Health and safety in biomass systems

Design and operation guide

Combustion Engineering Association

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Supported by

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Contents

Preface **1**

1 Introduction **3**

1.1 The biomass system
1.2 Aims and objectives

2 Health and safety in design and operation **7**

2.1 Legislation and regulations
2.2 Fundamentals of health and safety in design and operation

3 Biomass system risks **11**

3.1 Fuel delivery
3.2 Fuel storage and handling
3.3 Boiler and combustion

4 Biomass fuel delivery **14**

4.1 Tipping
4.2 Bulk bags
4.3 Pneumatic

5 Biomass fuel storage **17**

5.1 General arrangement
5.2 Confined spaces
5.3 Fuel level detection
5.4 Slips and falls
5.5 CO alarm
5.6 Electricity
5.7 Mechanical load
5.8 Mechanical risks
5.9 Water ingress
5.10 Feed failure
5.11 Dust explosion
5.12 Fuel storage fire

6 Biomass boiler and combustion **26**

6.1 Safe entry into boilers
6.2 Wet side explosion risks
6.3 Fire side explosion risks
6.4 Fire safety
6.5 Flue and chimney

7 Training and documentation **33**

7.1 Staff training
7.2 Documentation

8 Key legislative information **37**

8.1 Construction (design and management)
8.2 Health and safety at work
8.3 Provision and use of work equipment
8.4 Lifting operations and equipment
8.5 Machinery safety directive
8.6 Pressure system safety regulations
8.7 Pressure equipment regulations
8.8 Work at height
8.9 Manual handling operations
8.10 Confined spaces
8.11 Control of hazardous substances
8.12 Dangerous substances and explosive atmospheres

9 Appendix Useful Approved Codes of Practice **44**

Preface

This health and safety guide is written for 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. They have a number of legal responsibilities 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.

- **Clients** (an organisation or individual who undertakes or instructs design or construction work or has such work carried out for on their behalf) are 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.
- **Operators** will run, and may maintain the installation on a day-to-day basis and have a duty to ensure this is conducted without risks to themselves or others.

The concepts governing safe design and operation are the same regardless of project size, from the smallest domestic 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.

Health and safety considerations for biomass systems that are important for clients, operators or those involved in maintenance are summarised at the end of relevant chapters in a yellow box.

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About the Combustion Engineering Association

This guide is published by the Combustion Engineering Association (CEA), an educational charity that seeks to promote the science of combustion engineering and to promote best practice. The membership comprises the major fuel and energy producers/refiners covering oil, gas, coal, and biomass, the makers and suppliers of combustion engineering equipment and academic institutions concerned with the combustion engineering process.

1 Introduction

As fossil energy resources decline and fuel costs rise, the development of biomass systems in the UK expands, supported by measures such as the Renewable Heat Incentive and the Renewables Obligation. The rapid development of this industry has a positive environmental impact but, increasingly, there are questions over the safety of biomass systems. 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.

Conventions

This guide uses the following conventions when referring to:

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 (see next section).

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.

