WISH

Waste Industry Safety and Health Forum

REDUCING FIRE RISK AT WASTE MANAGEMENT SITES

This is good practice guidance based on the latest research and information available. In the pursuit of good fire risk management, parts of it may go further than is needed to achieve basic legal and regulatory compliance. Waste management operators must first comply with the law, regulation, regulatory standards, and the requirements of their permits, licences and similar permissions. However, to achieve good levels of fire risk management you may want to go beyond basic compliance.

This is the third version of the WISH 'Reducing Fire Risk at Waste Management Sites' guidance, the first having been released in October 2014 and the second in April 2017. As for its predecessors, this revised guidance is aimed at providing waste management operators with advice and information to:

- Reduce the likelihood and frequency of fires at solid waste management sites
- Where fires do occur, reduce potential safety, health, environmental, public health, property damage and business interruption impacts

Production of this guidance was facilitated via the WISH Waste Fires Working Group. Representation on the working group includes the following organisations:

- CIWM (Chartered Institution of Wastes Management)
- National Fire Chiefs Council (NFCC)
- ESA (Environmental Services Association)
- EA (Environment Agency)
- HSE (Health and Safety Executive)
- PHE (Public Health England)
- WRA (Wood Recyclers Association)
- TRA (Tyre Recovery Association)

Other organisations were also consulted on specific aspects, such as some of the main insurers on fire engineering issues, and other bodies are corresponding participants.

Involvement in the working group does not imply an organisation's agreement with all aspects of this guidance. The aim of the working group is to hold an open and informed debate on waste site fire risk to arrive at the best, good practice methods of mitigating this risk. WISH believes that this guidance represents best, good practice.

This guidance is supported by the National Fire Chiefs Council (NFCC), the Environmental Services Association (ESA), the Chartered Institution of Wastes Management (CIWM), the Scottish Environment Protection Agency (SEPA), Natural Resources Wales (NRW), and the Waste Industry Safety and Health Forum (WISH).

Guidance from some regulators, or specific sector bodies, may include alternative standards. While WISH may not agree with all the technical standards in some of this other guidance, it welcomes any effort to reduce fire risk at waste management sites. Where appropriate, this WISH guidance includes mention of such documents. However, if you are in any doubt about the standards which apply to your circumstances, you should first seek the advice of your regulators. You must always comply with regulatory standards and guidance.

It is not the intent of this guidance to be inflexible, and options and considerations have been given throughout to allow operators to tailor it to their circumstances. Nor is it the intent to provide a 'one-stop-shop' for waste managers on all aspects of fire risk – existing guidance and standards on general fire risk management and control, and in particular on life-safety, should be read in conjunction with this guidance. It is the intent of this guidance to provide a framework through which operators can reduce the risk of fire on their sites and minimise the business and societal impacts of any fires that do occur. This guidance is intended as an umbrella document. It gives advice applicable to a wide range of waste management and similar sites which handle solid combustible wastes, but it cannot cover every aspect of all forms of waste management operation. Operators need to be aware of other relevant guidance and standards, and of the need for their own specific assessment to tailor solutions to their specific situation and operations.

While we know far more about the combustion properties of wastes and other related issues than when this guidance was originally produced in 2014, fire risk management for wastes is still a rapidly developing field. As knowledge develops and as better information becomes available, further revisions of this guidance will be made to keep it up to date.

Contents

For ease of reading this guidance is split. Section 1 covers general issues such as scope and fire risks. Sections 2 – 7 provide specific guidance for waste management sites in four main areas: Whole site issues, in waste reception, during waste treatment and for the storage of wastes. Appendices are also included on issues such as fire spread in external storage, fire engineering and checklists to help you assess if your fire control is adequate.

To aid readers in seeing what has changed since the 2017 version of this guidance, a summary of main changes is provided at the start of each section, in green italic text.

Tips and case studies – throughout this publication you will find tips and case studies in green shaded text boxes. These are from the experience of various waste management operators and other persons. They should not be considered part of formal guidance and are there simply to provide informal advice. They are intended to inform and share knowledge and you should consider these tips in the light of your own specific requirements.

1. Introduction and scope

1.1 WISH waste fires guidance version III (what has changed?)

1.1.1 This is the third version of the WISH waste fires guidance (the first version was issued in October 2014, and the second in April 2017). The 2017 version was substantially different in many respects from the original produced in 2014. The main driver for these changes being the results of phases 1 and 2 of the WISH waste fire tests, conducted in 2015 and through 2016, and which advanced our knowledge of waste fires significantly. The revisions made for this third 2020 version are less substantive, but do include some significant additions and revisions, such as:

- Incorporation of the results of phase 3 of the WISH waste fire tests, such as additional information on the use of interlocking block walls as waste storage bunkers/fire walls
- A new appendix to provide a non-technical summary of the WISH waste fire tests. This was originally produced as a stand-alone document, but has been incorporated into this guidance for ease of use
- The addition of a list of commonly quoted technical and similar standards to appendix 4 on fixed technical fire systems. For each standard listed a brief summary of what it is and what it covers is provided. This addition has been provided as the result of reader feedback on the 2017 version of this guidance
- Various updates based on improvements in knowledge and practice

1.1.2 Despite many improvements in waste fire knowledge and experience, there are still areas where further work is required. Future versions of this guidance will include any developments in these remaining areas of uncertainty.

1.2 WISH waste fire tests

1.2.1 Prior to the publication of the original 2014 version of this guidance a thorough literature review and search was made by the HSL (Health and Safety Laboratories) and the authors of this guidance. The aim was to identify any existing guidance from across the world on waste fires, and any research and similar on the combustion properties of wastes. Very little information was found. This weakness was noted in the consultation process for the original 2014 WISH fire guidance.

1.2.2 To address this gap in knowledge, a series of waste fire tests were conducted:

- In 2015 smaller-scale laboratory type testing was conducted at the FPA (Fire Protection Association) research premises. These ‘phase 1’ tests provided baseline data on parameters such as burn rates and thermal heat outputs
- In 2016 larger-scale waste burn trials were conducted at sites in Yorkshire and Essex (phase 2 tests). These tests involved much larger volumes of waste and aimed to replicate as closely as practical ‘real life’ waste fires
- In 2017 a third phase of tests was conducted at the National Fire Training College in Gloucestershire. The principle aim of these was to assess different fire-fighting media and techniques and their effectiveness against waste fires. However, various confirmatory tests were also conducted to check the results of the phase 2 tests, and to assess the use of interlocking block walls in bunkered waste storage

1.2.3 A non-technical summary of phases 1, 2 and 3 of the WISH waste fire tests is provided as appendix 5 to this guidance.

1.3 Risks of fires

1.3.1 Fires involving wastes have the potential to cause significant harm:

- There is the risk of death and/or serious injury and health damage from high thermal energy and smoke inhalation
- Combustion products, even those from non-toxic materials, release airborne pollutants which can cause short, and long-term effects on human health, including potentially to public health
- Firewater run-off can transport pollutants into drainage systems, rivers and lakes, groundwater and soil, threatening water supplies, public health, wildlife and recreational use

- Property damage can be significant and costly, sometimes running into the £ millions
- Explosions, sparks and projectiles can harm people and spread any fire
- You may be prosecuted under environmental, fire and/or health and safety law. This can be costly in terms of fines, which have risen substantially in recent years. In addition, if personal responsibility can be proven, prosecutions against individual company directors or similar can be brought, the punishments for which if a person is found guilty may include imprisonment

1.3.2 There are also some less direct sources of potential harm, such as:

- The significant cost from the public purse and resources burden for the Fire and Rescue Services (FRS) and other agencies when responding to a fire
- Civil claims from third parties relating to nuisance or potential health effects and/or costs levied by environmental, fire and health and safety regulators
- You are likely to be responsible for the costs of clean-up, both on and off-site under the principle of the polluter pays. This can be expensive, as in many cases the solid remains of combustion products and partially burnt material can be classified as hazardous/special waste
- Interruption to your business and third party/neighbouring businesses - a major fire could effectively put you out of business
- Insurance premiums are likely to rise substantially following a major fire, or you may not even be able to secure insurance at any economic cost
- Reputational costs can be substantial and may affect how the local community and others view you
- A major fire could affect your environmental permit/licence/exemption, including any subsistence or other fees you pay
- If you lease your site a major fire could result in the termination of lease, or burdensome conditions being added to any lease

1.3.3 No one wants to have a fire, but the consequences of a major fire can be disastrous. Simply ignoring or underestimating the risk is not acceptable (legally, morally, commercially or operationally).

1.4 Scope of guidance

1.4.1 This guidance applies to sites where more than 50 cubic metres of solid combustible waste material is stored at any one time, although the principles apply to smaller sites.

1.4.2 Sites which are regulated under an environmental permit/licence/exemption are within the scope of this guidance. The principles of this guidance also apply to sites which are not regulated under a permit/licence/exemption. Whether under a formal permit or not, you must always comply with regulatory standards.

1.4.3 This guidance applies to the storage, treatment and handling of solid combustible wastes such as, but not limited to:

- Wastes from domestic, commercial and other sources
- Paper, cardboard, plastics, wood and wood product wastes of all types
- Rubber (natural or synthetic) wastes, including whole, shredded and crumbed tyres
- Fragmentiser wastes, such as that from vehicle dismantling
- Refuse derived fuels (RDF), solid recovered fuels (SRF) and similar waste fuels
- Any other waste which may pose a fire risk similar to the above

1.4.4 For historic reasons, WISH covers England, Scotland and Wales. However, WISH documents, including this guidance, are freely available to all, no matter their country or location. Fire risk is an issue not constrained by national boundaries.

1.4.5 This guidance supplements but does not replace any statutory requirements under Local Acts of Parliament, the Regulatory Reform (Fire Safety) Order 2005, Fire (Scotland) Act 2005 or any other applicable legislation and regulation. You should gain advice on your duties under statutory requirements.

1.4.6 Because of their specific issues and/or existing guidance this document does not apply specifically to:

- Landfill sites but, it would apply to a recycling plant at the entrance to a landfill site
- Composting sites, including in-vessel, green waste and anaerobic digestion plants, although the principles would apply to facilities at such plants such as over-size materials storage areas/bunkers
- Hazardous/special waste treatment and transfer facilities
- Waste to energy plants, incinerators and similar thermal treatments to the extent of the thermal treatment applied. It would, however, apply to a recycling plant as pre-treatment, reception/storage and mechanical handling of wastes etc at such a facility
- Some specific aspects of ELV (end of life vehicles) operations, such as air-bag dismantling. However, the general principles in this guidance do apply to ELV
- Sites which fall under the COMAH (Control Of Major Accident Hazards) Regulations

1.4.7 This guidance applies to fire risks associated with combustible wastes. It does not provide detailed guidance on reducing fire risk from ancillary facilities on sites such as welfare facilities, offices and similar or specific fire risks such as diesel storage tanks, gas cylinder storage and similar. You should refer to general and specific guidance for the control of fire risks associated with these non-solid waste aspects. You must also consider the risk from, and to, these facilities in your overall fire plan and assessment as they could be the source of a fire, contribute to its severity or be affected by a fire.

1.4.8 If you do not follow this guidance, or appropriate sector specific guidance, you should seek to ensure that the measures you take are equivalent or superior, and at least that they comply with regulatory and legal requirements, such as general fire law, construction and buildings standards and similar.

1.4.9 It is not the purpose of this guidance to duplicate other freely available general fire guidance which applies to all industries and sectors. This is particularly true for the issue of fire life-safety, for which there are plentiful other sources of information. For example, you will find little mention of issues such as escape path distances in this guidance because information on this type of aspect is easily available elsewhere. You must consider life-safety first.

1.5 Regulators

1.5.1 In most workplaces, including most solid waste management sites, your local Fire and Rescue Authority (FRA) is responsible for enforcing general fire safety and if you need advice you should contact them first.

1.5.2 Other regulators also have responsibilities: The HSE (Health and Safety Executive) covers specific risks and legislation such as DSEAR (Dangerous Substances and Explosive Atmospheres Regulations) and environmental regulators, such as the Environment Agency (EA), Natural Resources Wales (NRW) and Scottish Environment Protection Agency(SEPA) cover environmental and public health risks from fires at waste sites.

Note – at the time of publication of this guidance the three main environmental regulators in Britain (EA, NRW and SEPA) take slightly different approaches regards the standards applying to fire risk at waste management sites. You should ensure that you are familiar with the approach taken and standards required by your environmental regulator.

1.5.3 This multiple-regulators environment for fire risk means that you need to consider your various regulatory audiences. Having a fire plan/strategy agreed with your FRA may not mean that you have satisfied all of the requirements of your environmental regulator. Likewise, being compliant with your environmental permit/licence or similar may not mean you have complied with all general fire and safety law requirements. You must ensure you have covered all aspects of fire management in your assessments and plans. It is your duty as an operator to comply, and not the duty of regulators to ensure your compliance.

1.5.4 Since the publication of the 2017 version of this WISH guidance some sector specific bodies have produced their own guides, such as the WRA (Wood Recyclers Association, Tyre Recovery Association and RDF (refuse derived fuel) Industry Group. These guides provide sector specific advice on how to achieve an approved FPP (fire prevention plan) from the EA (Environment Agency) for England. However, WISH acknowledges that these sector specific guides also include much sensible and appropriate fire risk advice. WISH would recommend that operators in these specific sectors read their sector specific guidance alongside this WISH guidance, while keeping in mind that the aims of the documents and some of the standards included may be different.

Note – currently these sector specific guides are aimed at the regulatory regime in England. Other environmental regulator standards may be different, such as for free-air separation distances between waste storage stacks. You need to understand what the regulatory standards are which apply to your site. This is not to say that operators in Wales or Scotland should not read these current sector specific guides, but that they should keep in mind that there may be differences in the approach taken and standards applied by their regulator.

1.6 Insurers

1.6.1 Insurers also have a role to play and may set their own standards. You should consult with your insurer to ensure they are involved in your decision-making process, assessments and plans. You may achieve a standard that your regulators are content with, but which your insurers may not be content with because of property damage and business interruption risks – different stakeholders may concentrate on different issues and you should take account of this.

Tip – gaining advice on the technical aspects fire safety can be expensive. Insurers and insurance brokers can often be a good source of free or low charge advice. Many larger insurers have in-house fire technical experts and they have a vested interest in you not having a fire – if you have a major fire your insurer will also suffer cost implications. Insurers are an important stakeholder in your fire plans and can often offer good advice. See appendix 4 on fire/risk engineering for more detail.

1.7 Assessment and plans

Note – this section uses the expression 'fire plan'. Different regulators and other bodies may use different expressions. An environmental regulator may use the expression 'fire prevention plan', or an insurer or fire engineer may use the term 'fire strategy' etc. Often these regulators/bodies are talking about different aspects with the same outcome. An insurer fire engineer when using the expression 'fire strategy' may concentrate on fixed systems, such as sprinklers and water deluges, whereas your local FRS may want to see more about fire risk assessment, fire-fighting tactics and evacuation procedures. However, the basic principle is the same. What is the risk, how are you controlling it, and have you included it in your 'plan'?

For small sites you may be able to combine all of the various requirements of regulators and other bodies into one 'fire plan' document. But, for larger sites it is likely that you will need several documents, and you may also need specific separate documents such as emergency plans and employee training documents. This is an issue for you to decide on. The section below gives the basics, how you apply these to your site will depend on your specific circumstances and the complexity of your operation.

1.7.1 In general, under fire legislation you must carry out an assessment of fire risks at your site and based on this assessment put in place appropriate controls and measures (your 'fire plan'). General guidance on fire risk assessments and plans is available on the gov.uk web site (see appendix 6 on useful links and further reading). Other stakeholders and regulators may also have their own guidance and requirements you need to abide by. However, broadly a fire risk assessment involves:

- Identifying where on your site you have combustible and/or flammable materials
- Identifying where on your site you have potential ignition sources
- Identifying people, both on and off site, who may be at risk
- Identifying other than people what, such as the environment, may be affected and how

- Assessing what you already have in place, such as existing building construction, escape routes, fixed fire systems and similar, and if these are adequate
- From the above information putting in place your plan of controls and measures aimed at reducing the risk of a fire occurring and the impact should a fire occur

1.7.2 It is your duty as an operator to produce your fire risk assessment and from this put in place appropriate controls and measures as part of your fire plan. You may seek the advice of regulators, but in the end, it is not the duty of a regulator to ensure your fire assessment and plan is adequate – this is your duty.

Tip – fire risk assessments and plans can be complicated issues and you are likely to need competent advice if your site is at all complex. However, for smaller sites various cost-effective training courses are available and you could consider having one of your employees trained in fire risk assessment. Whatever the size of your site, this would also give you an accessible and in-house source of fire assessment advice for basic and general fire issues at an operational level rather than having to employ an external person.

1.7.3 Controls and measures as part of your fire plan may be physical, such as fire-fighting equipment or the segregation of combustible materials to prevent fire spread, or procedural, such as evacuation and emergency plans. For example:

- Your fire risk assessment may identify that wastes in a reception area (a combustible material) may be set on fire by hot exhausts on heavy mobile plant (an ignition source). You may decide that an appropriate control would be to instruct plant operatives to clear wastes from around exhausts at the end of each shift – and if so, you should include this in your instructions/procedures to mobile plant operatives
- You may identify that wastes (a combustible material) going through a shredder at your site (potential ignition source for reasons of friction and/or sparks) may be a fire risk. You may decide that an appropriate control measure would be to install an automatic water deluge at the shredder
- You may decide that self-heating (an ignition source) is a risk for some of the wastes (combustible material) you store at your site. You may put in place routine inspections of such wastes using thermal imaging equipment to assess any hot spots, and procedures on what operatives need to do if heating is occurring

1.7.4 Fire risk assessments need not be complicated, although you must ensure that you have identified all possible sources of fire and have appropriate controls in place.

1.7.5 You must also include in your assessment who and/or what (such as the environment) may be harmed by a fire and/or the consequences of a fire. For the environment or public health, you should use the established model of source, pathway and receptor. For example, if a fire occurs it is likely that water will be used to fight it, at least initially. This firewater will be contaminated with combustion products and other harmful substances. Where will the contaminated firewater run to and could it cause environmental damage, or lead to exposure for members of the public? Your controls should address this type of consideration. Guidance on the management of firewater is contained in CIRIA Report 736 (see further reading section in appendix 6 below) and from your environmental regulator.

1.7.6 It is also recommended as part of your plan that you discuss with your local Fire and Rescue Service (FRS) their likely fire-fighting strategy for your site, which may include a controlled burn to reduce firewater run-off and/or for fire-fighter safety, and if water is to be used an estimate of the likely volumes of firewater that will be produced to help you determine how much containment will be required. Likely FRS fire-fighting response should be part of your assessment process.

1.7.7 For waste management sites there may also be conditions in your environmental permit/licence/exemption regarding issues such as maximum waste inputs and/or storage limits, requirements for environmental and public health protection etc. These are a valid input into your assessment and must be included. Even if no such limits are stated in your licence or permit, the physical limitations of your site will impose practical limits to the amounts of waste can be handled and stored safely. These limitations should be assessed and considered as part of your fire risk assessment. Some environmental regulators may have their own guidance and requirements for fire prevention and similar plans. You should understand such guidance thoroughly.

1.7.8 For some aspects of your fire management you may need to read specialist guidance or take competent advice. For example:

- If you store gas cylinders (either for your use or waste cylinders) then you need to take account of this in your assessment and seek advice on issues such as cylinder cage construction and separation distances for cylinder stores
- If your waste processing plant includes dust extraction you may need to conduct a hazardous area classification (zoning – an assessment of where flammable atmospheres may occur) exercise under DSEAR. There are standard tests you can use to determine whether your dusts would require this approach

1.7.9 Whatever the complexity or otherwise of your assessment and plan the aim should be to ensure you have considered all risks and put in place appropriate controls.

1.8 Technical standards

1.8.1 There is no shortage of technical standards for fire risk: These include:

- British standards (BS standards)
- European standards (EN or BSEN standards)
- Building regulations and standards (may vary from country to country)
- Insurance industry codes and guidance (see tip-box below)

1.8.2 For technical aspects, such as specialist fire-fighting equipment and the standards for the installation of detection systems, you are very likely to require external specialist advice. There is little point, for example, in installing a sprinkler or deluge system if it is not to an adequate specification, is difficult to maintain, has not been installed correctly and/or does not meet your specific needs. See appendix 4 for more detail.

Tip – the insurance industry has produced its own codes on many aspects of fire safety, including technical standards: Ask your insurer for advice as they will often have access to these standards. For example, the guidance contained in standards and technical advice produced by the UK insurance industry through Fire Protection Association/RISC-A and the LPS standards, now produced by BRE Global. Useful other documents include those produced by the US NFPA (National Fire Protection Association) and FM Insurance (FM Global Data Sheets). These standards are generally accepted by insurers and their technical advisors/experts. If your site does not meet these standards then the purchase of insurance cover, or availability of insurance at an economic cost, may be difficult. Asking for insurer advice on technical standards in advance is likely to be better than arguing afterwards (in the end insurers are commercial concerns and they do not need to insure you). But, beware of applying general standards to waste management where it may not be appropriate. See appendix 4 for some issues which may be associated with insurance industry guidance.

Tip – for technical standards relating to issues such as the installation of fire detection, fire-fighting and fire suppression equipment, the suppliers of such equipment and reputable trade associations can also often be a useful (and likely free) source of advice (although beware commercial interest, and in some cases contradictory advice). Such suppliers, especially when they hold third party certification will be familiar with applicable standards for the products they supply and how they should be installed. However, care should be exercised to ensure that your choice of equipment and supplier is appropriate to your site. For example, an installer of shop and domestic fire equipment may not be that familiar with the standards required for industrial applications. Again, see appendix 4 for further detail.

1.8.3 Overall the technical standards applied to fire controls are complex and you need to be reassured that whatever you put in place meets these standards. If in doubt contact your local Fire and Rescue Service, environmental regulator and insurer.

1.8.4 One issue reported by readers of this guidance is that the specialists they talk to often ‘throw-around’ document numbers, such as BS this, EN that or NFPA the other, assuming a waste management operator knows what they are talking about. To assist, in 2018 WISH commissioned a review of technical and other similar fire standards which may be of relevance to waste management operators. From this review, a list of commonly quoted standards and similar has been added to appendix 4 of this guidance. For each standard listed a brief summary of what it is and what it covers is provided. This list is not exhaustive but covers the most commonly quoted technical and similar standards.

2. Whole site considerations

***Summary of main changes since the 2017 guidance:** Much of the section below is largely unchanged compared to the 2017 edition of this guidance. However, there have been some additions and revisions based on updated knowledge and experience, such as to the sub-sections on mobile plant and vehicles, hot-works and on water supplies.*

Typically, most waste management sites have three main areas of operation:

- A reception area/s where incoming wastes are discharged
- Treatment/processing area/s where wastes may be sorted, shredded, dried, sized etc
- Storage area/s where incoming wastes and/or outgoing wastes may be stored

Not all waste sites have all three areas as above. A simple waste transfer station may only, in effect, have a reception area. However, most recycling and recovery type sites will typically have all three types of area. These three main types of area are considered in more detail in their specific sections (3 – 7) below. This section covers issues which apply to the whole of your site and you should consider these before moving to specific issues.

2.1 Protection of human life

2.1.1 Fire risk management must start with the protection of human life (often called life-safety). This would include having adequate fire escape provision, which is clearly marked, lit, including emergency lighting where required, not blocked and which is kept unlocked during operational hours, and effective evacuation procedures in which all staff are trained. It is not the intent of this guidance to duplicate what is easily available elsewhere and you must ensure that you consult existing other guidance and your competent advisor to ensure that your fire management starts with the protection of human life.

2.2 Location and neighbouring sites/businesses/environment

2.2.1 If you suffer a fire it may have an impact on your neighbours, such as smoke being blown towards a residential area. Conversely, a fire at neighbouring premises may affect you and may even spread to your site. Your general location may also affect the level of fire controls you put in place. For example, if your site is geographically isolated it may take a longer time for the Fire and Rescue Service (FRS) to respond.

2.2.2 Location factors you may need to consider in your fire assessment include:

- Are there any sensitive receptors including schools, hospitals, care homes, major transport or other key infrastructure (such as main roads, railways, airports, overhead power lines etc), other businesses, shops, residential areas, rivers, canals and protected habitats that could be affected by a fire at your site?
- Where your assessment indicates that there is a risk to sensitive receptors, then you must work with your local FRS and environmental regulator to reduce the risk and potential consequences of a fire
- Do any neighbouring premises pose fire risks to your site or could a fire at your site have a catastrophic effect on neighbouring premises? For example, nearby gas storage facilities or other hazardous material storage/treatment site, garages and workshops storing fuels and similar (even rail lines which can produce sparks). If this is the case, you should liaise with these neighbours to ensure your and their accident/emergency plans take account of the possible risks. And, you may decide to arrange storage so that it is adequately separated from any higher-risk neighbouring premises. You may also want to hold joint fire/emergency plan drills and tests with your neighbours to ensure that in the event of a fire your response is co-ordinated
- How isolated is your site and what is the response time of the local FRS? Are your site fire-fighting provisions, water supply and similar adequate to take account of any delay in the FRS arriving at your site?

Tip – when considering receptors think about the pathway and how a receptor may be affected. For example, a large fire in a waste storage yard may cause damage to an overhead power line from the heat energy from the fire. However, the power line would need to run over the yard or be in close proximity, such as at the site boundary. Conversely, smoke can travel significant distances. For example, during a major fire at a large waste site planes taking-off from an airport 3 km away were delayed because the smoke plume was blowing into the airport’s flight path. Think about pathway and receptor and do not limit yourself to a fixed radius around your site for all potential impacts.

2.3 General ignition sources, causes of waste fires and precautions

2.3.1 From industry experience, it is worth noting the general issues below:

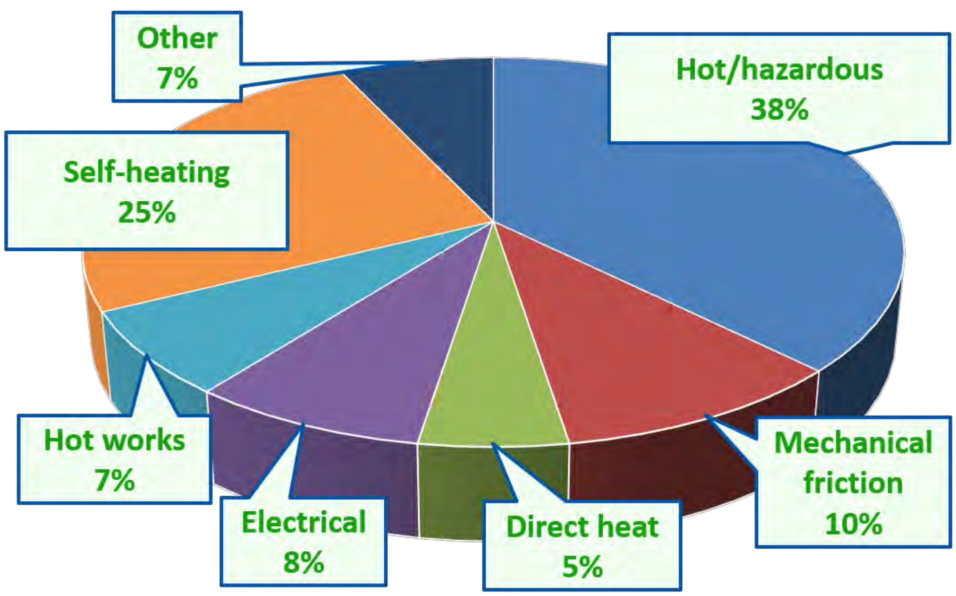
- While your employees may know your site rules and what to do in the event of a fire, you must also ensure all visitors, contractors and drivers using your site are aware of the correct safety and fire procedures to follow whilst on site

- Discarded smoking materials are a major ignition source. You should apply a no smoking policy or ensure suitable designated smoking areas are provided, situated away from combustible materials. Any designated smoking areas should be signposted and supplied with a 'butt-box', sand bucket or similar for discarded smoking materials
- You must control general sources of ignition such as heating pipes, naked flames, space heaters etc. Stacks of combustible and flammable materials such as waste stacks and fuel storage areas should in general be at least 6 metres away from these sources, or other controls put in place to reduce the risk
- As appropriate to your location you should put site security measures in place, such as security fencing, intruder alarms and CCTV, to minimise the risk of vandalism and arson. Your arrangements should cover both the working day and outside normal hours. If your site is located in an area where vandalism and similar is common you should consider a 24 hours manned security presence, or at least 24-hour coverage such as by drive-by security runs
- Electrical faults, both in processing equipment and general electrical systems, such as lighting and heating, can be a source of ignition. You should have regular and planned inspections of your systems. This should include portable electrical appliances (PAT) testing and fixed electrical equipment. You should also seek competent advice on issues such as grounding and bonding controls for electrical systems
- Fires may smoulder undetected after the end of the working day/shift. You should consider formal site 'close-down' procedures including inspection of the site after work has ceased to reduce the risk of a smoulder being undetected and turning into a fire
- Take advice on how to reduce the potential for fire to be spread by convection across the underside of roofs, through roof spaces and similar barriers to rising hot gases. In the Bradford Football Stadium fire a significant cause of loss of life was hot gasses rising under one part of the stadium roof, travelling along the roof and then descending many metres away at the other end of the stadium upon the spectators there causing asphyxiation and sparking significant secondary fires

Tip – thermographic cameras are becoming more economic to purchase and are also becoming more common in use on waste management sites. Such cameras can be used as part of routine inspections to identify electrical faults, over-heating equipment and other potential ignition sources. They can also be used during fire watches after hot-works, such as welding. Many waste operators who have invested in thermographic cameras enthuse about them and find them a useful tool in many areas, whether fire related or not. Alternatively, this type of service can also be contracted-in, although frequency may be an issue.

2.3.2 One of the major waste management companies recently analysed its fire report data. This data was from a five-year period, covered 120 plus sites and more than 300 reports of fires/smoulders. This analysis was for general waste recycling and recovery type plants, and may not apply directly to your site, but regards the most likely causation of fires the analysis provides some interesting data:

- 38% of fires were likely caused by hot or hazardous materials and items in wastes accepted at sites, such as hot ashes, lithium, vehicle and other batteries, gas cylinders, flammable liquids, aerosols etc
- 25% of fires were likely caused by self-heating, both in waste reception and storage
- 5% were likely caused by hot surfaces, 8% by electrical faults, 7% by hot-works such as welding and grinding and 10% by friction
- The remaining fires were caused by a variety of other smaller likely causes



Note – the data above is from one larger company with a wide range of recycling and recovery plants. This data may not reflect your specific situation, although it does give a starting point in terms of the common causes of waste fires.

2.3.3 If you have data for fire causation in your organisation you should use this to inform your site fire management and planning – where do your fires occur and what are the causes. If you do not have your own data, the above may provide a starting point.

2.4 Housekeeping and dusts

2.4.1 In general, the smaller the particle size of a combustible material the easier it may be to set alight. Likewise, it is generally easier to set alight loose and free/discarded materials than compacted materials. In particular dusts may pose a distinct fire risk if they come into contact with hot surfaces and other ignition sources.

2.4.2 Some specific aspects of dust control and fire are included in section 4 on waste treatment and for some systems you need to abide by the requirements of DSEAR (Dangerous Substances and Explosive Atmospheres Regulations). However, in general on dusts, small particle size combustible wastes, loose wastes and housekeeping you should:

- Introduce a regular maintenance and cleaning programme for all site areas including site machinery and buildings and ensure good housekeeping. This should aim to keep levels of dust, loose fibre and paper and other combustible materials in buildings and around the site to a minimum. It is recommended that general cleaning of dusts, debris etc occurs at least once a day when a site is operational
- Ensure that as part of your housekeeping that flammable materials, such as oils, greases, fuels, paints etc, are always stored correctly and put back in store after use
- Include housekeeping in your routine site inspections and act to keep your site as free from loose/discarded combustible wastes and dusts as practical

2.4.3 The importance of good housekeeping and dust control is often under-estimated. It has been calculated that a 1 mm layer of general dust if disturbed into the air to a height of 5 m can generate a dust cloud with a density of 100 g/m^3, and at 1 m height 500 g/m^3 – sufficient to result in a fire/explosion hazard on its own.

2.4.4 Dusts which have been allowed to accumulate on plant support structures, building supports, in ventilation ductwork and similar have also been shown to pose a significant fire spread risk. Significant accumulations of dust can form a pathway which allows a fire to spread quickly rather than staying in one place where it can be tackled more easily.

Tip – when designing recycling and similar plants consider access for housekeeping. Higher-level support structures etc are often not easy to access and as a result dusts often accumulate on these, posing a fire and fire spread risk. Or if access is an issue, consider installing angled or 'tented' plates which dusts will tend to fall-off rather than accumulate on

2.5 Heavy mobile plant and vehicles

2.5.1 Most waste management sites use heavy mobile plant, such as loading shovels, grabs and telescopic handlers. This plant can lead a hard life and is inevitably in direct contact with waste, much of which may be combustible. Other vehicles, such as visiting lorries, may also pose a risk.

Mobile plant can pose ignition risks to the wastes they come into contact with:

- Hot exhausts can ignite wastes trapped near them. You should instruct plant operators of this risk and ensure that wastes are cleared from around exhausts and other hot parts at the end of each shift
- Mobile plant should be fitted with fire extinguishers and you may wish to fit automatic fire extinguishing equipment under plant engine bonnets and other high-risk areas (your insurer may insist on this and you would be wise to check)
- You should ensure that mobile plant is well maintained to a specified schedule, in particular electrical systems which may be a source of fires. Note that maintenance schedules specified by suppliers may not be adequate for waste management use and you should consider whether you need to put in place more frequent maintenance
- Mobile plant should be parked after use away from waste stacks, waste left in reception areas and other places where wastes may be present, or parked in a protected area such as an empty block or similar waste bunker or behind a fire wall
- Mobile plant shovels, blades and similar may produce sparks such as when scraped along a concrete or metal surface/wall. You should consider this during your assessment. For high-risk areas and materials, you may even want to consider precautions such as specialist coatings for mobile plant shovels and blades to limit or prevent the generation of sparks
- The risk above may likely be low in most circumstances. However, if concrete in reception, storage and other areas is poor to the extent that metal reinforcing bar or similar is exposed then the risk of metal-on-metal contact and the production of higher-energy sparks may well increase – timely maintenance and repair of surfaces will assist in mitigating this risk
- If practical, specify the use of non-flammable hydraulic oils. This can be achieved with new plant but may not be practical for older equipment. You may want to check with the manufacturer

2.5.2 Other vehicles can also pose ignition risks:

- Many of the issues listed above, such as hot exhausts, maintenance and hand-held fire extinguishers, apply to other vehicles such as lorries, although it may be impractical to control some of these aspects with third party lorries using your site
- Lorry environmental performance has improved over time, including the use of regenerative filters in exhaust systems, such as those fitted to Euro VI lorries. These exhaust systems can 'over-heat' during their regeneration cycle resulting in a fire risk. If a filter starts to regenerate during tipping or while the vehicle is in close proximity to combustible wastes the driver should be asked to pause the cycle and the lorry moved to a safe place away from combustible materials. Or, you may wish to instruct drivers to push their pause button before they tip

2.5.3 Heavy mobile plant may also be useful in tackling fires, such as:

- Spreading wastes out so that a fire can be more easily tackled
- By removing wastes from the location of a fire to prevent fire spread, such as by 'sweeping' un-ignited wastes away from a pile of waste which is partially on fire or by moving waste stacks away from a stack which is on fire to reduce the risk of spread
- Removing wastes which are smouldering (if safe to do so) to a different location can make fire-fighting easier, such as by moving waste from inside a covered reception hall to the outside (in essence taking the fire outside where it can be fought more effectively), although consideration should be taken as to where smouldering waste is moved to as it could spread a fire through means such as wind-blown embers/brands
- By pushing soils or other inert material such as sand over a fire to starve it of oxygen
- In the moving of smouldering and similar wastes to allow a 'muddy puddle' approach to extinguishing a fire (dousing wastes in a pool of water – see appendix 5 section on phase 3 fire tests for more detail)

2.5.4 However, if you intend in your accident/emergency plan to use heavy mobile plant in this manner you must ensure:

- That plant operatives are trained and competent in the task – and that they are completely aware that any such action must only be done without risk to their own health and safety or that of others
- That the heavy mobile plant is suitable to the task, such as by having completely enclosed cabs, fire and heat protected hydraulic systems etc

- Such action is included in your site accident/emergency plan
- If you intend to use soils, sand or similar to smother a fire, that you always have an adequate stock of such on site to use

2.5.5 You should also consider where any unburnt, smouldering etc wastes could be moved to using heavy mobile plant – a ‘quarantine area’. The size and location of such an area is a matter for site specific assessment. In some cases, such as large pit-type waste reception facilities (such as are common at waste to energy and some other larger waste management plants), it may be better to leave a fire where it is, as it is already contained. You should consider your site’s specific situation and needs.

Tip – if you intend to use mobile plant to fight fires you should conduct drills with your operators. For example, by practicing sweeping wastes away from a stack/pile or pushing inert materials over wastes. The retrofitting of fire and heat protection systems (such as heat protection for hydraulic hoses and the use of non-flammable hydraulic fluid) to mobile plant can be expensive. But it is often an inexpensive addition at the point of manufacture. When replacing your heavy mobile plant think about its specification in advance.

2.6 Hot works

2.6.1 Hot-works, such as welding, grinding and cutting, take place at many waste management sites on a regular basis, such as during maintenance and repair. You should at least:

- Ensure staff and any contractors follow safe working practice when undertaking hot working, such as welding, grinding and cutting
- Ensure that fire extinguishers, hoses etc are provided at the scene of any hot work so that they can be used immediately should a fire occur. Such equipment should be stationed adjacent to the pathway of escape from the work area and not in a place where staff using them could be trapped by a fire
- In areas where wastes or other combustible materials are present hot-work should be a two-person job: One person doing the hot-work and a second watching – someone who is welding will rarely look behind them at where any sparks may land
- So far as practical wastes should be cleared away from the area of any hot-work before hot-work starts (any residual waste which cannot practically be moved can be damped down thoroughly with water in advance to reduce the risk of ignition)
- Combustible materials, including mobile plant hydraulic lines, should be covered by a fire blanket, and/or damped down with water as appropriate, before hot-work starts

- Conduct a fire watch at the scene of any hot-work at least 2 hours (or preferably more) after hot-work has finished – sparks from hot-work can smoulder for a significant time period. Note – your insurer may have specific requirements regards fire watch after any hot-works, and you would be wise to check this. Some insurers now require a 4-hour fire watch after hot-works – check, or your insurance may be invalid
- If hot-works take place close to the end of the working day you should still conduct a fire watch (easier is to plan hot-works for earlier in the day so that this is not the case)
- You should put in place a permit to work system to ensure that appropriate controls are in place before, during and after any and all forms of hot-work

Case study – at one waste management site a fire caused by hot-works occurred more than 8 hours after the hot-works had finished. This may have been an extreme example (in this case in combination with a failure to remove and/or damp-down combustible materials in the area – the fire smouldered in these materials unseen) but illustrates the potential risk.

2.7 Site/plant shut-down processes

2.7.1 A significant number of waste site fires occur after working hours. To reduce this risk, you should consider a formal close-down procedure including issues such as:

- Over-run of shredders, conveyors, screens, balers and similar to ensure that they are as clear of waste as practical
- Shut-off and lock-off of electrical power to plant and other equipment (commonly sometimes called lock-out/tag-out)
- Shut-off of other electrical items such as space/room heaters
- Clearance of wastes, debris and dusts which may have accumulated under and around equipment and machinery
- Ensuring that any flammable materials such as fuels have been secured
- A fire-watch at least 2 hours after the end of operations (again you may want to check with your insurer who may have specific requirements here)
- Spread out any waste loads awaiting processing or in reception areas to ensure that there are no undetected hot items or other materials which could start a fire
- Where practical the removal of wastes from processing or reception at the end of the working day, or at least reduce the amount of waste in such areas to a minimum
- Check that mobile plant has been moved to a safe distance or is protected
- Check that fire detection systems have been activated and are working
- Check that security systems have been activated and that gates and doors are secure

Tip – some recycling/recovery plant and equipment includes fans, for ventilation and extraction, for cooling (such as for hydraulic power packs) or as part of the equipment itself, such as for some air separation devices. Whether intended for cooling or not, these fans may have a cooling effect. You may want to consider arranging for fans to run-on for a period after shut-down to promote cooling. However, ensure that on emergency shut-down they stop immediately – such delayed shut-down should only be by using functional stop systems.

2.8 Water supplies

2.8.1 This section covers considerations for general water supply requirements for fighting waste fires. It does not cover:

- Water supplies for fixed technical fire systems such as sprinklers, deluges, water monitors and similar. There are technical standards which apply to these systems, including on water supplies. Appendix 4 covers fixed systems and the standards which may apply. If you have such systems, or are considering them, you will likely need external competent advice and will certainly need to involve your insurer
- Hand-held fire extinguishers. These are essential for life-safety and can be used to fight very small fires. However, they are very unlikely to be effective in fighting larger waste fires and operatives should not put themselves at risk attempting to do so

Tip – the technical standards on required water supplies for sprinklers, deluges etc are complex. Your insurer may have access to such technical standards (such as the FM Global Data Sheets and NFPA standards and relevant BS and EN standards) and may be able to provide such advice to you at low or no cost. In addition, some standards (such as NFPA) are available to read free-of-charge. See appendix 4 of this guidance for more detail.

2.8.2 The majority of larger waste fires are likely to be fought with water, in their initial stages at least. If you do not have a sufficient water supply the outcome of a major fire is likely to be predictable. The amount of water you may need will depend on a series of factors, such as how much and what types of wastes you have on site, how advanced a fire may be before fire-fighting commences and similar.

2.8.3 Fire and Rescue Service (FRS) experience from fighting waste fires indicates that large volumes of water may be required in some cases: Volumes as high as 10,000 litres per minute for several hours or more have been recorded for some very large waste fires. This is a high-end example intended to illustrate the large water volumes which can be required. It is not intended as guidance and some waste fires may require far less water to control (there is no 'standard' answer here).

2.8.4 The volume of water which may be desirable and/or effective is variable and there is the issue of contaminated firewater run-off (see below). For example, a large surface waste fire may require high volumes of water, whereas for a deep-seated fire in a waste stack continuing to spray water onto the stack after the surface fire has been 'knocked-down' may be ineffective because the water may not penetrate the waste pile to any significant degree (see appendix 5, non-technical summary of the WISH waste fire tests phase 3 results for further information). However, and pragmatically, having more water available than may be required is very likely better than running-out before a fire is under control.

- How good is the water supply to your site? If it is only a standard industrial/commercial supply, it is unlikely to be able to provide sufficient water volume or pressure for significant fire-fighting purposes
- Fire and Rescue Services (FRS) vehicles/tenders carry relatively small volumes of water (typically only a few thousand litres, or less) and unless the fire is small relying purely on the FRS to bring their own water supplies is unlikely to be effective
- How close is the nearest public hydrant to your site? Do you know where it is and how to access it? If the nearest hydrant is >100 metres away, or your site is large, you should consider an on-site hydrant/s and/or installing a fire main (distance is not the only factor here – if the nearest public hydrant is across a major road, rail line, on the other side of a canal or similar access may be impractical)
- There are standards for fire hydrants and water supplies, such as BS 750 and BS 9990 and hydrants needs to be checked and tested to ensure they comply. If you are relying on a public hydrant, consult with your local Fire and Rescue Services to check on the water flow and volume available from this public hydrant
- If the above is not practical, do you need to install water storage tanks on your site?
- Are there alternative water sources near to your site, such as rivers, lakes, lagoons, canals etc? And, could the Fire and Rescue Services (FRS) use these alternative sources? If you do identify alternative water sources, you may also need to consult with your environmental regulator to ensure such use is appropriate. Such alternative supplies also need to be safely accessible – a lagoon right next to a building on fire may not be safely accessible and you should consult with your local FRS

- If you have installed fixed fire suppression/extinguishing systems, such as sprinklers and water deluges, water supply requirements should have been part of the design specification for such equipment. However, you will still need a supply for fire-fighting equipment such as fire hoses and this also needs to be considered

Tip – if you intend to use an alternative water source such as a lagoon, then consider particulates which may be in this source (such as mud, silt etc). You may need to consider large capacity filters and/or floating suction inlet to allow such water to be used – or face the potential for pipes and the pumps handling water blocking entirely or working at a much-reduced effectiveness. In addition, if it will take time to access and use an alternative water supply such as a lagoon, it may be worth pre-installing pipework, pumps and similar to speed the process up.

2.8.5 You should check you have adequate water supplies when you carry out your fire risk assessment. If you have any questions consult your local Fire and Rescue Service (FRS). As above, on larger sites the provision of a private fire hydrant system with the necessary supply of water may be required.

2.8.6 You should include in your assessment whether you would plan to use water to damp-down waste materials (such as stacks) which are not already alight during a fire to minimise the risk of fire spread – if this is the case then your water supply will need to be adequate to do this in addition to fighting a fire.

2.8.7 The location of hydrants, on or off site, should be included in your accident/emergency plan and should remain easily accessible. On-site hydrants should also be tested periodically to ensure they work, and that they flow sufficient water for your needs.

2.8.8 In summary, no fixed guidance can be given regards water supplies, such as you will need ‘XX’ litres per minute per tonne of waste etc. There are a wide range of variables here, such as type of waste, amount of waste, and type of fire (outside-in or inside-out – see appendix 5 for information on these fire types). However, it is a matter of hard experience that a number of waste operators who have suffered fires have found to their cost that their water supply was inadequate, and you should consider water supply carefully.

2.9 Public hydrants

2.9.1 In addition to the above on the location of public hydrants, for sites which intend to rely significantly on public hydrant provision there are some other factors to consider.

2.9.2 There are standards regards water supply from public hydrants. For example, on industrial estates the flow available should be related to the size of the estate:

- Estates of up to 1 hectare – 1,200 litres per minute
- 1 – 2 hectares – 1,800 litres per minute
- 2 – 3 hectares – 3,000 litres per minute
- More than 3 hectares – 4,500 litres per minute

2.9.3 This type of standard is useful, but you may want to check that your nearest hydrant can really provide the flow you expect. For example, if an industrial estate has been expanded over the years the hydrant system may not have been upgraded accordingly, or if a new housing estate has been built next to an industrial estate overall water flow may be less than desirable. If in doubt contact your local Fire and Rescue Services (FRS) for advice.

2.10 Contaminated firewater

2.10.1 Should a fire occur it will most likely be fought, at least initially, using water (although foams and other agents may also be used). This water will very likely be contaminated once it has been used to fight a fire. Foams may also pose risks to the environment. If this firewater/foam escapes from your site, it may cause pollution – pollution you will likely be responsible for in terms of clean-up costs and potential civil or criminal action:

- All waste storage and stacks should be on an impermeable/fire resistant surface
- You should consider installing secondary and tertiary (back-up) containment facilities for firewater run-off such as:
    - Bunds
    - Storage lagoons
    - Drain shut-off valves/penstocks
    - Isolation tanks
    - Modified areas of your site, such as a bunded car park to contain water
    - Block drains and/or divert firewater to a containment area or facility using pollution control equipment such as firewater booms and drain mats

- All pollution control type valves, equipment and similar should be clearly marked, and their locations noted in your fire plan

Note – analysis has been carried-out on contaminated firewater from waste fires, including as part of phase 3 of the WISH waste fire tests. The specific nature of contamination will depend on a range of factors, such as the type of waste involved. However, in practical terms all contaminated firewater from waste fires should be considered a pollution hazard.

2.10.2 You may also wish to consider in consultation with the Fire and Rescue Services:

- Reducing the amount of firewater run-off by applying water through spray and fog-nozzles rather than jets or installing automatic fire suppression such as deluge systems which can apply water quickly and effectively directly to the heart of the fire
- Recycling firewater if it is not hazardous and it is possible to reuse. If you decide that recirculation may be practical at your site, you should consult with your local FRS first on issues such as suitability and location of and access to any take-off point from sumps or similar (there is little point in planning to recirculate firewater from a sump, for example, if this cannot be accessed easily during a fire)
- Separating burning material from the fire and quench it with hoses or in pools (the 'muddy puddle' approach – see appendix 5 for more detail), or in tanks of water. This has the advantage of reducing the amount of firewater produced
- A controlled burn – any decision to attempt a controlled burn must be taken by the FRS, in consultation with environmental and public health bodies, and should not be attempted by a site operator
- Burying the fire using soil, sand, crushed brick and/or gravel. This may be appropriate if there are limited water supplies and smoke is threatening local people, but it should only be used when:

    - Groundwater vulnerability is low
    - You have consulted your environmental regulator about this option beforehand
    - Contaminated material is removed and legally disposed of

Tip – Before deciding to smother or bury a fire consideration should be given to the likely timescales for the cooling and removal of the resulting entombment. Materials entombed in this way are likely to be insulated from heat loss and therefore liable to reignite upon re-exposure for periods of weeks, months or even years. If the decision is taken to smother a fire with a layer of inert material consideration should be given to ways of minimising the insulating effect of the smothering layer.

2.10.3 To decide which options are appropriate you should take account of the:

- Scale and nature of the environmental hazards on your site
- Risks posed to people, the environment and property
- Type of materials you store on site, the form they are stored in and the length of time and the best strategy needed to extinguish a fire involving them
- Availability of firewater containment facilities
- Local topography and different weather conditions and fire scenarios that could be reasonably expected

2.10.4 The containment facilities and pollution equipment you need will depend on the size of your site, the amount of material you store, and the fire-fighting strategy used. CIRIA C736 (see further reading appendix of this guidance) will help you identify the facilities and equipment you need for your site.

2.10.5 If you make a polluting discharge to the environment you will be committing an offence, unless you have a permit/consent to do so and the discharge meets the conditions of that permit/consent. Firewater discharges to sewer may also constitute a breach of sewage discharge consents and you should consult your sewage provider.

2.10.6 It is not the intention of this guidance to provide a comprehensive guide to contaminated firewater containment and management. Your environmental regulator will be able to provide you with more detail and information, and some environmental regulators have issued guidance which includes this issue.

2.11 Fire detection, alarm and suppression systems - overview

2.11.1 The specification, design, installation, commissioning and use of fire detection, alarm and suppression/extinguishing systems is a complex area, and often one where third-party approvals are required. For this reason, a separate appendix is provided to this guidance on the topic (see appendix 4). You should read this appendix to inform yourself of the options and issues involved. However, in general:

- For plant and equipment (such as recycling and recovery plant) fire detection, alarm and suppression should be part of the design risk assessment. For larger facilities the development of a separate fire strategy document is recommended
- Consider multiple approaches to detection and suppression rather than simply choosing a single item. For example, in some cases using more than one type of detector may be more effective than relying on a single type of detector

- Buildings systems should be compliant with the relevant building regulations, as supplemented by your risk assessment to take account of waste management use
- All fire detection, alarm and suppression systems should be maintained in good order and tested and checked as required – seek the advice of your competent person to ensure you are maintaining and testing/checking your systems as required

2.11.2 In addition to appendix 4 on fire/risk engineering, specific issues relating to detection, alarm and suppression/extinguishing systems at waste reception, waste treatment and storage areas are included in the relevant specific sections below.

2.12 Non-waste facilities on site

2.12.1 Virtually all waste management sites have offices, weighbridge, welfare facilities and other non-waste facilities. While these are not included specifically in this guidance, you should seek competent advice on fire management for these and you must ensure you comply with relevant standards such as those in buildings regulations:

- Such buildings should be included in your fire risk assessment, be provided with fire/smoke detection and, as required, manual break-glass points unless all areas of the building can be seen from any other area (such as a single room cabin)
- Detection and alarm systems should be connected to the overall system for the site – that is any alarm will cause an alarm across the whole site and visa-versa
- Fire extinguishers and, as required, other equipment of an appropriate type and number should be provided, along with training for personnel expected to use them
- In general, external waste stacks should be separated from such buildings by the separation distances given in appendix 1 of this guidance, option 1, or protected by other means such as fire walls/bunker arrangements. There may also be requirements in your property insurance policy, such as a set stand-off distance between waste storage and buildings, and you would be wise to check this

2.13 Fire appliance access

2.13.1 If Fire and Rescue Services (FRS) vehicles cannot get onto your site and/or cannot access all areas of your site to fight a fire, then the outcome may be disastrous.

2.13.2 Access for FRS vehicles to and around your site should be unobstructed at all times and meet as a minimum the requirements in the table below. You should also consider how fire appliances can turn around and manoeuvre once they have entered your site. Points you may want to consider include:

- If the FRS cannot access all parts of your site (see distances etc in table below), can the FRS access around the edges of your site via a public highway or similar? If not, such as if your site is right against a neighbouring building, then you will need to consider stand-off between stacks and the edge of your site to allow access (and to prevent fire spread – see appendix 1)
- Is there more than one entrance to your site which Fire and Rescue Service vehicles can use? Are you restricted to one entrance and therefore have a need for easier access around your site?
- Are there on-site height restrictions, such as overhead power lines, bridges etc?
- Are there any weight restrictions or issues at the access to or on your site which would make access by FRS vehicles difficult? Larger FRS vehicles, such as high-reach fire tenders, can weigh well in excess of 20 tonnes

Table: Typical FRS vehicle access requirements

Type of FRS appliance	Min width of road (metres)	Min width of gateway (metres)	Min clearance height (metres)	Min weight restriction (tonnes)
Water tender	3.7	3.2	3.7	12.5
High reach vehicle	3.7	3.2	4.0	24
Weight of vehicles may need to be confirmed with your local FRS as various types of vehicle are in use				

2.13.3 If you have any doubts regards how FRS vehicles may be able to access your site, you should contact your local FRS and seek their advice.

