Biomass ash

- 9:10 **Opening and welcome**,
  Sjaak van Loo, IEA Bioenergy Task 32 and ThermalNet Combnet

- 9:20 **Overview of biomass ash characteristics**
  Thermalnet WP2D
  Bill Livingston, Mitsui Babcock, UK

- 9:50 **Ash related problems when cofiring biomass with coal in PF burners,**
  Rob Korbee, ECN, Netherlands

- 10:10 **Characterisation of CTF Deposits from coal-biomass combustion.**
  Fraser Wigley, Imperial College, UK

- 10:45 **Coffee break**

Workshop programme

- 11:00 **Biomass ash deposition and corrosion processes**, Bill Livingston, Mitsui Babcock, UK
- 11:20 **Ash related problems in wood fired boilers and effect of additives,** Håkan Kassman, Vattenfall Power Consultant AB,
- 11:40 **Experience with ash deposition in poultry litter boilers** David Bowie, Mitsui Babcock, UK
- 12:00 **Experiences with wood/sludge cofiring in Sweden** Claes Tullin, SP, Sweden
- 12:20 **Discussion and conclusions,** Bill Livingston, Mitsui Babcock, UK
- 12:30 Closing

Biomass ash characteristics and behaviour in combustion systems

W R Livingston

IEA Task 32/Thermalnet Workshop

Glasgow

September 2006

MitsuiBabcock

Introduction
Thermalnet WP2D

- A key deliverable of WP2D is a review report on the current ‘state of the art’ on the characteristics of biomass ash materials and their impact on the design, performance and integrity of combustion, gasification and pyrolysis process.
- The combustion and gasification sections are now available in Draft form for comment.
- The documents will be placed on the Thermalnet website after this meeting.

Agricultural products	Forestry products	Domestic and municipal wastes	Energy crops
Harvesting residues	**Harvesting residues**	**Domestic/industrial**	**Wood**
Straws Corn stalks	Forestry residues	MSW/RDF Scrap tyres Wood wastes Sewage sludges	Willow/ Poplar Cottonwood
Processing residues	**Primary process residues**	**Urban green wastes**	**Grasses etc.**
Rice husks Sugarcane bagasse Olive/palm oil residues Fruuit residues	Bark Sawdusts Offcuts	Leaves Grass and hedge cuttings	Switch grass Reed canary grass Miscanthus
Animal wastes	**Secondary process wastes**		
Poultry litter Tallow Meat/bone meal	Sawdusts Offcuts		

Biomass ash fractions

- The **inherent inorganic material**, exists as part of the organic structure of the fuel, and is most commonly associated with the oxygen, sulphur and nitrogen-containing functional groups.
- Inorganic species can also be present in very fine particulate form within the organic structure of some of the fuels, and to behave essentially as an inherent component of the fuel.
- The **extraneous inorganic material,** which has been added to the fuel through geological processes, or during harvesting, handling and processing of the fuel.
- Biomass fuels are commonly contaminated with soil and other materials, which have become mixed with the fuel during collection, handling and storage.

Class 1 - water soluble			
	Compound	**Formula**	**Share of total element (%)**
Na, K	Nitrates and chlorides	Na,KNO_3, Na,KCl	>90
Ca, Mg	Nitrates, chlorides, phosphates	$Ca,Mg(NO_3)2$ $Ca,MgCl_2$ $CaMg_3(PO_4)_2$	20-90
S, P, Cl	Sulphate, phosphate and chloride ions	SO_4, PO_4, Cl	>80
Class 2 - organically associated			
Ca, Mg	macromolecules		0-35
Fe	Organic complexes		>80
S, P	Sulpholipids, amijno and nucleic acids, proteins		Variable
Class 3 precipitated as pure compounds			
Ca	Calcium oxalate	$CaC_2O_4.nH_2O$	30-90
Si	Phytolite	$SiO_2.nH_2O$	variable

