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Workplace Safety and Health Guidelines

Flammable Materials

WSHCOUNCIL

Year of issue:

Contents

1. Introduction

1.1 Scope and Objective

Fires can cause extensive damage to property, serious injuries and loss of lives. Highly flammable liquids like petrol and solvents are obvious sources of fuel but less apparent fuel sources such as sawdust and metal particles are also able to catch fire so long as the right conditions are met.

This Workplace Safety and Health (WSH) Guidelines aims to provide practical guidance on risk control measures that can be implemented to ensure the safety and health of workers who work with flammable materials daily. This Guidelines covers all industry sectors where flammable materials are used in smaller quantities[1].

The term "flammable materials" used throughout this Guidelines is used to refer to any organic or inorganic material (whether a solid, liquid or gas) that can be easily ignited, resulting in a fire. Examples of flammable materials are petroleum-derived oil and gas, volatile organics, and all substances listed in the Fourth Schedule of the Fire Safety (Petroleum and Flammable Materials) Regulations (see Annex A).

Please see Table 1 for suggested reading based on work activity.

[1] The scope of this Guidelines does not cover Major Hazards Installations (e.g. oil refineries, petrochemical and chemical plants) where large quantities of flammable materials are manufactured or stored. A useful reference for Major Hazards Installations is SCDF's Fire Safety Guidelines for Open Plant Structures in Oil, Chemical and Process Industries.

Work Activity	Suggested Reading
Purchasing a flammable material	Chapter 1.2 Legislation on Flammable Materials Chapter 2 Fire Basics Chapter 3 Fire Risk Assessment
Storing a flammable material	Chapter 2 Fire Basics Chapter 3 Fire Risk Assessment Chapter 4 Fire Prevention, Detection and Control Chapter 5 Storage of Flammable Materials Chapter 8 Fire Emergency Response Plan
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Table 1: Suggested reading based on work activity

Note that the WSH Guidelines on Flammable Materials replaces the Technical Advisory for Flammable Hazardous Substances earlier published by the WSH Council in September 2008.

1.2 Legislation on Flammable Materials

In Singapore, flammable materials are regulated or licensed by different authorities:

- The Ministry of Manpower (MOM) regulates the exposure to flammable materials at workplaces through the Workplace Safety and Health (WSH) Act and its subsidiary legislations (elaborated below).
- The Singapore Civil Defence Force (SCDF) regulates the import, transport and storage of petroleum and flammable materials (P&FM) via the Fire Safety (FS) Act and Regulations. More information on SCDF's Fire Safety, P&FM Licensing and Enforcement scheme covering requirements pertaining to on-site fire safety, storage & transportation of P&FM, as well as the set up of a Company Emergency Response Team (CERT) can be found at SCDF's website (www.scdf.gov.sg) under Building Professionals.
- The National Environment Agency (NEA) controls the handling, transportation, treatment and disposal of Toxic Industrial Waste (TIW) in Singapore under the Environmental Public Health (TIW) Regulations. A licensed TIW collector needs to be engaged to assist with the disposal of flammable waste materials (e.g., waste containing organic compounds, used and contaminated oils). The updated list of TIW contractors

licensed by the National Environment Agency (NEA) under the Environmental Public Health (TIW) Regulations may be found at NEA's website (www.nea.gov.sg) under Anti-Pollution & Radiation Protection > Chemical Pollution > Toxic Industrial Waste.

Workplace Safety and Health Act & Subsidiary Legislation

The Ministry of Manpower's Workplace Safety and Health (WSH) Act was passed on 1 Mar 2006 and extended to all workplaces on 1 Sep 2011. The Act stipulates the workplace safety and health obligations as well as the responsibilities of every person at work.

Under the WSH Act, the subsidiary legislation applicable to flammable materials at all workplaces include:

- WSH (Risk Management) Regulations; and
- WSH (General Provisions) Regulations.

The WSH Act and its subsidiary legislations spell out the requirements for employers, principals and self-employed persons in all workplaces to:

- conduct risk assessments to identify and control WSH risks (including the risk of fire);
- provide safe work facilities and arrangements for workers;
- ensure safety in machinery, equipment, materials used and work activities carried out;
- provide adequate instruction, information, training and supervision to workers; and
- implement risk control measures for dealing with emergencies.

The WSH (General Provisions) Regulations includes provisions for protecting workers and employed persons against hazardous substances (including flammable materials). The list of substances with hazardous properties is listed in the 5th Schedule of the WSH Act (see Table 2).

Under the WSH (General Provisions) Regulations:

- Hazardous substances (including flammable materials) used in a workplace are to be placed under the control of a competent person who has adequate knowledge of the properties of the material and its dangers.
- Flammable materials need to be stored, handled and disposed of properly so that they do not pose a risk to the health and safety of any person at work.
- Reasonably practicable steps must be taken to keep sources of heat or ignition separate from flammable materials in the workplace and from any process carried out at the workplace that may generate flammable gas or vapour.
- A means of fire extinguishment must be provided, and it must be readily accessible, adequate for the workplace-specific application, and tested at regular intervals by a competent person.
- A means of escape (to be kept free from obstruction) must be provided in the event of fire.

Hazardous Substances	
Corrosive substances	Substances which in contact with water, emit flammable gases
Flammable substances	Toxic substances
Explosives	Mutagens
Oxidising substances	Carcinogens
Pyrophoric substances	Teratogens
Gases under pressure	Sensitizers
Organic peroxides	Irritants
Self heating substances	Substances hazardous to aquatic environment
Self-reactive substances	

Table 2: Hazardous substances as per 5th Schedule of the WSH Act

Subsidiary legislations which specify additional requirements for work activity involving flammable materials are:

- WSH (Construction) Regulations 2007;
- WSH (Shipbuilding and Ship-Repairing) Regulations 2008; and
- WSH (Confined Spaces) Regulations 2009.

Industry stakeholders involved in construction activity, shipbuilding or ship-repairing activity, or work in confined spaces will need to be familiar with the above regulations and comply with the local legislative requirements concerning work with flammable materials.

More details on the WSH Act and its regulatory framework can be found at:
www.mom.gov.sg/workplace-safety-health/wsh-regulatory-framework/

2. Fire Basics

Fires can cause major disasters and result in the loss of lives in any workplace including buildings, construction sites, shipyards, manufacturing facilities, offices, warehouses, hotels, hospitals, food and retail establishments, as well as academic institutions. A fire outbreak can occur anywhere if proper fire safety is not practised and even residential areas are not spared. Such disasters can be avoided if there is a good understanding of how fires can be prevented and effectively controlled once they occur.

2.1 Key Definitions

Fire

Fire is a reaction in which a flammable material (e.g. a fuel source like oil or wood) combines chemically with oxygen in the air to produce heat, light and smoke.

Fire Hazard

As defined in the Fire Safety Act, a fire hazard refers to any matter or circumstance which increases the likelihood of fire or the danger to life or property that would result from the outbreak of fire. This includes:

- any alteration to any building in contravention of any law relating to building works or fire safety works such as might render escape in the event of fire more difficult;
- the overcrowding of any public building or any building used occasionally or regularly for public worship or religious ceremonies such as might render escape in the event of fire more difficult;
- any removal from any building of any fire safety measure which was provided in such building in accordance with plans approved by SCDF;
- the presence in any building of any fire safety measure which is not in efficient working order from the lack of proper maintenance or for any other reason;
- the obstruction of escape routes, passageways, common property or limited common property of any building such as might render escape in the event of fire more difficult; and
- any other matter or circumstance which would hamper SCDF in the discharge of its duties in the event of fire.

Specific examples of fire hazards which can increase the likelihood of fire at workplaces include:

- flammable/ combustible storage areas with insufficient fire protection;
- combustibles placed near equipment that generates heat, flame or sparks;
- equipment that utilizes combustible materials and/ or generates heat;

- electronic and electrical equipment in general;
  - cooking appliances e.g. stoves, ovens
  - heating appliances e.g. furnaces, boilers, heaters
  - other appliances e.g. dryers, irons, refrigerators, freezers
- electrical wiring in poor condition;
- electrical systems that are overloaded, resulting in hot wiring or hot connections, or failed components;
- rags soaked with solvent placed in open bins; and
- personal ignition sources e.g. lighters, matches.

Ignition Source

An ignition source is a source of energy sufficient to ignite a flammable material or atmosphere and include, but not limited to heat, naked flames, sparks, exposed incandescent material, electrical welding arcs, static electricity, hot surfaces of vehicular engines and diesel generators, and electrical or mechanical equipment.

Flammable

A material is described as flammable if it is easily ignited, causing a fire. A flammable material (e.g. petrol) is able to form an easily ignitable mixture with air at room temperature.

Combustible

A material is described as combustible if it burns easily as a result of contact with fire. A combustible material (e.g. paper or wood) will burn at temperatures above normal working temperatures.

Flash Point (FP)

The flash point of a flammable liquid is the lowest temperature at which it gives off enough vapour to form an ignitable mixture with air to produce a momentary flash upon the introduction of an external source of ignition. At flash point, the rate of vapour generation is inadequate to produce a sustained flame or fire.

Flammable vs Combustible Liquid

Based on the United Nations Globally Harmonised System of Classification and Labelling of Chemicals (GHS)[2], a flammable liquid is any liquid, or mixture of liquids, or liquids containing solids in solution or suspension (e.g. paints, varnishes or lacquers) with a flash point falling within the following criteria (see Table 3).

[2] GHS Classification Criteria for Substances and Mixtures (Physical Hazards)

Category	Criteria	Hazard Statement
1	Flash point < 23°C and initial boiling point ≤ 35°C	Extremely flammable liquid and vapour
2	Flash point < 23°C and initial boiling point > 35°C	Highly flammable liquid and vapour
3	23°C ≤ Flash point ≤ 60°C	Flammable liquid and vapour
4	60°C < Flash point ≤ 93°C	Combustible liquid

Table 3: GHS Categories for Flammable Liquid

Both flammable and combustible liquids are liquids that can burn. The key difference between a flammable and a combustible liquid is that the flash point of a flammable liquid is lower than that of a combustible liquid.

Flammable Gas

As per GHS[2], a flammable gas is a gas having a flammable range with air at 20 °C and a standard pressure of 101.3 kPa.

Flammable gases can be further classified according to the following criteria (see Table 4).

Category	Criteria	Hazard Statement
1	Gases ignitable when in mixture of ≤ 13% in air OR having a flammable range with air of ≥ 12% (regardless of the LFL)	Extremely flammable gas
2	Gases, other than those of Category 1, having a flammable range while mixed in air	Flammable gas

Table 4: GHS Categories for Flammable Gases

Flammable Solid

As per GHS[2], flammable solids are solids which are readily combustible, or may cause or contribute to fire through friction. Readily combustible solids (usually in powdered or granular form, or in the form of a paste) are particularly dangerous if they can be easily ignited by brief contact with an ignition source, such as a burning match, and if the flame spreads rapidly.

Flammable solids can be further classified according to the results of a burning rate test (see Table 5).

Category	Criteria
1	• Metal powders: burning time ≤ 5 min • Other solids: (a) wetted zone does not stop fire; and (b) burning time < 45 s or burning rate > 2.2 mm/s
2	• Metal powders: burning time > 5 min and ≤ 10 min • Other solids: (a) wetted zone stops the fire for at least 4 min; and (b) burning time < 45 s or burning rate > 2.2 mm/s

Table 5: GHS Categories for Flammable Solids

Flammability Limit (FL)

The lower and upper flammable limits define the range of gas-air or vapour-air mixture concentrations in which a flammable mixture exists. The limits indicate the minimum and maximum concentrations in air of a flammable gas or vapour at which ignition can occur. Concentrations below the lower flammable limit (LFL) are too lean to ignite (due to insufficient fuel); concentrations above the upper flammable limit (UFL) are too rich to burn (due to insufficient oxygen).

