Guidance on Design and Operation of Biomass Systems

Ref: BG05

CEA
Combustion Engineering Association

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FOREWORD

Guidance on Design and Operation of Biomass Systems (Ref: BG05) is a guidance document intended to provide advice to clients, designers and those who operate and maintain commercial or industrial (i.e. non-domestic) biomass systems using wood in the form of pellets or chips.

Those involved in the procurement, design, construction and the ongoing operation (including maintenance) of biomass systems have duties to co-operate and share relevant information required for the development of a safe system of work. They have a number of legal responsibilities (Duties of care) and to comply with these duties they should possess or have access to good, current knowledge of health and safety legislation and practice, as well as ensuring personnel they employ are competent to carry out the required tasks safely.

The concepts governing safe design and operation are the same regardless of project size, from the smallest commercial installation to the largest power station. While, this document focuses on the design and operation of new industrial and commercial installations, the information in this guide will also be relevant for smaller installations as well as the refurbishment or conversion of existing installations.

The content is most relevant to designers, building services designers and those practising as biomass specialists, e.g. for importers of biomass boilers. Those engaged in installing, operating or maintaining biomass systems will also find the content relevant and useful.

The following words convey specific meaning:

Should: Compliance with this clause is not essential to demonstrate compliance with this document where supported by risk assessment and/or design calculation and detailed documented consideration.

Shall: Compliance with this clause is required in order to claim compliance with this document.

Must: Compliance with this clause is a legal requirement within the United Kingdom.

About this guide

This comprehensive guide concentrates upon the unique issues associated with the design, construction, operation and maintenance of biomass systems. We trust that by studying the contents and following this advice your plant will operate safely and more efficiently and provide you with a trouble-free system. It can aid in informing site or project specific risk assessments. If in any doubt contact your manufacturer or system designer for advice.

It is aimed at the clients, designers and those who operate and maintain commercial or industrial (i.e. non-domestic) biomass systems using wood in the form of pellets or chips. It is intended to help them understand the necessity of health and safety, from a design and practical operational perspectives and to improve awareness of the associated legal requirements.

This guide covers the responsibilities for the safe and efficient operation of biomass plant, and the responsibilities for managing the safe design and operation of this type of equipment. In the operational context at least, the responsibility lies with the most senior person on site. However, they can delegate the responsibility for daily operations, but only to a suitably trained and competent person on site.

The Combustion Engineering Association (CEA) agreed to write this guide with the help of its Members.

Within this Guide there are a significant number of legal requirements, regulations and standards highlighted, however, these regulations and standards are periodically reviewed and they can and do change, but they are as accurate as possible at the time of publication.

The CEA cannot accept any liability for the information provided in this guide; however, be assured that we have consulted widely with our member companies during the compilation of this guide.

Acknowledgments

A special note of thanks must go to Alastair Nicol, Element Consultants, for bringing his extensive technical knowledge to bear in writing the bulk of this document, BG05.

Also, to the other members of CEA for their contributions:

- Industrial Boilerhouse Safety
- Energy and Environmental Solutions
- Deep Water Blue Ltd.
- Enervis

INTRODUCTION

The use of Biomass has increased significantly over recent years. This increase is, in large part, due to a perception that biomass is green, clean and sustainable. These conceptions are, in part, driven by market pressure and, in part, underwritten with Government commercial interventions. The rapid development and deployment of biomass has, in some cases, resulted in the un-informed design, review, installation and operation of allied storage and combustion technologies (with attendant fatality and injury).

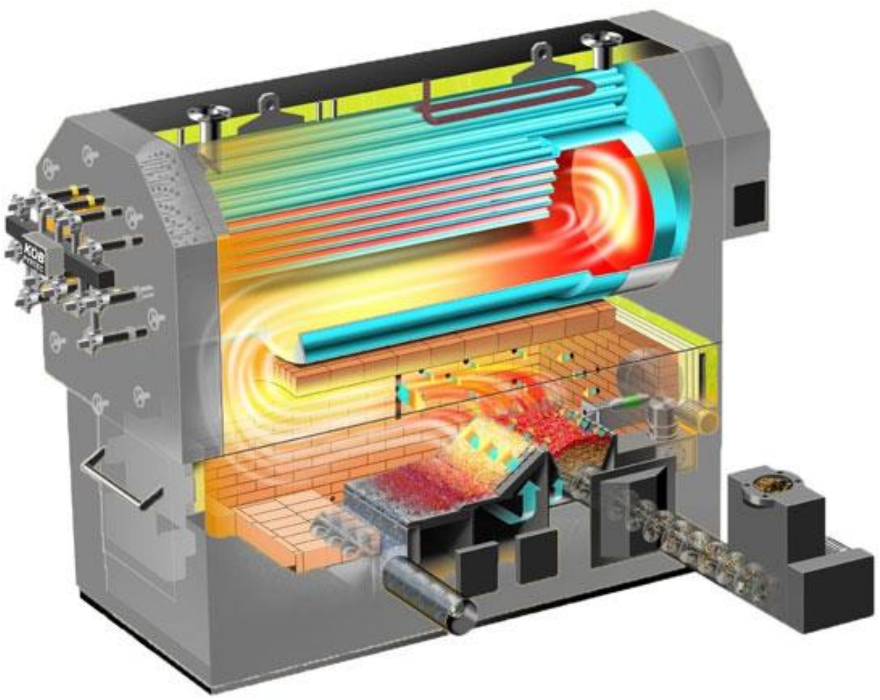
To date, there have been several serious accidents and at least one known fatality in the British Isles directly connected to biomass heating systems; accidents which could easily have been avoided if a process that ensures safe design and safe systems of work in biomass had been applied.

The most effective biomass systems are the result of a close working partnership between client, architect, mechanical and building services engineer where all aspects of design, management and operation are carefully considered and integrated, with an emphasis on health and safety.

Biomass systems are subject to the same general health and safety principles, codes of practice, and design, installation and operation standards that apply to gas, oil or coal fired boiler systems, including, for example, the provisions of the Pressure Systems Safety Regulations 2000.

The following are specifically excluded from the scope of this guidance document:

- Detailed design information as might be contained within a British Standard Installation Guide.
- Detailed information that would apply to all boilers regardless of fuel and might be regarded as “standard” boiler issues or pressure systems as governed by the Pressure Systems Safety Regulations 2000 (PSSR) or the Pressure Equipment (Safety) Regulations 2016 (PER).
- Installations where any fuel is pulverised. The hazard of dust explosions presented by such systems requires special design and operating criteria.



Biomass Boiler example

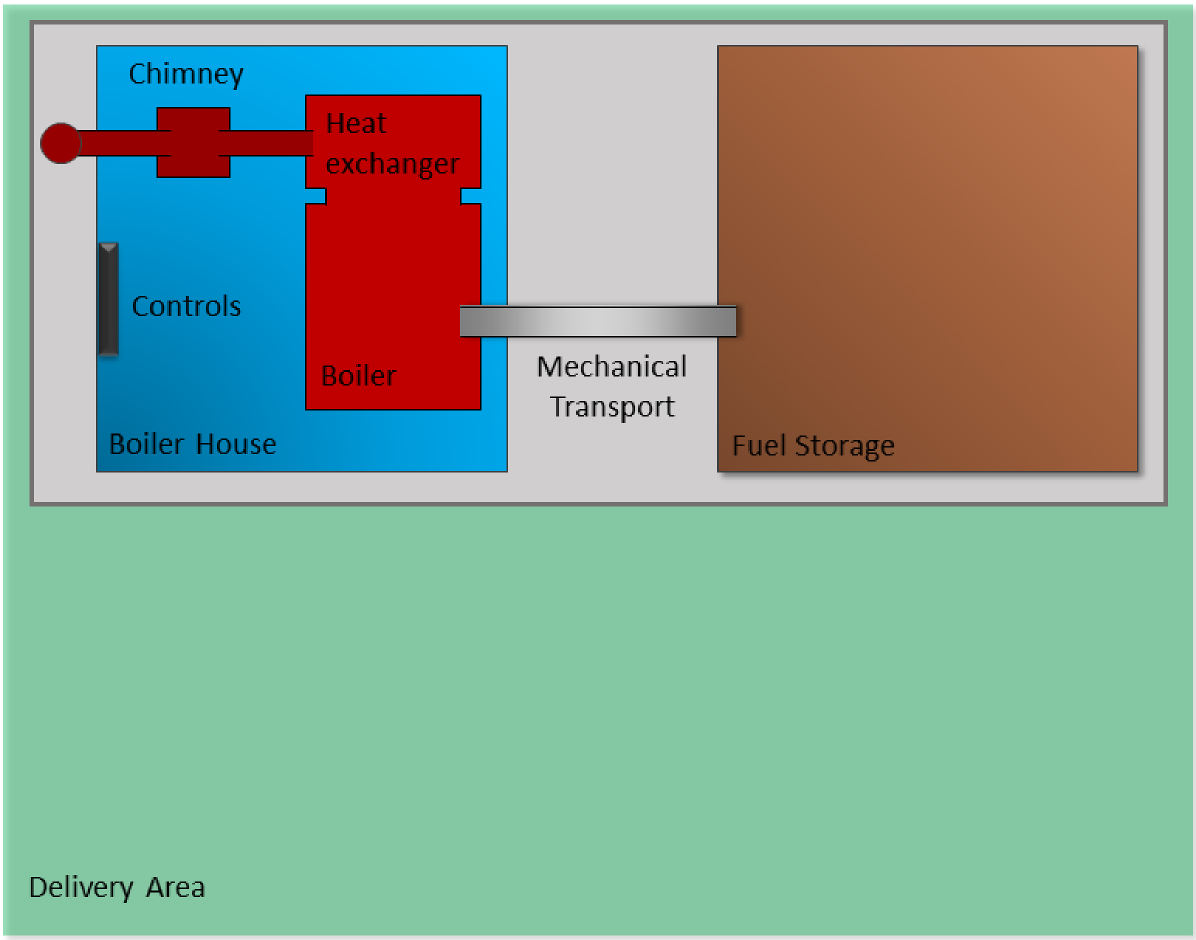
Image Courtesy of Chis Jewson - Zurich

1 THE BIOMASS SYSTEM

Burning wood may pre-date the use of other fossil fuels, but in the UK - only in the past ten to fifteen years - purpose-built biomass systems with equivalent functions to industrial sized coal, gas or oil-fired plants, have become real alternatives. This development has been driven by environmental motives and market incentives, following a trend already established for more than 20 years in some other European countries. The launch of the Renewable Heat Incentive government scheme in 2011 has stimulated further expansion of biomass systems in the UK.

A biomass system typically comprises the following components:

- external or outdoor area (fuel delivery),
- fuel storage (for example, in the form of a bunker or a containerised store),
- mechanical transport (such as augers or 'walking floors') to move the fuel to the boiler,
- boiler house (incorporating the boiler, chimney, controls etc),
- boiler (fired with biofuel),
- heat exchanger (to convert to hot water or steam),
- chimney (including fans),
- system controls.



Comparison to gas, oil and coal fired systems

Industrial-size biomass systems are a more recent development in the UK compared to gas or oil heating installations. Therefore:

- The UK does not have detailed biomass standards built up over the years;
- Clients, designers and operators do not currently have the depth of knowledge and understanding compared to gas, oil or coal fired systems;
- There is a popular misconception that biomass fuel, being an un-reactive solid, must be ‘safer than oil or gas’.

Gas

Natural gas is not stored on site but delivered through pipes and metering, for which detailed design codes exist. Fuel quality is defined and maintained by law. Natural gas boilers have fully integrated safety systems that cannot be fitted to biomass boilers. Carbon monoxide (CO) concentrations in the flue gases from natural gas boilers are generally very low (<50ppm) compared to those from solid biomass (up to 10,000ppm).

Oil

Oil is stored on site but the volumetric energy density is as much as ten times higher than biomass fuels and oil can be more readily pumped. Oil burners are sophisticated devices with little risk of uncontrolled combustion. Most heating oils are stored well below their flash points (the temperature at which they will ignite) so the fire risk is minimal.

Coal

As a solid, coal has comparable risks to biomass and most boiler plant does require some form of manual supervision. Many of the handling issues, including the potential for Carbon monoxide generation and explosion, are shared with Biomass.

