SERIES 14

CPD fundamentals

THE CONTINUING PROFESSIONAL DEVELOPMENT PROGRAMME

EiBI

"Energy in Buildings and Industry and the Energy Institute are delighted to have teamed up to bring you this Continuing Professional Development initiative"

MARK THROWER MANAGING EDITOR

energy institute

SERIES **14** | MODULE **01** | **BIOMASS**

Designing biomass safely

By Alastair Nicol, director of Element Consultants Ltd

The raft of health and safety legislation in the UK surrounding biomass boilers places onerous duties of care on the manufacturer of equipment, those integrating assemblies of equipment (installers who have conducted design) and specifically consultants advising installers. These duties of care require formal consideration of the foreseeable use and importantly misuse of equipment placed on and sold into the UK market.

A safe system of work is arguably therefore one where unsafe operating conditions will be prevented from occurring, when foreseeable use or misuse of the system has taken place. Is it foreseeable that a boiler operator will not always conduct checks? Is it then acceptable that a boiler will present an explosion risk if the boiler operator did not carry out checks? To fulfil the letter and indeed the intent of health and safety legislation in the UK (and European law) the system must incorporate fail safe mechanisms.

There have been at least three serious and potentially fatal biomass boiler explosions in the last 12 months. The nature, location and the exact mechanisms of failure must currently remain confidential but in the interests of safety and the promulgation of good practice the basic facts are considered.

In all three cases these explosions were smoke deflagrations. These explosions (very rapid transit of a flame front with allied pressure wave) represented three interesting scenarios, an overbed explosion, a fuel supply system explosion, and a flue explosion.

The release of energy in all cases was destructive and caused the projection of heavy boiler, flue or fuel system components (in one case weighing hundreds of kg) with

secondary damage. In two cases there was the potential for fatality had personnel been present- in a further third case personnel were present and whilst there was the potential for a fatal outcome - the staff escaped injury.

The explosions had certain combinations of factors that would make explosion almost inevitable, namely:

• Syngas smoke side explosions;• conditions arising after hot start (or effective hot start);

• inadequately considered control strategies;

• inadequate physical protection;• inadequate training; and

• inappropriate (but foreseeable) operator intervention or lack of intervention.

Smoke explosion requires the prerequisite mixture of carbon monoxide (primarily), other products of pyrolysis, and air at some point within the upper and lower explosive limits of that mixture and an ignition source or the attainment of an auto ignition temperature. Note that whilst the LEL (lower explosive limit) of CO maybe 12.5 per cent this will reduce in the presence of water vapour and reduce with temperature. The LEL of the syngas maybe a third of the LEL of CO and the conditions for explosion depend the interaction of moisture content and other products of pyrolysis.

There are two scenarios (et al) that give rise to a difficult but foreseeable situation. A grate fired biomass boiler is operated at high fire, but suddenly or rapidly reduced to low fire for an extended period with significant fuel already charged (arguably a control strategy failure) - this will result in the evolution of syngas in the boiler and flue system.

There also exists the potential to generate large quantities of explosive syngas without necessarily the flame front required to burn this in a

Produced in Association with energy institute controlled manner. This occurs if the boiler is started from hot, there is fuel charged to the grate and where there is pre-existing incandescent material or excessive heat, but no ignition of the syngas that will be evolved.

The control of gas air mixture and the physical establishment of ignition are of paramount importance under these circumstances and the control systems must manage these scenarios safely.

The syngas eventually fills the flue system. The consistency of mixture e.g. the ratio of carbon monoxide to air is not necessarily the same throughout the flue system. However, if at some point a flame front travels through the mixture it will transit zones of varying stoichiometry and flame speed eventually reaching a point where the mixture is not capable of combustion and where the shockwave ahead of the flame front was dissipated.

This gas is predominantly carbon monoxide but potentially hydrogen and other products of pyrolysis including tars, hydrocarbon vapours and water vapour. The LEL of carbon monoxide is approximately 12.2 per cent for these conditions but the vapour /gas mixture could have a significantly lower LEL exacerbated by the temperature which will reduce the LEL. The presence of water vapour in the flue gas will act as an accelerant in the case specifically of carbon monoxide at low concentrations because the water vapour supplies hydroxide and hydrogen atoms required for combustion. The moisture content of the fuel may be instrumental in determining the LEL and upper explosive limit (UEL) and the rate of flame propagation at lower concentrations of CO but it is not the primary cause of explosion. A minimum oxygen concentration of 5 per cent (4 per cent according to TRD) in the total flue gas mix is required but this is relatively low compared with most fuels.