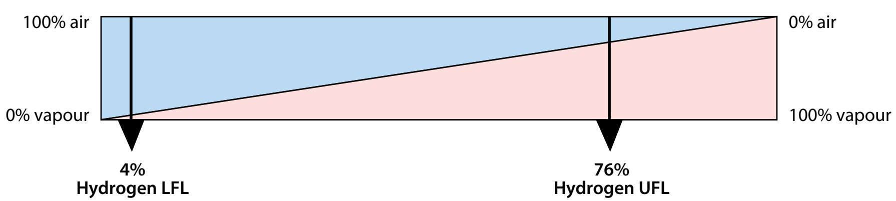


Figure 1: Lower and Upper Flammability Limits for hydrogen gas (expressed in terms of volume % at 25 °C and atmospheric pressure)

Refer to Annex B for a table showing the flammability characteristics of various liquids and gases.

Auto-ignition Temperature (AIT)

The auto-ignition temperature is the lowest temperature at which a flammable gas-air or vapour-air mixture is capable of extracting enough energy from the environment (e.g. from a hot surface) to self-ignite spontaneously without direct application of a flame.

Pyrophoric Substance

A pyrophoric substance is a substance which is spontaneously flammable in air at or below 55°C. Examples include: iron sulphide, finely divided metals (e.g., of aluminium, magnesium, uranium), liquid diphosphane, gaseous silane and various catalysts. To prevent a fire outbreak, always handle pyrophoric substances under an inert atmosphere (e.g., nitrogen).

2.2 How Fires Occur

Three components must be in place before a fire can be ignited, namely: (1) fuel, (2) oxygen AND (3) ignition/heat source. See Table 6 for common fuels, oxygen and ignition sources.

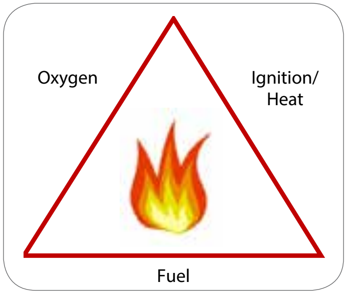


Figure 2: The Fire Triangle

Components of a Fire Triangle	Common Sources
Source of Fuel	**Solids** Wood, paper, textiles, plastic, metal dust, sawdust, sugar, flour **Liquids** Petrol, kerosene, diesel, turpentine, alcohols, solvents, thinners, cleaning agents, liquid waxes **Gases** Acetylene, hydrogen, liquefied petroleum gas (LPG)
Source of Oxygen	Air, oxygen, oxidising agents (e.g. peroxides)
Source of Ignition/ Heat	Open flames, welding arcs, hot surfaces, frictional sparks, electrical equipment, static electricity, lighted cigarettes

Table 6: Common fuels, oxygen and ignition sources

Oxygen, in particular, is difficult to remove as it is present in the air around us. Fuel can mix with air to form a flammable mixture. The ignition (or heat) source provides the energy to the flammable mixture to initiate a fire.

Once started, for a fire to remain in existence and spread, all three components must remain present:

- fuel for the fire to burn;
- oxygen for the fire to "breathe"; and
- heat to sustain the fire.

To extinguish a fire, all one needs to do is to remove any one or more components of the fire triangle (see Table 7).

Method of Fire Extinguishment	Targeted Fire Triangle Component
Cooling	Removal of "Heat" component e.g. by using water
Smothering/ Blanketing	Removal of "Oxygen" component e.g. by using a fire blanket, foam or inert gas like CO_2
Starvation	Removal of "Fuel" component e.g. by removing the fuel or stopping the fuel source

Table 7: Method of Extinguishment and its Impact on a Fire

2.3 Types of Fire

Based on Fuel Source

Fires may arise from fuel sources that are solid, liquid or gaseous in origin.

In general, fuels may be present in workplaces as:

- gases or vapours (e.g. as a result of liquid evaporation)
- liquids or mists (a dispersion of fine liquid droplets in air)
- solids or dust (a dispersion of fine solid particles in air)

Table 6 provides examples of fuel sources found in the solid, liquid and gaseous state.

Based on Fire Class

In Singapore, fires are classified[3] into five categories according to the materials undergoing combustion:

Class A Fire

Fires involving ordinary combustible materials (e.g. wood, paper, cloth, furnishing, plastics, rubber), usually of an organic nature, in which combustion normally takes place with the formation of glowing embers.

Class B Fire

Fires involving flammable liquids, solvents, oils, paints, thinner or liquefiable solids.

Class C Fire

Fires involving flammable gases.

Class D Fire

Fires involving combustible metals e.g. potassium, magnesium, titanium, sodium, lithium and zirconium.

Class F Fire

Fires involving cooking media (vegetable or animal oils and fats) in cooking appliances.

Based on Fire Scenario

Fires may occur in a variety of different scenarios:

Flash Fire

A flash fire is a momentary flame that moves rapidly through a cloud of flammable gas or vapour. It rarely lasts for more than a few seconds, and causes little damage to equipment and installations. However, it can cause severe injury to any worker(s) in its path.

Pool Fire

A pool fire is a fire that occurs on a stationary liquid surface, such as that of a flammable liquid spill or atop a storage tank containing liquid hydrocarbon. The nature of the flame depends on the fuel that is burning, with more smoke being generated by heavier hydrocarbons on fire. The heat radiated can negatively affect all workers and facilities in its vicinity, but its intensity will depend on the volume of liquid available as well as the duration of the fire.

Jet Fire

A jet fire will occur when a fuel released from a pressurised source is ignited close to its point of release. The ensuing jet of flame will last as long as the supply of fuel lasts under pressure. In addition to damage inflicted by the heat radiated, the flame jet may also cut through neighbouring objects, potentially setting off a domino effect.

[3] SS 578 : 2012 Code of Practice for Use and Maintenance of Portable Fire Extinguishers

Vapour Cloud Fire/ Explosion

An explosion can arise from the ignition of a vapour (or gas) cloud of flammable chemical. Two types of vapour cloud explosions can occur:

- A confined vapour cloud explosion occurs inside an enclosed environment such as in a vessel or pipe. The expansion of combustion products inside the enclosure often results in an explosion large enough to cause serious injury and damage to industrial facilities.
- An unconfined vapour cloud explosion occurs outdoors. Cloud formation typically begins with an unplanned release of a large quantity of flammable gas or vapourising liquid, creating a flammable cloud which subsequently ignites. If the speed of the flame front travelling through the cloud approaches detonation velocity, a massive over-pressure follows, resulting in an explosion with disastrous consequences.

Fireball

A fireball is a large highly luminous spherical burning mass of fire that rises into the air as a cloud or ball. Fireballs may result from the ignition of a rapidly formed cloud of flammable vapour or the ignition of flashing vapour arising from a bursting pressure vessel.

Boiling Liquid Expanding Vapour Explosion

A Boiling Liquid Expanding Vapour Explosion (BLEVE) is an explosion caused by the rupture of a storage vessel containing a pressurized liquid (e.g., liquefied petroleum gas) stored at a temperature above its boiling point.

BLEVEs are typically initiated by an external fire near the storage vessel, which causes its contents to vapourise and expand, resulting in a pressure build-up within the vessel. Should the vessel walls fail, the sudden decompression will cause rapid boiling of the remaining liquid content, resulting in an explosive overpressure at the point of rupture. Subsequent to vessel rupture, large quantities of vapour will be released to atmosphere. If the vapour is flammable, a fireball and/ or an unconfined vapour cloud explosion may ensue once the vapour is ignited.

Dust Fire/ Explosion

Combustible materials such as sawdust and metal dusts can cause a flash fire (and/ or dust explosion) due to the dispersion of fine particles in air, when in sufficient concentration and well-mixed with the oxygen in air.

A dust fire/ explosion is more likely to occur when the following conditions are met:

- Presence of combustible dust (i.e. a source of fuel) of sufficiently small particle size.
- The finely divided dust is dispersed into its immediate environment.

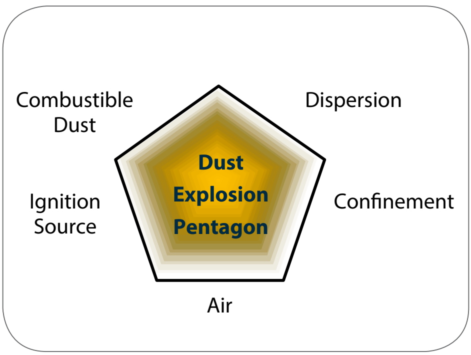


Figure 3: Dust Explosion Pentagon

- The dust cloud is in a confined environment (e.g. in a storage room or silo).
- There is air or oxygen in the environment.
- Presence of ignition source (e.g. heat or sparks).

Dust is generated in many industries such as the food, chemical, rubber and plastic processing, woodworking, and metalworking industry. The dust generated could be raw materials, intermediates, finished or waste products. In such cases, it is important that dust control measures are implemented as a cloud of combustible dust dispersed in air can readily catch fire and/ or explode violently if there is a source of ignition.

Dust control measures include:

- Replacing materials in the dust form with safer alternatives that come in a ready-to-use non-dust form.
- Designing building elements (e.g., smooth, easy-to-clean walls, sloped surfaces) and arranging equipment to reduce dust accumulation.
- Installing a dust collection system (e.g., by using a cyclone separator or through the use of a special vacuum) to prevent and reduce the escape of dust from processing equipment to the environment.
- Implementing good housekeeping practices to keep the workplace clean and safe through frequent cleaning to prevent dust accumulation.

To reduce the risk of combustible dust catching fire, an important approach would be to remove air/ oxygen from the immediate processing environment, for example, by introducing inert gas blanketing into a solids handling/ packaging system.

3. Fire Risk Assessment

Risk management (RM) is a critical instrument for improving workplace safety and health (WSH).

Under the WSH (Risk Management) Regulations, employers, self-employed persons and principals (including contractors and sub-contractors) are responsible for identifying safety and health hazards at the workplace and taking appropriate actions to eliminate the hazards or reduce the risks associated with the hazards.

The key components of the RM process are: Preparation, Risk Assessment, Implementation, Record-keeping and Review.

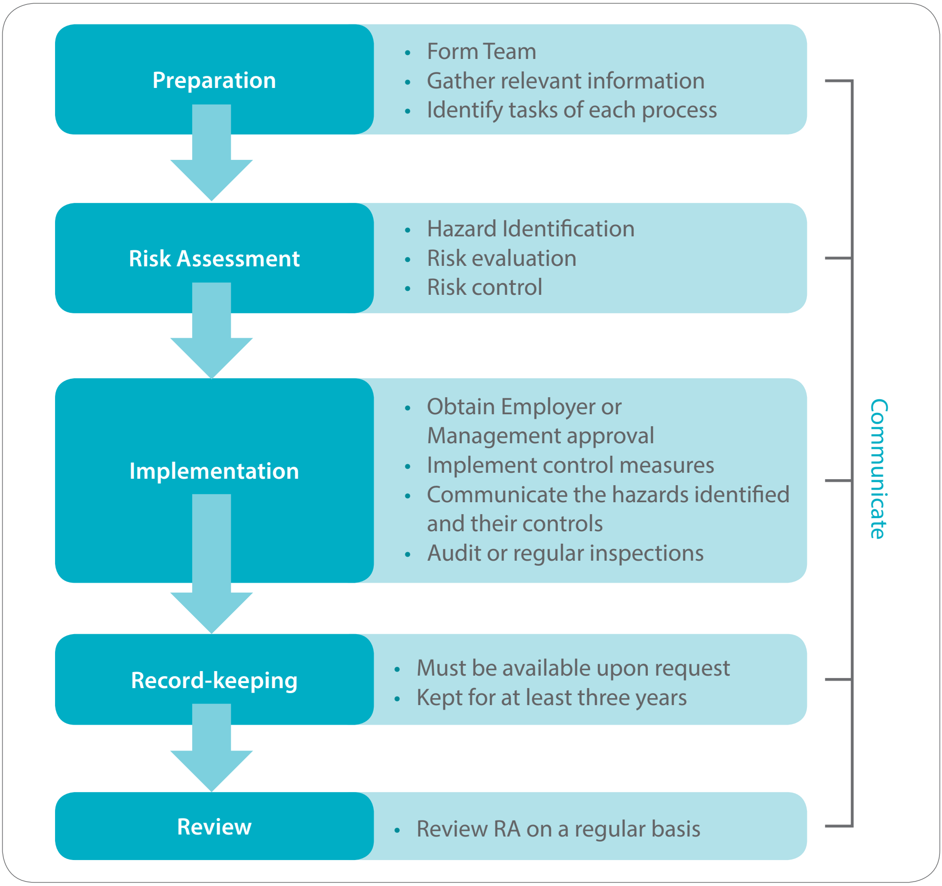


Figure 4: **Risk management process**

Risk management not only involves risk assessment (RA) for any work activity or trade, it includes the on-site implementation of control measures, hazard communication to workers and regular inspections and audit.