It all started with wood

And todays biomass plant

2 HEALTH AND SAFETY IN DESIGN AND OPERATION

Health and Safety legislation in the UK aims to protect persons from accident and injury by placing basic responsibility and duties on the parties engaged in any work activity. The primary health and safety legislation in the UK is the Health and Safety at Work etc. Act 1974 (HASAW), the requirements of which are aimed at ensuring the provision of safe systems of work for all.

The HASAW is supported by more specific legislation such as the Management of Health and Safety at Work Regulations 1999 (MHSWR). Construction and design specific legislation e.g. the Construction (Design Management) Regulations 2007 (CDM regulations), ensure the design of safe systems of work. These regulations apply to the health and safety management and require the identification and elimination of hazards during all phases of design and construction, during operation, maintenance and eventual decommissioning.

In practice, it may be possible to eliminate a hazard altogether. For example, by avoiding the use of asbestos, the associated hazard is eliminated in the first place. In many cases it may not be possible to eliminate all hazards and where these remain, associated risks should be carefully evaluated and controls and procedures put in place to eliminate or reduce them. Where a residual risk remains, the effects of the risk must be mitigated, for example by using personal protective equipment (PPE).

If the principles of designing a safe system are followed, including the rigorous review of a system's entire design, the resulting systems will be more robust operationally, easier to maintain and have lower overall running costs because the process will highlight functional and safety issues before the system is constructed.

2.1 Legislation and regulations

Health and Safety law is set out in a large number of regulations, some of which are supported by Approved Codes of Practice. This applies to oil, gas, coal and biomass systems and all types of boilers, including their design, construction, operation and maintenance (as well as eventual decommissioning). Key legislation is listed in Chapter 8 and the Appendix to this guide contains an overview of useful Approved Codes of Practice (ACoP's).

CDM regulations

The regulations set out the responsibilities of 'duty holders' such as designers, installers, clients and operators, in the context of health and safety legislation. These regulations apply to both design and construction. The responsibility of designers to ensure that a system can be built, operated and maintained safely is emphasised.

CDM regulations should be considered for all construction work. In practice, scenarios for applying CDM regulations fall into the following three categories:

- The construction work lasts longer than 30 days or 500 person days of construction work. In this case good and safe practice should be adopted but a CDM co-ordinator is not required.
- The biomass plant is part of a much larger construction or refurbishment work on the site and is likely to be a small percentage of an already notifiable project.
- The biomass plant is a new, stand-alone installation exceeding the 30-day rule. It requires HSE notification and the appointment of a CDM co-ordinator.

The Construction (Design and Management) Regulations 2007 are available at www.legislation.gov.uk.

Responsibility in design

Under the CDM regulations a designer is a legally defined duty holder with specified responsibilities and duties.

A designer must be competent (regulation 41) and, in the process of design, cooperate and co-ordinate with others involved in the process to ensure a safe design.

Regulation 11 of the CDM regulations summarises the duties of the designer.

For example, a designer should not rely solely on the manufacturers' instructions to provide a safe system of work. The designer must ensure that manufacturers' operational and maintenance instructions are relevant, appropriate and adapted or written for the specific application and use of equipment.

Designing to a known standard does not guarantee a safe system of work.

A 'suitable and sufficient' risk assessment is a legal requirement for any expected work activity. It is insufficient in a risk assessment to simply note that a system complies with a known standard unless that standard is a safety standard, addresses the relevant risks, and has been correctly applied.

A formal system for managing and evaluating health and safety in the design must be adopted and implemented.

2.2 Fundamentals of health and safety in design and operation

Identifying hazards

Designers should be aware that all hazards arising from the design and operation of a biomass system should be evaluated and addressed.

Because of the modular nature of a biomass system (as outlined above), the process of hazard identification (HAZID) and risk assessment should be applied to the system as a whole rather than its separate components.

Guidance

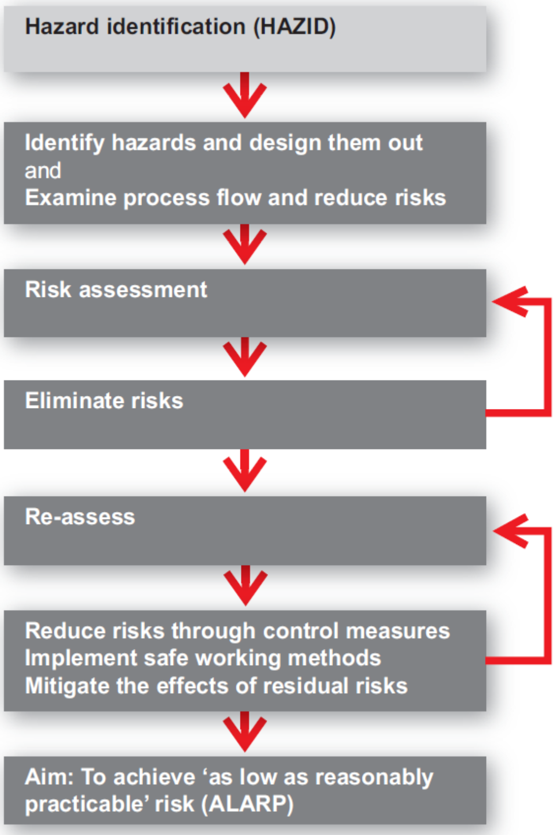
The Health and Safety Executive (HSE) offers general guidance on identifying hazards and evaluating them in the form of a leaflet (Five steps to risk assessment) downloadable from the HSE website (www.hse.gov.uk). A more extensive guide, Review of hazard identification techniques, is also available from HSE.

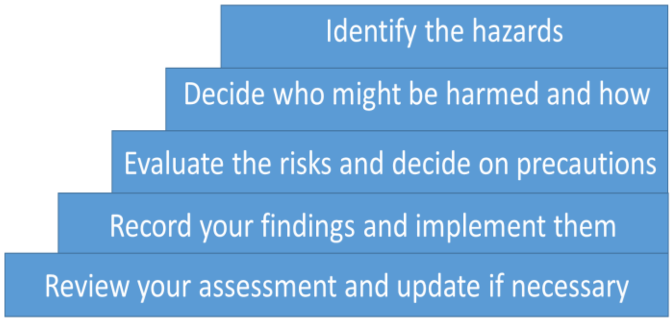
Although these guides are generic, the process of identifying and evaluating hazards and their associated risks can be applied to any biomass system installation and operation.

In summary, good design and safe operation requires:

- identification of hazards,
- elimination at source by designing out hazards,
- risk assessment and evaluation,
- control measures to reduce risk to the lowest practical level, including physical control measures and method statements,
- means to reduce the effects of any residual risk being realised, for example, through the use of personal protective equipment (PPE).

This is an iterative process and it is equally as valid for construction and ongoing maintenance as it is for design and operations.





The HSE 5 steps to Risk Assessment

Eliminating hazards

Oil and gas tend to be burned in standard plant that is usually automated to a high level. Biomass systems usually have to be bespoke to meet the geography of the site and the fuel storage arrangements. This means that often complex judgements have to be made. All biomass systems contain hazards – the objective is to design a plant where the risk is kept as low as practically possible.

A formalised and documented process of risk assessment should be started when the conceptual design begins and be modified and enhanced as construction progresses and operations commence. A Boilerhouse Technical Risk Assessment is a comprehensive assessment of all the risks associated with boiler operations, covering health and safety, environmental, manning and maintenance aspects amongst other matters, and this should be kept up-to-date and validated at every stage of the process.

Eliminate hazard first

The emphasis in design must be on eliminating hazards first and controlling any risks from remaining hazards thereafter, for example:

- Enclosed spaces, such as fuel stores, will be unavoidable. However, it might be possible to reduce the fuel storage risks by building above ground.
- If routine operations, such as periodic inspections of plant at high level, require work at height, can the design be changed so that this can be achieved working at a lower level or should a permanent access and inspection platform be provided?

Reduce risk if elimination is not possible

If a hazard cannot be avoided then control measures can reduce the risks, for example:

- Electrical power failure may result in the loss of water circulation and rapid overheating of water in the boiler heat exchanger. The risk of over-pressurisation may be reduced to an acceptable level with a combination of thermal siphoning, a safety valve, cooling loop and fire side combustion control measures. The manufacturer's installation and operation guidance should be consulted and other safety precautions applied as appropriate.
- Can an operator access moving parts? If they can, they almost certainly will. The hazard of moving parts may always remain, but interlocks, guards, training and method statements will reduce the risk.

Any residual risks which remain after the process of hazard elimination and risk reduction should be 'as low as reasonably practicable' risk (ALARP). For a residual risk to be considered ALARP, it must be possible to demonstrate that the cost involved in reducing the risk further would be grossly disproportionate to the benefit gained.

Operator method statements

Due to the relatively high level of manual involvement in the operation of biomass plant as compared to oil and gas, method statements (operative instructions) are important for safe operation. Many of the hazards detailed in the following chapters will either not be perceived as such or may be completely unknown to personnel not familiar with biomass.

All persons who are required to carry out any work activity must be given sufficient training to enable them to carry out their duties and use any equipment supplied for this purpose safely.

3 TYPES OF FUEL FOR BIOMASS SYSTEMS

Biomass boilers work most efficiently and cost-effectively when the best quality, appropriate wood fuel is used in accordance with the manufacturer's guidelines. If the wood fuel is too wet (or even too dry), extremely irregular in size/shape, or from a low quality crop source, the fuel feed can become obstructed or the boiler can combust the fuel at a much quicker and less efficient rate. The best type of wood fuel for your biomass boiler should be discussed with your boiler supplier.

Some of the different types of wood fuel for biomass boilers are:

- Wood Chip

  Small pieces of wood that have been cut to between 5mm and 50mm.

  This is preferred over larger twigs and dust like particles. Twigs can be included but if they are too large they can "bridge" and block the wood chip boiler feed system, and if they are too small they can disrupt the combustion of the biomass boiler.

  The same can occur from high bark content, so some care is required in the quality of the wood chip. Affecting factors for this is the raw material, chipper type and sharpness of the blade, handling etc.

  To produce wood chip fuel, trees are coppiced and the offcuts are chipped and then dried until the chip moisture meets requirements.

- Wood Pellet

  These are made up of sawdust or fine shavings of wood extruded under pressure so that the wood lignin binds the material into cylindrical shapes between 6mm and 10mm in diameter and 10mm to 30mm in length.

- Logs

  Logs for biomass fuel are typically 500mm in size and should be seasoned for between 1-2 years to ensure a moisture content of below 20%. Logs to be burned as biomass fuel are to be free from coatings and preservatives. Logs can be loaded directly into the log boiler without any other fuel handling process, as might be apparent with wood pellets or wood chip.

- Briquettes

  A ready substitute of Coal/wood in industrial boilers and brick kilns for thermal application. Biomass briquettes are a non-conventional source of energy. Renewable in nature, Eco friendly, non-polluting and economical. They do not necessarily require the addition of any binder/chemicals, so are 100% natural.

4 BIOMASS SYSTEM RISKS

Much of the equipment for biomass systems used in the UK is imported from the continent. Different European countries operate very different regulatory regimes and, although European standards are increasingly harmonised, significant variations remain. For example, annual inspections of installations by independent experts are compulsory in some countries but not in others.

The supply of a number of items of equipment is regulated by EU wide Product Safety Directives that set out common essential safety requirements that each category of product must satisfy to be placed on the market within the European community.

The CE mark (and accompanying Declarations of conformity) is the manufacturers' assertion that the product does indeed satisfy all relevant requirements. Building codes, on the other hand often set very specific requirements and vary between countries. These specific requirements may not be incorporated into or observed in the installation instructions, which apply in the country of origin.

The following sections present an overview of the most common risk areas inherent with the main activities in a biomass system, namely:

- fuel delivery,
- fuel storage and handling,
- boiler operations and combustion.

4.1 Fuel delivery

Biomass fuel is typically delivered by a lorry which would have to manoeuvre on site (often in a restricted location) and then tip into a below ground hopper or onto a mechanical conveyor. The fuel may also arrive in bags or be blown into a silo. Each of these forms of delivery has associated hazards:

- Reversing lorries in a restricted space that may be shared with other activities, e.g. car park, kitchen delivery area, or even playground. The number of UK incidents per year is unknown, but the potential for danger when vehicles and pedestrians' movements occur in close proximity in restricted spaces has long been recognised; reversing bulk lorries are known to be dangerous and fatalities have occurred.
- Large, below ground fuel storage has risks of falling from height.
- Fuel storage of any kind is considered an enclosed space and can present fire or asphyxiation hazards.
- Mechanical augers/conveyors pose hazards from unintentional human contact with their moving parts.
- Pneumatic delivery increases the risk of dust and explosion.