Note – the above distances are for FRS vehicle access to fight a fire. They are not distances primarily aimed at preventing or reducing the risk of fire spread such as between stacks of stored wastes. For guidance on such distances in external storage see appendix 1, and for general considerations on storage (both internal and external) see the specific sections on storage below.

Communication, training and drills

2.13.4 Many fires are averted or extinguished while small by the swift action of aware, well trained, and well drilled staff. In the development of your fire risk assessment and plans, you should consider and describe:

- How the key features of your fire assessment and plan will be communicated to your staff, and how will you ensure that they have understood
- How frequently key messages will be reviewed and refreshed with staff through, for example using toolbox talks
- What level of training staff need to play their part in the fire emergency plan, how frequently that training will need to be refreshed and renewed, and what system will be put in place to ensure that training renewal dates are not missed?
- Drills and exercises should be undertaken at regular intervals and should be varied in content to address the range of fires and circumstances that might be encountered on the site. Drills should be conducted at least once a year, and more frequently for higher-risk sites
- The effectiveness of response to drills and exercises (and real fires) should be critically reviewed, including time taken to evacuate, to identify improvements that need to be made and any messages that need to be fed back into your communications and training systems
- If your site/plant has fixed fire suppression/extinguishing systems fitted, such as sprinklers and deluges, then your training should include these. Your operatives need to be aware of how such equipment works, what are the consequences of activating such systems, and what their limitations are
- When the Fire Rescue Service (FRS) should be called, by who, how information will be provided to the FRS on their arrival and throughout the incident (this issue should also feed into your accident/emergency plan – see appendix 3)

3. Waste reception

***Summary of changes since the 2014 guidance:** Much of the section below is unchanged compared to the 2017 edition of this guidance. However, various small changes and additions have been made based on developments in experience and knowledge since 2017.*

All waste management sites have reception facilities, such as:

- Enclosed tipping halls where waste is discharged prior to being fed into sorting or similar plant or in preparation for transfer off-site
- Split level reception areas or similar
- Reception pits, where waste may be fed into treatment processes by grab crane, conveyor or similar systems
- External reception areas for wastes such as wood prior to processing

Note – this section is aimed at the reception and temporary storage of wastes in reception for short periods of time, typically not exceeding 72 hours, or shorter. This may be prior to treatment and/or transfer to another site. Note - time limits may be set in your environmental permit/licence or similar which you must comply with. This section does not cover wastes stored prior to treatment or transfer for longer periods of time. If you store wastes for longer periods of time prior to treatment or transfer, then you should also refer to the sections on the storage of wastes below.

3.1 Hot wastes and other hazards in reception

3.1.1 One of the most common causes of fires in reception areas is the receipt of 'hot' loads or loads with hazardous materials in them such as gas cylinders, batteries or containers of flammable liquids, which can subsequently cause a fire. Such fires may not be instantaneous – often hot/hazardous items can 'smoulder' deep in a waste pile undetected, bursting into flame overnight or on the weekend when no one is around to raise the alarm.

Note – research into the times fires start in waste reception areas is often difficult (the exact time a fire starts may not be known). However, data indicates that the most common times are Saturday nights, Sundays and first-thing Monday mornings. The former two times likely being the result of items 'smouldering' in waste piles before bursting into flames, the latter likely the result of items in wastes being disturbed when waste is first moved at the start of the working day, such as the first 'push-up' on Monday morning.

3.1.2 Hazardous materials and items include a wide range. However, one type has become a specific issue over the past few years – discarded lithium batteries. To address this WISH has produced a specific information sheet for waste operators on fire risk and rogue lithium batteries in waste streams (WISH INFO 08, available as a free download from the WISH web site (https://wishforum.org.uk/). The principles in this information sheet may also be applied generally to other types of battery in waste streams. This information sheet was originally produced by an ESA (Environmental Services Association) work group, and WISH is grateful for their efforts in this area.

3.1.3 You should ensure you have robust waste acceptance procedures that prevent unauthorised waste being accepted, so far as practical, and for limiting their potential impact so far as prevention is not practical:

- Consider implementing a fire-watch at the end of the shift/operational day – hot and hazardous materials and items can 'smoulder' in a stack of waste for some time before causing a full fire. Some wastes may 'steam' when received releasing water vapour which can be mistaken for smoke. Odour can be used as a check, but more effectively the use of thermal imaging cameras or similar may be better
- Consider not accepting higher risk loads late in the working day, or processing such wastes quickly rather than leaving them in reception over-night
- If practical try to empty reception areas of waste at the end of each working day, or if not practical try to minimise the amount of waste left in reception overnight
- All employees in reception areas should be instructed to look for fires, hot loads, hazardous materials and items, smoke and signs of smoulders – and what action to take if they see one (such as the use of heavy mobile plant to move suspect loads to a safe area, dousing suspect loads with water from a fire hose etc)
- Consider instructing your mobile plant operators to spread wastes out when they are received to make identification of smoulders and hazardous items easier
- Consider provision of an 'emergency/quarantine area' for suspect loads. Note – this must be different from your normal quarantine area for non-conforming loads as these may contain hazardous materials which you do not want to expose to hot wastes
- Where detection of loads which may pose a hazard may be difficult, such as pit-type reception facilities, you should consider fitting deluge, water monitor or similar suppression systems to fight any fire which may occur, and good standards of containment to reduce the risk of fire spread from reception to other areas

Tip – there will be times when the delivery of hot loads will be more likely and reminders to reception staff would be useful. Examples are the increased likelihood of "hot" barbecues and ashes in wastes delivered to HWRCs and from domestic sources after bank holiday weekends or during warm weather. Plus consider the likely increase in the appearance of hot ashes and other wastes from garden burners after the first warm dry weekends of spring and the potential presence of hot ashes from bonfires and the residue from fireworks in early November, or at other times of celebration where bonfires and/or fireworks may be an issue. The location of your site may also be a factor. For example, sites near coasts may receive incorrectly discarded emergency flares, or those in holiday areas may have a higher risk of camping-type gas cylinders being received.

3.1.4 If you do discover a hot load, or load containing hazardous materials, you should attempt to trace this back to the customer and take appropriate action to reduce the risk of such occurring again. You should also check your environmental permit/licence conditions, and you may need to report such loads to your environmental regulator.

Note – no matter how good your waste acceptance processes are, the risk of hot and/or hazardous items occurring in waste loads is unlikely to be 100% removed. This is not to say that you should not take precautions, but for many waste operators fires in reception may well still occur, and you should plan for such an eventuality and consider fire risk in waste reception very closely.

3.2 Fire detection, alarm and suppression/extinguishing systems at reception areas – specific considerations

3.2.1 Appendix 4 of this guidance includes detail of fire detection, alarm and suppression/extinguishing systems at waste management facilities, including in waste reception areas. You should read this appendix alongside the specific waste reception issues given below.

- For external waste reception areas providing fire detection, suppression etc may be more difficult than for internal reception areas. However, external detection and suppression/extinguishing systems are possible. Some sites have successfully installed camera type detectors over external reception bunkers and similar, and deluge, water monitors and similar. Just because your reception area is outside does not mean that you should not consider detection and suppression/extinguishing systems in your assessment and plan

- While this section applies to wastes in reception only for short periods of time, the greater the amount of waste in reception at any one time the higher the likely consequences should a fire occur. For large waste management and similar facilities where large amounts of waste are received you should consult your competent advice regards detection, alarm and suppression/extinguishing systems provision
- At some sites incoming materials are moved from waste reception directly into processing areas using conveyors or other mechanical handling systems. In such cases you will need to consider potential fire spread by such interconnection. You should consider provision of automatic fire suppression/extinguishing systems on conveyors to processing areas. You should also consider linking fire detectors so that the plant emergency-stops if a fire is detected to prevent the spread of a fire by conveyors or similar: This issue is discussed in more detail in appendix 4
- In some waste reception areas items of recycling/recovery equipment are located directly in the reception area. For example, a shredder as pre-treatment before waste is fed into a main processing area. In such cases you should consider protection such as listed in section 4 on waste processing, and in appendix 4 on fire systems. For example, for a shredder located in a reception area installing a water deluge system at the shredder
- At some sites the equipment located in reception areas is mobile, such as a mobile shredder. In these cases, you should consider moving the equipment at the end of each day to a safe location, or protecting it such as by a suitable fire wall or parking such plant in an empty waste bunker
- One potential problem with fighting fire in enclosed reception areas is smoke, which may obscure a fire and make it difficult for the Fire and Rescue Services to place water direct to the seat of a fire. You may want to consider, subject to your risk assessment, passive or automatic smoke vents in the roof or upper walls of your building over reception areas. However, you must consider this carefully as vents can cause interaction problems with some fire detection and suppression systems resulting in a delay in activation – you should seek competent advice on this issue
- You should consider potential operational issues which may affect the effectiveness of any suppression system you have installed. For example, if you have installed a sprinkler or deluge system around your reception bunker/push-walls (in essence, a pipe with nozzles installed on top of or just above your push-walls). This is unlikely to work effectively if the height of wastes in your reception area means such systems are ‘buried’. Likewise think about height for other reasons, such as waste piled to such a height that electrical lighting may pose an ignition risk

3.3 Other considerations in reception

3.3.1 If during abnormal situations, such as plant breakdowns, you need to exceed your normal reception area capacity you should put in place additional measures, such as a fire watch outside of operational hours. Ultimately you may need to cease accepting wastes so as not to compromise the fire safety of your site.

3.3.2 In most cases waste brought to a waste management site will be ‘fresh’ from where it arose. However, in some cases wastes may already been stored elsewhere for a period of time. For example, partially sorted wastes taken from one recycling plant to another for further treatment. Do you know how long wastes received at your site may have been stored at another site? If storage was for a significant period of time, there may be a risk of self-heating (see section 5 for more detail on self-heating) and you may want to check.

3.3.3 Finally, on reception areas, your waste reception area has a finite, safe capacity and you should not exceed this. Determine during your assessment what this capacity is and stick to it (there may also be conditions in your permit/waste management licence which must be followed).

Tip – try to think of obvious visual methods to guide your operatives regarding the maximum safe capacity in your reception area. For example, painting an obvious ‘max pile height’ line on reception bunker walls above which waste must not be piled.

4. Waste treatment and processing

***Summary of main changes since the 2017 guidance:** This section is largely unchanged compared to the 2017 version of this guidance. However, there have been sundry revisions to take account of developments in knowledge and experience.*

Waste processing systems vary widely, and this guidance cannot cover all of the technologies used. However, many recycling and recovery systems commonly include:

- Shredding, bag opening and similar devices which may themselves pose an ignition risk though friction, sparks from metal-on-metal contact, blunt blades and other similar causes. Hazardous items in wastes, such as gas cylinders, lithium and other batteries and flammable liquids containers, may rupture in a shredder causing a sudden and energetic fire, which may spread to other parts of the plant quickly
- Trommel, flat and other screens, air-separators and other gravity-based sorting systems. While these may not pose a high ignition risk, they are often close to items such as shredders. If a fire starts in a shredder or similar it may be just a smoulder because of a lack of oxygen: When fed into a trommel, air-separator etc the waste is then agitated and receives sufficient oxygen to ignite fully. The same mechanism may also apply to hazardous items such as hot ashes which have been wrapped and are opened and exposed to oxygen by the movement of screens and similar
- Mechanical handling systems, such as conveyors, if well maintained, should not pose a high ignition risk, but they can transport already alight waste rapidly around a plant so accelerating the spread of a fire. Many conveyors used in waste management are also rubber, which in itself is combustible
- De-dusting, cyclone and other similar devices – there may be a risk of dust explosion and you should seek specialist competent advice on these items and comply with legal requirements such as those under DSEAR (Dangerous Substances and Explosive Atmospheres Regulations)
- Mains/electrical plant rooms which may pose higher-voltage electrical ignition risks and control panels for items of recycling/recovery equipment

Each of the above common types of equipment is considered below. However, there are other items of equipment used in recycling/recovery systems such as optical sorting systems, magnetic and eddy current processes and other specific recycling/recovery equipment – you should assess any specific fire risks associated with other equipment you may use. You should seek competent advice on this and consider the various fire scenarios and causes which could occur (see appendix 4 for information on plant protection).

4.1 General ignition risks in processing

4.1.1 In addition to the specific risks associated with individual types of equipment, recycling/recovery plant may pose other general ignition risks (the presence of combustible waste is a given as a potential fuel source), such as:

- Electrical faults, faulty or damaged wiring causing sparks and heating
- Friction from slipping conveyors, damaged or worn bearings, damaged or worn drive motors, or metal-on-metal contact
- Direct heat from drive motors, hydraulic power-packs and other items which may generate significant heat
- Direct heat from specific items of equipment, such as optical sorting equipment and eddy current devices

4.1.2 For many of the above potential risks poor maintenance and cleaning regimes can have a role to play. A poorly maintained drive motor is more likely to overheat, a poorly maintained bearing, or one that has not been replaced to schedule, is more likely to collapse causing mechanical heat risk. Likewise, if dust and detritus is allowed to accumulate on items which are normally ‘hot’ then the risk of ignition will be higher, in particular if dusts etc become contaminated with oils, forming a readily ignitable mixture. Good maintenance, repair and cleaning can go a long way towards reducing the risk of a fire in processing plant.

4.1.3 You should seek advice from your competent person as to what fire suppression and management measures may need to be taken (and see appendix 4 for fire system advice). However, the following sub-sections offer some specific considerations for the common items of recycling and recovery plant.

4.1.4 At some sites processing equipment may be located outside, such as a mobile wood shredder in an open yard, and the fire suppression etc systems listed below may not be practical in such applications. However, this type of equipment often already comes with its own fire–fighting/suppression/extinguishing system installed, such as an automatic extinguisher system built-into a shredder. You may want to consider this type of system. At the least you should consider how you would fight a fire in such equipment. For example, would your fire hoses reach such equipment located in an open yard, and where is the nearest hydrant or other water source located?

4.2 Shredders, bag openers and similar

4.2.1 This type of equipment poses a higher risk of ignition from friction and/or metal-on-metal and similar contact, or hazardous items in wastes, such as a gas cylinder or battery going through a shredder. The rupture of such hazardous items in shredders and similar is a common cause of fire at waste management plants.

4.2.2 In addition, as shredders etc are often well enclosed for valid machinery safety reasons, fighting a fire may be more difficult as it may not be easy to get at. You should consider installing automatic water deluge or similar systems either in shredder etc housings, or above feed hoppers, as practical, to extinguish fires, and/or at conveyor outputs from shredders etc to prevent fire spread. Detection systems linked to such deluges or similar will need to be fast-acting if they are to be effective (see appendix 4 for detail).

4.3 Trommel screens, other screens, air-separators and similar

4.3.1 While trommel screens and similar may not pose a high ignition risk they can aerate wastes resulting in a smoulder turning into a full fire. For example, a carelessly disposed of disposable barbeque containing hot ashes which is ‘bounced’ open in a trommel screen. You should consider installing water deluge or similar systems either in trommel etc housings to extinguish fires, and/or at conveyor outputs from trommel screens etc to prevent fire spread.

4.4 Mechanical handling systems, conveyors etc

4.4.1 Conveyors and similar mechanical handling systems may carry a fire rapidly through your plant, and they may be an ignition source themselves as a result of friction:

- Consider conveyor water deluge/sprinkler systems, as identified by your risk assessment. These can be under-conveyor, over-conveyor or to the side of conveyors with deflection plates to divert water onto the conveyor. Under-conveyor systems may pose issues such as being more open to damage and/or causing a restriction to maintenance activities and will likely need protecting. Also see issues with under-conveyor/gantry sprinkler and similar systems with regard to ‘shaded’ areas under plant and support structures in appendix 4
- Consider installing slip sensors on conveyors to determine if a conveyor is slipping on its drive roller – the friction caused by such slippage may pose an ignition risk

- Fire alarm and detection systems should be connected to plant control systems so that if a fire is detected the plant stops quickly, so preventing burning wastes being transported through your plant

4.5 Balers and similar

4.5.1 Balers and similar equipment are common in many recycling plants. In general, these are robust and encased in steel, for machinery safety and other reasons. This makes then fairly resistant to fire. However:

- Aerosols, gas cylinders etc may rupture in balers. The baler itself may take the forces involved, but significant energy can escape via baler output areas, feed chutes etc and inspection doors/hatches to baler chambers may be 'blown-off' if the energy released is high enough. Baler operating positions and platforms should be away from such potential danger zones to protect the baler operator and others in the area and the physical integrity and robustness of balers, including access hatches and doors, should be sufficient to be able to contain the likely pressures involved
- Baler output areas should be kept clear, so far as practical, of detritus. Energy emitted from a baler output area if a gas cylinder of similar ruptures can result in fire spread, and the presence of detritus will only make this more likely
- You may want to consider suppression/extinguishing systems at areas such as baler feed chutes and hoppers, dependent on design and practical considerations

4.6 De-dusting systems, cyclones etc

4.6.1 The separation/ventilation of dusts and fines using extraction systems, cyclones and similar may pose dust explosion risks. For some of this type of equipment parts of the system such as at bag filters etc may be classified as hazardous areas (commonly called 'zoning'):

- Such systems should be subject to an assessment under DSEAR (Dangerous Substances and Explosive Atmospheres Regulations) and may require hazardous area classification (zoning) – you should seek competent advice on this
- Where required by a DSEAR assessment, controls such as spark detection/suppression, explosion resistant equipment, pressure release systems (such as blast panels) and water deluge or sprinkler systems or similar should be installed
- Any hazardous areas (zones) must be identified and signed – and employees should be aware of any such zones and the precautions to take

- The standards for electrical, mechanical, protective and other equipment in such systems are likely to be higher than for general electrical systems (ATEX rated) and you should seek competent advice on this
- Maintenance of DSEAR compliant systems should only be undertaken by a competent person (such as ‘Compex’ training), you may need to check on the competency of contractors or others undertaking this work – a general industrial electrical contractor may not have the knowledge required
- Ductwork associated with de-dusting and similar systems may provide an easy pathway for a fire to spread – that is through the ductwork. You may need to consider suppression systems and/or fire dampers in ductwork to prevent such fire spread, and you should clear ducts etc of detritus and dusts frequently (ducts full of dust have been implicated in fire spread at various waste management site fires)

4.6.2 De-dusting and similar systems are often aimed at the beneficial control of dusts around a plant. However, such systems may also concentrate the explosion/fire hazard posed and de-dusting and similar systems need careful consideration and likely specialist competent advice on their operation, maintenance and repair.

Tip – the materials transfer points at the end of conveyors are often a significant generator of dusts and also often the first areas to be enclosed as part of dust control measures. Such enclosures typically encompass the conveyor end bearings, which can become hot and pose a source of ignition. Suitable measures to address these risks need not be expensive if considered as part of the design and installation of the enclosure.

4.7 Mains/electrical plant rooms and control panels

4.7.1 Mains/electrical plant rooms and control panels pose specific issues, largely associated with the electrical ignition risk they pose:

- Mains/electrical plant rooms should be enclosed and constructed to appropriate fire resistance standards (consult your competent advisor). For critical installations you may want to go beyond the usual standards applied, for property and business interruption risk reasons
- Points where cables leave and enter mains rooms via ducts, tunnels etc should be appropriately sealed to prevent fire spread via such ‘holes’ in the integrity of the room
- Thermal imaging cameras used in regular surveys can be of use to detect electrical faults early and reduce the risks involved

- Mains/electrical plant rooms should be supplied with suitable (usually CO_2) hand-held extinguishers and doors should have vision panels to allow a fire to be seen before entry. You may want to go beyond this into fixed fire systems (see appendix 4)
- Control panels should either be located in enclosed rooms or constructed to a suitable IP (protection) standard to prevent dust ingress
- Electrical rooms should be fitted with automatic fire detection and manual call points. Depending on business criticality, such rooms or specific panels may also be fitted with automatic fire suppression

4.8 Picking cabins and workstations

4.8.1 Many general recycling plants include one or more ‘picking cabin’. These pose specific issues, in particular for life-safety:

- Picking cabins, control rooms and similar should be provided with appropriate fire extinguishers. You may also want to consider sprinklers or other suppression equipment in, and under, picking cabins
- Exits from cabins and similar should be provided with manual break-glass points
- Picking cabins should be provided with suitable smoke/heat detection systems – and these must not be turned off during operational hours
- Picking cabins are often in the centre of processing plant. Escape in the case of a fire is critical (picking cabins are often the only fully occupied location in processing areas). How would your employees escape from a picking cabin in the case of a fire which generates smoke making vision difficult? Escape routes from cabins need to be clear, signposted, lit, obvious and not convoluted and/or difficult to follow. In some cases, the ‘standard’ maximum escape route distances may be too long and shorter routes may need to be considered
- Some recycling and similar plants have secondary workstations outside of picking cabins, either for picking tasks or other reasons. Such workstations require careful thought in terms of issues such as machinery safety and exposure to dusts and noise. In terms of fire risk, such stations also need careful consideration. For example, placing a secondary workstation next to a higher-fire-risk item such as a shredder is unlikely to be wise
- Operatives in picking cabins and similar should be made aware of the risks associated with gas cylinders, larger lithium and other batteries, containers of flammable liquids and similar and that if such items appear on picking belts that the plant should be emergency stopped and the cabin evacuated until appropriate action can be taken to make the item safe and/or remove it

4.9 General considerations in processing areas

4.9.1 General considerations for fire management in waste processing areas include:

- Housekeeping in process areas needs to be of a good standard. Dust should be cleared from electrical conduits and systems, hydraulic power packs and similar and drive motors (and any other item of equipment which may produce heat or be an ignition source, such as optical sorting equipment)
- Thermal imaging cameras can be used to detect hot-spots around your plant, such as slipping conveyors, over-heating drive motors, faulty electrical systems etc. Such thermal imaging surveys need not be conducted every day, but can be part of routine maintenance and inspection regimes
- Hydraulic systems, including hydraulic oil tanks, may generate significant heat. In addition, most hydraulic oils are flammable and leaks from hydraulic lines and systems may result a fire which can spread quickly to wastes. In particular if the waste has been doused in hydraulic fluid from a leak first. Fires in mists and sprays of leaking hydraulic oils are a particular risk and can be highly dangerous. You should include hydraulic systems in your routine checking, testing and maintenance systems and you may want to consider installing fire suppression systems at/above hydraulic power packs, or using non-flammable hydraulic oils where practical. Detection systems should be linked to hydraulic systems to produce shut-down and de-pressurisation of the system in the event of a fire detection

4.10 Fire detection, alarm and suppression/extinguishing systems in processing areas – specific considerations

4.10.1 Appendix 4 contains specific advice, much of which is specifically aimed at waste treatment and processing systems. You should read appendix 4 for information on the issues, considerations and options available, and match these to your specific treatment plant – this is not an area where ‘one-size-fits-all’.

4.10.2 Processing areas of waste management sites typically contain items of plant etc which have the highest asset value on the site. A simple steel construction building may only have an asset value of <£1 or 2 million, but the processing plant and equipment in the building may have an asset value far in excess of this, often many £ millions. In addition, the loss of processing plant may result in substantial business interruption until plant can be replaced. Loss of plant may be catastrophic to your business.

4.10.3 The issue of fire detection and suppression/extinguishing in processing plant is discussed in detail in appendix 4. The approach taken in processing plant is likely to be different than that followed in reception and storage areas. Detection is likely to be required quicker, extinguishing systems are likely to be preferred over suppression systems, and plant actions such as emergency stopping of the plant if a fire is detected may be critical. If you have invested £ millions in costly processing plant, you would be wise to consider fire protection closely in processing areas.

Tip – it is not the intent of this guidance to provide in-depth insurance advice. However, your insurer is most likely to be interested in in how you are protecting your plant than any other aspect, because loss of plant often equals the largest loss of assets and therefore highest claim level. Take the time to discuss this issue with your insurer.

4.10.4 One potential problem with fighting fire in enclosed treatment areas is smoke, which may obscure a fire and make it difficult for the Fire and Rescue Services to place water direct to the seat of a fire. You may want to consider, subject to your risk assessment, passive or automatic smoke vents in the roof over treatment areas. However, you must consider this carefully as vents can cause interaction problems with some fire detection and suppression systems resulting in a delay in activation – you should seek competent advice on this issue.

4.11 Protecting your plant by separation/segregation

4.11.1 You should consider how your processing area is separated by distance and/or segregation by appropriately constructed barriers, such as walls, from waste storage and reception areas. In fire safety terms such separation/segregation of areas of a building is often called splitting into ‘compartments’ (although true compartments are rare in waste management plants), the aim of which is to prevent or reduce the risk of fire spread. This issue is discussed in appendix 4. Protection should be two-way:

- If a fire occurs in your waste storage and/or waste reception, how is your processing plant protected from fire spread?
- If a fire occurs in your waste processing area, how is fire spread to waste storage or waste reception controlled?

4.11.2 For example, you may want to consider the use of walls and/or push walls of an appropriate construction and height (both in terms of fire spread and robustness to withstand day-to-day waste management use) to segregate waste reception from waste processing to reduce the risk of fire spread, or to locate waste storage well away from waste processing. Or, you may need to consider other compartment techniques such as installation of wall-protecting deluge systems, automatic extinguishing systems in transfer conveyors to and from processing areas and similar. The principle being to provide a physical barrier between compartments, or where this is not 100% practical protect compartments in other ways.

Tip – your insurer is likely to place much importance on the integrity of the compartments in your building, in particular if a compartment contains expensive plant which should a fire occur may result in a high-value insurance claim. This may be difficult at waste management sites where wastes need to travel between compartments for the process to work, such as holes in walls to allow conveyors to pass through. Discuss this aspect with your insurer and consider how you will prevent fire spread between compartments.

5. Waste storage – general considerations

Summary of main changes since the 2017 guidance: *The revisions to this section are less substantive than those made between the 2014 and 2017 versions of this guidance. However, there have been some significant changes and revisions, such as to the section below on the use of block walls in fire walls or storage bunkers. In addition, some sections, such as on self-heating, have been updated to reflect improvements in knowledge.*

Many waste management sites store combustible wastes: Either wastes brought to site and awaiting processing and/or transfer or wastes/products which have already been processed and are awaiting transport off site. Examples of such wastes include, but are not limited to:

- Baled recyclates such as baled paper, cardboard and plastics
- Baled and wrapped SRF/RDF and other waste fuels
- Loose wastes such as wood, hard plastics, plastic bottle, tyres etc

Note – this section is not aimed at the temporary storage of wastes in reception for short periods of time, typically not exceeding 72 hours or shorter, prior to treatment and/or transfer to another site, or wastes in treatment. Rather it covers longer-term storage of wastes. For guidance on waste reception areas see section 3 above.

Waste storage at waste management sites can be internal (inside a building) or external (such as in stock yard). This section covers general considerations applicable to both external and internal storage. The following sections 6 and 7 cover issues specific to external storage and internal storage respectively. These specific sections should be read together with this general storage section to gain an overall picture of what is required.

5.1 Definitions of terms used in storage sections

5.1.1 For consistency, the following terms are used in all sections/appendices on storage:

- **Stacks** - stored accumulations of all forms of stored wastes, whether baled, as loose materials or otherwise stored
- **Bunkered/enclosed stacks** – wastes (either loose or baled etc) stored in a bunker or enclosure, such as a three-sided enclosure, where the walls of the enclosure are of an appropriate construction and height resulting in an effective fire shield/wall
- **Open stacks** – wastes (loose or baled etc) which are not stored in bunkers / enclosures, such as an open stack of paper bales or open stacks of loose wood

- **Loose** – wastes which have not been baled/wrapped, such as stacks of loose wood, tyres, plastic bottles etc. Such loose wastes could be either bunkered, or open (such as an open pile of loose wood)
- **Baled/wrapped** – wastes which have been baled and/or wrapped, or similar, as discrete 'packages/items'. Such baled and/or wrapped wastes could be either bunkered or open stacked

5.2 Safe storage capacity

5.2.1 The total amount of combustible waste stored at your site, and how it is stored, will influence the likelihood and size, duration, and impact of a fire should one occur. As part of your assessment you should assess the maximum safe amounts of waste you can store. This assessment should include:

- **For external storage** the stack sizes and separation distances given for option 1 in appendix 1 of this guidance, or from your assessment if your site falls into option 2 in appendix 1, and the considerations in section 6 below
- **For internally stored wastes**, the considerations given in section 7 below, and the general information in appendix 1 as guidance (see section 7.3 for detail)
- **For all storage**, safe access requirements, such as those given above in section 2 for Fire and Rescue Services vehicle access, and safe evacuation routes
- **For bunkered wastes**, the safe capacity of your storage bunkers, including freeboard to take account of flame height
- As applicable, quarantine area/s (of little use if full of wastes already)
- Any other restrictions relating to your site, such as the need for safe traffic movements around the site, stack stability and similar

5.2.2 If you store various different types of waste you should consider whether you also need to include specific storage limits for each type of waste, in particular if a specific waste type poses a higher fire risk such as plastics and rubber wastes.

5.2.3 You should also take account of any restrictions on amounts permitted and storage times in your site's permit/licence, or other similar regulatory permissions. These may be overall limits, or limits by waste type.

5.2.4 Based on the above you should be able to determine the maximum safe volumes of waste you can store at any one time, and in any one storage location. You should then compare this maximum volume with your waste inputs and processing capacity. Your management system should then be arranged so as to ensure that waste is transported off site before you reach your maximum safe capacity.

5.2.5 If the wastes on your site are subject to seasonal variation in demand and/or supply, it is important that you manage these variations to restrict waste volumes stored on site to within safe levels. Such seasonal variations should be included in your management system. The same principles apply when variations in off-take markets lead to a build-up of stock levels. Seasonal and/or market factors are not a valid reason for exceeding your site's safe storage capacity.

5.2.6 Ultimately your site, and each storage area of your site, has a finite safe, storage capacity. You should not exceed this capacity and your site management systems should manage waste inputs and outputs to achieve this end.

5.2.7 All of the stack dimensions and stack separation distances quoted in this guidance, and in appendix 1, are for 'standard' storage of wastes. For example, a stack of stored bales of waste on the ground in a storage yard, or in a bunker or an open 'pile' of wastes on the floor in a building. They do not apply directly to specialised storage systems such as enclosed silos used to store wood chip or similar wastes, racked storage such as used for some ELV (end-of-life vehicle) storage or similar, or treatment systems such as a large drying hall at a mechanical, biological treatment (MBT) plant, or other similar specialised system. For this type of specialised system competent advice should be sought, and for many it is likely that enhanced fire detection and suppression/extinguishing systems will be required. For some specialised storage systems other standards and codes may apply, in particular insurance industry codes – you should be aware of these.

5.3 Bunkering/enclosing wastes with firewalls as an alternative to limiting fire spread by distance

5.3.1 Reducing the risk of fire spreading from one storage stack to another is a critical component of any site's fire management strategy (see appendix 1 for more detail and examples). This can be achieved in two main ways:

- Leaving a physical, 'free-air', gap between stacks (often called a 'fire break') so that a fire is less likely to spread between stacks
- Placing a firewall between stacks to achieve the same end (this is commonly achieved on waste management sites by bunkering/enclosing stacks, such as by using three-sided enclosures/bunkers)

5.3.2 Overall the enclosure/bunkering of wastes may provide improvements both in terms of segregation between combustible wastes and overall storage capacity. For example, providing bunkered storage will mean that the free-air separation distances in option 1 of appendix 1 of this guidance would not apply (provided that the walls used are of an appropriate construction), that stored waste height does not exceed wall height (including freeboard to account for flame height) and that stored waste does not spill out from the bunker/enclosure. However, there are also potential disadvantages and you must consider these before deciding.

- Bunkering wastes does not remove the need to consider stack size. The combustible occupancy (how much combustible material there is and how energetically it will burn) is not affected by simply placing wastes in a bunker. In addition, bunkering wastes (or other uses of fire walls) does not completely remove the risk of fire spread, it only reduces the risk. Bunkering also does not stop smoke spread
- For very small particle size wastes, such as fines/dusts, and those where self-combustion may be an issue bunker stack size is particularly important. For example, for combustible 'fines' the stack sizes given in appendix 1, option 1, are unlikely to be appropriate because of the risk posed
- Consider stock rotation to remove older wastes – bunkers should be cleared to remove old waste from the back of the bunker frequently to reduce the risk of self-combustion (see below)
- Temporary wall/side structures for bunkers (such as mobile 'A' concrete frames or blocks, or bales of metal and other non-combustible wastes) need to be considered closely. If there are any gaps between blocks or frames, they will be ineffective at stopping fire spread. Permanent walls of a suitable construction are better at resisting fire spread, although tight interlocking blocks can also be effective
- Using combustible materials (such as using bales of paper to enclose loose stored paper) as the walls of a bunker is unlikely to be effective in preventing fire spread – if you choose to use bales to separate wastes then use non-combustible materials such as metals (but, see the information in appendix 1 regards plastics and rubber wastes because of their higher burn temperatures). In addition, achieving a tight and gap-free fit using bales may be difficult and such bunker walls will be less effective than interlocking block or permanent bunker walls

- Using steel walls to segregate waste stacks is an option. However, you should consider heat transfer through the steel, and in external storage that materials such as steel can heat-up in direct sunlight. The same principle may also apply to other materials which can conduct heat to a significant extent
- Using railway ‘sleepers’ in bunker construction is also an option. However, sleepers are combustible (in particular if they have been treated). They may resist fire for a time but will be far less effective than concrete or similar walls. In general, sleepers cannot be considered as fire walls
- Whatever construction method is used you will need to ensure that the walls are high and thick enough to stop fire spread from heat radiation. The Society of Fire Engineers Handbook 3rd edition (or updates of this), explains how to do this (see further reading and useful links appendix SFPE Handbook). However, and pragmatically, suitably thick concrete or interlocking block walls are likely to effective even if they have not been formally tested and approved
- You should have in place inspection/checking processes to ensure that wastes do not exceed wall height at any point (including leaving freeboard between wastes and wall tops), and that wastes do not spill out from bunkers/bays so defeating any segregation provided to resist fire spread. This also needs to include flame height and freeboard between waste height and bunker/wall height (a freeboard of 1 metre between waste and wall top is typically required)
- Access issues around bunkers should be considered. The ability of the Fire and Rescue Services to fight or contain the fire may be more difficult if access is impeded

Tip – when storing wastes in multiple three-sided bunkers why not plan your bunker layout with fire spread in mind? For example, if you have three bunkers in a row, two of which have combustible wastes in and one with non-combustible wastes, then put the non-combustible waste bunker in the middle so separating the two combustible waste bunkers.

5.3.3 Bunker (and any fire) walls should be sufficiently robust for the use they will be put to. The activities of heavy mobile plant when placing and removing wastes from bunkers, and during pushing-up, can cause damage to bunker walls, and they may suffer damage from other causes. Any holes, splits, cracks and similar will significantly reduce their effectiveness as fire walls. In addition, such cracks, holes etc in walls may promote local air-flows which in some circumstances may increase the risk of self-heating for some waste types or in the event of a fire introduce more air through ‘chimney type’ effects resulting in a more energetic burn. You should inspect bunker (and fire) walls routinely for damage and repair any such promptly (or take the bunker out of use).

Tip – for ease of stock rotation, why not have two smaller bunkers rather than one larger? Two smaller bunkers will mean that you can completely empty one bunker while still accepting wastes into the other.

5.3.4 One of the most common forms of fire wall/bunker wall used at waste management sites is the use of interlocking concrete and similar blocks. The effectiveness of such interlocking blocks when used as a fire/bunker wall was tested during phase 3 of the WISH waste fire tests (see appendix 5 for details). In general, the use of interlocking blocks was effective, subject to good construction methods, leaving sufficient freeboard between stored waste height and wall height and similar.

5.3.5 The issue of freeboard is noted several times above. This is the vertical distance between the height of stored waste and the height of the wall. In general, this should be at least 1 metre – less than 1 metre risks reducing the effectiveness of the wall in preventing fire spread. Certainly, allowing wastes to reach the top of, or above, wall height will compromise the effectiveness of the wall. In a similar manner, allowing wastes to spill out of the front of a three-sided or similar bunker will reduce the effectiveness of the wall in preventing fire spread.

5.3.6 Whatever the construction of your bunker and similar walls, if you do suffer a fire they may well be damaged by the fire. For example, concrete block and solid walls may 'spall' as the result of heat from a fire. If you do suffer a fire you should inspect bunker and similar walls for such damage and repair or replace as appropriate.

Tip – why not paint an obvious line on bunker and similar walls above which wastes should not be piled. This provides operatives with an obvious indication of when to stop putting more waste into a bunker or similar.

5.3.7 An extreme form of enclosing wastes is to store them in enclosed containers, such as ISO containers. For example, the storage of wastes in containers at a dockside. In these situations, stack size will not typically apply. Likewise, separation distances will not apply completely as wastes are enclosed on all sides. This approach may be particularly suitable for higher-risk materials such as very small (fines) sized combustible wastes or known self-heating waste types such as mattresses.

5.3.8 However, storing wastes in containers does not completely remove the risk of fire spread. For example, if you store wood, plastics etc in an open-top steel container right next to a building and a fire starts in the container, do not be surprised if the fire spreads to the building. When using open-top containers a gap should still be left between containers and between containers and other items such as buildings.

5.4 Self-heating and storage times

5.4.1 Some materials can spontaneously combust, and the risk generally increases when materials are stored for prolonged periods. In addition, and in general, the smaller the particle size the higher the risk, although this may not always be the case. Ambient weather conditions, density and other factors can also play a role.

5.4.2 Industry fire data indicates that self-heating is likely to be the second most common cause of fires at waste management sites, behind hot/hazardous items and materials in wastes. A significant amount of research has been undertaken into self-heating, including on wastes, and there are some standard tests which can be used. However, the application of such typically small scale, laboratory testing to real storage stacks can be problematic: Stacks often do not behave in the way laboratory tests predict they should. It is known that self-heating can occur in waste stacks, and that it causes fires, but the factors involved are complex and variable including:

- Particle size – generally, the smaller the particle size the higher the risk of self-heating. For example, chipped wood waste is more likely to self-heat than raw or pre-crush wood waste where particle size is much larger
- Ability to shed heat – self-heating may not be a significant issue if the level of self-heating does not reach the ignition temperature of the waste involved. In part, this is dependent on the ability of a waste pile/stack to shed any heat generated. For example, a pile of large particle size wood waste may effectively shed any heat generated via the air gaps between each piece of wood (air circulates through the pile/stack allowing heat from any self-heating to escape). For chipped wood the air gaps will be much smaller restricting the movement of air through a pile/stack so trapping heat in the pile. The ability to shed heat also depends on mass to surface area ratio – the larger the surface area relative to pile/stack size the better the ability to shed heat. Long, thin stacks will be better at shedding heat than square or round piles/stacks for this reason. From research, height of pile/stack is an important factor here. Once pile/stack height exceeds around 4 metres the ability of a pile/stack to shed heat tends to reduce significantly, subject to particle size and other factors

- Density – the higher the density the less likely self-heating may be. For example, baled wastes are less likely to self-heat than loose stored wastes because of their higher density post-baling

5.4.3 There are also other factors involved, such as moisture content. One important factor is the time wastes are stored for. Some waste types can start to self-heat within hours of being stored. However, and in general, for many types the longer wastes are stored for the more likely that self-heating may occur.

5.4.4 In general, the time limits below should be used to inform your stock management. These take account of known risk factors such as particle size and density.

Combustible waste type	Maximum storage time
Non-shredded or similarly treated wastes (that is wastes whose particle size has not been reduced)	6 months
Baled and compacted wastes	6 months
Shredded and similarly treated wastes (that is wastes whose particle size has been reduced)	3 months
Combustible fines/dusts and very small particle size wastes	1 month

5.4.5 The above time limits are starting points for your considerations on storage. For some wastes the above storage times may be too long and you should consider your waste types carefully for self-heating risk. You may also wish to consider whether enhanced fire monitoring and suppression/extinguishing systems may allow you to extend waste storage times. But you should seek competent advice before making this decision and be prepared to prove that your thinking is sound and supported by good technical evidence rather than opinion or general experience (previous experience may not be an adequate indicator of future events).

5.4.6 If baled wastes seem likely to exceed the above time limits, you may consider breaking the bales and re-baling them to reduce fire risk. Likewise, you may want to consider if the turning of loose stockpiles would reduce the risk of self-heating. However, care should be taken when breaking bales or turning loose piles/stockpiles.

- Breaking bales and turning stacks may itself cause a fire. Self-heating may occur within a stack, but because of the lack of oxygen a fire has not started. When you open the bale/turn the stack you may introduce sufficient oxygen resulting in a fire

- When breaking bales and turning stacks you should have fire-fighting equipment, such as hoses, at the scene so that you can deal with a fire more quickly if one occurs (hand-held extinguishers are unlikely to be sufficient)
- Likewise, you should consider breaking bales away from any combustible wastes, such as in a quarantine area, and for loose stacks moving other wastes away from the area before turning the stack
- If you have one, the use of a thermal imaging camera when breaking bales or turning stacks may assist in being able to identify any rapid rise in temperature

5.4.7 Considering the potential risks associated with breaking bales and turning loose stacks, the best approach may be to simply ensure that waste is stored for the minimum practical time on your site.

5.4.8 You should also communicate with your waste off-takers as appropriate. If a waste is stored at your site for a period of time and is then transported to an off-taker site (or another site), how long will it be stored at the off-taker's site? The risk of self-heating may not cease if a waste is transported from one location to another. Likewise, has waste been stored elsewhere before being transported to your site?

5.4.9 In general, on the risks of self-combustion and how you may seek to minimise these:

- You must use a clear recording method to show and record how long all wastes have been on site for, and this recording system should be updated frequently to ensure that it reflects current stock levels and storage times
- You should rotate stock to ensure older wastes are not retained for excessive periods. For example, taking older bales from the rear of a stack before newer bales at the front and emptying storage bunkers to ensure that older waste is removed – the 'FIFO' principle (first in first out)
- Moisture level may be a factor and you may need to monitor this, as practical for the type or waste you are storing and how it is presented (loose, baled etc)
- Keep material in its largest form prior to processing for its end market, for example keeping waste wood in bulk storage and only chipping it a short time prior to transport off site
- Visually inspect stored wastes frequently (at least once a week as a minimum)
- Temperature monitoring may be required (see below)

5.4.10 If you are storing wastes for any prolonged period of time, even within the timescales in the table above, you should consider monitoring the temperature of the wastes being stored. If you are storing wastes for more than three months you should monitor temperature. There are various methods for doing this, such as thermal probes, thermographic cameras and fixed heat detecting systems. However, none of these are completely accurate at measuring internal temperatures in larger waste stacks. The method you use will depend on the types of waste you are storing and their configuration, such as loose or baled. In particular, you should consider temperature monitoring if you are storing smaller particle size wastes such as SRF, RDF, wood chips and similar.

Tip – temperature probes and thermal cameras can be used to check on stacks, such as to identify whether hot spots are starting to occur. Equipment such as probes must be used correctly. For example, probing to the centre of a stack (difficult and may be impractical for denser wastes such as bales) to determine temperature rather than just at the surface where temperatures may be lower. A starting point for how often you need to check temperature will be risk assessment, including inputs such as your previous experience and advice from a competent supplier of such equipment or similar. The exact method you use to measure temperature will depend on the waste type and how it is presented (loose, baled etc). But, be aware that most methods of temperature measurement, including those which ‘look’ inside a stack, are not 100% reliable as indicators of actual internal temperatures, and that one part of the interior of a stack may be cool when the very next portion may be much hotter making your measurement potentially unreliable. Likewise, if you break a bale or turn/excavate a stack to determine internal temperature, it will start to cool as soon as you break it, also making any temperature measurement potentially unreliable.

Tip – experience from some waste operators is that self-heating fires are more prevalent in summer than winter (that is during warm weather). This is likely the result of warmer ambient temperatures resulting in energy already being in the ‘system’. If you do monitor temperature, you may want to do this more frequently during warm weather than cold.

5.4.11 Overall, self-heating is a complex issue with various potential parameters such as density, particle size, overall size of stack, ambient temperature and ability to shed heat etc. There are tests which you can have undertaken on your wastes, but the application of laboratory type testing to real waste stacks may be problematic. However, it is known that self-heating has been a common factor in various waste fires, and you should be aware of the risks and plan for them.

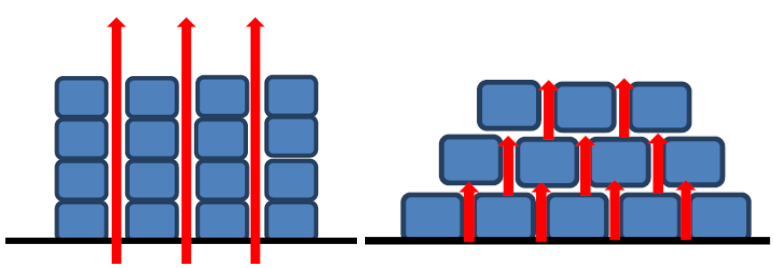
5.4.12 The document Spontaneous Heating of Piled Tyre Shred and Rubber Crumb (Health and Safety Executive – see further reading section) provides further advice on how you can control the risk of spontaneous combustion. Although written for the operators of tyre recovery facilities much of the guidance is generally applicable to the storage and treatment of other materials that can self-combust. Other references to information on self-heating are given in appendix 6, further reading and links.

Case study – one of the larger waste management companies imposed a series of management standards on their sites, such as on storage time, storage rotation, height of storage, not reducing the particle size of wastes until offtake had been arranged, baling wastes to increase density as soon as practical after treatment and similar. Over the period of two years this company halved the number of self-heating fires it was suffering. Self-heating may not be a completely predictable process, but we do know many of the factors involved and good site management aimed at these factors can and does work.

5.5 Baled wastes storage configuration issues

5.5.1 Baled wastes when stored may pose a specific fire risk issue associated with the configuration of storage. Typically bales of waste are stacked directly on top of each other. This results in continuous vertical air gaps between bales – in effect the creation of 'chimneys' between individual 'towers' of bales. If a fire occurs, these chimneys can result in energetic air-flow between bale towers so promoting a more rapid and energetic burn. This issue was identified during the waste burn tests in 2015 and 2016 on baled wastes:

- You should consider interlacing bales to break-up these chimneys – arranging bales in the same way as bricks in a wall rather than directly on top of each other
- In particular you should consider this for baled plastics/rubber where burn temperatures are higher than for other types of wastes (see appendix 1), interlacing bales may reduce burn temperature and how energetically a fire may burn



Far left: Standard bale storage may result in chimneys between bales promoting air-flow during a fire. Left: Interlacing bales may disrupt this chimney effect reducing air-flow and fire intensity

5.5.2 The above assumes that your bales are 'square', as is typical for bales of paper, plastics etc. However, there are other types of balers, such as those used to bale and wrap RDF and similar waste derived fuels. Bales produced by such equipment may be cylindrical rather than square. Typically, such cylindrical bales are stacked interlaced for stability reasons, and so any chimney effect may already be mitigated.

5.5.3 The effect of interlacing bales in storage will depend on various factors, and generally interlacing bales does not affect maximum heat output once a fire has fully developed. Because of this, interlacing bales would not generally affect the separation distances and stack size information given in option 1 of appendix 1. However, you may want to consider this form of storage, in particular for higher-risk waste types such as plastics and rubber.

5.5.4 What the fire tests did indicate is that interlacing bales slows fire growth within the stack itself. This could allow a fire to be tackled more easily in its early stages before it develops fully. Future waste burn trials will include assessing the effects of interlacing of bales, and some research on this aspect is already available. Future versions of this guidance may be revised based on such research developments.

5.5.5 While not directly a fire issue, interlacing bales may also have stability benefits. Bale stack collapses have resulted in serious and fatal injuries in the past and bale stack stability is a significant risk area. In addition, during a fire bale stack collapse may itself result in fire spread.

6. External waste storage

Summary of main changes since the 2017 guidance: *This section was revised substantially between the 2014 and 2017 versions of this guidance, largely because of the results of phase 2 of the WISH waste fire tests. For this current version fewer changes have been made and this section is largely unaltered compared with the 2017 version.*

Note – readers should read appendix 1 of this guidance on stack dimensions and separation distance information for externally stored wastes in conjunction with this main text.

Typically, more wastes are stored outside than inside buildings. This is for various reasons, such as greater available space and lower cost compared to internal storage. External storage has advantages and disadvantages, such as:

- Fires may be easier to fight than with internally stored wastes because of likely better visibility and easier access, provided that adequate stack size limits and stack separation distances are in place
- Conversely, fire suppression/extinguishing equipment, such as sprinklers and deluges, may be typically harder to design and install
- Fire detection equipment may also be more difficult to arrange

You should consider the merits of internal and external storage when compiling your storage plan for your site.

Externally stored wastes – overall considerations

6.1.1 One of the potential disadvantages of external storage is that, in general, the volumes of waste stored are much larger than for internally stored wastes. A lack of adequate separation distance (or fire walls) and excessive stack size combined with the typically higher overall volumes of waste stored externally can have serious consequences. Some of the largest waste fires experienced have been in external storage – some of these have burnt for days or even weeks and have been extremely difficult to control. Many of these fires have been exacerbated by the Fire and Rescue Services (FRS) not being able to access the fire adequately, and the spread of fire because there has been little in the way of stack separation or physical segregation, such as with fire walls etc. Conversely, well organised external storage stacks of reasonable size and with adequate separation (or fire walls) can be one of the safest forms of waste storage available.

6.1.2 If you store wastes externally you must consider stack size and separation between stacks, and/or the use of fire walls/bunkers. Appendix 1 gives guidance. You should use the guidance in appendix 1 to plan your external storage.

6.2 Detection, alarm and fire systems at external storage

6.2.1 For external storage areas the use of automatic detection systems poses practical problems, although some types of detection system can be fitted, and you should consider these if practical. Some sites have fitted camera or heat type detectors at external storage stacks and just because your storage is external this does not mean that you should not at least consider detection systems.

6.2.2 For external storage you should at least visually inspect stored wastes. Frequency should be determined by your risk assessment, but you should start with no less than once a week and you may want to increase frequency during the summer months. As noted above, you may also need to consider the use of temperature probes or thermal imaging, as practical.

6.2.3 As for detection, external storage areas pose challenges for fire suppression systems. You should at least consider whether on-site fire hydrants are required and whether you have an adequate water supply with which to fight a fire. You may also wish to consider deluge, water monitors or other systems for external storage areas as part of your assessment. For deluge and similar systems these can sometimes be fitted to external waste storage bunker wall tops, and water monitor systems are in fairly common use in external situations in some other industries.

6.2.4 For specialist storage systems the options for fire suppression will depend on the specific situation. For example, a deluge system fitted to a silo for storing wood chip, or a foam suppression system. For specialist storage systems you should seek competent advice.

6.2.5 Appendix 4 gives more detailed guidance on fire detection, alarm and suppression/extinguishing systems, including for external storage of wastes.

6.3 Arson, vandalism and other specific ignition risks

6.3.1 Some ignition risks may be lower with external storage. However, others may be higher. In particular the risk of arson/vandalism may be higher. It is often more difficult to protect external areas of a site from trespass than it is for buildings:

- You should include arson/vandalism risks (for example, the nature of the location your site is in) and security arrangements in your fire assessment for external storage
- If your site has a history of trespass, theft and/or vandalism you should consider enhancing your site security arrangements

6.3.2 Arson/vandalism may not be the only ignition threat externally stored wastes face:

- Are there any specific ignition risks posed by neighbouring premises, such as sparks from welding conducted outside and/or at your site boundary? Consider these and arrange your storage accordingly. For example, one known recycling plant is located next door to a firework factory which tests fireworks in an external area not far from the recycling plant's boundary – the recycling plant operator only stores wastes at the opposite end of their site to provide as much of a stand-off distance as possible
- There may be other ignition sources external to a site. If you know of any which may be applicable to your site, you should include these in your assessments

7. Internal waste storage

Summary of main changes since the 2017 guidance: *This section was revised substantially between the 2014 and 2017 versions of this guidance, large because of the results of phase 2 of the WISH waste fire tests. For this current version fewer changes have been made and this section is largely unaltered compared with the 2017 version.*

In general, less waste is stored inside buildings than outside, although this can vary from site-to-site. At many sites internally stored wastes are contained in walled bunkers and similar. However, some waste sites do store baled and other wastes inside buildings in 'open' storage and not contained in bunkers and similar. Internal storage has some advantages, but also has disadvantages:

- Fires may be harder to fight than with externally stored wastes because visibility may be impeded by smoke and access for Fire and Rescue Services (FRS) to fight fires may be more difficult
- Because of the above, if life is not at risk the FRS may decide (understandably) to simply contain a fire and let it burn itself out – this may well result in the loss of your building and/or any plant and equipment contained in it
- Conversely, fire suppression/extinguishing equipment, such as sprinklers and deluges, are typically easier to fit than at external storage areas
- Fire detection equipment may also be easier to arrange
- The risk of property and asset loss is likely to be higher than for externally stored wastes. A fire in internally stored wastes may spread to buildings and plant more easily than for externally stored wastes (provided externally stored wastes are adequately separated from buildings)
- While not a fire risk issue, storing wastes internally protects them from the weather, which for some waste types may be a quality issue, and at some sites storage of wastes internally may be a permit/licence requirement for nuisance control reasons

7.1 Internally stored wastes – overall considerations

7.1.1 If you store wastes internally you must consider stack size and separation between stacks, or the use of fire walls/bunkers. The information contained in appendix 1 may not be directly applicable to internally stored wastes, but the overall approach is, and likewise many of the principles are (see sub-section 7.3 below). You should consider the data in appendix 1 as a starting point, but in some cases not as absolute guidance, for the internal storage of wastes.

