RISCAuthority

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FPA Fire Protection Association

RC46: Risk control for biofuel manufacturing facilities

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Contents

Summary of key points

This document has been developed through RISCAuthority and published by the Fire Protection Association (FPA). RISCAuthority membership comprises a group of UK insurers that actively support a number of expert working groups developing and promulgating best practice for the protection of people, property, business and the environment from loss due to fire and other risks. The table below summarises the key points of the document.

Ensure effective process safety management	Ensure that careful consideration is given to key elements of a process safety management programme, including: • process hazard assessment, such as HAZOP • pre-startup safety review • operator training • emergency operating procedures
Provide a high standard of process safety controls	For process plants handling hazardous materials, a high standard of design is required to safely handle process deviations, including: • process control systems designed to shut-down processes safely in case of hazardous process disruption • redundancy of control systems, especially as relates to safe-shutdown • installation of process safety shut-off valves, including shut-down of flammable streams • pressure relief systems, designed for both process anomalies and external fire exposure
Avoid releases of flammable materials and aim to eliminate ignition sources	Careful selection of equipment for biofuel plants is important to avoid releases of flammable materials and to eliminate ignition sources. Key areas for consideration include: • equipment constructed from compatible and resilient materials • high integrity process pumps for handling volatile materials • appropriate hazardous area classification (for areas where explosive atmospheres may occur) and selection of suitable electrical equipment for hazardous area
Establish suitable site layout, construction and controls to avoid and contain fire spread and prevent environmental damage from water run-off	Good site layout and design is essential to avoid and contain fire spread on biofuel plants. Key elements include: • adequate separation distances to avoid fire spread between buildings, structures, equipment and yard-storage • keep any enclosed process structures to a minimum and locate processes using flammable liquids and gases in the open when practical • provision of sufficient natural and mechanical ventilation • use fire resisting and non-combustible building materials • suitable passive fire-safety including fire-spread limiting construction and fireproofing • application of fireproofing or direct water-spray cooling for critical structures, vessel and column supports and exposed pipe-rack columns, and fireproofing for control wirings and power cables necessary for safe plant shutdown • provision of suitable secondary containment systems such as bunds for areas where spills of ignitable liquids could occur • good standards of process area drainage and site-drainage design to minimise fire-water run-off • appropriate lightning protection for buildings, structures and equipment

Symbols used in this guide

Good practice

Bad practice

Discussion topic

FAQ Frequently asked question

Provide effective fire protection	Appropriate levels of fire protection are vital to controls fires. Key elements include: • a good standard of fixed fire protection such as automatic sprinklers or water-spray protection • suitable fire and flammable vapour detection • adequate resources and arrangements for manual fire control
Implement effective risk control and change management procedures	Good risk control management (human element) systems are essential to the safe running of biofuel plants. Key elements should include: • permit to work systems, incorporating specific procedures for process isolations and hot work • housekeeping checks and controls • process for selection and management of contractors working on site • avoidance and control of smoking on site • loss prevention inspections to identify site deficiencies and action corrections • incident analysis for accidents and near-misses • controls for unavoidable use of flexible hoses for hazardous materials
Maintain equipment in good condition	Appropriate systems for maintenance and inspection, for mechanical, electrical and instrumentation systems are essential to ensure that plant and equipment is operating safely and avoid failures that may lead to release of hazardous materials or electrical fires

1 Synopsis

This guide covers property risk control and fire safety in the commercial manufacture of liquid biofuels. Solid biofuels (biomass) and biogas are not covered in this guide.

The biofuel industry in the UK has grown from almost nothing in 2005 to an industry with a capacity to produce over 1.5 billion litres per year in 2021. The capacity of commercial biofuel manufacturing sites can vary widely from a few hundred thousand litres per year to hundreds of millions litres per year (ref. 1).

Biofuel plants are operated by a wide range of enterprises, with variable levels of experience in operating chemical process facilities. Problems at these facilities often arise from failure to adhere to good risk management and manufacturing practices for chemical manufacturing plants.

These recommendations are applicable fire safety and general risk control for batch and continuous process facilities manufacturing liquid biofuel; specifically biodiesel and bioethanol. Risk control recommendations are largely focussed on medium-sized and industrial-scale plants, but aspects relating small-scale producers are also discussed.

2 Scope, hazards and need to know

2.1 Bioethanol

Bioethanol is ethanol produced from crops grown specifically for this purpose. Blended with regular petrol, it provides a reduced carbon footprint from 100% fossil fuels. Britain's first bioethanol plant opened in 2007 producing 70 million litres of ethanol biofuel a year from locally grown sugar beet. The UK government has mandated the introduction of "E10" fuel, i.e. petrol containing up to 10% of sustainable bioethanol, from September 2021. (The previous standard was 5% bioethanol, "E5" fuel.)

Ethanol, with a flash-point of 13°C, is classed as a highly flammable liquid. Ethanol vapour has an explosive range in air of 3-19%. Bioethanol is water-soluble.

2.2 Biodiesel

Biodiesel is the predominant biofuel manufactured in the UK. It is composed of vegetable-based oil, usually fatty-acid esters. This can be combined with mineral-based diesel to produce a mixture suitable for fuel use. Most biodiesels have a flash-point of more than 100°C, so may be classed as combustible rather than flammable or highly flammable liquids. But the main raw-material in production is methanol, which with a flash-point of 11°C is classed as a highly flammable liquid. Methanol vapour has a wide explosive range in air of 6-36%. Methanol is water-soluble.

2.3 Hazards and controls

A primary fire hazard in biofuel production plants is the release of ignitable liquids, due to equipment failure or operator error, resulting in pool fires.

Equipment failures and operator errors can also lead to flammable vapour leaks forming accumulations within flammable concentrations, which can result in flash fires and deflagrations. A flammable vapour release within an enclosure or compartment can lead to a confined space vapour explosion, but the conditions to produce vapour cloud explosions (VCEs)*, where flame speeds accelerate to sufficiently high velocities to produce significant over pressures, are unlikely to exist in biofuel plants.

In biofuel manufacturing plants, frequent causes of flammable liquids and gases escaping into operating areas are pump-seal failures, hose failures, instrumentation failures and similar incidents. Equipment integrity is therefore critical to flammable liquids processing plants. When loss of containment does occur, it is critical that flammable liquid releases are detected

*VCEs normally require conditions where a large quantity of flammable material is released that rapidly vaporises to form a vapour cloud, within a congested or semi-congested plant environment.

and safely contained and flammable vapours safely dispersed, before coming into contact with any ignition sources.

Such matters will be considered as part of an assessment undertaken in accordance with the Dangerous Substances and Explosive Atmospheres Regulations 2002 (DSEAR) (ref. 2). See “Compliance with fire safety legislation” and “Glossary” sections below.

Also essential to fire safety for biofuel plants is a suitable process safety management (PSM) programme.

In all but very small biofuel plants using only proprietary equipment packages, the PSM programme must be unique to each plant, where each phase of the operation is systematically evaluated for potential hazards and problems that could be encountered during normal operation, start-up and shut down. A process hazard analysis (PHA), following a structured methodology, should be prepared by competent, experienced personnel, including representatives from engineering, safety and operations.

For continuous process plant, a structured and systematic technique for process hazard assessment, usually a Hazard and Operability Analysis (HAZOP), should always be applied.

For small batch biofuel producers, using proprietary equipment packages, where the equipment manufacturer has conducted a fire safety assessment and provided safe operating instructions, then a complex PHA may not be necessary. But as a minimum an uncomplicated step-by-step risk management approach, such as the HSE (Health and Safety Executive) Five Steps to Risk Assessment (ref. 3), should be applied.

- For process plant of any size, risk assessment should bring together dangerous substance and explosive atmospheres assessments (DSEAR/ATEX) with process hazards assessment, and general safety assessment, also incorporating equipment manufacturers safety recommendations. All risk assessments should be prepared by competent and experienced personnel.

Five Steps to Risk Assessment:

- **Step 1:** Identify the hazards
- **Step 2:** Decide who/what might be harmed and how
- **Step 3:** Evaluate the risks and decide on precautions
- **Step 4:** Record your findings and implement them
- **Step 5:** Review your risk assessment and update if necessary

Key fire and explosion hazards to consider are:

- reaction hazards, such as mixing of incompatible chemicals and process deviations
- ignition following a spill or release of ignitable liquid or vapour
- arson/malicious damage
- potentially dangerous activities such as breaking into pipes containing hazardous materials for maintenance, hot-work and smoking
- exposures from adjacent facilities and natural perils, such as lightning
- containment failure from tanks, vessels, pumps, piping-systems, etc
- impact
- human error

In line with HSE advice, the manufacture of biofuels in domestic facilities and manufacture of biofuels by people who are not trained and skilled in handling dangerous substances, is not appropriate.