Image (Right) - Dust test explosion at FM Global's Research Campus, Rhode Island

This document is written around the use of wood pellets and wood chips. Whilst the principles may be applied to other biomass fuels, the risks of each fuel must be assessed on an individual basis. However, the following principles apply broadly:

Wetter fuels tend to give lower risk of dust explosion but greater risk of anaerobic digestion during storage with the emission of CO and CO_2, and greater risk of autoignition (spontaneous combustion).

Finer fuels tend to give greater risk of dust explosion.

4.2 Fuel storage and handling

Hazards associated with storage and handling of biomass fuel include:

- explosion,
- fire,
- issues related to the Control of Substances Hazardous to Health Regulations (COSSH), e.g. toxic spores or carbon monoxide (CO) poisoning,
- mechanical failure of store walls,
- slips and falls,
- injury from contact with machinery and moving parts.

Image - Bosley Wood Flour mill explosion

The precise number of UK incidents directly associated with the above hazards and biomass heating systems is unknown. However, explosions from wood dust in saw mills and respiratory illnesses, slips and falls in sites handling bulk solids are regularly reported.

The only reported fatality associated with a biomass system in the British Isles was due to CO build up and asphyxiation in a fuel store. It is important, therefore, not to trivialise the risks associated with biomass fuel storage and handling.

4.3 Boiler and combustion

Boiler hazards exist in the following functional areas:

- wet side (water or steam),
- fire side (fire and explosion),
- flue ducts and chimney.

Wet side risks

Hazards from the wet side are very similar to gas or oil boilers. In particular systems for higher temperatures and steam boilers, may need to comply with the Pressure Equipment (Safety) Regulations 2016 (PER) and Pressure Systems Safety Regulations 2000 (PSSR). In practice, many biomass boiler houses will also contain oil or gas boilers working alongside the biomass system. Often these items must also comply with the pressure-related regulations. So design and construction of the whole site in accordance with these regulations should produce an installation that is fit for purpose.

The CEA has jointly produced two documents, Guidance on the safe operation of Steam Boilers (BG01) and Guidance on the safe Operation of Hot Water Boilers (BG02) which designers, owners and operators of biomass boilers will find useful.

The most important point which distinguishes biomass from oil or gas is the fact that a biomass boiler cannot be extinguished immediately. Biomass boilers have large thermal inertia caused by fuel burning on the grate and potentially also residual heat stored in the refractory. This presents a risk of excess temperature or pressure if the boiler must be shut down suddenly (e.g. if there is a power failure which would stop fuel feed motors and draft fans from operating). This risk can be reduced by including a buffer vessel, an emergency heat dump or cooling loops in the design.

The problem tends to be greater with wood chip boilers that are physically much larger than pellet boilers with similar outputs and hence have a larger thermal inertia.

Managing boiler temperature and pressure with biomass systems must be given very careful consideration, especially when dealing with steam systems where loss of electrical power or loss of feed water supply may present a far greater hazard than might be associated with oil or gas boilers. In many cases it is also necessary to include adequate standby for Loss of Mains Power (LOM) power generation.

Fire side risks

The likelihood of hazardous situations in the fire side is much higher than on the wet side. The combustion of biomass fuel involves the processes of pyrolysis and gasification and the production of potentially explosive gas mixtures on a large static fire bed of considerable depth and area. This differs from the essentially transient flame associated with oil or gas combustion. Due to the different combustion process, biomass boilers cannot be fitted with the same levels of interlocks as gas or oil fired plant.

Occasionally, un-combusted explosive gas mixtures can build up within a biomass boiler combustion chamber and flue which are subsequently ignited and an explosion of some form can occur.

Such explosions have occurred in the UK where severe damage was sustained and where there was the potential for severe injury. In almost all cases these explosions could have been avoided by ensuring competent Hazard Identification and the institution of safe working procedures. Correct operating procedures minimise the hazard but its presence can not necessarily be eliminated.

The risk of CO poisoning is always present with a biomass system as the flue gases generally contain higher concentrations than gas oil. Flue gas leakage and the “smell of wood smoke” is therefore of great concern. Hence the requirement in Building Regulations AD J 2010 to install a CO monitor in the same room as all solid fuel appliances. Sound design, good installation practice and maintenance should minimise the risks of CO poisoning.

Flue ducts and chimney

Large chimney systems can present an explosion risk due to the potential build-up of explosive gases as mentioned above. This is why in Austria, a country with very high deployment levels of biomass boilers, mandates the fitting of explosion relief for the flues of all non-domestic biomass boilers.

Whilst this is not legislated for in the UK, we would strongly suggest that this is considered as best practice within design.

5 BIOMASS FUEL DELIVERY

Choice of biomass fuel, method, frequency and duration of delivery, access requirements and the physical size of storage all impose practical constraints on location. These must be considered very carefully as part of the design, together with the risks from, for example, dust, noise or fire.

Hard standing is required for all types of biomass fuel delivery vehicles.

Access to fuel reception and storage areas should be controlled to prevent injury to operatives or pedestrians. Temporary and or permanent barriers may be used to control access as appropriate.

The delivery procedures should be evaluated, and a safe system of work developed and implemented.

A full risk assessment must be carried out to identify the risks posed by the delivery procedures and should include the following considerations:

- the most appropriate time for receiving deliveries,
- whether pedestrians might be present in the delivery area (for example in a school),
- the requirement for a reversing assistant or 'banksman' and/or sight line markings,
- suitability for typical lorries or whether more specialised vehicles may be required.

When a delivery lorry is unloading, it should also be taken into consideration that:

- heavy doors may be caught in winds,
- automatic doors should be suitably interlocked.

The following three sections describe the three different methods for biomass fuel supply; by tipper lorry, in bulk bags or pneumatic delivery. These sections detail the hazards and risks for each of these. In all cases, carry out a suitable and sufficient risk assessment, use the results to produce method statements for delivery, and adhere to them.

5.1 Tipping

The access area to a fuel pit or underground fuel store should have a raised upstand to prevent tipping lorries from reversing into the bunker. Some fuel stores are accessed via a ramp or bridge which the tipping lorry must reverse up or onto before delivering fuel. This is a significant complication. Ramps are often linked to accidents therefore the use of a banksman and clear sight lines is recommended.

Care and consideration should be given to the discharge of fuel by tipping as this procedure may well cause a significant change in the vehicle's centre of gravity (CG), thereby reducing stability.

When the CG changes this is what can happen

Open fuel pits must be protected with a suitable steel mesh that can take the full weight of the tipped fuel but is small enough to prevent personnel from falling through. Either a 100mm by 200mm or 200mm by 200mm grid would be typical.

Operatives should not be permitted to stand in the tipping zone at the rear of the vehicle in order to assist or control the tipping action, by using a rod, for example.

If rear gates or doors must be activated manually then this must be achieved from a position of assured safety.

The proximity of electrical power lines and minimum safe clearances should be checked at all stages of the project.

Telehandlers and front-loaders

Some biomass installations are designed to have the delivery lorry tip its content outside the fuel storage and a telehandler or front-loader equipped with a bucket is used to transfer the fuel. Untrained staff should never be allowed to operate either type of loader (or any item of work equipment). The Lifting Operations and Lifting Equipment Regulations 1998 (LOLER) applies to operations such as these.

5.2 Bulk bags

These are large polypropylene bags designed to handle chips or pellets. They can have a drawstring on the base and are generally unloaded using the telescopic arm on the lorry. The suspended weight can be considerable (in the region of one third of a tonne for pellets) and the risk to the operative needs to be assessed with LOLER in mind.

The use of lorry mounted crane and bag deliveries pose special risks from shifting the lorry's centre of gravity and potentially from other obstructions such as electrical power lines.

5.3 Pneumatic

Pneumatically transferred pellets offer the highest risk of dust explosion due to the potential for pellets to disintegrate during the transport and delivery process. All delivery pipes should have a smooth internal bore and bends should have a large radius to reduce the chances of pellets disintegrating. To prevent static discharge, they should also be:

- robustly constructed from suitable material; and
- electrically earthed.

There is HSE guidance on the prevention of static discharge during materials handling (HSG103 Safe handling of combustible dust – Precautions against explosions).

A method statement should specify maximum vehicle offload rates, based on minimum off-load time and/or maximum blower pressure, as too rapid a rate could cause pellets to disintegrate. It is important that the site operator enforces these rates as delivery lorry drivers may be incentivised to maximise the number of drops per day and consequences of fast delivery rates are hard to rectify after the delivery has been completed.

Some means of slowing down pellets during delivery should be used, for example, a rubber sheet or rubber lined cyclone. This will help to avoid pellet degradation and reduces the risk of dust explosions.

Venting

Fuel storage has to be vented during pneumatic delivery (with an output into a dust sock) to prevent pressurisation of the silo but avoid dust blow-out at the same time.

The volumes of air used by pneumatic delivery are large; the fuel supplier should be able to advise how large such a sock would need to be.

6 BIOMASS FUEL STORAGE

Biomass fuel storage comes in a variety of forms, such as:

- containerised fuel stores,
- walking floor tip areas,
- bunkers with tipping walls,
- above ground storage hoppers.

Biomass fuel storage should be located close to the boiler house. Extended conveyance and elevation changes lead to increased technical complexity (with health and safety implications) and higher capital investment and maintenance costs. They also increase the likelihood of pellet damage and dust formation. Pellets can be blown pneumatically but multiple handling operations can cause dust.

The preparation of a risk assessment and method statements for the storage of biomass fuel is an inherent part of the design of a biomass system.

6.1 General arrangement

Most fuel stores will be an enclosed space and are therefore potentially hazardous. The design should seek to minimise the requirement to enter the fuel store under any circumstances. Any requirement for in store maintenance or repair should be reduced in the design to a minimum. This means that:

- the fill system should load the bunker uniformly to its maximum level,
- the bunker extraction system should transfer the fuel in a controlled fashion, minimising 'dead' pockets,
- good design prevents the need for routine shovelling of large volumes of 'dead material' outside of the range of the extraction equipment,
- where practical, access to the drive and gearbox should be possible without store entry.
- The store should be ventilated to prevent the accumulation of Carbon Monoxide

Lifting lids

Heavy lifting lids or roof components, as incorporated in some biomass designs, operated manually or otherwise, present a hazard, particularly in windy conditions when latching or a restraint must be considered. As with all other storage designs, the impact of adverse weather must be considered. Designs that avoid lifting large roof components or heavy suspended weights are potentially much safer.

6.2 Confined spaces

Defined in the Confined Spaces Regulations 1997 and the Safe work in confined spaces Approved Code of Practice L101, a confined space is a place which is substantially enclosed (though not always entirely), and where serious injury can occur from hazardous substances or conditions within the space or nearby (e.g. lack of oxygen). A confined space is not necessarily enclosed on all sides, it may be small or difficult to work in and difficult to get in or out of, it may also be a place where people do not regularly work. Many fuel stores will satisfy this description.

L101 Regulation 1 17(c) Some spaces may meet the criteria to be a "confined space" when they are used to store certain specific items. Examples include a storage facility for wooden pellets used as fuel in heating systems.

Regulation 20(f) The expression "confined space" may also refer to areas used for storage of materials that are likely to oxidise (such as wood pellet hopper tanks).

With the exception of well-ventilated open storage, biomass fuel storage, large or small, is hazardous because it is effectively a confined space connected to a combustion chamber where carbon dioxide (CO_2) and carbon monoxide (CO) are produced.

The design of fuel storage should take into consideration the Confined Spaces Regulations 1997, the Work at Height Regulations 2007 and the Supply of Machinery (Safety) Regulations 2008.

Method statement

A method statement for entering and working in the fuel storage area will always be required and a 'permit to work' authorisation is advisable in most situations.