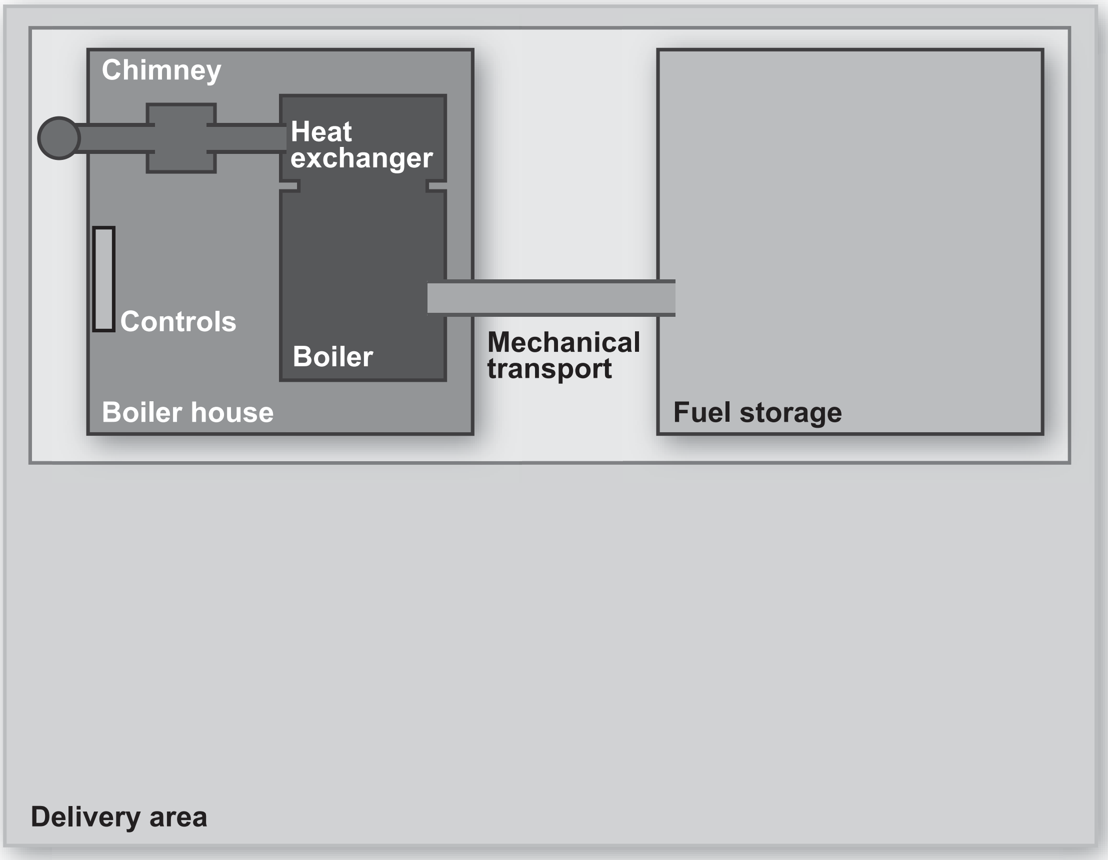
Method statement
A document describing the way a task or process is to be completed (also known as a safe work procedure or a standard operating procedure).

1.1 The biomass system

Burning wood may pre-date the use of other, fossil fuels, but in the UK only in the past five to ten years have purpose built biomass systems with equivalent functions to industrial sized coal, gas or oil fired plants 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 pipe 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
Also a solid, coal has comparable risks to biomass and most boiler plant does require some form of manual supervision. There is a geological age continuum; anthracite, bituminous coal, brown coal, peat and finally biomass, but the different combustion characteristics of these fuels make the use of specialised equipment necessary.

1.2 Aims and objectives

This guide aims to:

- Make designers aware of the hazards and risks involved in the development of biomass systems.
- Bring clients up to date with the health and safety issues involved with the daily running of biomass plant.
- Promote the thought processes and good practice that will result in safer design and operation of biomass systems.

The guide's objectives are to:

- Bring together, in one publication, considerations of basic relevant health and safety information for biomass systems.
- Provide information about hazards and risks for the various components of biomass systems.
- Inform readers of current UK legislation and relevant health and safety guidelines.

Outside the scope of this guide is:

- 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 Regulations 1999* (PER).
- Installations where any fuel is pulverised. The hazard of dust explosions presented by such systems requires special design and operating criteria.

This guide concentrates upon the unique issues associated with the design, construction, operation and maintenance of biomass systems and can inform a site/

project specific risk assessment. Risks associated with any system for hot water distribution, or steam generation and use, will be very similar to those within a conventional system are not covered in this guide.

Some of the principles of this guide may apply to other biomass products (such as straw and miscanthus), but when making such an extrapolation great care must be taken that any risks associated with novel aspects of the fuel are also covered.