“Farm Energy”, a US based on-line resource, provides general advice on safety in small-scale biodiesel production. See Further Guidance section.

3 Processes and storage related to biofuel production raw materials and bulk storage (ref. 4, 5, 6, 7, 8)

Fire safety issues relating to upstream processing of crops to form process feedstocks, with particular reference to dust explosion hazards, and bulk-tank-storage of alcohols (methanol, ethanol) and biodiesel, are not specifically covered in this guide.

For combustible dust hazards refer to:

- RC12 *Recommendations for the prevention and control of dust explosions*
- RC64 *Recommendations for fire safety with small biomass installations*
- HSG103 *Safe handling of combustible dusts*

For bulk-tank-storage of alcohols and biodiesel* refer to:

- RC57 *Recommendations for fire safety in the storage, handling and use of highly flammable and flammable liquids: storage in external fixed tanks*
- HSG176 *Storage of flammable liquids in tanks*

*Note that whilst biodiesels have a reasonably high flash-point, the fire hazards presented are still significant and it is recommended that the precautions for the storage of flammable liquids are for the most part followed.

4 Case Histories

Specific bioethanol and biodiesel plant fire-loss data is not yet well developed in the UK, but to provide an indication of loss frequency, statistics from the USA are available, which indicate around six significant fire and explosion biodiesel plant loss incidents every year.

Fire and explosion loss examples based on 2009 USA data (ref. 9):

- A mechanical seal on a circulation pump associated with a process heating unit failed. The resulting excessive heat created caused the fire.
- A faulty safety valve was blamed for a fire which destroyed one of two production lines. The vacuum control valve imploded, igniting biodiesel.
- Two workers were seriously injured in a biodiesel plant while mixing glycerine and sulfuric acid.
- At least one building was destroyed and several tanks when multiple chemical vessels exploded. The cause may have been lightning.
- An explosion occurred when a 38m^3 glycerine tank split-open, as a result of over pressurisation.
- An explosion in a reactor used to store biodiesel.

5 Risk control measures

5.1 Design overview

There is no single right-way to provide fire safety design for biofuel plants. But adequate levels of protection can be provided to achieve an integrated fire safety strategy using combinations of:

- good site layout
- properly designed and sized area drainage
- suitable passive fire-safety; e.g. fireproofing
- appropriate active fire-protection; e.g. fire-hydrants, fire-monitors, fixed water-spray or sprinklers

Other key design requirements are:

- sufficient ventilation; open-to-air process structures, mechanical ventilation for enclosed buildings
- comprehensive process-controls; e.g. interfacing equipment with fire detection and alarm systems, emergency shut-down systems, automatic isolation for flammable process feeds
- resilient process equipment, including high integrity process pumps
- suitable emergency pressure relief systems
- appropriate hazardous area classification (for areas where explosive atmospheres may occur) and selection of suitable electrical equipment
- appropriate lightning protection for buildings, structures and equipment. Refer to RISCAuthority RC35 *Protection of buildings against lightning strike* (ref. 10)

See Further Guidance section.

5.2 Site Layout

- Locate processes using flammable liquids and gases in the open when practical.

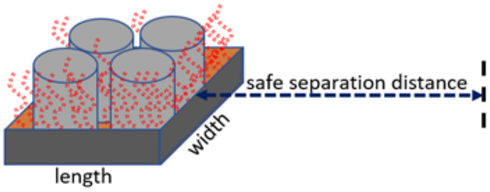
Key site layout considerations:

- Keep any enclosing structures to a minimum. Locate processes using flammable liquids and gases in the open when practical.
- Ensure that any equipment that could cause a spark, e.g. ordinary electrical equipment, is located outside of "hazard zones".
- Provide adequate separation distance between buildings, structures, equipment and yard storage to avoid fire spread.

At thermal radiation exposures under 12.5kW/m^2, fire is not expected to spread to other equipment, structures, or buildings, provided that essential exterior manual fire control is available, e.g. effective fire service response (ref. 14).

Outside process and tanks areas

For outside process and tanks areas where ignitable liquids fires could occur, indicative "safe separation distances" from the edge of spill control curbs and bunds, to maintain a thermal radiation exposure below 12.5kW/m^2, are provided in Table 1.



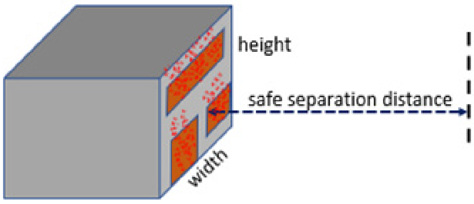
Spill fire size		Safe separation distance from edge of spill fire, metres	
Curbed or bunded area, width by length	Area, m^2	Ethanol/methanol	Biodiesel
5m by 5m	25	5	10
10m by 10m	100	10	15
15m by 15m	225	15	20
20m by 20m	400	20	25
25m by 25m	625	25	30
30m by 30m	900	30	35
Distances based on geometric view factor fire modelling and published ethanol fire test data, assuming windless conditions (ref. 11, 12, 13)			

Table 1: Indicative safe separation distances from contained spill fires

Enclosed process buildings handling ignitable liquids

Indicative "safe separation distances" from enclosed process buildings handling flammable and combustible liquids*, to maintain a thermal radiation exposure within 12.5kW/m² are provided in the Table 2.

Separation distances are a function of the width and height of the wall of the target process building facing the exposed equipment, structure, or building.



Building width / height	Wall construction	Safe separation distance, metres
10m by 5m	Wall expected to remain intact for the duration of the fire; with 25% openings (windows, doors, etc.)	12
15m by 6m		15
20m by 8m		20
10m by 5m	Wall expected to withstand fire penetration for more than 20 minutes, but less than the expected duration of the fire (assumes 75% openings)	20
15m by 6m		26
20m by 8m		34
Distances based on NFPA methodology (ref. 14)		

Table 2: Indicative safe separation distances from enclosed process buildings handling ignitable liquids

- How are safe separation distances to maintain a thermal radiation exposure within 12.5kW/m² determined? See 5.2 Tables 1 and 2. **Note:** 12.5 kW/m² is used in most building codes and is generally accepted as the level of heat radiation below which the pilot ignition of most cellulosic materials is unlikely to occur (ref. 14).

Fire spread

Safe separation distances may be reduced for exposing process buildings with distinct sections which carry minimal fire hazard. For example, for a process building where flammable liquids operations are confined within a compartmented section or adequately curbed area, representing 50% of the building floor-area, and the remaining area presently negligible fire hazard, then building-width can be proportionality reduced for the "safe separation distance" assessment; i.e. in this example the building width used for the safe separation distance can be 50% of the actual building width.

- Exposed buildings within safe separation distances can be protected by various means, including:
  - blank walls of non-combustible materials
  - elimination of wall-openings by filling with equivalent non-combustible construction
  - fire-resistant glass windows
  - automatic water-spray, outside over openings
  - automatic fire shutters or doors on openings
- Where manufacture cannot be undertaken in an open-to air structure or detached buildings, the process should be undertaken in a compartment with at least one external wall. This compartment should be separated from other manufacturing and storage areas by a continuous construction affording at least 120-minutes' fire resistance. Doors from the biofuel production area should open directly to the outside.

- Avoid ventilation dead spots where flammable vapours could accumulate.

5.3 Ventilation and Drainage (ref. 15, 16, 17, 38)

It is essential to prevent any flammable vapours accumulating within their flammable limits, hence process plant in open-to-air structures are preferred to maximise natural ventilation.

Adequate ventilation should be provided for any enclosed production and storage areas. The ventilation rate should be sufficient to maintain the concentration of flammable vapours within the area to no more than 25% of the lower explosive limit (LEL). Suitably arranged natural ventilation might be adequate, but mechanical ventilation systems may be required to meet the desired performance. Mechanical ventilation systems should provide a minimum ventilation rate of $0.3m^3$/min for each m^2 of floor area. Design should aim to eliminate any ventilation dead spots, where vapours could accumulate. The exhausted air should discharge to a safe place in the open air.

Natural ventilation meeting the above criteria, will usually only be suitable for small buildings. This may be achieved by fixed, permanent openings (such as airbricks or louvres) at high and low levels in the external walls of the building to the outside air. Typically, a total equivalent vent area of at least 1% of the total area of the walls and roof is required, the design dependent on building wind exposure. Ventilation openings circa 3% of the building surface area may be applicable where cross-flow ventilation is lacking.

For enclosed buildings and compartments where explosible vapour concentrations could accumulate under adverse conditions, suitable engineered controls such as explosion vents or lightweight frangible roofs should be provided.