The most essential step is to prepare a task-specific risk assessment. In such an assessment, the numbers of persons, number of exits, access stair dimensions and supervised working arrangements may all apply. The risks associated with fuel storage vary and a method statement for safe entry will have to be written depending on the risk level of a particular space. The following information can assist with this process.

One of the reasons why accidents occur within enclosed spaces is because they often look benign to the operative. The access door may look fairly large, the level of fume small and when a person is seen collapsed within a bunker there is a natural wish to rush in to assist. This is why written procedures attached to the boiler house wall or bunker door are so important. It is also important not to rely upon technology to confirm the safety of the installation unless the site is large enough to have complete confidence that this equipment is routinely checked and calibrated.

Except in the case of an annual inspection or maintenance, entry to a bunker will generally come about due to a plant failure. Even if a detailed method statement has been prepared, the nature of the failure may mean that the method cannot be followed in its entirety. If this is discovered upon entry, staff should exit the store and re-evaluate the plan from a position of assured safety.

To avoid a dangerous situation all biomass boilers connected to the fuel store should be shut down and left switched off for as long as necessary to ensure full gas dispersion **before entry** is attempted. There must be two people present before any entry to the store/bunker. It is also recommended that unless at least 50% of the area of any one of the four walls of the bunker are open to fresh air as an absolute minimum, the shutdown procedure above should be followed.

If any smoke, steam or fume can be seen or if there is reason to believe that smoke or fume from the boiler is being back fed to the fuel store (e.g. there is a smell) then entry should not be attempted until it can be assured this is dissipated (e.g. by checking with CO monitor).

Risk levels

The following three scenarios outline the type of fuel stores associated with high, low or medium levels of risk:

Scenario 1: High risk enclosed space

Such a fuel store could be made from a variety of materials including plastic, metal, marine plywood, masonry or concrete. The store may have top or high-level entry, or a restrictively sized manhole. The store may include machinery spaces below or above the fuel store where access for maintenance might be required.

A boiler and store may typically be contained within a commonly available or adapted container (e.g. a shipping container). Here the hazards may be compounded by flue gas leakage. Due to the fact that they may well be airtight, plastic and metal bunkers definitely fall into this category. Particular care needs to be taken with even the smallest installation in a garage or out-house, as the smaller volume may well exacerbate the level of CO and make a rapid exit impossible.

This type of space requires full ventilation and testing of air quality (CO level) before entry, the use of a harness and two fully trained operative (one working inside and the other outside). It may be safest on some sites to completely prohibit entry to such sealed units, unless completely empty. Climbing or clambering may be required.

Of particular concern is lone working in the context specifically of maintenance call outs. It is essential that containerised solutions are well ventilated and that safe operational procedures are drafted.

Scenario 2: Medium risk enclosed space

Such a bunker could be a large masonry or wooden bunker, or room or teaming well that might typically incorporate a full height, walk-in door or entry portal of similar size.

This also requires full ventilation and testing of air quality (CO level) before entry but harnesses may not be necessary. The boiler operative should be fully trained. A second person (whose only function should be to call for further assistance) should be present outside the bunker at all times.

Safe Entry to Fuel Storage

Operational and maintenance activity that requires entry to a large store will merit special precaution e.g. a risk assessed entry, Control of Substances Hazardous to Health (COSHH) test, extraction and evacuation procedures (written and tested) – and published emergency procedures to mitigate the effects of any hazard being realised for example: initial healthcare procedures or persons suspected of carbon monoxide poisoning or Oxygen deficiency.

The following sample method statement suggests the steps required for safe entry into fuel storage:

- Re-read/sign the method statement.
- Discuss with site manager.
- Carry out a (task specific) risk assessment for the situation on the day.
- Carry out the necessary procedures relating to the method statement including:
    - Complete paperwork,
    - Switch off the boiler,
    - Make sure an entry guardian is present at all times,
    - Isolate and lock off all mechanical and electrical equipment,
    - Visually check for the presence of any fume with both sight and smell
    - Ventilate the bunker for an appropriate length of time after the last vestige of smoke or fume has been detected to ensure it is well ventilated,
    - Ensure there are suitable access and egress positions,
    - Carry out necessary works (e.g. clear blocking fuel material from the extract auger),
    - Release paperwork, remove isolations and reactivate electrical supplies.
    - Restart the boiler.

Ventilation

It is quite clear that in pellet or wood chip storage, the ratio of storage to unventilated head space is significant in the determination of the concentration build-up of Carbon Monoxide (CO). If the ratio of head space is small the concentration will be higher. In smaller facilities where the ratio of headspace to that of total storage were lower, the unventilated concentrations achieved could, it appears, reach levels that would be immediately debilitating and subsequently fatal.

Some of the factors affecting the development of CO include the duration of storage, surface area, interstitial air (compaction) and temperature. Ventilation will be required to be increased to reduce the risk through higher temperatures (i.e. in summer), as this causes accelerated biological degradation.

Any design for ventilation must prevent layering and provide good air mixing in the headspace without dead zones. If the fuel is not mixed, stratification or binding may occur, creating pockets or layers of high CO concentration.

Where entry has to be affected to an unventilated fuel storage area then activity should also be considered in the context of the Confined Space Regulations.

6.3 Fuel level detection

If applicable, fuel store access doors and hatches should be fitted with a permanent sign, cautioning that these should not be opened without making sure that the level of fuel is below the opening. A safely designed system should enable a site operative to check fuel levels easily without entering or even opening the fuel store.

Methods range from simple to more sophisticated:

- Perspex viewing ports,
- Level probes,
- Ultrasonic level detection,
- Load cells.

6.4 Slips and falls

Fuel stores can create a slip and/or fall hazard and have a poor track record (anecdotally) in this area.

Underground fuel stores must be carefully considered in the context of the Work at Height Regulations 2007 where there is a risk of falling into a fuel bunker or pit. Ideally these hazards should be eliminated at the design stage. However, where these cannot be eliminated by the use of a mesh or grill cover (e.g. in large tipping operations), then harnesses and safety nets should be considered.

Ladders

All fuel stores other than those with full height walk-in doors should have fixed ladders both inside and outside next to the entry point, fitted with safety hoops if required. Portable ladders will slip on the fuel surface and their use should be avoided. If the fuel storage is a below ground pit, a fixed ladder may not be acceptable and stairs might be required.

The use of fixed ladders should form part of ‘working at heights’ training and operatives should carry out a (task-specific) risk assessment before entering a fuel store

Above ground stores that may be accessed by ladder or stair should have appropriate guard rails fitted and careful consideration should be given to the safe lifting or opening of access doors taking adverse weather conditions (snow, ice, high winds etc) into account.

6.5 Carbon Monoxide (CO) detection

If the risk assessment requires the use of a CO detection tool, it is essential that it is maintained following the manufacturer's instructions. A defective CO alarm or a CO alarm in the wrong place (e.g. near the door) is extremely dangerous.

The detection systems must at least detect at the level where any human operator might be. Additional low and high level alarms might be used to provide a robust alarm system and warning of "over pile" CO build up and stratification. This should be placed at head height on a wall near the boiler, visible from where an operative might be expected to stand and view the plant.

It is not recommended that a CO monitor is fitted immediately above the boiler itself or above a source of potential leaks of flue gas. It is important that the general level of CO within the working environment is measured and that the monitor is not tripped by, for example, the opening of a boiler inspection port. CO monitors in such locations can cause alarms to be considered as routine and then ignored.

6.6 Carbon Monoxide (CO) alarm

This section refers specifically to the fuel storage area. A biomass boiler house should have visible/audible CO alarm as required by the Building Regulations Approved Document J 2010.

Operators need to know the condition of air within a fuel store, but modern equipment tends to be very sensitive and can cause multiple false alarms.

Thus the following recommendations are made:

- CO alarms should be visual or audible alarms; it is not recommended that these are connected to an automatic system that will, for example, activate a fire protection system or summon the fire brigade. There are too many unknowns surrounding the possible cause of high CO within a bunker, especially rapid falls in atmospheric pressure.
- Making a choice between fixed or portable CO alarms is difficult. In a very dusty environment a permanently installed unit may give incorrect readings. Thus on sites other than those determined as low risk, a portable CO detector should be kept on site to check air quality in the bunker before entry.

High concentrations of CO can be an indication of plant malfunction or potential auto-ignition of the fuel. On large sites it could be beneficial to record and display the time variance of CO levels with permanent CO detection and check the biomass condition. Unfortunately, these levels also change with atmospheric pressure and can be complicated to interpret, but they do offer a unique early warning of fuel degradation.

CO recording equipment is not recommended on small and medium sites (possibly less than 1000kW) as it is unlikely that the site staff will have the expertise to interpret the data and thus could lead themselves into dangerous situations.

6.7 Electricity

In general, installation of electrical equipment in any areas with a substantial risk of dust accumulation should be avoided if at all possible. The safest option for fuel stores to be inspected is using battery operated or intrinsically safe lamps only.

If it is necessary to install electrical equipment within a fuel bunker, the equipment should be suitably IP (ingress protection) rated against dust ingress (IP 50 or 60).

Such equipment needs a level of installation and on-going maintenance expertise unlikely to be available from 'local' electricians. However, it is such persons who are likely to be called first in the event of an electrical breakdown.

If the fuel storage does contain biomass fuel or significant quantities of biomass dust, only battery torches should be used.

In view of the size of their combustion chambers, biomass boilers with even modest kW ratings can require entry into the actual combustion chamber itself for repair, cleaning or inspections. For such operations, sustained high-power lighting is needed but there is a risk of electrical transmission along the metal frame of the boiler. If battery-operated lighting is not suitable for such tasks, only low-voltage lighting should be used (24V).

6.8 Mechanical load

The physical structure of the fuel storage must be designed to take the most extreme loads that are caused by the weight of the fuel and any additional dynamic load imposed by the operation of the mechanical extraction equipment. Considerable strain can be put on extraction equipment if the pile of biomass fuel is dense (wet) or if the store is overloaded. There have been several examples of fuel store collapse in the UK, simply because the designer failed to comprehend the imposed loads.

A mechanical or electrical link should be included to ensure that that the extraction equipment does not destroy the transmission system or indeed the structure to which it is attached. Such links typically detect excess in:

- hydraulic pressure,
- mechanical force (by using shear pins).

Change of load

Fuel storage is generally designed to accommodate static symmetrical loads.

Introducing a cyclic load (possibly by means of a screw extractor) could cause structural damage to the bunker. This may need consideration at the design stage.

Change of fuel

Refilling a bunker designed for wood chips with pellets will dramatically increase both the load on the floor and on the walls. The greater the material density and the lower its angle of repose, the greater the pressure on external walls will be.

Suggested structural designs for fuel storage systems include:

- ACI 313/77 – American Concrete Institute (www.concrete.org)
- CP 110 – Institute of Structural Engineers (www.istructe.org)
- DIN 1055 – For steel bins.
- EuroCode 3 Part 4.1 – (www.bsigroup.co.uk)

6.9 Mechanical risks

Mechanical extraction equipment is inherently dangerous, but this can be mitigated partly through electrical isolation. The boiler and related equipment must be isolated and the isolating switch 'locked off' before entering a fuel store. The equipment should be confirmed as isolated by testing it before any work is undertaken.

The use of complicated or confusing electrical panel layouts should be avoided to prevent the hazard arising from incorrect isolation choice. Where practical, local and lockable isolation should be provided.

Mechanical interlocks can be incorporated which turn off power when a storage door or inspection hatch is opened, but a method statement and staff training may be an equally valid approach. The method statement should identify the method of isolation and its verification.

Equipment should not be turned back on until the maintenance has been carried out and the operative is a safe a distance away from mechanical parts.

6.10 Water ingress

Pellets swell if they become wet and this can lead to substantial mechanical failures. Wet fuel can also lead to fermentation which can have associated risks of dangerous gas (CO_2, CO) build-up in the fuel store.

Large scale storage of wet and untreated fresh wood will result in fungal contamination and the release of spores, giving rise to a COSHH risk. This may be particularly the case where the wood is stored with high moisture content and where temperatures are elevated.

Wet fuel also increases its density and therefore potential outward pressure on walls/fuel store. Fuel storage must be kept free from any water ingress as a result of rain or ground water. All below ground installations should have a sump from which water can be pumped.

6.11 Feed failure

In the event of boiler failure due to fuel shortage, there is often psychological pressure on operatives to enter bunkers to shovel fuel, or generally take short-cuts to restart the fuel feed to the boiler and restore heating to the building.