It is probably worth pointing out that if the pyrolysis/gasification process has produced a range of tar vapours and intermediates at temperature, the LEL might fall well below 12.5 per cent and the minimum oxygen content for the mixture may drop to a few per cent with elevated temperature. In summary, the risk from explosion is present unless there is controlled combustion on the grate and management of the flue contents. These are smoke explosions and not simply a carbon monoxide explosion.

In one case, the operator had evolved a new procedure to overcome inappropriate design after the second explosion. It can be argued the original and revised procedures retain severe risk for the operators. The problem was arguably simple failure on the part of the manufacturer and the seller to understand or observe their legal duties of care.

What lessons are to be learned? Inspection for first use under the pressure systems safety regulations (PSSR) should consider control but might not necessarily have considered the risk from a smoke side explosion.

In purchasing a boiler plant for manufacture or perhaps particularly from the systems integrator (who may have consultants designing for them) it is imperative that they comprehend the provisions of law governing design and that foreseeable use and misuse are adequately addressed in a formal design hazard identification process with the risk being managed thereafter. A simple reliance on operator intervention is not going to stand much scrutiny! Human nature is what it is.

Interlocked safeguards (physical control measures) have to be used where practical to prevent these foreseeable circumstances from occurring or manage the circumstances so that safe intervention can be made.

Unsafe circumstances should be avoided by ensuring that well considered operating practice is evolved. Operating procedures should evolve based on safety and not around optimal commercial practice which are subsequently window dressed.

Fuel feed must be inhibited on the basis of combustion space temperature, rate of rise of temperature, physical flame detection – or combinations of these, to supplement the inhibition of fuel charge on falling oxygen level (where fitted). Charging other than that required for ignition should not be permitted until a sufficiently high operational temperature is detected.

Restart and hot start should be enabled only after a predetermined purge period and with auto ignition. The flue gas content/condition must be determined because the purge action or natural draft may actually result in continued pyrolysis/gasification on the grate. Effective purging will only be achieved with the operation of an ID fan. Confirmation of the purged condition must be assured because unlike gas where the fuel air mix can categorically be stopped during purge –purging may exacerbate the evolution of combustible products.

Reliance on an oxygen reading from an O_2 probe to determine the likelihood of explosive mixture is not a reliable test where for example fuel is being pyrolysed as opposed to gasified. This is because an explosive mixture of syngas could be generated with very low equivalent CO threshold. On the other hand, the use of O_2 reading to determine a trend toward combustion conditions that may be "rich" and thus prone to the attainment of LEL is useful. As a minimum a combination of temperature and O2 measurement must be used.

BSEN for larger steam boilers give some guidance but do not specifically require CO detection. However, designing to a BSEN does not necessarily guarantee safe design, nor is designing to a BSEN determines that the designer has discharged duties of care for safe design - unless that BSEN is a safety standard. Notwithstanding the provisions of the BSEN good practice might dictate:

- the system must be purged (at least 5 times: the whole combustion, boiler, filters, ducts volume) before start up burner/ignition is operated (the effective subsequent duration of the purge period must be established or else repeated).
- the ID fan should remain operative at all times (at least so long that all remaining fuel is burned out under worst possible conditions and to allow for max amount of fuel with minimal or virtually no combustion air) regardless of boiler status although, only with minimum required draft;• as a matter of good practice CO detection in a flue gas system (in old TRD 604 Sheet 2 annex 1 –safeguarding against unacceptable gas concentrations in the flue gas O2 :4 per cent by volume, or CH4+CO+H2 :5 per cent by volume, however CH4+CmHn :2 per cent by volume) (CO sensor is also useful for increasing combustion efficiency!);
- the minimum auto ignition temperature in the furnace should be determined according to fuel type (usually 500°C is fine for most of the fuels) and introduced as a safety control value – before fuel charging is automated (BS EN 12952/12953); and
- depending on the design HAZID

energy institute

For details on how to obtain your **Energy Institute CPD Certificate, see entry form and details on page 28**

(Hazard Identification) and risk assessments should be considered. Moreover, other standards e.g. BSEN 50156 will reinforce these good practices when considered in the context of HAZID and risk assessments.

Simple logical interlocking should be adopted to prevent the sequence of incorrect operator intervention. The logic of the interlocking should be tested by formal documented HAZID, RA and the preparation of control measures.

In the event of a failed start where temperature has not been achieved the boiler should lock out and operate fail safe performance until safe clearance purge can be assured (see above).

