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Best Practice Guide for Handling of Biomass Fuels and Coal - Biomass Mixes

Wolfson Centre for Bulk Solids Handling Technology
University of Greenwich

SCHOOL OF ENGINEERING

UNIVERSITY of GREENWICH

The Wolfson Centre for Bulk Solids Handling Technology

Providing cost-effective solutions to industry's problems

Best Practice Guide for Handling of Biomass Fuels and Coal-Biomass Mixes

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BEST PRACTICE GUIDE
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1. INTRODUCTION

This report arises as a direct output of project B69 of the British Coal Utilisation Research Association (BCURA), a project which set out to look at identifying and resolving common problems of fuel handling in co-firing of coal and biomass, however the findings are equally applicable to handling of biomass alone. The study involved the participation of E.ON in collating power industry co-firing experiences gained over the period from about 1999 to 2007, as well as extensive characterisation and handling trials at The Wolfson Centre. The resulting document is intended as a guide for engineers, maintenance personnel, managers and procurement executives with responsibility for obtaining and operating equipment for handling of biomass either alone or mixed with coal, in solid-fuel-fired power stations.

Handling of biomass as well as coal/biomass mixes in existing and new power plants brings with it many issues that need to be addressed technically. There is a very rapid development of biomass capability especially within UK and Europe. It is expected that biomass co-firing and mono-firing will continue to expand in the immediate future, although this will depend on many factors such as government policies, availability of suitable biomass, capital investment in biomass co-firing capabilities and power generation efficiency.

This guide aims at addressing the identified major issues and then recommending best practice for handling of biomass (both with coal for co-firing, and alone) in solid fuel fired power plants, which can be useful to personnel, engineers on plant and for wider research purposes in existing or new co-firing installations. When handling biomass the major issues that were identified were of varied handling properties, moisture content affecting handling, and dust generation. The extent of all these being problems varies from biomass to biomass depending on the particle size and nature of the material. Regarding dust emissions, some biomass have large amounts of fines

hence can generate a considerable amount of dust emission themselves; however they also increase the propensity of the coal to emit dust when mixed together.

As far as existing systems are concerned most of the coal fired power plants that are co-firing biomass with coal are using a direct co-firing method in which the biomass material is mixed with the coal by co-milling or pre-mixing process at a suitable stage within the power plants. For a new system greater changes can be brought about which will help in better handling of biomass with the knowledge that has been generated from co-firing experiences as well as handling measurements. This guide looks at best practice for existing handling systems as well as new systems. There are fundamentals that are common to both hence they are dealt with first before going into dedicated sections for each of the two cases individually.

2. COMMON ISSUES FOR EXISTING AND NEW SYSTEMS

This section deals with issues that are faced commonly by both biomass mono- and co-handling in existing plants, and also in new systems. The best practice recommendations to take care of these issues are common to both situations, hence they are dealt with at the beginning of the guide.

2.1. Issues of dust emission and control

Greatly increased dust emissions and difficulty in control are issues faced by many power plants handling biomass and coal/biomass mixes. Dust levels and spillage during material handling have been found to be an issue with fuels such as cereal co products (CCP) and milled palm nuts (MPN) in co-firing coal power plants in the UK. The dusting tendencies of different biomass fuels, and even nominally the same fuel from different sources, has been found to be very different. Established standards for biomass fuels tend to be wide in this regard. Increased dust emissions can be generated due to variations in moisture level of the biomass being handled, also due to sub-optimal operating conditions within the plant, e.g. open access points, poor conveyor belt discharge trajectories. Dust is particularly an issue while handling biomasses that have large amounts of fines in them, such as CCP (normal samples can contain up to 30% fines, or even more), sunflower pellets and MPN. Additionally the biomass absorbs moisture from the coal in the case of co-milling or pre-blending co-firing processes, which causes the coal surface to lose moisture and hence become

dry. This situation causes more coal dust to be generated than when the power plant handles coal alone, in addition to the biomass dust.