RA basically refers to a careful examination of the factors that could cause harm to worker safety or health. The objective of RA is to find ways to mitigate or adequately control the risks posed by hazards as far as it is reasonably practicable.

The WSH (Risk Management) Regulations or RM does not expect all risk to be eliminated, but it does require companies to implement risk control measures to protect all persons at work as far as "reasonably practicable". An action is deemed practicable when it is capable of being done. Whether it is also reasonable takes into account the following: (i) the severity of any injury or harm that may occur, (ii) the likelihood of the injury or harm occurring, (iii) how much is known about the hazard and the ways to eliminate, reduce or control it, and (iv) the availability, suitability and cost of the safeguards.

The RM process may be used to foster a proactive accident prevention culture. By carrying out RA prior to commencing work, workplace hazards may be identified and risk control measures put in place to minimize the exposure to risk during work.

More information on the RM process may be found in the Code of Practice on Workplace Safety and Health Risk Management available at www.wshc.sg/riskmanagement

Guide to Fire Risk Assessment

With reference to Figure 4, the first two components of the risk management process are Preparation and Risk Assessment.

As fires can happen at any workplace (e.g. offices, warehouses, manufacturing facilities, construction sites, shipyards, etc) at any time, it is important that a fire risk assessment be carried out at each workplace and for each work activity prior to work commencement.

Prior to conducting a fire risk assessment, **preparation** involves establishing the context by gathering relevant information such as:

- Layout plan of building, plant, work site or factory;
- List of work locations and activities where flammable/ combustible materials are used, stored or present near heat, open flame, or sparks;
- List of equipment containing flammable/ combustible materials (whether as a fuel or as a process fluid) where a component failure may result in a fire;
- Relevant legislation, Codes of Practice and standards;
- Records of fire risk assessment previously carried out on the same premises;
- Details of existing risk control measures and emergency facilities;
- Fire safety inspection records including annual fire certification records;
- Records of fire-related near misses, past incidents and accidents ;
- Medical records of workers with fire-related injuries ;
- Guidance documents from material supplier and equipment manufacturer;

- Safe work procedures for the work activity involving flammable materials; and
- Other relevant information such as safety data sheets (SDS) and equipment technical data sheets.

There are basically three (3) steps in fire **risk assessment**:

1. Fire Hazard Identification
2. Fire Risk Evaluation
3. Fire Risk Control

3.1 Fire Hazard Identification

As defined in Section 2.1, a fire hazard is any object or situation which can increase the likelihood of fire. Fire hazards can be present under any one of the 3 components of a fire triangle, but are most commonly detected as sources of fuel or ignition/ heat. Note that as ambient air contains oxygen, air is normally not regarded as a fire hazard.

Fire hazard identification is a crucial step in fire risk assessment, since fire hazards can only be controlled if they are identified. This step involves identifying and listing all fire hazards associated with a specific work activity being carried out at a specific location. During the identification process, the aim is to spot all fire hazards at a specific workplace, listing all possible ways that a fire could arise, and to identify the groups of people that may be vulnerable to each fire hazard.

The following Table provides examples of fire hazards by fire hazard category:

Fire Component	Fire Hazard Category	Examples of Fire Hazard
Ignition/ Heat Source	**Naked Light:** Open flame or fires, exposed incandescent materials, any other confined source of ignition.	Flame from burning candle, blow torches, Bunsen burners, and campfire.
	Overheating: Fire due to excessive heat being applied or generated.	Unattended cooking, over-heating of deep fryer and electrical iron placed on ironing board.
	Hot Works: Welding and cutting operations.	Oxy-acetylene cutting and arc welding.

Ignition/ Heat Source	**Incendiary**: Fire deliberately set under circumstances in which the individual knows that the fire should not be set.	Malicious torching of materials in common areas.
	Electrical Origin: Fire as a result of electrical faults in the wirings, fixtures or electrical equipment.	Short circuit, overloading, and arcing.
	Sparks: Sparks generated as a result of friction or static electricity.	Grinding operations and motor vehicle impact. Static build-up during fuelling operation.
	Sunlight: Fire due to exposure to rays from the sun.	Glass refraction from rays from the sun.
	Spontaneous Ignition: Initiation of combustion of a material by an internal chemical or biological reaction that can produce sufficient heat to ignite the material.	Linseed oiled rags and ignition of nitrocellulose.
	Embers: Hot or smouldering ashes.	Ashes from burning incense and charcoal.
	Dropped Light: Ember/ smouldering materials dropped or indiscriminately disposed of.	Lighted cigarette butt and lighted match stick.
	Lightning: Electrical discharge of natural origin.	Lightning strike on a tree.
Fuel Source	**Exposure of Fuel to Heat:** Exposure to or contact with hot surfaces causing ignition.	Combustibles placed near to heated surface causing ignition.

Fuel Source	**Chemical Reaction:** Mixture of any substances causing exothermic reaction.	Magnesium fire and phosphorus exposed to air.
	Explosion: Sudden conversion of potential energy (chemical or mechanical) into kinetic energy with the production and release of gas(es) under pressure.	Explosives, dust explosion and ammunition.

Table 8: Fire hazard category and examples of fire hazards for each category (Source: National Fire Prevention Council's Fire Risk Assessment Guide)

The examples given in Table 8 serve as mental triggers to facilitate fire hazard identification. The examples are by no means exhaustive. Users of this Guideline are advised to study each workplace carefully to identify all possible fire hazards that may exist at the specific site.

Fire Hazard Identification through Label Information and Safety Data Sheets

Labelling for Flammable Materials

As per WSH (General Provisions) Regulations, any container containing a hazardous substance must be affixed with a warning label. The warning label should conform to Singapore Standard SS 586: 2014 – Specification for Hazard Communication for Hazardous Chemicals and Dangerous Goods – Part 2: Globally Harmonised System (GHS) of Classification and Labelling of Chemicals - Singapore's Adaptations.

The GHS label for a chemical that poses a fire hazard would indicate one or more of the following hazard pictograms:

Figure 5: GHS hazard pictograms for chemicals that can cause fire

The label on chemical containers is therefore an important means of hazard communication and will aid fire hazard identification.

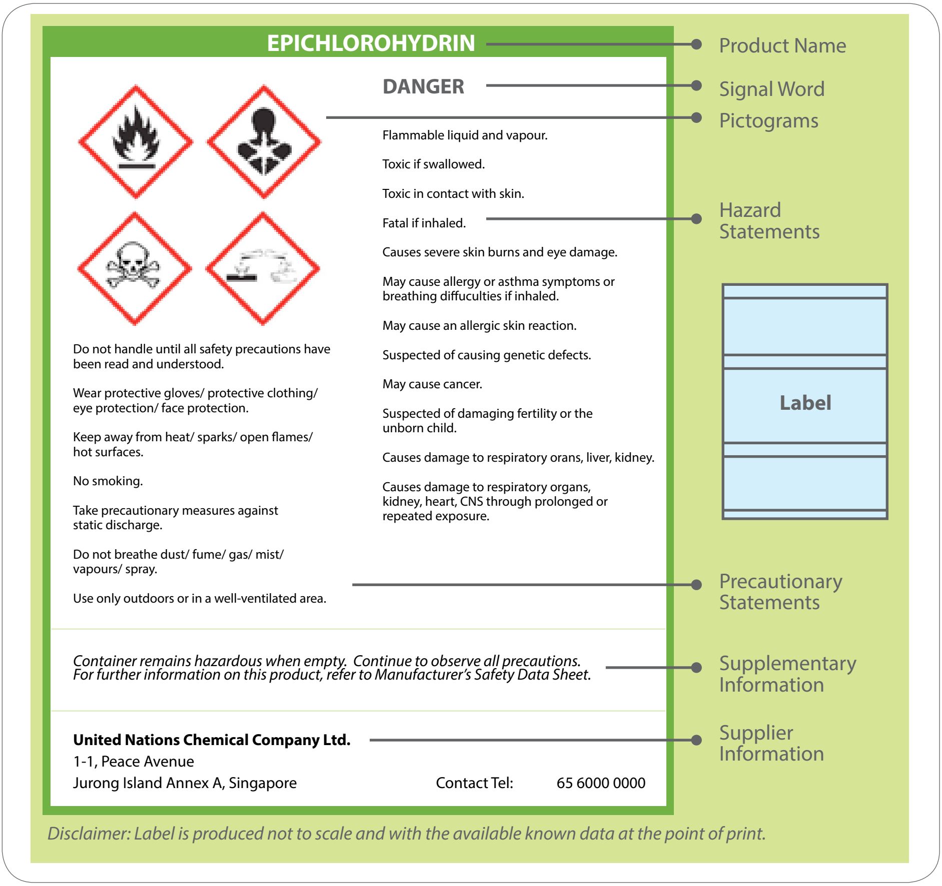


Figure 6: Example of a GHS container label for a flammable chemical (Source: SCIC Guidebook on the Globally Harmonised System of Classification and Labelling of Chemicals 2008)

Proper labelling will also help prevent accidental mixing of chemicals and reduce the chances of mistaking one liquid for another. Labels should be kept clean so that they can be easily read at all times. Unless it has been thoroughly washed, a container should never be reused for any liquid except the one marked on its label.

Further information

- Guidance on the Application of GHS Criteria to Petroleum Substances by IPIECA (2010)

Safety Data Sheets

A Safety Data Sheet (SDS) is a summary document containing important information on a material including its hazards and the precautions necessary to work safely with it.

SDSs are prepared by the supplier or manufacturer of the material and will contain more information about specific chemicals than a warning label can carry. Every chemical (including the same chemical at various concentrations) will have its own unique SDS.

Chemical users should obtain the SDS from the supplier or manufacturer of the specific material being purchased. To ensure that SDS information is up-to-date, it is good practice to regularly review and replace all data sheets that are more than 5 years old (based on the SDS date of issue).

Figure 7: **Refer to a safety data sheet for detailed information on a chemical.**

As per Singapore Standard SS 586: 2008 (2014) – Specification for hazard communication for hazardous chemicals and dangerous goods – Part 3: Preparation of safety data sheets, a SDS should contain <u>sixteen</u> sections as follows:

Section 1:	Identification
Section 2:	Hazards identification
Section 3:	Composition/ Information on ingredients
Section 4:	First-aid measures
Section 5:	Fire-fighting measures
Section 6:	Accidental release measures
Section 7:	Handling and storage
Section 8:	Exposure controls/ personal protection
Section 9:	Physical and chemical properties
Section 10:	Stability and reactivity
Section 11:	Toxicological information
Section 12:	Ecological information
Section 13:	Disposal considerations
Section 14:	Transport information
Section 15:	Regulatory information
Section 16:	Other information

The three sections most useful for fire hazard identification are Section 2: Hazards Identification, Section 5: Fire-fighting Measures and Section 9: Physical and Chemical Properties. If a chemical is a flammable, this will be stated on the first page of the SDS under Section 2. Information pertaining to the chemical's flash point (FP), auto-ignition temperature (AIT) and flammability limits (FLs) are typically found under Section 5: Fire-fighting Measures or Section 9: Physical and Chemical Properties.