Biomass	Forestry residue	SRC willow	Cereal straw	Oil seed rape straw	Olive residue	Palm kernel	Poultry litter
Ash (%)	2	2	5	5	7	4	13
Analysis (mg kg^{-1})							
Al	-	-	50	50	1,500	750	600
Ca	5,000	5,000	4,000	15,000	6,000	3,000	20,000
Fe	-	100	100	100	900	2,500	900
K	2,000	3,000	10,000	10,000	23,000	3,000	5,000
Mg	800	500	700	700	2,000	3,000	5,000
Na	200	-	500	500	100	200	3,000
P	500	800	1,000	1,000	1,500	7,000	14,000
Si	3,000	-	10,000	1,000	5,000	3,000	9,000

General types of biomass ashes

- High silica/high potassium/low calcium ashes, with low fusion temperatures, including many agricultural residues,
- Low silica/low potassium/high calcium ashes, with high fusion temperatures, including most woody materials, and
- High calcium/high phosphorus ashes, with low fusion temperatures, including most manures, poultry litters and animal wastes.

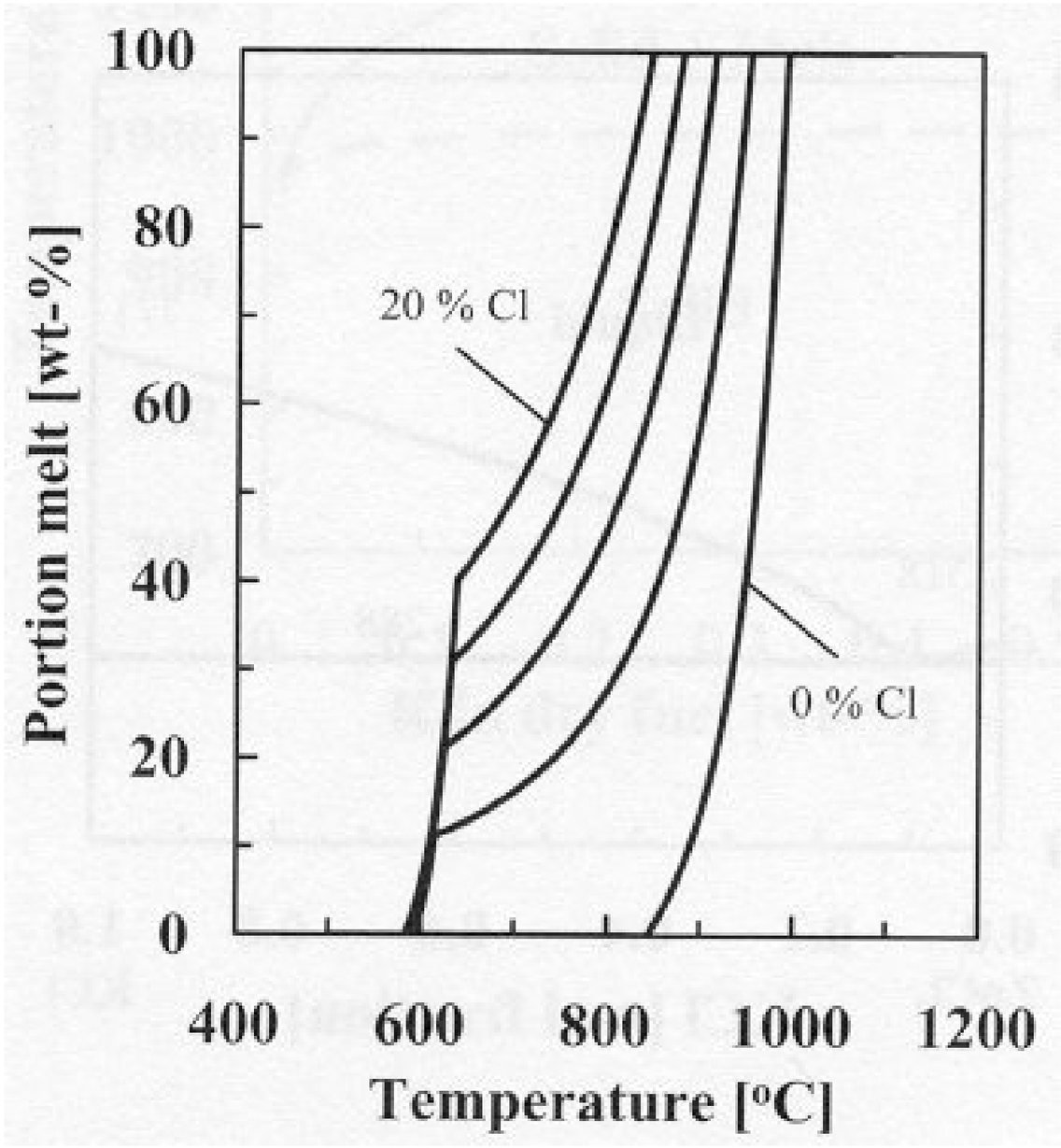
The most important ash-related issues in biomass combustors and boilers