7.1.2 Separation between internally stored wastes and building walls, plant and other equipment within buildings also needs to be considered. Experience in the industry is that fires in internally stored wastes are far more likely to spread to buildings and plant than for externally stored wastes.

7.1.3 As above, fires in internal storage areas may be more likely to spread to waste processing areas, and damage or loss of buildings and/or plant is always a risk. As a result, your insurer is likely to place more emphasis on internal storage than external storage fire management. You should seek advice from your insurer to ensure that you have met any requirements they may impose.

7.1.4 If you are storing wastes internally in large quantities, such as in warehousing, then you should seek competent advice on the precautions to be taken. These will depend on the type of building used, the types of waste being stored and what fire precautions are already in place. This is a specialised area, and the general standards applied to the warehousing of goods may not be appropriate to the internal storage of wastes.

7.1.5 Overall, for internally stored wastes:

- The best approach ideally may be not to store wastes internally, if practical, within your permit/licence and compatible with any waste product quality issues. Or, failing this to limit the amount of waste you store internally (or limit type of waste – see below on plastics and rubber wastes). Or, at least move wastes which will be stored externally to their allocated external storage areas as quickly as practical
- If practical, larger volumes of internally stored wastes should generally be stored in bunkers, or separated by fire walls – in general the restrictions on space in internal storage situations and the 'free-air' separation distances required would tend to make the use of bunkers and/or fire walls the most practical option in any case
- You may want to consider the use of fixed fire detection and suppression/extinguishing systems more carefully at internal waste storage areas (see appendix 4 for details)
- In particular for plastics and rubber wastes, the higher burn temperatures involved are likely to pose a higher risk of fire spread to buildings and plant. Enhanced and high-specification fire detection and suppression/extinguishing systems should be given careful consideration if you store plastics or rubber wastes internally. The most practical approach may be to not store plastics and rubber wastes internally, if this is practical and allowed in your site permit/licence

- The approach you take to fire risk in internally stored wastes will be dependent on a range of factors, including the layout and size of your building, its construction materials, the configuration of your storage and other factors specific to your building and how you are operating. This is a matter for site specific assessment, and you may need competent advice

7.2 Detection, alarm and fire systems at internally stored wastes

7.2.1 General guidance on fire detection, alarm and suppression/extinguishing systems is given in appendix 4. For internally stored wastes you should read this guidance carefully to ensure that if you do store wastes internally you have mitigated the risk adequately.

7.2.2 At some sites materials are moved from waste treatment/processing directly into internal storage areas using conveyors or other mechanical handling systems. In such cases you will need to consider the potential for fire spread by such interconnection. You should consider the provision of automatic fire suppression/extinguishing systems on the conveyors etc leading to internal storage areas.

7.2.3 One potential problem with fighting fires in internal storage areas is smoke, which may obscure a fire and make it difficult for the Fire and Rescue Services to direct water direct to the seat of a fire. You may want to consider, subject to your risk assessment, passive or automatic smoke vents in the roof over internal storage areas. However, you must consider this carefully as vents can cause interaction problems with some fire detection and suppression systems resulting in a delay in activation – you should seek competent advice on this issue.

7.2.4 You should consider potential operational issues which may affect the effectiveness of any suppression system you have installed. For example, if you have installed a sprinkler or deluge system around an internal storage bunker (in essence, a pipe with nozzles installed on top of or just above your bunker walls). This is unlikely to work effectively if the height you are storing wastes at means such systems are buried. Likewise think about height for other reasons, such as waste piled to such a height that electrical lighting may pose an ignition risk.

7.3 Application of appendix 1 on externally stored wastes to internally stores wastes

7.3.1 The stack separation distance information in appendix 1 is only directly applicable to externally stored wastes, because it is based on data from the waste burn tests conducted in 2016 which were conducted on externally stored wastes. However, there is some application to internally stored wastes and the general principles involved are the same.

7.3.2 The maximum stack heights and widths given in appendix 1 are applicable in outline to internally stored wastes. These heights and widths are based on stack stability, self-heating and effectiveness of fire-fighting using standard hoses. These factors apply to internally stored wastes as much as externally stored wastes.

7.3.3 Deviations from these stack heights and widths (as discussed in option 2 in appendix 1) are likely to require enhanced fire systems if the risks associated with internally stored wastes are to be mitigated. This is a matter for site specific assessment.

7.3.4 At its top end, the stack length information given in appendix 1 is unlikely to be appropriate for internally stored wastes, if for no other reason than those of building size and available space (but, see appendix 1 on separation distances related to length). This is an issue for site specific assessment, although the data in appendix 1 can be viewed as a starting point and guidance.

7.3.5 The 'free-air' separation distances between stacks, and stacks and buildings, and their relationship to stack length given in appendix 1 for externally stored wastes may not be directly applicable to internal storage. However, they are unlikely to be factors of magnitude out. As a result, the practical approach for internally stored wastes is likely to be the use of bunkers and/or fire walls between stacks. As for all stored wastes in bunkers and similar, bunker wall construction and height are critical factors.

7.3.6 The mechanisms for fire spread given in appendix 1 will apply to internally stored wastes, although the detail may vary. However, with internally stored wastes other fire spread mechanisms may be important. For example, hot combustion products are unlikely to dissipate to the extent they may with externally stored wastes, and the risk of fire spread through mechanisms such as 'flash-over' are likely to be higher. You will need to consider these other fire spread mechanisms more carefully with internally stored wastes, and you may need to seek specialist advice.

8. Disclaimer

Nothing in this guidance constitutes legal or other professional advice and no warranty is given nor liability accepted (to the fullest extent permitted under law) for any loss or damage suffered or incurred as a consequence of reliance on this guide.

The guidance is not a substitute for duty holder judgment and/or professional safety or other advisor's judgment. Notwithstanding the good practice in this guidance, duty holders are responsible for ascertaining the sufficiency and adequacy of their procedures for verifying and evaluating their organisation's compliance with health and safety law.

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The Waste Industry Safety and Health (WISH) Forum exists to communicate and consult with key stakeholders, including local and national government bodies, equipment manufacturers, trade associations, professional associations and trade unions. The aim of WISH is to identify, devise and promote activities that can improve industry health and safety performance. www.hse.gov.uk/waste/wish.htm

This guidance is issued by the Waste Industry Health and Safety (WISH) Forum to help control the safety and health risks associated with fires. Following the guidance is not compulsory, unless specifically stated, and you are free to take other action. But if you do follow the guidance you will normally be doing enough to comply with the law. Some parts of the guidance represent good practice and may go further than the minimum you need to do to comply with the law.

Appendix 1: Managing external storage stacks

Summary of significant changes from the 2017 WISH fires guidance*: The main content of this third version of appendix 1 of the WISH fires guidance is largely unchanged compared to the 2017 version. However, some updates and clarifications have been made based on developments in knowledge and reader feedback, and the structure of the appendix has been changed to assist comprehension. In addition, the sections in the introduction to this appendix contained in the 2017 WISH fires guidance which explained the differences between the 2014 and 2017 versions have been deleted, as these are no longer relevant.*

Note - please read this appendix carefully, rather than simply turning to its summary stack dimension and separation distance tables. The principles in the text are important if you are to interpret this appendix correctly.

Note - this appendix applies to the external storage of wastes. It does not directly cover the internal storage of wastes in buildings, although some of the principles will apply (see section 7.3 of the main text of this guidance). In addition, this appendix applies to the storage of wastes, and not directly to wastes in short-term reception areas, or in treatment/processing areas (see sections 3 and 4 of the main text of this guidance for advice on these areas), although again some of the principles will be relevant.

Note – please also see appendix 5 non-technical summary of the WISH waste fire burn tests for a summary of the underpinning science behind this appendix and for an empirical demonstration of how thermal heat transfer can cause fire spread from waste stack to waste stack.

Note – the stack dimensions in this appendix apply **BOTH** to wastes stored open and in bunkers. The separation distances given **ONLY** apply to open stacks and not to bunkered storage (provided that bunker/fire walls are appropriately constructed and used effectively).

Contents

1. Introduction

1.1. External waste storage stack fire risks

Some of the largest waste fires, and those which have taken the longest to extinguish or bring under control, have been in external waste storage stacks. This is not surprising as typically greater volumes of waste are stored outside than in buildings. These large waste fires have attracted the greatest amount of publicity, and potentially pose the highest risks to the environment and public health because of their size. The adequate management of external waste storage stacks is critical to reducing these risks, and in particular stack dimensions and separation distance between individual stacks (in the absence of fire walls) are key factors.

1.2. Why are stack dimensions and separation distances important?

The larger an individual storage stack of waste the more fuel it will contain and the greater the potential for a larger and more long-lasting fire (more waste = more fuel = larger fire). In addition, the larger an individual waste stack the more difficult it may be to fight a fire. For example, a stack is so large that water from fire hoses cannot reach all of the stack.

A fire in one individual storage stack of wastes may be manageable, provided the stack is of a reasonable size. However, if the fire spreads to other adjacent stacks, then the likelihood of a larger and potentially uncontrollable fire increases. Likewise, a fire may spread from a waste stack to a building or other combustible object.

- Limiting stack dimension limits the amount of fuel a fire has available, making fire-fighting likely easier and more effective (there are other reasons to limit stack dimensions – see below for more detail)
- Preventing fire spread from one stack to another also limits the amount of fuel a fire has available. This can be achieved by either separating stacks (free-air separation) so that a fire cannot jump between stacks, or the use of fire walls to achieve the same effect

However, it is accepted that waste management sites are finite in size, and stack dimensions and separation distances can have a direct effect on how much waste can be stored. Stack dimension limits and separation distance standards need to achieve good levels of fire safety and management, and be cautious and prudent, without going unreasonably beyond what is needed to achieve good levels of fire safety.

2. Factors affecting separation distances – how did WISH arrive-at its separation distances?

Fire spread has been a major factor in many large fires in externally stored wastes. Obviously, fire will tend to spread within any individual stack of wastes – there is little to stop it. However, fire spread between stacks, or between stacks and buildings etc, is also an important issue. There are two main methods of reducing the risk of fire spread between stacks or stacks and buildings etc:

- Provide an adequate free-air gap (separation distance/fire break) between stacks
- Place an effective fire barrier (wall/bunker wall) between stacks

Note - this section covers free-air separation distances and does not consider fire walls and bunkers (see section 3 below for more detail on these).

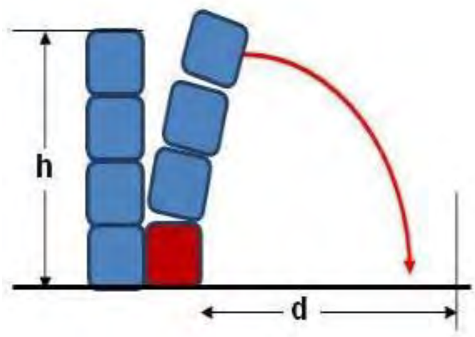
How wide a free-air separation distance needs to be will depend on fire spread mechanism – how a fire can spread. In addition, some mechanisms of fire spread are more useful than others when setting separation distances. In summary, we need to decide:

- What the main potential fire spread mechanisms are?
- Which of these mechanisms is the most ‘sensible’ and reliable to use as the basis to determine what is an adequate separation distance?

2.1. Fire spread mechanisms

Fires can spread between stacks via various mechanisms. For externally stored waste stacks the most significant potential fire spread mechanisms include:

- Stack collapse: The collapse of a stack on fire resulting in burning wastes falling, rolling etc and coming into contact with a second stack. How far wastes can ‘roll’ or travel as the result of a collapse varies dependent on the nature of the stack and the wastes, and waste configuration (shape of bale for example). This variability makes stack collapse an impractical mechanism as a guide to separation distances



Example of a stack collapse mechanism, assuming a bale at the base of the stack collapses first. The distance any bale, or part of a bale, will ‘roll’ is dependent on a range of factors making stack collapse too unpredictable to use as a guide to separation distances between stacks

- Flying/blown ‘brands’: Burning detritus blown from one stack to another (or building etc). This mechanism is unpredictable and depends on factors such as wind strength and direction, and active fire management can reduce the risk, such as by tackling any flying brands with hoses or similar. Flying brands do pose a risk of fire spread, but because of their unpredictable nature it is not practical to use them as a guide to separation distances
- Thermal energy transfer: Heat produced by a stack which is on fire resulting in the temperature of a nearby stack (or building etc) being raised to its ignition point and also setting on fire. This mechanism is capable of measurement and can be used as a guide to separation distances

The above is not to say that flying brands and stack collapse should be ignored. Site emergency response plans should include mitigations against these fire spread mechanisms. However, they are not useful as a practical guide to determining separation distances between stacks to reduce the risk of fire spread. Thermal heat transfer does provide a practical guide. The WISH waste burn trials conducted in 2015 and 2016 provided data which can be used to calculate separation distances based on thermal heat transfer (see appendix 5 for details).

2.2. Use of thermal emission data to determine separation distances

When an object, such as a waste stack, burns it emits heat. Unless this heat is ‘blocked’ by an item such as a fire wall, the thermal energy will travel through the air. If another combustible object, such as another waste stack, is placed in the path of this thermal energy it becomes a ‘receptor’. The temperature of the receptor will increase, and if it reaches its ignition point (the temperature at which it will burn) this second object will set alight. During the WISH waste fire burn tests, the heat emitted by a burning stack of bales of waste plastic was sufficient to melt a data-logger ten metres away and blister the paint on a porta-cabin nearly 30 metres away. Heat transfer between an emitter and receptor is a common cause of fire spread, and a tried-and-tested method used by fire engineers to calculate safe separation distances between combustible objects/materials.

One of the main outcomes of the WISH waste fire tests was to determine how much heat energy various types of waste emit when they burn. Research has been conducted in the past on this aspect, both on some waste types and more commonly on raw materials which may behave like wastes in a fire. However, such research typically used small scale laboratory type testing. The WISH tests moved beyond this laboratory type testing and involved much larger scale burn tests aimed at replicating what actually happens when a waste storage stack is on fire.

The non-technical summary of the results of the waste fire tests in appendix 5 goes into this topic in more detail. However, the tests resulted in a good set of data on thermal heat emissions for waste storage stacks. In terms of their heat outputs, the wastes tested during the waste burn tests can be split into two broad categories:

- Plastics and rubber: These waste types exhibited higher heat outputs when burnt during the tests. Surface temperatures during burns in some cases exceeded 1,200 degrees centigrade, and were consistently higher than for other waste types
- Other combustible wastes, such as SRF, RDF, wood wastes, paper etc: These waste types exhibited lower relative heat outputs when burnt. There were variations in surface temperatures, but within a practical range of 850-950 degrees centigrade

The temperatures quoted above are for the most frequent 'worst case'. These two broad categories form part of the basis for the standard separation distances information in option 1 below. However, there are other factors to be considered:

Receptor ignition properties: From the WISH burn tests we know the levels of thermal radiation produced when different types of waste stored in stacks burn. However, there is limited information available on the ignition properties of receptors. The receptor could be another waste stack, a building, parked vehicles, a wooded or bushy area next to a site etc. For the purposes of the standard separation distance information given in option 1 below, two receptor ignition property figures have been used:

- Research into the ignition properties of wastes has been conducted, in particular Swedish research on the ignition properties of baled RDF. This research indicates that a heat input of 10 Kw/m^2 is required to ignite baled RDF
- The accepted national standard for buildings protection regards ignition is a heat input of 12.6 KW/m^2 for solid unprotected surfaces (for non-UK readers please note this figure may be different in your country)

The above provides a practical range. That baled RDF requires less heat input to ignite than a typical building is not surprising. However, different types of waste may have different ignition properties. If you believe that your waste may have a different ignition property, then you could have your waste tested (see option 2 on bespoke distances below).

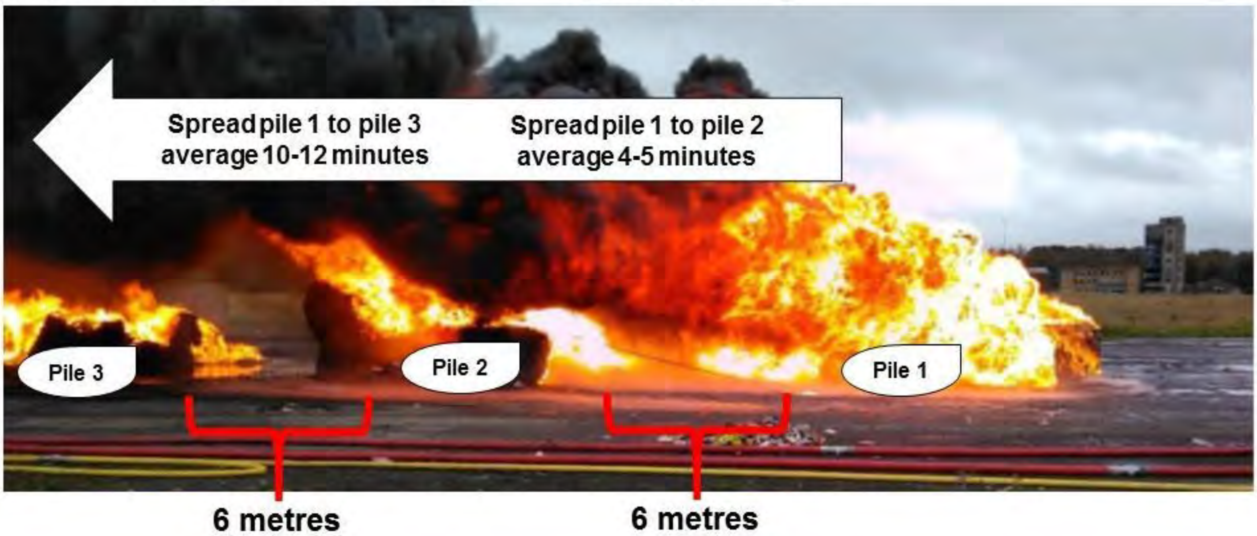
Angle of emitter and receptor: The angle between emitter and receptor is important. Heat transfer between two surfaces parallel to each other will be more effective than between two angled surfaces of the same dimensions. In fire science this issue is accounted for by use of a 'configuration factor'. The separation distance information given in option 1 below takes account of configuration factor for loose stacks. This is the reason why separation distance information for loose pile stacks with an assumed angle of repose of 45 degrees is quoted in addition to 90 degree (vertical) baled and similar stacks and buildings.

The separation distance information in option 1 below takes account of the above issues and translates much complex fire science into practical separation distances. However, it is accepted that there are variables still be to fully be understood, and there is nothing to stop anyone performing their own calculations rather than relying on the standard parameters given in option1.

The potential fire spread mechanisms of stack collapse and flying brands are discussed above and noted as being too variable to provide a practical basis for determining separation distances. However, the separation distances quoted in option 1 below are such that they are also likely to provide a reasonable degree of protection from these other potential fire spread mechanisms.

Some readers of this appendix have expressed surprise at WISH's choice of using thermal energy transfer as the basis for calculating free-air separation distances, and at the size of the distances arrived at. During phase 3 of the WISH fire tests an empirical test of the use of thermal energy to determine separation distances was carried-out (the test was repeated to ensure consistency). More detail is available in appendix 5, but in summary stacks were placed 6 metres apart and the first stack set on fire. The time for the fire to spread between the stacks was then measured. The graphic/photograph below shows the results in synopsis.

Photograph of actual tests. Note, bale stacks in partial collapse and extensive flames result in pre-burn distances not being clear in photograph. This test repeated four times to ensure consistency.



In brief, the results of the WISH fire tests provide the data require to calculate separation distances, and this approach is commonly used by fire engineers as a reliable method'

General views WISH fire tests, from left: Smaller scale laboratory burn tests, the 'porcupine' thermal sensor array used in larger scale stack burns, plastic bales burn test, RDF loose stack burn test, bale burn test general view.

3. Use of fire walls and bunkers to replace free-air separation distances

An alternative to using 'free-air' separation distances between waste stacks, or stacks and buildings etc, is the use of fire walls. The intent being to provide a 'block' to the heat produced by a burning waste stack so reducing the risk of fire spread. Fire walls can be linear, to separate two objects, or arranged as bunkers, typically in waste management applications three-sided. The topic of fire walls and bunkers is discussed in more detail in the main body of this guidance in section 5 and in appendix 4. Readers should read these sections before deciding on the use of fire walls/bunkers in external storage. However, specific to this appendix on external waste storage:

- When used to protect buildings height of fire wall needs consideration. Heat does not only travel horizontally - walls need to be high enough to protect upper portions of buildings
- Three-sided bunkers only protect from fire spread on the three sides where walls are installed. For the open side the full free-air separation distances need to be used
- Fire/bunker walls need to extend at least 1 metre above stored waste height to take account of flame height, and wastes should not spill/extend beyond fire/bunker walls. Please note that in some of the waste burn tests flame height exceeded 1 metre: The 1 metre freeboard noted above is aimed at achieving a reduced risk of fire spread

In addition, there are some practical aspects associated with fire wall/bunker use:

Fire walls/bunkers can be useful in reducing the space required to store wastes, by removing the need for wide free-air separation distances between stacks. However, access to fight fires is a consideration. What you do not want is to create a 'maze' of fire walls making access to fight a fire difficult, and potentially hazardous. Consider access issues when planning fire walls/bunkers.

It is fairly common practice in external storage at general waste recycling plants to use rows of metal wastes bales to separate stacks of combustible waste bales. The WISH waste fire burn tests showed a significant difference between the heat emitted by many combustible wastes when they burn and plastic and rubber wastes, plastics and rubber burning at much higher temperatures. For example, during the plastic baled waste stack burn test maximum temperature measured at the surface was sometimes in excess of 1,200 degrees centigrade. This is above the melting point of aluminium. The use of metals bales to separate bales of paper or similar may still be valid, but their use to separate plastics/rubber bales or similar may be ineffective. A 'fire wall' constructed of waste metals bales will be of little use if it starts to melt and falls-over.

For sites with restricted space, the use of fire walls/bunkers in external waste storage may be the most effective option to provide an adequate degree of protection from fire spread while maintaining reasonable space requirements on site. In particular for plastic and rubber wastes were separation distances in free-air are wider, because of their higher burn temperatures. However, fire walls/bunkers require good planning to be effective and careful thought should be given to their construction, use, configuration, maintenance and layout.

4. Factors affecting stack dimensions – how did WISH arrive-at its stack dimensions?

Some of the most difficult, long-lasting and largest waste fires experienced in recent years have been in large undifferentiated individual external waste stacks. Such 'mega-stacks' are clearly not acceptable because of the risks they pose, and the difficulties faced by the Fire and Rescue Services when attempting to fight such fires. Limits are required on stack size/dimensions, but as for separation distance what factors such limits may be based on needs consideration.

As outlined above, thermal heat transfer can provide a basis for calculating separation distances. This section considers the factors which may be used, and which may be practical to use, to determine limits on stack size/dimensions.

4.1 Burn-time, self-heating and stack volume as potential considerations

The more waste in a stack the longer a fire may potentially last for: How long, is a function of how much waste there is and the rate at which the fire burns at. During the WISH waste fire tests, the rate of mass loss during burning was measured for various waste types. The results were variable. Rate of burn varied between 1 tonne of some waste types taking only a few hours to burn-out to the same weight of other waste types taking more than 24 hours to burn-out.

For many waste fires the Fire and Rescue Services will fight the fire rather than letting it burn-out. But, in others a strategy of containment (controlled burn) may be used, such as to prevent contaminated firewater entering a nearby watercourse. For controlled burn, setting a time limit of a few hours, or even a day or two, for waste fires to burn-out and applying this to determine standard maximum stack size would result in maximum stack sizes of only a few tonnes for many wastes. This would obviously be impractical at virtually all waste management sites.

In addition, assuming that the Fire and Rescue Services do fight a fire actively, how long this may take will depend on a range of variables such as how advanced a fire is, available water supplies, how quickly they can mobilise, what fire appliances are available at any given time etc. Installing fixed fire systems such as water deluges and oscillating water monitors may increase the likelihood of a fire being brought under control/extinguished more quickly. However, fire/risk engineering is not based on distinct time limits against volumes of material stored, such systems are not common currently in external waste storage, and would in any case likely move a site out of the standard approach of option 1 into the bespoke approach of option 2 as given below.

With the current level of knowledge, setting a distinct time limit to burn-out or extinguishment and using this to try to determine a standard maximum stack size is fraught with problems, and unlikely to be practical. The only practical statement that can be made is that plans should be made to extinguish waste fires as quickly as possible.

Self-heating is another potential parameter to consider (see section 5 above for more detail). However, self-heating is a complex issue dependent on a wide range of variables, from particle size and density to waste type and external environmental conditions.

Surface area to mass ratio has a role to play, and research indicates stack height is also an important factor. In general, for cone or similar shaped stacks, the larger the stack the lower its surface area to mass ratio becomes, and the less able it is to shed heat caused by self-heating.

However, stack configuration is also a factor. A longer thinner stack may contain many hundreds of tonnes of waste and still largely maintain a surface area to mass ratio which allows heat to be shed, provided stack height is restrained. For example, a bale stack of 50 metres length x 20 metres width x 4 metres height when compared to a smaller stack of 20 metres length x 10 metres width x 4 metres height loses less than 30% of surface area to mass ratio, despite having five times the volume. Please note that in this example stack height remains at 4 metres, because of the role stack height may have in self-heating and for practical fire-fighting reasons (see below on stack height). In addition, larger particle size rigid wastes may allow sufficient air-gaps within a waste stack to allow heat to be shed other than at the stack's surface.

4.2 Practical fire-fighting and stability considerations

Most external stack fires are likely to be fought using manual hoses and similar, in the first instance perhaps by site staff and then by the Fire and Rescue Services. Standard manual hoses have a limited water-throw. This poses practical considerations. If the Fire and Rescue Services are confronted by a 10-metre-high x 60 metre diameter individual waste stack they are unlikely to be able to apply water over all parts of the stack using standard equipment.

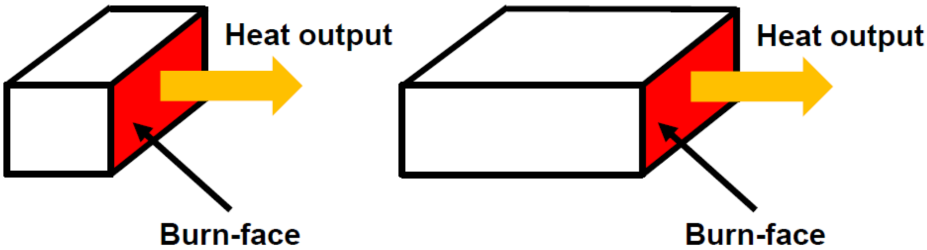
If a fire persists for a longer period of time, more specialised equipment may be brought to the scene, such as high-volume pumps. However, it must be assumed in a fire's earlier stages that standard equipment will be all that is available. The aim must be to extinguish waste fires quickly as the best option. Stack sizes set by using practical fire-fighting considerations reflect this aim.

In addition, stack stability is an issue. Stack collapse is a valid potential fire spread mechanism, and stack stability has other non-fire safety aspects such as falling materials or bales striking a person. Maximum height should also mitigate against stack stability issues.

4.3 Heat transfer and stack dimensions

As noted above, when a stack of waste is on fire it will emit heat. If the separation distance between the stack and another combustible object is insufficient, or a fire wall is not in place, then this heat may cause the second object to ignite.

The amount of heat emitted in any one direction will depend on the dimensions of the 'burn-face' of the stack facing the second object, and not primarily its overall volume. The diagram below illustrates this. The two waste stacks shown are of different volumes, but the burn-faces are the same dimension, and the heat output (represented by the amber arrows) in any one direction will likewise be largely the same.



For example, following the waste burn trials calculated separation distances were modelled for two stack volumes (450 m^3 and 750 m^3), but with the same burn-face dimensions. The difference between the two sets of separation distances was not significant.

Separation distance is largely a function of the amount of heat emitted per unit of area of a burn-face, and the dimensions of the burn-face. As noted above, wastes can practically be split into two categories: General wastes such as wood, paper, RDF etc which exhibit maximum burn temperatures of some 850 - 950 degrees centigrade and plastics and rubber wastes with temperatures of up to some 1,200 degrees centigrade. We know what the heat emissions per unit of area for these two temperatures are, which leaves burn-face dimension as a variable.

For a given stack height, the only variable is length/width. The longer/wider the burn-face the higher the heat output, and the wider the separation distance required to avoid fire spread. There is a 'sliding-scale' relationship between burn-face length/width and separation distance. This is not a straight-line equation. As length/width increases the effect on heat output at any given point on a receptor declines. This is reflected in the separation distance graphs in option 1 below.

Note – the terms 'width' and 'length' are used above. Obviously if a waste storage stack is 10 metres by 10 metres, its width and length are the same, and the terms stop making that much sense. In addition, if a waste stack is on fire its 'width' will emit heat and well as its 'length' – both the width and length will have burn-faces.

4.4 Other considerations

There are some other considerations which support the practical factors noted above:

- Stability of stacks is a fire and non-fire safety consideration. Slips in loose stacks may engulf personnel and bales toppling may strike persons in the area posing a risk of severe or fatal injuries. This would include Fire and Rescue Services personnel tackling a fire

- Stack collapse may impede the fire and rescue services and delay access for fire-fighting
- One technique used during waste fires is to remove unburnt wastes from a stack which is on fire using mobile plant. This is easier if a stack is not too high or too large
- Research indicates that stacks of more than 4 metres high may have problems shedding heat from self-heating, in particular for smaller particle size and/or flexible wastes

With the current state of knowledge, the most practical method of determining standard stack sizes is likely to be a combination of practical fire-fighting experience, stack stability, ability of stack to shed heat from any self-heating and stack configuration/dimensions relating to burn face dimension. This may change in the future as knowledge in this area develops, and in that case a revision to this appendix would be required.

In summary on stack dimensions:

- Maximum stack height of 4 metres (or maximum of four bales high whichever is lower) based on practical fire-fighting, stability and self-heating considerations
- Maximum stack width of 20 metres (provided access is available from both sides – if not maximum of 10 metres) based on practical fire-fighting considerations
- Stack length a variable based on the separation distance, which is achievable at any specific site. This allows flexibility to account for site dimensions and layout

5. External waste storage stack management options

5.1 Introduction to options

As can be seen from the above, calculating separation distances and assessing reasonable stack dimensions is a complicated, time-consuming and potentially costly task. The WISH tests are an extreme example, having been conducted on multiple waste types, stack sizes, variable situations etc, but to date they have taken more than three years and cost in excess of £175,000. However, the WISH tests have resulted in sufficient data for a set of 'standard' separation distances and stack dimensions to be arrived at. These may not be perfect, because of factors such as the variability of wastes, but they do provide a basic set of parameters without waste operators having to expend the time and cost of conducting their own tests.

In addition, as the aim was to obtain baseline data the WISH tests were conducted in the absence of enhanced fixed fire systems being in place, such as automatic water deluge, water monitor and similar systems (there would have been little point in trying to measure thermal outputs for a fire if an automatic deluge system kept putting it out…)

Taking account of the above, and to provide waste operators with flexibility, two options for stack management are given in this appendix.

5.2 Option 1 – standard separation distances and stack dimensions

Option 1 applies to waste management sites:

- With **only basic** fire-fighting provision, such as hand-held extinguishers and 'standard' fire hoses (sites which largely rely on the Fire and Rescue Services should an incident occur)
- **AND**, where waste operators do not wish to have their own bespoke fire engineering calculations performed to arrive at bespoke distances and dimensions

5.3 Option 2 – bespoke separation and distances and stack dimensions

Option 2 would apply to waste management sites:

- With **enhanced** fire-fighting provisions, such as fixed fire systems (for example automatic water deluges, oscillating water monitors or other similar equipment)
- **AND/OR** operators who do wish to have bespoke fire engineering calculations performed on their specific situation and/or wastes

Sections 6 and 7 below describe these options, and section 8 gives examples of site storage layout to illustrate the use of the stack dimension and separation distance information given.

6. Option 1: Standard separation distances and stack dimensions

6.1 Introduction to standard separation distances and stack size option 1

Note - this option 1 is aimed at waste management sites which **ONLY** have a basic level of fire provision, such as hand-held fire extinguishers and standard fire hoses, **AND** where operators do not wish to have bespoke fire engineering calculations performed. If your site has fixed fire protection systems at external storage such as automatic oscillating water monitors, or you wish to have bespoke fire engineering data calculated, then option 2 may be more applicable.

The standard separation distance and stack dimension tables/graphs given below have been split:

- Information and standards for **general** wastes (typical maximum burn temperature of circa 950 °C), **excluding** wastes which are predominantly plastics and rubber. These are split into tables for loose waste stacks and baled waste stacks
- Information and standards for wastes which are **wholly or mostly plastics and rubber** (typical maximum burn temperature of up to circa 1,200 °C). These are given separately because of the significantly higher thermal outputs of these types of waste. As for general wastes, tables are split for loose storage stacks and baled storage stacks

Please read the notes and information given to ensure you understand what each means.

6.2 Information and use of the tables and graphs

Some of the standards set in this appendix are simple, such as stack height and width. However, separation distances will vary dependent on the length of the stack (see above) on a sliding-scale. Because of this separation distances are shown as graphs. Two graphs are provided:

- **Graph 1.** Shows stack lengths and separation distances for general wastes, such as RDF, wood, paper etc (950 °C typical maximum burn temperature – see above). Four lines are shown on the graph: Loose stack to loose stack distances, loose stack to buildings distances, baled stack to baled stack distances and baled stack to buildings distances
- **Graph 2.** Shows stack lengths and separation distances for plastics and rubber wastes (1,200 °C typical maximum burn temperature – see above). Four lines are shown on the graph: Loose stack to loose stack distances, loose stack to buildings distances, baled stack to baled stack distances and baled stack to buildings distances

To determine your separation distance, mark your stack length on the horizontal axis and draw a vertical line up to the relevant coloured graph line (stack to stack, to buildings etc). Then draw a horizontal line across to the vertical axis and read-off separation distance. This can also be done in reverse. For example, your separation distance may be constrained by site size. The distance you can achieve can be marked on the vertical axis and stack length read-off on the horizontal axis.

For convenience, the terms 'stack length' and 'width' are used in the tables and graphs. However, when considering separation distances based on thermal heat transfer a burn-face could be on the long-side of a stack (length) or the short-side (width), or length and width could be equal. **Both** need to be considered – fire spread via heat can occur on **any** open side of a stack.

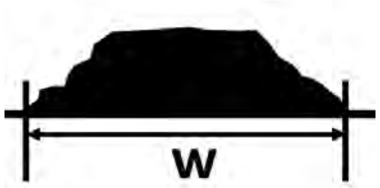
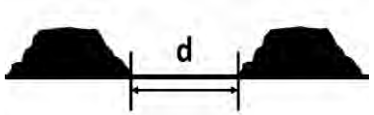
The aim of the tables and graphs is to give waste operators practical guidance they can use without the need to employ a specialist fire engineer to calculate bespoke separation distances. As a result, assumptions have been made to avoid complicating the issue, and a need to have multiple graphs and scenarios. The main assumptions made include:

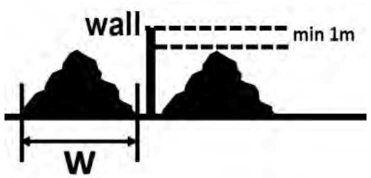
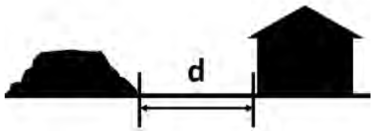
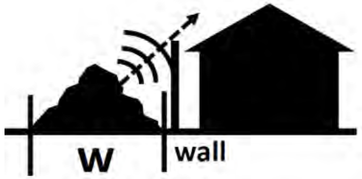
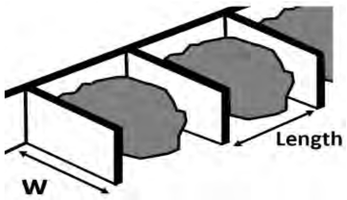
- That emitter (waste stack) and receptor (other waste stack or building) are parallel to each other. If this is not the case, then separation distance may reduce
- That loose waste stacks (piles) have an angle of repose of 45 degrees. If your loose stack has an angle of repose steeper than this then separation distance may increase, or if shallower distance may decrease
- Typical maximum burn temperature for the two broad categories of waste types noted (general wastes and plastics/rubber wastes) have been used. These reflect the typical worst-case fire scenarios observed during the WISH burn tests, such as 'inside-out' loose stack fires and bale 'chimney effect' fires (see appendix 5 for details)
- A receptor ignition property of 10 kW/m^2 has been used for waste stacks, based on research into the ignition properties of baled RDF. If you believe your wastes have a different ignition property you could conduct testing to prove this
- A receptor ignition property of 12.6 kW/m^2 has been used for buildings. This is the value commonly used for buildings with unprotected surfaces. However, for example, if your building is of concrete construction with no doors, windows or other openings in its face opposite your waste stack then the value of 12.6 kW/m^2 may be too low
- Graphs 1 and 2 assume a stack height of 4 metres. If your stacks are lower than this, you could employ a fire engineer to calculate bespoke separation distances. However, small differences in stack height are unlikely to have a significant effect
- To avoid over-complicating the tables and graphs a limited number of most common scenarios have been used. There are other potential scenarios, such as a bale stack next to a loose stack. However, the scenarios shown provide a basic set of standards
- 'Adequate access to allow fire-fighting' is used as a term in the tables. This should generally be a minimum of 5 metres, but may be varied dependent on site conditions, such as are there obstacles etc which would make 5 metres too narrow. In addition, access should be good on **all** sides of a stack, not just its length

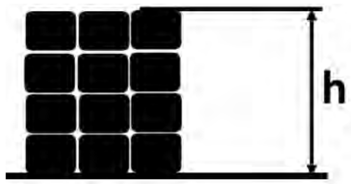
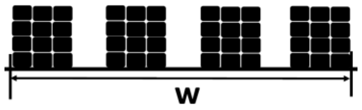
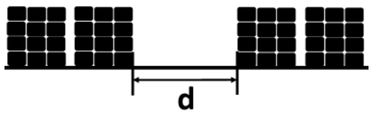
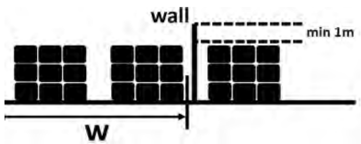
Finally, when using the graphs below take a practical and cautious approach. Separation distances should be rounded-up to the nearest whole number. Measuring stack length, width or height down to the millimetre is unlikely to have a substantive effect and would not replicate actual conditions on a waste site, which will vary from week-to-week – if in doubt exercise caution and prudence.

6.3 Summary tables of standard stack separation distances and stack sizes: OPTION 1

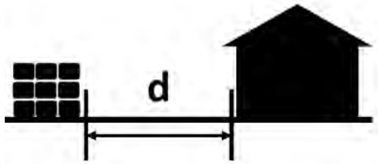
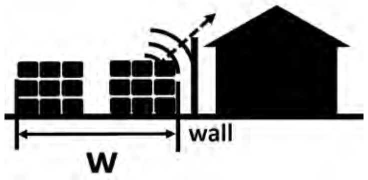
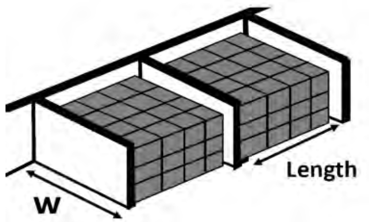
A. General combustible wastes (typical max burn 950 °C), EXCLUDING plastics/rubber

Parameter and standard	Commentary
Note: *The graphics used below are indicative only and should not be considered as being to scale or a guide to stack layout or configuration, number of bales suggested in a stack etc. They are for illustrative purposes only and should be treated as such. The terms length and width are used, but these are interchangeable, and* ***ALL*** *sides of a stack need to be considered.*	
1. Loose waste stacks: GENERAL wastes (typical max burn 950 °C), EXCLUDING plastics/rubber	
 **Max height (h) of stack = 4 metres**	Maximum height (h) of 4 metres is based on practical ability to fight fires using manual means such as standard hoses, and stability of stack to reduce the risk of fire spread from falling/rolling wastes.
 **Max width (w) stack = 20 metres (10 if access one side only)**	Maximum width (w) of 20 metres is based on practical ability to fight fires using manual means such as standard hoses. **NOTE** – 20 metres assumes good access from all sides of the stack to fight fires (minimum 5 metres). If this is not the case, then maximum width = **10 metres**.
 **Min 'free-air' separation distance between stacks (d) = See graph 1**	Separation distance will depend on stack length (or at their ends width – consider all sides of your stack) – the longer (or wider) the stack the wider the separation distance required. See graph 1, **blue** line to calculate separation distance for your stacks.

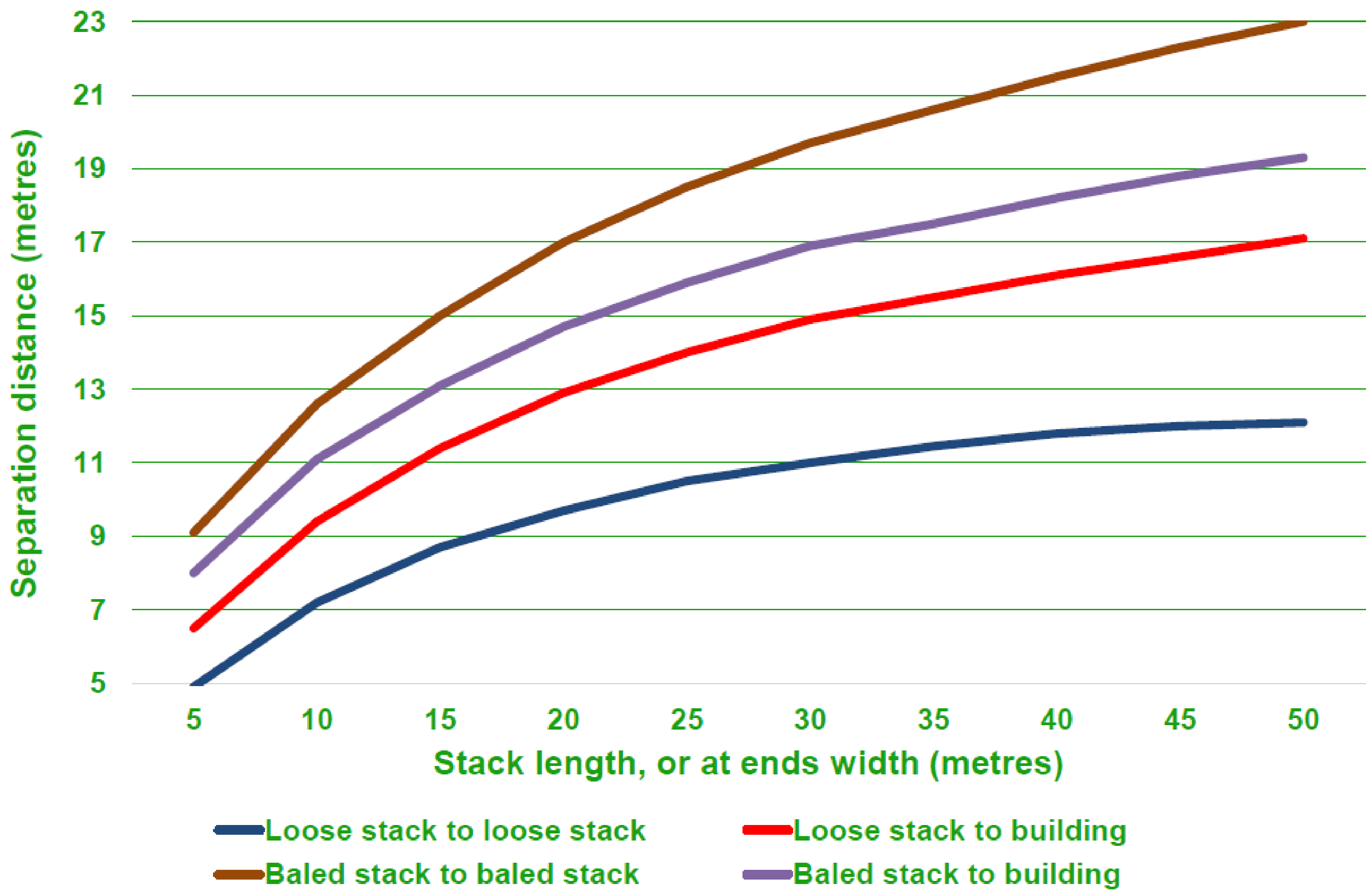
	**Alternative fire wall between stacks. Max stack width (w) = 10 metres**	Walls must be of suitable construction, and a minimum freeboard of **1 metre** left between waste and wall height to account for flame height. Stacks could be 'butt' against walls, but access to rear of stacks may be required for stock rotation and similar – this is a matter for site specific assessment. **NOTE** – access for fire-fighting will not be from both sides. This means maximum stack width = **10 metres**
Note: *Readers may look at the option above and ask: "Why would I do this as stack width is reduced to 10 metres and I might as well just have one 20-metre-wide stack". When considered as a fire wall between the length-sides of stacks this is a valid point. However, use of fire walls between the width-sides of stacks may have benefits. See the example stack layouts in section 6 below.*		
	**Min distance to buildings (d) = See graph 1**	Separation distance will depend on stack length (or at their ends width) – the longer the stack the wider the separation distance required. See graph 1, **red** line to calculate separation distance for your stack to buildings.
	**Alternative wall between stacks and buildings. Max stack width (w) = 10 metres**	Heat does not only travel horizontally. A wall height which is too low may result in heat radiated upwards and outwards travelling to an exposed upper portion of a building. Wall height should be sufficient to avoid this. A gap between wall and building should be left for general access. Unless this gap is substantive, access for fire-fighting will be from one side only and max stack width = **10 metres**.
Note: *Buildings can be on-site (such as a recycling plant waste hall) or off-site (such as a nearby industrial unit). The separation distances and/or fire wall information given above applies in both cases, including at site boundaries (heat does not stop at a site boundary).*		
	**Bunkered wastes. Max width (w) of bunker = 10 metres**	Maximum width (w) of bunkers = 10 metres (for reasons of practical fire-fighting as access is unlikely to be from both sides). Length of bunker is for site specific assessment based on stock rotation etc. A minimum of 1 metre freeboard should be left between waste and bunker height. **NOTE** - if open (length) side of bunker/s faces a building/other waste stack then see graph 1 for separation distance.

2. Baled waste stacks: GENERAL wastes (typical max burn 950 °C), EXCLUDING plastics/rubber		
	**Max height (h) = 4 metres or no more than four bales high, whichever is lower**	Maximum height (h) of 4 metres, or four bales high whichever is the lowest, is based on practical ability to fight fires using manual means such as standard hoses, and stability of bale stack to reduce the risk of fire spread from falling/rolling waste bales.
	**Max width of stack (w) = 20 metres (10 if access one side only)**	Maximum width (w) of 20 metres is based on practical ability to fight fires using manual means such as standard hoses. **NOTE** – 20 metres assumes good access from all sides of the stack to fight fires (minimum 5 metres). If this is not the case, then maximum width = **10 metres**. **NOTE** – within an individual bale stack gaps for access for stock rotation should be left between rows of bales. The gaps shown in the diagram left are illustrative only – you need to ensure adequate access, including use of forklifts or other plant for stock rotation
	**Min 'free-air' separation distance between stacks (d) = See graph 1**	Separation distance will depend on stack length (or at their ends width) – the longer the stack the wider the separation distance required. See graph 1, **brown** line to calculate separation distance for your stacks.
	**Alternative fire wall between stacks. Max stack width (w) = 10 metres**	Walls must be of suitable construction, and a minimum freeboard of **1 metre** left between waste and wall height to account for flame height. Stacks could be 'butt' against walls, but access to rear of stacks may be required for stock rotation and similar – this is a matter for site specific assessment. **NOTE** – access for fire-fighting will not be from both sides. This means maximum stack width = **10 metres**

Note: *Readers may look at the option above and ask: "Why would I do this as stack width is reduced to 10 metres and I might as well just have one 20-metre-wide stack". However, use of fire walls between stacks may have benefits. See the example stack layouts in section 6.*

 **Min distance to buildings (d) = See graph 1**	Separation distance will depend on stack length – the longer the stack the wider the separation distance required. See graph 1, **purple** line to calculate separation distance for your bale stack to buildings.
 **Alternative wall between stacks and buildings. Max stack width (w) = 10 metres**	Heat does not only travel horizontally. A wall height which is too low may result in heat radiated upwards and outwards travelling to an exposed upper portion of a building. Wall height should be sufficient to avoid this. A gap between wall and building should be left for general access. Unless this gap is substantive, access for fire-fighting will be from one side only and max stack width = **10 metres**.
Note: *Buildings can be on-site (such as a recycling plant waste hall) or off-site (such as a nearby industrial unit). The separation distances and/or fire wall information given above applies in both cases, including at site boundaries (heat does not stop at a site boundary).*	
 **Bunkered wastes. Max width (w) of bunker = 10 metres**	Maximum width (w) of bunkers = 10 metres (for reasons of practical fire-fighting as access is unlikely to be from both sides). Length of bunker is for site specific assessment based on stock rotation etc. A minimum of 1 metre freeboard should be left between waste and bunker height. **NOTE** - if open (length) side of bunker/s faces a building/other waste stack then see graph 1 for separation distance.

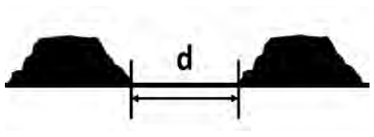
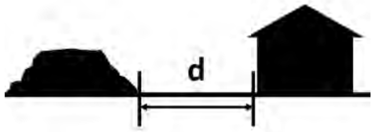
Graph 1. Stack lengths and separation distances GENERAL wastes (typical max burn 950 °C)

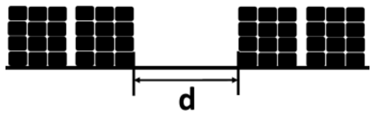
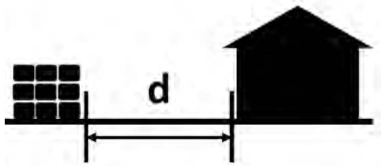


To determine your separation distance, mark your stack length on the horizontal axis of the graph and draw a line up to the relevant graph line (stack to stack, to buildings etc). Then draw a horizontal line across to the vertical axis and read-off separation distance. This can also be done in reverse. For example, at your site separation distance may be constrained by site size. This distance can be marked on the vertical axis and maximum stack length read-off on the horizontal axis (see section 6 on example stack layouts below for illustration of this use).

B. Plastics/rubber wastes (typical max burn 1,200 °C)

The waste fire burn tests showed that burning plastic and rubber wastes have higher burn temperatures and thermal emissions. As a result, separation distances are wider than for general wastes. Graph 2 below note these wider distances. Other information, such as relating to fire walls/bunkers, stack width and height, as given for general combustible wastes, are the same and are not repeated below.

Parameter and standard		Commentary/rationale
Note: *The graphics used below are indicative only and should not be considered as being to scale or a guide to stack layout or configuration, number of bales suggested in a stack etc. They are for illustrative purposes only and should be treated as such.*		
1. Loose waste stacks: Plastics/rubber wastes (typical max burn 1,200 °C)		
	**Min 'free-air' separation distance between stacks (d) = See graph 2**	Separation distance will depend on stack length (or at their ends width) – the longer the stack the wider the separation distance required. See graph 2, **blue** line to calculate separation distance for your stacks.
	**Min distance to buildings (d) = See graph 2**	Separation distance will depend on stack length (or at their ends width) – the longer the stack the wider the separation distance required. See graph 2, **red** line to calculate separation distance for your stack to buildings.
Note: *Buildings can be on-site (such as a recycling plant waste hall) or off-site (such as a nearby industrial unit). The separation distances and/or fire wall information given above applies in both cases, including at site boundaries (heat does not stop at a site boundary).*		

2. Baled waste stacks: Plastics/rubber wastes (typical max burn 1,200 °C)	
 **Min 'free-air' separation distance between stacks (d) = See graph 2**	Separation distance will depend on stack length (or at their ends width) – the longer the stack the wider the separation distance required. See graph 2, **brown** line to calculate separation distance for your stacks.
 **Min distance to buildings (d) = See graph 2**	Separation distance will depend on stack length – the longer the stack the wider the separation distance required. See graph 2, **purple** line to calculate separation distance for your bale stack to buildings.
Note: *Buildings can be on-site (such as a recycling plant waste hall) or off-site (such as a nearby industrial unit). The separation distances and/or fire wall information given above applies in both cases, including at site boundaries (heat does not stop at a site boundary).*	

Note - wastes are variable. The data above, and in graph 2 below, for plastics and rubber wastes are based on wastes which are wholly or mainly plastics or rubber. Some of the waste types included in the general wastes section and graph 1 above will contain a proportion of plastics/rubber, such as SRF and RDF. However, the proportion of plastics/rubber in such wastes is typically limited. If your waste type is a mixture but contains a substantial proportion of plastics/rubbers you may want to consider using the data above as for plastic/rubber wastes, or you want to have your waste tested to determine its burn temperature and thermal heat emissions. The 2015 and 2016 waste burn tests were conducted on 13 different types of waste (see the non-technical summary of the tests in appendix 5). The wastes tested were selected to be the most typical, but your wastes may vary from those tested. If you do decide to have your waste tested, WISH would be grateful if you could provide the result to it for the benefit of the waste management industry and future revisions of this guidance.

