Fire Protection Association®

RISCAuthority

Need to Know Guide RE5

Combined Heat and Power Systems

RISK INSIGHT, STRATEGY AND CONTROL AUTHORITY

REDUCING INSURABLE RISK THROUGH RESEARCH, ADVICE AND BEST PRACTICE

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1 Introduction

The purpose of this guide is to provide a high-level overview of the types and functions of Combined Heat and Power (CHP) systems and how a fire risk assessment of these systems can be approached. It is not intended as a detailed engineering guide, and users should expect to reference appropriate technical standards and consult with relevant engineering specialists in providing risk control solutions. The scope of this guide covers hazards relating to power and heat production. Power transmission hazards are not covered.

CHP systems are selected when there is a requirement for both electricity and heat, allowing the asset owner to optimise the energy efficiency. A CHP system utilises residual heat or steam, produced by generating electricity, to provide secondary facilities and processes with a reliable energy source. Supplemental heat recovered from the engine lubricating oil cooling systems and alternator coolant may also be harvested for water heating.

In basic terms, a CHP unit consists of an electric generator combined with equipment for recovering and using the heat produced by the 'prime mover' that turns the electric generator, such as a gas turbine or a reciprocating engine.

CHPs can achieve efficiencies at 75-80% when compared with discrete electricity and heat production, therefore delivering significant cost savings and reducing the carbon emissions that would be incurred by delivering the same energy requirements independently, where typically heat representing more than 40% of fuel is released into the environment.

Installations may also integrate absorption or adsorption chillers for cooling and chilling applications, in combination with cogeneration; this is known as 'trigeneration'.

2 CHP plant and equipment

As shown in *Figure 1*, a CHP facility consists of a fuel supply that provides energy for a mechanical prime mover, itself directly connected to an electrical generator, providing both electrical and heat energy. The electrical energy is transformed for grid transmission and local consumption by a number of transformers. The exhaust heat is passed to the end user either via a heat exchanger to raise steam and hot water or directly to the end user as steam from a steam turbine.

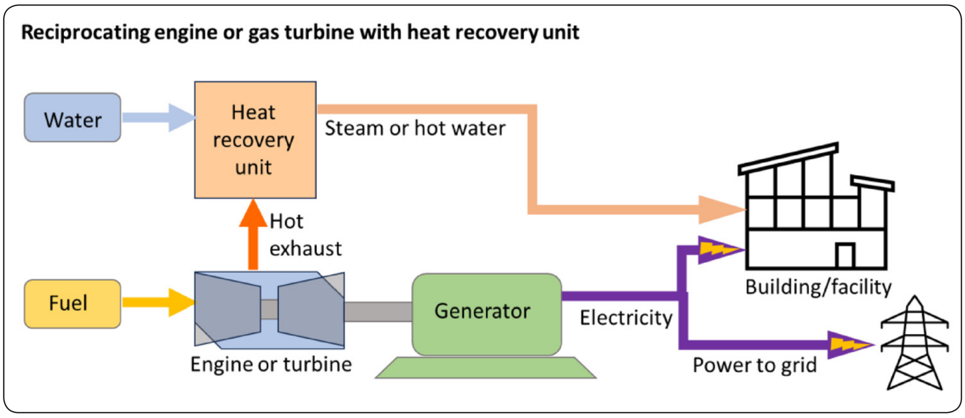


Figure 1: CHP overview

The principles of operation and risk control are the same irrespective of scale, i.e. for the range of units found, from compact CHP installations that can be found on farms and non-industrial locations to the large and very large installations used on major manufacturing sites.

The choice of CHP technology depends on several factors, such as the size of the facility, land availability, specific application requirements, available fuel and resources, lifecycle costs, and energy efficiency objectives

3 Fuel supplies

Fuels used in CHP units range widely from fossil fuels (e.g. diesel, fuel oil, natural gas) to renewable fuels, such as biogas, biodiesel, and biomass, even extending to hydrogen for fuel cells.

Biomass can be used as fuel for small-scale CHPs. Typically, biomass CHPs run on either low moisture content wood pellets or wood chips and usually rely on pyrolysis, which involves heating the fuel in the absence of air at high temperatures (>700°C). This produces syngas (synthesis gas) which is predominantly a mixture of hydrogen and carbon monoxide, which powers a combustion engine generator. Other renewable fuels that can power CHPs include biogas (produced by the anaerobic digestion of organic materials), liquid biofuels, biomass (including agricultural residues, waste wood, and straw), and commercial-grade wood fuels.

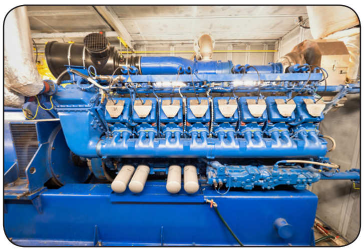
The hydrogen sulphide gas present in biogas from landfill and anaerobic digestion applications is highly corrosive, so suitable measures should be provided to detect and control concentrations in accordance with OEM recommendations for the prime mover and for personnel safety

Farms (and similar sites) running wood chip biomass-fuelled CHPs will often use some or all of the heat produced to dry the wood chip.

For more details on renewable fuels, refer to these RISCAuthority guides: *RC46: Risk control for biofuel manufacturing facilities*, *RC64: Recommendations for fire safety with small biomass installations, and Need to Know Guide RE4 Hydrogen Fuel*.

