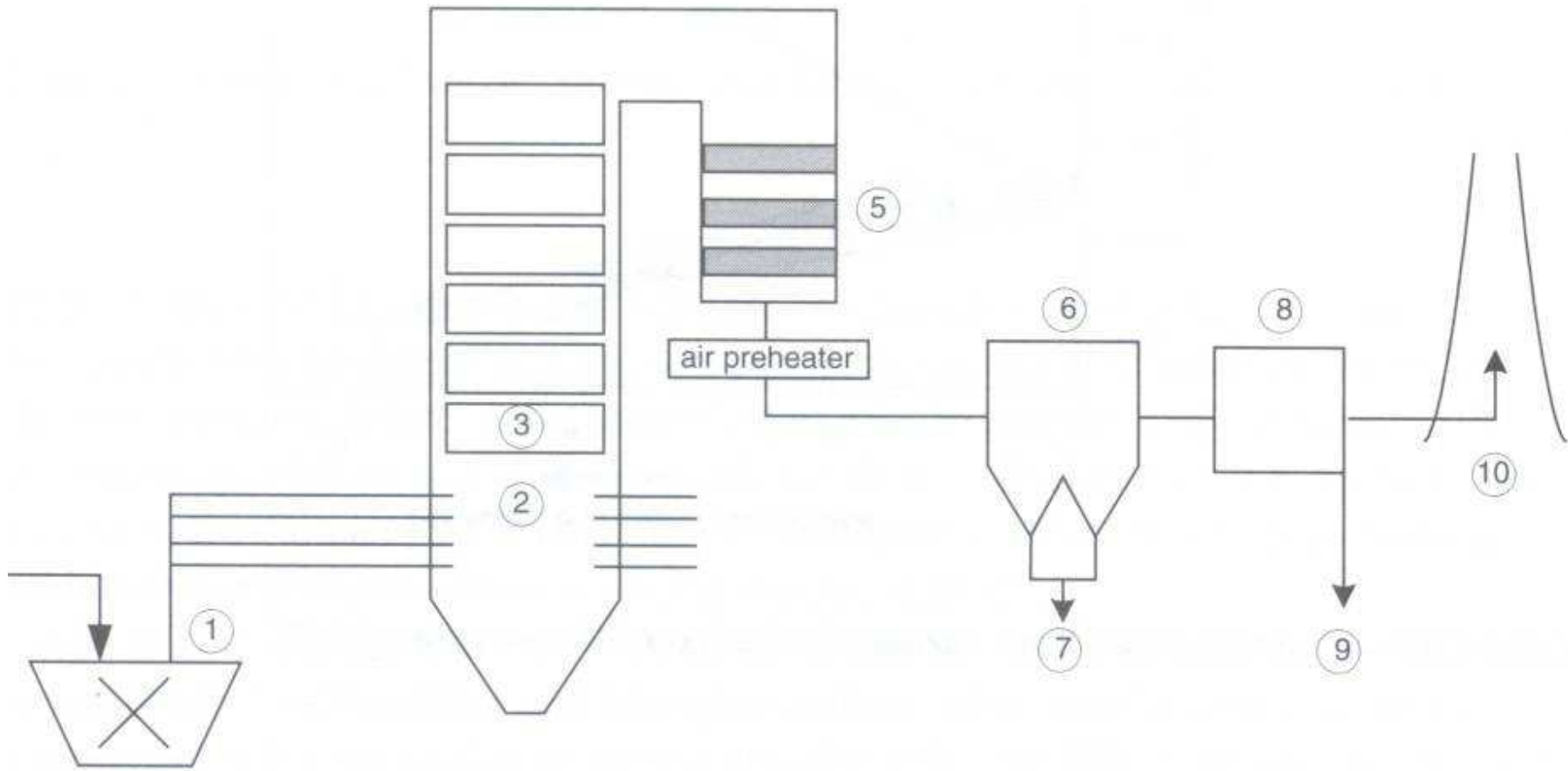
Stoker-fired boiler



Circulating fluidised bed boiler



Pulverised fuel boiler



Furnace slag formation

- The **partial fusion and agglomeration of ash particles** in the fuel beds of stoker-fired and fluidised bed-fired combustion equipment, can lead to poor combustion conditions, de-fluidisation of fluidised beds, and problems with ash removal and downstream ash handling equipment,
- The deposition of ash materials on **burner component and divergent quartz** surfaces in large pulverised fuel furnaces can result in interference with burner light-up, operation and performance,
- The deposition of fused or partially-fused ash deposits on **furnace heat exchange surfaces** reduces furnace heat absorption, and leads to increased gas temperatures both within the furnace and at the furnace exit.
- **Excessive furnace deposition** can lead to increased ash deposition and high metal temperatures in the convective sections of boilers, and it may be necessary to reduce load or to come off load for manual cleaning.
- The **accumulation and subsequent shedding of large ash deposits** on upper furnace surfaces can lead to damage to grates and to furnace ash hoppers, and to the defluidisation of bubbling fluidised beds.