Provide perimeter curbing for process areas with adequately sized gullies and drains to direct process spills and overflow from sprinkler and deluge systems to a safe location.

Floor detailing in process areas should be arranged to direct spills into sumps to reduce potential ignitable liquid burning areas.

Most chemical process plants of significant size and associated areas should be serviced by chemical drains that feed to an effluent treatment plant.

Site-drainage should be designed to minimise fire-water run-off, which may lead to environment damage. HSE Guidance note EH70 *The control of fire-water runoff from CIMAH (now COMAH) sites to prevent environmental damage*, provides useful guidance, even for those sites not falling under COMAH regulations.

5.4 Structural fireproofing (passive fire protection) (ref. 18, 19, 20)

Careful application of fire-resistant materials, such as fire-rated cementitious coatings, fire-rated cable and heat resistant wiring will limit fire damage that could lead to failure and collapse of structures. Serious consideration should be given for fireproofing of critical structures, vessel and column supports, exposed pipe-rack columns and control wirings and power cables necessary for safe plant shutdown. This is especially relevant for larger biofuel production sites.

In biofuel plant areas without adequate fixed water-based protection systems, where on-site fire teams and the Fire Service are unlikely to be able to effectively cool unprotected steel structures with fire-hose or fire-monitor streams and where area-drainage is limited or restricted, 90-minutes rated fireproofing is suitable for structures exposed to pool fires.

Critical power and control cables should be rated-to or protected-to at least 15 minutes (up to 30 minutes) fire resistance to facilitate a safe process shut-down.

The most commonly referenced standard internationally for testing and rating of fireproofing materials in areas exposed to hydrocarbon fires is UL 1709 *Standard for Rapid Rise Fire Tests for Protection Materials for Structural Steel*. The hydrocarbon fire curve is also covered in BS EN1363-2: *Fire resistance tests: Alternative and additional procedures*.

The most widely referenced standard internationally specifying fireproofing systems in areas handling and processing hydrocarbons is API - RP 2218 (*Fireproofing Practices in Petroleum and Petrochemical Processing Plants*). This standard intends to provide guidance for selecting, applying, and maintaining fireproofing systems designed to limit the extent of fire-related property loss from pool fires in the petroleum and petrochemical industries, but also provides a useful reference in other types of process facilities where comparable hazards exist.

An alternative to structural fireproofing is application of directional water-spray, normally

FAQ

- How can exposed structural members be protected from pool fires in existing plants? 5.4 Where it is impractical to fit fireproofing to existing structural members, directional water-spray directed into the webs of vertical and horizontal structural members, can be installed as an alternative.

forming part of an area water-spray or deluge system, directed into the webs of vertical and horizontal structural members. This is typically a simpler solution for retrofit protection.

See Further Guidance section.

5.5 Fixed fire protection

Water-based fixed fire protection is strongly recommended for biofuel production plants, as part of an integrated fire safety strategy.

Foam-enhanced deluge systems are often the best form of protection of flammable liquids hazards. For enclosed-building applications, foam-enhanced closed-head sprinkler protection may also be suitable. For open-to-air structures, where the primary objective of fixed protection is to provide cooling of structures and vessels in combination with manual fire-control, standard water-spray protection is suitable.

- The minimum recommended design density for water-spray protection of process plant is 10mm/min. Required design density can vary for specific equipment items. For foam-enhanced protection, a minimum design density of 7.5mm/min should be used. The foam supply should be sized for a minimum discharge period of 10 minutes.

- Sprinkler systems should be designed, installed, commissioned, and maintained in accordance with the LPC Sprinkler Rules (incorporating BS EN 12845) to standards certificated by an independent UKAS accredited third party certification body (ref. 21).
- Deluge/water-spray/foam systems should systems should be designed, installed, commissioned, and maintained in accordance with (ref. 22,23):
  - DD CEN/TS 14816:2008 – *Fixed firefighting systems – Water spray systems – Design, installation and maintenance*
  - BS EN 13565 Parts 1 & 2 – *Fixed firefighting systems – Foam systems*

  Alternatively, the equivalent NFPA Codes may be applied (ref. 24, 25, 26), i.e.:
  - NFPA 11 *Standard for low-, medium-, and high-expansion foam* (now incorporating the formerly issued NFPA 16 *Standard for the installation of foam-water sprinkler and foam-water spray systems*)
  - NFPA 15 *Standard for Water Spray Fixed Systems for Fire Protection*
  - NFPA 20 *Standard for the Installation of Stationary Pumps for Fire Protection*
- The minimum recommended design density for water-spray protection of process plant is 10mm/min. Required design density can vary for specific equipment items. For foam-enhanced protection, a minimum design density of 7.5mm/min should be used. The foam supply should be sized for a minimum discharge period of 10 minutes.

5.6 Fire Detection (ref. 27)

Automatic fire detection should be installed in all process areas without automatic fixed fire protection, irrespective of whether they are normally or intermittently manned. Special consideration should be given to selecting suitable approved fire detection technology for areas handling methanol and ethanol, as they burn with smokeless blue flames; e.g. ultraviolet, infrared, or IR/UV combined detectors.

Control and administration buildings and electrical equipment buildings should always be provided with automatic fire detection.

Systems should be designed, installed, commissioned, and maintained in accordance with BS 5839-1: *Fire detection and fire alarm systems for buildings. Code of practice for design, installation, commissioning, and maintenance of systems in non-domestic premises.* Use Category P1 (whole building coverage) or P2 (defined areas of building) systems as appropriate.

5.7 Vapour detection

Flammable vapour detection should be considered for areas where leaks and other unintentional releases could lead to flammable vapour accumulations.

Systems should be arranged with two alarm levels as follows:

- The lower alarm, normally set at no higher than 10% of the Lower Explosive Limit (LEL), should act as a warning of a potential problem requiring investigation.

- The higher alarm, normally set at no higher than 25% LEL, should trigger an emergency response and where practical shutdown of appropriate unit operations, typically process feed-pumps (subject to Process Hazard Assessment considerations).

5.8 Emergency response and firefighting

Emergency response plans should be developed and routinely tested, covering the range of crises that could occur to a facility. These include major incidents, fire and explosion, power failure, adverse weather (inc. freezing), flood, escape of water etc.

The need for an on-site Emergency Organisation will depend on the size of the facility and the level and availability of Fire Service response. Typically, site emergency organisations are formed from volunteers within the workforce, covering all shifts, who receive special training in first response to various crises, including fire and hazardous materials spills. This is above and beyond general staff training in how to respond during emergencies.

Of specific consideration for fire control of biofuel plants, methanol and ethanol are water-miscible (or polar) solvents and require different fire-fighting techniques to those of organic liquids, such as kerosene. Alcohols break-down any foam blanket that has been generated using standard AFFF or fluoroprotein type concentrates, as water in the foam blanket mixes with the alcohol, causing the foam blanket to collapse and re-expose the fuel surface. Hence, for these solvents, special fire-fighting foams with a polymer additive that precipitates out, forming a physical barrier between the fuel surface and foam blanket are needed, to be effective. But polar solvent fires can also be extinguished by dilution with water to below the concentration at which they sustain combustion*, unlike standard hydrocarbon liquids, such as diesel, gasoline, kerosene, etc. that do not mix with water.

Whilst biofuel production may not be the primary site activity for some small-scale biofuel producers, for example small production units on farms, it is essential that local Fire & Rescue Services are aware of the processing and chemical storage that is be occurring on site. This provides Fire & Rescue Services with the right information to be prepared for a biofuel production unit fire and advise on fire-safety for site-staff working on or in the vicinity of the production unit.

See Further Guidance section.

5.9 Process safety controls

- Process control systems should be designed to shut-down processes safely in case of hazardous process disruption and avoid/minimise the release of hazardous chemicals if a failure occurs.

Process control systems should be designed to shut-down processes safely in case of hazardous process disruption and avoid/minimise the release of hazardous chemicals if a failure occurs.

Key elements to consider are:

- redundancy of control systems, especially as relates to safe-shutdown
- process safety shut-off valves, including shut-down of flammable streams
- pressure relief systems, designed for both process anomalies and external fire exposure
- trips/interlocks need to be suitably designed to appropriate standards

Interlocks to emergency shut-down of processes and flammable streams, activated by heat detection, flame detection, or flammable vapour detection should be considered as part of an integrated emergency shutdown strategy.

See Further Guidance section.

5.10 Equipment and maintenance

Appropriate systems for maintenance and inspection, for mechanical, electrical and instrumentation systems are essential to ensure that plant and equipment is operating safely and avoid failures that may lead to release of hazardous materials or electrical fires.

Maintenance and inspection procedures should follow OEM (original equipment manufacturer) guidelines and risk-based good practice, as well as meeting statutory needs. Maintenance and inspection records should be logged on a suitable computerised Planned Preventive Maintenance system.