Overview of chapters

2 Health and safety in design and operation
The focus in this chapter is on the process of hazard identification and elimination, and risk assessment and reduction.

3 Biomass system risks
This second chapter provides a brief qualitative overview of the operation of biomass systems and ways to eliminate hazards and reduce risks.

4 Biomass fuel delivery
The hazards and risks are considered in more detail for the delivery of biomass fuel and the implications for design and operation.

5 Biomass fuel storage and handling
Fuel storage and handling has hazards and risks, which need consideration in design and operation and are looked at more closely in this chapter.

6 Biomass boiler and combustion
Hazards and risks arising from the combustion process and the working of the biomass boiler are described in more detail with reference to aspects of design and operation.

7 Training and documentation
This chapter highlights the importance of operative training and the operations and maintenance manual.

8 Key legislative information
The final chapter examines the key statutory regulations applicable to the procurement, design or operation of biomass systems. The appendix expands this information, listing a number of relevant Approved Codes of Practice (ACOPs).

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 *Health and Safety at Work etc. Act 1974* 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 (ACOPs).

The most important overarching legislation in the UK is the *Health and Safety at Work etc. Act 1974* (HASAW), which, together with the *Construction (Design and Management) Regulations 2007* (CDM regulations), applies to all biomass systems.

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 4[1]) and, in the process of design, co-operate 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 work activity expected. 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 the 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.

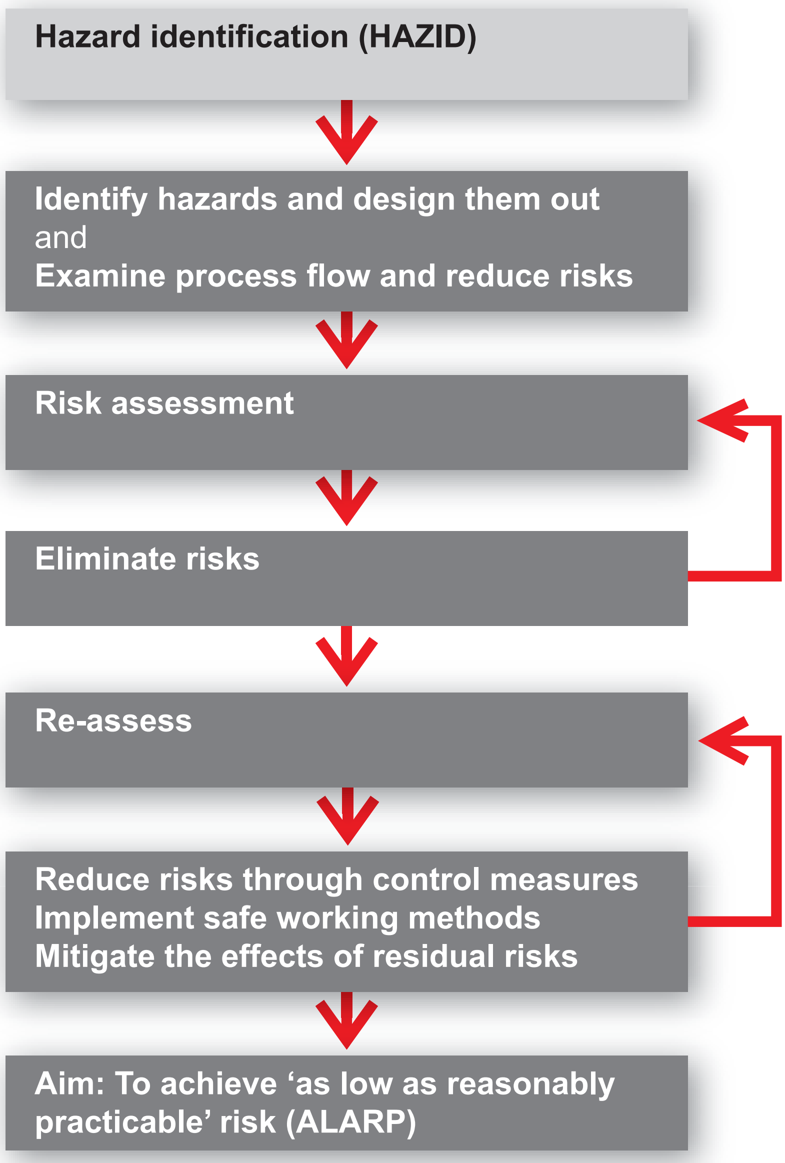
1 **http://www.hse.gov.uk/pubns/priced/l144.pdf** - paragraphs 193 to 222