Failure of fuel feed systems can result in combustion gases leaking back into the fuel store or other poorly ventilated space. Therefore, in such instances, the hazard from CO or other hazardous gases may be increased.

Arching

Arching and caving occurs when a void is created under biomass fuel which gets stuck in the storage (e.g. by the creation of fuel “bridges” within the store). This can be very dangerous, as if people enter the store and walk on the fuel, they can fall through the apparent surface of the fuel into this void and the mechanical extraction equipment below. Operatives should not be allowed to investigate without undertaking a thorough risk assessment. Agitating the fuel from the outside is the best remedy. Isolation of extraction equipment should be assured.

6.12 Dust explosion

As a generalisation, lump wood or chips are impossible to ignite except on a grate (or extremely rarely due to anaerobic action, as in a manure heap). However, fine wood dust (as collected in a saw mill) offers a very real risk of explosion in incorrectly designed equipment.

Wood pellets do not offer a significant risk of explosion if in a pristine condition but can become a risk if degradation leads to dust and the biomass is handled in a situation where there might be a source of ignition (e.g. static build-up). Settled pellet-dust which then accumulates on hot parts of equipment could also present a fire hazard. Dust concentrating around augers and other moving parts can eventually build up to a hazardous level whereby it can bind equipment so tight that a mechanical failure results under high tension. Given these hazards, good design, detailed operational instructions/method statements and operative training should seek to minimize the potential for pellet dust.

The following tend to increase the risk of pellet breakdown:

- excessive clearance between auger flights and case,
- excessively steep or long augers,
- excessively long filling points causing further break-up of broken pellets,
- aggressively angled flights,
- varying inter-flight volume caused by shaft joints,
- excessive auger speed (where the contents are starting to bounce and fly),
- low quality or waste wood pellets.

The dust explosion risk can be minimised by:

- electrically earthing of all steelwork, especially delivery pipes, (Note: Even plastic bunkers should be fitted with earthed steel pipework.)
- removing all electric lights, sockets and switches from a fuel storage,
- using appropriately rated electrical equipment,
- ensuring that augers are designed for the fuel type,
- filtered venting during blown delivery,
- sourcing pellets from an organisation which has suitable quality assurance (QA) procedures in place and can assure consistent pellet quality/integrity.

Great care should be taken to avoid any plastic component (for example, a pipe or screw conveyor case) coming into contact with moving dust.

Explosion relief

Because the hazard from dust explosion is uncertain and unpredictable, a further layer of protection should be added to largely enclosed stores or silos. A 'weak area' in the silo can effectively provide directional explosion relief. This could be a marine plywood panel set in the bunker roof or wall but should be secured appropriately to prevent the panel becoming a missile. The Health and Safety Executive's information sheet HSG103 'Safe handling of combustible dust' is available on its website www.hse.gov.uk

6.13 Fuel storage fire

Fires can start for various reasons:

- Burn-back from the boiler.

  This problem has now been effectively addressed by duplicate anti-burn back technology, which should form part of the design specification.
- Ignition from self-heating.

  This can be avoided by keeping the fuel dry and unlike in coalbunkers, reports of self-combustion are extremely rare.
- Ignition from a hot source within the fuel storage.

  For example, a steam pipe, electrical component or cigarette. This is avoided by good design and protocols (no smoking!). Hot pipes should not be run through fuel storage except in fuel pits to prevent freezing.

In case of fire in a fuel store

The operation and maintenance manual should include a method statement along these lines:

- Call the fire brigade.
- Switch off boiler and ventilation systems.
- Carefully close hatches and openings.
- Await fire brigade.
- Inform management.
- Follow the instructions of the fire brigade.

Whilst local fire brigades should be trained to deal with biomass fires, it is suggested that site staff should highlight the potential risk of structural failures of pellet bunkers (due to increased density and thus greater force loadings on bunker walls) or CO emission when fuel stores are flooded with water to extinguish fires.

7 BIOMASS BOILER AND COMBUSTION

Clients and designers must use equipment that is certified, tested and approved for use in the UK. The design and construction of boilers and allied pressure parts should be in compliance with the provisions of the Pressure Equipment (Safety) Regulations 1996 (PER) and Pressure Systems Safety Regulations 2000 (PSSR) as required (i.e. if they have they have a maximum allowable pressure greater than 0.5 bar, or steam at any pressure) and conform to acceptable British design standards, EU harmonised standards or internationally recognised code such as ASME (American Society of Mechanical Engineers) for design, construction and certification.

The key EU standard for the type of plant under consideration in this guide is BS EN 303-5: 1995 (for nominal heat output of up to 300 kW). Boilers above 300kW should be designed in accord with an internationally recognised code and comply, where necessary with PER and PSSR. There are grey areas with regard to some relatively large low-pressure warm water boilers, particularly if it is bespoke to a particular biomass fuel; however, all boilers should be safe, efficient and comply with all relevant EU directives including the Low Voltage Directive (LVD), Electromagnetic Compatibility (EMC) Directive and the Machinery Directive. Advice is available from Notified Bodies working in the area of Pressure Equipment Directive (PED), Boiler Efficiency Directive (BED) and Construction Products Directive (CPD). *(Construction Products Directive was withdrawn and replaced by the Construction Products Regulation (305/2011/EU)).* Recommended reading also includes BG01 Guidance on Safe Operation of Steam Boilers and BG02 Guidance on Safe Operation of Hot Water Boilers (LTHW – HTHW)

7.1 Safe entry into boilers

Boilers should always be assessed as confined spaces and only entered if there is no alternative means of performing a task. There must be a method statement regarding entry and cleaning. Boilers should be extinguished at least 24 hours before entry or for as long as is needed to lower the temperature for safe working.

Due to the presence of metal and moisture inside boilers, any electrical supplies (e.g. lighting or tools) should be low-voltage (24 V).

The risk assessment should consider:

- burner isolation verification
- excessive temperature of combustion chamber
- presence of mineral or ceramic fibre insulation (CMR)
- refractory collapse
- carbon monoxide monitoring (CO)
- PPE including breathing apparatus if necessary
- evacuation procedure
- electrical hazards

7.2 Wet side explosion risks

Wet side explosions, involving hot water or steam, are more serious and can be more powerful than fire side explosions.

The significant difference between biomass and oil or gas boilers is that there is a larger amount of residual heat that can remain within the combustion chamber from the fuel bed and refractory lining of a biomass boiler. This heat can be very substantial and the system designer must ensure its safe removal and disposal under all possible fault conditions. This is very different to a gas burner where closing the fuel feed valve effectively stops heat input instantaneously.

Pressure relief valve and gauge

Biomass boilers should never be operated without suitable pressure relief valves and pressure gauge, either on the boiler or on the connected pipe work. The pressure relief valve should be tested regularly and should be impossible to isolate. Discharge from the pressure relief valve should be naturally drained to prevent a head of water building on the discharge side. A pressure gauge is also extremely useful, even on low head, open vented systems.

Open vented heating systems

In open vented systems, special care should be taken in the design to ensure that the operation of mixing (or divert) valves cannot result in isolating or reducing the operational capacity of feed and expansion and venting arrangements. The potential for the refractory to store heat (as discussed above) should be considered in assessing feed water capacity, provision of expansion capacity and pressure venting arrangements.

Sealed hot water plant

Special consideration during design needs to be given to the conditions that will arise from lack of water circulation, electrical power failure or loss of the anti-flash margin (depressurisation) by dispersing heat by, for example, thermal siphoning or cooling loop dump radiator.

Steam systems

Discussions should be held with an experienced designer of steam systems, bearing in mind the large quantity of residual heat commonly stored within biomass boilers.

Particular thought should be given to power failure. The use of electrical standby generator with "Loss Of Mains" detection or steam driven backup feed pumps should be considered carefully. The over pressure and over volume capacity of the feed pumps should be sufficient to deal with emergency situations.

The lockout chain and restart procedures may necessarily require complete shutdown. Full compliance with PER and PSSR must be followed.

7.3 Fire side explosion risks

Biomass fuel has a high volatile content, which is released during the combustion process as a mixture of gases including:

- carbon monoxide (CO).
- Syngas

These gases usually burn during normal operation but excessive build up and uncontrolled combustion can cause a fire side explosion. This can happen in circumstances such as uncontrolled draft, excessive charging, delayed ignition, or accidental or uncontrolled admittance of air to the combustion space. In order to avoid the consequentially severe explosion risks, it is vital that:

- the boiler system is designed for the load.
- the correct controls are used for the boiler charging.
- the manufacturer's operating instructions are adhered to at all times.

Inappropriate manual intervention, for example by opening boiler doors or flue hatches when the boiler is operational, should always be avoided as this may lead to an explosive mixture being created in the combustion space. The risk of fire side explosions is significantly increased by oversized boilers cycling at low load or where hot restarts are automatically or manually initiated.

The most important route to eliminate fire side explosions is a good method statement followed by well trained staff. This method statement must make reference to initiating discussions with site management and/or the boiler manufacturer in the event of 'pops and bangs' during normal operation as this can indicate a fundamental problem.

Even minor pops and bangs can have serious consequences and may pre-empt a more severe incident, so they should all should be reported. Learning from near misses is an established health and safety procedure and an excellent way of avoiding more serious accidents.

Induced draft

The use of induced draft (ID) fans will in most circumstances reduce the risk from fire side or flue explosion. This is because ID fans will lower the concentration of flammable gas in the combustion chamber or other parts of the system.

An ID fan will maintain a negative pressure in the combustion chamber, but this may result in positive pressure in the ducts and flue, downstream of the fan. Due to the high CO levels within biomass boiler flue gas, the safest course of action is to design flues and ductwork to offer neutral or negative pressure to prevent gases being forced out of any cracks or gaps into the boiler house.

Where this is impossible, particular care should be taken with the design and sealing of flue and chimney to prevent this leakage. The flue system must be suitably rated for temperature and pressure.

Two explosion risk scenarios, either from delayed ignition or from rapid cycling, are explained further below.

Delayed ignition of a cold boiler

A typical sequence of events leading to an over bed explosion is:

- Fuel is added to the combustion chamber and the operative attempts to light the boiler.
- More fuel is added but the boiler still does not light.
- The centre of the fuel in the fire bed gets hot and smoulders, giving off CO, H_2 etc
- These gases mix with air and fill the combustion chamber and downstream ductwork.
- Eventually a flame breaks through and the gases explode.

In order to prevent this chain developing, the boiler should be left to purge from natural draft or from an ID fan on a low setting. A forced draft fan should not be used, except (dependent upon the details of boiler design) an overfire air fan with nozzles located well above the combustion zone. Fuel in the combustion zone should be cleared following any failed ignition.

Manual intervention

The majority of explosions happen following a power cut where draft control is lacking and/or manual intervention has taken place. The risks from manual interventions can be avoided by taking precautionary steps, including:

- provision of detailed operating instructions,
- adherence to operating instructions,
- following manufacturer's instructions when lighting the boiler,
- staff training.

In order to prevent fire side explosions, great care must be taken to avoid feeding excessive fuel on to the fire bed, particularly during start up. Fuel should always be removed from the combustion zone before attempting more ignition cycles than the boiler's automatic programme permits. This is best done by raking out any remaining or part burnt fuel. Do not attempt to prevent fire side explosions by purging using conventional forced draft fans – biomass boilers are very different to oil or gas boilers.

Explosion following rapid cycling

The second risk scenario occurs when the boiler and refractory are hot and there has been a demand call. Fuel has been charged to the grate and then the demand has been quickly satisfied. The boiler is now very hot and filled with wood that will continue to smoulder. If, due to a system malfunction or operator error, combustion-air is introduced in an uncontrolled manner and there is sufficient heat or a local ignition source (e.g. smouldering biomass) then there is the potential for the gas mixture to explode.

These conditions exist in all biomass boilers, but controlling automatic draft, charging and temperature feedback avoids dangerous build-up of gases. Controlled re-ignition and draft, and subsequent increasing burn are the safest way to handle this risk factor.

This scenario is particularly an issue with grossly oversized boilers and poor conceptual design serving intermittent loads. Appropriate matching of boiler size and heat demand profile can reduce these risks. Equipment failure or unusual heat patterns can result in abnormal operation and this must not result in an unsafe situation. It is appreciated this can be challenging, but the design must cater for such occurrences.