*For both methanol and ethanol, the effective heat of combustion decreases and flash-point increases, as water-content % increases. But quantities of water required to extinguish sizeable methanol or ethanol pool fires will be considerableand dilution down to below circa.10% methanol or ethanol may be required for fire extinguishment under typical conditions.

Activities should be properly planned and risk assessed, with written systems of work. Work should be conducted following a formal permit to work system.

There are many considerations regarding equipment selection and arrangements. Key issues include:

- **Use suitable construction materials for process equipment –** Process equipment and pipework handling flammable and combustible materials should be of metal construction, typically stainless steel. Plastics and frangible materials, such as glass, should be avoided.
- **Use high integrity process pumps –** To eliminate or significantly reduce the risk of pump seal failures leading to a release of flammable liquid, double-mechanical-seal pumps, magnetic-drive or canned (hermetically sealed) pumps should be used as appropriate, based on risk assessment. Pump selection requires careful consideration, including material volatility, viscosity and propensity to solidify. Manufactures guidance is also essential in pump selection.
- **Electrical equipment selection (ref. 28) –** Electrical equipment for areas where flammable atmospheres may be present should be selected and installed as appropriate for the "hazard zones" determined in the DSEAR assessment. See "Compliance with fire safety legislation" and "Glossary" sections below. Selection of equipment for hazardous areas is covered in EN 60079 *Explosive atmospheres – Part 14: Electrical installations design, selection and erection*.
- **Avoid use of absorbent lagging/insulation –** Oxidative self-heating can occur in absorbent materials contaminated by a variety of organic fluids, such as diesel or glycol saturation of absorbent insulation on pipe and vessels. Sufficient temperatures may be created to cause a fire.* Use of non-absorbent insulation that does not burn or contribute to fire, such as cellular glass insulation, is recommended.
- **Thermal oxidisers (ref. 29) –** Risk control for thermal oxidisers should follow RISCAuthority RC53 *Recommendations for fire safety in the use of thermal oxidation plant*.
- **Thermal fluid heating systems (ref.30) –** Risk control for thermal fluid heating systems should follow RISCAuthority RC26 *Recommendations for thermal fluid heating systems*.
- **Earthing and bonding –** All metal reaction vessels, metal receivers and extraneous metal items used as parts or supports for the process, should be bonded and earthed to prevent the build-up of static electricity.

See Further Guidance section.

- Fundamental to a process safety management programme is appropriate hazard identification and risk assessment. This requires a structured process to systematically identify, assess, control and manage risks arising from processes and operations.
  All risk assessments should be prepared by competent and experienced personnel.

5.11 Process safety

Fundamental to a process safety management programme is appropriate hazard identification and risk assessment. This requires a structured process to systematically identify, assess, control and manage risks arising from processes and operations.

Some common Process Hazard Assessment (PHA) methodologies are:

- fault and event tree analysis
- failure mode and effect analysis (FMEA)
- hazard and operability study (HAZOP)
- layers of protection analysis (LOPA)
- what-if/checklists

Other key elements of a process safety management programme include:

- a "pre-startup safety review" to confirm that applicable elements of the safety management programme have been implemented correctly to ensure a safe process startup. This is particularly important following prolonged periods of shut-down
- a comprehensive management of change programme. Written systems should be developed and implemented to manage both major changes and minor modifications to plant and processes that impact risk
- a programme to ensure that P&IDs (piping and Instrumentation diagrams) are kept up to date

*One of the main causes of fire in biodiesel plants is hot oil/fatty acid leaks onto lagging which then smoulders and catches fire. Typically, the fatty acid columns, used to produce a higher fatty acid content, operate at high temperatures and there is often a hot oil heating system.

- emergency operating procedures detailing how to make plant and process safe following an unsafe process anomaly or equipment failure
- operator training covering process start-up, normal operations, process shutdown and emergency conditions, including the correct response to process and fire alarms

5.12 Human Element Management Systems (ref. 2, 31, 32)

Human element management systems are an essential part of a risk management plan. Key elements of a comprehensive human element management programme include the topics described below:

- **Permit to work systems –** Permit-to-work systems should be designed as document procedures that authorise suitably skilled people to carry out specific work within a specified time frame along with precautions required to complete the work safely, based on a risk assessment. Individual permits should describe what work will be done and how it will be done (which may be detailed in a 'method statement'). Key issues to prevent fires and explosions include ensuring that vessels and pipelines handling flammable and combustible materials are suitably drained and isolated during works and that hot-works are carried out safely.

  Regarding hot-work outside of maintenance workshops, this should be avoided wherever possible, including any work that involves burning, welding, cutting, brazing, soldering, grinding, using fire or spark-producing tools, or other work that produces a source of heat or ignition. Hot-work should be carried out in conformance with the RISCAuthority RC7: *Recommendations for hot work*.

  Note that in areas where flammable and combustible liquids and vapours might be present, it is essential that air monitoring is carried out to ensure that flammable vapours are not present before commencing and during the hot works.

  Best practice for the control of process isolations is described in HSE HSG253, *The safe isolation of plant and equipment* (ref. 32).

- In areas where flammable vapours might be present, never permit hot-work unless air monitoring has be carried out to confirm that there are no flammable vapors.

- **Housekeeping –** High standards of housekeeping should be maintained to prevent the accumulation of combustible materials throughout the facility. Particular attention should be taken to immediately resolve and clean-up leaks or spills of alcohols, oils and other ignitable materials.
- **Management of contractors –** A control-of-contractors procedure should be implemented to ensure that only competent contractors are used on site, that they are suitably inducted and trained to understand site hazards and permit to work requirements, they work safely within agreed method statements, that they are suitably monitored and supervised by site personnel and they hold adequate liability insurance cover.
- **Smoking –** Prohibit smoking throughout the facility, or as a minimum have designated areas for smoking at least 10m away from Hazardous Areas (as defined in DSEAR, ref. 2), buildings, structures, equipment and exposed combustible materials. Appropriate notices should be prominently displayed.
- **Loss prevention inspections –** Systems of loss prevention inspections and audits should be employed to ensure that general loss prevention is checked on a continuing basis, covering aspects such as:
  - general fire safety
  - availability of emergency equipment (including fire extinguishers and fire hose reels)
  - general condition of building and structures
  - control of hazardous substances
  - safe storage of flammable and combustible materials
  - adherence to the smoking policy

  These inspections should be carried out by suitably skilled and trained employees, familiar with the site, at pre-agreed intervals based on the nature of the hazards present in each area. Records of the inspection and subsequent rectification of issues arising should be retained.

- Loss prevention inspections should be carried out by suitably skilled and trained employees, familiar with the site, at pre-agreed intervals based on the nature of the hazards present in each area. Records of the inspection and subsequent rectification of issues arising should be retained.

FAQ

- Why is it important to always investigate and analyse "near-misses"?
  See 5.12 - Incident analysis.

- Use of flexible hoses in process plant should be avoided. Where there is no alternative a hose register and inspection programme should be implemented

- To deal with spills or releases of hazardous materials, it is essential that a suitable emergency spill control procedure is in place to expedite removal of the hazardous substance to safe place.

- **Incident analysis –** Implement systems to investigate and analyse incidents and "near-misses" that have, or might have, resulted in damage, contamination or injury. Lessons learned from these investigations should be used to avoid reoccurrence of similar incidents.
- **Flexible hose management –** In general, the use of flexible hoses in process plants handling hazardous liquids should be avoided. But where there is no alternative a hose register and inspection programme should be implemented to ensure that:
  - the correct types of hose are in use for each application
  - hoses are routinely inspected and tested to make sure they are in good condition and have adequate electrical continuity (where required). Daily visual inspections and annual pressure tests are recommended
  - inspection records logged on a suitable computerised maintenance management system
  - hoses are suitably tagged and recorded in a database
  - connections are made using flange fittings, avoiding temporary/quick-fit couplings, except dry-break (self-sealing) couplings may be acceptable.
- **Site security –** Suitable security measures should be implemented to prevent intruders accessing the site, including perimeter fencing. Other protections may include installing security lighting, CCTV, intruder alarms, guarding and access control systems.

See further Guidance section.

5.13 Hazardous materials (ref. 2, 33)

Procedures should be in place for the safe use and storage of hazardous materials. In the UK, this is covered in the Control of Substances Hazardous to Health 2002 (COSHH) regulations. The Dangerous Substances and Explosive Atmospheres Regulations 2002 (DSEAR) are also relevant.

Material safety data sheets (MSDSs) should be available and referenced to establish the hazards relating to all chemicals used.