Graph 2. Stack lengths and separation distances plastic/rubber wastes (typical max burn 1,200 °C)

To determine your separation distance, mark your stack length on the horizontal axis of the graph and draw a line up to the relevant graph line (stack to stack, to buildings etc). Then draw a horizontal line across to the vertical axis and read-off separation distance. This can also be done in reverse. For example, at your site separation distance may be constrained by site size. This distance can be marked on the vertical axis and maximum stack length read-off on the horizontal axis (see section 6 on example stack layouts below for illustration of this use).

7. Option 2: Bespoke separation distances and stack sizes

Note - this section covers bespoke options for sites with enhanced fire systems at external storage areas, and/or those operators who wish to have bespoke fire engineering calculations performed on their specific situation or wastes. Option 1 above covers standard stack sizes and separation distances for sites with only basic fire systems in place, such as hand-held extinguishers and standard hoses, and operators who do not wish to have bespoke fire engineering calculations performed.

7.1 Introduction to bespoke separation distances and stack sizes - option 2

This section considers the factors which may move a site from option 1 (standard sizes and separation distances) to option 2 (bespoke sizes and distances). Sun-section 7.2 covers enhanced fire-fighting provision which may move a site from option 1 to option 2. Sub-section 7.3 covers bespoke fire engineering calculations for those operators who wish to consider these.

In terms of physical fire-fighting improvements, this appendix restricts itself largely to the common configurations of external waste storage, such as open stacks and stacks with fire walls or in three-sided bunkers etc. It does not consider specialised systems, such as silo storage of wood chips, or rack storage of end of life vehicles. This type of specialised storage needs specific assessment. In the case of silo storage this may include fixed water deluge systems within the silo, activated by fire detection systems such as those which monitor for early-stage fire combustion products. If you have a specialised storage system you should consult with competent fire/risk engineers to decide upon the system you will need (see appendix 4 of this guidance for more information).

7.2 Potential factors for inclusion in bespoke options: Fire-fighting provision

To move away from the standard stack sizes and separation distances given in option 1 above, any additional fire-fighting provision should address one or more of the under-pinning considerations which led to the standard parameter being set. Look at the considerations in the sections on separation distances and stack dimensions of this appendix used to set the standard parameters in option 1. Any rationale to move away from these standard distances and dimensions in option 1 must be directed at these considerations to be valid.

For example, stack width and height in option 1 are based partially on practical fire-fighting considerations, in particular using standard fire hoses. To move away from option 1, any additional fire-fighting provision needs to be aimed, at the least, at these practical fire-fighting considerations.

Example: You may have a three-sided bunker at your site containing larger particle size combustible wastes in storage (if you have smaller particle size wastes practical fire-fighting would not be the only consideration – self-heating may also be an issue and in this case the example below may not be appropriate). Option 1 gives a maximum width ((w) in the diagrams in option 1 for bunkers) of 10 metres. This is based on the practical aspects of fighting a fire using standard hoses – a width of more than 10 metres may mean that water from a standard hose cannot reach the rear of the bunker effectively. To address this consideration, you could install a dry fixed water deluge system on the top of the walls of the bunker (pipework with spray heads directed into the bunker). This deluge being fed by a pipe which ends in a 'dry-riser' connection. In the event of a fire the FRS can connect their hoses to this dry riser and introduce water into the system, so allowing the application of water across the bunker area. This may overcome some of the practical restrictions of fighting the fire using standard hoses and allow you to increase the width of waste (w) in the bunker to beyond 10 metres.

However, the above example does not overcome potential water supply issues. The Fire and Rescue Services (FRS) may be able to 'plug-into' the dry-riser, but do they have sufficient water to sustain the effective use of the deluge over a period of time sufficient to fight a fire adequately? FRS fire tenders only carry limited amounts of water, which may run-out before a fire is extinguished or under control.

Example: To overcome this you may install your own on-site water supplies, such as a fire water tank and pumps, to feed your deluge system (or a lagoon with pumps). This would remove the need for the FRS to supply water. It would also allow a quicker application of water because the deluge could be activated using your water supply before the FRS arrive. You may decide on manual activation of this deluge system, such as a button located in a safe place which operative push to activate the system.

However, what if your site is not manned 24/7? If a fire occurs out of working hours no one will be there to operate the deluge (or any other system) manually.

Example: To address this you may decide to install fire detection at the bunker which would automatically activate the deluge. This is likely to be quicker than a manual activation, in particular if your site is not occupied 24/7 (manual activation obviously requires someone to activate the system).

The examples above tackle the under-pinning practical fire-fighting reasons for setting a 10-metre width as given in option 1. Having a deluge aims at the ability to place water over the area of a bunker, and not rely completely on the use of standard hoses. Having an adequate water supply to feed a deluge aims at the practical limitations of the volume of water the FRS can carry in their fire tenders. Having automatic activation of the deluge system from fire detection aims at the practical issue of how long the fire and rescue services may take to attend your site, and set-up, and that your operatives are not on a 24/7 dedicated fire-watch at the bunker.

The above are example of the types of systems and approach which may move a site away from the standard specifications in option 1. The degree to which a site can move away from option 1 is a matter for technical fire/risk engineering assessment and will depend on a range of factors such as combustible occupancy (in the above example - the wastes in the bunker), technical specification of the fire system chosen (in the above example a deluge system) and other factors. For most waste operators this is unlikely to be a process they can pursue without competent fire engineering advice.

Note - all fire systems, such as deluges, must be specified, designed, hydraulically balanced, installed and commissioned to appropriate fire/risk engineering standards, and suitable third-party approval may also be required. This is not a matter of purchasing a length of hose, putting some holes in it and attaching it to a bunker wall. See appendix4 of this guidance for more details.

Detection systems are mentioned briefly in the example above. Detection systems are not in common use at external waste storage areas. This is largely because many types of detector do not work that well in external environments. However, there are systems which do work in external environments and are in use at some waste management sites. Having a detection system may allow early warning of a fire, provided it is reliable and capable of detecting a fire effectively in an external environment. However, on its own having a detection system in place at external waste storage is unlikely to be a reason for a site moving from option 1 to option 2, unless they are used in combination with other measures such as automatic fixed fire suppression/extinguishing systems. Having early detection of a fire is one thing, being able to do anything about the fire once detected is another matter.

7.3 Potential factors for inclusion in bespoke options: Bespoke calculations

The data given in option 1 is partially based on the results of the WISH waste burn test and also includes an assumption on the ignition properties of waste based on other research (the 10 kW/m^2 figure used). If you believe that the burn properties of your waste/s when stored in your specific stack configuration or their ignition properties are different then you always have the option of having your own tests conducted. If you do decide to do your own testing you should consider all of the factors involved, including that small-scale laboratory type tests may not provide realistic data for real-life waste storage stacks (see non-technical summary of the waste burn trials in appendix 5).

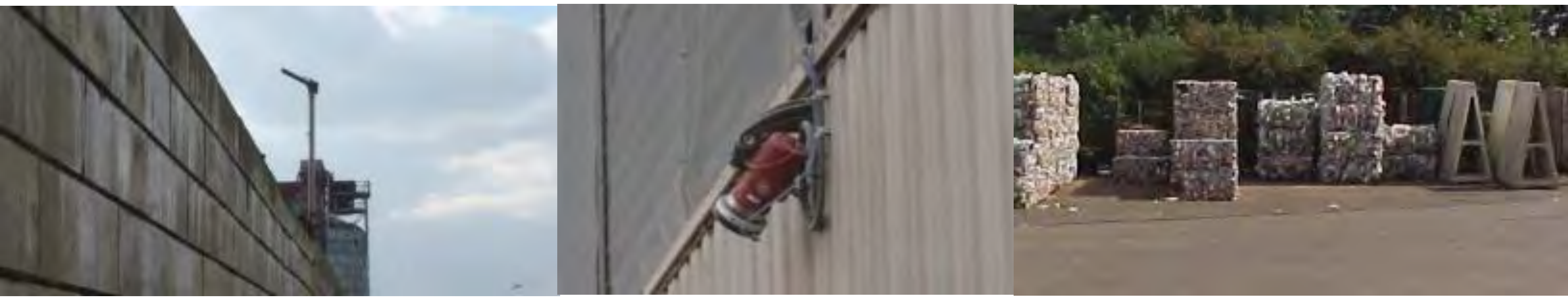
One of the main reasons you may wish to conduct your own testing is that you may believe that your wastes differ in composition from those tested during the WISH waste burn tests, and therefore will have different burn properties. For example, in option 1 above SRF and RDF are included in the general waste category (maximum burn temperature of some 950 °C) rather than the plastics and rubber wastes category (maximum burn temperature of some 1,200 °C). This is because of the results of the waste burn trials. However, if your SRF, RDF or other waste mixture contains substantive proportions of plastics/rubber then its burn temperature may be higher.

In addition, there are various assumptions made in option 1, such as on building construction, orientation of stacks to stacks or to buildings, loose stack angle of repose etc. These assumptions have been made based on knowledge of typical waste sites and aimed at operators who do not wish to have bespoke calculations conducted and simply want a 'standard solution'. If you believe that your specific site situation is different you have the option of having specific bespoke fire engineering calculations conducted to give you bespoke separation distance information.

Note - such bespoke fire engineering calculations as noted above very likely need to be carried-out by a competent fire engineer. Not many waste operators will have the required competence to perform such calculations in-house.

However, you should consider this route carefully. Unless your site-specific issues, waste types and storage configurations etc are significantly different than those outlined in option 1 you could spend a lot of time, trouble and resource on bespoke calculations with little return.

WISH would appreciate that if you do conduct your own tests or have bespoke fire engineering calculations conducted that you provide the information to WISH – such data may benefit the wider waste industry and inform future revisions of this guidance.



From left: Water deluge head mounted above external waste storage bunker wall (example only – deluge etc systems can be mounted lower or direct on walls), camera-type detector in external use above a waste bunker, standard bale storage ('A' frames in place for use as fire walls as required)

8. Examples of stack layout

8.1 Introduction and factors when planning stack layout

The graphics below are examples to illustrate how the stack dimensions and separation distances in option 1 above can be applied to stack layouts, including the use of fire walls/bunkers. The principles would also apply to option 2 bespoke dimensions and separation distances.

For reasons of simplicity only stack dimensions and separation distances are used in the graphics. However, there are other factors you may need to consider when deciding on your stack layout. These include the below (you should consider your specific site conditions):

- Location of potential ignition sources on your site
- Location/s of occupied buildings and high-asset value equipment and plant
- Escape and evacuation routes – must not be compromised by stack layout
- Location of flammable and/or hazardous substances kept on site, such as gas cylinder cages, diesel tanks, quarantine areas which may contain non-conforming wastes etc
- Locations of on or off-site fire hydrants, other water supplies and fire-fighting equipment – you do not want to block access to these with your stack layout
- Proximity and location/s of any infrastructure which may be affected by a fire, such as overhead power lines, major roads, rail lines etc
- Proximity and location/s of any off-site, third party buildings which may be affected by a fire
- Permitted amounts of wastes, and types of waste, allowed on site
- Provision of a 'quarantine' area, as appropriate to site specifics
- Operational practicalities such as movements of vehicles
- Stock rotation requirements, seasonality of supply/off-take etc

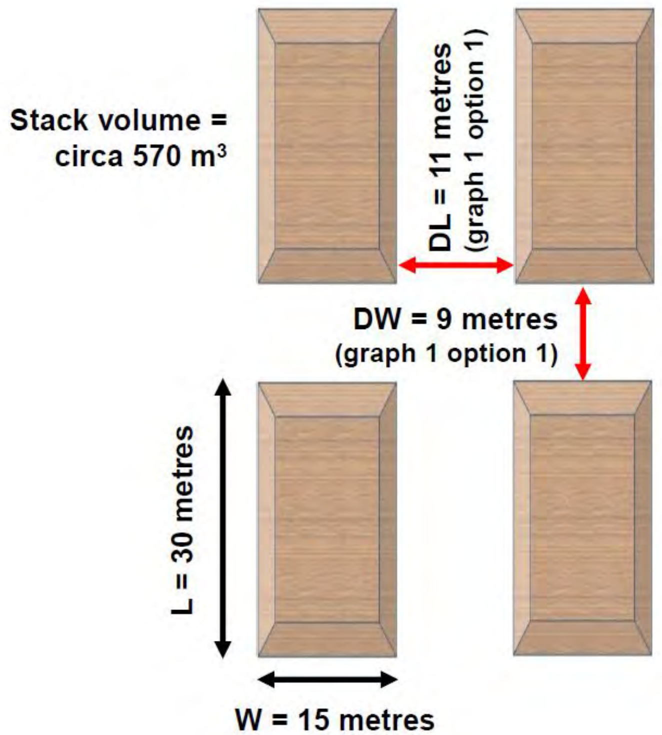
You are also likely to require a scale map of your site, and of the surrounding area (the one/s in your emergency response plan may be suitable).

Tip – you may want to cut-out 'shapes' from card or similar, representing items such as storage stacks (to scale). Plus, lengths of card representing separation distances etc (again to scale). You can move these around the map of your site to experiment with different layouts. Once you have settled on your layout you may also want to mark stack boundaries on the ground, such as with yellow road markings or similar, as an aid to operatives, and so you can see easily your storage plan is being obeyed.

Once you have decided on your storage stack layout you should record this and review it if anything changes. You should also induct your employees on your plan.

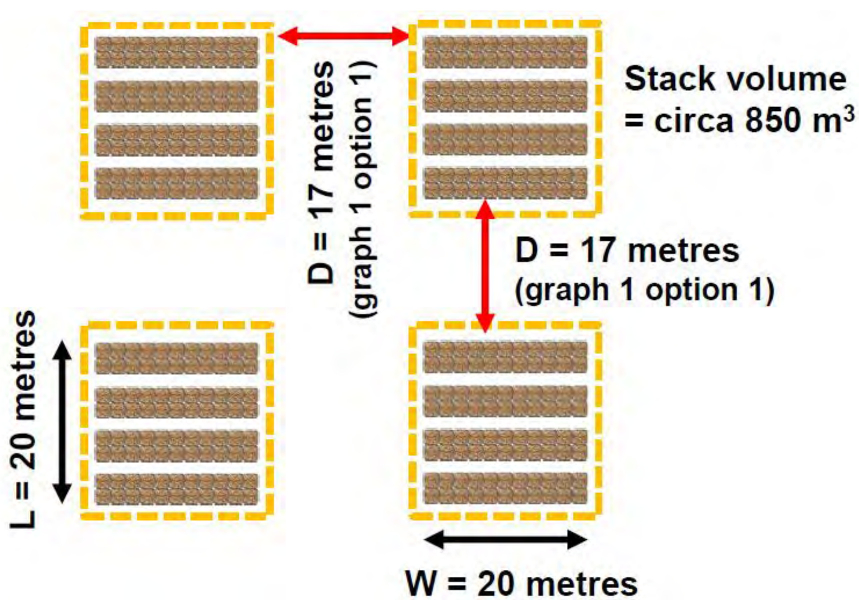
8.2 Examples of stack layout

A. Simple loose stack layout, pre-crush wood using free-air separation distances



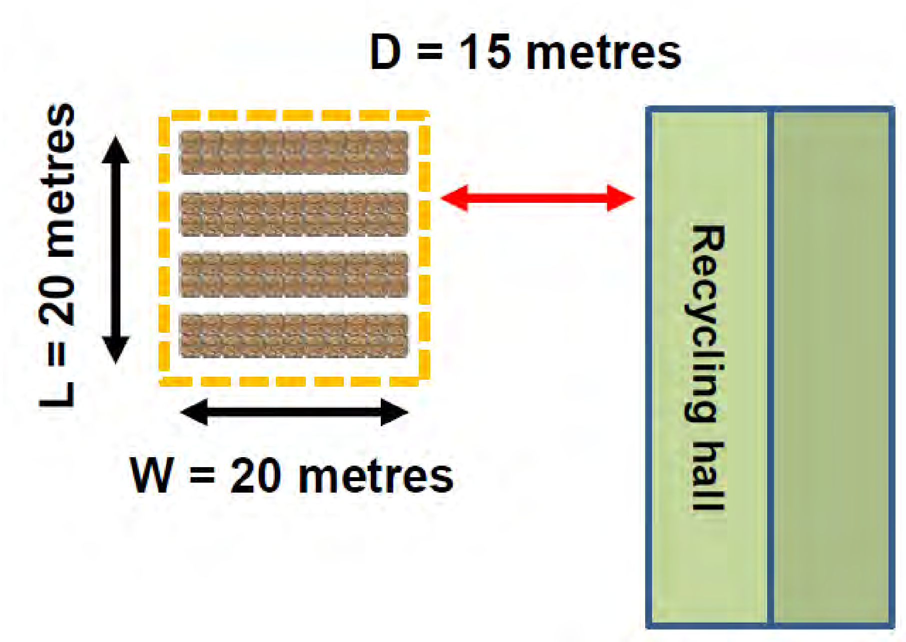
This example is pre-crush wood stored in loose stacks with free-air separation distances used to mitigate fire spread. Each stack is 30 metres long and 15 metres wide. As wood is a general waste for purposes of option 1, using graph 1 blue line (loose stack to loose stack distances) gives a separation distance on the length side of each stack of 11 metres (DL) and on the width side of 9 metres (DW). Each stack has a volume of circa 570 m^3, with total volume across all four stacks shown of circa 2,280 m^3 (equivalent to circa 450 – 500 tonnes density dependent). **NOTE: BOTH** length and width sides of stack considered.

B. Simple bale stack layout, baled paper/card using free-air separation distances



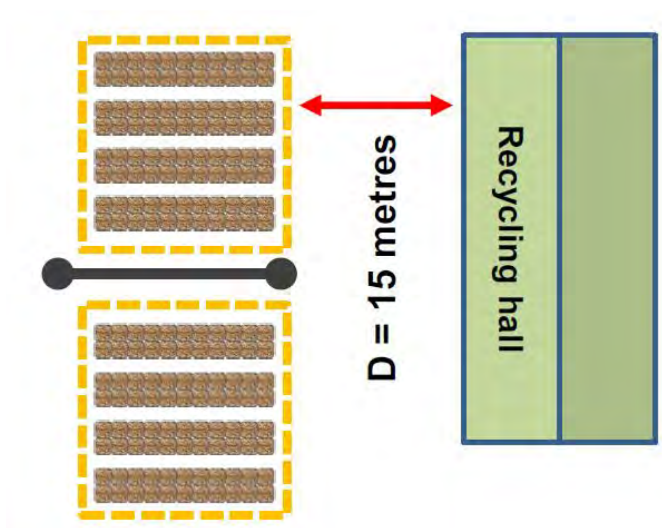
This is similar to above but using paper/card bales (each individual stack of rows of bales demarked by amber dotted line). These are general wastes, so graph 1 applies. Stacks are 20 metres square, giving a separation distance from the brown line in graph 1 of 17 metres each side. Excluding the gaps between bale lines for access, stack volume is circa 850 m^3, with a total volume across all four stacks of circa 3,400 m^3.

C. Example of restricted separation distance determining stack dimension



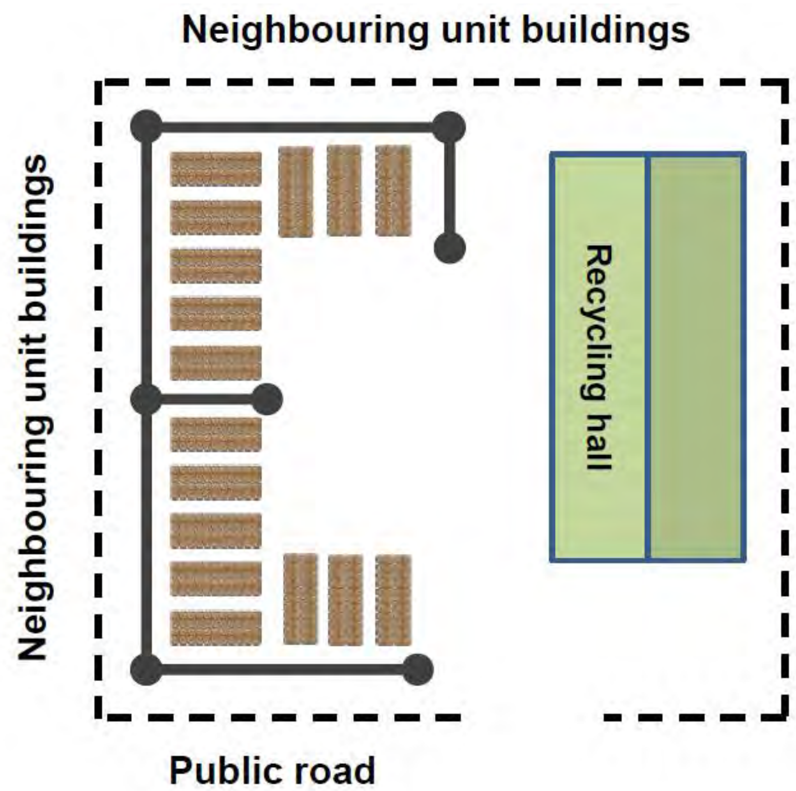
Limited space at this site means the maximum separation distance which can be achieved between recycling building and stack is 15 metres (D in graphic). Using paper/card bales as for example B above, graph 1 purple line gives a maximum stack length of 20 metres (mark 15 metres on the vertical axis of graph 1, draw a horizontal line across to the purple line, and then a vertical line down, giving stack length at some 20 metres). This is an example of a reverse use of the data in graphs 1 and 2.

D. Use of a single fire wall to extend storage capacity



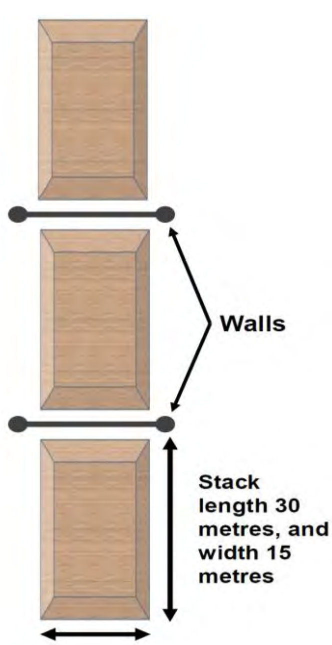
This is the same as C above, but the operator wishes to increase overall storage capacity in a limited space. Adding an appropriate fire wall as shown removes the need for a free-air gap at the width ends of the bale stacks. Each stack still has a length of 20 metres, and is still in line with graph 1, because the separation distance is determined by the burn-face of each of the stacks. Obviously, the integrity of the fire wall is critical – if it fails to prevent fire spread and both stacks ignite then overall burn face will be 40 metres, which would require a wider separation distance. Note – maintaining the 20-metre width of stacks in this example assumes good access for fire-fighting from both sides of stacks.

E. Use of a bunkers/fire walls to extend storage with buildings at site boundary



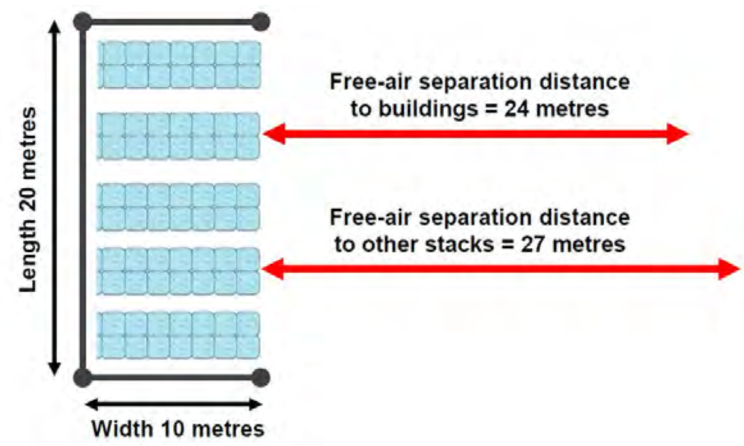
All of the above examples assume there is nothing at the site boundary. This example is the same site as example D above but assumes the waste site is on an industrial estate and has neighbouring industrial unit buildings close to its site boundary. Installation of additional walls to form bunkers around the storage stacks provides protection for these neighbouring units without free-air separation distances (a reasonable level of stand-off is still required). However, because access for fire-fighting is not available from both sides, stack width is decreased to 10 metres. In this example, extending the walls has allowed the operator to reduce the loss of overall site storage capacity to only circa 12% compared to the capacity of example D above.

F. Use of fire walls with loose stacks



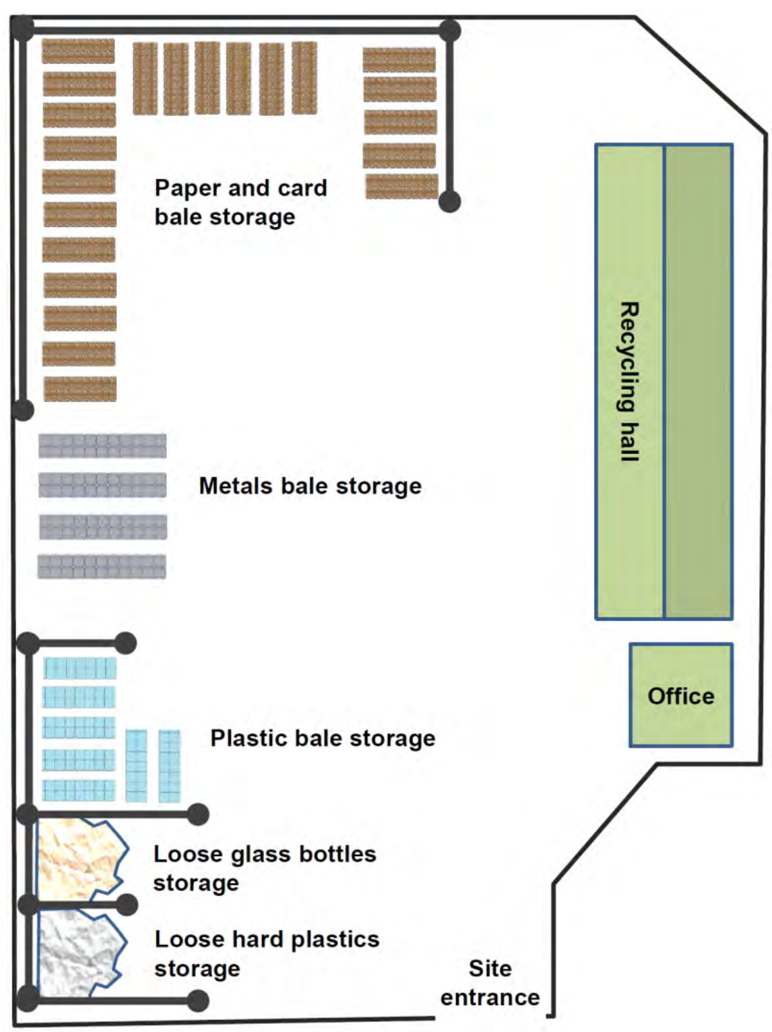
The use of fire walls is not restricted to bale stacks. This example shows a loose stack layout using fire walls to remove the need for free-air separation distances at the width ends of the stack. Assuming good access for fire-fighting is available from both sides stack width is not affected (shown at 15 metres but could be the 20-metre maximum). This type of 'sausage link' layout may be suitable for 'long and thin' waste sites and allows space to be maximised.

G. Plastic and rubber wastes



All of the above examples are for general wastes. For plastics and rubber wastes free-air separation distances are wider because of their higher burn temperatures (see graph 2 option 1 above). Use of bunkers is likely the practical option with this type of waste, such as the example of baled plastics shown here. However, an appropriate free air separation distance still needs to be left at the open side of the bunker (from graph 2 using stack dimensions shown).

H. Overall site storage example



For more complex sites overall site storage layout will require careful thought, either to be in line with the standards in option 1, or any bespoke solutions under option 2. The layout shown here simply an example, however: Paper and board bales are partially bunkered to preserve separation distances, but not on one side as distance is not an issue to the bunkered baled plastics bunker or baled metals, which are themselves not bunkered. Plastics bales are bunkered, with adequate free separation distance at the open side of the bunker. Loose glass (non-combustible), stored in a bunker for non-fire reasons has been placed between the plastic bales bunker and loose plastics bunker as a further precaution.

Appendix 2: Producing an accident/emergency plan

1.1 Accident/emergency plans are about how you plan for a disaster, such as a fire, and are aimed at reducing its potential effects. Potential effects could be to human health and safety, your buildings and/or plant, the environment, neighbouring premises and members of the public etc. All waste sites should have accident/emergency plans (often aimed at various potential types of disaster). Some organisations may want to go further than accident/emergency planning into disaster recovery and business continuity planning, but these topics are outside of the scope of this guidance. Accident/emergency plans are nearly always a requirement of environmental permits/waste management licences. Some environmental regulators have also produced guidance on emergency plans and response, and you should be familiar with any such relevant to your site.

1.2 Although you are responsible for producing the accident/emergency plan for your site, liaison with your local Fire and Rescue Service (FRS) and environmental regulator is recommended, as it will assist the FRS and environmental regulator with managing the risk in their area, enabling them to respond more effectively should a fire occur.

1.3 Larger waste fires tend to result in a ‘multi-agency’ approach – in addition to the FRS and your environmental regulator you are also likely to have the police on site and potentially other agencies such as those concerned with public health. You should anticipate this and tailor your emergency response accordingly. For example, how would you co-ordinate communications during a major incident between multiple agencies?

1.4 Your insurer is also likely to be interested in your plan, in particular property damage, disaster recovery and business continuity aspects. Consider discussing your emergency plan with your insurer, who may have relevant advice to give.

1.5 The effectiveness of your plan will depend on how well you train your staff. All staff and contractors working on-site must be aware of your plan and what they must do during a fire. You should have regular exercises (drills) to test how well your plan works and that staff understand what to do. There is little point in having a good quality emergency plan if no one has read and understood it.

1.6 Your plan should be available electronically and in hard copy**.** Give careful thought to where your plan is located. Employees need to have access, but the FRS also need to have access during an emergency. Many sites place copies of their plan in an 'emergency services information box' (also called a premises information box) located at the site entrance or similar so that the FRS can access the plan out of hours in an emergency. In the end, it is no use having a good plan in place if it is in the burning building and cannot be accessed.

Tip – an increasing number of Fire and Rescue Services (FRS) vehicles have on-board computers. If you lodge an electronic copy of your emergency plan with your local FRS, then they will be able to access your plan on the way to your site. Contact your local FRS and ask about this.

2. Content of your plan

2.1 The content of accident/emergency plans may differ, but should at the least include:

- Communication arrangements, such as named emergency contacts, key holders, incident controllers etc with their telephone numbers and likely response time (for out of hours)
- Communications arrangements with neighbours/nearby premises which may be affected
- Hazardous and combustible materials on site, including wastes, including locations, amounts, hazardous properties and other details - locations should be marked on your site map
- Specific hazards, such as gas cylinders, fuel stores etc – again mark on your site map
- Normal number of people working on site and usual hours of work
- Fire-fighting equipment on site (and off as relevant) and where this is located, such as location of fire hydrants, fire extinguishers, hoses, drench systems the Fire and Rescue Services (FRS) can plug-into via dry risers (and location of these risers) etc
- Location/s and detail of any fixed fire systems on site, such as sprinklers and water deluges, including locations of any external activation points for such systems
- Any other equipment on site which may be of use during a fire, such as heavy mobile plant which could be used to assist the FRS
- Any specific environmental issues, such as drainage issues for firewater, protected habitats neighbouring the site, aquifers underlying the site etc
- The procedures, such as evacuation, taking a role call after evacuation, fire-fighting and summoning the FRS, which employees and others on site must follow in the event of a fire. This must include the period before the FRS arrives
- Outside of issues such as how to call the FRS, these procedures should also include

    - Incident controller identification – who will be your main point of contact with the FRS and how are they identified?

- Procedures to ensure access is clear for FRS vehicles
- Communication of life-safety issues, such as any persons missing following a role call after evacuation has occurred
- Use of pollution control equipment to block drains and/or divert firewater to a containment area and/or operate any pollution control facilities, such as drain closure valves/or penstocks
- Processes outside of the normal, such as using soils to cover fires, removing un-burnt materials with mobile plant, re-circulating firewater to reduce run-off etc
- Processes relating to isolation of utilities connections such as gas and electricity

2.2 If you expect your employees to fight a fire until the FRS arrives then they must be trained to do so and any fire-fighting by site employees must not be to the risk of their health and safety.

2.3 As part of your accident/emergency plan you should have a map of your site showing at least:

- Layout of buildings (externally and internally, including fire exits and other access points)
- The above should include locations of storage bunkers, fire walls and other similar features
- Location of all stored wastes (externally and internally stored), what these wastes are, how much is in each storage area typically etc, and noting any specific wastes which may pose specific hazards such as plastics and rubber wastes
- Location of your quarantine area, as applicable
- Any locations where hazardous materials are stored on site (location of gas cylinders, process areas, chemicals, stacks of combustible materials, oil and fuel tanks etc)
- Main access routes for fire engines and others and any alternative accesses
- Access points around the site perimeter to assist fire fighting
- Location of hydrants (on and off site) and water supplies, including lagoons, water tanks etc
- Location of fire extinguishers, hoses and other fire-fighting equipment on site
- Any watercourse, borehole, or well located within or near the site
- Areas of natural and unmade ground
- Location and layout of fixed plant (such as recycling plant and equipment), and where mobile plant is usually parked out of normal work hours
- Location of protective clothing and pollution control equipment and materials
- Drainage systems, including foul and surface water drains, and their direction of flow and outfall points
- Location of drain covers, and any pollution control features such as drain closure valves/penstocks and firewater containment systems
- Location of utilities isolation points, such as for gas, electricity and water

- Location of any nearby sensitive receptors, such as schools, hospitals, residential, care and nursing homes etc, plus any protected habitats, water boreholes, wells and springs etc used for drinking water etc
- Location of any specifically hazardous off-site facilities, such as a gas storage yard next to your site, or another waste management site which a fire could spread to
- Location of any infrastructure which may be affected by a fire such a major road, rail lines, overhead power lines etc (note for this and the above off-site items a separate map of a different scale may be useful)

2.4 Your plan should also detail disaster recovery measures as appropriate including:

- Communications with customers and similar to stop wastes continuing to arrive at site during, and if the site is damaged to the extent it will not reopen quickly, after a fire
- The removal of burnt material using appropriate and lawful disposal – you will need to consult with your environmental regulator to ensure this
- The safe re-commission of plant
- Salvage operations

2.5 Following any fire your accident/emergency plan (and overall fire management measures) should be reviewed and improved as required.

2.6 It is not the intent of this guidance to be the comprehensive guide to accident/emergency planning and you should seek competent advice as to the detail content of your plan. Guidance is also available from various sources, such as the Environment Agency (and other environmental regulators), your local FRS and the Health and Safety Executive.

Tip – involve your local FRS in the production of your plan, or at least lodge a copy with them. Inviting your local FRS to your site so that they can familiarise themselves with site access, location of fire-fighting equipment, water sources etc and include this in their own plan for the site can also be of benefit – if your local FRS is familiar with your site this could save vital minutes should you have a fire.

Appendix 3: Checklists

The checklists below are not comprehensive, but they will allow you to make an outline assessment of your fire management. If you have any specific issues relating to your site, you should consider these in addition to the below. The below may be adequate for a small site, but for larger and more complex sites greater depth is very likely to be required, although the below can be used as baseline to start from. If you answer ‘yes’ to a question, then you may want to add detail in the ‘comments and actions’ column. If you answer ‘no’ to a question you should at least note in the ‘comments and actions’ column why, and preferably add actions to remedy the situation.

Note – alongside each individual table heading a reference to the relevant part of this guidance is given. You should complete the checklist with reference to these relevant sections to ensure you capture and consider all the detail required.

Issue/consideration	Yes / No	Your comments and actions
Basics: Advice and consultation (sections 1.3, 1.4 and 1.6)		
Do you have access to competent advice on fire management, fire risk assessment and plans, and if so who?		
Have you searched to ensure you are aware of and have seen relevant guidance on fire management for your site?		
Are any standards set in your environmental permit / license / exemption relating to fire management?		
Have you consulted with your local Fire and Rescue Services (FRS) on your site fire management and plans?		
Have you consulted with your environmental regulator on your site fire management and plan/s?		
Have you consulted with your property and business interruption insurer on your site fire management, plan/s?		
Has the advice of your environmental regulators, FRS and insurer been included in your fire management plan/s?		

Basics: Assessments and plans (section 1.5)		
Do you have in place a fire risk assessment for your site, including identification of ignition sources and fuels/combustible materials?		
Does your assessment, and the plan/s based on this, include protection of human life issues (life-safety)?		
Does your assessment, and the plan/s based on this, include protection of the environment?		
Does your assessment, and the plan/s based on this, include protection of your assets, property and plant?		
From this fire risk assessment have you produced and put in place a written plan/s to control fire risk?		
Does your plan/s include physical aspects such as fire-fighting equipment and procedural such as instructions to employees?		
Does your plan/s take account of the likely fire-fighting strategy your local FRS may take should a fire occur on your site?		
Have you reviewed your plan/s to take account of your consideration and actions from this checklist?		
Have you included non-waste facilities such as site welfare facilities and offices in your plan/s?		
Have you included fuels and ignition sources outside the scope of this guidance (derv tanks, gas cylinder stores etc) in your plan/s?		
Whole site considerations: Location and neighbouring premises (section 2.2)		
Are there sensitive receptors (infrastructure, schools, hospitals, care homes, water sources etc) which could be affected by a fire?		
If yes, have you considered these in your plan/s? Does your plan/s include off-site and well as on-site risks?		
Could a fire at your site have a catastrophic effect on a neighbouring site, such as a gas storage yard or similar hazardous installation?		

Could a fire at a neighbouring site (such as petrol stations, gas storage facilities etc) have a catastrophic effect on your site?		
If yes, have you liaised with your neighbour/s to ensure your and their plans account for this, including communication issues?		
Do you know what the likely response time for your local Fire and Rescue Services will be to attend a fire at your site?		
If your local FRS would be unable to attend your site quickly, have you accounted for this in your plans?		
Whole site considerations – general ignition sources and precautions (sections 2.3, 2.4 and 2.7)		
Have you identified all potential ignition sources/causes of fire at your site and included these in your plan/s?		
Have you included general ignition sources such as lighting, heating etc in your plan/s?		
Have you banned smoking on site and/or provided smoking areas away from combustible materials – and do you enforce this?		
Do you conduct appropriate routine testing of electrical equipment, both fixed systems and portable (PAT testing) equipment?		
Do you have adequate security arrangements (including out of hours) to reduce the risk of arson/vandalism?		
Have you considered a formal site close-down procedure to detect smoulders which may result in a fire after work has ceased?		
Do you have a housekeeping regime in place aimed at minimising litter, dusts, loose paper/fibres etc?		
Do you have appropriate storage facilities for hazardous materials such as paints, solvents, derv etc?		
Are the means of escape from buildings and from your site in adequate – do you have adequate fire escape provision?		
Have your employees been inducted on the fire precautions at your site, including emergency actions and escape?		

Have your employees been trained in the use of fire suppression equipment such as hoses and extinguishers?		
Do you include fire precautions in your site rules used with contractors, visitors, third party lorry drivers etc?		
Whole site considerations – heavy mobile plant and vehicles (section 2.5)		
Do you instruct plant operators/vehicle drivers to clear combustible materials from around exhausts etc at the end of each shift?		
Are your mobile plant/vehicles at least equipped with hand-held fire extinguishers?		
Are your mobile plant/vehicles equipped with automatic and built-in fire extinguishing systems?		
Do you maintain your heavy mobile plant/vehicles to prevent electrical faults and similar potential causes of fires?		
Do you park mobile plant/vehicles away from waste storage, reception and other waste areas after use?		
Have you considered the role mobile plant can play fighting fires, such as moving wastes away to prevent fire spread?		
If yes, have you trained your employees in the use of heavy mobile plant to fight fires?		
Whole site considerations – hot works (welding, grinding, cutting etc) (section 2.6)		
Do you have appropriate controls in place to minimise the fire risks of hot work (including permit to work systems)?		
Do these include the provision of extinguishers and/or hoses at the scene of any hot work?		
Do these include an instruction that all hot works are a two-person task (one watching and one doing)?		
Do you conduct a fire watch at least 2 hours (or longer as appropriate – some insurers require 4 hours) after hot works?		

Whole site considerations – water supplies (section 2.8)		
Have you assessed the water supply to your site relative to your potential fire risk – and is it adequate?		
Do you know where the nearest public fire hydrant to your site is – and is this in your emergency plan?		
If the nearest public hydrant is >100 metres away have you considered an on-site hydrant?		
Have you considered potential alternative water supplies such as lakes, lagoons, rivers etc in your plans?		
Have you considered the installation of on-site water tanks and mains to feed fire systems?		
If you have sprinkler, deluge etc systems in place have you gained advice to ensure your water supply is adequate to feed them?		
Have you discussed water supplies with your local FRS, and your environmental regulator?		
Whole site considerations – fire water and fire waste (section 2.9)		
Do you have a drainage plan for your site which identifies all places contaminated fire water may run to?		
Have you included the potential environmental effects of contaminated fire water run-off in your plans?		
Do you need to put in place containment systems to prevent contaminated fire water escape?		
Have you considered ways to reduce the amount of fire water which may be produced in the event of a fire?		
Have you considered in your plans how you would dispose of fire water and/or burnt materials which may remain after a fire?		
Have you consulted with your local FRS and environmental regulator on contaminated fire water issues?		

Whole site considerations – non-waste facilities (section 2.11)		
Have you included non-waste facilities (offices, welfare facilities, weighbridge cabins etc) in your plans?		
Are external waste storage stacks the distances given in appendix 1 (or otherwise protected) from offices, welfare facilities etc?		
Whole site considerations – fire appliance access (section 2.12)		
Have you assessed your site to ensure that FRS vehicles can access it easily (all access points)?		
Have you assessed your site to ensure that FRS vehicles can move around your site easily?		
Do these assessments include access widths, weight and heights of FRS fire tenders and vehicles?		
Are there any obvious issues with access to and around your site, such as overhead power lines, bridges etc?		
Whole site considerations – communications, training and drills (section 2.13)		
Are all of your employees trained in your fire plan/s and do they know what to do in the event of a fire?		
Do you test your emergency response (evacuation etc) frequently (fire drills etc), including with your local FRS as practical?		
Do you use toolbox talks and other communications tools to ensure your employees are aware and reminded on fire risks?		
Waste reception – hot/hazardous/flammable loads (section 3.1)		
Have you included specific issues relating to waste reception and reception areas in your plans?		
Does this include the potential for hot loads and/or hazardous materials in loads which may cause a fire?		
Have you put in place controls such as fire watch at the end of the day, not accepting high risk loads at the end of the day etc?		

Have you instructed and trained your employees to be on the look-out for hot loads and hazardous items?		
Waste reception – management (sections 3.2 and 3,3)		
Have you considered the potential for a fire to spread from your reception into other parts of your site/buildings?		
Have you considered the protection of any plant (such as shredders) located direct in your reception area/s?		
Have you considered abnormal situations in your plan/s and any additional precautions you will take in such situations?		
Have you determined the maximum safe amount of waste you can have in your reception area/s at any one time?		
Do you have a management system to ensure these maximum safe amounts are not exceeded?		
Did your consideration of maximum safe amounts in reception include any environmental permit/licence limits?		
Waste treatment/processing – general considerations and detection (section 4.1)		
Does your assessment include general plant/equipment fire risks such as direct heat and electrical and mechanical faults?		
Do you have an adequate maintenance programme in place to reduce the ignition risk posed by electrical and mechanical faults?		
Do you have housekeeping regime in place to remove dust and loose materials from motors and other potential ignition sources?		
Waste treatment/processing – specific items of equipment considerations (sections 4.2 – 4.8)		
Have you considered fitting fire suppression to shredders, bag openers etc which may pose a friction/spark risk of ignition?		
Screens and trommels can provide air to a smoulder resulting in a fire – have you considered fire suppression at screens/trommels?		

Conveyors/other mechanical handling equipment can spread a fire rapidly. Does your plant shut-down in the event of a fire detection?		
Have you considered slip-sensors on conveyors to detect potential friction and heating issues from this?		
For de-dusting systems and cyclones etc have you considered dust explosion issues?		
For de-dusting and cyclones etc have you had a DSEAR assessment completed and as required zoned such areas?		
Where de-dusting and cyclone etc have been assessed as being ‘zoned’ have you put in place appropriate precautions?		
Have you included specialised items of equipment, such as optical sorting systems, eddy-current devices etc, in your assessment?		
Are your mains/electrical plant rooms enclosed and appropriately constructed?		
Have you provided suitable fire detection and fighting equipment in mains/electrical plant rooms?		
Are control panels either in enclosed rooms or suitably protected from dust ingress?		
Have you included the risks posed by hydraulic systems (including fire spread should hydraulic fluid escape) in your assessment?		
Have you considered fire suppression such as sprinklers or similar at hydraulic power packs?		
For balers, are baler operative working platforms and areas out of the path of any potential ‘blast’ from gas cylinders etc?		
Have you considered gantry level sprinklers or similar at picking cabins above bunkers which may contain combustible wastes?		
Does your picking cabin/s or other workstations have manual fire alarm points and extinguishers at the least?		
Is fire escape from your picking cabin/s or other workstations easy, well-marked, lit and clearly understood by your employees?		

Waste treatment/processing – protection of plant and equipment (sections 4.9 – 4.11)		
Have you considered if a fire in waste reception or storage could spread to your plant? What have you done to protect your plant?		
Have you considered if a fire in your plant could spread to reception or storage areas? If so, what have you done?		
Have you considered a formal plant close-down procedure including running the plant to clear excess wastes, at the end of the day?		
Have you considered a fire watch at the end of the day to detect any smoulders which may result in a fire?		
Waste storage (internal and external) - general considerations – capacity (section 5.2)		
Have you determined what your site's overall maximum safe waste storage capacity is?		
Have you split this into safe storage capacities for different wastes types, different storage areas etc?		
Have you included issues such as seasonal variations and marketplace variations in your considerations?		
Have you included consideration of any higher-risk wastes in your storage capacity considerations?		
Have you included any environmental permit/licence standards in your storage capacity considerations?		
Have you a management system in place to ensure that you do not exceed your maximum safe storage capacity/ies?		
Waste storage (internal and external) – use of bunkers and fire walls (section 5.3)		
Are any bunkers/fire walls you use in storage adequate in terms of the fire spread protection they provide?		
Are any bunkers/fire walls you use in storage adequate in terms of their robustness and resistance to damage?		
Do you inspect any bunkers/fire walls routinely to check for damage, cracks, holes etc which may reduce their effectiveness?		

Does your stock rotation include removing wastes from the back of bunkers etc to prevent older wastes building-up?		
Do you have procedures and rules in place to ensure wastes are not stored beyond bunker capacity (height including freeboard and spill)?		
If you use bales of metals as a fire break, have you considered their effectiveness with higher-risk wastes such as plastics/rubbers?		
Waste storage (internal and external) – self-combustion and storage times (section 5.4)		
Have you considered whether the wastes you store may self-heat and pose a self-combustion risk?		
Have you set maximum storage times for wastes which may pose a self-combustion risk?		
Are the maximum storage times you have decided on in line with the times in this guidance?		
Do you have a management system to ensure wastes are not stored longer than maximum, and if they are what action you take?		
Does this management system include the rotation of stock to ensure that older stock is transported off site before newer stock?		
If you break bales or turn stacks as a control for self-heating, do you have controls in place to prevent ignition during these tasks?		
Have you considered monitoring of temperature in loose wastes stored externally, such as by using a temperature probe?		
Waste storage – external storage areas – general considerations (sections 6.2 and 6.3)		
Do you inspect your external waste stacks routinely to detect potential fire risks and ignition sources?		
Have you considered more frequent inspections during times of higher risk for vandalism etc, such as holiday periods?		
Have you considered fire detection and/or suppression/extinguishing systems at external storage stacks?		

Waste storage – external storage areas – stacks sizes and separation distances (appendix 1)		
Do you have an external storage plan which includes maximum amounts of waste to be stored in any one area?		
Do you have a management system in place to ensure maximum stack sizes and minimum separation distances are complied with?		
Have you read and understood the two options given in appendix 1 of this guidance, and decided which applies to your site?		
If you have decided option 1 given in appendix 1 of this guidance applies, why is this the case?		
If you have decided option 2 given in appendix 1 of this guidance applies, why is this the case?		
If option 1 applies, have you produced a storage plan which complies with separation distances/bunker specifications given in appendix 1?		
If option 2 applies, have you produced a storage plan which gives its own bespoke separation distances/bunker specifications?		
If option 1 applies, have you produced a storage plan which complies with stack dimension information given in appendix 1?		
If option 2 applies, have you produced a storage plan which gives its own bespoke stack dimension information?		
Does your plan (either option 1 or 2) include safe access for fire-fighting purposes?		
Does your external storage plan include all of the factors relating to layout given in appendix 1, section 6.1 of this guidance?		
Waste storage – internal storage areas – general considerations (section 7.1)		
Do you have an internal storage plan which includes maximum amounts of waste to be stored in any one area?		
Do you have a management system in place to ensure maximum storage capacity/ies are complied with?		

As part of this plan, have you considered the advantages and disadvantages of internal storage given in section 7.1?		
If you store higher-risk wastes such as plastics and rubber internally, have you considered risks and controls carefully?		
Have you sought advice (such as from your insurer) on the protection of buildings from fires in internally stored waste stacks?		
Waste storage – internal storage areas – separation distances, stack sizes and bunkers (section 7.2)		
Have you considered the separation distances/fire wall use issues in appendix 1 and applied these to your internal storage?		
Have you considered the stack size information in appendix 1 and applied this to your internal storage		
Fire detection, alarm and suppression/extinguishing systems (appendix 4)		
Have you considered fire detection, alarm and suppression/extinguishing systems at your waste reception?		
Have you considered fire detection, alarm and suppression/extinguishing systems at your waste processing area?		
Have you considered fire detection, alarm and suppression/extinguishing systems at your waste storage area/s?		
Where you fitted such systems, have you considered the design and specification issues in section 1 of appendix 4?		
Is your fire detection system reliable, robust and effective (see section 2 of appendix 4)		
Is your fire alarm system reliable, robust, clear and effective (see section 3 of appendix 4)		
Have you assessed your fire suppression/extinguishing systems against the issues in section 4 of appendix 4?		
Is your water supply adequate for your fire suppression/extinguishing systems, fire hoses etc (see section 5 of appendix 4)		

Have you considered plant control system interactions between your fire detection and plant systems?		
Have your fire suppression/extinguishing systems, site hydrants, hoses etc been commissioned to your insurer's requirements?		
Are your fire suppression/extinguishing systems, site hydrants, hoses etc tested and checked routinely to your insurer's requirements?		
Emergency/accident plan (appendix 5)		
Does your site accident/emergency plan include all of the issues listed in section 2.1 of appendix 3 of this guidance?		
Do the maps/plans accompanying your emergency plan include all of the issues listed in section 2.3 of appendix 3?		
Have you consulted on your accident/emergency plan with your local Fire and Rescue Services?		
Have you consulted on your accident/emergency plan with your environmental regulator?		
Have you consulted on your accident/emergency (and disaster recovery) plan with your insurer?		
Have you trained-out your accident/emergency plan to all of your employees – are they clear what to do in an emergency?		
Is a copy of your emergency plan posted in an obvious (and secure) location at your site entrance?		
Have you provided a copy of your accident/emergency plan to your local Fire and Rescue Services?		
Do you review your accident/emergency plan at least once a year to ensure it is up to date?		

Appendix 4: Fire/risk engineering for waste management plants/sites: Detection, alarm and suppression/extinguishing systems

Introduction

Note – this appendix covers a wide range of technical issues, many of which are likely not relevant to smaller waste management operations. However, some of the principles may still apply. Treat this appendix as a basic guide to fixed fire systems, and issues with these in waste management use.

Even the smallest waste management site is likely to require some basic form of fire detection, alarm and/or extinguishing/suppression, such as standard fire hoses, or at least quick access to a good water supply such as a public hydrant. The larger and more complex a site/plant is, the more complex and comprehensive the fire strategy and planning required. As a result, the more likely that more advanced fire systems may be required, such as sprinklers, deluge systems, water monitors, complex detection systems and similar. For very large and complex plants multiple systems are likely.

You may already have some fire systems in place at your site. However, what is acceptable to regulators and insurers has changed significantly over recent years and continues to change. A small open-air civic amenity/HWRC site is still very unlikely to require sophisticated fire systems, but increasingly these are being required at even fairly basic transfer and recycling/recovery sites, and for large and complex plants higher standards are very likely to be expected.