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.



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.

Eliminate hazard first

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

- Confined 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 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, 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 (in acronym form; 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.

HSE provides a series of articles on this subject (*ALARP Suite of Guidance*) on its website; **www.hse.gov.uk**.

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. Section 7.1 – Staff training, is also relevant.

3 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 by independent experts are compulsory in some countries but not in others.

The supply of a number 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 or observed in the installation instructions, which apply in the country of origin.

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

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

3.1 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 level fuel storage has risks of falling from height.
- Fuel storage of any kind is considered a confined 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.

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 auto-ignition (spontaneous combustion).
- Finer fuels tend to give greater risk of dust explosion.

See Chapter 4 – Biomass fuel delivery, for a detailed description.

3.2 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.

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.

See Chapter 5 – Biomass fuel storage, for a detailed description.

3.3 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 Regulations 1999* (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 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.

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 gasification and the production of potentially explosive gas mixtures on a large static fire bed of considerable depth and area while oil or gas combustion employs essentially a transient flame. Due to the different combustion process, biomass boilers cannot be fitted with the same levels of interlocks as gas or oil 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. There is anecdotal evidence of a significant number of these having occurred in the UK, in some cases resulting in blown-out boiler house windows and doors or even blown-open boiler hatches. Correct operating procedures minimise this hazard but its presence cannot 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. 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 suggest that this is considered as best practice within design.

Combined heat and power

This guide excludes the additional risks from power generation, which are very similar to those associated with any other power generating systems. All types of CHP plant are considered out of scope for this guide.

See Chapter 6 – Biomass boiler and combustion, for a detailed description.

4 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 too produce method statements for delivery and adhere to them.

4.1 Tipping

The access area to a fuel pit or underground fuel store should have a raised up-stand 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 reducing stability.

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

Telehandlers and frontloaders

Some biomass installations are designed to have the delivery lorry tip its content outside the fuel storage and a telehandler or frontloader 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 (see Section 8.4).

4.2 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.

4.3 Pneumatic

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

- robustly constructed from suitable material
- 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 and thus how large such a sock would need to be.

Summary for clients, operators or those involved in maintenance:

- Consider (with the designer) the impact fuel choice has on the size and frequency of delivery and the delivery method.
- Ensure access to fuel reception and storage areas is restricted at all times.
- Conduct a full risk assessment to ensure vehicles can deliver safely.
- Operatives should not be permitted to stand in the tipping zone.
- The risk from bulk bag deliveries needs to be assessed in the context of LOLER.
- Obtain and adhere to method statements for delivery.
- Fuel storage must be vented during pneumatic delivery.
- Suitable electrical earthing precautions must be made for pneumatic delivery.

5 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.

5.1 General arrangement

Most fuel stores will be a confined 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.

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.

5.2 Confined spaces

A confined space is not necessarily a fully enclosed space and many fuel stores will constitute a confined space as defined in the *Confined Spaces Regulations 1997*.

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* (see Section 8.10 and code of practice L101 in the Appendix), the *Work at Height Regulations 2005* (see Section 8.8) and the *Supply of Machinery (Safety) Regulations 2008* (see Section 8.5).

Method statement

A method statement for entering and working in the confined space 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 confined space. The following information can assist with this process.