To deal with spills or releases of hazardous materials, it is essential that a suitable emergency spill control procedure is in place to expedite removal of the hazardous substance to safe place. Before removal can be safely accomplished, hazardous materials will often need to be stabilised with appropriate chemicals or diluted. Where washing operations following a spill of hazardous material feed to an effluent plant, it is essential that in any situation where this is likely to occur, the staff running the effluent treatment plant are informed so that suitable controls can be implemented.

Generally, for biofuel production facilities, all hazardous raw materials and products should be stored in vessels or containers within bunds, curbs or other form of secondary containment to control any spillage or loss of containment. Storage tanks should be fitted with high-level alarms, suitably interlocked to prevent over-filling. Bunds should be constructed of non-permeable materials and should have the capacity of 110% of the largest vessel or container to be stored within it, or 25% of the aggregate storage capacity of the vessels or containers, whichever is greater (ref. 7).

Attention should be given to ensuring that hazardous materials, including biofuel, alcohols, acids, alkalis and glycerine (a by-product of biodiesel production) do not enter the site's water drainage systems. If oil and chemicals from the site enter the ground or watercourses, 'the polluter pays' principle will apply and those responsible can be required to pay for the decontamination. Fire risk associated with accumulation of ignitable materials in waste water systems should also be considered.

Also, care should be taken when handling waste products from the process. For example, residual methanol or un-reacted sodium methoxide catalyst could be present in biodiesel production waste. Waste products should be retained in suitable containers to await removal from the site by a competent waste carrier.

5.14 Compliance with fire safety legislation (ref. 2, 33, 34, 35, 36, 37)

- In premises to which the Regulatory Reform (Fire Safety) Order 2005 (or equivalent legislation in Scotland and Northern Ireland) apply, a fire risk assessment should be carried out and recorded. The assessment should be reviewed whenever there is a material change to the premises, its use, configuration, activities undertaken (include scale of such) or occupancy.
- An assessment should be undertaken by competent persons, to identify "hazard zones" in production, storage areas and any other relevant areas in the workplace, in accordance with the Dangerous Substances and Explosive Atmospheres Regulations 2002 (DSEAR).

  DSEAR sets out the link between zones and the equipment that may be installed in that zone. The equipment categories are defined by the ATEX equipment directive, set out in UK law as the Equipment and Protective Systems for Use in Potentially Explosive Atmospheres Regulations 1996.

  When the hazardous area classification study has been completed, a diagram should be produced indicating the hazard zones. The survey and production of the diagram should be completed before the plant is tested and commissioned.
- For all hazardous materials that are stored or used, a list of the substances present should be maintained, along with details of their quantities and locations, as required in the Control of Substances Hazardous to Health Regulations (COSHH) Regulations. These details should be readily available for use by the fire brigade.
- Companies must ensure that the relevant duties under both UK and EU REACH are met if they supply or purchase substances, mixtures or articles to and from:
  - a. the European Union (EU)
  - b. the European Economic Area (EEA)
  - c. Northern Ireland (NI)
  - d. Great Britain (GB) (England, Scotland and Wales)
- The Control of Major Accident Hazards Regulations (COMAH) are the enforcing regulations in Great Britain (Northern Ireland produces its own regulations) of the Seveso II Directive devised in Brussels following the Seveso disaster. They are applicable to any establishment storing or otherwise handling large quantities of industrial chemicals of a hazardous nature.

  It is unlikely that COMAH will apply to all but the largest biofuel plants. For example, the qualifying quantity of methanol is 500 tonnes for "Lower Tier" requirements.
- Chemical waste should be stored and disposed of in accordance with the requirements of the Environmental Protection Act 1990.

6 Summary of production technologies

There are a variety of options in the processes for production of bioethanol and biodiesel. Outlines of the predominant processes are described below. The process steps, materials and conditions for each individual site under evaluation can vary and should be assessed separately.

6.1 Bioethanol

Bioethanol is mainly produced by fermentation of sugar derived from crops such as sugar beet, maize and wheat.

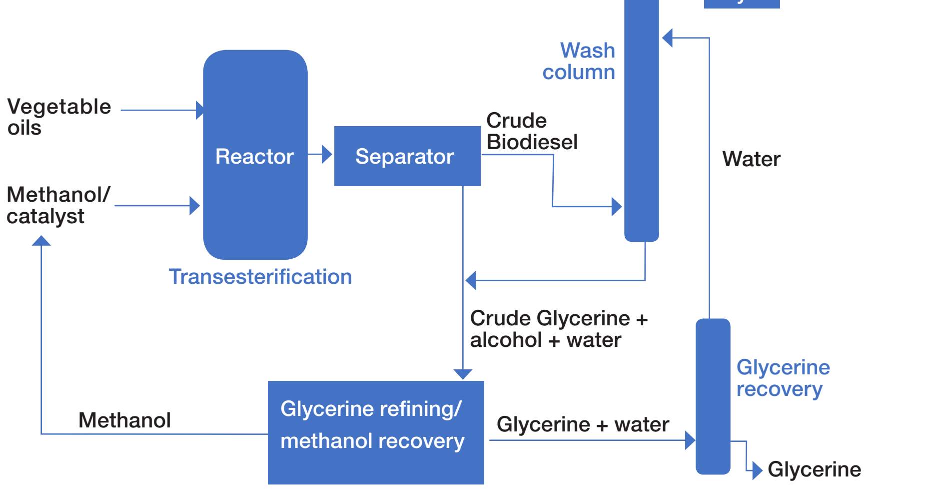
In a typical industrial process, the starch crop is processed with water to form a slurry, which is converted to complex sugars with addition of enzymes. This is then heated to kill-off unwanted bacteria, then another enzyme is added to produce the simple sugar dextrose that is fermented with yeast to produce a low concentration of ethanol in water. This stream is then distilled to produce a high concentration of circa 95% ethanol, which is further concentrated to 99% ethanol by dehydration. Other process steps include remove of solids.

6.2 Biodiesel

The predominant industrial process for manufacturing biodiesel is known as transesterification. This process is achieved by adding methanol to vegetable oil extracted from oilseed crops such as oilseed rape, palm oil and sunflower oil, or from waste oils and fats*. The process requires a catalyst to increase the rate of the chemical reaction between the methanol and vegetable oil. The catalyst used in the creation of biodiesel is typically either potassium hydroxide or sodium hydroxide, with over 75% methanol. Sodium methylate (sodium methoxide) is another common catalyst in biodiesel production. It is more effective than potassium hydroxide or sodium hydroxide, although more expensive. Sodium methoxide is supplied as a 30% solution in methanol for easier handling.

When the transesterification process is complete the catalyst can be recovered completely unaffected by the chemical reaction that it helped accelerate. This is along with glycerine (a by-product) are separated from the crude biodeisel.

Typical Biodiesel Process



*Waste oils and fats are the predominant biodiesel feedstock in the UK, e.g. used cooking oil from deep fat fryers

7 Glossary

Biodiesel

A fuel comprised of mono-alkyl esters of long-chain fatty acids derived from vegetable oils or fats.

Bioethanol

Ethanol produced from plants such as sugar cane or maize, used as an alternative to petrol.

Catalyst

A chemical, the presence of which is necessary for a reaction to take place, but which remains unaffected during the process.

Chemical processes associated with biofuel production

Some processes commonly found in biofuel manufacturing are briefly described below.

Acid hydrolysis

A chemical process to convert cellulose or starch to sugar using acid.

Dehydration

Removal of water.

The methods used in the bioethanol production process include a physical absorption process (using a molecular sieve), using chemical desiccants and azeotropic distillation (a technique of adding another component to generate immiscible liquid phases, e.g. addition of benzene to water and ethanol).

Distillation

A physical separation process, separating the components or substances from a liquid mixture by using selective boiling and condensation.

Fermentation

A process by which organic molecules such as glucose are broken down through the action on enzymes.

Transesterification

A process involving reacting vegetable oils or fats with alcohols.

Classification of hazardous areas

Hazardous areas are defined in DSEAR as “any place in which an explosive atmosphere may occur in quantities such as to require special precautions to protect the safety of workers”.

Area classification is a method of analysing and classifying the environment where explosive mixtures of gas/vapour/dust in air may occur, to facilitate the proper selection and installation of apparatus to be used safely in that environment, considering the properties of the flammable materials that will be present. Hazardous Area Classification (HAC) should be used when all other potential solutions (elimination, reduction, substitution etc.) have been considered and exhausted. Classifications extend to consider non-electrical sources of ignition, and mobile equipment that creates an ignition risk.

