Biomass: energy remedy or safety headache?

Retrofitting coal-fired powerplants to use biomass can bring its own hazards, says **Michael Merritt**

AS we look at alternative solid fuel options to supplant our dwindling fossil fuel reserves and in an attempt to limit our net carbon footprint, biomass is a word that has become increasingly prevalent in everyday life, whether in the media, at the local waste tip, on the 18-wheeler you just passed or even in plans to erect a biomass boiler in your town. But from a fire and explosion hazard perspective, is biomass really an issue? It's just recycled waste or wood, right? How can it be any worse than the coal that has been burned in these systems for decades?

The truth is that commonly-used solid biomass fuels lead to a whole range of problems not encountered with coal. These include problems that can arise in storage, handling and transport, to say nothing of the differences in fire and explosion hazards. All in all, there is a substantial learning curve to negotiate for the unwary who simply want to broaden their fuel options.

There is a diverse range of biomass types used globally. It can take the form of pelletised wood or chips; household waste; compost; biogas; and even dried sewage sludge.

In the UK and Europe, where the Dangerous Substances and Explosive Atmospheres (DSEAR – UK) and Atmosphères Explosives (ATEX – most other EU countries) regulations apply, the most common form of biomass used for the generation of electricity in power plants is wood based, sometimes as woodchips or mulch but more commonly in pelletised form.

Some power plants are designed and built exclusively for biomass whereas others are converted from coal to biomass and some even co-fired. The cost implications of designing and building a plant from scratch is often financially prohibitive, so the conversion route is often seen to be the most viable alternative. This is very much the case in the UK where there is an abundance of ageing coal-fired plants that cannot operate due to stringent emissions regulations. However, the physical differences between biomass and coal are often missed in the planning stages of these conversions, ie how the biomass behaves when it is transported and in storage and, most importantly, the implications of these behaviours from a fire and explosion hazard perspective.

pros and cons

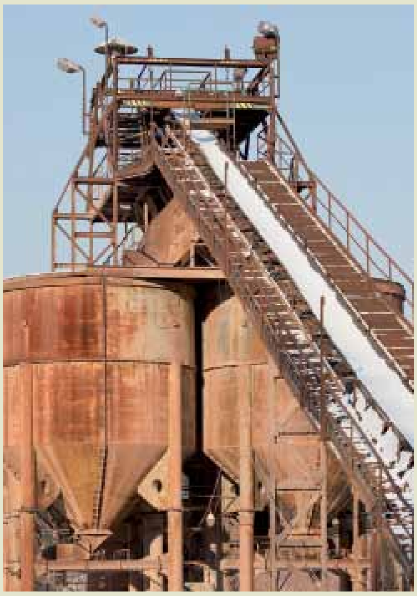
Whilst coal is (obviously) combustible and can form flammable dust clouds when finely divided, there is much evidence to support the fact that coal, even as dust, is not particularly sensitive to ignition. Not least, historical evidence includes very few incidents relating to fires and explosions associated with coal dust at coal fired power stations. Furthermore, coal is not readily friable, meaning the formation of fines, one of the key factors in creating a dust explosion, does not easily occur during typical handling operations.

Having visited a number of coal handling facilities it is clear that the ignition insensitivity of coal is widely recognised. It is not uncommon to find significant dust deposits on electrical motor casings, as well as in, and around, mechanical equipment such as belt conveyor rollers and bucket elevator boot voids. The concern is that the same mind-set may be adopted for biomass handling. After all, it's only recycled wood; surely it can't be any worse than coal?

One of the biggest differences between biomass and coal is how it behaves in contact with water. Coal stockpiles are usually left outside completely exposed to the elements until required. Although the overall moisture content may increase, coal is not particularly absorbent and this will not be detrimental to the material's physical characteristics as a fuel. Excess moisture will tend to be driven off during preparatory processing such as pneumatic conveying and milling. However, external storage of pelletised biomass is not feasible as the pellets will readily absorb water, causing swelling and deformation; ultimately rendering the fuel unusable. In fact, pellets are proven to absorb and retain moisture so effectively it serves as a pretty good cat litter material. Wetted biomass, if left for several days, also brings the issue of mould growth and spore production which presents a bio-hazard to personnel.