2.2. Best practice for dust emission and control

The main areas for dust emissions with a co-firing or co-milling plant are transfer points and towers. Minimising airborne dust settlement and avoiding a build up of dust are important for two reasons, first to protect the health of workers from the inhalation hazards of dust and spores, and secondly to prevent devastating "secondary explosions" which can occur if a small fire or localised dust explosion brings down a residue of settled dust. The key features that are to be designed or incorporated to accommodate co-handling or mono-handling of a range of biomass and to deal with this dust issue are as follows:-

- **Fitting dust containment systems to all open chutes. Checking whether existing dust containment installations are in place and are working. Also open drops of material should be eliminated and the stream of material should be enclosed completely wherever possible.**
- **Consider fitting dust extraction systems to open conveyor transfer points where complete enclosure is not possible, especially those conveying pure biomass fuels. This will help prevent dust levels going up in places like the shuttle conveyors where dust levels are usually high due to residual biomass being left on the belt. It is important to understand that the quantity of air that needs to be collected to prevent dust escape, is a direct function of the openings in the enclosure, so extraction must not be used as a replacement for enclosure, but in combination. The better the enclosure, the less costly the extraction system will be to buy and run, and the more effective it will be.**
- **Use of optimised transfer chute geometry in transfer points can help reduce dust emission by minimising impact zones. Ideally, properly optimised "hood and spoon" geometry should be employed in new system designs.**
- **Dust level monitors at high dust generation areas can give information that will pave the way for dust control and prevention of dust explosions.**

- **Dust suppression with water mists or sprays is not usually acceptable for biomass materials. Experience shows the sprays are too difficult to maintain in a workable condition, and finish up adding too much water (leading to moulding and flow problems) but still not suppressing the dust emissions.**

- **Reports have been received that in one case, foam dust suppression systems have been used with success, although the level of satisfaction has not been verified. Foam has the great advantage of using very much less water than misting or fogging, by one or two orders of magnitude; this greatly reduces the danger of moisture uptake, caking and mould formation by comparison, so it has some promise in theory. However if contemplating using this technology, apart from testing its effectiveness in suppressing dust, it would be necessary to check that (a) the water addition level is sufficiently low, (b) that there is no opportunity for moisture to collect in any adjacent areas, (c) the cost of operating the system including the foaming agent, (d) reliability of the foam-making equipment and (e) any possible effect of the foaming agent in combustion and ash quality.**

- **Wet cleaning is not recommended for biomass dust spillage. Biomass absorbs the moisture provided to it, which causes it to go mouldy. This makes it adhere, promoting further build-up, but it also causes emission of spores which are hazardous to health leading to "farmer's lung". Caked lumps begin to break up and cause blockages if they get back into the handling system. If wet material gets back into the system, under a load it will begin to cake causing flow problems in bunkers, chutes etc. After caking if the material stays in that condition for long duration of time if will lead to mould formation.**

- **The transfer points and towers should be kept free of rain ingress. They must also be sealed against draughts; the transport of dust through the internal environment is principally driven by internal draughts, so keeping these to a minimum will reduce the spread of dust from any areas of emission.**

- **Internal cleaning of transfer towers should be made as easy as possible by eliminating ledges. The purlins of the cladding could be covered with a thin internal cladding and as much as possible of the structure put behind this internal cladding. Exposed beams and the flat tops of equipment boxes can be fitted with dust shedders (angled plates or "tents") to prevent dust from settling on them. This is a simple and low cost measure which has proved very effective in other industries.**
- **Access points to conveyors, chutes and different parts of the plant should be closed properly after access by personnel, since this will help prevent spillage and reduce dust levels at these points. Also they must have hatches that seal shut.**
- **In situations where flow of material needs to be diverted one way or another, use a diverter arrangement that is enclosed, with an internal moving flap and not a moveable chute because the latter is impossible to seal properly for dust containment.**
- **Dust extraction can be considered in a required amount to ensure an inflow of air where there are unavoidable openings. If the enclosure is good, this will not need to be a large air extraction volume.**
- **Regular dry cleaning procedures for dust accumulations, when build up occurs, are recommended. A centralised vacuum cleaning system in transfer towers could offer value for money in speeding up cleaning and reducing labour.**
- **Workers undertaking cleaning or any other work in transfer towers or dust-contaminated areas must be made aware that biomass dust is more hazardous than coal dust, and must use appropriate personal protective equipment. Experience shows that the quality and ease of use of the PPE makes a big difference to its up-take. Manual tasks in particular, such as cleaning, are difficult wearing face-fitting dust masks and goggles; this leads to poor productivity, low morale and increased likelihood of accidents, whereas a good quality ventilated helmet or air-fed mask makes life much easier.**