3.2 Fire Risk Evaluation

Fire risk evaluation is a process of estimating the risk levels for the identified fire hazards, and is used as a basis for prioritising the necessary follow-up action(s) to control the fire hazards and minimise fire risk.

Fire risk evaluation comprises of 3 key components:

- Assess the potential severity of a fire outbreak
- Determine the likelihood of the fire occurring
- Based on (1) and (2), estimate the overall risk level of fire occurrence

1. Severity Assessment

Severity is the extent of damage or injury that can be caused by fire hazards. Severity can be classified into five levels (see Table 9).

Level	Severity	Description
5	Catastrophic	Fire could spread widely (beyond the immediate premises and into neighbouring premises), and may result in fatality or multiple major injuries and/ or causing extensive damage to property.
4	Major	Fire could spread easily (beyond the immediate premises), and may result in major injury and/ or causing damage to property.
3	Moderate	Fire could spread slightly (beyond point of fire origin but within the immediate premises) due to presence of neighbouring fuel source(s). Person(s) may not be on-site for early response to fire outbreak. Injury or ill health sustained may require medical treatment.
2	Minor	Localised fire (i.e., within point of fire origin). Fire is not likely to spread due to absence of neighbouring fuel source(s). Person(s) are on-site for early response to fire outbreak. Injury or ill-health sustained requires first aid.
1	Negligible	Fire is not likely or would be small and well-contained should it occur. No injury or ill-health is expected.

Table 9: Guidance for Fire Risk Severity Level, S (taking existing risk controls into consideration)

2. Likelihood Determination

Likelihood is the probability that a fire hazard will cause a fire of a specific severity, based on factors such as existing risk controls, past records of fire occurrence(s), as well as prior experience handling flammable/ combustible materials in a particular company or industry sector. Likelihood can be classified into five levels (see Table 10).

Level	Likelihood	Description
1	Rare	No fire has ever occurred. Flammables are not present .
2	Remote	Flammables are present. Fire not likely to occur under normal circumstances but still possible. Fire risk controls are in place in accordance to industry best practices.
3	Occasional	A fire has occurred before. Fire risk controls could be inadequate.
4	Frequent	Fire is a common occurrence - more than one fire associated with this work activity has occurred. Fire risk controls are inadequate.
5	Almost Certain	Fire happens so frequently (e.g. more than one fire per year associated with this work activity) that it is a continual or repeating experience.

Table 10: Guidance for Fire Risk Likelihood Level, L (taking existing risk controls into consideration)

3. Risk Estimation

The risk level of a fire, occurring due to a specific work activity at a particular location, can be determined once its severity and likelihood has been established.

Risk level may be estimated using the 5 × 5 risk matrix below:

Severity \ Likelihood	Rare (1)	Remote (2)	Occasional (3)	Frequent (4)	Almost Certain (5)
Catastrophic (5)	5	10	15	20	25
Major (4)	4	8	12	16	20
Moderate (3)	3	6	9	12	15
Minor (2)	2	4	6	8	10
Negligible (1)	1	2	3	4	5

Table 11: Recommended 5 x 5 Risk Matrix with Risk Prioritisation Number ratings (Green Zone = "Low Risk"; Yellow Zone = "Medium Risk"; Red Zone = "High Risk")

In the above matrix, the fire risk level and its corresponding Risk Prioritisation Number (RPN) is given in the cell at the intersection of the severity row and the likelihood column.

The RPN for each fire hazard is easily computed as follows:

RPN Rating = Severity Level (S) x Likelihood Level (L)

Both the colour of the cell and its computed RPN gives the estimated risk level, with greater RPN indicating higher fire risk:

RPN	Risk Level	Risk Acceptability
RPN ≤ 3	Low Risk	Acceptable
4 ≤ RPN ≤ 12	Medium Risk	Tolerable
RPN ≥ 15	High Risk	Not Acceptable

Table 12: RPN rating, risk level and risk acceptability

The RPN obtained will help determine if the fire risk is acceptable, tolerable or not acceptable.

3.3 Fire Risk Control

Based on the fire risk level obtained, the final (and most important) step is to implement control measures to bring down the estimated risk to an acceptable level. This can be done by reducing either the severity and/ or the likelihood associated with the specific work activity.

The following table lists the recommended action(s) for each fire risk level:

Fire Risk Level	Risk Acceptability	Recommended Action
Low Risk (RPN ≤ 3)	Acceptable	• No additional fire risk control measures may be needed. • Frequent review and monitoring of fire hazards are required to ensure that the estimated fire risk level is accurate and does not increase over time.
Medium Risk (4 ≤ RPN ≤ 12)	Tolerable	• Work activity is allowed to continue for now, but remedy action must be taken at an appropriate time. • Interim fire risk control measures, such as administrative controls or PPE, may be implemented while longer term measures are being established. • A careful evaluation of the fire hazards should be carried out to ensure that the fire risk level is reduced to as low as reasonably practicable (ALARP) within a defined time period. • Management attention is required.
High Risk (RPN ≥ 15)	Not acceptable	• Work activity is not permissible. • High fire risk level must be reduced to at least medium fire risk before work commences. • If practicable, the fire hazard should be eliminated before work commences. • Additional fire control measures are required to be introduced. The selected control measures should not be dependent on PPE. • Management intervention and review is required prior to work commencement.

Table 13: Recommended action for each risk level

In particular, fire hazards that are estimated to be "High Risk" must be given first priority and additional fire risk control measures put in place to reduce the fire risk level to "Medium Risk" or "Low Risk" before the work activity can be allowed to begin.

The following are examples of fire risk control measures associated with the handling of flammable and combustible substances (see Figure 8). Care must be exercised when selecting the control measures to ensure that they are appropriate for your workplace. Fire risk control measures should be selected based on the Hierarchy of Controls, starting with elimination or substitution wherever possible and ending with the use of personal protective equipment as a last resort:

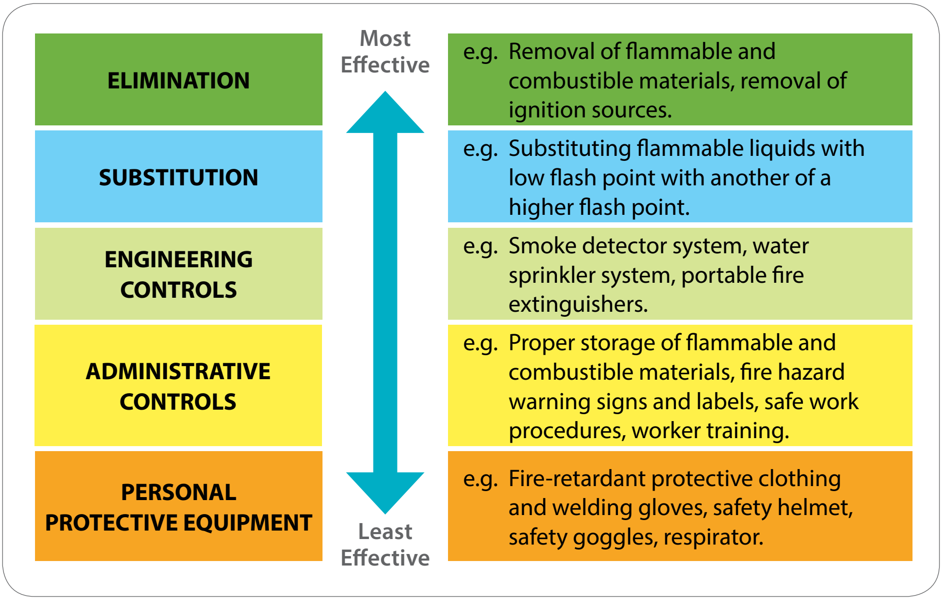


Figure 8: Example of fire risk control measures based on the Hierarchy of Controls

Elimination

The first priority of fire risk control is to eliminate the risk at source.

Eliminate fuel source

If the work or the process can be carried out without the need for flammable or combustible materials, the risk of fire (or explosion) arising from the ignition of such materials will be eliminated. For example, do not use oil or grease for lubricating valves, gauge connections or other parts of an oxygen delivery system.

Eliminate heat/ ignition source

Fuel sources should be located separately and away from heat sources. For example, store flammable materials in a fire-rated storage cabinet positioned in a cool and well ventilated location.

Eliminate oxygen source

For work involving flammable substances, oxygen elimination may be achieved by nitrogen blanketing and/ or by purging the associated vessel(s) or pipeline(s) to eliminate the presence of oxygen before use.

Substitution

If elimination is not possible, next best approach is substitution.

Substitute flammable and combustible substances with safer alternatives wherever possible. For example:

- Use water-based substances instead of solvent-based substances;
- Use substances with high flash point instead of low flash point;
- Replace dry powders with materials in paste or pellet form; and
- Employ safer methods of work such as brush or roller application instead of spraying.

Engineering Controls

Engineering controls serve to eliminate or reduce exposure to hazards through the use of specialised machinery or equipment designed to improve WSH.

For workplaces where flammable materials are handled or stored, fire safety must be considered at the design stage, and engineering controls incorporated into the plant or facility design as early as possible. Examples of engineering controls commonly implemented on industrial premises include the use of:

- intrinsically safe electrical devices (e.g., lamps) that are enclosed in explosion-proof housings;
- bonding and grounding to minimise static electricity build-up when nonconductive liquids or solids are hydraulically or pneumatically carried through metallic pipes, vessels, containers;
- fire-proof vessels, pipes, structures that are double-insulated to minimise damage due to fire;
- pressure relief/ explosion vents for pressurised storage tanks and equipment;
- separation distance to segregate flammable material storage from process areas;
- dikes to contain and carry away spills;
- ventilation/ extraction systems for any work involving flammable materials;
- flammable gas detectors sited at critical locations where loss of containment is possible;
- interlocking safeguards to facilitate safe shutdown of process plant or equipment during fire emergencies; and
- firefighting equipment and facilities (e.g., water sprinkler system, hose reel system, smoke control system).

Administrative Controls

Administrative controls refers to changes to work arrangements like staff rostering, training and work procedures that are put in place specifically to reduce or limit worker exposure to hazards present at the workplace.

Examples of administrative controls include:

- Performing a risk assessment (RA) or process hazard analysis (PHA) on all processes involving flammable and/ or combustible materials.
- Establishing safe work procedures (SWPs) for work involving the storage, use, handling and disposal of flammable materials.
  - Implementing a safe system of storage and disposal for flammable materials away from heat or ignition sources.
  - Instilling good housekeeping practices e.g., immediate clean-up of any spills and keeping the lids of containers and bins (of flammable materials) closed when not in use.
  - Prohibiting the use of open flames in areas where flammable vapour is likely to be present.
- Implementing a permit-to-work (PTW) system for hot work, or work involving flammable materials, such as spray painting in confined space.
- Instituting a preventive maintenance programme for all fire safety equipment such as smoke detectors, fire extinguishers, water sprinkler and fire alarm system.
- Installing safety signs and GHS labels to facilitate quick identification of the contents of a container and the hazard(s) it presents.
- Providing workers with training on:
  - safe work procedures;
  - permit-to-work system;
  - recognising GHS pictograms (including those that indicate a fire hazard);
  - understanding the SDS; and
  - emergency response plan.

Personal Protective Equipment (PPE)

PPE (e.g., fire-retardant protective clothing and gloves, safety helmet, safety goggles, respirator) can be used to protect persons from fire, heat, smoke and contact with flammable materials.

The use of PPE, however, does nothing to eliminate the hazard. The other fire risk control measures in the hierarchy of control (in particular, elimination and substitution) must take precedence and the use of PPE considered a last resort measure.

The following page gives an example of a completed RA form for a work activity where two chemicals are mixed giving rise to a flammable vapour-air mixture at the workplace.