So to protect the seemingly perishable biomass from water it is usually stored within flatbed sheds or large bespoke silos.

how a flammable atmosphere can form



A company looking to use an existing coal handling conveyor system for pelletised biomass. The part process involved a sub-level bulk receiving hopper of approximately 1000 m^3 into which rail carts would discharge 80,000 kg of pellets. A vibratory feeder was used to regulate the flow of pellets from the base of the hopper onto a 75 m long belt conveyor. The hazardous area classification for the plant, when it was handling coal, did not identify any potential flammable atmospheres either within the hopper or at the exit point, and the area was considered non-hazardous from a fire and explosion viewpoint. A trial was carried out using a 10,000 kg batch of biomass; the purpose of which was to ensure the existing equipment would do what it was supposed to for the new type of fuel. After only a few seconds of operation a dust cloud was observed leading out of the vibratory feeder which soon enlarged, engulfing the head of the conveyor and being entrained in the moving biomass on the conveyor, extending several metres horizontally.

This not only highlighted the increased potential of a flammable atmosphere being created where there was once none, but the implications that lead from this meant that the equipment present was not suitable for the now hazardous zone which was necessary in this area. Equipment rated for use in hazardous areas is inherently more expensive than equivalent un-rated equipment. Having identified one (highly visible) requirement for suitably-rated equipment, where else in the plant would this also be needed and what would the associated costs be?

The introduction of walls and a roof brings new issues relating to:

- perpetual handling of very dry material – making attritional fines generation more likely and yielding a more ignition sensitive and severely explosive dust (increasing moisture content reduces ignition sensitivity and explosion severity);
- accumulation of increasing levels of fines due to the absence of natural ventilation afforded by external, unconfined storage; and
- confinement of any dust cloud with ignition giving rise to a confined explosion rather than an unconfined flash fire.

Take for example, a 200,000 t shipment of pellets. This volume will comprise conservatively, of 0.01 % by weight of naturally-occurring fines (ie particle size < 500 µm); this equates to a total mass of 20 t of potentially flammable dust. For a lower explosive concentration typically in the range of 100 g/m^3, this equates to a potential flammable cloud volume of 200,000 m^3. This value is conservative and doesn't take into consideration fine dust generated by attrition caused by normal handling of the biomass which may have occurred during

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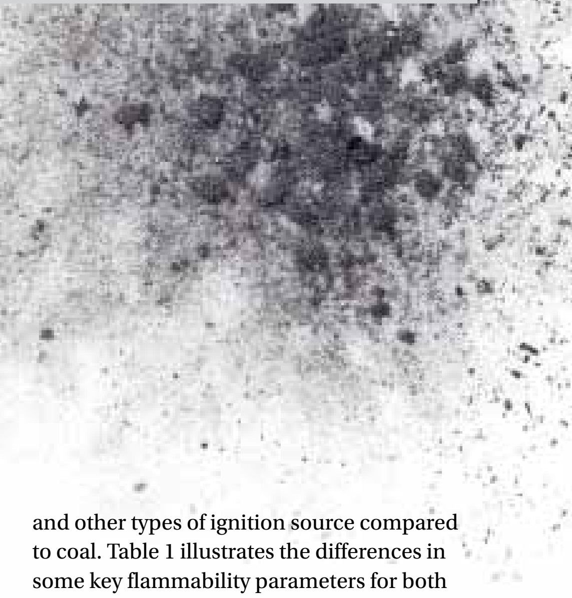

Classification of data	Ignition sensitivity			Explosion severity
Test parameters	*Layer ignition temperature (LIT) °C*	*Minimum ignition temperature (MIT) °C*	*Minimum ignition energy (MIE) mJ*	20 l sphere Pmax Kst (St class) bar g bar m/s
Coal dust (< 63 μm)	>400	670	>1000	7.0 81 (St 1)
Wood dust (< 63 μm)	330	420	50-60	8.2 161 (St 1)
Sewage sludge (dried < 63μm)	280	460	100–500	7.6 143 (St 1)

Table 1: Flammability properties for dusts (Source: Industrial Explosion Hazard Laboratory at Chilworth Technology)

shipment to the power station or during transfer. Clearly, these fines will be blended with the pellets and so you wouldn't expect to see this portion as a standalone bulk. However, the fines are known to concentrate in certain circumstances during handling, usually when the biomass is free falling, for example, from one conveyor to another or as it is dropped at height from a tripper conveyor. Where sufficient concentration of fines occurs there is an increased risk of a flammable atmosphere being formed.