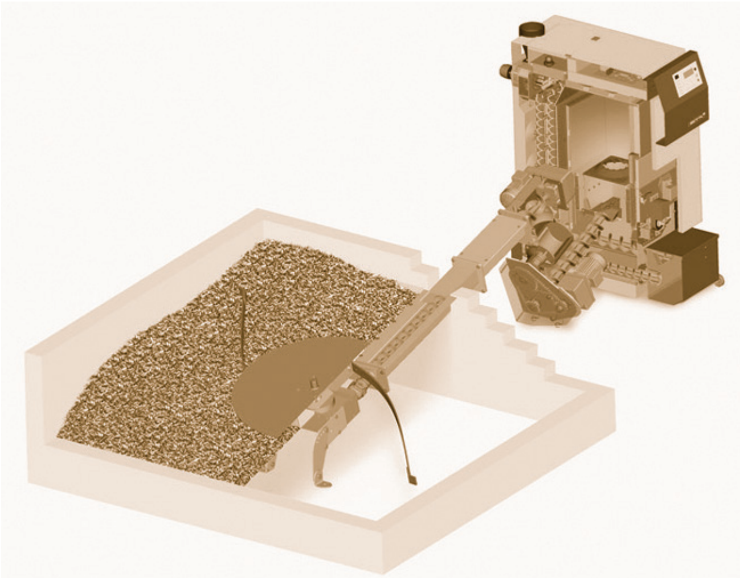
In the event of a failed start, with ignition bypassed, the fuel feed should be inhibited unless furnace temperature is reached (temperature to be determined and agreed). If there has been an

incorrect shutdown a restart must not be possible until the boiler condition is determined as safe. In addition, t

he auto ignition heater should self-test and report and failure to detect impedance will result in lockout of the starting procedure. Finally, t

he SCADA control systems must provide intelligent control and prevent foreseeable operator interventions as well as a response to measured parameters.

Flue duct blast relief is routinely incorporated into the flue systems of CHP, coal fired boiler and other, indeed some manufacturers incorporate blast relief into the smoke box of the biomass boilers.



Design responsibilities

The legal duties of care imposed by various regulaltions , not least CDM 2015, are onerous. Generally there is a duty of care is a duty of care to minimise hazard arising from design and to subsequently control the risk of any residual hazard being realised. The process of HAZID (Hazard Ideentification) is used to identify and hopefully eliminate hazards as part of the collaborative and co-operative design process.

The HAZID and Risk assessment must reflect the complexity of the project. Steam generation and particularly power generation will necessarily require robust HAZID. This must address thoroughly Hazard derived from design, construction, operation and decommissioning. Most are thoroughly familiar with the impact of CDM during the construction phase. However it is worth stressing stressing the legal duties of care imposed on the designer under CDM.

It is necessary to address properly the process of design and not simply to pay " lip service" to the process of HAZID and Risk assessment. The question of insurance and indeed contractual claim may also become issues in the event of a design failing where there was no adequate design HAZID and risk assessments and where it was demonstrated the designer had failed to observe their legal duties of care. These are matters for speculation, but reflect the very high risk strategy taken when due process is not observed.

The process of design HAZID and RA is an iterative process and for a project of this size, where there are many single or compound causes of failure you may be best advised to retain the rolling HAZID and design risk register on a data base assuring that these are reviewed periodically and/ or on design change.

There is a legal requirement for co-operation under CDM 2015. Co-operation in the context of design as well as construction. Thus, specifically if there is doubt or concern regarding the safety of a system – or if there is a means of redesigning to eliminate hazard (And that might mean a reduced operating or maintaining hazard) then there is an obligation on the designers to fulfil their duties of care to eliminate Hazard and ensure that control measures reduce residual risk to be ALARP (as low as reasonably practical)

It is important that the Hazid team has the opportunity for genuine exploration and discussion of hazard and that if hazard cannot be eliminated by design change, that the subsequent iterative risk assessment and design of control measures should be conducted by a design engineer who is competent and understands the consequences of the Hazard being realised.. Where there is more than one designer, their duties of care might be regarded as joint and several and it must be ensured that the HAZID is co-operative.

The key rules to obey are:

- identify the hazards;
- design the hazards out;
- control the risk from hazard; and
- mitigate against the effects of residual hazard being realised.

For details on how to obtain your **Energy Institute CPD Certificate, see entry form and details on page 28**

energy institute

C P D SERIES 14 » MODULE 01 » MAY 2016

ENTRY FORM

BIOMASS

Please mark your answers on the sheet below by placing a cross in the box next to the correct answer. Only mark one box for each question. You may find it helpful to mark the answers in pencil first before filling in the final answers in ink. Once you have completed the answer sheet in ink, return it to the address below. Photocopies are acceptable.