Boiler fouling

- The formation of **fouling deposits** on the surfaces of superheater, reheater and evaporator banks occurs at flue gas temperatures less than around 1000°C,
- This is a much slower process than slag formation, with ash deposits growing over a number of days.
- Convective section fouling is one of the most troublesome biomass ash-related problems, because of the relatively high alkali metal content, and hence the high fouling potential.
- Fouling reduces the heat absorption in the convective banks, and results in increased flue gas temperatures.
- Increased fouling also increases the gas-side pressure drop across the banks, and can eventually lead to ash bridging between the tubes.
- Ash deposits on economiser surfaces at low flue gas temperatures tend to be relatively weakly bonded.

Slag formation mechanisms

- **Ash particle inertial impaction** is the dominant process in high temperature slag formation, and for larger ash particles. The rate of deposition by impaction is a function of the particle flux, and of the deposition efficiency.
- The **condensation of volatile inorganic species**, in vapour or fume form in the flue gases, on cooled surfaces, is of particular importance for biomass materials because of the relatively high levels of volatile species in these fuels,
- **Chemical reactions** occurring within the deposits, and particularly oxidation, sulphation and chlorination processes.
- **Thermophoresis**, the transport of small, gas borne, ash particles to cooled surfaces by the effects of the local gas temperature gradients, is only important for very small, sub-micron particles and particularly during deposit initiation.

Convective section fouling

- Convective section ash fouling is largely driven by the deposition of **volatile inorganic species** in the ashes, principally the alkali metals, and in some cases phosphorus compounds, by a volatilisation-condensation mechanism.
- The volatile species will condense on any cooled surface, initiating deposit growth and acting as a bond between the non-volatile, non-fused ash particles which adhere to the deposits.
- On deposition, there is also a tendency for the alkali metal compounds and other inorganic species to **sulphate**, a reaction with the sulphur oxides in the flue gases, which can add significantly to the mass and volume of the deposits.
- The **physical properties of the ash deposits** depend largely on the ash chemistry and on the flue gas temperature at the deposition site.
- **On-line cleaning techniques** tend to be relatively ineffective if the deposition is extensive and, off-line, the deposits cool to a hard dense solid, which can be very difficult to remove.
- The deposits formed on boiler surfaces in contact with flue gases at **lower temperatures**, i.e. below about 600-700°C, depending on the chemistry, tend to be relatively weakly bonded. They are more friable in nature and are usually easier to remove both on and off-line.

Deposit shedding mechanisms

- The principal means of on-line control of deposition is the use of the **installed sootblowers**. These devices direct a high velocity jet of steam, water or compressed air at the deposits, and employ a combination of mechanical impact and thermal shock to break up and remove the deposits.
- The deposit material removed in this way may be carried forward with the flue gases, but can also accumulate elsewhere in the furnace or in the convective pass of the boiler.
- The **natural shedding or detachment of deposits** also occurs. This can occur when deposits grow too large for the adhesive forces to support them, or due to the effect of thermal expansion differences between the ash deposit and the boiler tube, during shutdowns and boiler load changes.
- The **detachment of large accumulations of slag** can result in damage to components or in troublesome accumulations of ash lower in the furnace.
- **Heavily fused** deposits of low viscosity can drip on to surfaces lower down in the furnace or boiler.
- In the boiler convective section, **fly ash particle impact erosion wear** can result in the reduction of the thickness of fouling deposits, particularly on the sides of tubes.

The control of ash deposition

- The **careful design of the furnace and boiler convective section**, which recognises properly the characteristics and behaviour of the fuel ash, is of prime importance. The incorporation of specific furnace and boiler design features to minimise ash deposition, and to aid the removal of ash and the avoidance of ash accumulation.
- The correct design, operation and maintenance of the **combustion equipment and of the on-line cleaning systems** are important issues.
- **Intensive cleaning** of the furnace and boiler surfaces during outages can be very effective in increasing the operating times between outages.
- There are **specialised on-line deposition monitoring and sootblowing control systems** that are commercially available and that can assist significantly with the optimisation of the sootblower operations and the control of ash deposition.

Biomass ash erosion

- Particle impact erosive wear processes are associated with hard ash particles,
- The erosion rate is a function of the erosive particle flux and the velocity, viz:

$$\text{Erosion Rate} = kmv^{2.5}$$

- Biomass materials generally have much lower ash contents than conventional solid fuels,
- Biomass ashes, in general, tend to be less erosive in nature than most solid fuels – lower quartz and pyrite levels,
- The only exceptions are high quartz ashes, e.g. rice husks, which can be erosive in nature.

Boiler tube corrosion factors

- The tube material – higher chrome alloys are more resistant.
- High flue gas and metal temperatures - generally superheater outlet elements are at high risk.
- The chemical composition of the ash deposit material at the metal-deposit interface. High alkali metal and chloride contents are undesirable.
- The chemical composition of the flue gases - high chloride contents are undesirable.
- The operating regime of the plant – large numbers of start-ups and shutdowns are undesirable.

Conclusions

- Ash deposition and boiler tube corrosion processes are key issues in the design and operation of biomass combustors and boilers.
- In the main, biomass materials and their ashes tend to be less erosive and abrasive than more conventional solid fuels.
- The key to avoidance of serious deposition and corrosion in biomass combustion plant is in the design phase. It can be very difficult to compensate for poor design after the plant is built.
- The designer of the combustion equipment and boiler plant must have the appropriate fuel assessment and design tools.