Special attention should be given if existing CHP installations are converted from conventional fuels into renewable fuels, to ensure that a full risk assessment to identify potential equipment degradation and general fire-safety issues is completed

4 Design


Gas-fired reciprocating engine

A number of prime mover technologies are used in CHP systems, principally:

- Internal combustion engines (reciprocating engines)
- Steam turbines
- Gas turbines
- Stirling engines.

CHP installations will either be 'packaged CHP' units designed and supplied as complete installations that can be readily connected to a building's electrical and heating systems, or 'custom CHP' installations that are designed and assembled according to site-specific specifications.

Packaged CHP units, which typically use well-known technologies such as reciprocating engines, range in size from 50 kW to over 1 MW electrical capacity and are usually provided with integrated remote monitoring and control, requiring less training and involvement for site personnel.

In recent years, gas turbines have been the most widely used prime mover for large-scale, custom CHPs, with conventional gas turbine sizes ranging from 500 kW to 350 MW. However, developments in technology have resulted in the availability of smaller gas

Turbine-generator set

turbines (microturbines) that are now available as packaged CHP units, typically in the 30–400 kW electrical output range.

Combined cycle cogeneration systems, installed as custom CHPs, usually utilise gas turbines in conjunction with steam turbines, where high-grade exhaust heat from the gas turbine is fed to a heat recovery boiler, and the steam produced is passed to a steam turbine to generate additional electricity (via the Rankine cycle). The lower-pressure steam from the steam turbine is used for site/process heating. Combined cycle plants are typically powered by natural gas, although fuel oil, or other fuels such as syngas, may be used. Combined cycle cogeneration systems can achieve up to circa 90% overall energy efficiency.

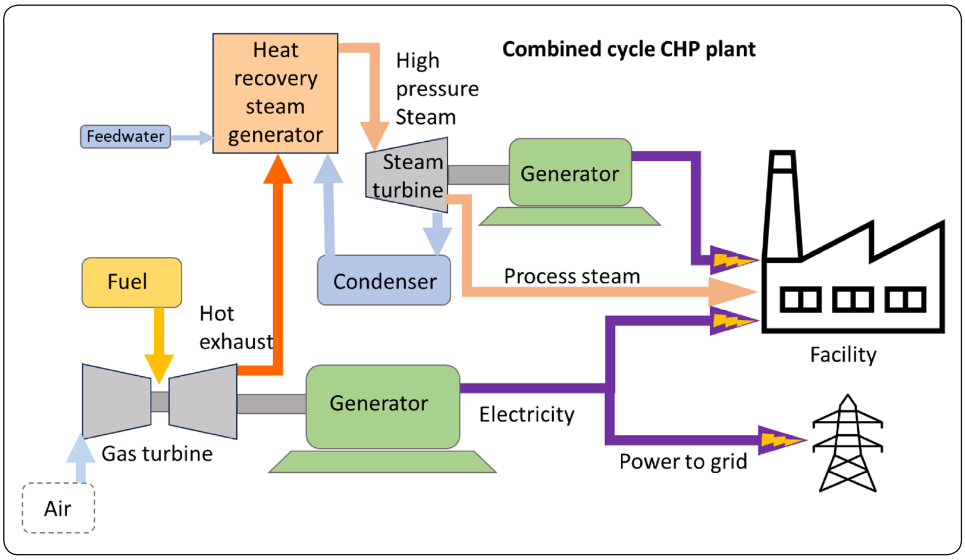


Figure 2: CHP incorporating a steam turbine to achieve a combined cycle

Whilst not strictly CHP installations, it is worth mentioning photovoltaic-thermal (PV-T) hybrid solar systems, which increase electricity production by cooling the PV panels and utilise the removed thermal energy to heat water, usually for domestic use. Standard PV systems are covered in RISCAuthority *Need to Know Guide RE3, Rooftop-mounted PV Solar Systems*.

5 Operation

It should be noted that CHP packages are intended for operational use and are typically not suited to provide an emergency stand-by power source for vital areas of demand. Emergency power backup systems need to be suited for automatic restarting (often from cold) and the take-up of full load output in a matter of seconds.

Electrical supply connections for CHPs can be set up as either 'grid parallel mode' or 'island mode'. Grid parallel mode operation is prevalent in the UK, where the CHP connection operates in conjunction with the local area electricity supply system by having closed electrical connections between the CHP plant, the site, and the power utility grid. Once synchronised with the power utility grid, plant operators do not have control over the frequency and the voltage, but the active and reactive power on the CHP unit(s) can be controlled from the plant. In island mode, the CHP plant is not electrically connected to an external electricity system.

CHP installations have their own control and monitoring systems, interconnected to provide a single integrated system. Normally, these systems incorporate controls for condition-monitoring equipment, which provides warnings and automatic shutdown in the event of component malfunction, as well as long-term management and operation of the plant. The programmable logic controllers (PLCs) for these systems should normally include metering, control, and protection systems required for the safe start-up, operation, and normal shutdown of the equipment.