There are various reasons behind this shift. The industry's fire record is an obvious driver, which has led to an increasing focus by regulators and the imposition of tougher guidance on the application and enforcement of fires issues in permitted activities. One of the other main drivers is asset protection and insurance. Waste management is not a popular industry for property insurers because of fire risk, and the standards being required by insurers are increasing. Your insurer is a key stakeholder: Waste management companies which fail to satisfy their insurers are likely to find insurance increasingly difficult and costly to obtain. Insurability to one side, if you have invested significant funds in a complex recycling, recovery or similar plant it makes good business sense to protect your investment.

All of the above means that waste management operators are increasingly having to consider technical fire/risk engineering – a specialised and complex discipline. Unless you work for a very large company with its own in-house competent fire engineer, you are likely to need an external competent advisor to help you identify what type, specification and design of detection, alarm and extinguishing/suppression system/s would be effective and practical.

- As a waste operator, you do not need to be a fire/risk engineer, but the more you know about the principles the more likely it is that you will end-up with systems which are effective and match your needs. This is the same as if you were purchasing a new loading shovel. Simply asking a supplier for a loading shovel is not enough. What size, what wastes will it handle and how, what attachments are required, are there any site restrictions relevant, what controls will I need to have in place when using it etc? Just asking a fire consultant/supplier for a sprinkler system without having an ongoing engagement with them risks you ending-up with a system which may be ineffective or does not fit with your needs
- Waste management sites are not warehouses, offices or shops. Wastes are not standard stored products. Applying standard fire systems to waste management sites/plants risks any system fitted being ineffective in the event of a fire
- Knowledge on how wastes burn, and which types and specifications of fire systems are effective with waste fires, is a rapidly developing area. What was acceptable five years ago is unlikely to be acceptable today. You may be able to identify fire engineering guidance and standards which apply to your waste management operations, but you must also ensure that these are up to date and still relevant. The rapid development of understanding in this area means that standards based on older assumptions may no longer be considered valid

This appendix is not comprehensive and will not make you a fire/risk engineering expert, and it is not intended to be a technical document or provide all of the information you may need to ensure your fire systems are adequate. It does intend to give you a basic level of information on some of the issues involved. You should always seek competent advice and assure yourself that your systems are effective, appropriate and that they will work in the event of a fire.

Tip – many larger insurance companies and insurance brokers have in-house fire/risk engineers. You should liaise with your insurer to gain access to this advice, and to ensure that any fire systems you install are to your insurer’s requirements. What you do not want to do is to install an expensive system to find-out that your insurer will not accept it and that further systems and/or work is required.

Note – while your insurer may be a critical stakeholder, there are others. Environmental regulators will also have requirements, as will your local fire and rescue services (FRS). You will need to satisfy all of these stakeholders and accept at times that they may have differing priorities, standards and requirements. Your insurer may be a good place to start, but you should also consult with your environmental regulator and local FRS to ensure whatever systems you decide on satisfy all stakeholder requirements.

Note – this appendix does not cover the issue of contaminated firewater run-off and control in any detail. When deciding on what fire systems you may want to install you should consult with your environmental regulator and available guidance on this issue. For example, if you install a high specification water deluge, where will the water go when you use it?

Note – the main body of this guidance is arranged in sections covering waste reception, treatment and storage. In each of these sections specific fire systems issues relating to reception, treatment and storage are discussed, plus a reference to this appendix. You should read the specific mentions in the main guidance under reception, treatment and storage alongside this appendix.

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1. Design of fire systems

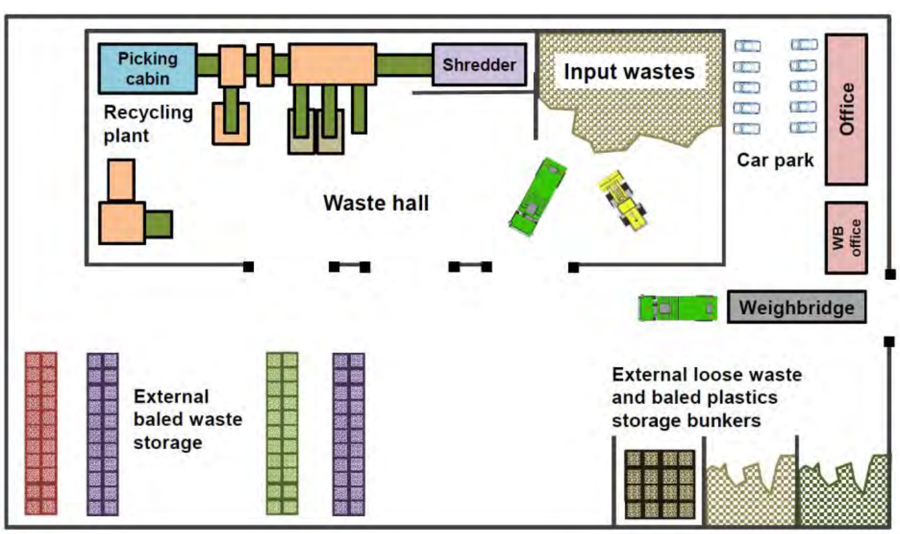
Note – if you are familiar with the basics of fire/risk engineering, such as the differences between sprinkler, deluge, water monitors, detector systems, suppression and extinguishing systems etc, you may want to read this section first. However, if you are not, you may want to skip this section and read the rest of this appendix first, then return to this section. Throughout this section the example of a basic recycling plant is used to illustrate the issues raised. This is simply an example and should not be considered any form of recommendation as to what systems may be appropriate for your plant/site. Please also note that the graphics used are not to scale and are intended simply as illustration.

1.3. What do you want your fire system to achieve?

Suppose you have decided that you want to install fire systems at your plant/site, or you may have existing systems which you want to upgrade. A starting point is to consider 'what do you want your fire systems to achieve'. This may seem an obvious question, but one which is often missed-out.

Life safety is paramount, and you must ensure the safety of your employees and others on your site. It is not the intent of this appendix to repeat guidance on fire life-safety, which is freely available elsewhere. But, in all of your decisions, life safety must be your top priority. Beyond life safety, you will likely want to protect the parts/components of your site which have the greatest value to your business. This may be the capital cost of replacement/asset value, and business interruption impacts.

The illustration below shows an example recycling operation, consisting of a waste hall, waste reception area within the hall, recycling plant (shredder, screens, over-band magnets, baler etc) and external storage for baled and loose recyclates. Ancillary facilities such as offices and weighbridge are also shown. This example will be used to illustrate the principles you may want to follow.



1.4. Factors for design and design process

Asset value, cost and time of replacement and business interruption

For most recycling facilities it is the recycling/recovery equipment/plant itself which represents the highest asset value. Total or partial loss of equipment/plant as the result of a fire may cost £ millions. Loss of plant is also likely to represent the highest business interruption risk. Even fairly minor damage to a recycling plant as the result of a fire can result in significant downtime, extending to weeks or even months.

In addition, within your plant there may be items of equipment which are more critical than others. 'Standard' parts such as conveyors and drive motors may be capable of replacement fairly quickly. But, a bespoke shredder, optical sorting array or similar may take far longer to replace. What in your plant is critical, and which items would take the longest to replace? A start here would be your asset list, which should list all of the components of your plant, and their values. However, please remember to include control systems, cabling etc – this may not be identified on your asset list but may be costly and take a significant period of time to replace.

At the other end of the scale, a fire in an external waste storage bunker may be spectacular but may not involve significant asset damage or business interruption. Your environmental regulator may take a completely different view of this, and this is one of those areas where you may need to satisfy the differing demands of different stakeholders.

Often buildings may not be as critical as plant and equipment. For example, if you lost part of your waste hall from fire could you continue to operate (subject to permission from your environmental regulator)? What temporary arrangements could you put in place if you lost part or all of a building?

- List the asset/replacement values/cost of plant and equipment on your site – try to be as specific as possible and drill-down to details such as individual critical components
- Consider likely timescales to replace, in particular for critical and/or bespoke items of equipment which may take longer to replace. Do not forget the control systems associated with your plant as these can take significant time to replace
- List the asset/replacement value/cost of buildings and other ancillary facilities on your site and likely replacement times, including porta-cabins and similar and possible temporary arrangements you may be able to put in place

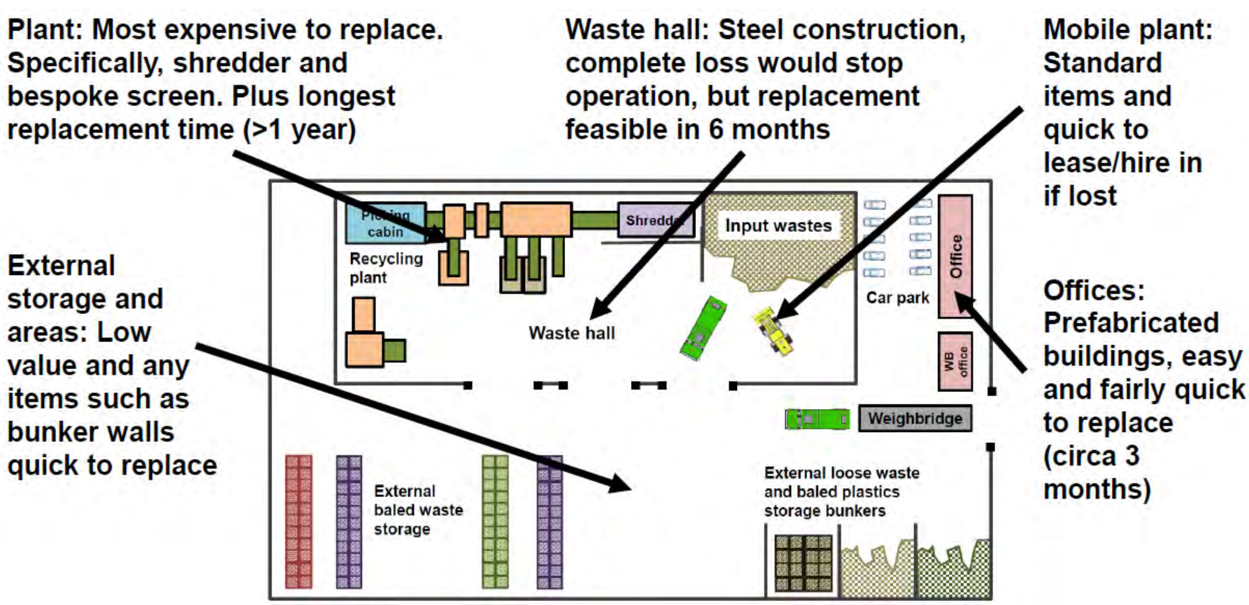
Note – the asset values you have listed may not be replacement cost. If your plant is old, then you should factor in inflation. If your plant was supplied from abroad, have currency exchange rates changed? Would installation, design and similar be more expensive today?

- Based on replacement times, consider what your business interruption costs might be for any loss of an item of plant, building etc. It may be that a fairly minor or cheap component poses a higher business interruption risk than a larger or more expensive item (if this is the case, you may want to hold such a component in stock rather than have to wait for order and replacement times)
- Consider what you would do if you lost your plant. For many waste management operations this would include diversion of wastes to alternative waste management facilities. What would this cost you in terms of transport and gate price? Even complete loss of a facility for a time would often not result in total business interruption, as the wastes would be diverted elsewhere – the cost would be the 'increased cost of working' during diversion

The above process should give you a good idea of which parts of your site you want to protect the most. And, potentially those parts which you can 'ignore' (at least partially) in terms of protection as they would be easy, cheap (or at least less expensive) and quicker to replace.

Do not forget the contents of buildings, such as ICT equipment, or plant control systems. It is often the case that replacement of a plant control system and its associated wiring and ancillaries takes just a much time as replacing the plant itself. In addition, if your plant control systems are old, they may not still be 'supported', and a complete redesign of control systems may be required – this can take time.

You should now be in a better position to answer the question: 'what do I want to protect'. However, answering the question: 'what do I want my fire systems to achieve' also requires thought.



Combustible occupancy

Once you have the information above, the next step is to add combustible occupancy - what will burn on your site, how much of it is there and locations. Wastes are the obvious combustible occupancy at waste management sites. For example, in the above illustration the wastes in the reception area, wastes being processed by the plant, wastes in external storage etc. Be specific, for example, mixed commercial wastes in reception, mixed wastes on conveyors, plastics, paper, metals etc in storage. What do you have on site which will burn and where is it?

But, do not forget other combustible occupancy:

- Not only wastes burn. Rubber conveyors, wiring, hydraulic oils in power packs etc also have substantial combustible occupancy
- Do your buildings contain combustible items, such as insulation? If you are planning a new site/plant then specifying non-combustible wall, insulation and panels would be a good start (and may be required by your insurer)
- Diesel and other flammable materials stores

Fire scenarios and risks

Next you may want to consider what the likely fire scenarios and impacts at your site may be. Industry data indicates that the most common causes of fires at waste management facilities are hot/hazardous materials in wastes (such as lithium batteries, badly extinguished hot ashes etc) and self-heating. There are other causes, such as mechanical heat and friction, electrical faults and the 'usual suspects' of discarded smoking materials and hot works such as welding and grinding. Management controls, site procedures and rules etc should be targeted at these ignition risks, but in terms of fire systems likely scenarios should be considered as an input to design. There may be other potential sources at your site – think about these.

Apply this thinking to your assessment of asset values, replacement costs and business interruption and/or increased costs of working. Overlay potential fire scenarios with combustible occupancy and the information you have listed regards asset values and replacement times and costs.

For example, if you lost your weighbridge (a critical and fairly expensive component) to a fire it is unlikely that you would be allowed to continue to operate until it was replaced. Debris under the weighbridge may accumulate, and a discarded cigarette from a driver may ignite this. How likely is this to damage the weighbridge substantially, and provided you control debris build-up by housekeeping and enforce site smoking rules, how likely is this scenario? In addition, a temporary weighbridge could be hired-in fairly quickly.

Conversely, for example, a hazardous item such as a lithium battery or gas cylinder may ignite wastes being fed into the shredder at the start of your recycling process, and such a fire could spread quickly to the rest of your plant via the action of conveyors. The outcome of such a fire could be disastrous in terms of asset value and business interruption. Likewise, self-heating or discarded ashes could cause a fire in wastes in your reception area, and such a fire could spread to the waste hall, and recycling plant. Consideration of fire scenarios will inform the nature and specification of fire systems.

Under-pinning design concept

At this point you will almost certainly want some external input, such as from a competent fire/risk engineer/consultant. However, you will have the basic information you need to conduct a meaningful and effective conversation with the fire/risk engineer, and you should be able to start to answer the question: ‘what do I want my fire system to achieve?’

The job of the engineer/consultant is to start turning your aspiration into a working and practical ‘under-pinning design concept’. You may already have some basic ideas of what you want, but these may not be practical, would not be achievable within standards, or may be very expensive – you may need to consider alternatives and go through several iterations before you have something which is workable, represents good risk management, and is cost effective and compliant with standards.

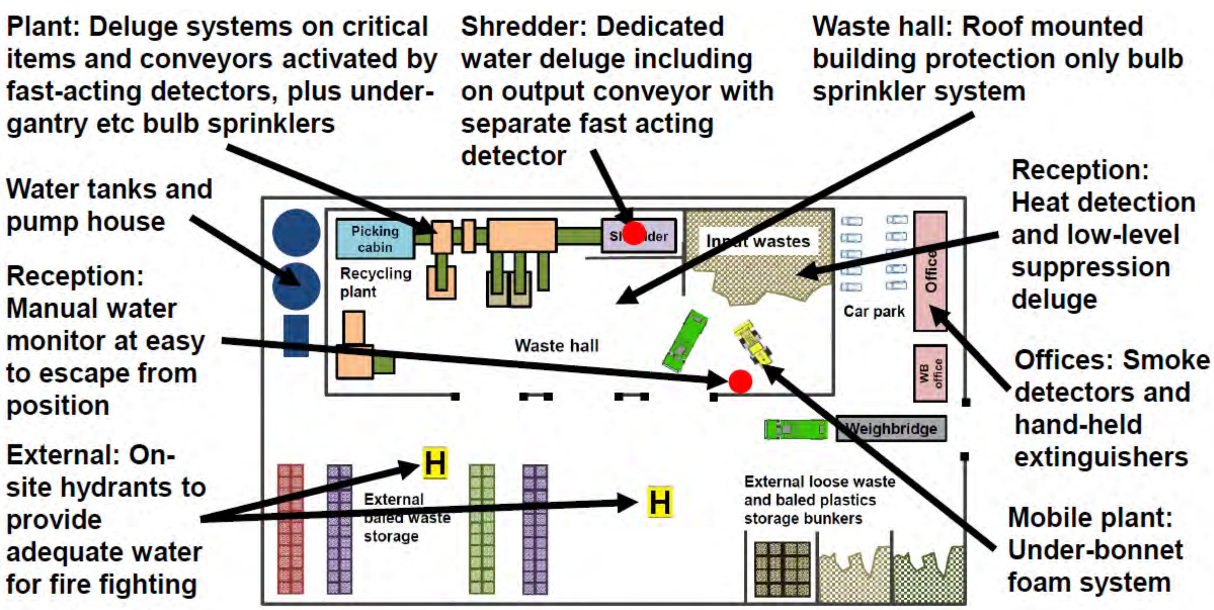
For example, you may decide that you want to protect against a fire in your shredder, as described above. One option may be installing a water deluge system above the shredder (this is simply an example - there other options). Such a deluge would need to extinguish any fire, rather than only suppress it. This would inform the specification, water density requirements etc for the deluge. The deluge would need to activate rapidly, so you would need a fast-acting detection system such as IR/triple IR. And, the detector would also need to emergency stop the plant to prevent any fire being spread via the movement of its output conveyor. You may also want a deluge system over the shredder output conveyor as a back-up, activated by the same detector.

Likewise, for example, you may want to install a heat-detecting type detector system at the waste reception area, to give early warning of a fire. You may decide that you would only want to suppress a fire in this area to allow time for your local Fire and Rescue Services to arrive, and for your operatives to use the site’s loading shovel to excavate the waste and take it outside to be drenched (see below on links to procedures etc). One option may be a low-level water deluge system, or oscillating water monitors. You may also decide you want a manual system, such as a manual-use water monitor for use in fighting such a fire. And, for out of hours fires (common in this type of scenario) the alarm may need to be monitored 24/7 such as by an external 24-hour responder system. Or, alternatively if your site is occupied 24/7, you may decide that you will rely on manual systems only at your reception area, such as manual hoses or water monitors.

If a fire does develop out of control, you may want to protect the waste hall itself, such as by installing roof mounted sprinklers. If this system is only aimed at building protection, a suppression sprinkler system may be adequate, and its specification and water density requirements may be fairly low.

These are only examples and illustrations of options and scenarios. You should take the time with your competent fire/risk engineer to assess each scenario and its potential impacts across the whole of your site, including business interruption.

This should include external areas and ancillary facilities and buildings. For example, you may decide for practical, asset value and low business interruption risk reasons that you will not provide any automatic fire systems at external waste storage areas, but that you will provide on-site fire hydrants to allow such fires to be fought with an adequate water supply. Likewise, you may decide that you will install smoke detectors and alarm in site offices but no suppression/extinguishing systems and that you will rely on hand-held extinguishers in offices.



Part of your under-pinning design concept should certainly include likely water demand requirements for the options you are investigating. Water tanks and mains to feed fire systems are often the most expensive parts of a system, and there may be practical issues to consider, such as gaining planning permission for large water tanks. You do not want to commit to a system/s which you cannot put in place, or which would be too expensive relative to the risks posed.

Note – the location of water tanks and pump rooms needs consideration, although for many waste sites space restrictions may mean there are few options. Ideally, tanks should be in an easily accessible location where the Fire and Rescue Services (FRS) can access them if required. The diagram above shows water tanks in one corner of the illustration site. This may not be the ideal location and away from the building may be better. Ultimately, practical considerations are likely to dictate location, but at least accessibility should be considered.

This appendix is mainly concerned with fire/risk engineering as applied to fire systems such as detectors, suppression/extinguishing systems etc. However, there are other aspects of fire/risk engineering which you may want to include in your design. For example, using the above illustration, having identified the risk of fire spread from your reception area to your plant, you may also want to increase the height of the separating wall between reception and plant as a physical barrier to fire spread. Or, you may want to reroute your plant control systems and cabling to reduce the risk of fire damage to this type of component. Take the opportunity of the design process to consider wider fire/risk engineering aspects. See specific sections below on fire compartments and walls and smoke vents for examples.

Consultation with stakeholders

Your under-pinning design concept will now need testing against stakeholder needs. The best place to start is likely to be with your insurer, but you will also need to consult with your environmental regulator and local Fire and Rescue Services. They will all have their own priorities and input. This can be a frustrating process, but one which is essential if you are to achieve a solution which is acceptable. Be prepared to change your design concept based on the needs of your stakeholders.

Detail design

Once you have acceptance from your critical stakeholders your under-pinning design can be developed to detail design, giving a scope which suppliers and installers can work to. This would include specific water densities and flows, scope of systems, hydraulic calculations etc. It should also include the standards/codes your fire systems need to be designed, procured and installed to.

Your detail design must also fit with the design of your recycling/recovery plant and, where relevant, the building it is in. There is little point in a detail fire systems design in isolation which ignores the design, layout and configuration of your plant and/or building.

Tip – different insurers sometimes have different requirements regarding approvals and certifications of fire system components, such as for detectors, suppression/extinguishing systems etc. At some point in the future you may want to change insurers. If you have committed to specific standards individual to one insurer, which other insurers may not accept, this may be difficult. Try to future-proof your design. Some level of over-specification may be relatively inexpensive (a marginal cost) during initial design and installation, but much more expensive to retrofit.

Installation and commissioning

Installation is a critical phase. You may have a good quality detail design document and scope, but actually transforming this into reality can be another matter. In addition, if you have specified particular standards you want to make sure this is what you get.

If your plant is a new build, then installation of fire systems will need to be co-ordinated with installation of the plant, construction of buildings etc. For example, it is usually easier to install a roof-mounted sprinkler system before installing recycling/recovery plant, but obviously gantry/low level sprinkler systems require the plant to be in place before installation. Manifolds to feed fire systems need space, pipework needs to be routed taking account of plant layout. Likewise, installation of water tanks and water mains will need to be co-ordinated with civil engineering works. Project management and managing the interface between your plant installer, buildings contractor and fire systems designer and installer is critical.

If you are adding fire systems to an existing plant the interface between your day-to-day operations and installation will need managing. Installing fire systems takes time and may require shut-down for phases of the installation. Night/weekend working may be possible, but likely more expensive.

If possible, try to ensure that your insurer is involved during the installation phase, such as arranging site visits during installation by your insurer’s fire/risk engineer. They may well spot issues which can be addressed easily during installation, but which would be more difficult and costly to address at the end of installation. Your competent fire/risk engineer should also be involved during installation to ensure you are getting the quality and detail of what you have asked for.

For example, changing spray heads on a deluge system if they are not up to standard may be fairly straightforward, assuming the pipework is to standard. But, having to dig-up a new underground water main because sectional control valves have not been installed to the correct standards and locations will be far more expensive and time consuming.

All fire systems, detectors, alarms, plant controls linked to alarms/detectors and suppression/extinguishing systems, require commissioning to ensure they function correctly. Based on this commissioning your system can be certificated. Your insurer may want to witness this commissioning or have specific requirements for commissioning. Consult with your insurer to ensure their needs are met. You may also want to invite other stakeholders to witness commissioning.

Summary of process

Step	Comment
Asset value/replacement cost	List assets and their values and replacement costs. Include plant and equipment, control systems, buildings and ancillary items
Business interruption impacts	For the above assets identified, how long would they take to replace? What would be the lead-time for replacement?
Identify critical components	From asset value/replacement cost and replacement lead-time identify the critical components of your plant/site which you want to protect
Combustible occupancy	What do you have at your site which can burn? Waste may be the obvious items, but what other combustible or flammable materials are present?
Fire scenarios	What are the most likely fire scenarios at your site? How would these fire scenarios occur and their causes? What fire spread risks exist?
Under-pinning design concept	Using the above, and likely working with an external competent fire/risk engineer, identify options for fire systems and produce an under-pinning design concept
Consultation	Check your under-pinning design concept is acceptable to your insurer, environmental regulator and Fire and Rescue Services
Detail design	Work-up your under-pinning design concept into a detail design and scope which a fire systems designer and installer can work to
Installation	Install fire systems. Keep your insurer and other stakeholders involved throughout to ensure required standards are met
Commissioning and testing	Commission and test your fire system to ensure it does what you expect it to do, including plant actions. Likely your insurer at least will want to witness commissioning

1.5. Links to site procedures/plans, training and employee awareness and knowledge

Emergency response, disaster recovery and business continuity planning

Elsewhere in this guidance emergency planning is covered. Your fire systems, and the process by which you arrived at what fire systems you want, should feed into your emergency plan. And, you may want to expand your emergency plan to include disaster recovery and business continuity planning.

As part of the process above you will have identified plant, buildings etc replacement costs and timescales, waste diversion plans and costs etc. These are valuable inputs into a business continuity plan. If you suffer a major fire resulting in your plant being down for a significant period of time, business interruption costs are very likely to be a major factor. Planning in advance, such as waste diversion planning, listing potential suppliers and lead-times etc for replacement plant, buildings, temporary buildings etc can save valuable time when you are trying to get back to ‘business as usual’. Every week you are down for costs money.

This type of information is also valuable to your insurer to calculate the likely costs associated with a major fire at your site. If you have under-estimated replacement costs and/or business interruption costs you may find yourself under-insured. Conversely, good planning can reduce the potential impacts, and therefore may have a positive effect on your insurance premiums.

Your emergency plan should also include information on what fire systems you have in place. For example, you may have installed a ‘dry-riser’ as part of your fire systems, through which the Fire and Rescue Services (FRS) can introduce additional water to your systems. This needs to be included in the emergency services information part of your emergency plan so that the FRS know this option exists at your site and where the dry-riser is. Likewise, if you have installed a deluge system with a manual activation point in a safe location, this needs to be marked on your emergency plan. And, you should consult with your local FRS so that they are familiar with your fire systems, such as by Fire and Rescue Services visits to your site.

However, if a fire does occur at your site it may not be your local FRS who attends – they may be busy on another call. You should anticipate that a different FRS may attend, who are not familiar with your site. Controls for fire systems, dry-risers etc need to be clearly signed and obvious, and your emergency services information pack should include clear directions and information.

Case study. A real example shows the value of this. At a fire at a waste management site the detection and alarm system was linked to a 24/7 responder service. The local FRS were out on another call, and so an alternative FRS from a nearby town was called to the scene instead. They had never been to the site before. They arrived before any site staff. The building the fire was in had a manually activated deluge system, the controls of which were in an obvious lean-to building next to the waste hall. But, the controls for the deluge were not clearly marked. The Fire and Rescue Services pushed the obvious and large red button in the middle of the control panel, thinking that this would activate the deluge – it was actually the emergency stop for the deluge system pumps… Site staff arrived and wasted critical minutes re-setting the system before the deluge could be activated (fortunately the fire was controlled and extinguished with only minor damage).

Employee awareness, information and training

Your employees need to know what your fire systems are and, in outline, how they work. This issue is covered in more detail in the specific sections below. However, in brief if you have manually activated systems your employees need to know what these are, how to operate them and what they are designed to achieve. Your employee procedures, rules and training should include your fire systems.

As part of your planning and design process as above you may have identified actions you expect your employees to carry-out in the event of a fire. For example, using the site's loading shovel to excavate wastes to allow them to be drenched outside a building, or to use site fire hoses to damp-down areas next to a fire to reduce the risk of fire spread. If you expect your employees to perform such actions then they must be trained, competent and aware of the risks involved. Identify where in your planning and design process you expect intervention by your employees and include this in your procedures, awareness and training for employees.

1.6. Selecting the right consultant/contractor/supplier

Your insurer is very likely to have requirements for designers and installers of fire systems, such as the BRE 'red book' (search the internet for BRE red book for details). However, such accreditations may not be sufficient to ensure waste management operators achieve effective fire systems. Experience is that 'standard' fire systems may not be effective at waste management plants/sites. The reasons for this are discussed in more detail in the sections below. However, just selecting a designer, consultant, installer etc from a standard approved list may not be sufficient for waste managers.

Your insurer may also insure other waste management operators/sites and may be able to suggest suppliers, consultants, engineers and installers who have waste management experience:

- Ask your peers/competitors – fire safety is not a competitive event and sharing knowledge across the industry will only help in the longer-term
- Ask potential suppliers, engineers, installers etc if they have previous waste management experience and whether they can provide references
- Be wary of potential suppliers, engineers, installers etc who simply suggest a standard solution rather than taking account of your specific situation

You may also need more than one supplier. For example, a contractor who installs fire systems may not be able to also provide detail design services. For larger waste management operations, it is common to have a design fire/risk engineering consultant and a separate installer, although they obviously need to co-operate and consult with each other.

Having considered the basics of design, the sections below now take a look at specific types and components of typical technical fire systems.

2. Fire detection

2.1. Detection introduction

Detection systems typically aim to provide one or more of the consequences listed below:

- Activation of an alarm to inform people that a fire may have started to allow them to evacuate and/or take measures to fight or suppress a fire, or for more advanced systems to inform the Fire and Rescue Services (FRS) or 24 hour responder (formally an ‘alarm receiving centre’) direct via ICT link that a fire may have started. Please note that some FRS have conditions on the use of alarm receiving centres and you should discuss this with your local FRS
- Early warning of a developing situation that may lead to the outbreak of fire (such as thermal imaging/heat detection, or detectors which look for combustion products before flames or other obvious signs of a fire are apparent). Typically, this form of early warning is intended to allow actions to be taken to prevent an actual fire starting
- Activation of a fire suppression/extinguishing system or systems, such as a deluge system
- Plant actions, such as the emergency stop of conveyors to prevent a fire spreading
- Other actions, such as the closing of automatic fire doors and/or shutters

Often detectors perform multiple tasks, such as a flame/visual type detector activating a water deluge system and an alarm to inform people that a fire has started. To respond to a fire, you first need to know that a fire may have started or may be about to start. Unless you have employees in every part of your site/plant 24/7 all dedicated to watching for fires, detection systems are likely required.

2.2. Fire detection system types

Fire detectors come in many different types and specifications, such as:

- ‘Standard’ smoke’ detectors – these may be acceptable in an office or welfare facility, but are very unlikely to be appropriate in an operational environment
- Beam detectors – these ‘throw’ a beam of light to a receptor. Typically, smoke interrupting the beam activates the detector
- Aspirating detectors – typically, these draw air through a network of tubes to a detector which looks for smoke and/or other combustion products which may indicate a fire has started
- UV/IR/triple IR detectors and similar ‘visual’ type detectors – these ‘look’ for specific light frequencies associated with flames, sparks and fires
- Heat sensing systems such as heat-camera type detectors which react to temperature changes – obviously these look for heat and temperature changes
- Heat sensitive wires which react to changes in temperature
- Video type/pattern recognition systems which ‘look’ for smoke or other signs of fire
- Specialised systems such as carbon monoxide sensing or other combustion product sensors

The above are only examples – there are various other types of system and variations on existing types of system. New systems come to the market all of the time. Key is ensuring that the detection system you specify will do what you want, is reliable and is effective.

Tip – fire detectors come certificated to various standards. Your insurer may have specific requirements, such as only accepting detectors certificated to LPCB (Loss Prevention Certification Board) or FM (Factory Mutual). There are also EN standards which all should comply with. Check with your insurer before you fit a system, or risk fitting one they will not accept. That a specific detector does not have a formal certification may not result in your insurer not accepting it (it may that the detector is new and has not gained certification yet). Consult with your insurer – they may accept test data and similar as proof that a detector is effective. Conversely, a detector may have certifications but would not be effective in your application (see below on robustness of detectors).

Tip – more than any other area of fire/risk engineering new detection systems come to the market all of the time. The suppliers of these are naturally keen to sell their products. Beware being sold systems which are not appropriate for waste management use, or do not meet with your needs. Ask suppliers for proof that their detector is effective and reliable in waste management operations, and ask for references you can check on, such as another similar waste management plant where the detector has been installed and used reliably and effectively. Conversely, a new type or model of detector may be just what you need. Keep a balance between natural cynicism and being open to new ideas.

Factors when selecting fire detection systems

Specific assessment of potential fire scenarios and the environment detectors will be used in is required to determine the type of detector to be used, in what application, the locations of detectors etc. One size does not fit all here - different types of detector may be required in different areas of a site/plant, based on the need for speed of detection and what suppression and plant control system actions etc are required.

Robustness and reliability

Waste management operations often involve dusty, moist and other forms of extreme environment. Detectors used in waste management facilities need to be robust and reliable. If they are not, the outcome is likely to be either that they do not work effectively, or that they produce frequent false-alarms and detections.

Detectors such as beam detectors and standard 'smoke' type detectors may be suitable for offices and control rooms but are unlikely to be reliable or effective in most operational waste management applications because of dust, moisture and other factors. Experience is that many beam detectors are affected by dusts and similar and produce false alarms in waste management environments. This often results in operators turning-off beam detectors during operational hours and then turning them back on out-of-hours or using timers to achieve the same end. This is less than ideal.

In some applications protection for visual-type and similar detectors, such as UV/IR/triple IR/camera type etc detectors, may be required. For example, ‘air-shields’ may need to be fitted for reliability reasons (air shields blow clean air in front of the detector to keep it clean and effective). In other applications physical protection may be required, such as protecting a flame detector in a conveyor cover from ejected wastes. Another example would be frequent ‘blocking’ of tubes in an aspirating detection system because of moisture and dust. Frequent cleaning of tubes may be required, or the use of automatic cleaning systems which blow compressed air through the tubes to clear them. If an automatic system is used, the compressed air needs to dry to avoid moisture mixing with dust to produce an intractable block in tubes.

For some types of detector air-flow may be an issue. For example, locating an aspirating detector system near to roller shutter doors that are usually open may mean that smoke from a fire never reaches the detector (or is delayed) because of the air-flow from the open door. Likewise installing an aspirating detector in a ‘dead-air’ space in a roof void may also have the same effect, but for the opposite reason. This may be solved by careful consideration of location of the detector, or a different type of detector may be required.

Speed of detection

In general detectors may be fast acting (such as IR/UV, triple IR and similar), medium acting (such as aspirating systems) or slow acting (such as some carbon monoxide and similar detection systems). What actions you want the detector to produce, and therefore the type of detector chosen, will be affected by how quickly you want these actions to occur. For example, a detector above a conveyor may be intended to stop the conveyor quickly – if it does not the speed of the conveyor may result in a fire being carried along the conveyor and so spread. There is little use fitting a slow/medium speed acting detector in this type of application as by the time it alarms the fire will have already spread. Conversely, for general area use a medium acting detector may be appropriate.

Consider life safety also when deciding on detection. Is a slow acting detector really appropriate to inform all on site quickly that a fire has started and that they may need to evacuate? You may need more than one type of detector to satisfy different needs, and in different parts of your plant.

Tip – this is not always the case, but often quick acting detectors tend to be directional (they look for a fire in one specific area), whereas slower detectors tend to be able to cover a wider area (such as one aspirating detector system covering an entire waste hall). There is often a balance here – think about what you want the detector to cover and how essential is its speed of reaction.

Interactions and blocks

It is not unusual for a large waste management sites/plants to have more than one type of detection system in place. For example, at a recycling plant there may be a dedicated deluge system over a shredder feed hopper, activated by an UV/IR detector (quick acting). Plus, an aspirating system for general alarm purposes covering the whole of the hall the shredder is in and, perhaps, to deploy lower-level deluges over stored wastes in bunkers in another part of the hall. A fire starts in the shredder, the UV/IR detector detects this quickly and the specific shredder deluge deploys extinguishing the fire. But there is still smoke in the air which two minutes later is detected by the aspirating system which deploys the general deluges over the stored waste bunkers. Where different detector types are used potential interactions need considering, to avoid suppression system clashes and unintended consequences (see consequences matrices below).

Interactions between detectors of the same type may also be an issue. For example, you may decide that to reduce the risk of false activations that you will install two visual-type detectors which activate a deluge system over a shredder, and that both detectors must activate to set-off the deluge (commonly, and incorrectly, called a ‘double-knock’ system). This is unlikely to be acceptable to your insurer. If one detector is blocked/dirty or faulty then the one remaining detector will not set-off the deluge as both are needed to do this. In this case three detectors would be more appropriate to ensure there are always two to activate the deluge.

In the same way as air-flow and dust can affect some types of detector, physical obstructions can affect others. For example, installing a visual-type detector looking at a pile of wastes in a reception area will be of little use if you routinely park a loading shovel in front of it, so blocking its ‘view’. Likewise, for bunker walls, and for a visual-type detector mounted over a conveyor – it cannot ‘see’ under the conveyor of through the bunker wall. Think about physical blocks when considering detector location and the number of detectors required.

2.3. Summary table detector robustness and example applications

The table below gives general detector types, comments on their likely robustness and issues, and example potential applications. It is not intended to be comprehensive, and all detector applications require specific assessment. The below is simply a guide and is not intended as a set of strict rules.

Detector type	Robustness in waste management application	Speed of response	Potential example applications
Standard smoke detectors	Very unlikely to be robust enough for operational areas	Medium	Offices, control rooms and welfare facilities
Beam detectors	Can be affected by dust/moisture and experience is that often not robust in operational areas	Medium	Internal waste storage areas where dust and moisture are not an issue
Aspirating systems	Likely need to be harsh environment systems, and not placed in dead-air areas or where air flow such as from roller doors could prevent or delay activation	Medium	Internal waste reception areas, general detection in processing areas, internal storage areas, but only if dead-air or air flow issues are not relevant
Visual IR/UV/triple IR type detectors	May need protection such as air-shields in operational areas, and beware of their ‘view’ being blocked by obstructions	Fast	In process areas to activate deluges over conveyors, shredders and other specific items of plant etc, or above storage bunkers
Heat sensing/thermal camera type systems	‘View’ may be blocked by obstructions and often require ‘programming’ to specific situations. May not be accepted by insurers	Medium to fast	Internal waste reception and storage areas, such as bunkers and pits
Heat sensitive wires	Prone to damage and unlikely suitable for general detection	Medium to fast	Conveyor and similar, but speed of reaction may be an issue

Video smoke and similar detectors	Fairly new to waste management	Medium to fast	Potentially waste halls
Gas (carbon monoxide etc) sensing systems	Specialised and require specific assessment	Medium to slow	Storage silos used for treated wastes, enclosed waste treatment systems and similar

2.4. Detecting 'inside-out' fires – an unresolved problem

Waste fires in loose piles/stacks of waste, such as loose wastes in a bunker or an external store of piled wastes, tend to come in two types (see appendix 5 for more detail):

- Outside-in fires – where the fire starts on the surface of a pile of waste
- Inside-out fires – where the fire starts inside the pile, such as from self-heating or a damaged lithium battery buried in a pile of waste

Outside-in fires are 'easy' to detect – there will be flame, heat and/or smoke at the surface of the pile which can be detected. Inside-out fires are less easy to detect. There may be substantive levels of heat inside the pile, but little or no heat, smoke etc at the surface to detect. During phase 3 of the WISH fire tests (see appendix 5 for detail) various detectors were tested on inside-out fires. None was fully effective at detecting inside-out fires until the fire/smoulder was close to the surface of the waste and/or had broken-through to the surface. During one test internal temperature inside the pile was in excess of 600 degrees centigrade, but at the surface temperature was ambient with no visible smoke.

Note – inside-out fires only really occur in loose piled/stacked wastes. Baled wastes very rarely suffer from inside-out fires because of their density.

Note – problems with detecting inside-out fires in loose piles/stacks of waste depend on the particle size of the wastes and air gaps. For example, with whole or pre-crush wood waste there will usually be air gaps between the particles of waste. Heat, and smoke, from an inside-out fire within the pile will likely travel to the surface via these air gaps and can be detected. However, if particle size is small, and/or the wastes are flexible, these air gaps tend to disappear 'trapping' heat and smoke within the pile where they cannot easily be detected.

There are options which can be considered, but currently none of these are perfect, fully practical or fully effective at detecting an inside-out fire before it reaches or breaches the surface.

Thermal probes

These have been in use at green waste composting and similar operations for many years. A probe is pushed in the pile to measure internal temperature. However, there are issues:

- The waste needs to be ‘soft’ enough to allow a probe to be inserted. For example, attempting to push a probe into a bale of waste is likely to only result in damage to the probe
- Size/configuration of pile is also a factor. Most green waste composting windrows are fairly narrow, and long. A one or two-metre long probe can usually reach towards the centre of a pile. However, with a 20 metre by 20 metre pile of RDF or similar an excessively long probe (circa 10 metres) would be required, which would likely not be practical and difficult, if not impossible, to insert fully into the pile
- Research indicates that ‘hot-spots’ inside a pile of waste tend to move-around, likely as available oxygen/fuel is exhausted. It may be a matter of chance whether a thermal probe just happens to be inserted at the right place

Thermal probes may be a good option with some waste types in some stack configurations, but with many waste types and stack configurations they are likely not to be 100% effective and/or practical.

Thermocouples

During the waste fire tests an array of thermocouples was placed in piles of waste to monitor internal temperatures. ‘Strings’ of thermocouples can also be used in a similar manner – spread through a pile of waste to monitor internal temperature. In a test environment these were both effective ways of detecting internal temperature in a pile of waste. For operational use there is the obvious problem that such systems are sacrificial – whenever the pile is moved or worked on the thermocouples are destroyed. In addition, the thermocouples need careful placement if they are not to be damaged, which during normal waste operations is unlikely to be practical. In brief, this is an expensive and likely impractical way of solving the problem and uneconomic for most waste operations. It may be that thermocouples can be used for long-term storage of wastes where the wastes are left undisturbed, but this would be a matter for cost-benefit analysis to determine if such a measure was proportionate.

In summary, there is currently no 100% effective and/or practical and/or economic method of detecting inside-out fires in a waste pile before the fire/smoulder approaches or breaches the surface. This is not to say that detection systems and/or thermographic cameras should not be used at piles of loose wastes, simply that waste operators should be aware of their limitations.

Detection systems are the most rapidly changing and developing area of fixed fire systems, and it may be in the future that an effective and cost-effective method of detecting inside-out fires in advance of them breaking-out will be developed. If such occurs, this guidance will be revised.

2.5. Maintenance, testing and cleaning

Whatever type of detectors you install, they also need to be accessible for maintenance, testing and cleaning. Mounting detectors in inaccessible places, or where routine maintenance requires the use of scaffold or an elevating work platform is likely to result in them not being maintained correctly. Think about access when deciding on detector location.

- Read the manual for the detector and ensure cleaning and maintenance occurs to the correct frequency, content and quality. Maintenance and cleaning requirements vary. For example, aspirating systems require the blow-out of their pipework to prevent build-up of dusts etc which may impair their effectiveness (dependent on the aspirating system this may be very specific and include the use of dried compressed air as a requirement)
- Maintenance and checking applies both to the detector, and its power supply, wiring to alarms etc – the whole system needs maintenance not just the detector itself
- Ensure detectors and their associated systems are tested and checked at the required intervals by a competent person, likely an external person

3. Fire alarm

3.1. Fire alarm introduction

The purpose of a fire alarm system is to inform all on site (and in some cases off site, such as a critical neighbour/receptor) that a fire may have started. This is to allow people to respond to a fire quickly, such as by evacuation or seeking to fight a fire.

Note – life safety is the first concern and response by employees to any alarm must be carefully considered with this in mind.

3.2. Alarm requirements

You should consider what you want to happen if a fire alarm is activated and based on this what are your requirements for the alarm system. In general:

- Fire alarms should be clearly audible across the whole of a site, including in offices, welfare facilities, weighbridges etc. This is likely to require multiple 'sounders'
- If your site/plant is a noisy environment, you may need visual back-up such as strobe lights or similar so that any person in a noisy area is aware that the alarm has been activated, including those in heavy mobile plant cabs which may be insulated from noise and persons who may be wearing hearing protection. This may include beacons on the outside of buildings

- If a fire starts out of working hours (and many do) and your site is not manned 24/7 who will hear the alarm? You may need to install an alarm system which is linked to a 24/7 responder, an automated call service, and/or your local Fire and Rescue Services direct
- If you are using detection systems which sense temperature rises prior to fire breakout you need to ensure that those involved have a clear understanding of how to react to this, and to actual fire break out, and when escape becomes a higher priority than continuing to try to control fire outbreak

3.3. Alarm and detection system plant interactions

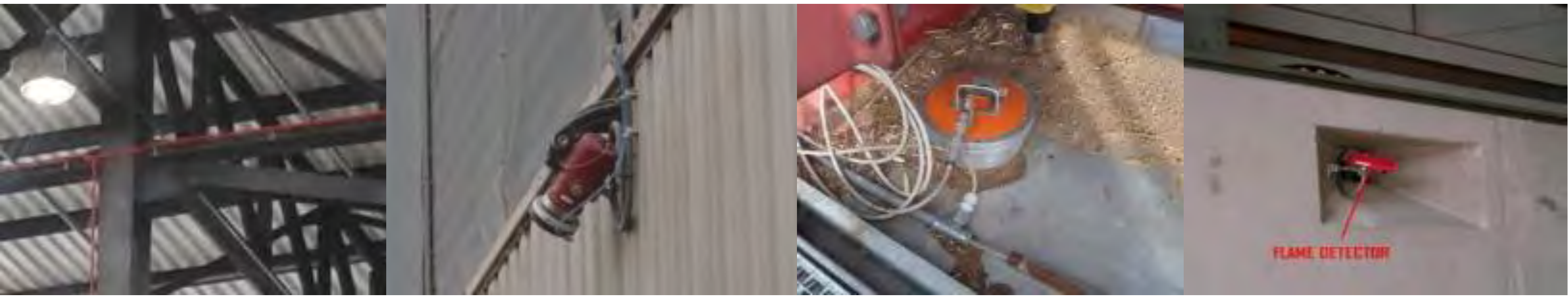
It is not unusual for fire detection and alarm to be on one system and for plant control to be on a different separate system (such as a SCADA system). If you want your detection and alarm system to produce actions in your plant, such as shut-down, then these systems must be compatible. If you expect your employees to hear the alarm and then manually activate emergency stops or similar you run the risk of them not doing this exactly as you want – in extreme situations when under stress people rarely do what they are expected to do 100% of the time.

3.4. Manual alarm points

In addition to alarms activated by detectors, the majority of sites will also have manual alarm points, such as break-glass points. These need locating in clearly visible locations and according to relevant standards. As for detector systems, they need routine testing and checking to remain effective.

3.5. Wireless alarm systems

The use of wireless alarm systems can be attractive because they do not require extensive (and costly) hard-wiring. However, wireless systems need to be acceptable to your insurer, and can suffer from interference. They may be an option, but you should check with your insurer before fitting.



Left to right: Aspirating detector (red pipework) at a waste recovery site, visual type detector in external use overlooking a waste storage bunker, specialised gas detector at a wood chip storage silo, flame detector set in a waste bunker wall

4. Fire suppression/extinguishing systems

4.1. Suppression/extinguishing system introduction

Fire suppression/extinguishing systems are aimed at either extinguishing fires or suppressing them until the Fire and Rescue Services can attend. You should be clear what type of system you want. Do you want the system to extinguish a fire, or only suppress it? For example, for a system installed over a conveyor, shredder or similar it is likely you will want the system to extinguish a fire (and quickly), whereas for a storage area you may consider suppression to be appropriate. This is a critical decision and should be a key part of your design process (see above).

Note – you should ensure that you know what type of system you have: Suppression or extinguishing. There have been some large fires where the operator has assumed that a system will extinguish a fire, when all it was designed to do was to suppress a fire to allow other actions, such as by the Fire and Rescue Services, to be taken, with the obvious disastrous outcome.

Systems may be manual or automatic and may be for manual use or fixed. Examples of fixed systems would include sprinkler, deluge and foam systems. Examples of manual use systems would include manual water monitors (cannons), fire hoses etc. The sections below attempt to explain the differences between these, how they are designed and specified and how they may be applied to waste management sites. However, this is a very brief overview of what is a highly technical area and should not be considered in any way as being comprehensive or definitive. However, first it is useful to consider how fire suppression/extinguishing systems are specified, and what guidance is available on fire systems relevant to waste management.

4.2. Combustion properties of wastes, occupancy and effect on systems

One of the under-pinning factors in the design of any fire suppression/extinguishing system is the combustion property of the material which may catch fire. For example, a sprinkler system designed to suppress a fire in a warehouse storing steel motor components will need to provide less water than one designed to suppress a fire in the same situation where baled paper is being stored. The more energetically a material may burn and the more of it there is the more water (or foam etc) is required.

How energetically a material may burn is only one factor in what is often called ‘combustible loading’ (sometimes also called combustible occupancy). In brief, what is there in a building or area which can burn, how much of it is there and how energetically it will burn = combustible loading. This may seem obvious, but the more of a combustible material there is, and how energetically it will burn, is fundamental to the design and specification of fire suppression/extinguishing systems.

This fundamental issue affects the design and specification of sprinkler, deluge and similar systems. It also affects water monitors, hoses and overall water supplies. A standard fire hose which flows perhaps 100 litres of water a minute is unlikely to have much effect on a 500 tonne pile of waste on fire, and a water main capable of only providing 200 litres a minute to a water monitor is likewise unlikely to be sufficient for a large waste fire.

The standards used by fire/risk engineers to assess combustible loading typically use the system of 'commodity class'. Some wastes fit neatly into this system. But, for mixed wastes and waste products commodity class is less easy to allocate because of their variable composition. The commodity class of a material is a critical input into fire systems design.

For example, if a waste contains less than 5% by weight or volume of specified types of plastic it is likely to fall into 'commodity class 3'. If it contains 5% - 15% by weight or 5% - 25% by volume it would likely be 'class 4' (the higher the class, the more energetically a material burns). If it contains more than the above of specified types of plastic it would likely fall into a specialised 'high hazard class'. The design, specification and water flows required will vary significantly between the above three cases. As an illustration of the potential effect commodity class can have, a sprinkler system designed for a class 4 material may have twice the water demand as the same system for a class 3 material.

Note – different types of fire suppression system use different types of water supply measurement. For sprinklers and deluges a water 'density' such as mm/minute or litres/m^2/minute is typically used, but for hoses, water monitors etc a simple flow rate such as litres/minute is typically used.

How much (the amount) of a combustible material is present is dealt with by area of cover of a system. For example, a deluge system over a conveyor may be specified at a water density of 20 mm/m^2/minute 'over the whole area of the item to be covered'. Using this example, if the conveyor is 1.5 metres wide and 10 metres long, a water demand of some 3,000 litres a minute would be required. If you have five conveyors each with its own deluge the total water demand if all of the deluges are activated will be significant. For sprinkler systems the 'area' used is different because usually not all sprinkler heads will activate (see below).

Combustible wastes are the obvious combustible occupancy in waste management plants. However, there are other items which can also burn, such as rubber conveyors, electrical wiring insulation, wall panel insulation etc. These are likely to be considered when a fire suppression system is being specified. For example, you will not help yourself by installing combustible wall panels – think about this type of issue during building construction and design.

In addition, dusts can be a significant issue and can affect combustible occupancy. For example, if a deluge system has been specified based on the type and amount of waste present it may be ineffective if you also allow dusts to build-up through poor housekeeping, because the overall combustible occupancy will be higher than the system was designed to cope with.

Avoiding ledges and other flat surfaces where dust can accumulate, by the installation of inclined or curved planes on such surfaces which dusts tend to ‘run-off’, can help to minimise dust build up.

Another issue which often affects waste management plants is that we change them… The original design for a plant may include that wood is stored in a specific storage bunker. Then after a few years this changes, and plastics start to be stored in the bunker. This would significantly affect the combustible loading (plastics being a much higher commodity class than wood). If a deluge, sprinkler etc system was specified over this bunker based on wood, it will very likely not be effective if asked to suppress/extinguish a plastics fire. Similarly, if you change the layout of storage bunkers/areas, their configuration etc, you may need to reassess your fire systems to ensure they remain effective. We know that we change our plants and sites – change is one of the only constant factors in waste management. Considering this it may be wiser when specifying fire systems to assume worst case, even if this costs more.

In addition to combustible occupancy and the amount (area) of material there is, other factors also apply in system design, such as building height for roof mounted sprinkler and deluge systems. These are included in the sections below on specific types of system.

4.3. Existing guidance on fire engineering for waste management

There are existing guidance and standards for the specification of fire systems, some of which are mention waste management (although the majority do not). Generally, these guidance/standards documents originate with insurers, although there are other sources:

- NFPA standards, ACE guidelines and FM data-sheets – technical insurance documents (beware these often need interpretation by competent risk engineers)
- EU EN and local standards – European and national standards
- National FPA (Fire Prevention Association) guidance produced by national fire organisations, and also from the CFPA-E (EU FPA association) and LPC (Loss Prevention Council)
- Industry guidance, such as this WISH guidance
- Regulator guidance, although this rarely includes technical fire engineering specific standards

Note – a list of commonly quoted standards, a summary of what each is and what they cover is given at the end of this appendix.

Some available technical fire/risk engineering guidance/standards tend to fall into two types (please note this is a generalisation and there are various standards such as EN and FPA standards which would not fit into the categories below):

- There are under-pinning technical design standards, such as NFPA13 on sprinklers, NFPA15 on deluges etc. These describe the process to design a fire system from scratch. They start with basic principles such as combustible occupancy and apply no matter the type of site or material considered. They also often include installation, construction and other standards
- The other type of guidance tends to be sector specific, such as NFPA850 guidance on power generation, WtE plants etc. These do not give the technical process required to design a system from scratch. Rather they give guidance and 'stock' suggested specifications for fire suppression systems. For example, NFPA850 is about power generation plants, but includes suggested specifications for fire systems for the storage of alternative fuels such as RDF

For the designer of a fire system it may seem easier to look at the sector specific guidance than to use the under-pinning technical design standard to design a system from scratch – the suggested specification is given to the designer 'on-a-plate' rather than having to go through the full technical design process. However, this approach may be flawed.