- **Floor and work platforms should be kept as open grids to prevent dust accumulation, but ensure the ground floor is fully enclosed and sealed to the ground, and access doors have automatic closers that are not prevented from operating.**
- **Adequate measures must be put in place to protect against dust explosion. Many biomass dusts are more sensitive to ignition than coal dust, and with their greater tendency to travel and deposit through the workplace this leads to an increased risk. Additionally, the need to use much more effective enclosure gives rise to new explosion risks, not just because the enclosures themselves have the potential to bust under explosion pressure but also because they can add to the danger of explosions being conducted from one part of the plant to another. Thorough risk assessments must be carried out by the plant owner in accordance with DSEAR regulations. The quality of these risk assessments is paramount; accurate assessments will lead to sensible decisions on ATEX zones, avoiding excessive costs in buying overrated equipment. More guidance on this can be obtained through SHAPA[1].**

3. ISSUES TO ADDRESS IN EXISTING SYSTEMS

3.1. Common handling problems

Existing systems are those coal-fired power plants that handle and co-fire a variety of biomass such as saw dust, CCP, MPN, Olive pellets, Short Rotation Coppice (SRC) etc. in the pre-existing coal handling systems in different mix ratios. In the UK currently there are 18 coal-fired power plants that handle "biomass" as classified by Department of Business Enterprise and Regulatory Reform (BERR). Some of the common issues faced by such plants are as following:-

- **Arching in bunkers – This is an issue in existing bulk solids industry when storing biomass or coal/biomass fuel mixes for a long time. Arching can be of two basic categories, mechanical and cohesive arching. Mechanical arching occurs due to interlocking of particles that are large in comparison to the hopper outlet (such as wood chips, especially from demolition or waste wood).**

[1] Solids Handling And Processing Association, www.shapa.co.uk

Mechanical arching is rare in power plant bunkers owing to the large size of the equipment relative to the particles being handled. Cohesive arching occurs as a result of the strength acquired by the bulk solid through consolidation during storage. This varies from biomass to biomass; some are susceptible to consolidation as soon as they stand still, and some susceptible to "time consolidation" or "caking" leading to growth of strength with time in static residence.

- **Biohazards for personnel – Mould growth occurs in biomass and coal/ biomass mixes when it is supplied with high percentages of moisture and the humid environment, which is often found in long-term storage in core flow bunkers. Moisture transfer from the coal increases moisture content of the biomass in the mix that in turn causes intense mould growth. Coal/biomass mixes or biomass alone that absorb moisture either cake forming an agglomerate or ferment allowing spore concentrations to grow on the material and generate toxins, which are potentially harmful for inhalation for plant personnel. Some work has already been carried out in identifications of such toxins in industry for grain dust, which is endotoxin (HSE, 2007). Occupational exposure to airborne endotoxins causes short-term illness and may also contribute to serious long-term illness. At present there are no occupational exposure limits in place for endotoxins (HSE, 2007). The example of grain dust is similar to CCP, MPN, and other biomass dusts, which are being handled in power plants and these also can also develop such toxic spores and hence potential effect on lungs, skin and eyes. "Farmer's lung" (extrinsic allergic alveolitis) is a respiratory disease affecting the lungs caused as a direct result of exposure to agricultural spores produced by microorganisms (moulds) on hay, straw and similar farm produce. Many of the commonly handled biomass fuels incorporate these materials so if the dust is allowed to become mouldy and then becomes airborne, workers are at risk. Short term asthmas attacks may result, and repeated exposure can lead to long term chronic debilitating loss of lung function.**