- The formation of fused or partly-fused agglomerates and slag deposits at high temperatures within furnaces and stoves,
- The formation of bonded ash deposits and accumulations of ash materials at lower temperatures on surfaces in the convective sections of boilers,
- The accelerated metal wastage of furnace and boiler components due to gas-side corrosion under ash deposits, and due ash particle impact erosion or ash abrasion of boiler components and other equipment,
- The formation and emission of sub-micron aerosols and fumes,
- Biomass ash impacts on the performance of flue gas cleaning equipment, and
- The handling and the utilisation/disposal of ash residues from biomass combustion plants, and of the mixed ash residues from the co-firing of biomass in coal-fired boilers.

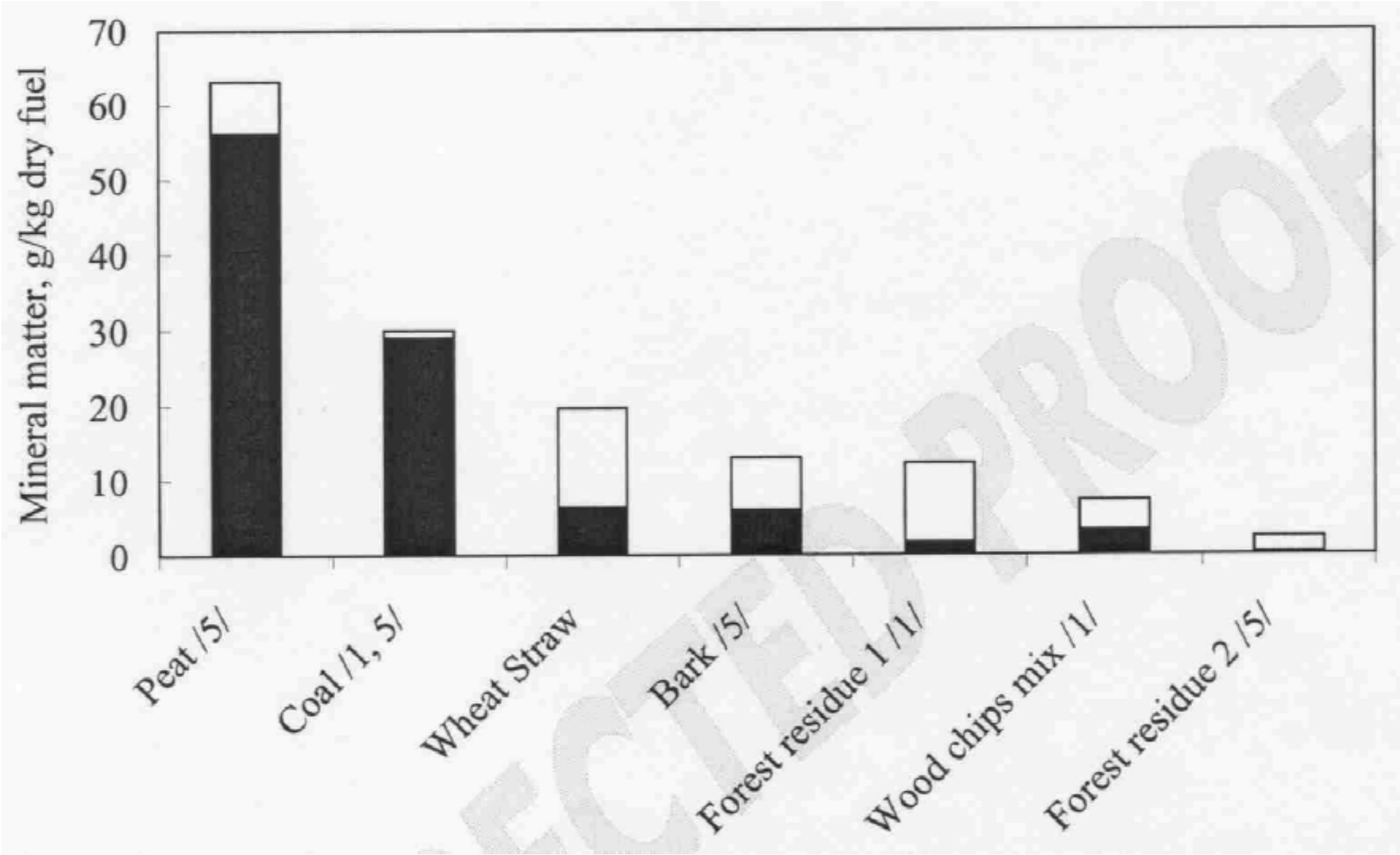
Biomass ash characterisation techniques

- Chemical analysis – S and Cl contents and the major and trace elements,
- Ash fusion tests Melting curves and Ash Fusion Test Equilibrium Phase Diagrams
- Slagging and Fouling Indices – ranking methods based on the chemical analysis and Ash Fusion Test data.
- Chemical fractionation techniques – water, buffer and acid solutions.
- Mineralogical and microscopic techniques using both optical and electron microscopy.