Igniting a Boiler

A boiler may incorporate an automatic charging and ignition sequence with hot air blower or it may be that the boiler is ignited manually.

Where manual ignition is used then it is imperative that the manufacturer's instructions for ignition sequence are followed to the letter.

Under no circumstances should a volatile accelerant be used. A volatile accelerant may give rise to a flammable vapour cloud and explosion. It may be acceptable to use fire lighters and kindling.

7.4 Fire safety

Anti-burn back

The early days of automated biomass combustion in Europe saw many incidences of fire arising from burning back from the fire bed into the fuel storage. Duplicate anti-burn back devices, as specified by the manufacturer, have now virtually eliminated this issue. Usually two systems are fitted due to the level of risk. The designer of the plant and their client should confirm the practical operation of the anti-burn back devices used on the boiler. Care should be taken that if a water supply is required for one of these (e.g. a drenching system) that it is of the highest integrity. If installed outside and equipped with water dump units, these should be fitted with trace heating or only be filled with non-flammable anti-freeze. On very large sites foam injection may be used.

Appropriate inspections of flexibly tipped rotary valves (which are designed to prevent burn-back) are required as abrasives in fuel can wear them down, degrading the seal. Full compliance with the principles of Building Regulations AD J 2010 should remove the risk of the boiler igniting the boiler house or the fuel store in any type of installation.

The extraction transport and stoker augers will typically be protected with star valves or mechanical isolation devices. These provide a measure of fire protection and serve to prevent gas flow from the boiler to the fuel store. These parts can wear out and It is therefore imperative that these systems are effectively maintained.

Soot and ash handling

Soot

Anecdotal evidence describes spontaneous soot fires. Soot and deposits removed from the boiler walls during cleaning, should always be stored outside in a metal container. Boiler and chimney soot are well known carcinogens due to high levels of polycyclic aromatic hydrocarbons (PAHs) and must be disposed of appropriately.

Ash

Ash can contain glowing embers. It should only be handled in metal containers and should be stored outside if possible. Completely combusted grate ash from clean biomass has a low level of PAH (in contrast to soot) and thus presents a lower risk.

All fly ash, poorly combusted grate ash or ash from contaminated wood, presents a health hazard and should ideally (and in some cases legally) be disposed of as hazardous waste. In some boilers fly ash and grate ash are combined.

The grate ash removed from a biomass boiler may still contain plentiful volatile content to cause rapid ignition when sufficient combustion air is available.

Therefore, if ash is augured to a closed ash hopper (as is often the case on modern systems) care should be taken in the design and operation to prevent sudden opening of the ash-hopper lid as the rush of air this causes can re-ignite the volatile content.

It is not possible to eliminate all dust (mainly in the form of fly ash) in a biomass boiler house, and fly-ash is particularly pervasive. This fine particulate emission is likely to contain volatile organic compounds (VOCs) and polycyclic aromatic hydrocarbons (PAHs), even from clean wood. Handling ash, sweeping the boiler house and doing associated tasks require staff training and the use of appropriate personal protection equipment (PPE), including full overalls, an adequately rated dust mask, and eye protection. Cleaning boilers is a particularly dirty task and staff must be fully acquainted with the risks. In practice, a disposable respirator of class FFP2 (EN 149) or re-usable cartridge P2 (EN 143) is likely to be sufficient. Both filter at least 94% of airborne particles. In larger boilers, where it is necessary to enter the boiler, the appropriate risk assessment and method statements must be prepared. Special consideration should be given to the use of a temporary ducted air system to provide clean air in the vicinity of the operator.

Ash containers and ash removal must be considered in the context of the Manual Handling Operations Regulations 1992.

7.5 Flue and chimney

As indicated above, fire side explosions resulting from delayed ignition are a real hazard for all biomass boilers. The most important factor is following correct procedures, but many continental countries assume flue system explosion relief will be included in the design. In factory-made systems, this should be designed by the flue system supplier.

Inspection hatches/explosion relief on chimneys (especially in public areas) should be well secured to prevent the panel becoming a missile.

Existing chimneys

When fitting a new boiler system to an existing chimney, the total chimney volume should always be kept to a minimum, e.g. by relining to reduce the volume of potentially combustible gases in the flue. Explosion relief should be incorporated into the flue pipe connector.

Tar fires

Tar fires can occur when tar builds up in the chimney and flue ductwork from poor fuel and prolonged low fire operation. This tar usually burns off incrementally, but if it ignites this can cause the chimney to glow bright red.

The following steps should be taken to avoid chimney fires from tar:

- The flue must be temperature rated for a solid fuel.
- The flue seals must be rated for pressures that will be sustained.
- The flue should be checked and cleaned annually by a professional chimney sweep. Waste must be removed to a licensed landfill site as the boiler owner is responsible for waste produced on their site.
- The flue must be cleaned through its whole length from the back of the boiler to the top of the flue. After cleaning, all components must be re-secured, e.g. all bolts on inspection plates.
- A detailed visual inspection of the flue draft stabiliser should be carried out annually (draft stabilisers can suffer cracking through repeated mechanical action).
- Lagging must be replaced where it has been removed to aid cleaning.
- Corrosion from condensation should be checked annually.
- Any problems should be fixed or reported and noted in the logbook.

In case of a chimney fire

The following actions form the basis of a method statement:

- Stop the boiler firing by switching off at the main isolator.
- Call the fire brigade.
- If you perceive no risk to yourself and the fire is relatively young, close the flue draft stabilisers and (ideally) cover combustion fan air inlets.
- Await fire brigade.
- Inform management.
- Follow the instructions of the fire brigade.

Chimney Inspection

All chimneys and flues shall be regularly inspected by users to identify any damage, corrosion of leakage, paying particular attention to holding down bolts, guys and stays, and lightning conductors. Formal inspections using qualified steeplejacks are recommended every 3 – 4 years.

8 BOILER MAINTENANCE

Boiler maintenance is essential, and this should be conducted in consultation with the manufacturer's recommended procedures. The maintenance of a biomass boiler will typically require internal inspection and a wide range of safety issues.

The materials used in construction and the residues of combustion present special COSHH risks. It is routinely the case that Ceramic or mineral fibre (CMR) gasket material is used to join air supply, flue and recirculation ducts. Mineral or ceramic fibre blanket is often used as a protective sandwich between metal and solid refractory block.

CMR sealing may also be used to strip seal inspection hatches and main or opening boiler doors. Where there is little natural furnace draft and the ID fan is off during inspection, opening the doors will result in the dispersion of fibre from the seal and suitable precautions for staff engaged in operating or maintain the boiler should be taken.

Cleaning will potentially result in the disturbance of gasket material and a schedule of hazardous construction materials should be obtained as part of the O&M manuals.

Cleaning may also require entry to the boiler and here the additional risks must be addressed.

Where the boiler shutdown is to be prolonged, e.g. for several weeks, then the smoke side should be stored in a condition that allows continuous natural ventilation.

Particular attention should be made to cleaning procedures and or cleaning chemicals that may, in contact with ash or combusted residuals, produce flammable gaseous by-products.

Fuel (Particularly wet fuel) should not be stored on the grate during prolonged shutdown.

Where the boiler has a wet ash bath this should be drained and cleaned and stored in an empty and dry condition. Galvanised components should not be routinely immersed in an ash trough.'

Prior to re-entering service, the boiler should be thoroughly ventilated and subsequently purge, prior to any attempt (manual or otherwise) to ignite the boiler.

The pH of wet ash systems should be monitored and the water should be changed regularly in accordance with the manufacturer's instructions.

The correct operation of auto ignition components should be tested prior to re-entering the boiler to service.

8.1 Water Treatment

Boiler water treatment is a critical aspect of operating any boiler plant and water treatment of biomass boilers whether steam or hot water, shall be carried out in accordance with BG04, which requires a boiler water treatment risk assessment and written control scheme.

To minimise the risk of incorrect treatment and analysis only persons trained and competent in boiler water treatment should be involved in operations or management of the boiler water treatment regime.

9 TRAINING AND DOCUMENTATION

9.1 Staff training

Biomass boilers, in particular steam systems, are in general unsuitable for unmanned operation. Some suppliers of biomass systems suggest that 'automatic' plant needs no manual intervention. However, a level of manual involvement more frequent than for example, the annual inspection of a gas boiler, will be necessary.

This could be carried out by outside contractors or on-site staff. In either case, biomass plant requires trained operatives.

Training is a legal requirement under the Health and Safety at Work etc. Act 1974 and other legislation. Proof of suitable training, regularly reviewed, audited, and refreshed as required, is evidence of good practice. Adequate training is important to ensure that equipment is operated safely, and good levels of site safety are maintained.

Staff training is mentioned in many sections of this guide, for example in relation to working at heights, mechanical risks, explosion risks and the handling of ash. It is also a requirement of regulations such as COSHH and PUWER.

Ideally the operative should attend training in the Combustion Engineering Association's Biomass Boiler Operation Accreditation Scheme. This will teach operatives all aspects of the biomass system, ranging from the principles of combustion to the hazards of soot, and leads to qualification as Biomass Boiler Operative. See the Association's web site; www.cea.org.uk.

9.2 Documentation

An 'operation and maintenance manual' and a 'health and safety file', as required by the Construction (Design and Management) Regulations 2007, should be available for the management and operators of the plant. These may form one document for smaller installations or two separate documents with cross referencing in larger biomass systems. Both documents should be in English.

This documentation must be site specific. It is unacceptable for the manuals to contain large volumes of complex advice not applicable to the particular site. This will merely confuse many operatives.

A 'logbook' should also be maintained, recording, among other things, operational data, safety checks and maintenance activities. Hard backed log books (e.g. page-a-day diary) are the recommended method of keeping a day-to-day log of ALL activity that occurs in the boiler house. Even if there is no actual activity that needs attention, the visit should be recorded. The Manager responsible for the boilerhouse should sign off the logbook on a weekly basis after checking the activities recorded. Other records such as water treatment reports and emission reports etc. should also be checked, understood, and retained in a safe place away from the actual boiler, to prevent loss in the event of an incident such as a fire.

Operation and maintenance manual

The operations and maintenance manual describes all aspects of the duties of the operator and contains all the information relevant for the safe operation and maintenance of the biomass plant. It should incorporate emergency and breakdown procedures including details of the nearest contacts and emergency services.

The operation and maintenance manual will typically contain:

1. Contents.
2. Vocabulary.
3. Complete system description.

   Provided by the project contractor, describing the equipment and principles of operation and control, together with the scope of work undertaken.
4. Schedule of mechanical engineering equipment.

   Details of all major items of equipment supplied as part of the contract.
5. Schedule of electrical controls and instrumentation equipment.

   Details of all major items of equipment supplied as part of the contract including:

   - listing of all inputs and outputs,
   - listing of action software configurations,
   - two copies of software (one on-site, one off-site),
   - instructions for switching on, operation, switching off, isolation, fault finding and for dealing with emergency conditions,
   - instructions for any necessary precautionary measures.
6. Operation routines for each piece of equipment in the boiler house and fuel storage, usually provided by the manufacturers.
7. Planned maintenance procedures.

   Provided by the project contractor, including instructions for servicing and the frequency and materials to be used, to maintain equipment in a good safe condition. (The minimum expected service life for any standby power supplies should be stated.)
8. Detailed method statements covering every operation to be carried out.

   This is essential as very few operatives will have any experience of operating a biomass boiler house and should include:

   - fuel ordering,
   - vehicle reception,
   - off-loading,
   - entry into the bunker,
   - operation of the boiler,
   - cleaning the boiler,
   - ash handling and disposal,
   - soot handling and disposal,
   - a comprehensive list of actions arising from foreseeable operational problems.
9. Manufacturers' spares lists and ordering instructions.
10. Emergency procedures.

11. Health and safety information relevant for operating, maintaining or removing the plant in the future by others, including:
    - details of any residual hazards the contractor is aware of and how they have been dealt with (e.g. materials containing asbestos),
    - any hazards associated with the materials used (for example, coatings that should not be burnt off),
    - the removal or dismantling of installed plant (for example, lifting arrangements),
    - equipment for cleaning or maintaining the plant,
    - health and safety systems in the plant (for example, fire detection and alarms).