Hazardous areas are classified into zones based on an assessment of the frequency of the occurrence and duration of an explosive gas atmosphere, as follows:

Zone 0	An area in which an explosive gas atmosphere is present continuously or for long periods
Zone 1	An area in which an explosive gas atmosphere is likely to occur in normal operation
Zone 2	An area in which an explosive gas atmosphere is not likely to occur in normal operation and, if it occurs, will only exist for a short time

Combustible liquid

For the purposes of this guide, combustible liquid refers to a liquid that has been excluded from being classified as a flammable liquid by any of the criteria for sustaining combustion but can still be ignited.

Combustible liquids have similar properties to flammable liquids. The difference lies in their flash point range. Combustible liquids have a higher flash point than flammable liquids and therefore they are less volatile.

Deflagrations

See flash fires and deflagrations.

Ester

Any of a class of organic compounds that react with water to produce alcohols and organic or inorganic acids. Esters derived from carboxylic acids are the most common.

Explosive Limits

The minimum concentration of a particular combustible gas or vapor necessary to support its combustion in air is defined as the Lower Explosive Limit (LEL) for that gas. The maximum concentration of a gas or vapor that will burn in air is defined as the Upper Explosive Limit (UEL).

Alternative terms are Lower Flammable Limit (LFL) and Upper Flammable Limit (UFL).

Extremely flammable

Liquids which have a flashpoint lower than 0°C and a boiling point (or, in the case of a boiling range, the initial boiling point) lower than or equal to 35°C (ref. Health and Safety Executive).

Fatty acid esters (FAEs)

FAEs are a type of ester that result from the combination of a fatty acid with an alcohol. Biodiesels are typically fatty acid esters made by the transesterification of vegetable fats and oils. Methanol is typically the alcohol used, producing fatty acid methyl esters (FAME).

Fireproofing (passive fire protection)

A systematic process, including design, material selection, and the application of materials, that provides a degree of fire resistance for protected substrates and assemblies.

In this guide fireproofing refers primarily to fireproofing-material providing a barrier, coating, or other safeguard that gives protection to structures (normally steel) against the heat from a fire, without additional intervention.

Flammable liquids

Liquids which have a flashpoint equal to or greater than 21°C and less than or equal to 55°C and which support combustion when tested in the prescribed manner at 55°C (ref. Health and Safety Executive).

Flash-point

The lowest liquid temperature at which, under certain standardised conditions, a liquid gives off vapours in a quantity such as to be capable of forming an ignitable vapour/air mixture.

Flash fires and deflagrations

A flash fire is a sudden, intense fire caused by ignition of a mixture of air and a dispersed flammable substance such as a flammable gas, flammable or combustible liquid in aerosol/ fine mist, or combustible dust. It is characterized by high temperature, short duration, and a rapidly moving flame front.

Deflagration is a term describing subsonic combustion propagating through heat transfer; hot burning material heats the next layer of cold material and ignites it.

High integrity process pumps

Alternatives to single-mechanical-seal pumps that provide greater protection against failures which could lead to release of the material being handled. The predominant types are double-mechanical seal, magnetic-drive and canned pumps.

A double mechanical seal pump has two primary seals with a barrier or buffer fluid area in between. The barrier fluid pressure can be monitored to provide an immediate alarm in case of seal failure.

Magnetic (mag) drive and canned motor pumps are two types of sealless pumps.

With magnetic drive pumps the electric motor (the driver) is coupled to the pump by magnetic means rather than by a direct mechanical shaft. The pump works via a drive magnet that eliminates any shaft seals.

A canned motor pump is a centrifugal pump with hermetically sealed electric motor mounted on a single shaft, eliminating the requirement for sealing device. The entire rotating assembly is immersed in the pumped liquid. A part of the pumped liquid is bypassed through the motor, for cooling of motor and lubricating the bearing.

Highly flammable liquid

Liquids which have a flashpoint below 21°C but which are not extremely flammable (ref. Health and Safety Executive).

Ignitable liquids

For the purposes of this guide, ignitable liquids refers to liquids that can be ignited, including extremely flammable, highly flammable, flammable and combustible liquids.

Oxidising agents

Oxidising agents (or oxidisers) are chemical species that tends to oxidise other substances, i.e. cause an increase in the oxidation state of the substance by making it lose electrons.

From a fire risk perspective, oxidising agents are substances that are not necessarily combustible themselves but may contribute to or cause combustion of other material by yielding oxygen. Oxidising agents are especially hazardous in the presence of ignitable substances.

The full range of hazards for each oxidising agent should be established by reference to appropriate material hazards data sheets (MSDSs).

Process Hazard Analysis (PHA)

Predominant PHA methodologies are briefly described.

Fault and Event Tree Analysis

Fault tree analysis (FTA) is a top-down, deductive failure analysis in which an undesired state of a system is analysed using Boolean logic* to combine a series of lower-level events.

*A form of algebra which is centred around simple words known as Boolean Operator; “Or”, “And” and “Not”.

Event tree analysis (ETA) is a forward, top-down, logical modelling technique for both success and failure that explores responses through a single initiating event and lays a path for assessing probabilities of the outcomes and overall system analysis.

Failure Mode and Effect Analysis (FMEA)

The process of reviewing as many components, assemblies, and subsystems as possible to identify potential failure modes in a system and their causes and effects. For each component, the failure modes and their resulting effects on the rest of the system are recorded in a specific FMEA worksheet.

Hazard and Operability Studies (HAZOP)

A HAZOP is a qualitative hazard assessment technique based on guide words which is carried out by a multi-disciplinary team. This methodology identifies deviations from the way a system is intended to function: their causes, and the hazards and operability problems associated with these deviations.

Layers Hazard of Protection Analysis (LOPA)

LOPA is a risk management technique commonly used in the chemical process industry that can provide a more detailed, semi-quantitative assessment of the risks and layers of protection associated with hazard scenarios.

What-if/checklist

What-If Analysis is a structured brainstorming method of determining what things can go wrong and judging the likelihood and consequences of those situations occurring.

The What-If/Checklist Analysis technique, employed through a team of people with a variety of backgrounds, typically operations, maintenance, engineering and safety, combines the creative, brainstorming features of a What-If Analysis with the systematic features of a Checklist Analysis. This identifies both the general types of incidents that can occur in a process or activity, along with process specific hazards, as a qualitative analysis to determine whether the safeguards against the potential incident situations appear adequate and recommend ways for reducing the risk of operating the process.

8 Checklist

		Yes	No	N/A	Action required	Due date	Sign on completion
8.1	**Site layout and buildings (section 5.2)**						
8.1.1	Are processes using flammable liquids and gases in the open when practical?						
8.1.2	Is equipment that could cause a spark, e.g. ordinary electrical equipment, located outside of “hazard zones”?						
8.1.3	Are separation distance between buildings, structures, equipment and yard-storage adequate to avoid fire spread?						
	Are exposed buildings within safe separation distances protected by one of the following:						
8.1.4	• Blank walls of non-combustible materials?						
8.1.5	• Elimination of wall-openings by filling with equivalent non-combustible construction?						
8.1.6	• Fire-resistant glass windows?						
8.1.7	• Automatic water-spray, outside over openings?						
8.1.8	• Automatic fire shutters or doors on openings?						
8.1.9	Are enclosed biofuel manufacturing buildings detached from other buildings and structures?						
8.1.10	If enclosed biofuel manufacturing buildings are not-detached, is the process undertaken in a compartment with at least one external wall, separated from other manufacturing and storage areas by a continuous construction affording at least 120 minutes’ fire resistance? With doors from the biofuel production area opening directly to the outside?						
8.1.11	Is appropriate lightning protection for buildings, structures and equipment in conformance with RISCAuthority RC35 Protection of buildings against lightning strike?						
8.2	**Ventilation and drainage (section 5.3)**						
8.2.1	Are production and storage units in open-to-air structures (that maximise natural ventilation)?						
8.2.2	If production and storage units are in enclosed areas, is suitably designed mechanical or natural ventilation provided for enclosed production and storage areas?						
8.2.3	For enclosed areas is ventilation rate sufficient to maintain the concentration of flammable vapours within the area to no more than 25% of the lower explosive limit (LEL)? And is exhausted air discharged to a safe place in the open air?						
8.2.4	For enclosed buildings and compartments where explosible vapour concentrations could accumulate under adverse conditions, suitable engineered controls such as explosion vents or lightweight frangible roofs should be provided.						
8.2.5	Is perimeter curbing for process areas provided, with adequately sized gullies and drains to direct process spills and overflow from sprinkler and deluge systems to a safe location?						
8.3	**Passive fire safety (section 5.4)**						
8.3.1	Is appropriate fireproofing provided for critical structures, vessel and column supports, exposed pipe-rack columns and control wirings and power cables necessary for safe plant shutdown?						
8.3.2	Are critical power and control cables rated to or protected to at least 15 minutes (up to 30 minutes) fire resistance to facilitate a safe process shutdown?						

