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SUWIC Innovations in Thermal Waste to Energy Technologies

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Sustainable cities require the generation of electrical energy from those fractions of wastes that cannot be economically reused or recycled, including the 'carbon dioxide neutral' biomass components. The energy content of these solid materials can be recovered by burning directly or after processing into refuse-derived fuel (RDF). Alternatively, the combustion process can be staged by the production of intermediate fuels using either pyrolysis or gasification. Co-processing of the material with coal generally increases plant utilisation and thus reduces costs.

The design, operation and maintenance of waste combustion, pyrolysis or gasification plants requires detailed understanding of the processes occurring within a reacting packed bed of solids, or combustion of the derived liquids or gaseous fuels. Both of the latter can be modelled using well-established computational fluid dynamic codes (CFD). Previously, there has not been available a validated, comprehensive and fundamentally based code for mathematically modelling the combustion/pyrolysis/gasification process within a packed bed of solid particles on a stationary or moving grate. Bearing in mind that pyrolysis and gasification are sub-sets of combustion we have developed a generalised model of bed combustion. This code, known as FLIC, solves iteratively the flow field within a reacting bed of randomly packed particles, including radiant heat transfer. The equations governing the processes of drying, pyrolysis, de-volatilisation and char burnout within the waste particles are evaluated. Since the burning of volatiles and CO in the channels is mixing limited, flame reactions also occur in the gas phase above the bed. The conditions evaluated at the surface of the bed are the boundary conditions of conventional CFD modelling of the mixing and reactions in the secondary combustion zone in the freeboard above the bed and in the gas clean-up system. This permits the evaluation and minimization of emissions such CO, VOCs, NOx, heavy metals and dioxins. In fact, dioxins from incinerators now only contribute 3% of the total UK dioxin emissions.

Pyrolysis of waste can generate a storable char fuel. This is achieved by heating a bed of the material slowly in a closed container to about 500°C from which air is excluded. This decomposes the organic material to release liquid products that can be condensed then purified and burned to efficiently generate heat and power. The carbon char remaining is a valuable fuel that can be easily separated whilst it is still hot from any inert material that was originally present. The char from pyrolysis contains much of the original carbon and has a high-energy content.

The validation of our reacting bed modelling code (FLIC) has been achieved by measurements in a pot burner using various wastes and biomass materials. Additionally, a small 'ball instrument' that has been specifically developed to contain instruments has complemented these measurements by withstanding temperatures up to 1000°C for well over an hour. This novel device passes through industrial moving grate furnaces with the waste and records parameters such as oxygen concentration, vibration and several temperatures onto a computer memory chip. The ball is recovered from the ash pit and the information is downloaded onto an Excel spreadsheet for detailed analysis and verification of the FLIC predictions.

Our new gasification concept offers the prospect of achieving the goal of high efficiency power generation from char or coal by utilizing ultra superheated steam (USS). The method uses low-grade steam from sources such as process cooling, waste incineration and local industry, and then enhances it to a temperature above 1600°C. This is achieved by adding oxygen to the steam to form "artificial air"; gas is then burned in this artificial air to produce an ultra-superheated steam flame. Char, biomass or powdered coal are injected coaxially into the high temperature steam flame where they react in about a second to produce a gas that is free of tar and consists largely of CO, H_2 and CH_4. Significantly, the high temperature steam provides the enthalpy for the endothermic gasification reactions. This feature ensures that tar formation is avoided and any ash is cooled below its melting point before it arrives at the reactor walls. This process provides a route to the future hydrogen fuel based economy.

These innovative waste to energy technologies form part of an integrated urban sustainability program.