Example of Risk Assessment

Risk Assessment Form

Department:	Specialty Chemicals	RA Leader:	Supervisor	Approved by: Signature:		Reference No.
Process:	Chemical Mixing	RA Member 1:	Senior Technician			
Activity Location:	Level 1	RA Member 2:	Technician 1			
Original Assessment Date:	30 Jan 2013	RA Member 3:	Technician 2	Name:		
Last Review Date:	30 Jan 2015	RA Member 4:	Chemical Supplier	Designation:	Manager	
Next Review Date:	30 Jan 2017	RA Member 5:		Date:	30 Apr 2015	

Hazard Identification				Risk Evaluation				Risk Control						
Ref	Work Activity	Hazard	Possible Injury/ Ill-health	Existing Risk Controls	S	L	RPN	Additional Controls	S	L	RPN	Implementation Person	Due Date	Remarks
1	Mixing of chemicals A and B	Flammable vapour-air mixture in the flammable range with presence of ignition source	Fire and/ or explosion leading to fatality, severe injuries, burns (including workers, visitors, sub-contractors, members of public)	• Smoking, open flames, sparks, heating are prohibited in process area. • Stationary metallic pipes, parts and equipment are bonded and grounded. • Maintenance programme implemented. • Management of change programme implemented. • Training provided for handling, use, storage, disposal of flammable substances. • Training provided on the use and maintenance of safety control measures. • Emergency planning includes fire and explosion hazards.	4	3	12	Control fugitive flammable vapours from processes by using suitable enclosures, vapour collection systems and equipment design. Equip mixing tank with explosion vent/ pressure relief device. Separate mixing operations from other work areas by explosion-resistant barriers.	2	2	4	Senior Technician	30 Jul 2015	
2	Hazards and control measures listed in this example are not exhaustive													

3.4 Risk Management and Management of Change

Risk Management

With reference to Figure 4, preparation and risk assessment is followed by implementation and review where risk control measures are physically implemented, communicated to employees, audited for conformance, and periodically reviewed for implementation effectiveness. In the event where work-related ill health, near misses or an accident occurs, an immediate review of the risk assessment is necessary. Otherwise, all risk assessments should be reviewed at least once every three years by default.

Risk management includes record-keeping which involves setting up a risk register (i.e. the collection of RA forms for a worksite) as well as keeping relevant records, for example, of RA training sessions, RM implementation audits and RM process management reviews, for a minimum duration of 3 years.

Management of Change

As changes may occur after an initial RA is complete, it is important to subject any contemplated changes (whether minor or major, temporary or permanent) to workplace facilities or operations to a second RA to ascertain the impact of the change on employee safety and health before being implemented. Written procedures to manage changes (e.g., new materials, new equipment, and new procedures) should be established and implemented.

Considerations to be addressed prior to any change include:

- the reason and/ or technical basis for the proposed change;
- the necessary time period for the change to be effected;
- the authorisation required for the change; and
- the update to hazard communication and operating procedures required as a result of the change.

All employees whose job tasks will be affected by the change must be made aware of the change and receive the necessary training to handle the change before the change is made.

Further Information

- Code of Practice on WSH Risk Management
- Fire Risk Assessment Guide by National Fire Prevention Council

4. Fire Prevention, Detection and Control

The identification and implementation of adequate risk control measures is an important aspect of risk assessment. This chapter offers practical ideas and possible solutions for occupiers/ employers/ employees to consider when conducting a fire risk assessment.

4.1 Fire Prevention

The term "prevention" when used in relation to fire means to do everything possible to prevent the fire from starting in the first place. Fire prevention is the most effective way to eliminate a fire risk.

Taking reference from the fire triangle in Figure 2, fire prevention can be achieved by making sure at least one of its components (e.g. fuel, oxygen or ignition/ heat source) is absent from the work environment or in sufficiently reduced quantity, so that conditions are unfavourable for fire to be initiated.

In general, fire prevention can be achieved by any one (or more) of the following means:

- Eliminate/ reduce fuel.
- Eliminate ignition/ heat sources.
- Avoid flammable conditions.

Good housekeeping and the proper storage of flammable materials away from heat/ ignition sources is another important way to prevent fires and this is covered separately in Chapter 5: Storage of Flammable Materials.

4.1.1 Eliminate/ Reduce Fuel

Regardless of whether the fuel being used is in the solid, liquid or gaseous form, the elimination or reduction in fuel inventory means that there will be no or less fuel to burn should a fire occur. This approach is consistent with the key principle of inherently safer design "Minimise" which recommends that the amount of hazardous material (i.e., flammable material in this case) be reduced to the minimum necessary for daily operations.

In line with the concept of inherent safety, the total elimination of the dependency on fuel (e.g., by switching from fuel-based heating to electrical heating) or its substitution with something less hazardous (e.g., by replacing petrol with diesel which carries a higher flash point) are further measures to explore on a case-by-case basis wherever practicable.

4.1.2 Eliminate Ignition/ Heat Sources

In areas where fuel sources are present, the next useful approach to preventing fires is to eliminate all heat/ ignition sources in the vicinity. This requires a thorough examination of the work environment to identify potential ignition/ heat sources followed by removal or repositioning to a safe distance from the fuel source. The recommended safety distance will depend on various factors like the quantity and physical state (solid, liquid or gas) of the fuel, as well as its properties e.g., its volatility and whether generated vapours are denser than air. Additionally, the use of intrinsically safe electrical and communications devices (e.g., radio handsets, on-site testing instruments and portable lighting) is essential in any work area where a flammable atmosphere may exist.

Two ways of eliminating ignition sources are suggested below:

Ban Smoking at Critical Work Areas

As lighted cigarettes are known to cause fires, many companies have chosen to ban smoking in the workplace, particularly at work areas where flammable materials are handled or stored. The ban may be restricted to only critical work zones or enforced companywide (e.g., cigarettes, lighters and other potential mobile ignition sources being declared at security posts and surrendered prior to entry).

Prevent Static Buildup

Static build-up can occur when non-conductive liquids (e.g., fuels like petrol, diesel or kerosene) are carried through metallic pipes, vessels, containers. A static build-up can give rise to electrostatic sparks which can carry sufficient energy to ignite the vapours of the liquid being transferred. Methods to prevent static build-up include the use of anti-static additives and proper bonding and grounding (earthing).

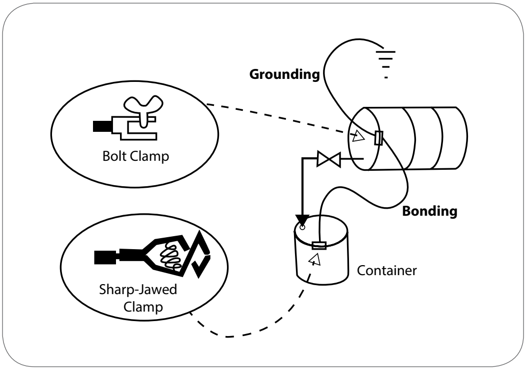


Figure 9: Example of bonding and grounding

Bonding is done by making an electrical connection from one metal container to another. This is to ensure that there will be no difference in electrical potential between the two containers and, hence, no sparks will be formed.

Grounding is done by connecting a metal container to an already grounded object that will conduct electricity. This could be a buried metal plate, a metallic underground gas piping system, or a grounded metal building framework.

Refer to sections 6.1 and 6.2 for more on bonding and grounding applications.

4.1.3 Avoid Flammable Conditions

In situations where there is a possibility for fuel and ignition/ heat sources to co-exist, it becomes critical that flammable conditions be avoided to prevent the outbreak of fire.

In general, flammable conditions may be avoided by any of the following measures:

Lower the Flammable Gas/ Vapour Concentration

This can be achieved through better ventilation whether naturally-occurring (e.g., by working in the open or in a room with open windows) or artificially-generated (e.g., through mechanical room ventilation). With improved ventilation, flammable gas or vapour accumulation may be prevented and any present in the work environment will be diluted to below its LFL so that it exists at a concentration too lean to ignite.

Lower the Temperature of the Flammable Material

This can be achieved by storing the flammable material in a cold environment (e.g. in a cold room or in an explosion-proof refrigerator). At temperatures lower than its flash point, a flammable material would be incapable of ignition.

Inert Gas Blanketing

This refers to the use of an inert gas (e.g., nitrogen and carbon dioxide) to displace and dilute the oxygen in the headspace of a storage container or vessel so that a flammable atmosphere cannot exist. Note that the use of inert gases will result in new hazards, as many of them are asphyxiants which can cause severe breathing difficulties.

Hot Work Permit System

Hot work refers to any work where an ignition or heat source is brought into a work environment where flammable materials are present. Common hot work activities include welding, soldering, cutting, brazing, grinding and drilling.

A hot work permit is essentially part of a Permit-To-Work (PTW) system where a permit is required before hot work can be allowed to proceed. See Figure 10 as an example. For hot work to be authorised, site conditions must first be checked by a competent person to ensure that flammable/ combustible materials have been removed from the work area, flammable conditions are non-existent (via flammable gas testing) and fire protection measures (e.g., on-site water sprinklers, fire watch and fire extinguishers) are in place.

1. Permit Title	**2. Permit Number** – referenced to other relevant permits

3. Place of Work
- specifies the exact location where the work will be taking place

4. Description of Work
- provides overview of the work activities to be carried out

5. Hazard Identification
- includes existing hazards and new hazards introduced by the work

6. Necessary Precautions
- permit evaluator (i.e., the safety assessor) signs to confirm that the necessary precautions (e.g., flammable material removed from place of work, followed by gas testing) have been taken

7. Protective Equipment
- includes use of equipment safeguards (e.g., isolation devices, machine guards)and personal protective equipment (e.g., heat-resistant gloves and coveralls) suitable for the work to be carried out

8. Authorisation
- permit issuer (i.e., the authorising manager) signs to confirm that the necessary precautions and protective equipment are in place and approves the permit
- checks that there is no ongoing incompatible work and specifies the location, date and time duration of the permit

9. Acceptance
- permit acceptor signs to confirm he/ she understands the work to be carried out, the hazards involved and the necessary precautions
- also confirms that the information on this permit has been explained to all workers involved

10. Extension/ Shift Handover Procedures
- signatures confirming that checks have been made and the place of work remains safe for continued work and that the new permit acceptor/ new workers coming on board are fully aware of the hazards involved and the necessary precautions
- permit updated with new time of expiry

11. Hand Back

- work location checked to ensure no sign of fire after the work is complete
- for hot work inside a building, fire command centre notified if impairment to the building's fire protection system has occurred
- signed by the permit acceptor notifying that the work has been completed
- signed by the permit issuer certifying that the work is complete

12. Cancellation

- permit is officially cancelled and the work is no longer allowed to continue

Figure 10: **Typical components of a hot work Permit-To-Work form**

4.2 Fire Detection and Warning System

Should a fire occur despite fire prevention measures being in place, the next best thing one can implement is an early warning system to alert workers in the vicinity to the presence of a flammable gas or fire. A fire, if detected early, will be relatively easy to put out while it is still small.

Early warning systems can be activated automatically via the use of on-site gas, fire, and/ or smoke detectors or manually (e.g. via fire alarm call point).

4.2.1 Automatically-activated Warning System

Installing an automatic system that can both detect fire and raise the alarm will significantly increase fire safety and bring with it the following benefits:

- Early detection of fires when business premises are closed e.g., after office hours and during weekends.
- Early detection of fires in typically unoccupied work areas e.g., storage tank farms, storerooms and equipment rooms.
- Simultaneous operation of other protective devices, such as:
  - automatic operation of fire control system;
  - automatic emergency shutdown of key plant processes and equipment;
  - automatic shutdown of the building ventilation and air conditioning system;
  - automatic closure of fire doors;
  - automatic operation of escape stairway pressurisation system; and
  - automatic notification to the firefighting and rescue service.

Automatic detection can be based on flammable gas detection (before the onset of fire) or heat, flame or smoke detection (after the onset of fire).

Gas Detection

Gas detectors are used to identify the presence of a flammable gas or vapour within a work area. Once a flammable gas or vapour accumulation is detected, the gas detector can be programmed to sound an alarm, warning all personnel in the vicinity to stop work and quickly leave the area, since the atmosphere is no longer safe for continued work.

Gas detectors come in two basic types - fixed and portable gas detectors.