One of the reasons why accidents occur within confined spaces is because they often look benign to the operative. The access door may look fairly large, the level of fume back 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.

As a result of this, as an absolute minimum, unless at least 50% of the area of any one of the four walls is open to fresh air, all biomass boilers and fans connected to the store should be switched off and left for as long as is required to ensure full gas dispersion before entry is attempted. Two people must be present before entry. If any fumes can be seen or if there is reason to believe any fume back may be occurring (e.g. there is a smell) then entry should not occur until 30 minutes after this has dissipated.

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 confined 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.

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 domestic 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 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.

Scenario 2: Medium risk confined space

Such a bunker could be a large masonry or wooden bunker, or room or teaming well that must 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.

Scenario 3: Low risk confined space

The bunker may have a ventilation window. Such a bunker could be a small masonry or wooden bunker, or an open fuel store where, effectively, entry is not required as at least 75% of the volume can be reached with long handled tools. Alternatively, it could be a large barn or building where the operatives can walk around the stored biomass. The site may be too small to be able to realistically guarantee the calibration of a CO monitor.

This still requires full ventilation with the main entry door prior to entry for a prescribed period of time. (This is despite the louvred window or other opening). The person entering the bunker should make a thorough inspection that there is no sign of fume or smoke back into the bunker. Such fume will be likely to contain CO and will be highly dangerous. The second person should witness the entry procedure, but may not need to be present at all times.

No climbing or clambering is required.

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 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.

5.3 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.

5.4 Slips and falls

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

Even underground fuel stores must be carefully considered in the context of the *Work at Height Regulations 2005* (see Section 8.8) 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. 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 (see Section 5.2).

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.

5.5 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 AD J 2010* (see Chapter 6).

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.

5.6 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). However, 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 in to 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).

5.7 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:

- electric current,
- 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. Concrete bunkers are particularly prone to the problem of cyclic loads as they are less flexible than other structural materials.

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[2], 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**)

5.8 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.

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 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.

2 The (critical) angle of repose is the steepest angle of descent of the slope relative to the horizontal plane when material on the slope face is on the verge of sliding. This angle is given by the number 0°-90°.

5.9 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 confined space of a fuel store.

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.

5.10 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 confined/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.

5.11 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[3] 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,

3 BS EN 14961-1:2010 *Solid biofuels*, defines biomass fuel specification and grades.

- 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[4] 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 web site; **www.hse.gov.uk**.

5.12 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.

4 A "rule of thumb" for sizing this panel that can be used is: $1m^2$ of explosion panel per $6m^3$ of bunker volume.

Only fire alarms that detect high temperature or the rate of temperature rise should be used.

There is minimal risk of fuel storage fires with wood chips as it is generally too wet and much too coarse. A large open stockpile which is too wet or (rarely) too dry requires turning. Unturned and wet wood chips may compost and self-ignite.

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.

Summary for clients, operators or those involved in maintenance:

- Ensure that risk assessments and method statements for the storage of biomass have been prepared.
- Ensure that storage capacity is sufficient and designed for the longest time between deliveries.
- A task specific risk assessment should be prepared and method statement should be used for entering and working in any fuels store or confined space.
- Always ventilate fuel stores before entry.
- Install and use calibrated CO detection in accordance with the manufacturer's instructions.
- Ensure that fuel level can be checked without opening access doors.
- Training for work at height should be provided as appropriate and for fixed ladders.
- It is essential that operators know the condition of air in a fuel store.
- Only electrical equipment that is suitably rated should be used in fuel stores or potentially explosive atmospheres.
- Method statements should be used to identify and implement mechanical and electrical isolation for safe working.
- Operatives should be prevented from investigating fuel obstructions without the preparation of a risk assessment and method statements.
- Ensure that fuels stores are cleaned regularly to prevent dust accumulation.
- Method statements for emergency procedures, including fire, should be prepared and training provided.

6 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 Regulations 1999* (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) 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: 1999[5] (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).