- **Slip hazards - There is also a slip hazard involved when trying to wash down the biomass fines because it absorbs much moisture during wet washing, and ultimately becomes slippery on floors.**

- **Storage (long term) – Typically, to be stable, biomass materials require to be handled below a certain limiting moisture content. This is typically 14% for materials which have been studied, but there may be different levels for other materials that have not been part of this study. In particular, granular biomass materials which are in the pelletised or bulk form which have moisture in excess of 15% to 20% wet basis is problematic due to rapid loss of structure (e.g. pellet breakdown) and rapid biological activity which can lead to heating of the storage pile, loss of dry matter, and a significant deterioration in the physical quality of the fuel (Van Loo** *et al*, **2008). Also experimental works carried out in this project have indicated that caking of coal/biomass mixes occur within bunkers due to high moisture content (transferred from the coal) and compaction loads. The strength of these moulds that form inside the bunkers vary with co-firing ratios and moisture content but can be high enough to cause severe flow problems in bunkers.**

- **Milling biomass issues – Mills in traditional pulverised coal fired boilers are usually capable for producing coal particle top size of around 300μm. When biomass is feed into the same mills they are generally more difficult to grind than coal mainly due to their fibrous and elastic nature. Experience from world over has shown issues, when initial test trials were carried out at different mills in power plants. An important study was carried out in Australia was reported by Van Loo** *et al* **(2008), the aim of which was to gain fundamental insight into milling behaviour of coal/biomass blends for co-firing operations. It was found that the introduction of biomass increased the mill power by as much as 20 % even at a blending ratio of 5 %, indicating that blending ratios as high as 10% weight may give rise to significant operational problems in vertical spindle mills as stated by Van Loo** *et al* **(2008). Mill safety is an issue with many biomass blends, which require trials according to the biomass type used. Under certain conditions of temperature and heating, accidental fires in mills units are possible as concluded by Moghtaderi (2001).**

3.2. Best practice for existing systems

Some of the potential steps to be taken to minimize or eliminate issues for existing systems which are handling coal, biomass and coal/biomass mixes are the following: -

- **Dry bulk storage – The biomass material must be stored and handled under cover, in enclosed buildings and conveyors. Open belts and stockpiles exposed to UK weather conditions will result in increased moisture content, which will damage the fuel, make it unsuitable for handling, milling and burning, and lead to substantial safety hazards. Covered flat stores work adequately well but operatives working in these need to be protected from dust. Silos are much more efficient, safer, and require far less manning, but are vastly more expensive.**
- **Dust containment – The key principles of dust containment have been discussed in Section 2 above. When adapting an existing coal handling system for co-handling the following steps should be taken:-**
- **Audit dust containment measures**
    - **Check that covers over belts, transfer points etc are serviceable and kept closed. Look for openings in covers, un-covered drops, open chute tops, gaps in containment and expect to take action over these.**
    - **Look for un-sheeted areas on towers where the wind may be blowing through causing windage, steps should be taken to enclosing these.**
    - **Considering localized dust extraction where containment is not possible, remembering that this is more expensive option and any improvement in containment will reduce extraction costs.**
    - **Checking for any wet dust suppression systems and disable them unless they are working effectively and producing a very fine mist using minimum of water.**
    - **Setting in place a routine for checking dust build up and where necessary dry clean up at suitable intervals.**
- **Audit for flow and handling facilities – Check for areas where stagnant material may be retained, for example mill feed bunkers, which operate in core flow. This can be done by commissioning wall friction tests with some samples of candidate blends and hence predicting the flow pattern from the established design charts. In vessels where a core flow pattern is expected, preparation should be made to draw down to empty on a regular basis, at most**

every few days and also to clean it out from time to time, for example by flailing, if material cakes. Finally feeder interface evaluation should be undertaken on the bunkers to check whether they will have increasing capacity.