6 Hazards, risks, and controls

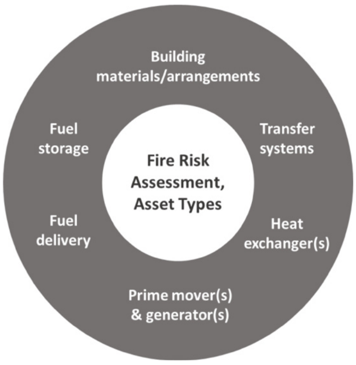


Figure 3: Fire risk assessment focus asset areas

CHP plants combine the application of technologies covering fuels, prime movers (rotating and reciprocating machinery), electrical power production, and heat transfer.

The causes of fires and explosions at CHP facilities, resulting in significant plant damage, can be categorised as a weakness in design decisions and compliance, material selection, operational practice, management controls, maintenance culture, and human error. Fires and explosions often occur following machinery and equipment breakdown and failure events.

Examples of known events on CHP assets include fuel over-pressurisations causing pipe ruptures, overheating due to poor design or poor operational controls, combustion system failures, electrical failures causing a short circuit, arcing, and other equipment failures.

To assess the fire hazards presented by CHP units and the appropriate control measures, it is necessary to evaluate each section of a CHP installation. This relates to buildings/enclosures, fuel storage, transfer and delivery systems, prime movers (including waste product treatment/exhaust), generators, and power and heat delivery systems. *Figure 3* illustrates the asset types to be risk assessed.

Protection controls/measures need to be appropriate for each component operation of the CHP and for the installation as a whole

For packaged CHPs, much of the risk assessment should have already been completed by the OEM as part of the design, and the fire risk assessment will focus on how the installation impacts its environment on the plant, including detachment from critical portions of the property.

For more complex custom CHP installations, structured hazard identification and risk assessment methods such as fault and event tree analysis, failure mode and effect analysis (FMEA), and hazard and operability (HAZOP) studies should always be applied. These methodologies are described in RC46: Risk control for biofuel manufacturing facilities.

Common in the power-related industries is the application of 'bowtie analysis', which joins together fault and event trees to provide a diagram that demonstrates causes and consequences around a central (or top) event. The principle of ALARP (As Low As Reasonably Practicable) should also be applied. ALARP levels are reached when the required resources and cost of further risk reduction measures become unreasonable/disproportionate to additional risk reduction that may be obtained. HSE guidance is available here: https://www.hse.gov.uk/enforce/expert/alarpglance.htm

Performing suitable hazard identifications at design and pre-operation are essential through the phases of a CHP project

Designing fire safety measures for CHP installations requires diligent consideration of the specific hazards, layout, and operational characteristics of the facility, as shown in the table below.

Hazard Assessment	Controls
Carry out suitable fire and process risk assessments. Identify the potential fire hazards regarding: • electrical equipment • oil systems • fuel systems/storage • hot gases • flammable/combustible materials. Determine the fire risk associated with each hazard and the consequences of a fire.	Identify and prioritise fire protection measures based on the fire hazards and criticality of each part/area of the CHP installation. These measures include: a. Equipment design, including design of fuel piping and ignitable/hazardous materials storage and handling b. Equipment location and layout c. Construction and location/layout of buildings and structures d. Ventilation to avoid overheating and buildup of combustible fumes e. Safety controls and interlocks f. Active and passive fire protection measures g. Fire risk management h. Training and emergency planning i. Maintenance and inspection j. Code/regulations compliance.

Fire risk assessment and controls

By way of example, solid fuels, such as biomass, present both fire and dust explosion exposures.

Event	Risk Areas	Controls
Dust explosion	Primary areas of concern are: • enclosed vessels such as bins and hoppers, dust collectors, and storage silos • secondary transport systems such as conveyors.	a. Area classification for electrical controls b. Separation, isolation, and segregation of dangerous processes from each other c. Layered protection systems including fire prevention, and installed fire and explosion protection.

Dust explosion controls

Organic-based thermal oils used for heat transfer may be used with some CHP installations, i.e. for elevated temperature applications. These typically present additional fire safety considerations relating to the transportation, storage, and use of ignitable thermal oils. These heat transfer fluids are nearly always operating at temperatures above their flash points, and their systems are often characterised by large holdups and high flow rates of thermal oil. The high system temperatures and pressures at which they operate make them prone to leakage and more substantial failures, leading to large heat transfer fluid releases that will often result in significant fire or explosion events.

Event	Risk Areas	Controls
Over-heating and loss of containment of oil, followed by ignition	Primary areas of concern are: • storage • transportation • use of ignitable thermal oils.	a. Pipework design and material selection b. Leak detection c. Flange guards d. Pipework routing e. Plant shut down f. Installed fire protection.

Oil loss and ignition controls

Each CHP installation will vary in its complexity, so it is recommended that risk control specialists, including insurers' technical advisers, are consulted for new CHP installation projects, to provide risk management and risk control advice for both the construction and operational phases of the installation lifecycle.

Another key consideration is to ensure that the operations and maintenance (O&M) teams fully understand the safety controls that have been provided as part of good design to manage inherent risks and do not introduce any measures or practices that breach or weaken these controls.