This example shown in box 1 illustrates a biomass dust cloud being formed during handling. Other situations during handling where potential flammable dust clouds are generated would be during off-loading into the storage shed or storage silo. Often silos can be protected from the effects of an explosion by fitting explosion relief panels or suppression systems. Sheds however, are a different matter and require a thorough investigation into the potential of a flammable atmosphere forming, identification of all potential sources of ignition to include but not be limited to electrical equipment and mechanical equipment (ie front shovel loaders) and the formation of robust mitigation measures. After all, personnel are often present in these areas and in following with the hierarchical 'Three Rules of ATEX' approach: 1. do not have a flammable atmosphere, but if you do, 2. do not ignite it, but if you do, 3. do not hurt anyone. Obey any one of the rules and you are complying with the legislation.

There are, of course, options to minimise the formation of flammable atmospheres, including dry fogging (atomised water) to help limit fugitive dust emissions and forced ventilation. The applicability of these should be investigated, as each will have advantages and disadvantages depending on their application.

So clearly biomass is more likely to form a dust cloud during handling compared to coal. But is it any easier to ignite than coal? The reality is that laboratory testing has shown biomass to have a higher sensitivity to ignition from electrostatic discharges and other types of ignition source compared to coal. Table 1 illustrates the differences in some key flammability parameters for both fuels.

Variants of coal and biomass are likely to yield different results but generally speaking, the data obtained from testing of biomass over a relatively long term showed that biomass has a higher sensitivity to ignition from both hot surfaces and electrostatic spark discharges and also is of higher explosion severity potential compared with that of coal. It should also be noted that each type of biomass exhibits different explosion ignition sensitivity and explosion severity. Data for wood dust will not be consistent. Different types of wood (and other potential biomass feed stocks) have variable properties which must be assessed on a case-by-case basis.

self-heating and localised-fire risks

The risk from fire or explosion from the dispersed fines is just one issue which requires due consideration. Another potential risk is thermal oxidation (smouldering) of the stockpiled biomass leading to fire or explosion. Self-heating can occur within the heaped material if left for prolonged periods. It's the same principle as a compost heap, only on a much larger scale. The issue with self-heating leading to a localised fire is that the burning rate properties of wood are far worse than that of coal and hence the speed at which fire spreads in the material is much faster. The incident on 27 February at RWE Tilbury in the UK demonstrated just how easily fire can spread if not detected and quenched at a very early stage. The fire started in a store containing 4,000 t of wood pellets and one stage involved over 120 fire fighters. The RWE investigation report stated that a number of contributing factors were the cause of the fire. It is understood that a small localised smouldering nest likely generated from self-heating of stockpiled biomass was fed increased levels of oxygen when neighbouring hoppers were moved, resulting in the fire.