CO monitor

As indicated already in Sections 2.3 and 5.5, a CO monitor is required in the boiler house by the *Building Regulations AD J 2010*. This should be placed at head height on a wall near the boiler, visible from where an operative might be expected to stand and review 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.

6.1 Safe entry into boilers

Boilers should always be regarded 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).

5 Heating boilers. Heating boilers with forced draught burners. Heating boilers for solid fuels, hand and automatically fired, nominal heat output of up to 300 kW. Terminology, requirements, testing and marking

The risk assessment should consider:

- excessive temperature of combustion chamber,
- use of personal protection equipment including breathing apparatus,
- presence of mineral fibre insulation,
- refractory collapse,
- evacuation procedure,
- burner isolation verification.

6.2 Wet side explosion risks

Wet side explosions, involving hot water or steam, are more serious and much more powerful than fire side explosions (see Section 6.3).

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.

The water side should be vented regularly to ensure that air and other gases do not build up inside the boiler as this can cause corrosion.

Pressure relief valve and gauge

Biomass boilers should never be operated without a suitable pressure relief valve(s) 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 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 is required.

6.3 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),
- methane (CH_4), hydrogen (H_2), explosive.

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, 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.

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 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 in the combustion chamber reduces the number of over bed pops and bangs compared to relying on natural draft. 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 in to 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.

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 and CH_4.
- 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.

6.4 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.

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 be disposed of as hazardous waste.

However, 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, a 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, this will be a confined space and 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* (see Section 8.9).

6.5 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.

Efflux velocity cones should not be fitted to the top of chimneys. These are required for coal-fired plant where the fuel had significant sulphur content but this is not the case with biomass.

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 should be checked and cleaned annually by a professional chimney sweep. Waste must be removed to a licensed landfill site as in theory the boiler operator 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.

Ensure (politely!) that the fire brigade understands the risks associated with fires in chimneys – it is best to seal with foam.

Summary for clients, operators or those involved in maintenance:

- A risk assessment and method statement for entry and cleaning of a boiler is essential.
- The correct function of all safety devices including, pressure relief, emergency cooling and air venting systems should be checked in accordance with an approved schedule.
- It must be impossible for the safety devices, including relief valves to be isolated.
- The manufacturer's operational instructions for the boiler should be adhered to at all times.
- Operators should be provided with thorough operating and emergency procedures training, written guidance and appropriate method statements and adhere to these procedures.
- Abnormal start (failed start) procedures should be provided and observed to protect operators.
- Confirm the practical operation of anti burn back equipment.
- Ash and soot are carcinogenic; all cleaning operations require training, method statements and the use of appropriate PPE.
- Chimney and boiler soot must be disposed of as hazardous waste.
- Flue should be checked and cleaned annually.
- Detailed inspection of the flue draft stabiliser should be carried out annually.
- Method statements for emergency circumstances e.g. chimney fires must be drafted.

7 Training and documentation

7.1 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 will 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**.

7.2 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.

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.

Summary for clients, operators or those involved in maintenance:

- Biomass plant requires trained operatives regardless of whether these are employees or externally contracted staff.
- A client has a duty of care to ensure staff are appropriately trained and safeguarded.
- Operatives and maintainers have a duty of care to observe method statements and safe working procedures.
- Operatives should have received accredited boiler operator training.
- All emergency procedures should be published.
- All operatives and maintainers should be trained in emergency procedures.
- A comprehensive operations and maintenance manual should have been prepared and should always be available.
- A plant logbook and service records should be maintained.

8 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 regulation can apply in N Ireland, Wales and Scotland.

8.1 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. The authors strongly advise clients and designers to carefully read L144 Approved Code of Practice *Managing Health and Safety in Construction* (see Appendix). 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 by the authors to be reasonably foreseeable and should therefore be dealt with appropriately.

8.2 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

As explained before, 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.

8.3 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.

8.4 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 (FLT) 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.