Adequate maintenance and good housekeeping are key elements of fire safety for CHP systems

7 Specific issues with OEM-owned CHPs and CHPs on non-manufacturing/small sites

Packaged CHP plants may remain in the ownership of the OEM/supplier and be leased to the end user, with services under contract through the leasing agreement. This removes the end users and their insurers from many aspects of risk assessment and risk management, concerning hazards and hazard controls for these leased CHP units, which are typically unmanned and remotely operated. This can lead to CHP units being 'black box' installations, with focus only on their function and without full consideration of their potential hazards and impact on the site. Also, end users of leased CHP packages need to be aware that, in addition to the physical fire and explosion exposures that may arise, their business may be (or become) heavily reliant on the electrical power and heating services provided, with potential to significantly impact site efficiencies and possibly viability, should an extended interruption to CHP services occur.

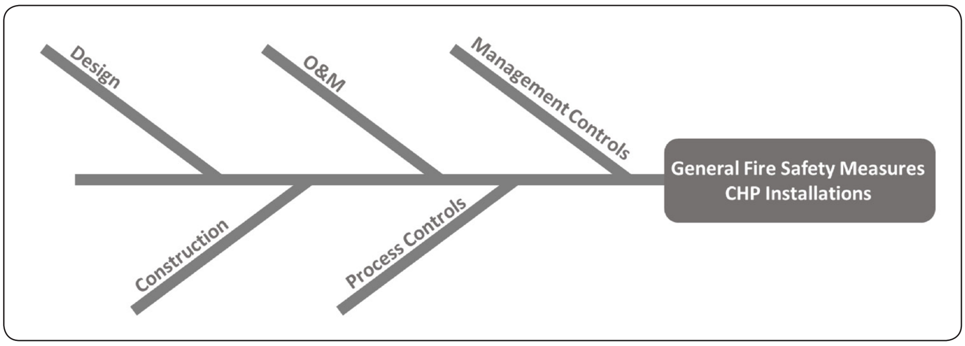
Issue	Solution
Proximity of the CHP installation to the end user's own assets and infrastructure will often create fire (and possibly explosion) exposures, and the separation between a separately owned CHP plant and a client's plant, may be overlooked in the procurement process for the CHP.	Project managers should fully engage site safety and engineering functions to fully assess exposures to site assets, such that fire separation/segregation arrangements form part of the project plan in siting/housing the CHP equipment.
Fire detection will often not be routinely cross connected to the end-user's site fire alarm system unless this is specifically required.	• Directly connect CHP package fire detection to the site/factory fire alarm system, or link to an alarm panel at a constantly attended location (i.e. the site gatehouse or building services/maintenance offices, if constantly manned). These fire detection alarms, as with other fire alarm signals, should be linked to off-site alarm monitoring when available. • If the CHP OEM/leaser does not allow a direct alarm connection, another solution, whilst less desirable than a direct connection, is the provision of external sounders and beacons (connected to the CHP alarm system) installed in locations that are audible/visible to site personnel, who can initiate an emergency response without the delay associated with waiting for a call or text from the CHP provider/operator.
Attention focused on minimising outages through process controls and technical services means that most CHP packages are not supplied with installed fire suppression. There may be a CHP package option with factory-fitted fixed fire suppression. When not available, retrofits may not be practical or agreed upon by the CHP supplier, whether this be related to fixed fire suppression for generator compartments, fuel tanks, dust generating/handling equipment, or the electrical panels that form part of the equipment package.	In the absence of fixed fire suppression, fire safety is heavily reliant on the CHP supplier having provided a well-designed installation that is safely operated and suitably serviced, and on good fire separation/segregation features.

A biogas reciprocating engine generator installed on a farm

Aside from CHP ownership issues, some smaller CHP users who are adept at maintaining their own machinery, such as farmers, may elect to maintain their CHP units themselves, especially where familiar equipment such as diesel engines are used. This local maintenance may not be aligned to the requirements of power generation systems, with an increased likelihood of equipment failures leading to loss; therefore, the services of suitably trained and skilled OEM-approved CHP mechanics and technicians should always be used.

8 General fire safety measures for CHP installations

The following diagram and table utilise the phases of a project lifecycle to set out typical hazard controls.



These best practice recommendations are intended to highlight many of the key risk control measures for CHP installations, but the list is not exhaustive, and detailed risk control and engineering standards and guidelines should be referred to.

1. General CHP Fire Safety	
Design	
1.1. Design standards	CHP plant and equipment should be designed to appropriate codes and standards. Selected key technical codes and standards are provided in this table and the tables following. **Note:** This is not an exhaustive list and the latest editions should be referred to.
1.2. Explosion venting	As appropriate, based on the fire risk assessment, provide suitably designed explosion overpressure venting for fuel explosions.
1.3. Flammable vapour detection	Where flammable vapour leaks and other unintentional releases could lead to flammable vapour accumulations, flammable vapour detection should be installed. A typical arrangement is an alarm, set for 10% of the Lower Explosive Limit (LEL) and fuel system shutdown, possibly supplemented by the inerting of the prime mover enclosure via a fire suppression system discharge at 25% LEL. An alternative approach is to initiate high ventilation at 10% LEL and isolate gas supplies at 20% LEL. **Note:** The minimum concentration of a particular combustible gas or vapour necessary to support its combustion in air is defined as the LEL.
1.4. Hazardous zones	Ensure that electrical equipment is selected and located in accordance with a suitable hazardous zones assessment (DSEAR/ATEX)*, for flammable vapour or explosible dust risk, as appropriate. *Packaged reciprocating gas engine containers that are listed as 'Zone 2NE (negligible extent)' for DSEAR/ATEX have a container 'purge' sequence to maintain the container rating.* * Dangerous Substances and Explosive Atmospheres Regulations 2002 (DSEAR)
1.5. Earthing and bonding	Where flammable liquids, gases or vapours, or combustible dusts are stored, transferred, or handled, metal tanks/silos, equipment, pipes, and other components susceptible to static build-up should be bonded and earthed to prevent the accumulation of static electricity, which could lead to sparks.