An example of a melting curve for alkali metal salt mixtures



Summary data from chemical fractionation tests



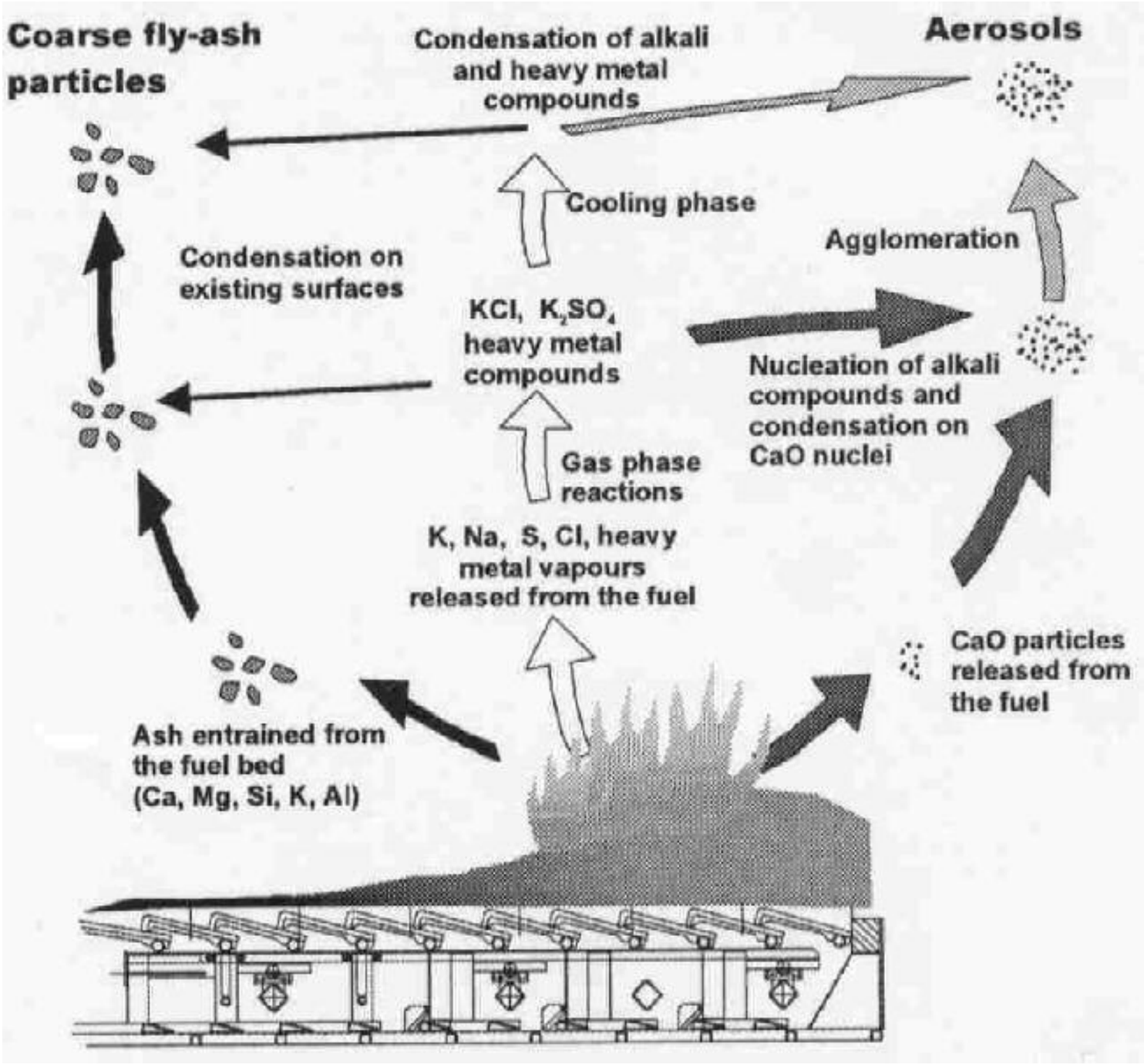
The key biomass mineral transformations in flames

- The fusion or partial fusion of quartz and silica particles and, at high temperatures, interactions to form alkali and alkaline eath metal silicates,
- The fusion or partial fusion of alumino-silicates,
- The decomposition of carbonates, oxalates, chlorides, etc. and other inorganic salts,
- The volatilisation of alkali metals and some heavy metals,
- Particle fragmentation by thermal shock and the rapid release of gaseous species from particles, and
- The coalescence of intra-particle mineral particles.

Principal types of biomass combustor

- **Grate combustors** are generally employed for the small and medium sized industrial/commercial applications,
- **Fluidised bed combustors**, of the bubbling bed and circulating types, are commonly employed for the medium to large industrial/commercial and utility applications,
- **Pulverised fuel combustors**, which are employed for large industrial and utility applications, i.e. for the co-firing of biomass materials in large coal-fired boilers, and for 100% biomass firing (relatively rare).