Fixed gas detectors are typically located near flammable material storage and handling areas. They are commonly mounted on rigid metal supports, with a cable connecting the detector to a centrally-located computer system for continuous monitoring.

Portable gas detectors are used to monitor the atmosphere around a worker (e.g., during hot work and when working in a confined space) and are usually worn on clothing or clipped onto one's belt or harness. They are usually battery operated and will transmit warnings via a series of audible, visible and sensory signals (e.g., alarms, flashing lights and vibrations) before a dangerous concentration of flammable gas is reached or once the concentration detected is above a fixed percentage (usually 10%) of the LFL.

To ensure detection accuracy, all gas detectors (whether fixed or portable) should be recalibrated at a stipulated frequency according to manufacturer's recommendation.

Figure 11: A portable gas detector

Fire Detection

Fire can be easily detected by the presence of a flame or by the heat generated by the flame.

Flame detector. These operate by recognising the specific bandwidths of light emitted by a fire. Flame detectors are typically used in locations where immediate detection of fire is needed. As a direct line of sight to the fire is required for flame detectors to operate properly, it is often necessary to train a few of these detectors at a specific work area to achieve full coverage.

Heat detector. These operate by sensing the temperature of the work environment. Some are designed to operate once a fixed ambient temperature has been reached whereas others detect the rate-of-temperature-rise associated with a developing fire. Fixed heat detectors are often used in kitchen areas in place of smoke detectors as these may frequently actuate due to the smoke arising from cooking activities.

Smoke Detection

Smoke is the result of incomplete combustion. Where there is fire, there is usually smoke. The detection of smoke, therefore, indicates the likely occurrence of a fire. Smoke detection can be achieved in two ways:

Ionisation smoke detector. These detect the small particles contained in smoke. The detector in these units consists of a small amount of radioactive material to ionise the air. When smoke enters the chamber, the smoke particles become ionised as well and this changes the electrical conductivity of the air between the electrodes in the detector. This allows the smoke particles floating in air (including those invisible to the naked eye) to be detected. Once smoke is detected, the alarm will be triggered.

Photoelectric smoke detector. These detect all types of smoke, but are ideal for smoke with larger particles, such as smoke from burning furniture. Two key principles used in photoelectric detectors are light obscuration and light scattering. Light obscuration smoke detectors work by projecting a light beam on a photosensitive device. When smoke particles enter the detector, they block the light beam and hence reduce the intensity of light reaching the photosensitive device. Similarly, light scattering smoke detectors operate with a light source and photosensitive device. The difference here is that the photosensitive device is not placed along the path of the light beam. As smoke enters the detector, light is reflected (scattered) from the smoke particles onto the photosensitive device, causing the alarm to be activated.

Figure 12: Ceiling-mounted smoke detector

All detectors, whether used for detecting gas, fire or smoke, must be tested regularly (e.g., monthly, quarterly, semi-annually and/ or annual testing according to manufacturer recommendations) to ensure that they are functional and will operate as intended in the event of a fire.

4.2.2 Manually-activated Warning System

Manually-activated fire alarm call points are designed for the purpose of raising an alarm by a person once a fire emergency condition is discovered. Activating the manual call point would instantly trigger the fire alarm, alerting all persons in the premises to prepare for emergency evacuation.

Figure 13: Fire Alarm Call Point

Manual fire alarm call points should be mounted along escape routes (e.g. passageways and exits points) and be easily accessible. This is to ensure that one does not have to go out of the way to raise the fire alarm and that the alarm can be readily activated by a person evacuating the premises. An installation height of 1.4 m (measured from the middle of the call point to the floor) is recommended. More information on fire alarm call points is given in SCDF Fire Code 2013 and Singapore Standard CP 10: 2005 Code of Practice for Installation and Servicing of Electrical Fire Alarm Systems.

Modern fire alarm call points are typically interfaced with the fire alarm panel which will pinpoint the exact location of the call point being activated. This will allow security, firefighting and rescue personnel to quickly determine the approximate location of the fire and respond as appropriate.

4.3 Fire Control

Controlling (or mitigating) a fire includes the on-site measures taken to prevent fire spread, reduce the duration of a fire and/ or extinguish the fire.

4.3.1 Prevent Fire Spread

Once a fire has broken out, one of the primary objectives of fire control is to prevent the fire from spreading to neighbouring work areas. Measures taken to prevent fire spread need to be put in place before any work involving flammable materials is attempted.

Figure 14: Example of a diked storage area

Measures to prevent fire spread include:

- Storing flammable materials in separated storage clusters instead of crowding everything into a single area;
- Ensuring sufficient separation distance and/ or erecting fire-resistant walls between storage clusters of flammable materials ;
- Installing a spill control dike around each storage cluster for secondary containment and to limit the spread of pool fires;
- Installing fire doors and ensuring these are kept shut (e.g., by means of a self-closing mechanism) when not in use; and
- Practising safe housekeeping at all times to ensure that flammable materials are stored safely and all routes for access and egress are free from obstruction and flammable materials.

4.3.2 Reduce Fire Duration

With measures to prevent fire spread in place, the next challenge in fire control is to reduce the duration of the fire. For fires involving continuous flow of a liquid or gas, best way to control the duration of fire is to starve the fire by shutting-off the source of fuel e.g., by stopping the liquid pump/ gas compressor and/ or closing the valves between the fuel source and the point of fire.

4.3.3 Extinguish the Fire

Firefighting involves doing whatever it takes to put out (extinguish) the fire. With reference to Figure 2, extinguishment requires the removal of any one or more components (i.e., fuel, oxygen, ignition/ heat source) of the fire triangle. Fire extinguishment may be achieved by cooling, smothering and/ or starvation (see Table 7).

4.3.3.1 Portable fire extinguishers

Portable fire extinguishers can be very effective for controlling small fires. The four common types of fire extinguishers used in Singapore are dry powder fire extinguisher (most common), carbon dioxide fire extinguisher, foam fire extinguisher and pressurised water fire extinguisher (least common due to the widespread adoption of other on-site water dispensing fire fighting facilities e.g. water sprinkler system and firewater hose reels).

Extinguisher Type	Action
Dry Chemical	Smothering and interference with the combustion process
Carbon Dioxide (CO_2)	Mainly smothering and some cooling
Foam	Mainly smothering and some cooling
Water	Cooling

Table 14: List of Common Fire Extinguisher Types and their Action on Fire

Extinguisher Type	Suitable for:	Remarks
Dry Chemical (Multi-purpose)	Class A, B, C and electrical fires	Most versatile with wide applicability. However, residue is corrosive and sticky and may cause damage to delicate electrical equipment.
Carbon Dioxide (CO_2)	Class B, C and electrical fires	Very clean leaving behind no residue. Excellent for use on electrical equipment. Must be applied very close to the fire as spraying range is short.
Foam	Class A, B fires	Not to be applied on electrical equipment as foam contains water. Good for application on oil fires.
Water	Class A fires only	Inexpensive to refill and maintain. Limited applicability. Not to be applied on electrical equipment as water is a conductor of electricity and will severely damage the equipment. Not to be used on oil fires as oil will, in general, float on water.

Table 15: List of Common Fire Extinguisher Types and their Applicability by Fire Class

Most workplaces will be equipped mainly with ABC dry chemical fire extinguishers placed strategically all around with CO_2 fire extinguishers stationed near electrical equipment.

In general, the dry chemical fire extinguisher can be used on chemical, paper or electrical fires. Whilst the CO_2 extinguisher can be used on chemical, flammable liquid/ gas or electrical fires, it is the extinguisher of choice for fires involving electrical equipment.

Water as an extinguishing agent should be reserved for use on fires involving combustible materials such as wood, paper, cloth and plastics.

Good practice is to call for immediate replacement once any fire extinguisher is found to be used, damaged, vandalised or if the indicator on its pressure gauge is in the red zone. Fire extinguishers should also be regularly serviced in accordance to the timeline stipulated by the supplier.

Should a person's clothes be on fire, carry out "stop, drop and roll" by telling the victim to stop running (running causes the flames to grow larger), getting the victim to quickly drop to the ground, and asking the victim to roll from side to side (whilst covering his/ her face with his/ her hands) till the fire goes out. If a fire blanket is available, use it to wrap the victim as this will help accelerate flame extinguishment. The use of dry chemical or CO_2 on the victim, however, is not recommended due to possible complications.

General Guide on the use of a Fire Extinguisher

Attempt to extinguish only small fires with a portable fire extinguisher and always fight a fire from a location that allows escape.

To use a fire extinguisher:

- Pull out the safety pin;
- Aim the fire extinguisher nozzle at the base of the fire;
- Squeeze the handle of the fire extinguisher to release the extinguishing media; and
- Sweep the nozzle from side to side and aim the discharge at the base of the fire starting from the front and working towards the rear until the fire goes out

If the fire cannot be extinguished, immediately evacuate the premises and close the doors as you leave (to limit fire spread). The building fire alarm system should be activated and SCDF (dial 995) notified at the earliest possible time.

Figure 15: **ABC dry chemical fire extinguisher**

To ensure that portable fire extinguishers are in good working order and ready for use, they must be maintained in fully operational condition at all times. The owner or occupier of a premise is responsible for the inspection and maintenance of all fire extinguishers installed on the premises. The list of certified portable fire extinguisher servicing companies can be found on SCDF website (www.scdf.gov.sg).

4.3.3.2 Fixed firefighting facilities

Onsite firefighting is supported by a pressurised fire mains system comprising a water source, fire pumps and a distributed piping network supplying firefighting water to fire hydrants, water risers, fire hose reels, fire monitors, water curtains and automatic fire deluge/ sprinkler systems.

Through the fire mains system, firefighting personnel are provided with a reliable and versatile water system capable of providing different methods with which to engage a fire. For example, water can be supplied as a straight stream for combating deep-seated fires or as a spray for combating combustible liquid fires where cooling and minimum agitation is desired.

For oil-based fires, the use of firefighting foam (created by mixing foam concentrate with air and the water available on-site) is recommended as the coat of foam created on the surface of the oil will block the oxygen supply and smother the fire.

Fire Hose Reels

A fire hose reel contains a rolled-up high pressure hose that is designed to carry water to the location of a Class A fire. The length of a fully extended fire hose is typically up to 30 m. Fire hoses must be connected to the mains water supply e.g., via a riser. There will be an inlet valve (normally in the closed position) to allow water into the hose. A nozzle attached to the end of the hose enables the person fighting the fire to control the discharge of water to the fire. A water throw of 6 to 9 m is expected under optimal operating conditions.

Some fire hose reels are located within cabinets whilst others are mounted directly on the wall.

Figure 16: Fire hose reel located inside a cabinet

General Guide on the use of a Fire Hose Reel

- Check that the nozzle is in the closed position.
- Turn on the inlet valve to allow water into the hose.
- Remove the nozzle from its bracket and proceed to run out the hose to the fire location. Seek help to unroll the hose and ensure that the hose is not kinked as this will affect the water flow.
- Adopt a firefighting position that is a safe distance away from the fire, checking to ensure there is a clear line of retreat should the fire be uncontrollable.
- Open the nozzle and direct the stream of water at the base of the fire, following through with a sweeping action till the fire is extinguished.

If the fire cannot be extinguished, immediately evacuate the premises and close the doors as you leave (to limit fire spread). The building fire alarm system should be activated and SCDF (dial 995) notified at the earliest possible time.

Automatic Fire Sprinkler Systems

A fire sprinkler system is an active protection measure providing an overhead water (or foam) spray for on-site fire suppression. Sprinkler systems are commonly found in work premises both indoor (e.g., mounted on the ceilings inside a building or over designated equipment within a factory) as well as outdoors (e.g., mounted over a flammable material storage area or over a tank container stationed in a loading/ unloading facility).