1. General CHP Fire Safety	
1.6. Fire detection	Install appropriate types of automatic fire detection (e.g. smoke detectors, heat detectors, and flame detectors) in all areas relating to CHP installations, including fuel handling/storage, control, and electrical distribution. Refer to the *FPA's member-only guide Fire Alarm and Detection Systems* for further guidance.
1.7. Fixed fire protection	As appropriate, based on the risk assessment, provide fixed fire protection for all fuel handling and storage, power generation equipment, and oil-filled electrical equipment. Sprinklers, water-spray, and foam-enhanced sprinklers/water-spray are the best forms of area fire protection. NFPA 850, Recommended practice for fire protection for electric generating plants and high voltage direct current converter stations is the internationally recognised standard for the fire protection of power generation installations, providing granular guidance on where and how to provide fixed fire protection, along with detailed design specifications. Fire protection guidance, based on NFPA, is summarised for key power plant areas in the Appendix.
Construction	
1.8. Construction and location	a. Ideally, locate CHP installations in non-combustible outbuildings or outside non-combustible weatherproof enclosures. b. Where installation inside primary buildings cannot be avoided, then room enclosures should be cut off from the rest of the facility by construction rated for at least 2 hours.
O&M	
1.9. Access	CHP buildings, enclosures, and rooms shall be dedicated-use, i.e. not used for any other purpose and accessible only by those required, who are fully trained and competent to operate, maintain, test, or inspect the CHP equipment. Storage of combustible materials other than those required for day-to-day operation (manuals, filters, etc.) should be strictly prohibited.
1.10. Critical spares	For large installations, ensure that requirements for 'strategic spare parts' are fully considered and implemented. This relates to parts and components that would not normally be expected to fail but are critical to plant operation and have a long lead time to source (as opposed to operational and maintenance spares that can be expected to be used routinely or at some point in the lifetime of the equipment).
1.11. Emergency response	Develop and routinely test emergency response plans that include procedures for shutting down equipment, evacuating personnel, and coordinating with local fire and rescue services.
Process Controls	
1.12. Safety interlocks	All safety interlocks for emergency shutdown of CHP installations, such as overspeed, over temperature, and high vibration, should be hard-wired between the plant items and the main control and monitoring system.
1.13. Emergency alarms	Connect all fire, emergency, and equipment anomaly alarms, to sound/indicate at a constantly manned control room, alarm centre, or other constantly attended location where appropriate action can be taken.

1. General CHP Fire Safety	
Management Controls	
1.14. Safe working systems and preventive maintenance	Ensure that suitable safe systems of work and preventive maintenance programmes are implemented, and that work is carried out by suitably trained and qualified technicians in accordance with OEM recommendations. **Note:** Some of the routine maintenance tasks may be carried out while the prime movers are operating, but routine shutdowns for maintenance and servicing are also required.
1.15. Hot work	Avoid hot work (hot cutting and welding) in CHP areas, especially where flammable or combustible fuels are present. Where practical, take parts or equipment requiring hot work to a suitably arranged maintenance workshop. Where hot work in CHP areas is unavoidable, refer to RISCAuthority *RC7: Recommendations for hot work*, also ensuring that fuel systems are suitably isolated and drained/inerted as necessary, per a fire risk assessment.
Selected key technical codes and standards	
• 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 • BS EN 13463 – Non-electrical equipment for use in potentially explosive atmospheres • BS EN 60079 – Explosive atmospheres (multi-part document) • HSE HSG253 The safe isolation of plant and equipment • Explosion relief (HSE), https://www.hse.gov.uk/comah/sragtech/techmeasexplosio.htm • RISCAuthority RC35: Protection of buildings against lightning strike • RISCAuthority RC42: Recommendations for fire safety of unattended processes, 2011 • FM DS 12-14 Waste Heat Boilers	

9 CHP component operations – specific fire safety controls

These best practice recommendations relate to specific CHP component operations and supplement the general fire safety measures above.

2. Engines and turbines (prime movers)	
2.1. Shutdown controls	Equip all engines and turbines with automatic controls that shut down the engine/turbine if it starts to overheat, overspeed, experience high vibration, or suffer any other dangerous conditions specific to their type, which can be monitored.
2.2. Ventilation	Provide adequate ventilation for prime mover enclosures to avoid overheating.