A schematic diagram of biomass ash behaviour on a grate



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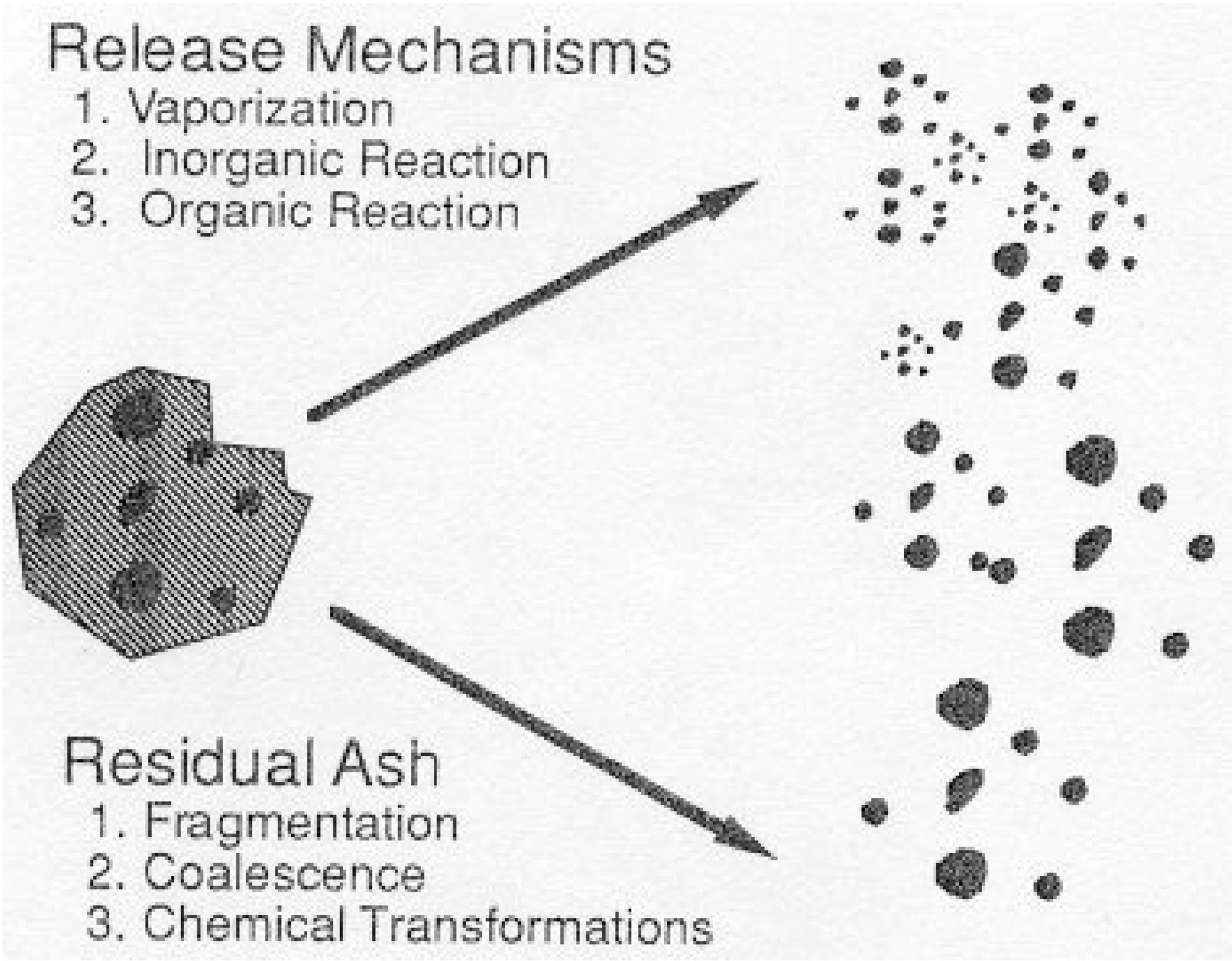
The fate of biomass ash material during combustion processes.



Conclusions

- The mineral and other inorganic components of biomass materials are very different chemically, mineralogically and microstructurally from those of the more conventional solid fuels
- There has been significant R&D and other technical work on these subjects, and there is increasing industrial experience with biomass processing and co-processing with more conventional fuels.
- The industrial experience is principally with combustion and co-combustion systems, but also with gasification and pyrolysis processes.
- Many of the process problems in operating biomass plants have been ash-related.
- The ash characterisation and testing methods are largely in place and the processes are reasonably well understood.
- There are, however, still significant ash-related design and operational problems at industrial scale.