When writing sector specific guidance assumptions need to be made about the material involved, design of the building etc. Most sector guidance includes caveats that the suggested specifications given are just that, and that specific site situations need to be considered. These caveats may largely go ignored by some suppliers and designers.

For example, a suggested specification in sector guidance may assume that the waste being stored is mixed domestic wastes. But you may be storing plastics. Likewise, the sector guidance may assume a specific type of building design and height. But your building may be higher or of a different design. Beware designers who simply quote from an item of sector guidance.

- How old is the guidance? Knowledge of the combustion properties of wastes has developed significantly over the past few years, such as the recent WISH waste fire tests in the UK
- What assumptions have been made to arrive at the suggested specifications in any guidance? Are these assumptions compatible with your situation and plant?

The suggested specifications given in general guidance may not be correct for your wastes and your site/plant. If you simply use these suggested specifications and do not do the specific assessments and calculations for your specific situation then you risk your fire systems being under-specified (or over-specified in some situations). You may end-up with a system which costs you a significant amount of money, but which fails to perform as expected in the event of a fire.

4.4. Basic types of suppression/extinguishing system

Manual and non-manual fixed systems

Fixed non-manual systems are those which are fixed in one place and do not require a person actually at the system to use it, such as sprinklers and deluges or automatic oscillating water monitors.

Fixed manual systems are those which while fixed in one place require a person actually at the system to use it, such as a manual fire hose, or a manually aimed water monitor (cannon). Manual-use systems require a person holding/operating the suppression/fighting equipment at the location for it to work (note – as hand-held fire extinguishers are not fixed to a structure they are not fixed systems, and as such are not covered in this section – there is plenty of other guidance on extinguishers if you require information on these).

Manual use systems have their potential problems. If a fire hose is in an area which is actually on fire, then there is little chance that anyone will be able to use it. Likewise, during a fire significant amounts of smoke may be generated. If a manual-use water monitor is in the path of this smoke a person will not be able to access the monitor to use it. There are some ways of potentially reducing this issue. For example, a simple half-wall may provide sufficient protection to allow a person to stand behind it and use a water monitor fixed to the wall (please note such arrangements **MUST** be immediately next to fire escape to the outside to allow a person fighting a fire to escape easily and must not be used at any risk to human life).

Conversely, manual systems are typically flexible and can be useful to tackle smoulders and small fires before they can grow and spread. For example, a loading shovel operative at the reception area of a recycling plant notices a small amount of smoke coming from a recently tipped load. They get out of their cab, un-roll a fire hose and drench the area so extinguishing the fire. Information from waste management company fire investigation reports indicates that this is just how many smoulders and small fires are dealt with, effectively and with little risk to human health.

However, relying completely on manual systems risks not being able to access these systems in the event of a larger fire, for reasons such as smoke and heat. Non-manual fixed systems may be more appropriate and effective in the event of a larger fire.

Care must also be taken with the water supply to some manual systems. For example, deluges and sprinklers etc operate at fairly high pressures (typically 6 - 10 bar). This is not suitable for a fire hose - the operator would be 'thrown all over the place' by the pressure. If fire hoses are supplied from a pumped water supply which is also used for deluges and sprinklers, then pressure reduction valves are likely to be required.

Note – if you expect your employees to use manual-use fire systems such as hoses then they **MUST** be thoroughly trained, and they **MUST NOT** use systems if there is any risk to their safety.

Note – this appendix does not cover hand-held fire extinguishers – there is plenty of guidance easily available on types and use of fire extinguishers. You should include hand-held extinguishers in your fire plan, but except for the smallest of fires you should not rely on them.

Manual activation and automatic systems

Fixed systems also fall into two general types: Manual activation and automatic activation systems.

Manual activation systems require a person to activate them. For example, a deluge system not linked to a detector which requires manual activation, such as by pressing a button in a control room. **Automatic systems** do not require any manual intervention, such as sprinkler systems or a deluge activated by a fire detector. In some cases, systems can be both manually activated and automatic. For example, a deluge system which activates automatically from a detector, but which can also be manually activated by pressing a button should the detector fail to activate the system.

Manual activation only systems are generally less reliable because human beings make mistakes and may panic in the event of a fire and so not activate the system. Conversely, a detector may have failed or have not detected a fire before it is seen by a person, and in such cases manual activation is useful. For some systems, such as deluges, both automatic and manual activation is the likely best option. If you have manually activated systems (or automatic systems which can also be manually activated):

- At least two manual activation points should be provided for each suppression system. For example, for a deluge system a button in the control room and a second button on a panel external to the building in a safe location. If a control room is full of smoke no one is likely to enter it to activate the system and an external activation point may be the only safe option
- Manual activation systems should be simple and obvious, such as a large, well signed red button in a convenient and obvious location. If an operative needs to access a computer programme, or press several buttons, or go to another room to activate a system the risk of failure will increase

Automatic systems are those which activate automatically when a fire is detected by a detector, or in the case of sprinkler systems when a ‘glass’ bulb bursts. For sprinkler systems experience is over many years that activation is reliable. Heat reaches the sprinkler bulb, which bursts releasing water. However, for other systems such as deluges and automatic water monitors activation is via detector/s. These detectors must be reliable and located such that they can detect a fire quickly enough for the deluge, monitor or other system to activate reliably and effectively (see above on detector selection). The advantages of automatic activation systems are:

- They are more reliable than manually activated systems – this has been proven many times
- They work when no one is there to manually activate a system, such as out-of-hours, or if manual activation is via a button in a control room and no one is in the control room

Training, instruction and awareness are critical, and the more complex a system the more critical they become. Your operatives should understand your fire system and be trained in its use. For example, a complex plant may have ten separate deluge systems installed in conveyors, shredders etc. If a fire occurs, one or more of these may need to be activated manually. For example, a fire starts in one shredder, and the automatic detection system fails to activate the deluge over this shredder. If an operative is confronted by a control panel with ten buttons (one for each deluge in the plant), which they have not been trained in and are not clearly labelled as to which button activates which deluge the outcome is predictable. The operative will push every button they can, ‘letting-fly’ with all deluges. This may have operational consequences and reduce water supply to the deluge over the shredder (that is the one really required) to the extent that it is ineffective.

4.5. Specific automatic fire systems

There are many types of fire system. Typically, the most common ones in use at waste management sites are sprinkler systems, deluge systems and water monitors. Some sites also have foam systems and other specific systems. The sections below give an overview of these commonly used systems, and for sprinkler systems outlines some of the issues waste management sites may have with them.

Sprinkler systems

Sprinkler systems are networks of water pipes with ‘spray heads’ on them. The spray heads are equipped with heat-sensitive ‘glass’ bulbs. These bulbs burst when exposed to heat so releasing water. Sprinklers can be wet systems (where water is always in the pipework system), dry systems (where water is not in the pipework and only flows into it when a bulb/s burst) or pre-action systems (where water is not normally in the system, but is allowed to flow into the system via a valve if a fire detector detects a fire - that is the pipework system ‘pre-charges’ with water ready for potential use if a bulb/s bursts).

Activation of wet systems is obvious – when the bulb/s burst the water in the pipework comes out of the spray head/s. With dry systems if a bulb/s burst this causes an air pressure drop in the pipework system, which activates a valve allowing water into the system which fills the system and comes out of the spray head/s where bulbs have burst. For pre-action systems (assuming the detector has worked and allowed water into the system) activation is as for wet systems.

The difference between these types of system is speed of reaction to a fire. Wet systems are quickest as there is no time delay while water fills the system. With dry systems there may be a delay while water fills the system.

Wet systems generally require more maintenance and will need to be equipped with drain down points. Wet systems need to be trace heated/insulated if they are installed in external and unheated open areas, such as large open waste halls, where they may be a risk of freezing. Some systems are operated wet during the summer months, and dry during the winter months (sometimes called a semi-dry or alternate system). You should know what type of system your plant has, in which areas and have an awareness of the implications.

The specification of sprinkler systems is usually given as a water density as mm of water per minute (sometimes over an area such as per metre^2). The higher the density the more water delivered over any given area. The area given varies because of factors such as the differences in speed of reaction between dry and wet systems, and combustible occupancy. The speed of reaction is important: For dry systems it is assumed that a fire may have grown during the delay while water enters the dry system, so the area cover specification is higher than for wet systems.

In general, wet systems are preferred because of their faster reaction. But, in many waste plants wet systems may not be practical and dry and/or pre-action systems are more common.

Normally during a fire not all sprinkler bulbs will burst, only those exposed to sufficient heat (despite what is often shown in films). The specifications of sprinkler systems are based on this premise - that is the water flow calculations involved assume only some bulbs burst. However, in some cases the area specification is 'across whole area'. This is generally for smaller areas such as hydraulic power pack rooms where specific area specifications would not make sense.

Sprinkler systems must be ‘balanced’ to ensure that adequate water volume and pressure reaches all parts of the system. This is achieved during design by the use of ‘hydraulic calculations’. These hydraulic calculations must take account of other systems which may activate at the same time to ensure adequate water flow and pressure to all systems, and must assume worst case situations such as flows at the least favoured sprinkler head rather than most favoured (such as sprinkler head furthest away from the water supply rather than closest).

Sprinklers have been proven over many years to be reliable. However, they do have some limitations. In particular for waste management sites: If there is a large vertical distance between waste storage/treatment and sprinkler heads then heat from a fire will take time to reach the sprinkler head and activation may be delayed, or not occur at all. This is an issue in high waste halls (see below).

This is not to say that sprinklers in this type of situation are not effective in terms of building protection - if sufficient heat to cause building damage reaches a roof then the sprinklers will certainly activate and are likely to help protect the building structure. However, in high waste halls sprinklers are unlikely to be effective in dowsing an open flame fire in the waste itself and may need supplementing by other systems, such as deluges and/or automatic water monitors.

Roof height and sprinkler systems: Sprinkler systems activate using frangible bulbs at the spray heads. When exposed to heat these bulbs burst causing the sprinkler to activate. Fundamental to sprinkler systems is that heat must reach the sprinkler head for the system to activate, and that only those heads where the bulbs burst will flow water.

Deluge systems are different (see below). They may look like sprinkler systems, but the spray heads are open and do not have bulbs. Deluge systems are activated by a separate detector, such as IR, triple IR etc. The detector sees a fire and activates the valves and pumps etc associated with the system. The same principle applies to other suppression systems such as automatic oscillating water monitors, which are activated by a separate detection system.

Because sprinkler system bulbs need to be exposed to heat for the sprinkler spray head/s to activate, the height of the building is a critical factor. The further away vertically from a fire a sprinkler head is the more time it will take for heat to reach the sprinkler head, and the longer the time delay before the sprinkler head will deploy. The longer the time delay before the sprinkler head deploys, the larger the fire will be before it deploys. The larger the fire, the more water will be required to suppress the fire. In brief, the greater the vertical distance between potential fire and sprinkler system, the greater the water density and flow required. There are other factors such as evaporation of water droplets, but time delay is the main issue.

Experience from fire/risk engineers is that vertical distances of more than around 6 or 7 metres between a fire and sprinkler head/s can result in unacceptable delays in sprinkler activation, or no activation at all (note – the 6 or 7 metres quoted above is not intended as strict guidance and will depend on specific situation and system).

Case study. A fire at a UK waste transfer station in 2015 illustrates this: The vertical height between the fire and sprinkler system was around 7 to 8 metres. Despite there being a substantial fire in the transfer hall for at least five hours only one sprinkler head deployed (the one directly above the fire). The water flow provided by this one sprinkler head likely had little effect. The fire was extinguished by the local Fire and Rescue Services, with no injury and minimal property damage.

In addition to the risk of delays in sprinkler activation, high waste halls can also pose water supply issues - the higher the hall the greater the water flow/density required, because of the likely delay in activation. For very high waste buildings this may result in unacceptable (or at least very costly) water demand requirements.

The above does not mean sprinklers are not suitable for waste management. Sprinklers have been proven over time to be effective. However, their use in high halls may need careful consideration.

Gantry level sprinklers and ‘shaded areas: Another problem for roof mounted sprinkler systems is that many recycling/recovery halls contain a lot of obstructions such as plant and equipment (conveyors, screens, gantries etc). These will block (shadow) water from a roof sprinkler system.

For example, if a fire starts under a conveyor water from a roof sprinkler may not reach it - the water hits the conveyor and runs-off rather than hitting the fire. In these situations, gantry/low-level sprinkler systems should be considered to supplement roof systems. These are sprinklers located under or alongside conveyors etc. Gantry/low level sprinklers have two advantages:

- They overcome the shadow effect
- They are likely to be far closer to a fire and will activate more quickly

In general (codes/standards vary), where any gantry, conveyor, screen, conveyor etc is >1 - 1.2 metres wide gantry/low level sprinklers should be fitted. Careful placement of gantry/low level sprinkler systems is required to avoid pipework and sprinkler heads being damaged by plant movements, including mobile plant, and maintenance requirements should also be a factor to consider. This shadowing issue can also apply to roof mounted deluge systems.

Deluge systems

Deluge systems are similar to sprinkler systems, but they have ‘open’ spray heads rather than bulbs. Deluge systems activate when a fire detector detects a fire (the detector activates a valve which releases water into the deluge system). Unlike sprinkler systems, where water will only come out of the spray heads where the bulb has burst, for deluge systems water will come out of all of the spray heads in the system.

Deluge systems can cover entire areas (such as a waste storage area) or specific items (such as a conveyor, a trommel screen or a shredder feed hopper). They can be roof mounted, or mounted at a lower level, such as wall-mounted above a waste storage bunker or above conveyors. Where a deluge covers an entire area, the detector cannot usually spot exactly where a fire is (most detectors simply detect a fire in an area rather than where exactly in that area the fire is). As a result, for deluges covering an entire area their specification is given as a water requirement across the whole area.

Where deluges are in conveyors, screens etc the same specification of across the whole area is given, but in these cases, it is the area of the specific item being protected (such as the area of the conveyor, shredder feed hopper, screen etc). This is because the detector/s are in/over the specific items and can detect much more specifically where the fire is. Note - detectors must be specific to items for this to be the case. It is no good having one in-item detector covering five conveyors. Most of this type of deluge system has 'legs' (also called zones), such as five legs covering five conveyors (one leg for each conveyor). In these cases, water calculations should take account of the worst-case scenario. For example, for a seven-leg system the worst case may be only that four legs would need to activate.

Deluges covering whole areas can have very high-water supply needs, because the detector does not know where the fire is and the whole system is activated. For this reason, deluges covering an area are often also split into legs/zones covering different zones in the area. Each zone has its own detector which only activates the deluge leg feeding the deluge over the specific zone. This reduces water supply requirements but requires multiple and/or complex detector systems.

The specification of deluge spray heads and number of heads should be such so that the whole area is covered. This will depend on factors such as distance from deluge head to item being protected etc. Of course, deluge systems are reliant on their detector/s, and in most cases a manual activation facility should also be provided (see above on manual activation).

Oscillating and non-oscillating water monitors

Automatic oscillating water monitors function like large garden sprinklers. They are normally activated by fire detectors (in the same way as automatically activated deluges), although manual activation can also be provided. The detector detects a fire and releases water into the oscillating monitor pipework system and so to the monitor spray head/nozzle. The hydraulic pressure of the water in the system also causes the monitor to oscillate from side-to-side so spraying the water over the area covered. In the case of a manually activated system a person activates the monitor by pressing a button or similar.

Non-oscillating water monitors operate in the same way, but do not move from side to side and rather provide a directed spray at a smaller area or specific point.

Where oscillating monitors are used, they must cover the entire area being protected with no 'blind spots'. If blind spots do exist, they should be covered by supplementary means, such as a deluge spray head under a monitor to fill a blind spot directly under the monitor where water from the monitor cannot reach.

The assumption when designing oscillating water monitor systems should be that one monitor may fail. For example, if two monitors are installed then the whole area must be capable of being covered by the remaining one monitor on its own. If four monitors are installed, then the whole area must be capable of being covered by any three monitors etc.

Water flow requirements for monitors are different than for deluges and sprinklers and are usually expressed simply as a total water flow through each monitor, or overall flow through all monitors in an area. This water flow is dependent on combustible occupancy, in the same way as water density is determined for sprinkler and deluge systems. As for deluges and sprinklers water volume and pressure/hydraulic calculations for monitors must take account of multiple suppression systems potentially being in use in any one area at any one time to ensure adequate water flow and pressure in all systems. And, that all monitors will receive adequate water flow.

Placement of oscillating water monitors should be considered in terms of maintenance requirements, potential damage from plant and equipment movements and to avoid any blocks (such as bunker walls or plant/equipment which may block the water spray from a monitor). As most oscillating monitors move from side to side design drawings often show the 'arc' of movement and water ‘throw’ - this should reach all parts of the area to be covered. Nozzle type used should also be considered - too tight a nozzle may produce a water stream which could 'blast' wastes around so promoting fire spread - wide area cover nozzles may be better for many waste management applications.

Foam systems

Foam fire suppression systems are not common in waste management plants but seem to be becoming more popular for reasons such as that they typically require lower water demand than equivalent water deluge, sprinkler or monitor systems. Typically, foam systems include a foam storage tank/vessel for the foam suppressant concentrate. A fire detector activates the system by pumping water into the system, which mixes with the foam concentrate, producing the foam which is sprayed onto a fire through spray heads/nozzles or similar.

Foam suppressants come in different densities and types, and foam ‘mix’ and delivery systems come in different types – this is a complex area and it is essential that the correct foam type and mix/delivery system is used for the specific application at your site.

Foam systems depend on smothering a fire, so excluding oxygen, to work effectively. For piles/stacks of wastes the foam must cover the entire surface of the waste including any irregularities and dips, or the foam must 'cling' to sides of any pile to effectively exclude oxygen. This can be difficult to arrange in waste management applications. Foam systems were originally designed for liquid fires, and as a matter of physics liquids are always flat – this is not the case for most wastes.

In addition, another potential issue with foam is that large open-flame waste fires tend to generate lots of heat and thermal air turbulence, which may blow foam away and/or evaporate it.

Foam systems can also be used in enclosed conveyor systems, or with other similar enclosed recycling and recovery equipment. The foam 'floods' the enclosure to exclude oxygen. As for other uses, the density and type of foam and delivery system type used should be tailored to the application.

Foam suppression systems have been used in many industries to good effect and have been used in some waste management applications effectively. Set against this, they are typically more complex than simpler water fire systems and require detail design and tailoring to specific applications. The benefit is that they use less water, which on large systems may be a significant factor.

If you are considering a foam system you should consult with your environmental regulator as run-off from a fire may contain contaminants which require specific attention in terms of pollution.

Tip – some insurers have very specific requirements for foam systems, and some may not accept foam systems at all. You should liaise with your insurer to ensure that any foam system you are considering will be acceptable to them.

Water mist, gas, and aerosol etc suppression systems

The above are the most common types of suppression system found at waste management plants. However, there are other systems such as gas, water mist and aerosol systems. Typically, these may be installed where there is a perceived risk of damage to equipment being caused by the use of high-flow water fire systems such as sprinklers. For example, MCC (motor control) or electrical equipment rooms, or at hydraulic power-pack enclosures. Water mist, gas and aerosol systems, and other similar, require very careful and specific design – they are limited, and specialist applications and you would be well advised to consult with your insurer before considering such systems. They must be completely tailored to their application and environment. In addition, they are typically more complex and have higher maintenance and check/test requirements. They can be a valid alternative to high-flow water systems, but if you decide you need gas, water mist etc systems then you need to accept this likely higher design cost and complexity and higher maintenance resource. And, ensure that required maintenance is actually carried-out, or you risk the system becoming ineffective.

Tip – many insurers are not that keen on gas, water mist, aerosol etc systems, or they require some specific design criteria to be met. If you decide you want gas, water mist, aerosol etc then you should liaise with your insurer to ensure you do not end-up with a system your insurer will not accept.

4.6. Sprinkler, deluge, monitor, foam etc system design

Sprinkler, deluge, water monitor, foam etc suppression system designs are not generic. For example, the design of a sprinkler system can change based on factors such as the commodity class of the waste, the storage height of the waste and distance to the sprinkler heads, the storage configuration of the waste (where and how stored), the building height/clearance (distance between waste and ceiling). In addition, the area of operation of a sprinkler system can change based on factors such as whether the system is a wet, dry or pre-action system, roof slope etc. These factors are very likely to be different from site to site. This is a case of one-size-definitely-does-not-fit-all. Fire systems are not standard, and you should ensure that whatever system/s you decide to install are designed and specified for the wastes you store or process, the building they are in and the specific requirements and environment of your site/plant. And, if you change the types of waste you store or process, their storage locations, the layout of storage etc you will need to reassess your fire systems.

4.7. Summary table automatic fire systems, issues and example applications

The table below gives automatic system types, comments on their use in waste management, and example potential applications. It is not intended to be comprehensive, and all system applications require specific assessment. The below is simply a guide and is not intended as a set of strict rules.

Automatic system	Comments/issues	Example waste management applications
Roof level sprinklers	Robust and reliable, but if vertical distance between wastes and sprinklers is circa >6-7 metres may suffer delayed or no activation in high waste halls	Lower waste buildings where vertical distance wastes to sprinklers is less of an issue, above plant/equipment systems (where distance to sprinkler head is not an issue) and as building protection
Gantry level sprinklers	Removes problem of shaded areas under plant (conveyors, gantries etc) which water from roof level systems may not reach. May be prone to physical damage and may need protection	Under conveyors, access gantries, screens and similar which may block water from roof level systems

Roof level deluges	As for roof mounted sprinklers but activated by detector. Delayed or no activation less of an issue. But water demand can be high (sometimes very high) leading to multiple deluges zones to reduce water demand and complex multiple detector systems to activate individual zones	General use waste halls, above wastes stored internally, waste bunkers etc
Lower-level deluges	Water demand may be less than for roof deluges, and may be easier to target specific areas, but multiple/complex detector issues may remain	At waste storage areas and bunkers, under conveyors and similar
Dedicated deluges	Deliver water direct to where it is needed, but can be difficult to arrange in some plant, and higher water demand may result in complex, multi-leg systems. Typically require fast detector systems to be effective	Above shredder input chutes, in conveyor systems, in/above trommel and other screens
Oscillating or fixed water monitors	May have lower water supply needs than equivalent deluge systems but must be capable of covering whole of area within their operating arc. Obstructions (plant, gantries etc) may block water stream from monitors, and nozzle type may need careful selection to avoid burning wastes being ‘blasted’ about promoting fire spread	Larger waste reception, treatment or storage halls/areas where roof sprinklers may not be effective and where obstructions from plant and walls is not an issue. Note – some oscillating water monitor systems are in use in outside applications and may be an option for external storage of wastes
Foam systems	Lower water supply needs than equivalent water sprinkler, deluge etc systems, but foam itself and systems may be costly. May not be effective if all of the waste cannot be ‘enclosed’ in foam, and may be affected by thermals from large fires (‘blown away’ or evaporated)	In-conveyor systems or other enclosed items of plant, applications where wastes are fairly ‘flat’ so that foam can enclose whole of surface
Water mist, gas, aerosol etc systems	Specialised, may be expensive and have expensive maintenance and check requirements. No standards in place and insurer acceptance critical. But, can pose less of a risk of damage to electrical etc systems when activated	MCC and electrical rooms, subject to insurer acceptance

Summary: There are multiple options when choosing fire suppression/extinguishing systems. The critical factor in choice must be effectiveness. But, other factors such as water demand and cost may also be valid. Beware any consultant or supplier who ‘jumps’ quickly to a single option without careful consideration of use, environment and other specific aspects of your site/plant.

5. Water demand, supply and water mains

5.1. Water demand, supply and water mains introduction

The principle aims of any water supply to a fire system are that the supply is reliable and adequate. Most fire suppression and fighting systems consume large volumes of water. Sufficient water supplies must be available on-site to fight a worst-case scenario fire. Dependent on various factors, insurance standards require on-site water supplies to last typically for 90 to 120 minutes (examples only and may be higher, or lower).

Some people ask why water supplies need to last for so long, stating that water supply would only be required until the fire brigade arrives. The average fire brigade tender only carries some 1,800 - 6,000 litres of water, depending on type of tender - enough to supply a reasonable size sprinkler system for perhaps a minute or two... Unless you have a water main, tank or alternative supply which can be fed into the Fire and Rescue Services vehicles and pumps they will be of limited use. In addition, and understandably, the Fire and Rescue Services may not want to enter a smoke-filled and hazardous building to fight a fire if life is not at risk.

In general water supplies can come from three sources:

- Water tank/s on site with pumps feeding a water main
- A non-tank fed fire/water main on site, such as from a commercial supply main
- Alternative water supplies such as a near-by river, canal, lake, lagoon etc (in some rare cases wells can be used, but their capacity and recharge characteristics must be adequate)

Left to right: Large foam system under test at a waste recovery plant, sprinklers in action at a recycling plant, manual-use water monitor at a waste site, under-gantry sprinkler head and pipework at a recycling plant

Water supplies can be either pumped (typically from on-site water tanks or from alternative water supplies) or un-pumped (typically from site fire/water mains).

When calculating total water supply requirements for your fire systems the realistic worst-case must be assumed. Generally, this is all fire suppression/fighting systems in the highest water flow requirement area/compartment of the site being active at any one time. The exception would be for in-conveyor and similar deluge systems where a worst-case scenario may not include all of the legs/zones of the deluge. Plus, allowance should be made for manual hoses/monitors etc.

For example, the highest water flow requirement area of a site may have in place a sprinkler system, a seven-leg in-conveyor/screen deluge system and manual fire hoses/monitors and hydrants. Total water demand would be the flow requirement for the sprinkler system plus flow requirement for the worst-case number of legs in the deluge system (for example, four legs out of the seven) plus an allowance for the manual hoses.

For example, total flow requirement for the above sprinkler, deluge and hose system, might be as high as 10,000 litres of water a minute. If the supply needs to last for 120 minutes, this means that on-site water tanks (or other sources) would need a volume of some 1,200,000 litres. This is 1,200 m^3 of water, or 1,200 tonnes. Often the most expensive parts of any fire suppression system are the tank, pumps and water main required. In brief, fire suppression systems can consume very large volumes of water very quickly.

You should consult with your environmental regulator on this aspect. Using the above example, where will the 10,000 litres of water flow to if the fire system is activated? Containment of contaminated fire water is an issue you should consider carefully and in consultation with your environmental regulator.

5.2. Alternative water supplies

If alternative water supplies, such as from a nearby river, are to be used to supplement tanked or mains supplies, then these need to be capable of being accessed promptly. There is little point in assuming that a near-by lagoon/lake/canal can be used as part of water flow requirements if it would take three hours to arrange pipes and pumps to this lagoon/lake/canal (in these cases fixed pipes and on-site pump capacity may be required). Alternative water supplies also need to be reliable: Relying on a lagoon which is only half full or empty for part of the year may result in water shortage issues. In addition, the alternative water supply may contain grit, gravel, sediments etc and filter systems may be required to reduce the risk of blockages in pipework and hoses and damage to pumps.

Overall, alternative water supply requirements need careful thought - it is far better to do this in advance rather than wait for a fire and then run-out of water after a short period of time or be unable to access water quickly and effectively.

One source of alternative water supply is the recirculate water. For example, water from a deluge system may flow into a sump on site from which it can be pumped back into the deluge system, or water run-off from hoses may flow into a lagoon where it can be recirculated from. This sounds attractive as a way of reducing water storage requirements, but can have issues:

- Grit, gravel, sediment etc can be an issue, as for lagoons, rivers etc
- Recirculating fire water may concentrate hazardous substances and/or biological agents – the water will have passed through burning wastes, and the more times water passes through this cycle the more these may concentrate. This may pose health issues to those fighting the fire
- The eventual run-off water may be more concentrated in its contamination than water only used once, which may pose environmental damage issues
- How will you capture the water? For sites with sumps this may be easier, but otherwise there will need to be a method to channel ‘used’ fire water to where it can be accessed

If you are considering recirculating fire water, you should consult with your Fire and Rescue Services and environmental regulator. There may be compromises you can arrive at. For example, using recirculated water in fixed systems such as deluges but not manual systems such as hoses (that is not in systems where a person may be at the ‘point of delivery’ and so may be exposed to harm).

While there may be some small-scale exceptions, it is very unlikely that an un-pumped water supply, such as a commercial main, will be able to provide anything like sufficient volume or pressure to feed even a moderately sized fixed fire system.

5.3. Water mains and supply to fire systems

Large waste management plants will typically have a water ‘fire main’ to supply their fire systems, fed from a water tank or other reliable supply. This main may be a ring-main around the whole site, or a single main with branches. In most applications for large sites a ring-main may be better as water can be fed from both ends of the ring, so if a leak or block occurs water supply can be maintained.

For example, at a smaller site equipped with a sprinkler system and manual-use water monitors a single underground main from a water tank may be installed, feeding a manifold at the waste hall. Pipes from this manifold feed the sprinkler system and each monitor. In this type of arrangement, you may want to consider having two mains legs from the tank to feed the manifold from both ends. In the event of a leak in one leg, this leg can be valved-off to maintain water supply.

For larger sites with multiple fixed systems an underground ring-main is more likely. From this ring-main, 'lead-ins' come-off the main to manifolds in the waste hall/s etc. Pipes from these manifolds feed specific fire systems. Between each lead-in off the ring-main an isolation valve (sectional valve) must be fitted. This is in case of a leak or other failure in the main or a lead-in - the affected section can be valved-off and water fed from the other end of the ring-main. Whatever system is used, valves and other parts of the system must be to fire engineering standards - normal water valves and other components are not good or reliable enough.

Water supplies can be pumped or un-pumped. Un-pumped supplies are unlikely to be able to supply the pressures required for sprinkler and deluge systems (6 – 10 bar often being required). Un-pumped supplies may be sufficient to feed hydrants and fire hoses, provided the flow is adequate. For sprinkler, deluge etc systems pumped supplies are very likely to be required.

Pumps must be able to supply adequate water volume and pressure for the systems they feed. In most cases two pumps are better than one, in case of failure. The more volume of water a pump provides the lower the pressure becomes. Fire pumps should have 'performance curves' provided by their suppliers showing the relationship between volume provided and pressure - maximum supply requirement must be within this performance curve.

Typically, water mains and lead-ins will be underground, with the lead-ins coming to surface to feed manifolds and systems. For above-ground pipes consideration must be given to freezing, and pipes either lagged or fitted with trace heating up to the point at which they become 'dry', if dry systems are installed (no water in the pipe in normal circumstances). Beyond control valves between wet and dry sections pipes typically do not need to be protected. However, drain-down points must be provided so that following tests of systems (or use) water can be drained out of dry sections to prevent freezing and pipe failure.

At a maximum one lead-in from a main should normally only supply up to five applications. One sprinkler system would be one application, one deluge is one application, one hose or hydrant is one application, one water monitor is one application (for multiple water monitors where one monitor is duty and one stand-by these may sometimes be considered in some situations as one application).

However, this is a maximum and good risk engineering should be used - having just one lead-in to a large sprinkler system may leave it open to failure. The number of lead-ins and number of applications on each requires risk assessment to prevent large sections of fire suppression equipment being impaired in the case of a leak or similar failure in the main and/or a lead-in.

Ideally, each application should have its own lead-in, but this is often not practical. One potential solution is to run above-ground pipes between manifolds where lead-ins split to feed systems. In this way a manifold can be supplied from both ends in the case of a leak or other failure.

All pipework, (and all fire system components) including feed pipes to sprinklers, deluges etc, must be to the appropriate standard, including their construction, materials used, joints etc. For example, the standards in NFPA for water pipes to supply fire systems. As above for sprinklers and deluges, all pipework must be hydraulically balanced to ensure adequate water flows. Valves and other pipework items must be to fire engineering standards - general water supply valves etc are not reliable enough for fire systems as a failure in just one valve can have severe consequences should a fire occur.

5.4. Supply to hoses and other manual systems

Manual systems, such as hoses, can be fed either from pumped water supplies, or non-pumped supplies such as a water main running around a site with hydrants located on it. The pressures in these different systems will be different. It is not possible to predict what water flow will be required for manual systems. This will depend on many factors, such as how many hoses are used both by site staff and/or by the Fire and Rescue Services if they attend a fire. As a result, water demand requirements for such systems are normally simply given as an 'allowance'. This allowance depends on factors such as combustible occupancy and requires calculation by a competent person.

Note - where hoses and manual-use monitors are both provided the calculated allowance should be provided for each system: For example, if the allowance is 2,800 litres/minute then this should be 2,800 for hose use and an additional 2,800 for manual monitor use.

Where required, on-site hydrants should be easy to access, clearly signed and typically spaced around buildings at no more than 75 metre intervals (dependent on site-specific assessment). And, any hoses kept on site should be long enough to reach all parts of the site from the nearest hydrant.

Left to right: Fire water tanks and pump house at a recycling plant, inside a pump house, foam storage tank and systems at a large waste recovery plant

6. Other factors

6.1. Plant control actions

Detectors activate alarms and/or suppression systems. They can also instruct plant control systems, such as emergency-stopping conveyors to prevent fire spread. The specific plant actions required when detectors activate in the event of a fire is a matter for careful assessment. For complex waste management plants, it is critical that it is clearly understood what actions (fire system actions and plant actions) are produced by specific activations of detection systems. For example, for a fire detection in one area of a plant you may want conveyors in that area to stop, but for other parts of the plant to continue operating to clear wastes from adjoining areas to reduce the risk of fire spread.

For large and complex plants, a consequences matrix is one way of recording these actions. Typically, consequences matrices start by listing the detection systems in each compartment/area of the site/plant. Next to these is noted what alarm the activation of a detector produces, then what fire systems are activated and then what plant control actions occur when a detector is activated. This can provide a clear and concise view of what does what and what activation produces what actions.

Consequences matrices can also be:

- Used during plant and fire system design to ‘think-through’ detector activations and what suppression/extinguishing system and plant actions are required, and in what order
- Extended to include what actions are expected of employees for specific scenarios and detector and alarm activations, which can then be used as a training aid
- Used as a checklist to test actions for existing plants – for example, it may be expected that a detector activation in one area produces specific alarm, fire system and plant actions, but does it really? There are examples of waste management plants conducting checks using a consequences matrix only to discover that their suppression/extinguishing systems and plant actions do not occur as they expected

6.2. Life safety

In developing and designing a fire system you will need to ensure that an assessment and allowance is made for any situation where you have employees in an area where fire systems may activate, or who may be affected by the actions of automated fire systems. You will need to ensure that the automated responses aimed at containing and dealing with fire, smoke, and fire water run-off cannot inadvertently trap or delay the escape of personnel.

6.3. Electrical systems and fire systems

In developing and designing a fire suppression system you will need to ensure that consideration is given to the potential for water from fire suppression systems or fire water run off to interact with the plant electrical systems. Although the automated fire activation systems may isolate the electrical supplies to the area, where fire has been detected machinery can retain significant quantities of stored energy, especially where an emergency shutdown process has been executed.

Junction boxes and electrical panels within the arc of water monitors (especially cannons) need to be rated to resist the water they may be exposed to. Electrical systems should be at high level, or where unavoidably floor mounted, raised up on plinths to a level where they will remain clear of any fire water run-off. Critical systems may need further protection, both from fire and the actions of fire systems.

6.4. Commissioning, testing and maintenance

Fire detection, alarm and suppression/extinguishing systems are complex equipment, and in common with all complex equipment they need to be commissioned, tested and maintained.

- All newly installed fire detection, alarm and suppression/extinguishing systems must be commissioned to ensure that they function as expected and required. Commissioning testing will also allow the supplier/installer to issue a certificate for the system, which your insurer may want a copy of. Your insurer may also have specific requirements for commissioning and may want to witness commissioning tests – you should liaise with your insurer on this. For a simple detection and alarm system commissioning may be straightforward (a function test). For more complicated systems commissioning may be lengthy and complex

- All fire detection, alarm and suppression systems need regular maintenance, testing and checking. Detail of the timing and content of specific maintenance, checks and tests required should be provided by the supplier/installer. However, your insurer may also have specific requirements (see below on insurer requirements) which you should also include in your maintenance, testing and checking regimes. Maintenance, testing and checking should be recorded, and these records kept, as for any item of equipment. Systems should also be subject to defect reporting and repair regimes. In serious cases a defect in a fire detection, alarm or suppression/extinguishing system may mean that operations, or part of an operation, may need to stop until a repair can be made (and you should certainly inform your insurer of any such defects and consider additional temporary controls such as manual fire watches). You may wish to identify any such potential critical impairments in advance and plan for them

Tip – for large complex sprinkler, deluge etc systems commissioning may involve live-testing of the system. This may be difficult to arrange or may pose a risk of damage, such as live testing of a wide area deluge which releases thousands of litres of water onto equipment (something you really only want to occur if there really is a fire). In these cases, a combination of air pressure testing of pipework to ensure no leaks, and volume testing of mains and lead-ins may be better. For example, discharge of water from a lead-in from a main into a tank rather than the actual system it feeds to assess water flow and pressure.

Experience is that in the event of a fire detection, alarm and suppression systems can fail, or not perform as expected, for a variety of reasons. This may be because the system is under-specified or unsuitable for the application and environment it is being used in. However, one of the most common reasons is that the system has not been maintained, tested and checked as it should have been. Or, that a defect in the system had been identified but not addressed.

6.5. Fire compartments and fire walls

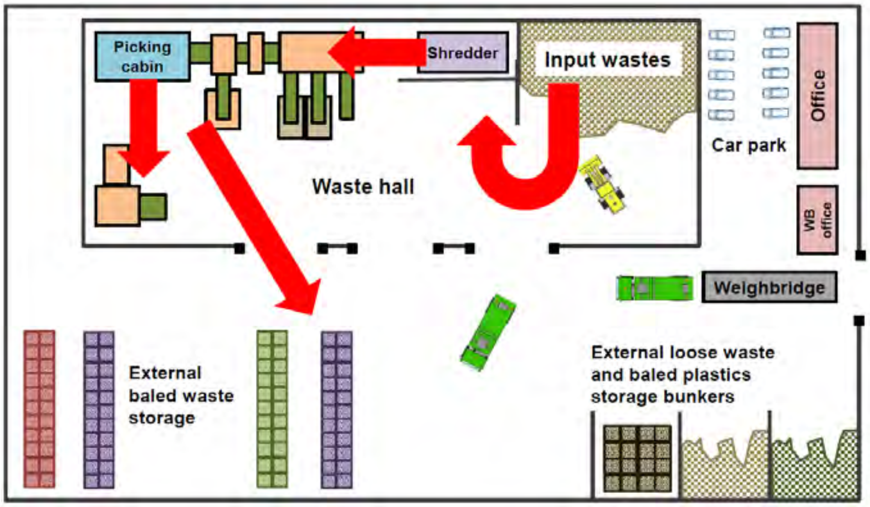
Compartments

The use of fire compartments is common in many types of building. For example, a large office building is likely to be split into ‘compartments’ separated by fire walls with fire doors. The aim of splitting buildings into such fire compartments include reducing the risk of fire spread, so reducing damage, allowing time for people to evacuate more safely, and allowing fire systems such as sprinklers time to do their job.

However, in many waste management applications fire compartments are difficult to arrange and may be impractical. This is usually because of a need to move materials (wastes) between sections of the plant/building. Using the illustration recycling plant given in the section above:

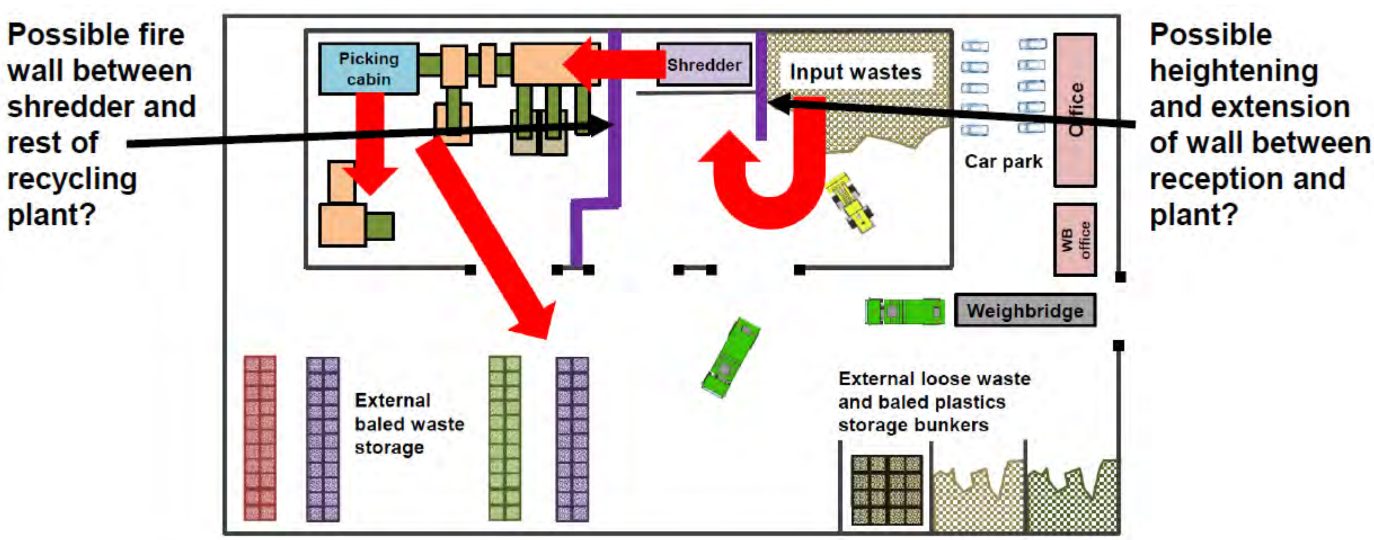
- Wastes need to be moved from the reception area to the input shredder of the processing part of the plant (in this case by use of a loading shovel, grab crane or similar)
- Wastes once fed into the shredder at the start of the process then need to travel via the shredder’s output conveyor into the rest of the plant for separation into recyclates
- Once separated wastes need to be moved to the baler, or to external storage

This type of practical requirement tends to mitigate against splitting waste management plants into compartments. However, this is not to say that compartments are impossible, or that the idea of splitting a plant to reduce the risk of fire spread should not be attempted. The illustration recycling plant diagram below shows possible required waste movements, as indicated by red arrows.



As noted in the section on design above, two of the main fire risks at the illustration recycling plant above are fires in the waste reception area (self-heating, hot and hazardous materials in input wastes etc), which could spread to the recycling plant, and fires in the shredder (gas cylinders, lithium batteries etc), which could also then spread to the rest of the recycling plant.

Using the illustration, it may be possible to install a fire wall between the shredder and the rest of the plant, splitting the building into two compartments. How practical this is will depend on mobile plant movements, structure of the building and other factors (and is likely to be easier at a new build than as a modification to an existing plant). If you are designing a new build plant, then extending the length of the shredder output conveyor will make installation of a fire wall easier – fire/risk engineering should be considered alongside process engineering in new builds. And, of course there will need to be a 'hole in the wall' to allow the output conveyor from the shredder to pass through to the rest of the plant (see below on fire shutters etc).



While this would not split the building into 'true' compartments, consideration could also be given to raising the height of and extending the length of the push-wall between waste reception and the shredder to reduce the risk of fire spread (see below on fire walls at bunkers etc).

However, even if you can split your facility into compartments, there will very likely still be a need to move wastes between compartments, typically via conveyors, resulting in imperfect fire walls with 'holes' in them. Fire can spread through such holes by various mechanisms, such as:

- The conveyor itself may have combustible components, such as rubber belt conveyors
- While the conveyor may have been emergency stopped in the event of a fire, residual wastes may still be on the belt which can cause fire spread
- Hot combustion products, such as gasses, can transfer heat via any 'hole in the wall' igniting combustible materials on the other side, or radiative heat itself can breach the wall via the hole
- If the conveyor bed and carriage are steel, then this can heat-up in a fire carrying this heat through the fire wall by conduction

There are various options here:

- Fire shutters – these are typically 'hatches' which slide into place in the event of a fire blocking the hole in the fire wall. These may be difficult to arrange in waste management plants because of the irregular shape of holes required to pass conveyors – they may be impractical to fit and/or ineffective in use because they do not fit exactly in the 'hole'. Fire shutters also require routine cleaning (debris such as wastes can stop them closing) and maintenance. Shutters can be automatic and triggered via the same detector/s as deluge and other systems, or manual (automatic is usually preferred for the obvious reasons)
- Water curtains – these spray a curtain of water across the 'hole'. Some insurers do not accept water curtains as they have proven to be ineffective in some cases in stopping high levels of radiative heat passing through – and waste fires can be intense. Check with your insurer before you decide on the use of water curtains
- Deluges – typically arranged longitudinally along conveyors passing through holes. Obviously the longer the conveyor the longer the deluge array can be, and the more likely it is to be effective

If using deluges and/or curtains at holes in fire walls you should consider all of the potential mechanisms for fire spread. For example, deluges should be extended to under the conveyor, and may need to cover conveyor carriages etc to reduce the risk of heat transmission. You may also use combinations, such as a fire shutter backed-up by a deluge.

Note – the examples above assume that a conveyor is the potential issue. There are other mechanical transfer methods such as automated grab cranes, screw elevators and others. As for many other aspects of fire/risk engineering at waste management facilities, specific assessment is required if an effective outcome is to be achieved.

One area where compartments are often seen at waste management plant is with MCC rooms, hydraulic power-packs and similar. These are often in separate compartments (rooms, containers etc) protected by fire walls. For example, it may be practical, depending on your plant's layout, to locate MCC rooms and power-packs in steel containers/separate buildings (such as a brick outhouse) outside of the building: Why place such critical items in higher fire risk areas such as recycling halls unless you have to? If you do have to locate such items in waste halls and similar, protecting them by the use of compartments would likely represent good risk management.

Whatever their location, components such as MCC rooms and power-packs suffer the same 'holes' problem as conveyors, albeit to a lesser extent. They need to be connected to the plant, such as via cabling, hydraulic hoses and pipes etc.

These connections need protecting:

- All holes/breaches in fire walls need sealing, such as with fire resistant foams
- You may want to consider other protection to cables, pipework etc, and where you locate them to make them less prone to damage during a fire
- Hydraulic power-packs should be interlocked to shut-down and depressurise in the event of a fire, via link to your fire detection and alarm systems (non-flammable hydraulic oils may also be possible dependent on the technical specification of the power-pack)

One of the most common faults found during site fire inspections are holes 'drilled' in fire walls to allow cables, pipework etc to pass through the wall without any sealing or other protection being applied. In particular during the installation of plant and during new builds such faults should be high on your agenda during periodic inspections of works and 'snagging' lists.

Fire walls

There are set standards for fire walls, and you should consult with your insurer to ensure you have selected the correct standard. Typically, fire walls are 'rated' by how long they will resist fire spread, such as 30 minutes, 60 minutes, two hours etc. The more critical a component (or life safety aspect) the higher the rating of fire wall required. A 30-minute rated fire wall in an office likely would not be appropriate to protect an MCC room or other critical component.

Fire walls also formally need to be installed by accredited installers, as for other fire related systems. Again, your insurer should be able to advise you, and see the BRE website for information. Notwithstanding this, and on a practical note, a 300 mm thick concrete wall is likely to provide a good degree of fire resistance whether it has been installed by an accredited installer or not. To be effective a fire wall needs to be able to resist fire and not have any breaches in it which could result in fire spread. In addition to the issue of ‘holes’ in fire walls as noted above:

- Railway sleepers cannot be considered as fire walls – they are made of wood, which in itself is combustible, and have frequently been treated with flammable preservatives
- A bunker constructed of blocks may provide an adequate fire wall. But, concrete ‘A’ fames may not as there are likely to be gaps at the corners of the bunker where the ‘A’ frames do not meet exactly. Conversely, ‘A’ frames arranged in a linear wall to separate waste stacks, or waste stacks from a building wall, may be adequate because there are no corners to contend with
- Steel walls may resist fire, but they will heat-up during a fire and may transfer heat. As such their use may be limited. For example, steel walls between a series of waste bunkers may not be effective as a block to fire spread. However, if the bunker is stand-alone then while heat may radiate from the external face of the steel wall this may be acceptable (this type of application requires specific assessment)
- Recently, some flexible ‘curtain’ fire wall materials have been brought to the market. If you are contemplating such you must discuss with your insurer as they may not accept these

One of the most common use of fire walls in waste management is in storage bunkers (and reception areas etc), both internal and external. In addition to the points noted above on fire walls, in general:

- Bunkers in waste halls and similar (internal use) do not result in fire compartments – they are open-topped and cannot be considered as compartment walls
- Fire walls in bunkers and similar are of little use if wastes are piled above their height, or if wastes spread-out beyond the wall ends. In general, at least 1 metre ‘freeboard’ should be left between waste height and wall top to account for flame height in a fire. You will need to control waste height and spread in bunkers and similar as part of your site rules and their enforcement
- Construction of bunker walls should be appropriate to their use as fire walls (see above), and maintained to ensure damage such as by mobile plant does not degrade effectiveness

One use of fire walls is to reduce the need for separation distances between waste storage stacks. For example, in the illustration plant used above plastic bales have been stored in a bunker. Provided that the walls of this bunker are appropriate and waste height and spread is being controlled this can be a good method to reduce the need to separate waste stacks by distance, so maximising site area. However, this type of use needs consideration – see main body of this guidance under storage.

6.6. Smoke vents

Smoke vents are openings located in the roof and/or upper walls of buildings. Their aim is to vent smoke and hot combustion products during a fire, so removing heat and energy from the fire and allowing better vision of a fire when fighting it. Vents may be:

- Fixed open – in such cases vents are normally located in the upper walls of buildings rather than the roof to prevent obvious problems such as rain ingress
- Automatic – vents which open in the event of a fire automatically, such as hydraulic or electric opening linked to the building's fire detection and alarm systems (usually with a back-up manual activation point in a safe location, as for deluges etc)
- Manual – vents which are opened manually, such as by pressing buttons in a control room and external panel in a safe location

Smoke vents can be the topic of debate, and some insurers and Fire and Rescue Services may have negative views of smoke vents (this is one area where you should consult with your insurer and local Fire and Rescue Services before you install). They can also have other problems:

- By venting smoke and heat vents may prevent heat from reaching sprinkler bulb heads, so preventing them from activating or delaying activation, and may also prevent smoke from reaching detection systems such as aspirating systems so preventing or delaying activation
- Vents may promote air-flow (chimneys) so encouraging a fire rather than helping

This is not to say that vents should not be installed – in some situations they have been proven to be beneficial. However, you should seek competent advice, and consult with your insurer and Fire and Rescue Services before fitting them.

6.7. Insurer requirements

Many insurers have specific requirements for fire alarm, detection and suppression/extinguishing systems. If you fail to meet these specifications and requirements your insurance may be invalidated. The basic rule here is: **TALK TO YOUR INSURER FIRST**.

- Certification/standards for fire detection, alarm and suppression/extinguishing equipment. Many insurers require specific certifications for fire systems, such as LPCB (Loss Prevention Certification Board) or FM (Factory Mutual). If you install a system which is not certificated to your insurer's requirements, they may not accept it and you may need to start again

- Certification standards for installation and design of fire detection, alarm and suppression/extinguishing systems: As for the equipment itself, your insurer may insist that systems are designed and installed to specific standards. These may be design standards such as NFPA and FM standards, or they may be standards for installation, such as installers being certificated to LPCB standards. Again, if the designers of any system do not design it to your insurer's required standards and/or if installation is not by a certificated/approved installer then your insurer may not accept the system
- Standards for commissioning of systems: As above, your insurer may have specific requirements for the commissioning of fire systems
- Standards and conditions for maintenance, testing and checking of fire systems. These are often included in property insurance policies as conditions. For example, that sprinkler systems, fire pumps etc should be tested and checked to given timescales and standards. In the event of a fire you may be asked to prove that you complied with these conditions and requirements – if you cannot your insurance may be invalidated
- Impairment of fire detection, alarm and suppression systems: It is common for property insurance policies to include a condition that you must inform your insurer if any part of your fire system is impaired, such as faulty, damaged, not operational etc. You should inform your insurer if any part of your fire system/s is not working for whatever reason. Your insurer may require you to take specific action, for example if a detection system is faulty that you commence a dedicated fire-watch (you may want to anticipate such actions in advance – this would be good risk management in any case). If your system is impaired and you have not informed your insurer, in the event of a fire your insurance may be invalidated

You should read your property insurance policy (and any schedules and variations) carefully to ensure you are aware of conditions and requirements for testing, maintenance, impairments, certifications etc. If you are in any doubt you should contact your insurer for advice.

Tip – extract fire system requirements and conditions from your insurance policy. Then list these, and incorporate them into your operating procedures, testing, checks and maintenance regimes. Then ask yourself: 'in the event of a fire could I prove I complied with these conditions, such as by producing records?' If you cannot, you may have a problem making a claim.

Tip – many insurers require installers and maintainers to be accredited to the 'BRE red book'. Search the internet for 'BRE red book' to access the BRE web site, which includes lists of approved installers etc. But, check with your insurer first as they may have different requirements.