2. Engines and turbines (prime movers)	
2.3. Exhaust arrangements	Route and protect/insulate engine exhaust ducts and outlets to avoid proximity to any combustible materials or other materials/ equipment susceptible to heat damage or ignition. Ensure that all penetrations through the building/enclosure structure are appropriate for the temperatures that they will be exposed to and that all products of combustion are adequately and deliberately removed from the space without interfering with other building systems.
2.4. Engine lubrication	Implement a programme of engine lubricating oil sampling and testing. **Note:** The presence of water or other liquid contaminants, or of metallic or non-metallic solids, provides an indication of excessive wear or leakage, while the condition of the oil itself, such as its acidity and viscosity, provides essential data for assessing the engine condition.
Selected key technical codes and standards	
• NFPA 37 Standard for the Installation and Use of Stationary Combustion Engines and Gas Turbines • FM DS 13-26 Internal Combustion Engines • FM DS 7-77 Testing of Engines and Accessory Equipment • FM DS 13-17 Gas Turbines	

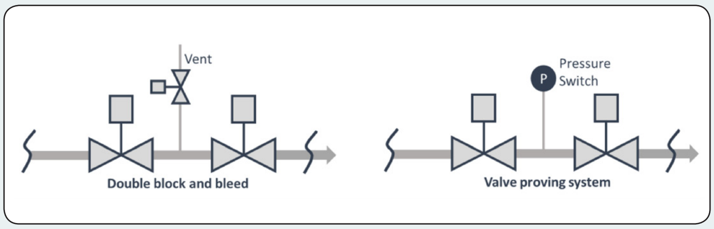
3. Pumps, pipes, and vessels	
3.1. Pump selection	As appropriate, based on the risk assessment and industry good-practice guidelines, to eliminate or significantly reduce the risk of pump seal failures leading to a release of ignitable liquids, use high-integrity pumps for handling hot oils and other ignitable fluids, e.g. double-mechanical-seal pumps, magnetic-drive or canned (hermetically sealed) pumps. Refer to RISCAuthority *RC46: Risk control for biofuel manufacturing facilities*.
3.2. Insulation selection	Use non-absorbent, non-combustible, closed cell insulation material for oil pipes, suitable for the temperature employed.
3.3. Valve orientation	Where possible and allowable with regard to valve type and design, position oil pipe valves with stems oriented in the horizontal position to allow stem seal leaks to drip away from the pipe and insulation.
3.4. Pressure systems	Ensure that Pressure Systems Safety Regulations (PSSR) are fully complied with, and before using any qualifying pressure equipment, a written scheme of examination (WSE) is in place and an examination undertaken. Refer to *HSE, Safety of pressure systems; Pressure Systems Safety Regulations 2000*.

4. Biomass	
4.1. Stores	Provide purpose-built stores for biomass fuel. Biomass stores should preferably be independent buildings linked to the heating installation by the biomass feed system. Where this is not possible, the store should be separated from the remainder of the building by a form of construction that provides at least 60 minutes fire resistance. Entry and fuel delivery provisions should be from the outside of the building only.
4.2. Dust controls	Apply engineering principles to avoid and control dust explosions, including isolation, segregation, and separation of the various hazardous parts of the process, along with layered protection systems for fire prevention, fire protection, and explosion protection. • Spark detection, linked with fire extinguishing systems and area sprinkler or water-spray protection, are common fire protection strategies. • Care should be taken during delivery and movement of the fuel (including during maintenance or repair operations) to minimise the distribution of dust in the atmosphere.
4.3. Explosion vents	Provide suitably designed explosion venting for biomass storage vessels and dust collectors.
4.4. Transport systems	Provide suitable fire safety controls for biomass transport systems, proportionate to their size and location. • For example, consider spark and linear heat detection for along biomass conveyors, interlocked to shutdown, with the possible addition of localised automatic fire suppression for key hazard areas. • Also ensure that suitable controls and interlocks are provided to shut down conveyors when friction-heat is generated, such as when slippage or misalignment occurs.

Selected key technical codes and standards

- RISCAuthority RC12: Recommendations for the prevention and control of dust explosions
- RISCAuthority RC64: Recommendations for fire safety with small biomass installations
- HSG103 Safe handling of combustible dusts
- NFPA 61 Standard for the Prevention of Fires and Dust Explosions in Agricultural and Food Processing Facilities
- NFPA 68 Standard on Explosion Protection by Deflagration Venting
- NFPA 69 Standard on Explosion Prevention Systems
- NFPA 664 Standard for the Prevention of Fires and Explosions in Wood Processing and Wood Working Facilities

5. Fuel gases	
5.1. Fuel gas burner management controls	Provide suitable gas burner management controls to ensure safe ignition and operational shutdown, flame stability monitoring (turbines), and triggering emergency shutdown in case of anomalies.

5. Fuel gases	
5.2. Minimum gas train controls	a. Provide at least one clearly marked manual shut-off valve located in a remote location outside the fire hazard area of the prime mover for emergency shutdown, providing positive shut-off of fuel to the prime mover. b. Provide automatic fuel gas safety shut-off valves to stop the flow of gas to gas-fired prime movers when an unsafe condition has been detected, and to prevent any gas leakage into combustion equipment when this is not operating. These are normally arranged as two safety shut-off valves in series, downstream of the pressure regulator, with a valve-proving system (VPS) to check the gas-tightness of these valves, or as 'double block and bleed (DBB)' isolation, i.e. double isolation valves with an intermediate atmospheric vent.  c. Provide high and low gas pressure alarms/interlocks.