		Yes	No	N/A	Action required	Due date	Sign on completion
8.3.3	For biofuel plant areas without adequate fixed water-based protection systems, where on-site fire teams and the Fire Service are unlikely to be able to effectively cool unprotected steel structures with fire hose or fire monitor streams and where area drainage is limited or restricted, is 90-minutes rated fireproofing provided.						
8.3.4	For exposed structures in areas not protected by fireproofing, is directional water-spray (normally forming part of an area water-spray or deluge system) provided, directed into the webs of vertical and horizontal structural members?						
8.4	**Fixed water-based fire-protection (section 5.5)**						
8.4.1	Is suitable fixed water-based fire protection installed to appropriate rules, i.e. sprinklers, deluge/water-spray, or foam systems?						
	For installed fixed water-based fire protection, are minimum recommended design criteria achieved:						
8.4.2	• minimum density of 10mm/min for water-spray protection of process plant?						
8.4.3	• minimum density of 7.5mm/min foam-enhanced protection of process plant, with foam supply designed for a minimum discharge period of 10 minutes?						
8.5	**Fire and flammable vapour detection (section 5.6 and 5.7)**						
8.5.1	Is automatic fire detection installed in all process areas (excepting areas with fixed fire protection actuated by fire activated elements)?						
8.5.2	Is automatic fire detection installed in all control and administration buildings and electrical equipment buildings?						
8.5.3	Is flammable vapour detection installed in areas where leaks and other unintentional releases could lead to flammable vapour accumulations?						
	Where flammable vapour detection is installed, is this arranged with two alarm levels as follows:						
8.5.4	• a lower alarm, set at no higher than 10% of the Lower Explosive Limit (LEL), providing a warning of a potential problem requiring investigation?						
8.5.5	• a higher alarm, set at no higher than 25% LEL, triggering an emergency response and where practical shutdown of appropriate unit operations, typically process feed-pumps (subject to Process Hazard Assessment considerations)?						
8.6	**Emergency response and fire fighting (section 5.8)**						
8.6.1	Are emergency response plans developed and routinely tested, covering major incidents including fire and explosion, power failure, adverse weather (inc. freezing), flood, escape of water?						
8.6.2	Is there an appropriately sized on-site emergency organisation?						
8.6.3	Are suitably located fire hydrants and fire monitors provided with an adequate fire water supply?						
8.7	**Process controls (section 5.9)**						
8.7.1	Are process control systems designed to shutdown processes safely in case of hazardous process disruption with the following systems features:						
8.7.2	• redundancy of control systems, especially as relates to safe shutdown?						
8.7.3	• process safety shut-off valves, including shutdown of flammable streams?						
8.7.4	• pressure relief systems, designed for both process anomalies and external fire exposure?						
8.7.5	• trips/interlocks need designed to appropriate standards?						

		Yes	No	N/A	Action required	Due date	Sign on completion
8.7.6	• interlocks to emergency shutdown of processes and flammable streams, activated by heat detection or flammable vapour detection?						
8.8	**Process equipment (section 5.10)**						
8.8.1	Are appropriate systems in place for maintenance and inspection of mechanical, electrical and instrumentation systems?						
8.8.2	Do maintenance and inspection procedures follow OEM (original equipment manufacturer) guidelines and risk-based good practice, as well as meeting statutory needs?						
8.8.3	Are maintenance and inspection records logged on a suitable computerised maintenance system?						
8.8.4	Is process equipment constructed from suitable materials?						
8.8.5	Are high integrity process pumps used as appropriate for volatile liquids?						
8.8.6	Is electrical equipment appropriately selected, based on a suitable hazardous area classification for areas where flammable atmospheres may be present? (Also see DSEAR below.)						
8.8.7	Is use of absorbent lagging/insulation precluded?						
8.8.8	Is the risk control guidance in RISCAuthority RC53 Recommendations for fire safety in the use of thermal oxidation plant, followed?						
8.8.9	Are all metal reaction vessels, metal receivers and extraneous metal items used as parts or supports for the process, bonded and earthed to prevent the build-up of static electricity?						
8.9	**Process safety (section 5.11)**						
8.9.1	Is a suitable structured process hazard assessment system (PHA), such as HAZOP, implemented?						
	Does the site process safety management programme include:						
8.9.2	• a "pre-startup safety review" to confirm that applicable elements of the safety management programme have been implemented correctly to ensure a safe process startup?						
8.9.3	• a comprehensive management of change programme, covering both major changes and minor modifications to plant and processes that impact risk?						
8.9.4	• a programme to ensure that P&IDs (piping and Instrumentation diagrams) are kept up to date?						
8.9.5	• emergency operating procedures detailing how to make plant and process safe following an unsafe process anomaly or equipment failure?						
8.9.6	• operator training covering process start-up, normal operations, process shutdown and emergency conditions, including the correct response to process and fire alarms?						
8.10	**Human element management systems (section 5.12)**						
8.10.1	Is there a suitable permit-to-work systems with procedures that authorise suitably skilled people to carry out specific work within a specified time frame along with precautions required to complete the work safely, based on a risk assessment?						
8.10.2	Are process isolations controlled in accordance HSE *HSG253*, *The safe isolation of plant and equipment* (ref. 30), or equivalent guide?						
8.10.3	Does the permit-to-work systems include a hot work permit system in conformance with the RISCAuthority RC7 *Recommendations for hot work*?						
8.10.4	Is air monitoring carried out to ensure that flammable vapours are not present during hot works in areas where flammable and combustible liquids and vapours might be present?						

		Yes	No	N/A	Action required	Due date	Sign on completion
8.10.5	Are high standards of housekeeping maintained to prevent the accumulation of combustible materials throughout the facility, including immediate attention to and clean up of leaks or spills of alcohols, oils and other ignitable materials?						
8.10.6	Is a control-of-contractors procedure is implemented to ensure that only competent contractors are used on site, that they are suitably inducted and trained to understand site hazards and permit to work requirements, they work safely within agreed method statements, that they are suitably monitored and supervised by site personnel and they hold adequate liability insurance cover?						
8.10.7	Is smoking prohibited throughout the facility, or as a minimum designated areas for smoking are provided at least 10m away from Hazardous Areas (as defined in DSEAR, ref. 2), buildings, structures, equipment and exposed combustible materials. Appropriate notices are prominently displayed?						
	Are systems of loss prevention inspections and audits implemented to ensure that general loss prevention is checked on a continuing basis, covering aspects such as:						
8.10.8	• general fire safety?						
8.10.9	• availability of emergency equipment (including fire extinguishers and fire hose reels)?						
8.10.10	• general condition of building and structures?						
8.10.11	• control of hazardous substances?						
8.10.12	• safe storage of flammable and combustible materials?						
8.10.13	• adherence to the smoking policy?						
8.10.14	Is a system for incident analysis implement to investigate and analyse incidents and "near-misses" that have, or might have, resulted in damage, contamination or injury?						
8.10.15	Is use of flexible hoses in process plants handling hazardous liquids avoided, or where there is no alternative, is a suitable flexible hose management programme, including a hose register and inspection programme implemented?						
8.10.16	Are suitable security measures implemented to prevent intruders accessing the site, including perimeter fencing?						
8.10.17	Have other security protections including security lighting, CCTV, guarding and access control systems been appraised?						
8.11	**Hazardous materials (section 5.13)**						
8.11.1	Are procedures in place for the safe use and storage of hazardous materials?						
8.11.2	Are material safety data sheets (MSDSs) available for all chemicals used?						
8.11.3	Is a suitable emergency spill control procedure in place to expedite removal of the hazardous substance to safe place?						
8.11.4	Are all hazardous raw materials and products are stored in vessels or containers within bunds, curbs or other form of secondary containment to control any spillage or loss of containment?						
8.11.5	Are storage tanks for hazardous materials fitted with high-level alarms, suitably interlocked to prevent overfilling?						
8.11.6	Are storage tank bunds constructed of non-permeable materials with a capacity of 110% of the largest vessel or container to be stored within it, or 25% of the aggregate storage capacity of the vessels or containers, whichever is greater?						