Critical ignition temperatures

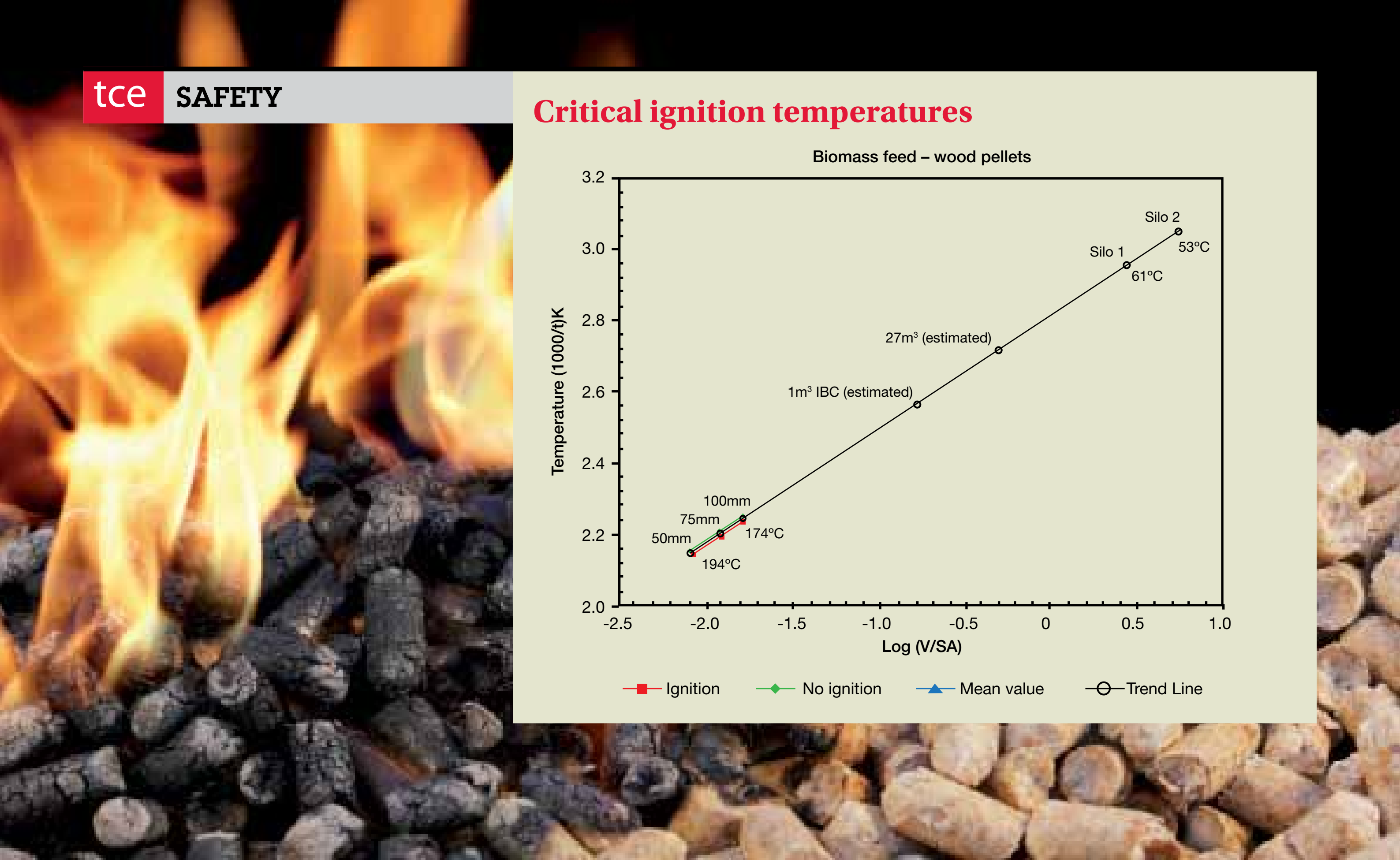

Figure 1: the critical ignition temperatures for a wood pellet extrapolated from small-scale basket testing to large-scale bulk storage silo conditions.

fires and explosions at biomass handling facilities:

May 2007 – large explosion at Sittard, the Netherlands, at a biomass facility that produces fuel from plants and other organic matter.

17 August 17 2009 – a fire at Biomass One, US, that started in pile of sawdust that was heated in the Florida sunshine.

October 2010 – a woodchip dust explosion at Pinksdrev, Belarus killed three workers.

The vast size of biomass storage facilities has a profound impact on the potential initiation temperature of self-heating events. Figure 1 depicts the critical ignition temperatures for a wood pellet extrapolated from small-scale basket testing to large-scale bulk storage silo conditions. As can be seen, critical ignition temperatures can approach ambient temperatures at large scales – rendering the threat of self-ignition ever present.

Conversion of a coal-fired power station to that of 100% biomass or co-fired is not a simple transposition of safety matters. The new risks which come with handling and storing biomass need to be identified at the design stage of the project so as to capture and manage the risk realistically and effectively. Identifying risks from fire and explosions after the plant has been commissioned will prove costly in both time and money – and even lives.

The legacy of coal handling must not be adopted when moving to biomass handling. Biomass poses a much greater risk of flammable atmosphere formation, in areas where none existed when handling coal, and these risk areas must be identified by suitable means long before the commissioning stage. In any case, a review of the hazardous area classification must be performed. Often, the increase in frequency of flammable atmospheres will mean that existing equipment will need to be either replaced or demonstrated as being suitable by way of suitable risk assessment.

There are options available to minimise the formation of flammable atmospheres although these should be systematically reviewed on a case-by-case basis to demonstrate that they will be effective in the environmental conditions in which they will operate.

The principle of biomass conversions are an energy remedy and provided that the risks are assessed at an early stage, suitable fire and explosion prevention measures can be specified, implemented and managed effectively for the lifetime of the plant. With such foresight, there is no reason why DSEAR/ATEX compliance should become a headache. tce

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