6. Liquid fuel	
6.1. Burner controls	a. Provide suitable liquid-fuel burner management controls to ensure safe ignition and shutdown procedures, monitor flame stability (turbines), and trigger emergency shutdown in case of anomalies. b. Valves shall be provided to shut off the flow of fuel in the event of a pipe break or fire. At least one manual shut-off valve located away from the prime mover, ideally outside of the engine room, should be provided for emergency use. Solenoid valves interlocked with other controls may also be used to shut off fuel supplies.
6.2. Automatic fuel shut-off	Except for CHP installations powering emergency systems, or those that are constantly attended, where appropriate (based on the fire risk assessment) automatic fuel shut-off valves should be arranged to close upon activation of the fire detection system covering the engine installation, including auxiliary equipment. A simple alternative is the use of suitable fusible links arranged, on release, to shut spring-close fuel valves. (These valves are held open by a wire held in tension by a fusible link, and snap shut when the fusible link is activated by heat and releases the wire.)
6.3. Fuel tanks	Provide fuel tanks supplied by pumps with: a. an overflow line b. a high-level alarm c. a high-level automatic shut-off.
6.4. Spill control	Design on-site liquid fuel storage to minimise the potential for spills, overfilling, and leaks from fuel tanks and the engine itself. Limit fuel tanks' size with regard to location and enclosure construction to minimise fire spread in the event of fuel releases.

6. Liquid fuel	
6.5. Tank bunds	Provide storage tank bunds constructed 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.
Selected key technical codes and standards (gaseous and liquid fuels)	
• IGEM/UP/2 Installation pipework on industrial and commercial premises • IGEM/UP/9 Application of Gas systems to gas turbines and supplementary and auxiliary fired burners • IGEM/UP/12 Application of burners and controls to gas fired process plant • IGEM/UP/16 Design for Natural Gas installations on industrial and commercial premises with respect to hazardous area classification and preparation of risk assessments • HSE L56 Gas Safety (Installation and Use) Regulations 1998 (GSIUR) as amended. Approved Code of Practice and guidance • RISCAuthority RC46: Risk control for biofuel manufacturing facilities • RISCAuthority RC57: Recommendations for fire safety in the storage, handling and use of highly flammable and flammable liquids: storage in external fixed tanks • RISCAuthority Need to Know Guide RE4 Hydrogen Fuel (includes general fire safety measures) • HSG 140 Safe use and handling of flammable liquids • HSG 176 Storage of flammable liquids in tanks • NFPA 30 Flammable and Combustible Liquids Code	

7. Organic-based thermal oil systems	
7.1. Safety interlocks	Provide key safety control interlocks to include: a. means to prove minimum fluid flow through the heater at all operating conditions, interlocked to shut the burner down when fluid flow is insufficient b. fluid excess temperature and high-pressure protection c. a high stack temperature switch, interlocked to shut off the burner and circulating pump d. a minimum liquid level switch or similar device for the expansion tank(s), interlocked to shut down the system pump and burner.
7.2. Expansion tank	Sufficiently size the thermal oil system expansion tank (that serves as the safe outlet for increases in thermal fluid volume due to thermal expansion) to accommodate worst case events and interlock to shut down the system if head pressure is lost, or low liquid level occurs.
7.3. Vented fluids	Route vented fluids from pressure relief devices such as safety relief valves to a safe location, such as a properly arranged catch tank.
7.4. System segregation	Limit thermal oil leakage and release potential by providing system segregation using shut-off valve and check-valve arrangements commensurate with the size and complexity of the system.
7.5. Relief valves	Use only safety relief valves and other overpressure protective devices designed for organic fluid service, designed for the maximum temperature that may be encountered.

7. Organic-based thermal oil systems	
7.6. Separation	Segregate thermal oil systems from critical portions of a property, ideally by separation, but where location within a facility is unavoidable, locate within cut-off rooms with a minimum of 2 hours fire resistance.
7.7. Spill control	Provide bunds and drains as appropriate (per the fire risk assessment) to contain and control ignitable fluid spills.
7.8. Fireproofing	Fireproof exposed structural steel, including vaporiser or heater support legs, for a minimum of 90 minutes fire resistance.
7.9. HT fluid samples	Routinely (at least annually), remove a sample of the heat transfer fluid for laboratory analysis to check for contamination or deterioration.
Selected key technical codes and standards	
• RC26: Recommendations for thermal fluid heating systems • NFPA 87 Standards for Fluid Heaters • FM DS 7-99 Heat transfer fluid systems	

10 Glossary

Biogas

Biogas consists mainly of methane and carbon dioxide and can also include small amounts of hydrogen sulphide, and siloxanes, along with some moisture. When biogas is cleaned up and upgraded to natural gas standards, it is known as 'biomethane' and can be used in a similar way to methane.

Chillers for CHP systems

Chillers fired using thermal energy recovered from CHP prime movers are used in commercial buildings and industrial plants to provide air conditioning, refrigeration, and process fluid cooling. Absorption chillers use fluid refrigerants and absorbents, e.g. water/lithium bromide (refrigerant/absorbent). The absorption cycle is a process by which a refrigeration effect is produced through the use of two fluids and heat input rather than electrical input, as in the more familiar vapour compression cycle. Adsorption chillers are similar but use a solid sorbent (typically silica gel) and a fluid refrigerant (typically water).