- **Minimise time in static residence of blended material – This is vital as far as biomass and coal/biomass mixes are concerned. Biomass materials easily absorb moisture from external sources (such as coal in co-firing environments) when being mixed in blenders as well as during transportation on conveyor belts. Plant experience has shown that caking occurs in the bunkers handling coal/biomass mixes and biomass alone if material is allowed to stay inside the bunkers for long time. This can lead to high failure strength depending on the type of biomass that is being handled. By reducing the residence time coal/biomass mixes and biomass, being stored in the bunkers, caking issues can be mitigated. Firstly in the case of biomass pellets it absorbs moisture and forms agglomerates within the bunkers that in turn causes self-heating. This is particularly a problem in core flow bunkers where there is first in- last out flow pattern as shown in Figure 8.1. If in a situation where bunkers don't operate in mass flow, it is important to take their contents down to empty on a regular basis if there is any danger of caking of coal/biomass mixes with in the bunkers. In such situations undertaking caking characterisation of the material will prove beneficial. Also the following issues can be avoided: -**

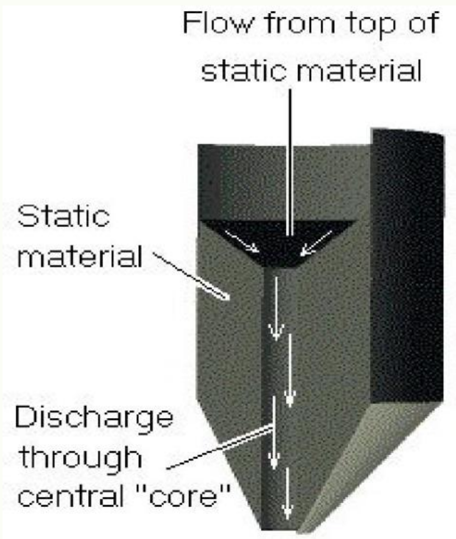

Figure 1. Core flow pattern in a bunker, commonly found in many storage silos and mill feed bunkers etc. which have not been designed to give mass flow

- **Bridging or arching in the bunkers can be avoided by design of the bunker and discharging system to give mass flow (Figure 8.2) as rightly said by Van Loo** *et al* **(2008), but modification of the existing system to mass flow might prove expensive.**
- **Reducing the residence time of coal/biomass mixes also greatly reduces the potential of mould growth occurring in the mixes inside the bunker which in turn reduces chances of harmful spores that could develop inside the mould that could have effect on the health of personnel working on plant.**

- **Feeder interface – Many proprietary designs of feeder use an interface arrangement that gives dead material, which tends to increase stagnant areas and lead to caking and flow issues. Small changes in design detail, however, can make very big improvement as shown below.**
  - **Belt and chain feeders are the usual choice on mill feed bunkers whereas uses of screws are rare. Belt feeders if given a tapered slot outlet it will provide an even feed along the length of the belt allowing movement of material in the hopper in the direction of belt travel which in turn helps reduce belt wear and driving torque. In this manner it also overcomes issues faced with parallel slot outlet and helps avoid dead zones.**
  - **Increasing pitch single screw feeder with increasing diameter shaft will help in uniform drawdown of material from the hoppers with mass flow. This overcomes issues faced by constant pitch screw feeders and graduated pitch screw feeders such as dead zones. But when the number of screws increases per feeder then they have to be designed suitably.**
- **Wall lining to reduce wall friction – Many manufacturers in recent years have been using wall lining for their storage vessels to reduce the wall friction between the walls and the bulk solids to obtain more reliable flow patterns and reduce flow problems. The experience of the Wolfson Centre in its work in designing hoppers and silos commercially, are that they are not always beneficial (Bradley** *et al***, 1999). But this depends on the material and**

circumstances, no one material could be said to be universal in its application. Materials like Tivar 88, which is a type of UHMWPE are potentially the good ones and it has been proved beneficial in industrial experiences (Goldberg *et al*, 1991). But Tivar is susceptible to heating. Stainless steel wall material is usually recommended for use in mill feed bunkers; the finish is critical and should be 2B or better.