8.5 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 marking 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.

8.6 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, any gas (including natural gas), liquid petroleum gas (LPG) or similar. 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. As indicated in Section 6.2 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.

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

8.7 Pressure equipment regulations

The Pressure Equipment Regulations 1999 (PER) 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 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.

8.8 Work at height

The *Work at Height Regulations 2005* (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.
- Grills of a suitable aperture can prevent falls in to a bunker. Screens should be just large enough to allow passage of the biomass fuel but not, say, an operative's foot.

8.9 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 – see Appendix) 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.

8.10 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. See for example Section 5.2 Confined space - Fuel storage and Section 5.1 Safe entry into boilers.

8.11 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. See Section 6.4 Fire safety – Soot and ash handling.

8.12 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. This is considered in Section 5.11 – Dust explosion. 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 confined spaces such as a poorly ventilated fuel store or boiler house. See Section 5.2 – Confined spaces and Section 5.5 – CO alarm.

9 Appendix

Useful Approved Codes of Practice

The Approved Codes of Practice (ACOPs) and guidance documents listed below can be ordered in print format from HSE (**www.hse.gov.uk**) at a cost or downloaded free in PDF format. See the 'Legal reference' list in the HSE full catalogue.

L144 **Managing health and safety in construction**
Construction (Design and Management) Regulations 2007
ISBN 978-0-7176-6223-4

L143 **Work with materials containing asbestos**
Control of Asbestos Regulations 2006
ISBN 978-0-7176-6206-7

L138 **Dangerous substances and explosive atmospheres**
Dangerous Substances and Explosive Atmospheres Regulations 2002
ISBN 978-0-7176-2203-0

L137 **Safe maintenance, repair and cleaning procedures**
Dangerous Substances and Explosive Atmospheres Regulations 2002
ISBN 978-0-7176-2202-3

L136 **Control and mitigation measures**
Dangerous Substances and Explosive Atmospheres Regulations 2002
ISBN 978-0-7176-2201-6

L135 **Storage of dangerous substances**
Dangerous Substances and Explosive Atmospheres Regulations 2002
ISBN 978-0-7176-2200-9

L134 **Design of plant, equipment and workplaces**
Dangerous Substances and Explosive Atmospheres Regulations 2002
ISBN 978-0-7176-2199-6

L131 **Approved classification and labelling guide** (Sixth edition)
Chemicals (Hazard Information and Packaging for Supply) Regulations 2002 (CHIP 4)
ISBN 978-0-7176-6370-5

L127 **The management of asbestos in non-domestic premises**
Regulation 4 of the Control of Asbestos Regulations 2006
ISBN 978-0-7176-6209-8

L122 **Safety of pressure systems**
Pressure Systems Safety Regulations 2000
ISBN 978-0-7176-1767-8

L113 **Safe use of lifting equipment**
Lifting Operations and Lifting Equipment Regulations 1998
ISBN 978-0-7176-1628-2

L101 **Safe work in confined spaces**
Confined Spaces Regulations, 1997
ISBN 978-0-7176-6233-3

L56 **Safety in the installation and use of gas systems and appliances**
Gas Safety (Installation and Use) Regulations 1998
ISBN 978-07176-1635-0

L24 **Workplace health, safety and welfare**
Workplace (Health, Safety and Welfare) Regulations 1992
ISBN 978-0-7176-0413-5

L23 **Manual handling**
Manual Handling Operations Regulations 1992 (as amended)
ISBN 978-0-7176-2823-0

L22 **Safe use of work equipment**
Provision and Use of Work Equipment Regulations 1998
ISBN 978-0-7176-6295-1

L21 **Management of health and safety at work**
Management of Health and Safety at Work Regulations 1999
ISBN 978-0-7176-2488-1

L5 **Control of substances hazardous to health** (Fifth edition)
The Control of Substances Hazardous to Health Regulations 2002 (as amended)
ISBN 978-0-7176-2981-7

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