    This may also be contained in the health and safety file and should be cross referenced.
12. All commissioning data, tests on completion data and test certificates, as well as reports/logs on the commissioning process.
13. Manufacturers' handbooks and service manuals including fitting instructions.
14. 'As installed' versions of drawings requested in clear plastic envelopes. Copies should be available in AutoCAD format.
15. A full process and instrumentation diagram.
16. A full set of wiring diagrams.

Health and safety file

The health and safety file should contain:

1. Description of the project including consultants, contractors and other personnel.
2. Any survey and pre-construction information relevant to future operations on the site or future activities in the building.
3. Materials and hazardous materials used on the site or in construction.
4. Description of the construction work:
    - structural information,
    - mechanical and electrical services.
5. Cleaning work.
6. A description of the maintenance activities cross-referenced to the operation and maintenance manual
7. A description of hazardous equipment or areas.
8. 'As built' drawings:
    - schedule of materials,
    - schedule of the operation and maintenance manuals,
    - schedule of equipment with health and safety implications,
    - as installed electrical systems,
    - as installed steam plant,
    - structural specification and drawings.

10 GLOSSARY OF TERMS

Biomass System

A heating or combined heat and power (CHP) system, using a boiler fired with wood pellets or wood chips, including components such as the fuel storage and chimney.

Clients

An organisation or individual who undertakes or instructs design or construction work, or has such work carried out on their behalf. Responsible for providing accurate and relevant information to designers and others involved with all stages of the project. They should ensure they employ persons competent to perform the desired tasks. Where the client is also the owner of the system, they will also be responsible for the health and safety of those who operate and maintain the installation.

Designers

As defined in the Regulations, are responsible for the safe design and configuration of all components that make up the biomass system. Designers must identify and eliminate hazards from the design to provide a system that can be operated safely. They should also provide all relevant information along with the system that will allow it to be operated safely including information on any residual risks.

Fuel

Biofuel in the form of wood pellets or wood chips.

Fuel Store (Storage)

A bunker or containerised storage, below or above ground for the storage of biofuel.

Method Statement

A document describing the way a task or process is to be completed (also known as a safe work procedure or a standard operating procedure).

Operators

The individuals who will run and may maintain the installation on a daily basis. They have a duty to ensure this is conducted without risks to themselves or others.

Syngas

Syngas or 'synthetic gas' is a name of any fuel gas mixture derived from combustible materials, either solid or gaseous. In view of the conventional combustion technologies syngas is mainly derived from biomass or solid waste products (RDF, MSW, sludges,…). Its composition depends on the source material/fuel and its energy content, but in general consists mainly of combustible gases Hydrogen (H_2), Carbon monoxide (CO), Methane (CH_4) and some other higher-order Hydrocarbons (C_xHy), and non-combustible gases, mainly Carbon dioxide (CO_2) and Nitrogen (N_2).

One should note that any combustion of combustible or flammable materials, whether it is solid, liquid or gaseous, produces synthetic gas under certain conditions, i.e. oxygen deprived / sub-stoichiometric process, lower combustion/gasification temperatures.

Quality of syngas depends on its a) energy content and b) its cleanliness.

a) Energy content of the syngas depends mainly on the source material, i.e. biomass, RDF/MSW, sludge, etc. and its energy content (which heavily depends on moisture and ash content) and the process the material has gone through, i.e. combustion, gasification, pyrolysis.

In general, the rule is the 'higher the energy content of source fuel, the higher the energy content of the syngas will be'. Syngas derived from biomass and RDF can in general have following energy contents based on the process involved:

Partial gasification	2-5 MJ/Nm^3
Full gasification	4-8 MJ/Nm^3
Pyrolysis	8-15 MJ/Nm^3

It should be noted that it is possible to derive syngas with higher energy content, i.e. above 13-15 MJ/Nm3 with appropriate Pyrolysis technology/process and if fuel prepared for the process is of suitable quality (low moisture and ash content).

11 KEY LEGISLATIVE INFORMATION

Information on UK health and safety legislation and guidelines mentioned in the sections below can be found on the HSE website (www.hse.gov.uk). In many cases, HSE also provides open learning guidance to these subjects. Electronic downloads or printed copies of actual legislation can be obtained from; www.legislation.gov.uk.

National variations on the legislation and regulations can apply in Northern Ireland, Wales and Scotland so please check your local government regulations and HSE guidance.

11.1 Construction (design and management)

Due to the duration of a typical installation, it is highly likely that the construction of many biomass systems will be under the control of the Construction (Design and Management) Regulations 2007 (CDM regulations). For the purposes of these regulations, a project is notifiable if the construction phase is likely to involve more than:

- 30 days; or
- 500 person days of construction work.

The key aim of the CDM regulations is to integrate health and safety into the management of the project and to encourage everyone involved to work together to:

- improve the planning and management of projects from the very start,
- identify hazards early on, so they can be eliminated or reduced at the design or planning stage and the remaining risks can be properly managed,
- target effort where it can do the most good in terms of health and safety,
- discourage unnecessary bureaucracy.

These regulations are intended to focus attention on planning and management throughout construction projects, from design concept onwards. The aim is for health and safety considerations to be treated as an essential, but normal part of a project's development – not an afterthought or bolt-on extra, hence their great relevance to this document.

Whilst simple in concept, the description of such an integrated approach is necessarily complex but not productive to repeat the regulations here. Clients and designers should carefully read *L144 Approved Code of Practice Managing Health and Safety in Construction.* This is downloadable from the Health Executive's web site; www.hse.gov.uk. Particularly relevant in the context of biomass are Sections 138 and 143 of this document.

In Section 138, regular reviews of the design involving all members of the design team are promoted to make sure that proper consideration is given to buildability, usability and maintainability. When considering 'buildability', meetings should include the contractor so that difficulties associated with construction can be discussed and solutions agreed before the work begins. When discussing usability and maintainability, involving the client or those who will be responsible for operating the biomass system the will ensure that proper consideration can be given to the health and safety of those who will maintain and use the system once it has been completed. Doing this during the design stage can result in significant cost savings for the client, as rectifying mistakes after the structure has been built is always expensive.

Section 143 indicates that designers don't have to:

- take into account or provide information about unforeseeable hazards and risks,
- design for possible future uses of structures that cannot reasonably be anticipated from their design brief,
- specify construction methods, except where the design assumes or requires a particular construction or erection sequence, or where a competent contractor might need such information,
- exercise any health and safety management function over contractors or others, or
- worry about trivial risks.

All of the risks in this document are considered to be reasonably foreseeable and should therefore be dealt with appropriately.

11.2 Health and safety at work

The Health and Safety at Work etc. Act 1974 (HASAW or HSW) is the primary legislation for occupational health and safety in the UK. The Health and Safety Executive (HSE) is responsible for enforcing the Act. Together with Local Authorities, HSE also enforces Regulations (Statutory Instruments) relevant to the working environment.

HASAW makes provision for:

- securing the health, safety and welfare of persons at work,
- protecting others against risks to health or safety in connection with the activities of persons at work,
- controlling the keeping and use and preventing the unlawful acquisition, possession and use of dangerous substances,
- controlling certain emissions into the atmosphere.

In practice

The hazards in a biomass plant are more complex than in an oil or gas system, and efforts need to be made to reduce the ensuing risks. The regulations listed below assist in the identifying the primary hazards but do not substitute, for example:

- purchasing appropriately third-party certified equipment compliant with relevant standards,
- designing a boiler house in accordance with good engineering practice,
- compiling an operations and maintenance manual which is checked and, where necessary, corrected during commissioning,
- ensuring the plant is operated and maintained by trained personnel.

11.3 Provision and use of work equipment

The Provision and Use of Work Equipment Regulations 1998 (PUWER) requires that equipment provided for use at work is:

- suitable for the intended use,
- safe for use, maintained in a safe condition and, in certain circumstances, inspected to ensure this remains the case,
- used only by people who have received adequate information, instruction and training,
- accompanied by suitable safety measures, e.g. protective devices, markings, warnings.

In practice

These regulations will, among other things, be relevant for the use of power tools for cleaning boiler heat exchangers and for shovels as well as for the operation of the boiler and fuel handling equipment.

11.4 Lifting operations and equipment

The Lifting Operations and Lifting Equipment Regulations 1998 (LOLER) requires that any lifting equipment used at work for lifting or lowering loads is:

- strong and stable enough for particular use and marked to indicate safe working loads,
- positioned and installed to minimise any risks,
- used safely, i.e. the work is planned, organised and performed by competent people,
- subject to ongoing thorough examination and, where appropriate, inspection by competent people.

In practice

The regulations are complex and any fork-lift truck or any overhead crane or other lifting device would need full LOLER compliance. However due to their good safety record, the document entitled *LOLER: How the Regulations apply to Agriculture* indicates that “LOLER should have no implications for machines such as foreloaders and telescopic handlers when used for their normal design purpose”. It is felt worth repeating that even these will be required to have full LOLER if they are used for any other purpose than handling bulk solid fuel within their design parameters.

11.5 Machinery safety directive

The Supply of Machinery (Safety) Regulations 2008 place duties upon those who bring machinery and safety components to the market, or put it into service in the UK and sets out the essential requirements which must be met.

There are four steps to meet the requirements:

- The responsible person should ensure that machinery and safety components satisfy the relevant essential health and safety requirements of the Supply of Machinery (Safety) Regulations 2008 and that, where appropriate, relevant conformity assessment procedures have been carried out.
- The responsible person must issue a Declaration of Conformity (or a Declaration of Incorporation) with the finished product so that it is available to the user (or final machine assembler). This will contain various details such as the manufacturer's address, the machinery type and serial number, and the harmonised European or other standards, used in design.
- When the first two steps have been satisfactorily completed, the responsible person, or person supplying or assembling or putting into service the final product, should affix the CE mark if they are satisfied it is safe.
- When machinery is placed on the European market, user instructions must accompany it in the language of the end user. In the case of partly completed machinery (PCM), instructions for the assembly of the PCM must be supplied.

The European Commission has published the first of a series of guides to the machinery safety directive (Guide to application of Directive 2006/24/EC). It explains the scope and clarifies the application of the directive to machinery and other equipment included within the definition of 'machinery', in particular in relation to other product safety directives. See http://ec.europa.eu.

In practice

These regulations relate to the design of equipment and following the manufacturers' installation instructions is likely to provide compliance.

The key risk in biomass plant is rotating and moving machinery. The simplest rule is to guard exposed parts, unless a clear working statement (and if necessary, a permit to work system) ensures locking off before entry into the hazardous workspace.

11.6 Pressure system safety regulations

The Pressure Systems Safety Regulations 2000 (PSSR) require that anybody who designs, or supplies or operates any pressure system shall ensure it is properly designed, constructed and maintained, to prevent danger.

In practice

The regulations only apply to 'relevant fluids' which are steam at any pressure, and any gas (including natural gas), liquid petroleum gas (LPG) or similar at a pressure greater than 0.5bar. They do not apply to ordinary hydraulic heating systems or sanitary water systems filled with water and operating below 100°C, although such systems should comply with *Building Regulations G3: Hot water supply and systems*. Legal compliance with G3 is not required within industrial premises but the concepts contained are very useful in producing a safe design.

Where a biomass boiler is to provide steam, full compliance with PSSR especially with respect to blow-down systems is required. Some designs of biomass boiler have much larger thermal mass than their equivalent oil or gas unit. PSSR in particular will require management of this heat such that the system remains safe at all times.

Modified, stayed, hot water boiler designs, (generally rated to 8barg) which have been pressed into service as steam boilers, have proven particularly susceptible to inadequate bottom blowdown (mud blowdown) where the design makes it particularly difficult to create sufficient flow inertia to clear the "mud" adequately. Multiple bottom blowdown locations may be required.

Details of the necessary systems are considered beyond the scope of this document.

11.7 Pressure equipment (Safety) regulations

The Pressure Equipment Regulations 1999 (PER*) as amended by the Pressure Equipment (Safety) Regulations 2016* require that all pressure vessels placed on the market within the EU shall be CE marked and 'in fact safe'.

In practice

Similar to the PSSR regulations, these do not apply to low pressure warm water systems and the purchase of CE marked boilers and pressurisation systems from reputable manufacturers will ensure compliance. Large (>200mm pipework) or high pressure (>10bar) hot water systems and all steam systems are included.