QUESTIONS

1. Syngas is:
- ☐ Is essentially carbon monoxide
- ☐ Is a mixture of carbon monoxide and other products of pyrolysis
- ☐ Methane
- ☐ Is a mixture of hydrogen and carbon monoxide

2. The lower explosive limit for carbon monoxide will
- ☐ reduce with temperature and increase with water vapour content
- ☐ Increase with temperature
- ☐ reduce with temperature and reduce with water vapour content
- ☐ Increase with water vapour content but decrease with temperature

3. The lower explosive limit of syngas could be
- ☐ 12.5 per cent
- ☐ 30 per cent
- ☐ potentially as low as a 1/3 that of measured CO content
- ☐ 5 per cent

4. Restarting a hot boiler
- ☐ Is a lot easier because combustion will be improved
- ☐ will be easier because ignition is certain
- ☐ Is easier because the air is already heated
- ☐ Can be potentially hazardous

5. Some boilers require manual confirmation of ignition, this should be achieved by
- ☐ Opening the door to the combustion space and physically checking and assuring a flame front has been safely established.
- ☐ Checking carefully that a flame front is established using a purpose designed view port only - And following the manufacturer's instructions in the event of a hung start.
- ☐ By repeatedly attempting automatic restart sequence if you are not sure
- ☐ Manual ignition with firelighters

6. A designer
- ☐ Has limited responsibility under current UK and EU legislation
- ☐ Has onerous duties of care to ensure design safety
- ☐ Must legally transfer responsibility for design to the installing contractor
- ☐ Has limited responsibilities under CDM 2015

7. A designer has a duty of care to
- ☐ Conduct comprehensive HAZARD identification and eliminate avoidable hazard where practical
- ☐ Provide physical measures to reduce the risk of hazard being realised
- ☐ Prepare and provide comprehensive operational and instructional manuals - which incorporate emergency procedures
- ☐ All of the above

8. In the context of the CDM regulations
- ☐ Manufacturers and consultants are designers
- ☐ Consultants and contractors are designers
- ☐ The Client and the Contractor are designers
- ☐ Any party that influences the design holds legal duties of care as a designer

9. In respect of steam boilers built to BSEN standards
- ☐ The Lambda reading (O2 per cent) is a useful and reliable indication of explosive mixture in the combustion space
- ☐ CO monitoring is required by BSEN standards to prevent explosive flue gas mixture
- ☐ Purging is not specifically required by BSEN standards
- ☐ A minimum charging temperature must be determined

10. The incorporation of blast relief in the flue system
- ☐ Eliminates a Hazard
- ☐ May be considered an effective physical control measure
- ☐ Provides a safe system of work
- ☐ Mitigates the effect of realised HAZARD

Please complete your details below in block capitals

Name .... (Mr. Mrs, Ms) ....

Business ....

Business Address ....

....

.... Post Code ....

email address ....

Tel No. ....

Completed answers should be mailed to:

The Education Department, Energy in Buildings & Industry, P.O. Box 825, GUILDFORD, GU4 8WQ

C P D **fundamentals**

THE CONTINUING PROFESSIONAL DEVELOPMENT PROGRAMME

How to obtain a CPD accreditation from the Energy Institute

Energy in Buildings and Industry and the **Energy Institute** are delighted to have teamed up to bring you this **Continuing Professional Development** initiative.

This is the first module in the fourteenth series and focuses on Biomass. It is accompanied by a set of multiple-choice questions.

To qualify for a CPD certificate readers must submit at least eight of the ten sets of questions from this series of modules to EiBI for the Energy Institute to mark. Anyone achieving at least eight out of ten correct answers on eight separate articles qualifies for an Energy Institute CPD certificate. This can be obtained, on successful completion of the course and notification by the Energy Institute, **free of charge** for both Energy Institute members and non-members.

The articles, written by a qualified member of the Energy Institute, will appeal to those new to energy management and those with more experience of the subject.

Modules from the past 13 series can be obtained free of charge. Send your request to editor@eibi.co.uk. Alternatively, they can be downloaded from the EiBI website: www.energyzine.co.uk

SERIES 13 MAY 2015 - APR 2016	SERIES 14 MAY 2016 - APR 2017
1 Heat Pumps	1 Biomass
2 Industrial CHP	2 Behaviour Change*
3 ESOS	3 Energy Management Standards*
4 Compressed Air	4 Air Conditioning*
5 Refrigeration	5 Internet of Things*
6 Shading Systems	6 Training for Energy Management*
7 Transformer Technology	7 Data Centre Management*
8 Solar Thermal Energy	8 Metering & Monitoring*
9 Fuel Cells	9 Boilers & Burners*
10 District Heating	10 Demand-Side Management*

** ONLY available to download from the website after publication date*

Level 2: Energy Management Professional (EMP)

Continue your professional development in energy management by undertaking a professiomnal qualification with the Energy Institute.

ABOUT THIS COURSE

Want further training? Gain all the knowledge and skills required of a professional energy manager and achieve a professional qualification with the Energy Institute's Level 2: Energy Management Professional 150 hr online course.

This course is new for 2016 and is currently available to pre-book. For further details and pricing please visit www.energyinst.org/level2 or contact education@energyinst.org.

energy institute