Fuel cells

Electrochemical devices that convert the energy of a chemical reaction directly into electricity, with heat produced during the process. Typical fuel sources are hydrogen or natural gas.

Gas turbines

Internal combustion engines, which run on fuel gases or liquid fuels, in which expanding gases from the combustion chamber drive the blades of a turbine. In CHPs, power is taken as torque from the turbine to drive electrical generators. The waste heat produced is captured for CHP heating applications. Gas turbines used in CHP units are either types derived from aircraft jet engines or types originally designed for power generation applications.

Internal combustion engine/reciprocating engine

Reciprocating engines used in CHP systems are internal combustion engines that operate on the same principles as petrol and diesel vehicle engines. For power generation applications, many reciprocating engines use gaseous fuel, most commonly natural gas. The waste heat produced is captured for CHP heating applications. They are often used in smaller-scale CHP installations.

Microturbine CHP

Microturbines are compact gas turbines, with a power rating of circa 25–500 kW, that are suitable for use for distributed power generation and heat recovery in non-industrial applications, such as commercial and residential buildings.

Rankine cycle

The Rankine cycle is a thermodynamic cycle that converts heat into mechanical energy, which usually gets transformed into electricity by electrical generation. This process is widely used by power plants where water is converted into steam in a boiler or heat exchanger, which then expands through a steam turbine producing useful work.

Organic Rankine Cycle (ORC) CHPs use organic fluids to generate electricity from low-temperature heat sources, such as geothermal or waste heat. They are particularly useful for recovering heat from industrial processes.

Steam turbine

Steam turbines extract thermal energy from pressurised steam and use it to do mechanical work on a rotating output shaft, i.e. driving the power generator in CHP installations.

Stirling engine

A closed-cycle regenerative heat engine that is operated by the cyclic compression and expansion of a permanent gaseous working fluid (air or other gas) between different temperatures, resulting in a net conversion of heat energy to mechanical work.

Appendix – Fixed fire protection design

Key fixed fire protection design specifications and considerations:

a. Water-based fixed fire protection specifications:

Area	System type	Minimum density, mm/min	Minimum area of sprinkler operation, m^2	Comments
Fuel handling structures and areas subject to accumulations of fuel or fuel dust	Automatic sprinkler or water spray systems	10.2	232	Ref. *NFPA 850*. Use an operating area of 279m^2 for biomass storage buildings (increased by 30% for dry pipe systems).
Combustion engine and gas turbine rooms/ enclosures	Automatic sprinkler protection	12.2	230	*Ref. NFPA 37 – Installation and Use of Stationary Combustion Engines and Gas Turbines*.
Areas beneath the turbine-generator operating floors that are subject to oil flow, oil spray, or oil accumulation (typical for steam turbines)	Automatic sprinkler or foam-water sprinkler systems	12.2	464	*Ref. NFPA 850*. Coverage should take into consideration obstructions from structural members and piping (and other services) beneath the turbine-generator.
Lubricating oil lines above the turbine operating floor	Automatic sprinkler protection	12.2	–	*Ref. NFPA 850*. Careful consideration should be given to protection of turbine bearings, i.e. to address concerns regarding water on hot turbine surfaces.
For full design specifications reference the relevant NFPA code				

b. Consider automatic sprinkler, foam-water spray, or water spray, for oil-filled electrical equipment. As a minimum, automatic fire detection should be provided.

c. Select sprinkler heads rated for the temperature conditions in different parts of the CHP installation and ancillary areas.

d. Gaseous fire suppression systems may be an alternative to water-based systems in some specific circumstances, but this must be based on a full fire protection engineering assessment, with due regard to maintenance of gas concentrations and safety of personnel.

   Refer to the RISCAuthority suite of *Active Fire Protection Guides (AFPGs)* for details of the different types of gaseous suppression systems available.

   Note that gaseous suppression systems will normally require strict application of safety controls and interlocks, as defined in the AFPGs.

e. Where feasible, based on the risk assessment, CHP unit fuel valves should be arranged to close automatically as part of an automatic shutdown, on actuation of fixed fire protection systems for engines and turbines.

f. Where fixed fire protection is not an option, consideration should be given to manual foam firefighting solutions for oil and fuel fire hazards, e.g. mobile foam units, or semi-fixed foam-water systems.

Websites

Websites for referenced technical codes and guidelines:

RISCAuthority/Fire Protection Association	https://www.thefpa.co.uk/
HSE (Health and Safety Executive)	https://www.hse.gov.uk/
British Standards	https://www.bsigroup.com/en-GB/standards/
NFPA Codes (National Fire Protection Association)	https://www.nfpa.org/for-professionals/codes-and-standards
IGEM (Institution of Gas Engineers and Managers)	https://www.igem.org.uk/technical/buy-technical-standards/all-technical-gas-standards.html
FM Global Data Sheets	https://www.fmglobal.com/research-and-resources/fm-global-data-sheets

Other useful websites:

The UK government has published a guidance series for "*Combined heat and power – how the UK supports the use of combined heat and power (CHP) or 'cogeneration', which avoids network losses and reduces emissions*":
https://www.gov.uk/guidance/combined-heat-and-power

Energy Solutions Center (USA): Understanding Combined Heat and Power (CHP):
https://understandingchp.com/

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