6.8. Summary on technical fixed systems

Fire system engineering is a complex and technical area. For example, the NFPA document NFPA13 on sprinkler system design is more than 440 pages long. For all but the simplest of fire detection, alarm and suppression/extinguishing systems competent external advice will very likely be required. Most waste management companies simply do not have the competency in-house to design sprinkler, deluge etc systems. However, be careful when selecting external advice - a local fire engineering company may not be aware of the issues associated with waste management plants and may recommend and install a 'standard' system which may not be effective at a waste management site. Ultimately, you should ensure that your specific needs are assessed and that your fire detection, suppression, fighting and alarm systems are adequate to and effective for the specific risks, situation and environment of your site.

6.9. Notes from the phase 3 WISH waste fire tests

The phase 3 WISH waste fire tests were primarily aimed at assessing the effectiveness of different fire-fighting media (water, water with wetting agent and foams) and FRS (Fire and Rescue Services) techniques against waste fires. However, two issues are worth mentioning in this appendix on fixed technical systems.

- Water with a wetting agent added proved most effective when fighting waste fires with FRS fire hoses. It may be possible to use wetting agents in fixed systems, such as deluges and water monitors. However, the addition of a wetting agent to water in these systems requires careful thought as this may change the characteristics of the system and may pose problems with pumps, valves and similar. This is an area where further research is required before any firm recommendations can be made
- Various types of detection system were tested during the phase 3 tests. In general, all of the detection systems tested were effective at detecting a fire at the surface of a waste stack. However, none were effective in detecting a deep-seated fire within a waste stack when the waste type in storage was of a small particle size or the waste type was flexible leading to little in the way of air spaces within the pile. For larger and more rigid waste types, such as pre-crush wood, air circulating through the pile allowed heat and smoke to escape, which could be detected. However, for RDF and similar air circulation is limited, if present at all, and none of the detectors tested could detect a smouldering fire buried deep with the pile until the fire breached the surface of the pile

For more detail see appendix 5 of this guidance.

7. Commonly quoted standards

7.1. Introduction and scope

This section is an overview of a selection of standards and similar commonly used or of relevance to the waste management industry. Not all of the standards and similar deal directly with waste or waste sites, but all contain information, specifications and criteria etc, which can be useful for dealing with fire safety on waste management and processing sites.

This guide only highlights a selection of key standards and similar that might be of use to waste site operators. The list of included documents is not intended to be all-encompassing and other codes, standards etc should always be consulted when required or more appropriate for the matter at hand. There is no intention for this guide to give direction or advice on fire safety, to advise on the suitability of one standard over another or to be used as a complete reference to fire safety standards. This document is a brief overview of certain key standards and similar and how they might be of relevance.

7.2. List of commonly quoted standards and brief summaries for each

The below lists commonly quoted standards and similar. However, for ease of use first below is an 'index' of the standards included. The summaries following this 'index' are in the same order as the index, and in alphabetical and then number order.

Index of standards included

ACE Technical Risks: Energy from Waste – Fire Systems
BS 7974:2019
BS 8110-2:1985
BS 8489-1:2016
BS 9999
BS EN 710:1997+A1(2010)
BS EN 1992-1-2:2004
BS EN 12845
BS EN 12845
BS EN 14243-1
BS EN 14243-2
BS EN 14243-3
BS EN 15357
BS EN 15359

NEN 6060
NFPA 12:2018
NFPA 13:2016
NFPA 15:2017
NFPA 18:2017
NFPA 18A:2017
NFPA 20:2019
NFPA 22:2018
NFPA 25:2017
NFPA 750:2019
NFPA 850:2015

ACE Technical Risks: Energy from Waste – Fire Systems

The ACE Technical Risks Engineering Information Bulletin Guidance Document: Energy from Waste – Fire Systems Document.

Discusses general fire safety but with specific reference to the requirements of Energy from Waste sites and so covers topics such as waste site-specific fire separation recommendations and such like. This guidance document is no longer supported by ACE Group but can still be found in use regardless. A general document covering many aspects of fire safety systems in Energy from Waste sites, parts can be used with respect to waste processing and transfer sites. Please bear in mind that some of the standards referred to may be previous editions of current standards or superseded altogether by new documents. In brief, useful, but not supported anymore and may be out of date in some areas.

BRE 187 2nd Edition (2014)

External fire spread – Building separation and boundary distances

General guidance document covering fire spread between the exteriors of buildings. Particularly of use during the design stage of building works. This is a guidance document widely used throughout fire engineering for calculating whether external fire spread from a building elevation is a risk. Used alongside WASTE 28, can be used to determine whether a building is at risk of external fire spread from nearby waste piles/bale storage.

BRE 368

Design methodologies for smoke and heat exhaust ventilation

General guidance document for smoke and heat exhaust ventilation systems covering the design of such systems for use in large spaces. Has a fast/ultra-fast fire growth category that can be broadly applied to waste fires but is generally aimed at atria spaces and car parks rather than warehouse-type buildings and does not have any industrial occupancy groups. Useful as a guidance document when designing a SHEV system but has no specific, relevant categories for waste sites.

BS 476-3:2004

Fire Tests on Building Materials and Structures – Classification and Method of Test for External Fire Exposure to Roofs

General standard covering tests for fire penetration of a roof by external fire and capacity for flame spread on the exterior surface of a roof. Defines fire test methods and criteria. Primarily useful for during the design stage of a building. Nothing high hazard/risk factor or otherwise categorically specific. To be used as a general document as required for ascertaining the standard to which materials and roof systems have been tested when designing for building works and specifying roof construction and materials.

BS 476-4:1970

Fire Tests on Building Materials and Structures – Non-Combustibility Test for Materials

General standard covering the British Standard test for determining whether a building material can be classified as non-combustible. Defines the fire test method and test criteria. Nothing high hazard/risk factor specific. To be used as a general document to support decision-making and discussion around building material choices when designing for building works and specifying material requirements and choices.

BS 476-6:2009

Fire Tests on Building Materials and Structures – Method of Test for Fire Propagation for Products

General standard covering the test methods for testing fire propagation. Usually used to test materials intended for use as internal wall and ceiling linings. Defines fire test method and criteria. Nothing specific to high hazard/risk factor or other similar categories. Useful as a general document for clarity and supporting information when designing building works, specifying material requirements and making material selections.

BS 476-7:1997

Fire Tests on Building Materials and Structures – Method of Test to Determine the Classification of the Surface Spread of Flame of Products

General standard covering the fire test method and criteria for measuring lateral flame spread along the vertical surface of a material. Nothing specific to high hazard/risk factor or similar categories. Recommended for use for clarification and supporting information when designing building works, specifying material requirements and selecting suitable materials for fire safety purposes.

BS 476-10:2009

Fire Tests on Building Materials and Structures – Guide to the Principles, Selection, Role and Application of Fire Testing and Their Outputs

General standard covering the basic principles of fire tests, the inputs and outputs of the BS 476 series of tests, the equivalent ISO and EN (International and European) tests. The standard also covers which tests suit which purpose, and how the output of each test defines what it can be used for and its role in the test suite.

This document is not specifically relevant to waste sites, however the standard is broadly useful for helping with the understanding of which tests can be used to give which classifications, and what material characteristics are quantified by each test. This is helpful when designing building works as it allows for a better understanding of what should be given as the fire safety specifications for materials in order for them to provide the required performance.

BS 476-11:1982

Fire Tests on Building Materials and Structures – Method for Assessing the Heat Emission from Building Materials

General standard covering the test method for determining the heat emission from a material. Defines the test method and criteria. Nothing high hazard/risk factor specific. To be used as a general document in support of designing building works, particularly when deciding on heat emission requirements and identifying suitable materials.

BS 476-12:1991

Fire Tests on Building Materials and Structures – Method of Test for Ignitability of Products by Direct Flame Impingement

General standard covering the British Standard test method and criteria for the ignitability of materials when in direct contact with flame. Usually referred to during the design stages of building works. Nothing high hazard/risk factor specific, useful during the design stage of building works as a supporting document to help in determining suitable performance requirements and finding qualified materials for fire safety purposes.

BS 476-13:1987

Fire Tests on Building Materials and Structures – Methods of Measuring the Ignitability of Products Subjected to Thermal Irradiance

General standard covering the British Standard test method and criteria for the ignitability of materials when exposed to thermal irradiance. Has nothing specific to high hazard/risk factor or similar purpose groups or categories. Useful for understanding test criteria and results to aid in specifying fire safety performance requirements and then selecting appropriate materials during the design stages of building works.

BS 476-20:1987

Fire Tests on Building Materials and Structures – Method for Determination of the Fire Resistance of Elements of Construction (General Principles)

General standard detailing the British Standard fire test method and criteria for quantifying the fire resistance of elements of construction.

General document with nothing specific to categories such as high hazard of high-risk factor. Useful during design stages to support decisions regarding fire resistance requirements and then suitable materials.

BS 476-21:1987

Fire Tests on Building Materials and Structures – Methods for the Determination of Fire Resistance of Loadbearing Elements of Construction

General standard covering the test methods for the British Standard test to determine fire resistance for loadbearing parts of construction. Gives the requirements for specimen selection, and design as well as equipment, procedures, criteria and test conditions. Applies to beams, columns, floors, walls and flat roofs. To be used in conjunction with BS 476-20. Nothing specific to categories such as high hazard or high-risk factor. Most useful during the design stages of building works to give an understanding of the BS test, how it works, what it tests for and what elements can be tested. Helpful when specifying fire resistance requirements or selecting appropriately resistant materials.

BS 476-22:1987

Fire Tests on Building Materials and Structures – Methods for Determination of the Fire Resistance of Non-Loadbearing Elements of Construction

General standard detailing the British Standard test for measuring the fire resistance of elements of construction not intended to bear loads. Details the test methods, conditions and criteria. Used in conjunction with BS 476-20. Nothing high hazard/risk factor specific. Most useful during the design stages of building works to give an understanding of the BS test, how it works, what it tests for and under what conditions. Helpful when specifying fire resistance requirements or selecting appropriately resistant materials.

BS 476-23:1997

Fire Tests on Building Materials and Structures – Methods for Determination of the Contribution of Components to the Fire Resistance of a Structure

General standard covering the British Standard fire test procedures for quantifying the contribution made by a component to the total fire resistance of a structure or assembly. Details specimen selection, design and construction, specimen edge conditions, test equipment, procedures and criteria. Applies to suspended ceilings protecting steel beams as well as intumescent seals used with fire resisting, single-action, latched timber door assemblies. Used in conjunction with BS 476-20. Nothing specific to categories such as high hazard or high-risk factor. Most useful during the design stages of building works to give an understanding of the BS test, how it works, what it tests for and what elements can be tested. Helpful when specifying fire resistance requirements or selecting appropriately resistant materials.

BS 476-24:1987

Fire Tests on Building Materials and Structures – Methods for Determination of the Fire Resistance of Ventilation Ducts (AKA: ISO 6944-1985 Fire Resistance Tests – Ventilation Ducts)

General standard covering the British/International Standard test method and criteria for when determining the resistance of ventilation ducts under given fire conditions. Details specimen selection, design and construction, test conditions, equipment, procedures and criteria.

General document that contains nothing high hazard/risk factor specific. Most useful during the design stages of works to aid with the specification of fire resistance requirements and with the selection of suitable products to meet said requirements.

BS 476-31.1:1983

Fire Tests on Building Materials and Structures – Methods for Measuring Smoke Penetration Through Door sets and Shutter Assemblies – Method of Measurement Under Ambient Temperature Conditions

General standard detailing the British Standard test method and criteria for measuring smoke penetration through door sets and vertical shutter assemblies. Measures smoke control performance, but not fire resistance performance. Has nothing specific to high hazard/risk factor or similar categories. Most useful during the design stages of building works for clarifying what smoke control classifications mean, what safety requirements are needed, and which products fit those requirements.

BS 476-32:1989

Fire Tests on Building Materials and Structures – Guide to Full Scale Fire Tests Within Buildings

General standard providing guidance concerning the British Standard tests simulating building fires through full scale experiments. Details specimen selection, design and construction, test conditions, equipment, procedures and criteria. Has nothing specific to high hazard/risk factor or similar categories. Most useful during the design stages of building works as clarification and supporting information to help with determining fire safety requirements and suitably qualified products or commissioning test works in order to quantify the performance of a fire engineered solution.

BS 476-33:1993

Fire Tests on Building Materials and Structures – Full-scale Room Test for Surface Products

General standard covering the British Standard full-scale room test. Details the test principles, method, conditions, equipment and criteria. Nothing high hazard/risk factor specific, helpful as part of the design stages of building works as clarification and supporting information to help with determining fire safety requirements and suitably qualified products or commissioning test works in order to quantify the performance of a fire engineered solution.

BS 5306-0:2011

Fire Protection Installations and Equipment on Premises – Guide for Selection of Installed Systems and Other Fire Equipment

A mostly general document covering various types of fire-fighting media, such as water and foams, as well as various types of fixed system such as sprinklers or hydrant systems, the use and control of these systems and the identification fire hazard categories and selection of the optimal system to account for such hazards. Has an appendix giving some clarification regarding suitable fire systems for different hazard categories. However, this appendix is quoted from BS EN 12845 and is thus not included here. Otherwise, is useful as an overview of the various fire suppression options available under the British Standards for fire protection.

BS 5306-1:2006

Code of Practise for Fire Extinguishing Installations and Equipment on Premises – Hose Reels and Foam Inlets

A general standard covering the design, installation and maintenance of hose reels and foam inlets. Contains nothing regarding high hazard/risk factor categories. To be used when required as a general standard where such systems are proposed, under design or installed.

BS 5306-3:2017

Fire Extinguishing Installations and Equipment on Premises – Commissioning and Maintenance of Portable Fire Extinguishers – Code of Practice

A general standard covering the initial commissioning of portable fire extinguishers as well as their subsequent maintenance. Also covers dealing with obsolete extinguishers which no longer have standard maintenance schedules. Contains nothing regarding high hazard/risk factor categories. To be used when required as a general standard where portable extinguishers are proposed or installed.

BS 5306-4:2001+A1(2012)

Fire Extinguishing Installations and Equipment on Premises – Specification for Carbon Dioxide Systems

A general standard dealing with the design, installation and maintenance of carbon dioxide suppression systems. Contains nothing regarding high hazard/risk factor categories. To be used when required as a general standard where such systems are proposed, under design or installed.

BS 5306-5.1:1992

Fire Extinguishing Installations and Equipment on Premises – Specification for Halon 1301 Total Flooding Systems

A general standard covering the characteristics, design, installation and maintenance of halon 1301 total flooding fire suppression systems. Contains nothing regarding high hazard/risk factor categories. To be used when required as a general standard where such systems are proposed, under design or installed.

BS 5306-5.2:1984

Fire Extinguishing Installations and Equipment on Premises – Specification for Halon 1211 Total Flooding Systems

A general standard covering the characteristics, design, installation and maintenance of halon 1211 total flooding fire suppression systems. Contains nothing regarding high hazard/risk factor categories. To be used when required as a general standard where such systems are proposed, under design or installed.

BS 5306-8:2012

Fire Extinguishing Installations and Equipment on Premises – Selection and Positioning of Portable Fire Extinguishers – Code of Practice

A general standard covering suitability and positioning of portable fire extinguishers. Contains nothing regarding high hazard/risk factor categories. To be used when required as a general standard where portable extinguishers are proposed or installed.

BS 5839-1:2017

Fire Detection and Fire Alarm Systems for Buildings – Code of Practice for Design, Installation, Commissioning and Maintenance of Systems in Non-domestic Premises

General standard detailing the planning, design, installation, commissioning and maintenance of fire detection and alarm systems. Contains nothing regarding high hazard/risk factor categories. To be used when required as a general standard where fire alarm and detection systems are proposed, under design or installed.

BS 7974:2019

Application of Fire Safety Engineering Principles to the Design of Buildings.

Document covering the methods and applications of fire engineering for building design, a general fire safety code for all hazard types and risk factors, helpful for when fire engineered solutions are required.

Nothing high hazard/risk factor or otherwise categorically specific. To be used when required as a general standard for such systems.

BS 8110-2:1985

Code of Practice for Concrete for Special Circumstances.

While still mentioned on occasion, has been superseded by BS EN 1992-1-1:2004 below. Refer to BS EN 1992-1-1:2004 instead.

BS 8489-1:2016

Fixed Fire Protection Systems – Industrial and Commercial Watermist Systems

Code covers water mist systems overall, under a range of hazard types. Covers most aspects of designing, installing and maintaining a water mist system, detailing the requirements of such a system and how to meet them. Very relevant where water mist systems are installed, under design or proposed. It should be noted that this standard is based on providing proof that the water mist system will work on a specific fire load density. The manufacture of the system will therefore be required to provide test evidence as specified in the standard. It is therefore recommended that this test data is provided at the enquiry stage of a project. For most waste sites the High Hazard category excerpts will be of immediate interest. The rest of the document covers the either lower hazard or the general aspects of water mist systems.

BS 9990:2015

Non-Automated Fire-fighting Systems in Buildings – Code of Practice

A general standard giving guidance and recommendations on the design, installation, commissioning and maintenance of systems such as wet and dry fire-fighting mains, private hydrants and other water supplies and supply pumping. To be used in conjunction with parts BS 5306 parts 1, 3 and 8. Nothing high hazard/risk factor or otherwise categorically specific. To be used when required as a general standard where such systems are required, proposed, under design or installed.

BS 9999

Fire Safety in the Design, Management and Use of Buildings – Code of Practice

General standard covering fire safety as a whole and applying to most non-residential buildings. Particularly useful during the design stages of any building works. This is primarily a code of practice that addresses life safety issues and elements of its recommendations may not be acceptable to insurers or the Environment Agency in particular with regard to the relaxation of structural fire resistance and the duration of the water supply for the suppression systems. Note, regarding sections 6.2 – 6.4: where piled or stacked waste is over 50% plastic by volume, the fire growth rate should be classed as category 4, and the resulting risk factor then A4. Under BS 9999, an A4 risk factor is unacceptable unless moderated by a suppression system or sprinklers. See Table 4, particularly footnote A in the standard for further guidance.

BS EN 710:1997+A1(2010)

Safety Requirements for Foundry Moulding and Coremaking Machinery and Plant and Associated Equipment

Document covering the risks and management thereof relating to machinery and plant in foundries. Largely irrelevant except for the select reference included here. Makes select references to the usage of plant in high-heat environments, as occurs when plant is used to remove burning waste from storage and transfer sheds. In particular, the risk of hydraulic fluid ignition.

BS EN 1992-1-2:2004

Eurocode 1, Part 1-2: General Actions – Actions on Structures Exposed to Fire

Supersedes BS 8110-2:1985. Follows on from BS EN 1992-1-1 and parts 1 and 2 of BS EN 1991-1. General document covering the overall principles and rules regarding the effects of fire on concrete. To be used when required as a general standard regarding concrete subjected to fire loads. The below section, and the rest of section 5.4, however, may be of particular use in the design of partition walls separating stockpiles or acting as thermal barriers.

BS EN 12845

Fixed Firefighting Systems – Automatic Sprinkler Systems – Design, Installation and Maintenance

General document covering automatic sprinkler systems, the requirements for these systems and how to meet those requirements. Very useful where sprinklers are proposed, under design or installed. For the majority of sites, the High Hazard category will be the most appropriate, and those excerpts are included below. For non-hazard specific or lower hazard aspects, refer to the rest of the code.

BS EN 13501-1:2018

Fire Classification of Construction Products and Building Elements – Classification Using Data from Reaction to Fire Tests

A general document covering the method and criteria for categorising the reaction to fire of construction products. Has no specific high hazard/risk factor content. Helpful as part of the design stages of building works as clarification and supporting information to help with determining fire safety requirements and suitably qualified products in order to achieve adequate fire reaction performance.

BS EN 13501-2:2016

Fire Classification of Construction Products and Building Elements – Classification Using Data from Fire Resistance Tests, Excluding Ventilation Services

A general document covering the method and criteria for categorising the reaction to fire of construction products. Has no specific high hazard/risk factor content. Helpful as part of the design stages of building works as clarification and supporting information to help with determining fire safety requirements and suitably qualified products in order to achieve adequate fire reaction performance.

BS EN 14243-1

Materials Obtained from End of Life Tyres. General Definitions Related to the Methods for Determining Their Dimensions and Impurities.

Provides definitions for sample collection and preparation for when determining the dimensions and impurities of end of life tyre materials. Useful for providing additional clarity when working with BS EN 14243.

BS EN 14243-2

Materials Obtained from End of Life Tyres. Granulates and Powders – Methods for Determining the Particle Size Distribution and Impurities, Including Free Steel and Free Textile Content.

Provides test methods for determining the particle size distribution and the impurities of granulates and powders derived from end of life tyres.

Allows for standardised testing, categorisation and description of end of life tyre materials.

BS EN 14243-3

Materials Obtained from End of Life Tyres. Shreds, Cuts and Chips – Methods for Determining Their Dimension(s) Including Protruding Filaments Dimensions

Provides test methods for determining the dimensions of shreds, cuts and chips derived from end of life tyres. Allows for standardised testing, categorisation and description of end of life tyre materials.

BS EN 15357

Solid Recovered Fuels – Terminology, Definitions and Descriptions.

Standardised definitions of various terms relating to SRF. Useful if needing additional clarity when using standards dealing with SRF.

BS EN 15359

Solid Recovered Fuels – Specifications and Classes

Gives standardised classifications and specifications for SRF and the principles for those classifications and specifications. Useful for additional clarity as to what standards might consider SRF or not and how to classify SRF for use with other standards.

End-of-Life Vehicles Regulations 2003 + Amendments (2010)

The End-of-Life Vehicles (Amendment) Regulations 2003 No. 2635, 2010 No. 1094

Regulations dealing with the storage and disposal of end-of-life vehicles (ELVs). General regulations not dealing with fire or waste sites specifically but does contain one clause dealing with fire which may be of use to waste sites dealing with ELVs.

FPP Guidance

Guidance – Fire Prevention Plans: environmental permits

(Retrieved 19/06/2019 from https://www.gov.uk/government/publications/fire-prevention-plans-environmental-permits/fire-prevention-plans-environmental-permits). *Guidance provided by the EA to help waste site operators achieve compliance with FPP requirements. Provides information about what the FPP requirements means in practical terms and advice on how to meet these requirements. A targeted document aimed at helping waste operators manage fire risk and damage on site and compile a suitable FPP for compliance with EA requirements.*

Guidance on BATRRT and Treatment of WEEE 2006

Guidance on Best Available Treatment, Recovery and Recycling Techniques (BATRRT) and Treatment of Waste Electrical and Electronic Equipment

Provides guidance on treating, recovering and recycling WEEE safely and in accordance with the WEEE Directive. A general document, there is some mention of fire precautions. Relevant to most waste site operators as many sites deal with WEEE to an extent.

NEN 6060

Dutch standard covering Fire Safety of Large Fire Compartments.

This standard isn't available in English, but for operators with interests in the Netherlands, this standard could be of use and operators should be aware of it.

Most waste transfer and processing sheds are classed as large compartments, and so this standard would apply.

NFPA 12:2018

Standard on Carbon Dioxide Extinguishing Systems

General standard covering the design, installation and maintenance of carbon dioxide suppression systems. Nothing high hazard/risk factor or otherwise categorically specific. To be used when required as a general standard where such systems are proposed, under design or installed.

NFPA 13:2016

Standard for the Installation of Sprinkler Systems

General standard covering the design, installation and maintenance of automatic fire sprinkler systems. Does not cover water mist systems. For the majority of sites, the High Hazard category will be the most appropriate. For non-hazard specific or lower hazard aspects, refer to the rest of the code.

NFPA 15:2017

Water Spray Fixed Systems for Fire Protection

General standard covering the design, installation and maintenance of water spray suppression systems. Nothing high hazard/risk factor or otherwise categorically specific. To be used when required as a general standard where such systems are proposed, under design or installed.

NFPA 18:2017

Standard on Wetting Agents

General standard covering the usage of wetting agent in automatic water suppression systems. Covers the usage of foams. Nothing high hazard/risk factor or otherwise categorically specific. To be used when required as a general standard for such systems. Often used in conjunction with NFPA 18A.

NFPA 18A:2017

Standard for Water Additives for Fire Control and Vapour Mitigation

General standard covering water additives and their usage in automatic water suppression systems. Covers the use of surfactants. Largely contains nothing high hazard/risk factor or otherwise categorically specific bar a few select paragraphs. To be used when required as a general standard where water additives are proposed or in use. Often used in conjunction with NFPA 18.

NFPA 20:2019

Standard on Stationary Pumps for Fire Protection

General standard covering the design and installation of water supply pumps for fire protection systems. Nothing high hazard/risk factor or otherwise categorically specific. To be used when required as a general standard for such systems.

NFPA 22:2018

Standard for Water Tanks for Private Fire Protection

General standard covering the design, installation and maintenance of water supply tanks for fire protection systems such as the supply tank for sprinkler systems. Does not define hazard groups or make any reference to high hazard groups or risk factors etc., but, makes a singular reference to hazards greater than Ordinary Hazard Group 2.

NFPA 25:2017

Standard for the Inspection, Testing and Maintenance of Water-Based Fire Protection Systems

A general standard applicable to sprinkler, standpipe, hose, fixed water spray, water mist and foam water systems as well as private fire hydrants. Covers inspection, maintenance and testing of these systems and how to update systems to account for changes in occupancy or processes etc. that impact the fire safety of a site. Has no high hazard category defined but does make a few select mentions to special hazard systems and is also of use as a general standard that applies to most fire suppression and protection systems.

NFPA 80A:2017

Recommended Practice for Protection of Buildings from Exterior Fire Exposures

General guidance on preventing fire spread between building exteriors through use of suitable separation distances. Makes no reference to high hazard groups or high-risk factors but does account for varying severities of fire load. The severe fire load category may be more relevant to waste operators depending on site characteristics.

NFPA 750:2019

Standard on Water Mist Fire Protection Systems

General standard covering the design, installation and maintenance of water mist suppression systems. The High Hazard category has been removed from this revision of the standard (as of 01/05.2019), and the lower hazard categories do not apply particularly well to waste transfer and processing, so this is now to be used when required as a general standard for such systems.

NFPA 850:2015

Recommended Practise for Fire Protection for Electric Generating Plants and High Voltage Direct Current Converter Stations

Standard covering fire protection systems for electric generating plants with specific reference to plants generating from alternative fuels including RDF and rubber tyres. Covers fire protection and fire suppression systems generally as well as specific measures for plants using RDF, rubber tyres or other alternative fuels. Applies to a degree to many waste sites, even if just the fuel-specific sections. Useful, in particular as a standard more directly focussed on waste sites and applicable to general fire safety. Note -the generic water density figures quoted may not apply to specific waste types and may result in under-specification and is somewhat out of date when compared to the WISH fire tests data.

Appendix 5: Non-technical summary waste fire tests

WASTE FIRE BURN TRIALS

Summary non-technical report

This document provides a non-technical summary of waste fire burn tests conducted in 2015, 2016 and 2017 – the 'phase 1, 2 and 3 tests'. It is aimed at providing underpinning and background information for readers of the WISH waste fires guidance and to waste operators in general.

Contents

1. Introduction

Prior to the publication of the original 2014 WISH 'reducing fire risk at waste management sites' guidance (WISH 28 fires guidance) a thorough literature search was made by the HSL (Health and Safety Laboratories), and the authors of the guidance. The aim was to identify any existing waste fires guidance, research and similar information on the combustion properties of wastes from across the world. Very little relevant information was found. This weakness was noted in the consultation process for the 2014 WISH waste fire guidance.

In the absence of comprehensive detail information on the combustion properties of wastes, and with an urgent need at the time in 2014 to provide the waste industry with guidance on waste fire risk management, what information sources which could be found were used for the 2014 WISH guidance. Sources included buildings fire research, caravan fire research, information from standard insurance industry codes and other similar sources. WISH was not alone in this approach. Various other waste management fire guidance and similar documents from other bodies also being based on the same or similar, and generally non-waste, information sources. The flaws of this approach were noted in the 2014 WISH fire guidance, which stated: *"As knowledge on the burn properties of specific wastes improves, experience of real fires accumulates and as better information becomes available, revisions of this guidance will be made to keep it up to date."*

Specifically, on waste storage the consultation letter accompanying the 2014 WISH fires guidance (included in the guidance as an appendix) stated: *"There is little available fire testing or science specific to wastes to provide a firm under-pinning for the available information on stack sizes and separation distances – most of the current information is based on operational and fire-fighting experience. There is data on raw materials. Much of this indicates that the separation distances in table 1 in appendix 1 are conservative and separation distances in excess of those currently available for wastes may be required at sites with no fire prevention measures. For example, data on virgin, raw paper and plastics suggests separation distances between 10 - 11 metres and 18 - 27 metres respectively – that is well in excess of those distances quoted in table 1 of appendix 1. Whether this data for raw materials can be applied direct to wastes is not known - real testing on wastes is required."*

To address this gap in knowledge, in late 2015 and throughout 2016 and 2017 a series of waste burn test were conducted. In late 2015 smaller scale laboratory type testing was conducted at the FPA (Fire Protection Association) research premises. These 'phase 1' tests provided baseline data on parameters such as burn rates and thermal outputs. However, some of the results obtained from this laboratory type testing did not reflect the experience of the Fire and Rescue Services (FRS) when actually tacking waste fires. In brief, for some parameters the laboratory type testing was missing some factor or factors relevant to actual large-scale waste fires.

In 2016 larger-scale waste burn trials were conducted at sites in Yorkshire and Essex (the phase 2 tests). These tests involved much larger volumes of waste and aimed to replicate as closely as practical 'real life' waste fires. The results of these tests matched much more closely the experience of the FRS when fighting real waste fires and revealed some of the different mechanisms at play during waste fires. Both phase 1 and phase 2 tests were conducted on a variety of wastes such as loose and baled wastes, plastics, paper and board, rubber, wood wastes, waste derived fuels such as RDF and SRF and others.

These phase 1 and 2 tests provided a much better understanding of how wastes burn, and firmer fire science on which to base guidance on issues such as waste storage stack separation distances. The tests also provided useful additional information, such as on the interlacing of stored waste bales as a potential method of reducing chimney effects. The results of the phase 1 and 2 tests were used in part as the basis for the revision of the 2014 WISH guidance. Revised WISH guidance including the outputs from the phase 1 and 2 tests was issued in April 2017. To accompany this revised 2017 WISH guidance a non-technical summary of the phase 1 and 2 tests was also released.

However, the phase 1 and 2 tests did not provide all of the information required. It was always anticipated that a phase 3 series of tests would be required, in particular to test the effectiveness of different fire-fighting techniques and media on waste fires. These phase 3 tests were conducted at the National Fire Training College in Gloucestershire in late 2017.

Above: General views from phase 1 and phase 2 waste burn tests.

2. Phase 1, 2 and 3 tests and methods used

As noted above, the waste burn trials were conducted in three phases:

- **Phase 1:** Smaller scale laboratory type waste burns, conducted at the FPA (Fire Protection Association) research facility in Gloucestershire
- **Phase 2:** Larger scale waste burns tests, conducted at Pollington in Yorkshire and Barling in Essex
- **Phase 3:** Specific tests aimed primarily at testing the effectiveness of different fire-fighting techniques and media, conducted at the National Fire Training College

Phase 1: Smaller scale laboratory type tests

Nine types of waste were tested:

1. Baled cardboard
2. Baled LDPE plastic
3. Baled HDPE plastic
4. Baled RDF (refuse derived fuel)
5. Baled SRF (solid recovered fuel)
6. Loose tyre crumb
7. Loose screened wood chip
8. Loose pre-crush wood
9. Loose wood fines

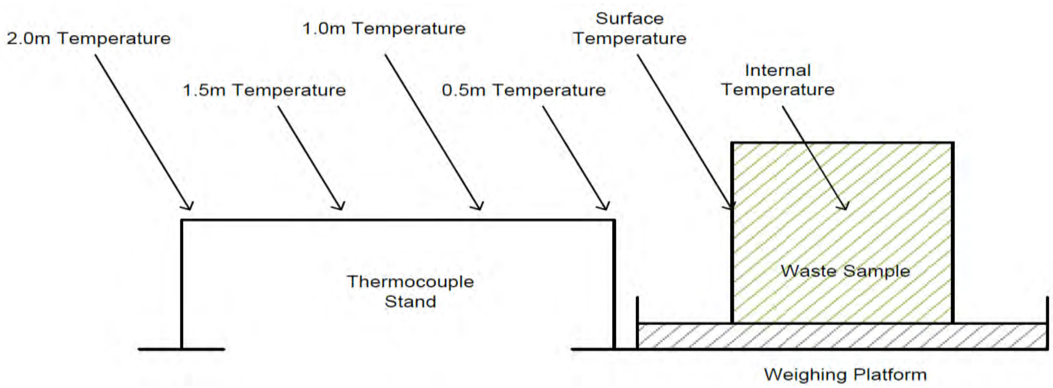
Sample size varied from 42 kg to 1,350 kg. This being largely conditioned by the configuration of the wastes tested: Bales of waste were impractical to split and would have defeated the object of the tests on baled wastes, representing the top end of these weights. Loose wastes represent the lower end. Loose wastes were contained in a mesh ‘cage’ for the purposes of testing. Bales were burnt whole.

All samples were burnt on the same test rig. This rig included load cells to allow weight loss during burning to be measured, thermocouples to measure temperatures within the waste sample and at the surface, and heat sensors at various distances from the samples.

A diagram of the test rig is shown below. Ignition of the samples was via the use of domestic firelighters, supplemented in some cases by the use of petrol as an accelerant (some wastes proved difficult to ignite). Samples were not allowed to 'burn-out' but rather were extinguished once steady state burning had been achieved.

Heat flux sensors were used to measure heat outputs, and fumes emitted during tests were captured via a 'smoke hood' allowing measurement of carbon monoxide concentration. A summary of the findings from the smaller scale tests is given in section 4.

Diagram 1: Test rig used in smaller scale tests



Phase 2: Larger scale tests

The larger scale phase 2 tests were aimed at replicating actual conditions experienced during waste fires. Thirteen waste types were tested:

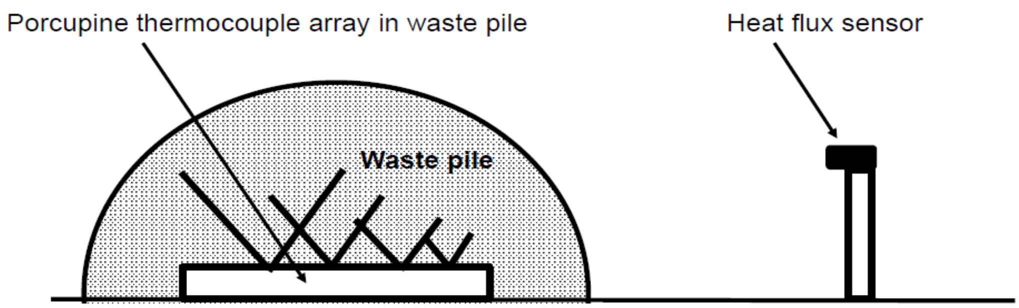
1. Loose untreated (raw) wood waste
2. Loose un-screened pre-crushed wood
3. Loose screened pre-crush wood
4. Loose wood fines
5. Loose RDF (refuse derived fuel)
6. Baled RDF (refuse derived fuel)
7. Loose SRF (solid recovered fuel)
8. Baled SRF (solid recovered fuel)
9. Baled high-density plastic
10. Baled low-density plastic

11. Baled paper and card
12. Loose frag fluff (plastics, foams etc from dismantling of end-of-life vehicles)
13. Shredded rubber (tyre)

The phase 2 tests were conducted externally (in the open-air). This was the only practical option but did result in restrictions associated with preventing environmental nuisance.

For loose pile waste burns a thermocouple array (the ‘porcupine’) was embedded in the waste piles allowing temperature measurement at varying depths through the pile. This was obviously not possible with baled waste burns. Temperature measurement at the surface using external sensors was conducted for all burns.

Diagram 2: Test arrangement used in larger scale tests on loose waste pile stacks



Ignition for surface (outside-in) burns was via use of a ‘blow-torch’, or in some cases for bales domestic firelighters. Ignition for deep (inside-out) burns was via domestic firelighters introduced to the centre of piles. Unlike the smaller scale phase 1 tests, wastes were allowed to ‘burn-out’, with the exception of loose plastics, which emitted large volumes of black smoke and was extinguished before burn-out occurred.

Weight of waste burnt varied, for the same reasons as above for the smaller scale tests. Maximum weight in any one burn was circa 10 tonnes. Multiple burns on some waste types were used to check test methods and repeatability. The most burnt wastes being pre-crushed wood waste and RDF. A summary of the findings from larger scale tests is given below.

Phase 3: Fire-fighting tests

The primary aim of these tests was to determine the effectiveness of different fire-fighting techniques and media on waste fires. Much of the value of these tests accrues to the Fire and Rescue Services (FRS), and is not of primary, direct interest to waste operators.

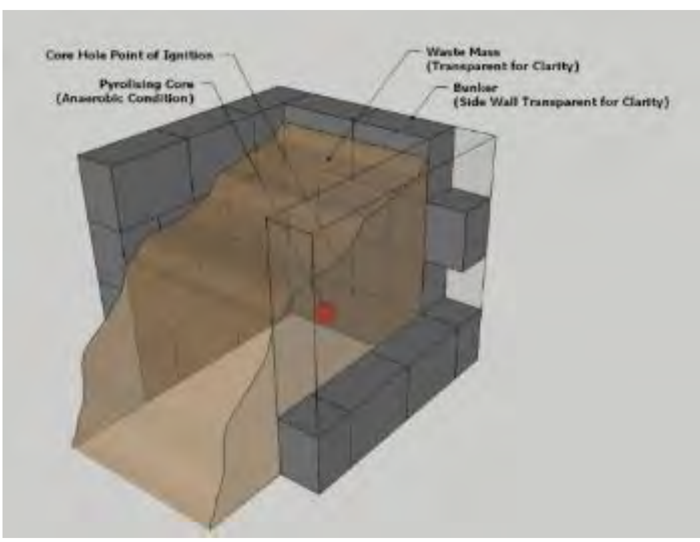
The phase 3 tests took place at the National Fire Training College in Gloucestershire. Different fire-fighting techniques, such as where hose streams are aimed at, were tested, and different fire-fighting media, in particular:

1. Water (by far the most common media used against waste fires)
2. Foams ('CAFs') as an alternative to the use of water on its own
3. Water + wetting agent, aimed at reducing surface tension and enhancing water penetration into wastes which are on fire

While the phase 3 tests were primarily aimed at fire-fighting, the opportunity was also taken to clarify and confirm some of the results of the phase 1 and 2 tests, in particular:

1. Effectiveness of interlocking block walls and bunkers against fire spread
2. Practical test of the modelled free-air separation distances from phase 2

Diagram 3: General arrangement of bunker tests



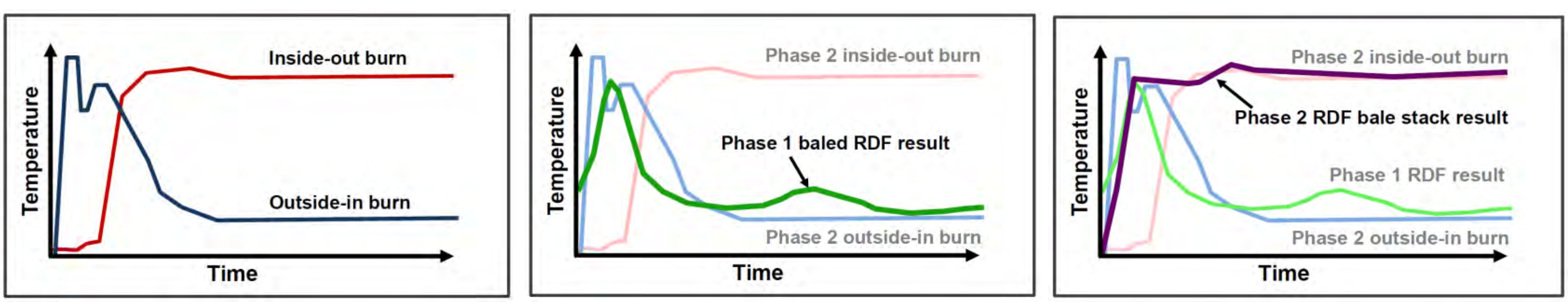
3. Summary of findings phases 1 and 2

Note: All of the graphs in this section are indicative only. They are aggregates or examples from data from the various waste burn tests conducted. Lines on the graphs are relative to each other, but no units have been given on axis scales (see text). Please note in particular than vertical axis scales have been set to allow best presentation of the data. The graphs are illustrative and provided for ease of understanding rather than as absolute data.

3.1 Overview

The primary aim of the phase 1 and 2 waste burn trials was to provide underpinning science on which to base waste stack separation distances for the 2017 revision of the WISH fire guidance. The original 2014 guidance distances having been based typically, and in common with much other similar guidance, on non-waste data. However, other outcomes were expected to be of benefit to current knowledge on how wastes burn. This summary simply presents the results of the tests without interpretation or indication of their application. The use of these results will be in their application over time.

The smaller scale phase 1 tests provided much useful data. However, they often did not reflect Fire and Rescue Services (FRS) experience of real-life waste fires. It became obvious during the tests that the phase 1 trials were sometimes missing one or more factors at play in real-life waste fires. The phase 2 larger scale tests aimed to rectify this by replicating as closely as practical the conditions of real-life waste fires.



Some of the graphs used in this section are 'sequential' with following graphs showing lines from previous graphs as tints. This is for illustrative purposes and to allow an easier view of the information in the text of this section

3.2 Burn mechanisms and other factors

Industry and Fire and Rescue Services (FRS) experience is that waste fires often do not behave in the same manner as fires in other materials. With loose waste stacks/piles, sometimes a smouldering, slow fire with fairly low heat outputs occurs, while in other cases fires in loose waste stacks are energetic with higher heat outputs. For baled waste stacks rapid spread of fire is often noted across the stack, and fires are typically energetic and have high heat outputs. One desired outcome of the waste burn trials was to try and explain these differences, and why they occur.

Baled wastes phase 1 smaller scale tests

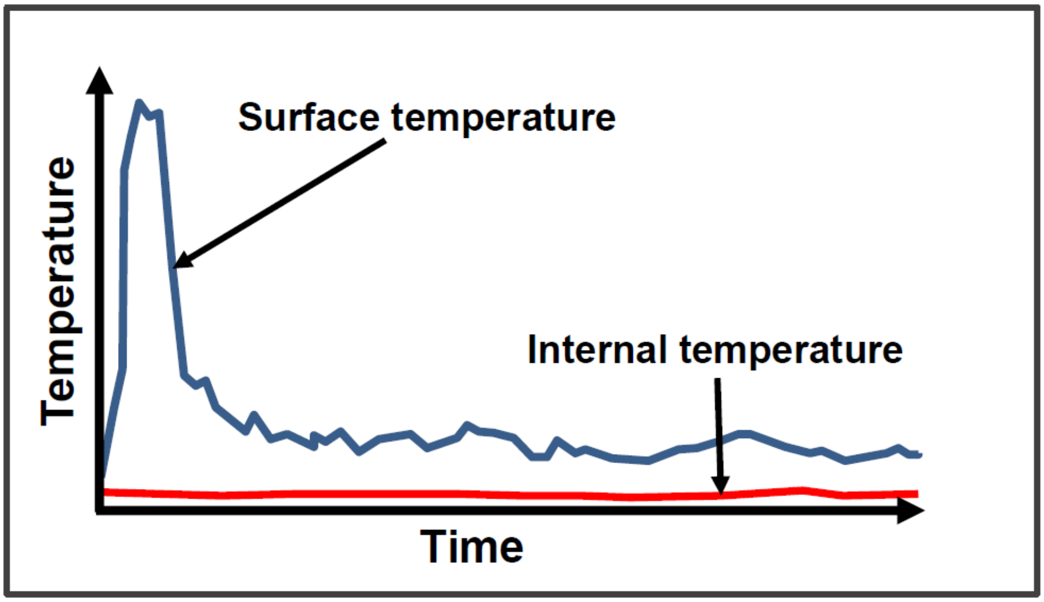
For baled wastes during the smaller scale phase 1 laboratory type tests the typical pattern observed for fire development was: Initiation of the fire followed by a rise in surface temperature once the fire ‘caught’. However, after a fairly short period of time surface temperature then fell to a steady state burn at lower temperatures than expected, and lower than often experienced by the FRS when tackling real-life waste bale stack fires.

Fire penetration into the baled waste samples was not high, likely partially the result of poor air-flow within the bale and relatively high density. In addition, typically a ‘char’ layer formed on the surface of the bale restricting fire penetration, and so access for the fire to new fuel. This is illustrated by the differences observed between surface and internal temperatures in baled wastes during the phase 1 burns (see example of baled SRF in graph 1 below). Examination of bale samples post-burn also showed ‘charring’ at the surface, but little or no fire penetration into the bale.

As an observation from the baled waste tests, many bales were difficult to ignite requiring substantive heat inputs before a fire occurred. This would tend to mitigate against casual arson as a major cause of fires in baled wastes – a determined attack is likely required.

From left: Baled RDF pre-burn, baled LDPE plastic pre-burn, during burn and post-burn (note bale post-burn showing relative lack of fire penetration leaving the bale largely unburnt)

Graph 1: Phase 1 illustrative baled SRF burn internal and surface temperatures



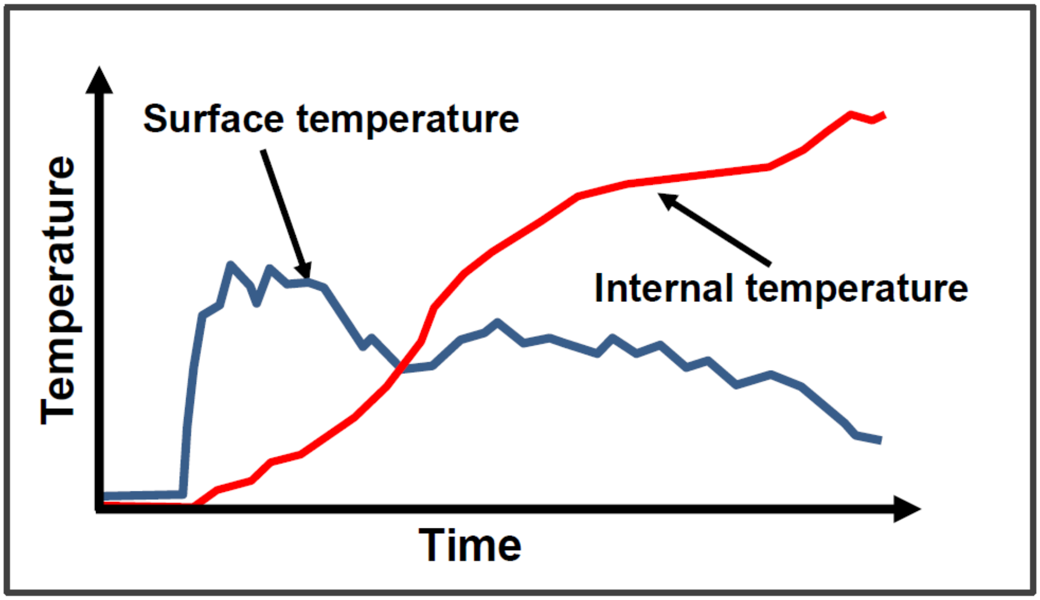
Loose wastes phase 1 smaller scale tests

Conversely, for most loose wastes a different pattern was observed: As for baled wastes, surface temperature rose rapidly once the fire 'caught', but surface temperatures remained higher, and internal temperature also rose (see graph 2 loose pre-crush wood).

The lower densities and more open structure in the smaller loose waste samples in phase 1 laboratory type tests seems to have allowed more air-flow into the waste, better fire penetration and a 'cleaner' burn. As for baled waste phase 1 burns, this is often not the experience of the FRS when tackling actual loose waste storage stacks where 'smouldering' type burns have been noted. Unlike baled wastes, examination of most smaller loose waste samples post-burn during the phase 1 tests revealed much more complete combustion, with little unburnt waste.

From left: Loose pre-crush wood waste pre-burn (note retained in mesh 'cage'), in initial phases of burn, during steady state burn and post-burn (note much more complete combustion than for baled wastes)

Graph 2: Phase 1 illustrative loose pre-crush wood internal and surface temperatures



Issues with phase 1 smaller scale tests

As noted in section 3, the weight of samples used in phase 1 varied significantly (42 kg to 1,350 kg). Using the examples of pre-crush wood and baled SRF as above, approximate densities of samples were: Baled SRF 0.5 tonnes/m^3, and for pre-crush wood 0.14 tonnes/m^3. In addition, the more open structure of larger sized loose wastes, with typically more ‘rigid’ particles, allowed more air-spaces in the sample promoting a more complete burn.

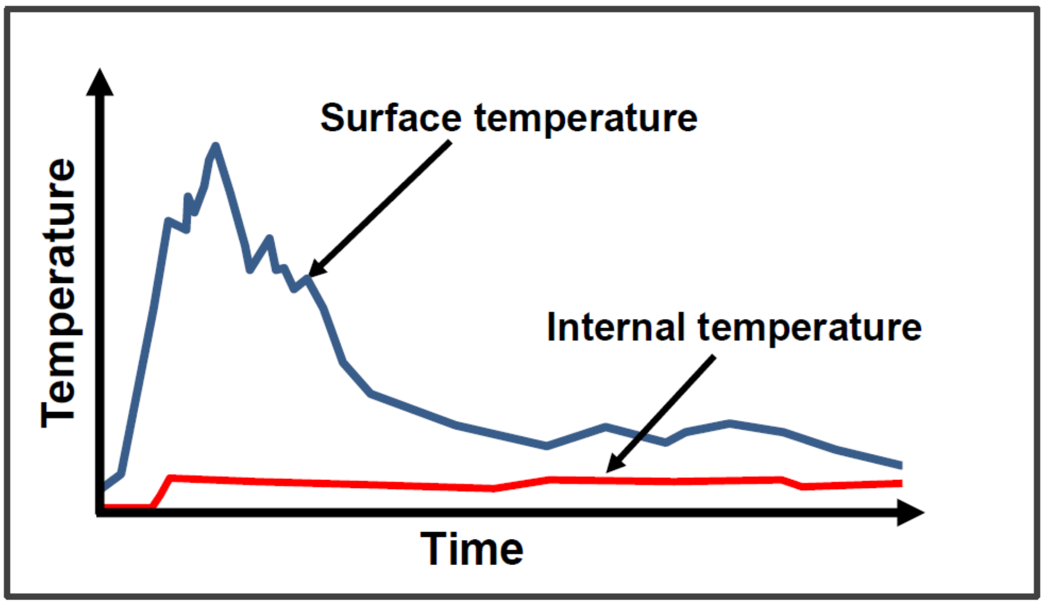
For baled wastes densities are realistic – they are as presented in baled wastes. For loose wastes the smaller sample size results in densities which do not completely replicate real-life storage conditions: Loose wastes stored in real life will compact to a degree under their own weight because of the qualities stored. In addition, any air spaces may be degraded. These factors were missing in the phase 1 tests (although see below on raw wood and other very large particle size wastes, which may not compact as much).

Issues such as sample size and an inability to replicate real-life during laboratory tests are not that unusual. For example, and while outside of the waste burn trials conducted in 2015 and 2016, laboratory tests to determine any self-heating properties for various waste types suffer from the same effect: The densities and sample size which can practically be achieved during small scale laboratory testing do not replicate real-life, and the results of such small scale laboratory tests need to be viewed with caution.

Phase 2 loose waste larger scale tests and checking scalability

To check the scalability of phase 1 tests on loose wastes, one of the first tests conducted in phase 2 was a large-scale loose pre-crush wood stack burn. This large-scale test provided different results to the small-scale laboratory type test on the same waste type (see graph 3 below). The pattern shown being more like that for baled wastes than for the small-scale loose waste tests conducted in phase 1, although less distinct than for baled waste.

Graph 3: Phase 2 illustrative large scale burn loose pre-crush wood



Also, as for baled wastes a 'char' layer formed at the surface of the pile on most of the larger loose waste storage piles, restricting fire penetration, and resulting in a more prolonged 'smouldering' type burn once the initial phase of burn had declined. This pattern replicates more closely typical FRS experience when tackling some loose waste pile fires.

This is not to say that the results obtained from phase 1 smaller scale burn tests are not useful. However, because of scalability issues some of the results need to be treated with caution as they may not replicate real-life.