- **Flow corrective inserts or static inserts – A bunker experiencing core flow will usually have a central draw down of materials, which are fine and light weight leaving behind coarse and heavier particles near the bin walls to come out last or stick to the walls. This type of flow pattern will cause several types of problems (Johanson *et al*, 1966). Many of the existing installations of bunkers are core flow and replacing them with designed mass flow bunkers is not economical. Flow corrective inserts can some times solve flow problems in such bins (Johanson, 1967). However, the placement and dimensions of the insert within the bunkers is critical for the desired flow pattern to be achieved. The positioning of the structural members to support inserts can increase the flow problems if they are not designed and placed correctly. Much work has been already carried out in this area for designing inserts according to requirements of different bunkers. However, more work is needed to extend the existent knowledge for newer materials and plant handling conditions.**
- **Flailing – where there is problem in core flow bunkers drawing the material down as close as possible to empty on a regular basis is recommended, say every few days, to avoid the on-set of mould formation leading to caking. Once there is any sign of the last material being reluctant to discharge, flailing can be used to get the materials moving. The longer the caked material is left, the harder it is to remove and this in turn leads to an increase in dead inventory.**
- **A hopper that mass flows and handles coal when mixed with biomass will continue to work in mass flow if the mixed material has a low wall friction value. Wall friction value can be measured using Jenike Wall Friction Tester and design charts (Arnold *et al*, 1980) used to assess the adequacy of the bunker design before starting co-firing.**

4. DESIGN FOR NEW SYSTEMS AND EQUIPMENT TO HANDLE COAL/BIOMASS MIXES, AND BIOMASS ALONE

Note: the recommendations in this section are to be applied in addition to the "Common Issues" discussed in section 2

The probability of further co-firing and mono-firing of biomass in UK solid fuel power plant is high for new systems for the immediate future with current legislation in place. Co-firing in new and existing coal fired power plants is expected to occur at least until 2015, whereas mono-firing is anticipated to increase towards and beyond that timescale. In such a situation understanding further possibility for new systems to mono- and co-fire biomass and coal/biomass mixes is vital for wider concerns of meeting the sustainable renewable energy targets.

Obviously for stations designed for mono-firing of biomass, the following guidelines should be considered mandatory. As far as coal-fired power stations are concerned, if there is a provision for a parallel, separate handling and feeding stream all the way from reception to furnace, co-milling and handling of coal/biomass mixes is unlikely. If the station is not designed with this from the outset, recent experiences of the volatility of fuel price and availability, wholesale electric prices and environmental policy shows us that we should expect a wide range of fuel mix possibilities, even if only coal is envisaged at the outset. The wise engineer should therefore design to accommodate this wide range of possibilities no matter what the expectation is at the stage of starting the project. Many of the features needed do not significantly alter the price if designed appropriately from the start, but if left out can cause trouble and expense to retro-fit, maintain and service.

For new systems the following are the points to noted for best practice.

- **Dry bulk storage – The biomass material must be stored and handled under cover, in enclosed buildings and conveyors. Open belts and stockpiles exposed to UK weather conditions will result in increased moisture content, which will damage the fuel, make it unsuitable for handling, milling and burning, and lead to substantial safety hazards. Covered flat stores work adequately well but operatives working in these need to be protected from dust** including mould spores. Silos are much more efficient, safer, and require far less manning, but are vastly more expensive.

- **Fuel stock rotation – Many biomass materials are biologically active to some degree, degrading and becoming harder to handle and more dangerous if stored unused for long periods of weeks or months. For this reason, stockpile management to ensure stock rotation, and silo design to ensure mass flow (below) are essential. As a general rule, the higher the moisture content of the biomass, the more important this issue is.**
- **Bunker design - designing hoppers for mass flow has been thoroughly proven to eliminate issues associated with poor discharge, arching (mechanical and cohesive) and rat holing. Mass flow is a flow pattern that can be made (by careful design) to occur inside bunkers or silos, in which every particle of the bulk solid material moves when some material is taken out of the outlet. In simple words it could be said as 'first in first out' flow. Mass flow is desirable in bins and hoppers for the reliable flow of materials especially if they can go off and cake with time, a common tendency of biomass materials and coal/biomass mixes. There are immense benefits in designing for mass flow as depicted in Figure 2.**