There are two common types of sprinklers - standard sprinklers (used in e.g., factories and warehouses) and concealed sprinklers (for architecturally sensitive areas such as hotel lobbies, office buildings and restaurants). Sprinklers are typically triggered by a heat sensitive element (e.g., a glass bulb or a fusible link) located within the sprinkler head. Standard sprinklers may be affixed with a sprinkler guard to protect sprinkler heads in areas where they are susceptible to physical damage.

It is important that all fire safety equipment (e.g., gas/ fire/ smoke detectors, fire alarm system, fire extinguishers, fire hose reels, fire sprinkler system) are regularly inspected and maintained. This will ensure that they are in good working condition and will operate as intended during a fire emergency.

Further Information

- SCDF Fire Code 2013
- CP 10: 2005 Code of Practice for Installation and Servicing of Electrical Fire Alarm Systems
- CP 52: 2004 Code of Practice for Automatic Fire Sprinkler System
- SS EN 3: 2012 Portable Fire Extinguishers (EN 3 Series)
- SS 575: 2012 Code of Practice for Fire Hydrant, Rising Mains and Hose Reel Systems
- SS 578: 2012 Code of Practice for Use and Maintenance of Portable Fire Extinguishers

Figure 17: Standard sprinkler with guard

Figure 18: Concealed sprinkler

5. Storage of Flammable Materials

Proper storage is essential to protect flammable materials from ignition sources. Through proper storage, fires can be prevented and better controlled (to minimise fire spread) should it occur.

This chapter focuses on fire safety measures for minor storage (involving a small cluster) of flammable materials.

As per Singapore Standard SS 532: 2007 Code of Practice for The Storage of Flammable Liquids, "minor storage" refers to the storage of flammable liquids, in various locations, in small quantities no larger than the set quantities specified in the standard.

In general, minor storage refers to any storage of flammable liquid (i) less than or equal to 50 litres or 2.0 litres/m2, and (ii) not more than 200 litres per minor storage area. The criteria for classification as minor storage, however, varies with the location of storage (e.g., in a residential building, in a commercial building, in a storage warehouse, in a laboratory, in a factory, etc) as well as the degree of flammability of the liquid being stored (e.g., extremely flammable versus highly flammable). Details of the classification criteria can be found in Table 2 of SS 532: 2007.

Note that storage of petroleum and flammable materials (P&FM) is regulated by SCDF and a P&FM storage licence may be required (depending on storage quantity) prior to bringing such materials onto your premises. More information on fire safety and P&FM licensing may be found on SCDF website (www.scdf.gov.sg).

Specific guidance on the storage of flammable gases can be found in NFPA 55: 2013 Compressed Gases and Cryogenic Fluids Code and NFPA 58: 2014 Liquefied Petroleum Gas Code. Suggested references for specific storage situations (namely, hazardous material warehouses, LPG cylinder installations and laboratories handling chemicals) are provided in the References section of this Guidelines.

Recommended Practice for Minor Storage of Flammable Materials

- Keep the amount of flammable materials in storage as small as possible.
- Keep storage areas away from any heat and ignition source.
- Ensure that storage areas are well-ventilated so that flammable vapour concentrations (e.g., due to spillage or leaks) can be kept low (below the LFL).
- Store flammable materials in a cool (e.g., under a shelter or under temperature-controlled environments if necessary) and dry (to prevent metal container corrosion as well as workplace slips, trips and falls) location.
- Store flammable materials in areas accessible by emergency response teams. Ground floor storage is recommended as this will provide for easier access during an emergency.

- Store flammable materials separately, away from process and production areas and other combustible materials. This separation will reduce the spread of any fire originating from the flammables storage area. The separation will also protect the stored flammable material from exposure to fires in neighbouring areas, as well as accidental contact with incompatible materials (e.g., oxidizers).
- Store flammable liquids with flash points lower than room temperature under appropriate conditions (e.g., under refrigerated conditions). Do not store flammable liquids in a standard refrigerator meant for household use as they are not designed to be free of ignition sources. Store small quantities of flammables only in a laboratory-safe or explosion-proof refrigerator. The refrigerator's temperature needs to be set lower than the flash point of the most readily ignitable substance stored in the refrigerator.
- Do not store flammable materials in areas that may jeopardise escape in the event of fire. In particular, make sure that storage containers do not block fire lifts, fire exits, stairwells and any aisles leading to exits.
- Store flammable materials in separate minor storage clusters separated by a suitable safety distance (see Table 16 for guidance on minimum separation distance) or fire-resistant walls.
- Store larger quantities in metal drums placed on spill control pallets or within a dike. Smaller quantities may be stored in a fire-rated (minimum 1 hour) storage cabinet designed to protect its contents from the heat and flames of an external fire.
- Do not use plastic or glass containers for storing flammable liquids unless storage in metal containers affects the purity of the liquid or if the liquid causes excessive corrosion of the metal container.
- Inspect all incoming containers to ensure that they are not damaged. Do not accept delivery of defective containers.
- Affix all flammable material storage containers with GHS labels and keep them closed when not in use.
- Practice good housekeeping and immediately clean up any spills that occur in the storage area.
- Allow only trained, authorised personnel into storage areas.
- Inspect storage areas regularly for any deficiencies such as damaged or leaking containers, poor ventilation or non-approved equipment. Correct all deficiencies as soon as possible.
- Provide storage areas with adequate firefighting and spill clean-up equipment.

5.1 Separation Distance for Minor Storage

The following guidance on minimum separation distance is based on Singapore Standard SS 532: 2007 Code of Practice for The Storage of Flammable Liquids:

Indoor Storage	Minimum separation distance	
	Non-sprinkler protected area	Sprinkler protected area
Between two indoor minor storage areas	10 m	7.5 m
Between indoor minor storage area and a flammables storage cabinet	5 m	3 m

Outdoor Storage	Minimum separation distance
Between outdoor minor storage area and boundary of the company's premises	1.5 m
Between two outdoor minor storage areas *	7.5 m

Outdoor-to-Indoor Storage	Minimum separation distance
Between outdoor minor storage area and indoor minor storage area	5 m

** Placing more than one outdoor minor storage is not encouraged as this increases the fire risk*

Table 16: **Minimum separation distance for various indoor and outdoor storage configurations**

5.2 Hazard Communication at Storage Areas

As per Singapore Standard SS 586: Part 1: 2014 Specification for Hazard Communication for Hazardous Chemicals and Dangerous Goods – Part 1: Transport and Storage of Dangerous Goods, dangerous goods (this includes flammable materials) package stores are to be provided with warning placards to be posted on-site at the storage location.

For indoor storage of flammable materials, the warning placard is to be posted at each entrance to the store. For outdoor storage, the warning placard is to prominently displayed at the storage area.

The relevant placards for storage of flammable materials are as follows:

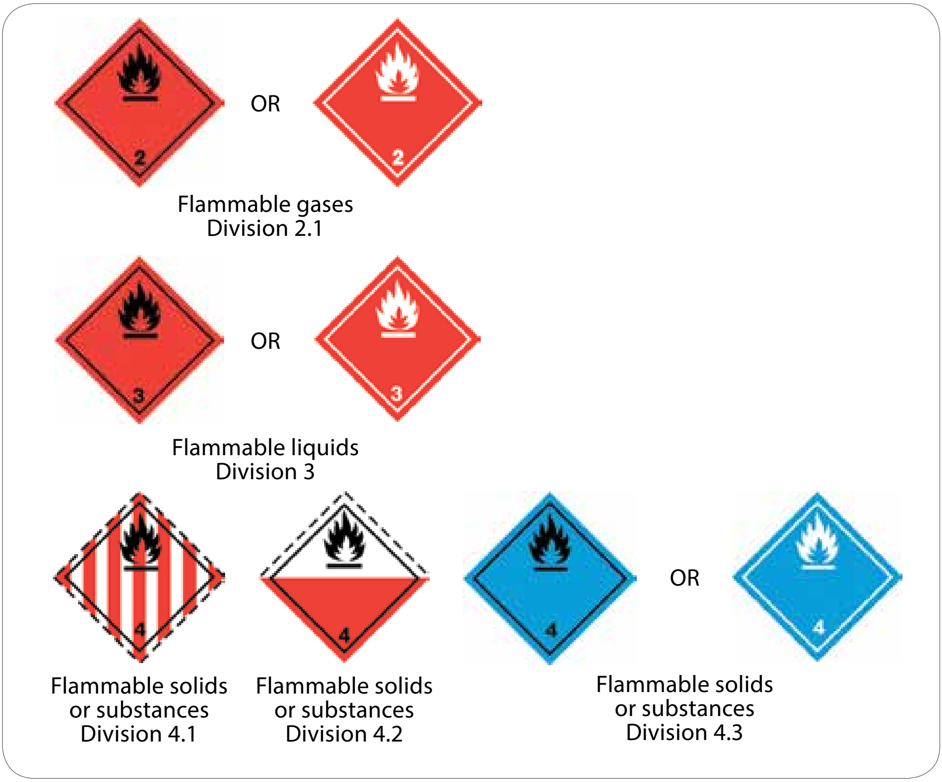


Figure 19: Storage placards for flammable materials based on United Nations' Recommendations on the Transport of Dangerous Goods (UNRTDG) (Source of images: www.unece.org)

UNRTDG Classification of Flammable Materials

Class 2 (DG): Gases
- Division 2.1 Flammable gases
- Division 2.2 Non-flammable, non-toxic gases
- Division 2.3 Toxic Gases

Class 3 (DG): Flammable liquids

Class 4 (DG): Flammable solids or substances
- Division 4.1 Flammable solids, self-reactive substances and solid desensitised explosives
- Division 4.2 Substances liable to spontaneous combustion
- Division 4.3 Substances which emit flammable gases on contact with water

Figure 20: **Classification of Flammable Materials based on UNRTDG**

The size of each warning placard must not be less than 250 mm by 250 mm.

Along with the placards, the posting of suitable warning signs (e.g., "No Smoking" sign) is also recommended.

Further Information

- SS 586: 2014 Specification for Hazard Communication for Hazardous Chemicals and Dangerous Goods – Part 1: Transport and Storage of Dangerous Goods
- United Nations' Recommendations on the Transport of Dangerous Goods (Volumes I and II)

6. Handling of Flammable Materials

Flammable materials present a fire hazard in any workplace as they are readily ignitable, easily causing a fire. Users of flammable materials are advised to consult this chapter prior to attempting any work involving a flammable material.

Recommended Practice for Safe Handling of Flammable Materials

- Consult the SDS for each material you work with, identify those that are flammable and understand their flammability characteristics. The other hazards of the material may need to be addressed such as health toxicity and reactivity, and general guidance can be found on the SDS.
- For each material identified as flammable, ensure that its container is correctly labelled (see Section 5 on GHS labelling) to indicate the hazardous nature of its contents.
- Check each container to ensure that it is not damaged and that its safety features (e.g., relief vent, flame arrester, any spring-loaded mechanism) are in good condition and working properly.
- Obtain the completed risk assessment form for the work activity to be performed. Identify the existing risk controls already in place and the additional control measures that need to be taken to further bring down the risk level associated with the work activity.
- Practice good housekeeping and check that your work area is free from combustible materials.
- Familiarise with the fire emergency response plan for your specific work area.
- Inspect your work environment and confirm that there are no ignition sources (e.g., open flames, sparks, hot surfaces) in your work area.
- Put on the appropriate PPE (e.g., safety goggles, fire-retardant coveralls and gloves) prior to any work activity involving flammables. Be familiar with the correct PPE for day-to-day operations, as well as for emergencies.
- Work behind a splash guard or face shield when working with a machine or process that ejects flammable or combustible liquids.
- Use only the minimum amount of flammable material for your work. It is good practice to keep no more than a day's supply of flammable material in your immediate work area. Return any leftover material to the proper storage area or cabinet at the end of each work day.
- Bond and ground metal containers before transferring flammable liquids (or powders).
- Where practicable, carry out the transfer of flammable materials under local exhaust ventilation or via closed system transfer (e.g., through fixed piping systems) so as to avoid the creation of flammable vapour concentrations in the atmosphere. If this is not possible, ensure that the work environment is well-ventilated before dispensing or using a flammable material.