		Yes	No	N/A	Action required	Due date	Sign on completion
8.11.7	Are storage tanks for ignitable liquids are arranged and protected in accordance with RISCAuthority RC57 Recommendations for fire safety in the storage, handling and use of highly flammable and flammable liquids: storage in external fixed tanks?						
8.11.8	Are combustible dust hazards are arranged and protected in accordance with appropriate section of RC12 Recommendations for the prevention and control of dust explosions and RC64 Recommendations for fire safety with small biomass installations?						
8.11.9	Are measures in place to prevent hazardous materials, including biofuel, alcohols, acids, alkalis and glycerine from entering the site's water drainage systems?						
8.11.10	Is suitable care taken when handling waste products from the process?						
8.11.11	Are waste products retained in suitable containers to await removal from the site by a competent waste carrier?						
8.12	**Compliance with fire safety legislation (section 5.14)**						
8.12.1	Has a suitable and sufficient fire risk assessment been undertaken for all premises to which the Regulatory Reform (Fire Safety) Order 2005 (or equivalent legislation in Scotland and Northern Ireland) applies?						
8.12.2	Does the assessment consider staff remote from the process area who may be affected by smoke and heat in the event of a fire?						
8.12.3	In business critical areas, do the implications for property protection and business continuity, as well as life safety, feature prominently in the assessment?						
8.12.4	Has an assessment been undertaken in accordance with the Dangerous Substances and Explosive Atmospheres Regulations 2002 (DSEAR) that identifies hazard zones in the workplace?						
8.12.5	Are the risk assessments the subject of periodic review, including at the time when any changes to the process, the substances involved, the method of storing or handling the substances or the treatment of waste solvents are being considered?						
8.12.6	Has reference been made to the relevant fire and rescue service to become aware of the levels of response in the areas in which the premises are located?						
8.12.7	Does this site fall under criteria for reporting under the Control of Major Accident Hazards Regulations (COMAH) 2015 (or equivalent legislation in Northern Ireland) and if so have all necessary measures been taken to prevent major accidents involving dangerous substances and limit the consequences to people and the environment of any major accidents which occur?						

Signature ………………………………………………………………………… Name ………….................................………… Date ……..........…

Annex – Miscellaneous technical specifications

Protection measure	Recommended design
Ventilation for enclosed production and storage areas where flammable vapours could accumulate	Ventilation rate sufficient to maintain the concentration of flammable vapours within the area to no more than 25% of the lower explosive limit (LEL) • Mechanical ventilation systems should provide a minimum ventilation rate of 0.3m^3/min for each m^2 of floor area. Design should aim to eliminate any ventilation dead spots, where vapours could accumulate. The exhausted air should discharge to a safe place in the open air • Natural ventilation (usually only be suitable for small buildings) should provide a total equivalent vent area of 1% to 3% of the total area of the walls and roof
Flammable vapour detection alarms	**Lower alarm** set at no higher than 10% of the Lower Explosive Limit (LEL), arranged as warning of a potential problem **Higher alarm** set at no higher than 25% LEL, arranged to trigger an emergency response and where practical shutdown of appropriate unit operations
Fireproofing for structures exposed to pool fires in biofuel plants	Minimum 90-minutes fire resistance (An alternative to structural fireproofing is application of directional water-spray directed into the webs of vertical and horizontal structural members)
Fireproofing for critical power and control cables	Minimum 15-minutes (up to 30 minutes) fire resistance to facilitate a safe process shut-down
Water-spray / deluge protection for process plant	Minimum 10mm/min
Foam-enhanced water-spray for protection for process plant	Minimum 7.5mm/min with a foam supply duration of at least 10 minutes

Further Guidance

Hazards and controls

- "Farm Energy" advice on safety in small-scale biodiesel production: *https://farm-energy.extension.org/safety-in-small-scale-biodiesel-production*

Design

- BS 5908-1: *Fire and explosion precautions at premises handling flammable gases, liquids and dusts: Code of practice for precautions against fire and explosion in chemical plants, chemical storage and similar premises*
- BS 5908-2: *Fire and explosion precautions at premises handling flammable gases, liquids and dusts: Guide to applicable standards and regulations*
- HSE HSG143, *Designing and Operating Safe Chemical Reaction Processes*

Structural fireproofing (passive fire protection)

- Energy Institute, *Guidance on passive fire protection for process and storage plant and equipment*

Emergency response and firefighting

- Energy Institute, *Model code of safe practice – Element 14 – Emergency preparedness*

Process safety controls

- Control systems (HSE), *https://www.hse.gov.uk/comah/sragtech/techmeascontsyst.htm*
- Relief systems / vent systems (HSE), *https://www.hse.gov.uk/comah/sragtech/techmeasventsyst.htm*

Equipment and maintenance

- Energy Institute, *Process safety management framework – Element 15 – Inspection and Maintenance*
- Energy Institute, *Model code of safe practice – Part 15 – Area classification for installations handing flammable liquids*

Human element management systems

- Energy Institute, *Process safety management framework – High Level Framework for Process Safety Management*

References

1. Overview of UK Biofuel Producers, Ecofys, 2014: *https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/308142/uk-biofuel-producer.pdf*
2. Dangerous Substances and Explosive Atmospheres Regulations 2002 (DSEAR): *https://www.legislation.gov.uk/*
3. Managing risks and risk assessment at work (HSE) *https://www.hse.gov.uk/simple-health-safety/risk/steps-needed-to-manage-risk.htm*
4. RISCAuthority RC12 *Recommendations for the prevention and control of dust explosions*
5. RISCAuthority RC64 *Recommendations for fire safety with small biomass installations*
6. HSG103 *Safe handling of combustible dusts*
7. RISCAuthority RC57 *Recommendations for fire safety in the storage, handling and use of highly flammable and flammable liquids: storage in external fixed tanks*
8. HSG176 *Storage of flammable liquids in tanks*
9. Biodiesel Plant Safety, *Biodiesel Magazine*: *http://www.biodieselmagazine.com/articles/4055/biodiesel-plant-safety/*
10. RISCAuthority RC35 *Protection of buildings against lightning strike*
11. HSE Specialist Inspector Reports Number 29, Major Hazard Assessment: A Survey of Current Methodology and Information Sources, 1991
12. Thermal Radiation Hazards of Liquid Pool & Tank Fires, IChemE Symposium Series No. 97
13. HSE, RR1144 *Measurements of burning rate and radiative heat transfer for pools of ethanol and cask-strength whisky*, 2019
14. NFPA 80A *Recommended Practice for Protection of Buildings from Exterior Fire Exposures*
15. HSG 140 *Safe use and handling of flammable liquids*
16. NFPA 30 *Flammable and Combustible Liquids Code*
17. HSE Guidance note EH70, *The control of fire-water runoff from CIMAHsites to prevent environmental damage*
18. UL 1709 *Standard for Rapid Rise Fire Tests for Protection Materials for Structural Steel*
19. BS EN1363-2 *Fire resistance tests: Alternative and additional procedures*
20. API - RP 2218 *Fireproofing Practices in Petroleum and Petrochemical Processing Plants*
21. LPC Sprinkler Rules *(incorporating BS EN 12845)*
22. DD CEN/TS 14816: 2008: *Fixed firefighting systems — Water spray systems — Design, installation and maintenance*
23. BS EN 13565 – Parts 1 & 2 – *Fixed firefighting systems – Foam systems*
24. NFPA 11 *Standard for low-, medium-, and high-expansion foam* (now incorporating the formerly issued NFPA 16 *Standard for the installation of foam-water sprinkler and foam-water spray systems*)
25. NFPA 15 *Standard for water spray fixed systems for fire protection*
26. NFPA 20 *Standard for the installation of stationary pumps for fire protection*
27. BS 5839-1 *Fire detection and fire alarm systems for buildings. Code of practice for design, installation, commissioning, and maintenance of systems in non-domestic premises*
28. EN 60079 *Explosive atmospheres – Part 14: Electrical installations design, selection and erection*
29. RISCAuthority RC53 *Recommendations for fire safety in the use of thermal oxidation plant*
30. RISCAuthority RC26 *Recommendations for thermal fluid heating systems*

31. RISCAuthority RC7 *Recommendations for hot work*
32. HSG253 *The safe isolation of plant and equipment*
33. Control of Substances Hazardous to Health Regulations (COSHH) Regulations 2002: *https://www.legislation.gov.uk/*
34. Regulatory Reform (Fire Safety) Order 2005, Fire (Scotland) Act 2005, Fire Safety (Scotland) Regulations 2006. Fire and Rescue Services (Northern Ireland) Order 2006: *https://www.legislation.gov.uk/*
35. UK & EU REACH chemical regulations: *https://www.legislation.gov.uk/*
36. Control of Major Accident Hazards Regulations (COMAH) 2015: *https://www.legislation.gov.uk/*
37. Environmental Protection Act 1990: *https://www.legislation.gov.uk/*
38. HSG 51 *The storage of flammable liquids in containers*

Key websites

- RISCAuthority guidelines visit: *https://www.riscauthority.co.uk/public-resources/documents*
- HSE (Health & Safety executive) publications: *https://www.hse.gov.uk/*
- Energy Institute publications: *https://publishing.energyinst.org/*
- NFPA codes visit: *https://www.nfpa.org/Codes-and-Standards/All-Codes-and-Standards/Free-access*

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