11.8 Work at height

The Work at Height Regulations 2007 (WAH) address all aspects of work at height including the selection and use of work equipment, and the way the work is planned, organised and managed. The regulations are intended to minimise the risk of falls whilst working at height, which is one of the most common causes of fatalities and injuries at work.

In practice

Even falls from relatively low heights can be serious. In practice, the regulations can apply to (falling from) an elevated object as well as (falling into) a hole such as a fuel bunker.

All plant must be inspected and method statements introduced which ban working above, or adjacent to, any drop where the operative can lose control of their balance and fall. Some simple rules of thumb include:

- Never allow the use of unsecured ladders anywhere on a biomass plant.
- Never allow walking on metal surfaces (especially painted surfaces) adjacent to drops, except on horizontal chequer plate surrounded by handrails and kicking straps. This is particularly relevant for bunker tops.
- Grilles of a suitable aperture can prevent falls into a bunker. Screens should be just large enough to allow passage of the biomass fuel but not, say, an operative's foot.

11.9 Manual handling operations

The Manual Handling Operations Regulations 1992 (as amended 2002) apply to a wide range of manual handling activities, including lifting, lowering, pushing, pulling or carrying. The guidance on the regulations (L23) gives useful practical advice for employers, managers, safety representatives and individual employees on how to reduce the risk of injury from manual handling.

In practice

These regulations will, for example, be relevant in the context of:

- Grate and fly ash bins.
- Hatches and doors.

  It is very important that hatches (often fabricated from steel) can be safely manhandled back into position such that closing bolts can be started on their threads. Consider the use of a hinge or small davit with chain for any access plate in excess of 15kg.
- Shovelling chip or pellet biomass.

11.10 Confined spaces

The Confined Spaces Regulations 1997 defines a confined space as a place that is substantially enclosed (though not always entirely), where serious injury can occur from hazardous substances, or conditions within the space or nearby (e.g. lack of oxygen).

In practice

These regulations are very relevant to biomass systems. Please see section 6.2 for further information.

11.11 Control of hazardous substances

The Control of Substances Hazardous to Health Regulations (COSHH) is the law that requires employers to control substances that are hazardous to health. You can prevent or reduce workers' exposure to hazardous substances by:

- finding out what the health hazards are,
- deciding how to prevent harm to health (risk assessment),
- providing control measures to reduce harm to health,
- making sure they are used,
- keeping all control measures in good working order,
- providing information, instruction and training for employees and others,
- providing monitoring and health surveillance in appropriate cases,
- planning for emergencies.

Most businesses use substances, or products that are mixtures of substances. Some processes create substances that could cause harm to employees, contractors and other people.

In practice

Fly ash, soot, and boiler and chimney deposits are all well-known and proven carcinogens. Additionally, exposure to dust arising from fuel deliveries can have adverse consequences for health. Where possible designs and working practices should aim to eliminate or reduce the levels of these substances. Where residual levels of these substances are still present, operatives should wear appropriate dust masks and overalls, and should wash after significant exposure.

11.12 Dangerous substances and explosive atmospheres

The Dangerous Substances and Explosive Atmospheres Regulations 2002 (DSEAR) places duties on employers to protect people from risks to their safety from fires, explosions and similar events in the workplace. This includes members of the public who may be put at risk by work activity.

Dangerous substances are substances used or present at work that could, if not properly controlled, cause harm to people because of a fire or explosion. They can be found in nearly all workplaces and include such things as solvents, paints and varnishes, flammable gases such as liquid petroleum gas (LPG), dust from machining and sanding operations, and dust from foodstuffs.

Employers must:

- find out what dangerous substances are in their workplace and what the fire and explosion risks are,
- put control measures in place to either remove those risks or, where this is not possible, control them,
- put controls in place to reduce the effects of any incidents involving dangerous substances,
- prepare plans and procedures to deal with accidents, incidents and emergencies involving dangerous substances,
- make sure employees are properly informed about, and trained to control or deal with the risks from, the dangerous substances,
- identify and classify areas of the workplace where explosive atmospheres may occur and avoid ignition sources (e.g. from unprotected equipment) in those areas.

In practice

These regulations primarily cover the formation and/or escape of gas and subsequent hazardous ignition.

The risk of release and then explosion of delayed "over bed" ignition gas into the boiler house (i.e. from inside the boiler to outside the boiler) where it is subsequently ignited by a secondary source (e.g. a luminaire) is considered negligible and from the perspective of the biomass installation the boiler house would not normally need to be an electrically zoned area.

The only significant risk is the explosion of dust from degraded pellets in the fuel storage. If the boiler house contains other fuels or risks then electrical zoning may be become relevant.

Carbon monoxide (CO) is a serious risk factor in enclosed spaces such as a poorly ventilated fuel store or boiler house.

11.13 The Environmental Permitting (England and Wales) (Amendment) Regulations 2018

All combustion plants rated between 1 MW and 50 MW nett rated thermal input will be required to comply with the Medium Combustion Plant (MCP) Directive which has been transposed into UK legislation through changes to *The Environmental Permitting (England and Wales)(Amendment) Regulations 2018, The Pollution Prevention and Control (Scotland) Amendment Regulations 2017*, and *The Pollution Prevention and Control (Industrial Emissions) (Amendment) Regulations (Northern Ireland) 2018*.

This legislation requires the registration of all new combustion plants put into first use after 19 December 2018 and the registration of existing combustion plant before 1/1/24 for plants individually 5 MW and above, and 1/1/29 for plants rated from 1 MW to <5 MW. Where more than one new plant is on a site the new plants will be aggregated to a single MCP.

From the date of first use (in the case of new plants) and from 1/1/25 (for existing 5-50 MW plants) and 1/1/30 (for existing 1-5 MW plants) the emissions from those combustion plants must not exceed specified emission limit values (ELV) for NOx, SOx and dust (total particulates), and these will be measured at specified intervals along with CO (no limits currently set for CO).

Plants rated 20 MW and above will be measured annually, and plants below 20 MW will be measured every 3 years. Measurements are defined at a temperature of 273,15 K, a pressure of 101,3 kPa and after correction for the water vapour content of the waste gases and at a standardised O2 content of 6 % for medium combustion plants using solid fuels.

Biomass plants will have to comply with tight emissions limits (all in mg/Nm^3) and other permit conditions, using secondary abatement systems if necessary:

pollutant	**Existing 1-5MW boilers from 1/1/30**	**Existing 5-50MW boilers from 1/1/25**	**new 1-50MW boilers from 19/12/18**
SOx	200mg (300 for straw) (N/A if exclusively woody biomass)	200mg (300 for straw) (N/A if exclusively woody biomass)	200mg (N/A if exclusively woody biomass)
NOx	650mg	650mg	300mg for 5-50MW 500mg for 1-5MW
dust	50mg	30mg for 20-50MW 50mg for 5-20MW	20mg for 20-50MW 30mg for 5-20MW 50mg for 1-5MW

Local Authorities may impose tighter limits in areas with poor air quality.

The Environment Agency (EA) in England and their equivalents in the devolved UK administrations will administer the new legislation and will consult with Local Authorities where there may be a combustion plant in or close to a Local Air Quality Management zone. This may mean tighter ELVs will be applied. Sites that currently have environmental permits for other activities will have any MCPs added to their permits at the due date.

The EA have produced detailed guidance on how these regulations will be applied.

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12 REFERENCES AND FURTHER READING

The following is a list of applicable documents current at the time of preparation of this publication.

This is an indicative, not comprehensive list.

- Free copies of all legislation are available from www.legislation.gov.uk
- Legislation marked with an asterisk (*) is supported by Approved Codes of Practice and Guidance (ACoP) published by HSE.
- Legislation marked with a double asterisk (**) is supported by more than a single ACoP

1. Pressure Systems Safety Regulations (PSSR)*
SI 2000 No. 128 (SI 2004 No. 222 in Northern Ireland)

2. Pressure Equipment (Safety) Regulations (PER)
SI 2016 No. 1105

3. Health and Safety at Work etc Act 1974 (HSWA, HASAW or HSW)

4. Management of Health and Safety at Work Regulations (MHSWR)
SI 1999 No. 3242

5. Provision and use of Work Equipment Regulations (PUWER)*
SI 1998 No. 2306 (SI 1999 No. 305 in Northern Ireland)

6. Construction (Design and Management) Regulations (CDM)*
SI 2015 No. 51 (SI 2016 No. 146 in Northern Ireland)

7. Control of Substances Hazardous to Health Regulations (COSHH)*
SI 2002 No. 2667 (SI 2003 No. 34 in Northern Ireland)

8. Dangerous Substances and Explosive Atmosphere Regulations (DSEAR)**
SI 2002 No. 2776 (SI 2003 No. 152 in Northern Ireland)

9. Lifting Operations and Lifting Equipment Regulations (LOLER)*
SI 2998 No. 2307 (SI 1999 No. 304 in Northern Ireland)

10. Confined Spaces Regulations 1997*
SI 1997 No. 1713 (SI 1999 No. 13 in Northern Ireland)

11. Work at Height (Amendment) Regulations 2007 (WAH)*
SI 2007 No. 114 (SI 2007 No. 135 in Northern Ireland)

12. The Supply of Machinery (Safety) (Amendment) Regulations
SI 2011 No. 2157

13. Personal Protective Equipment at Work Regulations*
SI 1992 No. 2966 (SI 1993 No. 20 in Northern Ireland)

14. Manual Handling Operations Regulations*
SI 1992 No. 2793 (SI 1992 No. 535 in Northern Ireland)

15. Building Regulations 2010 Combustion appliances and fuel storage systems
Approved Document J
ISBN 978 1 85946 680 3

16. Five steps to risk assessment leaflet (INDG 163)
http://www.hse.gov.uk/pubns/indg163.pdf

17. HSG103 (Second edition) Safe handling of combustible dusts: Precautions against explosions

18. BS EN 303-5 1995 Heating boilers for solid fuels, hand and automatically fired, nominal heat output of up to 300 kW

19. BS EN 12952-1:2015 Water-Tube boilers and auxiliary installations

20. BS EN 12953-4:2018 Shell boilers. Workmanship and construction of pressure parts of the boiler

21. Low Voltage Directive (LVD) 2014/35/EU

22. Electromagnetic Compatibility (EMC) Directive 2014/30/EU

23. Machinery Safety Directive 2006/42/EC

24. Pressure Equipment Directive (PED) 2014/68/EU

25. Boiler Efficiency Directive (BED) 92/42/EEC

26. Construction Products Directive (CPD) 89/106/EEC *Note: Construction Products Directive was withdrawn and replaced by the Construction Products Regulation (305/2011/EU).*

27. L5 (Sixth edition) Control of substances hazardous to health . The Control of Substances Hazardous to Health Regulations 2002 (as amended). Approved Code of Practice and guidance

28. L22 (Fourth edition) Safe use of work equipment. Provision and Use of Work Equipment Regulations 1998. Approved Code of Practice and guidance

29. L23 (Fourth edition) Manual handling. Manual Handling Operations Regulations 1992. Guidance on Regulations

30. L25 (Second edition) Personal protective equipment at work. Personal Protective Equipment at Work Regulations 1992. Guidance on Regulations

31. L101 (Third edition) Safe work in confined spaces. Confined Spaces Regulations 1997. Approved Code of Practice and guidance

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33. L122 (Second edition) Safety of pressure systems. Pressure Systems Safety Regulations 2000. Approved Code of Practice and guidance

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35. L153 (First edition) Managing health and safety in construction. Construction (Design and Management) Regulations 2015. Guidance on Regulations

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37. BG02 Guidance on Safe Operation of Hot Water Boilers (LTHW – HTHW)

38. BG03 Blowdown Systems, Guidance for Industrial Steam Boilers

39. BG04 Boiler Water Treatment, Guidance for Shell Boilers, Coil Boilers, Steam Generators and Hot Water Boilers

40. BG06 Hot Wells and De-aerators, Guidance for Industrial Installations.

41. BG08 Temporary Steam and Hot Water Boiler Plant, Guidance for Safe Installation and Use.

42. BS 845-2: 1987 Methods for assessing thermal performance of boilers for steam, hot water and high temperature heat transfer fluids.

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