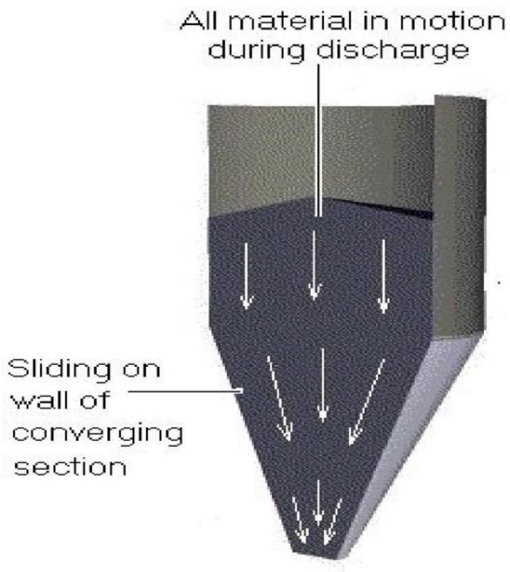

Figure 2. Mass flow pattern in a bunker

Bradley *et al* (2006) enumerated the following benefits of mass flow: -

- **"First in first out" flow pattern gives optimum stock rotation and minimum residence time.**
- **Bulk density of the drawn solid is constant, and practically independent of the head of material in the bin – giving more consistent metering.**
- **There are no dead regions within the bin.**
- **Hang-ups and surging are less likely.**
- **Though materials are segregated when filling into the silo, they are remixed during discharge.**

The disadvantages of mass flow include high wall pressures, wear occurring on bunker walls and, due to the steeper converging section, the height of the bin is relatively taller. In order to obtain mass flow in a bunker it has to be designed according to the characterisation of the potential materials' flow properties (which is discussed below in more detail). For many biomass materials such as pellets, MPN etc. the well established Jenike design method will deliver very reliable mass flow designs, but for those materials which have particles with the potential to "entangle" or "nest", such as chopped straw or miscanthus, saw dust or shredded paper, the Jenike method does not work and new methods of characterisation and design are emerging (Bradley 2009).

- **Feeder interfacing – Opting for a feeder interface that will give even draw down right across the hopper outlet is recommended in the case of biomass and coal/biomass mixes, to avoid caking or spoilage of stagnant material. This can also solve problems arising from segregation further along in the handling chain.**
- **Characterisation of materials – Many biomass materials have been trialled and tested in current coal fired and dedicated biomass power plants all over the world and these have brought up their own set of issues mainly in the areas of dusting, handling, caking, ash content and slagging temperature. Biomass materials depending on their particle size, moisture content, elasticity, and fibrous nature will develop their own individual flow characteristics within**

power plants. Measuring the handling properties of these biomass materials before they are chosen for a co-firing or dedicated biomass power plant will help avoid and mitigate many of the flow issues. This characterisation allows a suitable choice of new handling equipment, but also gives an indication of whether a new biomass fuel will go through the existing handling equipment. Hence these materials undergoing flow property measurements tests to determine their characteristics with respect to wall friction, tensile strength, internal friction, bulk density, segregation, caking, attrition - (degradation), dust emission and mould growth will help selection of a suitable design, also it will help save considerable amount of money in the long term by avoiding problems that power plants commonly face due to poor design at the outset of the plant development and installation.

- **Choose carefully a set of biomass fuels around which to design the handling plant. It is critically important to realise that different biomass materials – or even different grades of the same material – can have very different flow properties and so require different handling solutions which are often not cross-compatible. For example, a plant which has been designed to work with shredded straw will not be able to handle wood pellets, and vice-versa. Even within one material, differences in grade and processing conditions can alter the handling properties enormously; taking "wood chips" for example, chunky material produced by a field chipper will behave quite differently, and need different handling hardware, from fine ground material produced in a hammer mill. It therefore follows that the choice of a handling solution will determine what range of fuels can be fired in future, because experience shows that handling properties actually vary far more than combustion properties, both between different biomass fuels, and within individual species.**
- **Other Storage and preparation issues – Storing of biomass will bring with it issues as discussed earlier and this varies for different biomass.**
    - **Storage trials have to be carried out for individual biomass applications. Considerable amounts of investigation have already been undertaken trying different types of biomass storage in co-firing environments and many conclusions have been reached regarding**

biomass piles, self ignition, ventilation as discussed by Van Loo *et al* **(2008) in his handbook.**