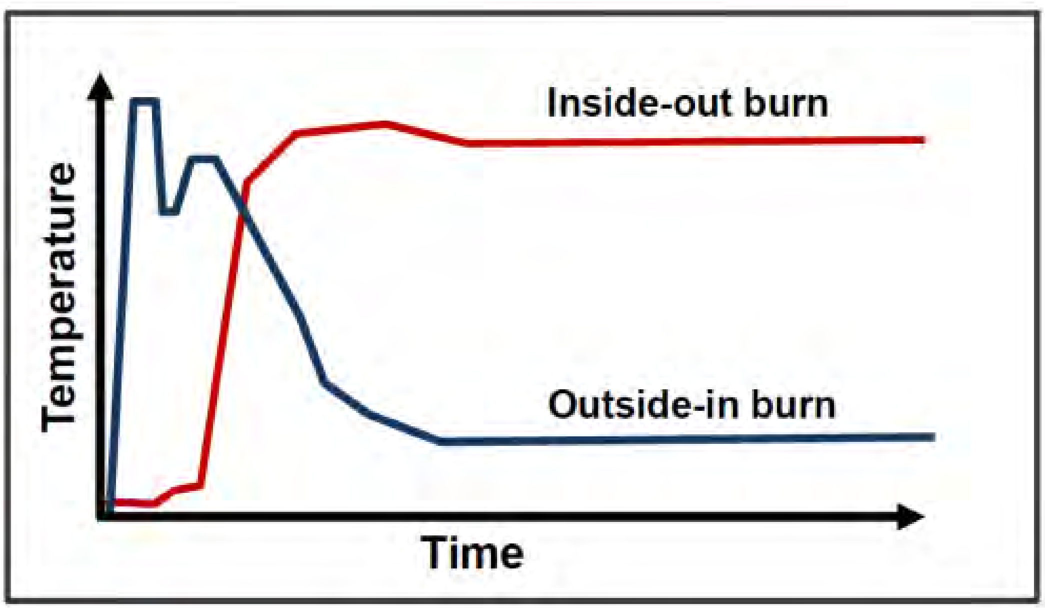
'Inside-out' and 'outside-in' mechanisms with loose waste stacks

All of the burns conducted during phase 1 smaller scale tests and the above loose pile larger scale burns were ignited at the surface of the pile or bale. This replicates some of the known causes of waste fires, such as discarded smoking materials, arson, direct heat, hot-works, open flames etc. However, not all waste fires start at the surface.

A significant number of waste fires start within the waste stack, such as from self-heating or hot/hazardous items buried in the waste. In particular, for loose waste stacks/piles such causes are significant (see below for baled wastes).

To replicate such 'inside-out' burns during phase 2 tests on loose waste stacks domestic firelighters were used, placed down a tube leading to the centre of a loose waste stack, and the tube then sealed to prevent air ingress. This resulted in quite different results than those identified during 'outside-in' burns where ignition is at the surface of a loose waste stack (see typical outside-in and inside-out burn results in graph 4 below).

Graph 4: Illustrative loose waste stack outside-in and inside-out burn temperatures



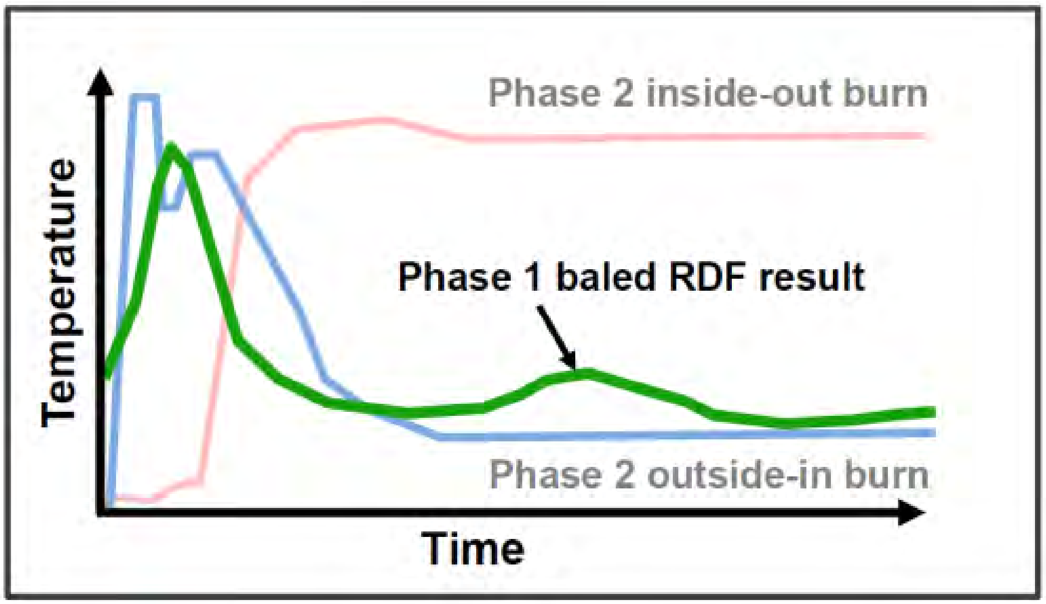
During inside-out burn tests fires took longer to develop. Probes within the loose waste stacks (the 'porcupine') show the build-up of a 'super-heated' bed within the waste stack. This slowly burns outwards, and then breaches the surface as a fully developed and energetic fire. This inside-out mechanism results in sustained higher temperatures, rather than the dying-back of temperatures observed during loose waste stack outside-in fires.

These two mechanisms for loose waste storage stacks (inside-out and outside-in) agree with FRS experience of fighting actual loose waste stack fires. In some cases, a smouldering type fire is experienced (outside-in mechanism), whereas in other cases a vigorous and energetic fire is experienced (inside-out mechanism).

Phase 2 larger scale baled waste stack tests and 'chimney' effects

As stated above, the results obtained from phase 1 smaller scale tests for baled wastes do not reflect FRS experience when fighting real baled waste stack fires. In general, the results of phase 1 testing on baled wastes show a burn pattern similar to an outside-in fire with loose wastes (see graph 5 below). This type of 'smouldering' fire is not what is typically experienced in real-life with baled waste storage stacks, where the typical experience is of intense and energetic fires with sustained high heat outputs.

Graph 5: Illustrative outside-in and inside-out burn temperatures compared with an example smaller scale baled waste test result



Inside-out burns are relevant to bales of waste, but there are problems with this inside-out mechanism. Self-heating for some waste type bales, such as SRF and RDF, is an issue, but is likely to be less so for other waste types such as bales of plastics. Inside-out fires caused by hot/hazardous items in wastes is also less of an issue for baled wastes. Baled wastes are typically made of processed wastes, such as having been sorted by mechanical and/or manual means. Hot/hazardous items are more likely to have been removed during such processing (this may not be the case all of the time for some waste types such as 'crude' RDF which has not had extensive processing applied).

In addition, an inside-out burn in a bale would not account for the rapid and energetic spread of a fire across a baled waste storage stack, as is often observed in real-life.

Part of the phase 2 tests on multiple bales in a storage stack was to identify any mechanism not identified by the phase 1 tests on single bales which may be at work to produce the intense fires and rapid spread of fire often experienced by the FRS when tackling waste bale storage stack fires.

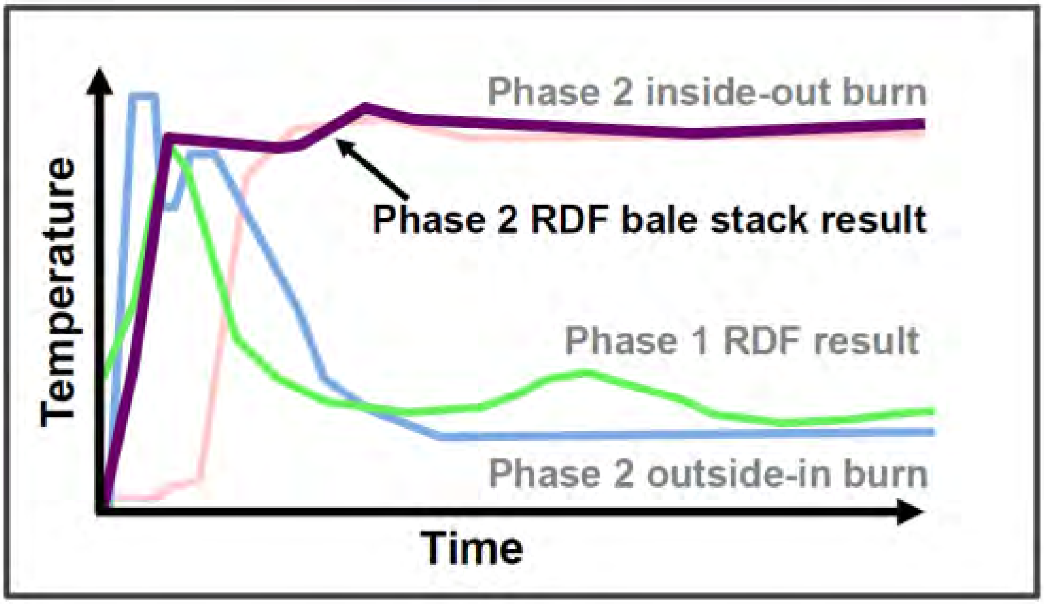
The phase 2 larger scale bale burn tests used 'simulated' baled waste storage stacks containing multiple bales. It was not practical to build stacks containing 100s of bales. For most phase 2 baled waste tests six bales were used, arranged as two columns. These were placed against a concrete bunker wall to replicate a wider stack, and for safety reasons related to stack collapse risks.

Ignition of the phase 2 larger scale bale waste fire tests was at the surface of the waste, as for phase 1 tests. Initially the fire progressed as for phase 1: Temperature rose, and a 'char' layer started forming reducing the fire's ability to access new fuel, until the fire reached the vertical gaps between the bales. At this point energetic air-flows (chimney type effects) were produced in these vertical gaps resulting in accelerated fire growth and an energetic burn which was sustained. Fire at these gaps was energetic enough to 'strip' any char layer from bales allowing the fire to access new fuel more readily. As a measure of how energetic the burns were fire 'vortices' were observed at the tops of vertical gaps between bales and between bales and supporting bunker walls (see photographs below).

Graph 6 below shows surface temperatures over time during phase 2 baled waste tests using RDF bales as an example. Compared to the phase 1 tests for the same waste, the larger scale phase 2 tests identified a much more energetic burn with higher temperatures sustained throughout the burn.

From left: Development of fire vortex behaviour during bale burn tests, visible fire vortex at top of gap between bales during bale tests, development of fire spread in gaps between bales, leading rapidly to a fully developed fire (see bale comments above)

Graph 6: Illustrative comparison with bale stack burn test temperatures



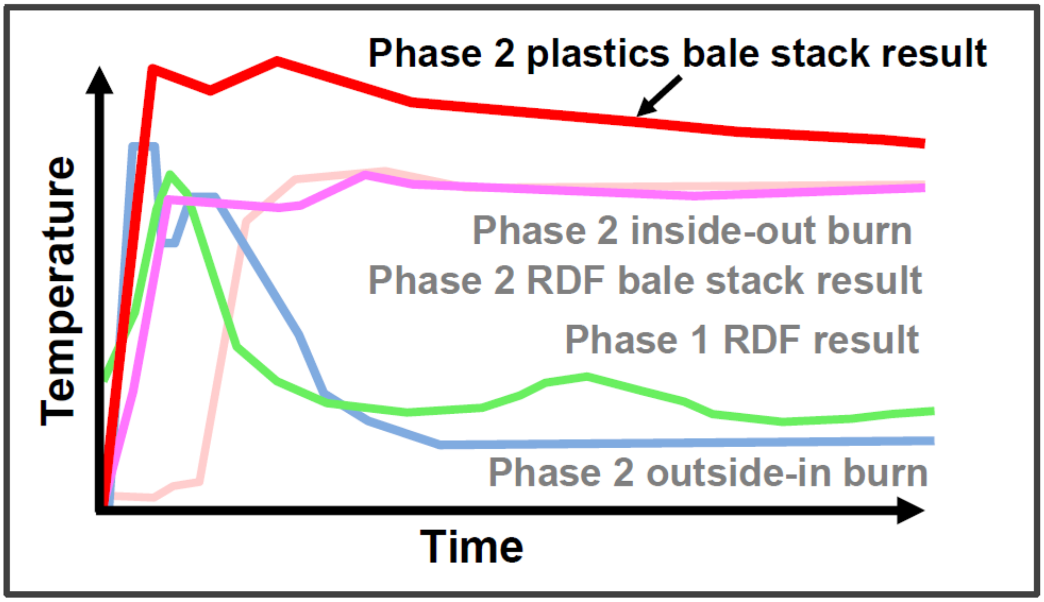
These chimney effects seem to be the likely cause of the energetic and sustained fires with rapid fire spread across baled waste stacks often experienced by the FRS when fighting baled waste stack fires.

Phase 2 baled waste tests burn temperature differences

Burn temperatures are discussed in more detail below. However, it is worth noting the results of the phase 2 baled waste tests on baled plastics. As for other baled stack tests the fire accelerated once it reached the vertical ‘chimneys’ between bales. In the case of baled plastics, temperatures rose to 1,200 degrees centigrade, or higher (the sensors used were calibrated to 1,200 degrees). These high temperatures were sustained and resulted in a melted data-logger and blistered paint on a porta-cabin located 25 metres away from the fire.

From left: HDPE bale burn during phase 1 smaller scale tests, and same post-burn showing relatively intact bale. Compared to larger scale simulated plastics waste bale stack burns

Graph 7: Illustrative comparison between plastics and other typical other wastes during bale stack burn tests



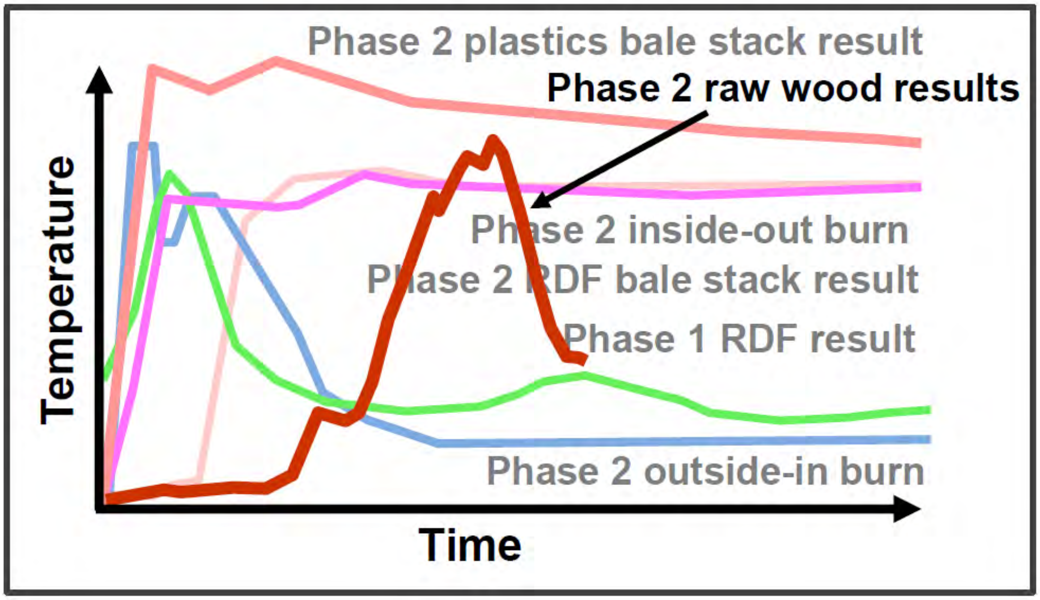
These results largely support FRS experience during fire-fighting of plastic waste bale stacks where temperatures were such that access to fight the fire was, at best, problematic.

Large particle size, 'rigid' waste types in loose piles

One exception to the above inside-out, out-side in and bale stack test results was raw wood waste. This waste type comprises larger particle size items, such as parts of pallets, discarded furniture and similar. In addition to be larger, these particles are also rigid and less prone to compaction when placed in a loose waste storage stack/pile.

Smaller particle size wood wastes (approximately 25 mm – 60 mm particle size), exhibit observed air-gaps when stacked of less than 10 mm. In the case of these smaller particle sized wood wastes fire penetration was limited to 50 mm – 150 mm before a smouldering burn set-in. This was not the case with larger particle sizes such as in raw wood waste where air gaps were larger, allowing fire penetration to the interior of the pile. Peak temperatures during burns of these larger particle size wastes were achieved and sustained as a steady state burn, the decay of which was linked to the available fuel being exhausted. In brief, the burn was similar to what would be expected from a 'bonfire'. This different burn progress is shown in graph 8 below, compared to other burns.

Graph 8: Illustrative comparison with raw wood (large particle size)



Raw wood is not the only larger particle size waste with rigid particles. Bulky hard plastics wastes (such as from discarded garden furniture, plastic pipes and larger children's toys) and whole tyres also have large particle sizes and are fairly rigid. These waste types were not tested, and direct comparisons cannot be made. However, industry knowledge is that bulky plastic wastes have been involved in serious and energetic fires.

3.3 Burn temperatures

Various factors, such as the mechanisms outlined above, affect the burn temperature of wastes. For external stacks weather can also have a role to play, such as wind direction and strength. In practical terms there is no realistic method to 'choose' the type of waste fire which may occur, or what weather conditions may be if a fire occurs. The typical or 'realistic' worst case scenario needs to be used.

For many of the types of waste tested maximum burn temperatures occurred in a roughly 100-degree window, between 840^{0}C and 950^{0}C. There was then a roughly 200-degree gap to the maximum burn temperatures of plastic and rubber wastes (1,127^{0}C to 1,200^{0}C). Please note that at the top-end this maximum of 1,200^{0}C may have been more as the heat sensors used were only calibrated to 1,200^{0}C. Taking account of the variability in wastes and how they are presented and the test results, in practical terms this allows wastes to be placed into two 'bands' for the purposes of calculations for issues such as stack separation distances.

Table 1 below shows maximum burn temperatures for the various wastes tested. The shading applied indicates the two rough bands as described above.

Table 1: Summary burn temperatures for different waste types

Waste type	Surface temperature (typical maximum)
Pre-crush wood waste (un-screened)	840^{0}C
Raw wood waste	850^{0}C
Paper/ card baled	850^{0}c
Pre-crush wood waste (screened)	860^{0}C
Refuse derived fuel (RDF) loose	900^{0}C
Refuse derived fuel (RDF) baled	900^{0}C
Solid recovered fuel (SRF) loose	950^{0}C
Solid recovered fuel (SRF) baled	950^{0}C
Shredded rubber	1,127^{0}C
Plastic HD baled	1,200^{0}C
Plastic LD baled	1,200^{0}C

Note: Some wastes, such as RDF and pre-crush wood, data based on multiple burn tests, whereas for others based on a lower number of burns. Temperatures should be treated as summary – various factors can affect as noted above.

Subject to the information provided by the waste burn tests on various the burn mechanisms and factors outlined above, these results are perhaps not surprising. Some waste types are ‘single stream’ such as wood and paper wastes. These are likely to burn in a similar manner to raw materials of the same type, if presented in the same form and configuration and subject to the same burn mechanisms as their waste counterparts. Other wastes are mixtures, such as RDF and SRF. Also subject to form and configuration and burn mechanism considerations, the results above align with systems such as the commodity class system on which sprinkler and similar equipment specifications are based (at its upper end this commodity class system is largely based on the amount of specified plastics in a material).

3.4 Mass loss/burn rate

During the smaller scale phase 1 tests the rate of mass loss during burns was measured via load cells underneath the test rig on which wastes were placed. This was not practical for the larger scale phase 2 tests. Mass loss during phase 1 burn tests was measured during the initial stages of burning, at steady state burn and peak burn. These mass loss results from phase 1 are summarised in table 2 below.

Table 2: Summary rate of mass loss data from phase 1 smaller scale tests

Waste type	Rate of mass loss (grammes/second)		
	Initial burning	Steady state burning	Peak burn rate
Baled cardboard	59.5	3.5	63.3
Baled LDPE plastic	87.3	NA*	184.3
Baled HDPE plastic	39.0	66.4	106.9
Baled RDF (refuse derived fuel)	32.8	12.8	33.6
Baled SRF (solid recovered fuel)	20.2	10.7	37.7
Loose tyre crumb	17.6	5.7	17.6
Loose screened wood chip	6.2	2.8	10.9
Loose pre-crush wood	32.1	3.5	32.6
Loose wood fines	5.3	0.5	8.3

** NA. LDPE extinguished early as a result of the ferocity of burn for safety reasons*

Ignoring the very low steady state mass loss for wood fines, lowest mass loss rate was 2.8 grammes/second (loose screened wood chip at steady state burn), and highest 184.3 grammes/second (baled LDPE at peak burn). In more practical terms, these lower and upper figures being 0.01 tonnes per hour, and 0.66 tonnes per hour respectively. All of these results were obtained from tests involving the surface ignition of wastes and do not account for some of the burn mechanisms outlined above.

As noted above, in many respects the smaller scale burn tests did not replicate fully Fire and Rescue Services (FRS) experience of real waste fires, or in some cases the results of the larger scale phase 2 burn tests. However, the mass losses noted at peak burn temperatures obtained during the smaller scale tests indicate that for many wastes burn-out times are likely to be extended. There are variables here, and the data cannot be directly applied to real life waste fires, but it does give an indication.

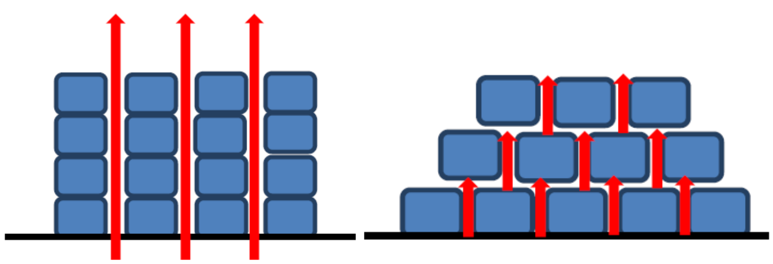
This may have implications if a 'controlled burn' strategy is pursued by the FRS, such as for reasons of reducing potential contaminated fire-water run-off. Even for smaller waste storage stacks, burn-out times are likely to be measured in days rather than hours.

3.5 Other findings: Interlacing bales and carbon monoxide

The above represents the main outcome of the waste burn trials. However, two other outcomes are worth noting:

Interlacing of bales to reduce chimney effects

As noted above chimney effects during the larger scale burns on baled wastes are a significant factor in fire spread and how energetic a waste stack burn will be. This prompted consideration of alternative bale stack configurations which may reduce these chimney effects. For one burn test bales were interlaced – placed as bricks in a wall rather than stacked vertically on top of each other. The aim being to break-up the vertical gaps.



Far left: Standard bale storage, and left: Interlaced bales. Red arrows indicate potential air flows

The results of this test revealed that once the fire was fully developed peak temperatures were not affected. As such interlacing bales would not, for example, be a reason for shorter separation distances between stacks aimed at reducing fire spread risk. What was affected was the rate of fire growth in its initial stages. Interlacing bales roughly doubled the time required for the fire to develop fully. This may allow a bale stack fire to be fought more effectively in its early stages, so preventing its development into a full fire. However, this was only one test and the results should be treated as indicative. Future waste burn tests aimed at proving this theory have been suggested.

Carbon monoxide (CO) emissions in phase 1 tests

The phase 1 smaller scale tests were conducted on a test rig, including an air extraction hood and system located over the rig. This allowed CO concentrations during burns to be measured using a flue-gas analyser. CO concentration is an indicator of inefficient combustion. The results obtained were generally as expected: Smouldering fires produced the highest CO concentrations, whereas ‘cleaner’ burns exhibited lower concentrations. However, as the phase 1 tests in many cases failed to replicate real-life waste fires there are few conclusions which can be applied to such real-life situations.

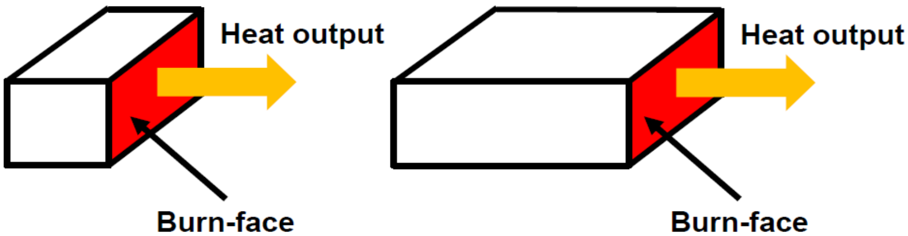
3.6 Application of phase 1 and 2 tests to WISH waste fires guidance

One of the primary aims of the phase 1 and 2 waste burn trials was to provide data from which waste storage stack separation distances information to reduce the risk of fire spread could be calculated. In this respect the trails were successful, and the separation distances information in the revised 2017 WISH waste fires guidance is based on the results of the tests. This was to address the acknowledged gaps/flaws in previous guidance which are often largely based on non-waste data.

The waste burn trials also aimed to provide data on which maximum stack sizes information could be based. In this respect the results were more mixed. Modelling using the data from the waste fire tests to determine stack separation distances did reveal that such distances seem to be relatively insensitive to overall stack size/volume. Two overall stack sizes were used in the modelling: A 450 m^3 stack and a 750 m^3 stack. The differences in modelled separation distances using these two stack sizes was less than 1 metre, and for all but one waste type less than 0.5 metres. This would indicate that overall stack volume is not a highly significant input to determining separation distance. This is not to say that stack size is irrelevant to fire management, only that overall volume does not seem to affect separation distance significantly.

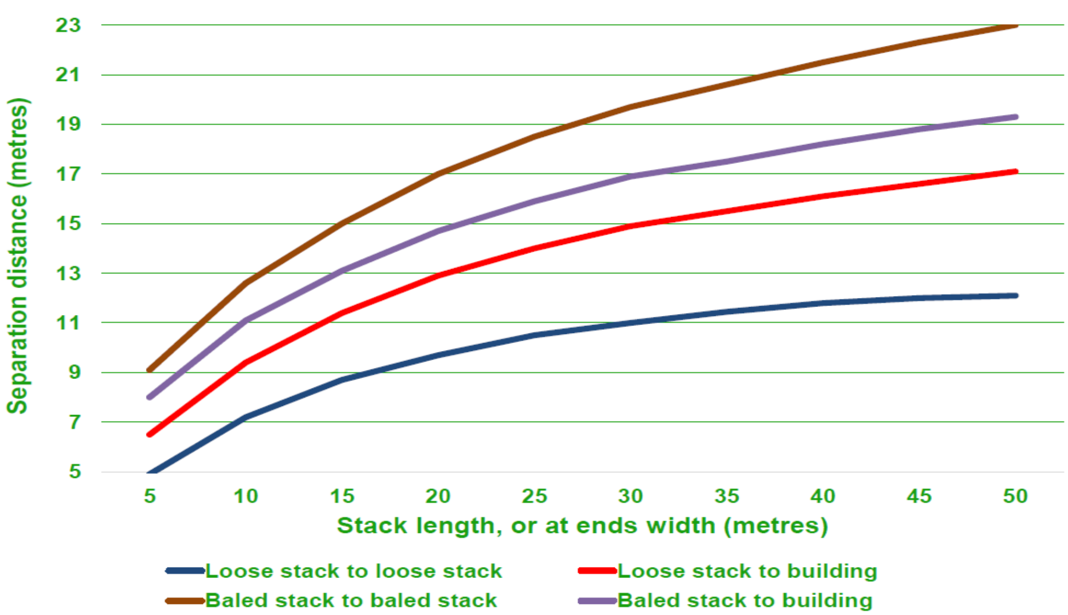
However, modelling of the results did indicate that stack configuration, or more accurately stack length and ‘burn-face’ area, did have a significant effect on separation distance. When a stack of waste is on fire it will emit heat. If the separation distance between the stack and another combustible object is insufficient then this heat may cause the second object to ignite. However, the amount of heat emitted in any one direction will depend on the dimensions of the ‘burn-face’ of the stack facing the second object, and not primarily its overall volume.

The diagram below illustrates this. The two waste stacks shown are of different volumes, but the burn-faces are the same dimension, and the heat output (represented by the amber arrows) in any one direction will likewise be largely the same.



Separation distance is largely a function of the amount of heat emitted per unit of area of a burn-face, and the dimensions of the burn-face. As noted above, wastes can practically be split into two categories: General wastes such as wood, paper, RDF etc which exhibit maximum burn temperatures of some 850 - 950 degrees centigrade and plastics and rubber wastes with temperatures of up to some 1,200 degrees centigrade. The revised 2017 WISH fires guidance provides a maximum stack height of 4 metres, for practical fire-fighting reasons. This leaves stack length as the variable to determine separation distance.

As a result of the above, the data from the waste burn trials can be modelled to provide separation distances as graphs showing a 'sliding scale' between stack length and separation distance. An example graph of this for general wastes (850 – 950 degrees' centigrade burn temperatures) is shown below.



To produce this modelling various assumptions needed to be made, such as angle of repose for loose waste stacks. A summary of these assumptions is given in appendix 1 of the 2017 revised WISH waste fires guidance.

Other results and outcomes of the phase 1 and 2 waste burn trials were also used in the revised 2017 WISH fires guidance, such as on interlacing bales in stacks as a potential method for reducing initial fire growth. As further fire research and testing is undertaken on wastes the outcomes will be included in future iterations of the WISH fires guidance.

General views of the phase 3 fire-fighting tests – see section 4 below for detail

4. Summary of findings phase 3

Note: All of the data and information given in this summary are averaged and summary based on multiple burns of wastes to ensure a reasonable level of consistency. As with all of the tests, the variability of wastes, weather conditions and similar mean that results should not be taken to the 'last decimal point'. However, they are indicative and from multiple tests.

Most of the detail results of the phase 3 tests were aimed at informing the Fire and Rescue Services (FRS) regards effective means of fighting waste fires. These results will be included in National Operational Guidance for fire brigades. However, the tests are also of interest to waste operators. The sections below give a summary of the tests, and points of interest to waste management site operators and other interested parties.

Note: Some or the information below is firmly aimed at the Fire and Rescue Services. It is **NOT** the intent of this section to encourage or inform waste operators on fire-fighting techniques for their own operatives. Fighting fires is a specialist area requiring training, specialised equipment and clothing, and experience – waste operatives should **ONLY** attempt to fight any fire if it is safe to do so.

4.1 Fire-fighting media and techniques

Two configurations of stored wastes were used in the phase 3 tests:

- Piled loose stacks of waste in interlocking block bunkers
- Baled waste tests in 'open-yard' conditions

These configurations were chosen to replicate as close as practical typical fire scenarios encountered by the Fire and Rescue Services (FRS) at real waste site fires.

Three types of fire-fighting media were tested on these two waste storage configurations:

- Water on its own
- Water plus wetting agent
- Wet class A CAFS (foam)

Piled loose waste tests in bunkers

Bunker bays were filled with circa 17 tonnes of RDF (refuse derived fuel) and ignited via lance inserted in a pipe to middle of the pile to simulate an 'inside-out' burn. Thermocouples to monitor internal temperatures were installed within the waste piles. Fire were allowed to breach the surface and develop, and then attacked with the three fire-fighting media. Not all inside-out fires developed fully during the tests, although test results and conclusions were not significantly affected by this.

Water: Use of water jets knocked the visible fire down but had little effect on the internal temperature recorded by thermocouples only 1 metre below surface of the piles. That is temperature within the piles was largely unaffected. From observation, penetration of water into the piles was only circa 0.2 metres, accounting for the lack of significant effect on below-the-surface temperatures. The application of copious amounts of water did not result in lower internal temperature – the water simply ran-off without significant effect, other than posing a potential environmental risk.

Foam: The use of foam also resulted in visible flame being knocked-down, but quicker than was the case with water. Sub-surface temperatures at 1 metre below surface level were more affected than with water. Foam also seemed more effective at preventing burn-back than water (that is flames knocked-down by the foam tended not to reappear).

Water plus wetting agent: As with water on its own, jets knocked the visible fire down. However, penetration into the waste was much better at 1 – 1.5 metres, and sub-surface temperature was even more affected than with foam, down to 2 metres below surface level. As with water on its own the application of copious amounts of water plus wetting agent did not result in any further reduction in internal temperature – the water plus wetting agent simply ran-off the pile with little or no further effect.

Re-ignition: Following the fire-fighting tests water plus wetting agent was 'injected' into the piles via the pipe used to ignite the wastes. This was continued until water was seem running out of the joints between the interlocking blocks of the bunkers and the internal temperature of the piles was at ambient. However, after some 12 hours, the internal temperature of the piles had risen again. In summary, the waste had re-ignited despite there being no external signs of a fire. Excavating the wastes and dousing them being the only effective method of preventing this re-ignition.

The results of these tests are of more direct use to the FRS. However, in summary:

- Water plus wetting agent proved the most effective, followed by foam, and then water on its own. However, in all cases penetration into the wastes was insufficient to fully extinguish the internal fire
- Continuing to apply water/foam/water plus wetting agent after visible flames had been extinguished provided no additional benefit, and poses the risk of environmental harm from contaminated water run-off
- Re-ignition of piled wastes is a significant risk, with excavation and dousing being the only practical method of extinguishing internal fires

Practical applications of the information above will require further consideration. For example, it may be of value for waste site operators to hold an IBC (intermediate bulk container) of wetting agent on site for use by the FRS in the event of a fire. Further consideration of this type of application is required before definitive advice can be given. Waste operators should consult with their local FRS on this aspect before taking any action.

It should be noted that the tests were on RDF, which has a relatively small particle size and is non-rigid – that is air spaces within the stack are negligible. The behaviour of the three media used is likely to be different with larger particle size and/or rigid wastes such as pre-crush or raw wood wastes, as media penetration into stacks of such wastes is likely to be much higher. These piles behave like a ‘bonfire’, of which the FRS has extensive experience already.

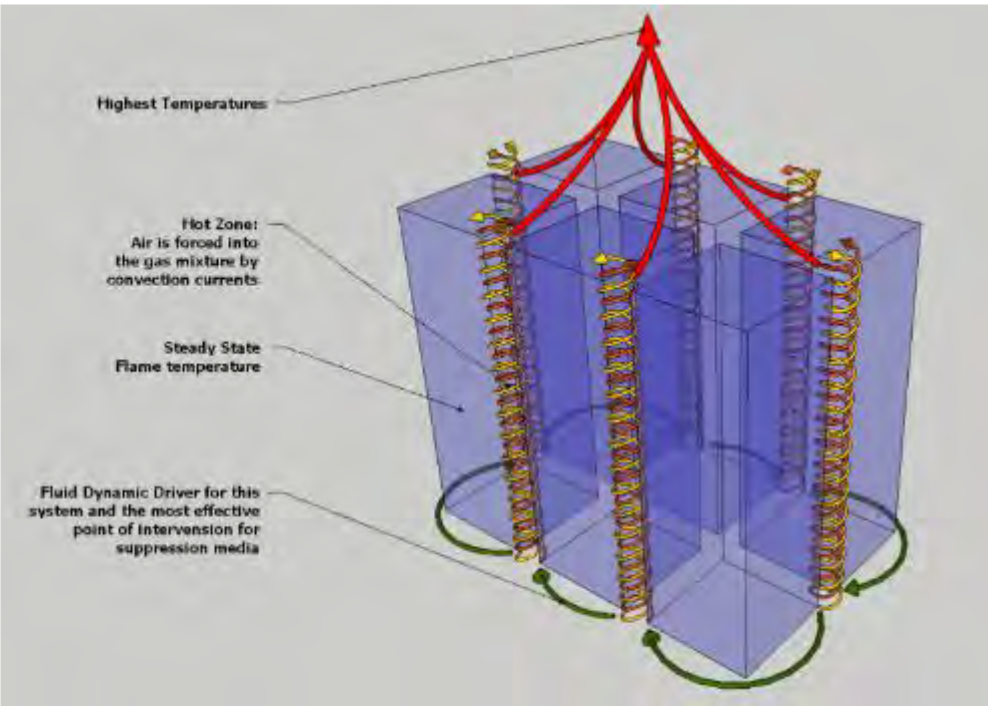
Note: While not tested, the use of inert materials such as soil or sand to ‘entomb’ a fire has been used effectively in the past on waste fires. However, this technique does not extinguish internal fires and gradual excavation and dousing would still remain the only practical option to extinguish a fire completely.

Baled waste tests

Mixed waste plastic bales were assembled into a ‘mini-stack’ three bales wide and long and three bales high (total of 27 bales). Waste plastics were used because of their higher burn temperatures (worst case scenario). Ignition was on the up-wind side of the bale stack producing an outside-in fire (inside-out fires are rare in bales because of their density). From ignition to full involvement of the stacks in the fires was less than 4 minutes.

As for the loose wastes in bunker tests, the three different fire-fighting media of water, foam and water plus wetting agent were then used to attempt to extinguish the fires. In addition, different fire-fighting techniques were used, such as directing jets from hoses into the gaps between bales and at the base of the fire. However, this type of information is likely of more use to the FRS than waste operators.

General arrangement of bales used in tests (only six bales shown)



Note: The diagram above incudes graphic representation of the chimney effects seen in baled waste fires, as discussed elsewhere in this report.

Water: Two 45 mm jets were applied to the fires (typical equipment used by the FRS when they first arrive at a site where a fire is occurring). Even after applying some 20,000 litres of water for 20 minutes the fire was not fully extinguished.

Foam: A class A wet solution CAF was used. This was significantly more effective than water and resulted in the fires being extinguished on average in 7 minutes. Run-off was also markedly less than for water on its own. However, it was also observed that the ‘throw’ of foam from hoses was less than for water, making fire-fighting more difficult.

Water plus wetting agent: Two 45 mm jets were used, as for water on its own. Water plus wetting agent proved the most effective with fires being extinguished in on average 2 minutes, and with the least run-off.

Summary table of baled waste tests

Media	Detail	Volume water used	Time to extinguish
Water	2 x 45 mm jets at 7 bar	20,000 litres	20 minutes (not extinguished)
Foam	Class A wet solution CAF, 2 x 128 litre/minute jets	1,800 litres	7 minutes
Water plus wetting agent	2 x 45 mm jets at 7 bar, with wetting agent at 0.3% by volume	1,800 litres	2 minutes

As for the loose waste in bunkers tests, water plus wetting agent proved the most effective fire-fighting media, with foam second and water on its own last. Further consideration is required to make detail comment, and most of the information gained in these tests will be of most direct use to the FRS.

It is worth discussing the potential use of wetting agents in fixed fire systems such as sprinklers and deluge systems. To an extent, the design of systems with spray heads, such as sprinklers and deluges, relies on water droplet size. Wetting agents work by reducing water surface tension, and this may result in smaller droplet size so changing the behaviour of a sprinkler or deluge system. In brief, the use of wetting agents in sprinklers, deluges and similar is not currently recommended, and further research in this area is required.

However, the use of wetting agents in oscillating and fixed water monitors may be a valid option. Monitors emulate the action of hoses and are not as reliant on droplet size. However, there are variables here and the advice of a competent fire engineer would need to be sought, and effectiveness may well vary dependent on the design specifics of any system. In brief, this is unlikely to be as simple as adding an IBC of wetting agent with a proportionating valve in the water supply to a monitor system.

4.2 Effectiveness of bunkers in reducing fire spread

It is common for wastes to be stored in three-sided bunkers. The walls of these bunkers may be solid concrete, block construction, steel plate or other. For solid concrete and steel (fabricated, not A frames and similar – see the 2017 WISH guidance for this type of bunker construction) there are existing standards. It should be obvious that railway sleepers and non-interlocking blocks with gaps are unlikely to offer adequate fire spread protection.

However, one of the most common forms of construction for bunkers is the use of interlocking concrete blocks. The effectiveness of this type of construction in preventing fire spread has been the topic of debate, although some suppliers have had their products tested.

Three waste types were used in these tests: RDF (refuse derived fuel), loose plastic wastes and wood waste. For some of the bunker walls the interlocking blocks were left ‘dry assembled’, for others proprietary intumescent sealant was applied between the blocks. The fires lit in these bunker tests varied in timescale, with some bunker walls being subjected to 48 hours plus of fire exposure. In summary of the results:

- In general, the interlocking block walls performed well. The outside walls of the bunkers exhibited little thermal transfer, remaining ‘cool’ (or at worst only warm) to the touch throughout the tests, and heat damage to the blocks was not substantive
- Smoke and heat were observed escaping from between the dry-assembled blocks. The risk of fire spread from such escape would depend what is on the other side of the bunker wall, its location and combustion properties
- The block walls sealed with intumescent sealant performed better than those dry-assembled, and the sealant was still intact after the fires. The use of intumescent sealant would seem a cheap and effective method of enhancing the effectiveness of interlocking block bunker walls regards restricting fire spread
- The 2017 WISH guidance includes that a 1 metre freeboard should be left between waste height and wall height. This is to account for flame height in a fire. During the tests, even with this 1 metre freeboard flames were observed to be drawn-up and lick-over the bunker walls. Similarly, to the case for small gaps in interlocking block walls, the impact on fire spread would depend on what is on the other side of the wall. However, it is impractical to build bunker walls of an infinite height, and greater freeboard would likely only draw the flames up higher. A 1 metre freeboard is not perfect, but does provide a significant reduction in fire spread risk

Note: The importance of considering what is on the other side of a bunker wall is critical. If what is on the other side of the wall is a free-air gap of sufficient distance or a non-combustible material then the protection any bunker wall needs to provide is lower than if a building, another stack of combustible wastes or similar is on the other side of the wall. This type of consideration should be part of site storage planning.

Summary table of interlocking block bunker tests

Material in bay	Duration	Max temperature	Comments
RDF (refuse derived fuel)	50 hours	400 – 500 °C	Slight heating through block, but still able to hold bare hand on the outside edge of blocks. Some flame penetration through gaps in blocks down wind of the fire
Loose plastic wastes	2 hours	1,100 °C	Slight heating through block, but still able to hold bare hand on the outside edge of blocks
Pre-crush wood	20 hours	950 °C	Post fire spalling of the inner face of block but remained stable

4.3 Practical test of separation distance

As described in section 3 of this report, the results of the phase 2 tests were used to model free-air separation distances required to prevent fire spread from thermal radiation and resulted in the separation distances noted in the 2017 WISH guidance. However, some readers of the WISH guidance have expressed a level of disbelief regards the often relatively wide separation distances included in the 2017 WISH guidance, compared to the separation distances included in some other documents on waste fires.

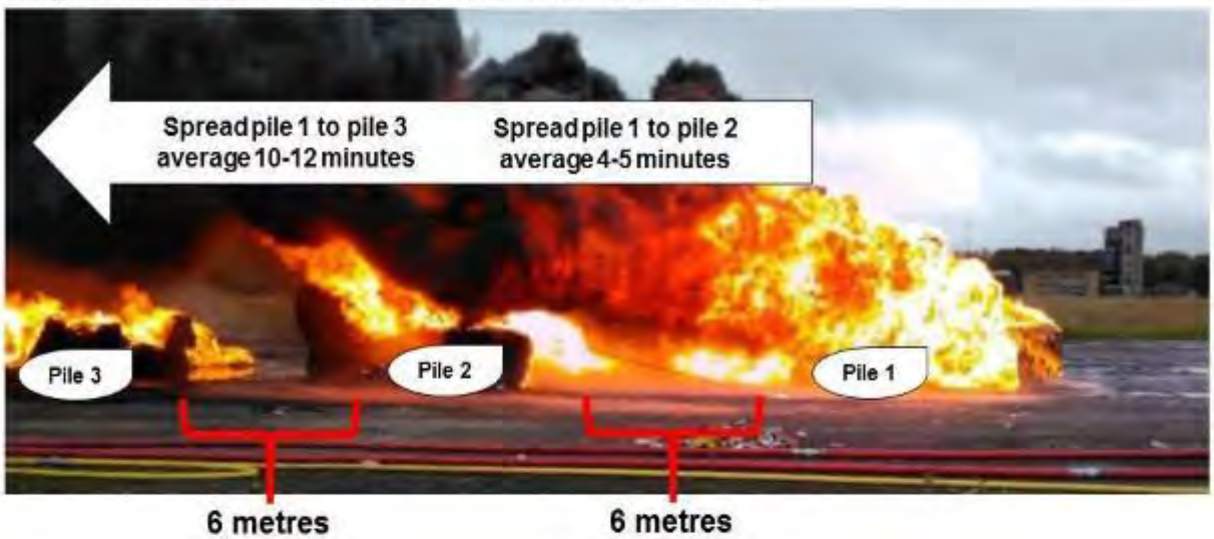
The opportunity was taken during the bale fire-fighting tests in the phase 3 tests to undertake an empirical test of separation distance. During these tests a main bale stack was constructed (as detailed above). Two further, smaller piles were also assembled, the first 6 metres from the first stack, and the second a further 6 metres away (see diagram below).

Fire spread between pile 1 and pile 2 occurred within 4-5 minutes, and all three piles were fully involved in the fire within 10-12 minutes. This test was repeated, with the same results.

Instinctively, the relatively wide separation distances in the 2017 WISH guidance may seem excessive, and the use of plastic wastes for the tests is a worst-case scenario because of their higher burn temperature. However, as these empirical tests indicate the WISH guidance distances are realistic. Certainly, relying on relatively narrow separation distances is unlikely to be effective in preventing fire spread.

Photograph with overlaid graphics of empirical test of separation distance

Photograph of actual tests. Note, bale stacks in partial collapse and extensive flames result in pre-burn distances not being clear in photograph. This test repeated four times to ensure consistency.



4.4 Other findings

During the phase 3 tests on bunkered wastes various fire detection companies took the opportunity to perform tests of their detection products, in particular of visual heat and smoke detection systems. In summary:

- All of the detector systems used detected fires once they had breached the surface and became open flame fires

- However, none of the detector systems tested were 100% effective in detecting sub-surface fires in the RDF used in the tests. This is likely the result of the lack of significant airgaps in loose stacks of RDF (or other smaller particle size/non-rigid wastes). This lack of air gaps means that heat and/or smoke cannot effectively escape from the stack, and as a result there is nothing for the detector to detect. This effect is likely to also apply to other small particle size/non-rigid wastes where any air gaps are likely small and/or insignificant
- For stacks of larger particle size/rigid wastes such as raw and pre-crushed wood waste, or stacks of bagged waste, the air gaps present in such stacks may likely allow hot air and smoke to escape so allowing better detection at the surface
- Obviously placing thermocouples through a pile of waste will detect heat, but this type of technique is likely only practical if wastes are being stored for longer time periods as the thermocouples are effectively sacrificial

Note: The thermocouples placed in the waste stacks used in the bunker tests allowed sub-surface temperatures throughout the stacks to be monitored. The sub-surface heat from internal fires appears to 'move around' in the stack and is often localised (heat is apparent in one part of a stack but not in another). The use of thermal probes to monitor for internal fires in waste stacks has been the topic of debate, in particular the practicality of pushing a thermal probe into some types and configurations of waste stack. The results of the phase 3 tests would indicate that the use of thermal probes, where practical, may be of use, but may depend on a level of 'chance' as to whether the probe hits a hot spot or misses.

As noted above, fires in loose waste stacks may re-ignite after the obvious surface fire has been extinguished, and that this re-ignition may take place many hours after apparent extinguishing of the fire. In addition, wastes and other materials which have been burnt may undergo chemical change which makes them more prone to re-ignition. Landfill is the most common disposal route for wastes from waste fires. Unless the waste is excavated and thoroughly doused before such disposal, landfill may not be a wise disposal route.

Appendix 6: Useful links and further reading

The list below is not comprehensive but does provide an overview of useful documents you may wish to consider. Other guidance is available – you should ask your competent advisor.

Health and Safety Executive, fire/explosion pages: http://www.hse.gov.uk/fireandexplosion/index.htm

Gov.uk, How to comply with your environmental permit:
https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/298102/LIT_7123_79744e.pdf

Environment Agency – Fire Prevention Plans: Environmental permits:
https://www.gov.uk/government/publications/fire-prevention-plans-environmental-permits

Contact details for your local fire and rescue service: http://www.fireservice.co.uk/information/ukfrs

Advice on fire risk assessment for factories and warehouses:
https://www.gov.uk/government/publications/fire-safety-risk-assessment-factories-and-warehouses

Other guidance on fire risk assessment: https://www.gov.uk/government/collections/fire-safety-law-and-guidance-documents-for-business

WISH (Waste Industry Safety and Health) Forum guidance: www.wishforum.org.uk

Environmental Services Association DSEAR guidance: http://www.esauk.org/esa_reports/index.html

For the full Regulatory Reform (Fire Safety) Order 2005:
http://www.legislation.gov.uk/uksi/2005/1541/contents/made

Spontaneous heating of piled tyre shred and rubber crumb – HSE:
http://www.hse.gov.uk/rubber/spontaneous.htm. FM (Factory Mutual) technical note 8-3 also includes information on tyre storage fire hazards.

BS EN 15188:2007 Determination of the spontaneous ignition behaviour of dust accumulations.

Building Research Establishment Information Paper: IP23/82. Spontaneous Combustion – isothermal test methods. BRE Bookshop.

SFPE Handbook 3rd Edition - Ch 2 Conduction of heat in solids - National Fire Protection Association – SBN: 0877654514

CIRIA Report C736, 2014 Containment systems for the prevention of pollution:
http://www.ciria.org/Resources/Free_publications/c736.aspx

Environmental Protection Handbook for the Fire and Rescue Service:
http://www.ukfrs.com/pages/research.aspx

Technical insurance standards under the FM Global Data Sheets are available as free downloads at: www.fmglobaldatasheets.com. However, please note that many of these are not waste specific, and the data in them may not be directly applicable. But they may provide good general information.

Appendix 7: Glossary

Accident/emergency Plan	Part of a written management system that includes an assessment of fire risk on the site and what measures are in place to prevent, detect, suppress, mitigate and contain fire. Note – this is a term used in environmental permits/waste management licences. Other terms, such as emergency plan, fire plan etc, may be used in other regulator aspects. While outside of this guidance, you may also want to consider disaster recovery and business continuity planning
Brands/embers	Small items of material which are on fire, or smouldering which may blow or otherwise travel between stacks and similar and spread fire
Bund	A type of secondary containment. Usually an impermeable construction designed to hold polluting substances that leak, are spilt or run-off from a storage area
Combustible materials	In the context of this document, solid materials that can ignite and burn, such as textiles, wood and paper
Competent advice	Competent advice on fire safety and its technical aspects is critical to good fire control management. Competent advice sources may include: • In-house health and safety specialists – provided that they have sufficient knowledge and experience of fire management and the standards applied • Your local Fire and Rescue Services (FRS). Please note that your local FRS may be best being consulted after you have produced draft management processes, design of site etc • Regulators such as the Environment Agency, Scottish Environment Protection Agency and NRW (the Health and Safety Executive, but only for specific fire issues such as DSEAR). Please note that while such regulators can provide advice this is not their primary role • Insurers – your insurance company may have internal fire management specialists who you can call on at no or lower cost than going to an external consultant • External consultants – suitably competent external consultants. Please ensure that these are experienced and knowledgeable about fire management and standards Note – different stakeholders, such as insurers and regulators, may have different priorities and you may need to consult with more than one type competent advice to gain a full picture
Controlled burn	An operational fire-fighting strategy where the application of fire-fighting media such as water or foam is restricted or avoided, to minimise damage to the environment
Exemption	Low risk waste handling operations that don't require a permit or licence. Most exemptions need to be registered with the EA/SEPA

Protected habitat	Examples include: Site of Special Scientific Interest (SSSI), Area of Special Scientific Interest (ASSI), Special Area of Conservation (SAC), Special Protected Area (SPA), National Nature Reserve, Sites of international conservation importance – Ramsar site, Area of Outstanding Natural Beauty (AONB), National Scenic Area
Hazardous substances	Materials that can harm human health and/or damage the environment
Hazardous/special Waste	Wastes, specified in the European Waste Catalogue, that may be harmful to human health or the environment
Permit/waste management licence	A document issued by your environmental regulator that controls the environmental impact of your business activities. It has conditions which you must follow to prevent your business harming the environment or human health
Firewater run-off	Water that has been used to fight a fire, likely to be contaminated with the products of combustion and un-burnt materials that are washed off the site
Fire risk assessment	A structured and systematic examination of the premises/site/buildings etc to identify the hazards from fire. Once identified, a hazard is significant, identify who and/or what is at risk and whether the existing fire precautions are adequate so that the risk associated with the hazard is acceptably low. If the existing fire precautions are not adequate you must take additional action to minimise the risk either by removing or reducing the hazard or by providing adequate control measures
Flammable material	Materials that ignite easily and burn rapidly with a flame. Liquids and articles are usually defined as flammable if they possess a flash point of 60°C or lower
Flashpoint	The lowest temperature at which a liquid produces enough vapour to form an ignitable mixture in air
Foul sewer	Sewers or pipes that collect foul water (sewage and trade effluent) and convey it to a sewage treatment facility. They can be owned privately or by the local sewage treatment provider
Groundwater	Water that is below the surface of the ground in the saturation zone, and in direct contact with the ground or subsoil. The saturation zone is where all the cracks in the rock and all the spaces between the grains of rock and within the soil are filled with water
Penstock/shut-off valve	A sluice or gate valve fitted in a sewer or drain that can be closed automatically or manually to contain spillages or firewater
RDF/SRF	Refuse derived fuel/solid recovered fuel (various types of fuel derived from wastes using various treatment processes)

Secondary containment	A structure such as a bund that surrounds a storage area, designed to contain pollutants in the event of a fire or spillage
Sensitive receptor	Human receptors include hospitals, nursing homes, schools, residential areas, places of work, transport networks. Environmental receptors include source protection zones, surface waters, potable abstractions, groundwater, protected habitats, fisheries
Stack	A pile of solid combustible materials. Any spaces within it will not allow free passage, or exceed one metre in width at their narrowest point
Surface water drain/sewer	Sewer or pipes that collect uncontaminated surface water only, from buildings, roads and yards, which usually discharges directly into rivers, the sea or groundwater
Spontaneous combustion	Combustion which occurs without an external heat or ignition source being applied
Tertiary containment	A device or structure such as a firewater lagoon, that provides additional containment should secondary containment fail