  - **Reduction of moisture content by drying is a potential solution to many issues. Thermal drying using rotary, moving bed or fluidised bed dryers is relatively popular but cost and energy requirements are high. Natural drying is another process that is currently practiced by many countries for reducing the initial moisture content of biomass wood chips. Drying, however, will tend to increase the freedom of the fines to escape from the bulk and also make the particles more susceptible to breakage leading to additional dust formation.**

- **Getting trajectories right at transfer points – will help in reducing the dust emissions caused from biomass fines, less spillage of material and better visibility during operation of the plant. Full "hood and spoon" design of transfer point chutes, undertaken using thorough trajectory modelling, has the potential to lead to significant benefits in reducing the emission of dust from transfer points, but also for reducing the damage to particles the increases their fines content. Note that the hood and spoon need to be adjustable on site to ensure the benefits are optimised.**

- **Design in a high level of containment, and convenience of opening and closing of access points – Access points in different parts of the handling chain especially along transfer points, conveyors, chutes should be easy to access and open and close. This will help in carrying out various activities such as maintenance, measurement of dust levels, understanding of the flow regimes etc. If the access points are convenient to use it will encourage the personnel on plant to keep them closed.**

- **Allow space for retrofit – Because different biomass materials handle very differently, and there is more price volatility of biomass materials compared with coal, there will in the future be pressure on any plant to fire fuels for which the handling equipment is not suitable. If retrofit modifications to transfer points, chutes, feeders and bunkers, to make them suitable for materials not originally envisaged, can be made at moderate cost, then significant economic benefits can be obtained by being able to buy fuels which**

are available at lower cost. Experience shows that one of the main difficulties in retrofit modifications is obtaining the space and headroom to put in alternative equipment alongside the original kit. Allowing generous space in and around structures assists in this regard.

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The document has been verified and endorsed by the Solids Handling and Processing Association and Materials Handling Engineers Association

6. REFERENCES

Arnold PC, McLean AG and Roberts AW, 1980. *Bulk solids: storage, flow and handling.* **2nd Ed, TUNRA Bulk Solids Handling Research Associates, The University of Newcastle, Australia.**

Bradley MSA, Bingley M, Pittman AN, Lee G and Farnish RJ, 1999. Effects of the properties of bulk solids on the relative performance of polyethylene and stainless steel wall lining materials in mass flow hoppers and other applications; *Proceedings of the Institute of Mechanical Engineers,* **214, Part E, p 53 - 61**

Bradley MSA, Farnish RJ, Rees AR, Johanson JR, Clague K; Storage and Discharge of Powders and Bulk Solids; ISBN: 86166 228 9, 2006

Bradley MSA, Discharging the Impossible: Understanding the flow of Biomass and Waste Materials; 2009, *Engineering a successful Biomass Power Plant: The Problems and Solutions;* **Institute of Mechanical Engineers Seminar. London.**

Goldberg E, Bermes S and McAtee K, 1991, TIVAR-88 provides reliable gravity discharge form coal storage silos: A case study. *Bulk Solids Handling,* **11 (1), p 79-83**

Health and Safety Executive (HSE) 2007. The HSE Grain Dust Study – workers exposure to grain dust contaminants, immunological and clinical response; RR540 Research report

Johanson JR, Kleysteuber WK, 1966. Flow corrective inserts in bins; Chemical Engineering Process, 62 (11), p 79 - 83

Johanson JR, 1967, The Placement of inserts to correct flow in bins; *Powder Technology*, **1, p328 - 333**

Van loo S, Koppejan J, 2003. Handbook of Biomass Combustion and Co-firing. Enschede, twente university press, The Netherlands.

Van loo S, Koppejan J, 2008. The Handbook of Biomass Combustion and Co-firing. Earthscan, 1st Ed, London

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