- When transferring a flammable material, work in an area where a fixed gas detector has been installed or use a portable gas detector to continuously monitor the work environment. Programme the detector to raise an alarm before dangerous concentrations are reached.
- Always keep containers of flammable material closed when not in use in order to minimise the escape of flammable vapours.

6.1 Bulk Handling of Flammable Materials

ISO tank containers (i.e., tank containers built to standards set by the International Organisation for Standardisation) are commonly used for the bulk transportation of chemicals (including flammable materials) within Singapore via the use of prime movers and trailers. ISO tank containers are made of stainless steel and come in a variety of sizes ranging from 27,000 to 40,000 litres[4].

For transporting smaller bulk quantities of chemicals, Intermediate Bulk Containers (IBCs; size ranging from 1,000 to 1,250 litres per IBC) and cylindrical metal drums (200 litres per drum) are typically used.

Other types of containers used for carrying flammable materials include tube trailers (e.g., for transporting compressed hydrogen) and gas cylinders (e.g., for transporting liquefied petroleum gas).

For work involving bulk loading/ unloading of a flammable material, it is important to ensure that the following are made available on-site at the loading/ unloading facility prior to work commencement:

- automatic water sprinkler system
- fire extinguisher(s)
- emergency stop button
- eye wash and safety shower
- first aid box
- spill control kit

Loading/ Unloading of ISO Tank Containers

An ISO tank container can be loaded or unloaded from its top or bottom. On a standard tank container, there is a manhole and at least one valve at its top, and another at its bottom. Loading and unloading is achieved by connecting hoses from the loading/ unloading facility to the valves of the tank container. Loading or unloading is then carried out by gravity, pressurisation or pumping.

[4] Refer to Fire Safety (Petroleum and Flammable Materials) Regulations for maximum allowable laden weight for vehicles transporting petroleum or any flammable liquid in bulk.

For safe loading/ unloading of a flammable material to/ from a tank container, it is critical to prevent static build-up through electrical bonding and grounding. Grounding (earthing) connections are typically provided at the bottom front and rear of each ISO container to prevent differences in electrical potential arising between the tank container, the body of the vehicle, the piping used and the ground during the loading/ unloading operation. Proper bonding and grounding (earthing) will prevent the formation of electrostatic sparks which can ignite the vapours of the material being transferred.

Further guidance on the safe handling of chemicals in logistics operations is available in SCIC's Guidebook on Transport & Handling of Dangerous Goods.

Figure 21: **Bonding and grounding of an ISO tank container**

1. Bonding wire

2. Grounding wire

Loading/ Unloading of Intermediate Bulk Containers and Pallets of Metal Drums

IBCs are reusable industrial containers designed for the transport and storage of bulk liquid and granulated materials. The most common IBC is the single-use plastic composite IBC – a white/ translucent cube-shaped plastic container (typically made of polyethylene) housed within a tubular galvanized iron cage. For flammable materials, the use of metal IBCs (fitted with a venting device) is recommended for enhanced fire resistance. IBCs are designed to be stackable and moved with a forklift or a pallet jack.

An alternative to the use of IBCs is the use of palletised metal drums (typically 4 to 6 drums per pallet). Each pallet of drums (also known as barrels; typically made of steel) is also stackable and can be moved with a forklift or a pallet jack.

When loading/ unloading an IBC or a pallet of drums from the back of a lorry/ truck or when moving it with a forklift within the work area, extra care must be taken not to puncture or drop the containers as this will cause a spill resulting in the formation of a flammable vapour cloud.

When filling an IBC or drum with a flammable liquid, proper bonding and grounding is again necessary to prevent the formation of electrostatic sparks during the transfer. Specially-designed drum funnels, fitted with a flame arrester, may be used to affect the safe transfer of flammable liquids. A large diameter funnel will also help to minimise the risk of spills.

Figure 22: Intermediate Bulk Container (IBC) vs palletised metal drums

Further Information

- WSH Guidelines on Safe Loading on Vehicles
- WSH Guidelines on Safe Operation of Forklift Trucks

6.2 Dispensing Small Quantities of Flammable Materials

Many companies receive flammable liquids in metal drums or IBCs, and then fill smaller containers from them. While there are different types of small containers that can be used, the use of safety cans is recommended for safer handling of flammable liquids.

Using unsuitable containers such as open cans, buckets or pails is a dangerous practice as the escape of flammable vapours cannot be prevented. In general, the use of glass containers is not advised as these are easily breakable and will increase the chance of a serious spill.

The use of non-reusable glass or plastic containers is acceptable only in special cases where the required liquid purity (e.g., analytical reagent grade or higher) is affected by storage within a metal container, or if the liquid causes excessive corrosion of the metal container.

Metal Drum

Fully-filled metal drums can be very heavy and trying to move one by hand can be difficult, dangerous and bad for your back. Always use a mechanical aid (e.g., a specially designed drum cradle or trolley) for moving individual drums around.

Note that drums used for storage of flammable liquids will require venting to relieve pressure build-up (e.g., due to exposure to heat) and prevent the creation of a vacuum (e.g., when liquid is being dispensed). As either pressure or vacuum can cause failure of the metal drum, the use of metal drums with automatic pressure- and vacuum-relief is essential.

Each drum vent should also be fitted with a flame arrester for protection against flashback from external ignition sources.

Dispensing from Metal Drum to Safety Can

A flammable liquid transfer pump with anti-static flexible hose may be used to facilitate safe transfer from a metal drum to a safety can.

As static build-up can occur during the transfer of flammable materials from one metal container to another, bonding and grounding (earthing) is necessary before transferring to prevent the generation of electrostatic sparks and possible vapour ignition. The use of anti-static flexible cables/ wires and spring-loaded clamps may be used to achieve an effective on-site bonding and grounding solution.

Bonding both containers and grounding one of them basically "drains off" static charges and prevents the discharge of sparks. All grounding and bonding connections must be from bare metal to bare metal. It is therefore critical that all dirt, paint, rust or corrosion is removed from every electrical contact point.

Figure 23: **Bonding and grounding necessary for transfer between metal containers**

1. Bonding wire

2. Grounding wire

Safety Can

Portable safety cans are recommended for carrying, storing and dispensing small quantities of flammable liquids. They are available in different shapes and in capacities ranging from 0.5 to 25 litres. Safety cans are usually made of metal or very low conductivity plastic.

The special feature of safety cans is that they have spring-loaded self-closing spout caps. These caps automatically open when the vapour pressure builds up inside[5], allowing vapours to escape and preventing rupture of the can (e.g., when exposed to fire).

The cap-operating mechanism of a safety can also cause the spout cap to automatically close once pouring is complete, or if the can is dropped. This instant cut-off capability allows one-handed control for safer dispensing without spills. Flexible metal safety hoses can be threaded into the spout cap of the safety can for added control.

Safety cans also typically house a wire mesh flame arrester screen inside its cap spout. These serve to prevent a flashback (from an external ignition source) from reaching the flammable liquid inside the cans.

[5] Note that while this is a safety feature, it could create a hazard under some conditions. Do not store a safety can in a warm, enclosed space (such as in a vehicle) as vapours venting from a safety can may accumulate to within the flammable range and all it would take is a spark to cause a fire. For transporting small amounts of flammable liquid, use a pressure-resistant and non-venting container instead of a safety can.

Never use any safety can that is damaged. If repairs using approved replacement parts cannot restore the damaged can to a safe condition, it should be discarded once it has been properly cleaned.

Health Considerations

As flammable materials may also be toxic (i.e., harmful to human health), it is important to also take the necessary precautionary measures to minimise exposure and protect one's health when working with a flammable material.

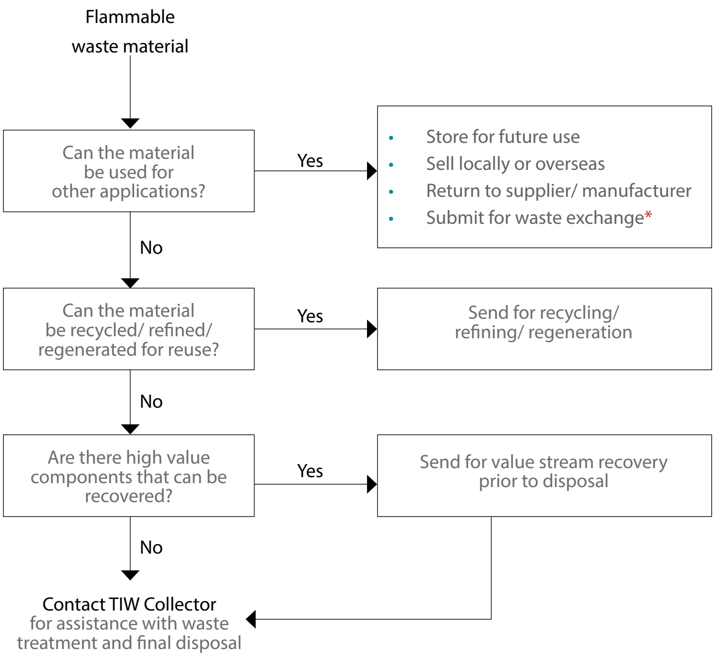
Taking Care of Your Health when Handling Flammable Materials	
Avoid inhaling flammable gases & vapours • Work with a closed material transfer system • Work under local exhaust ventilation • Use a suitable respirator (e.g., air purifying or air-supplied as necessary) • Minimise the duration which a container of flammable material is kept open	**Avoid skin & eye contact with flammable liquids** • Work behind a shield (e.g., a lowered sash of a laboratory fume cupboard) whenever possible • Wear the necessary PPE (e.g., face shield, chemical resistant coveralls, boots and gloves) • Minimise fall distance and splashing by pouring slowly and keeping the containers close to each other. Use a guiding rod to facilitate the material transfer as necessary.

Table 17: Precautions to be taken to avoid bodily contact with a flammable material

7. Disposal of Flammable Materials

Waste refers to any material which can no longer be used for the purpose it was originally intended for. As flammable waste materials (including waste containing flammable materials) can easily catch fire, it is important that they be disposed off safely, properly and responsibly. Responsibility for flammable materials extends beyond careful storage and handling, and does not end until the materials have been disposed off properly. This is so that the fire risk associated with flammable materials can be effectively managed and not cause harm to person(s) handling the waste or damage to downstream waste treatment facilities, property or the environment.

Below is a simple flowchart (see Figure 24) to explore if the opportunity for reuse or recovery exists prior to disposing a flammable material:



*As waste to one company may be a resource to another, the exchange of waste would result in "waste" being put to good use whilst reducing the overall quantity of waste to be disposed.

Figure 24: **Decision flowchart for flammable waste disposal**

As most companies do not have on-site hazardous waste treatment or incineration facilities, the services of a licensed Toxic Industrial Waste (TIW) collector will be necessary to achieve proper and safe disposal of flammable materials as well as the containers in which they reside.

The updated list of TIW contractors licensed by (NEA) under the Environmental Public Health (TIW) Regulations may be found at NEA's website (www.nea.gov.sg) under Anti-Pollution & Radiation Protection > Chemical Pollution > Toxic Industrial Waste.

Recommended Practice for Safe Disposal of Flammable Materials

- Do not dispose flammable materials together with general waste as our solid waste management system is not designed to specially handle flammable materials and this will raise the potential for fire outbreak during downstream waste handling.
- Do not pour flammable liquids into storm water drains or down the sink as this will pollute the environment, raise the potential for fire within the sewer system and increase the burden on our wastewater management system.
- Put on the appropriate PPE (e.g., safety goggles, fire-retardant coveralls and gloves) prior to handling flammable waste materials.
- Store flammable waste materials in the same way as unused flammable materials (e.g., in a suitable closed container placed in a well-ventilated environment or in a storage cabinet for flammables and located safely away from heat/ ignition sources). The chosen container (typically made of glass, plastic or metal) should be in good condition, durable, leak-proof and compatible with its contents.
- Clearly label each flammable waste container as "HAZARDOUS WASTE" together with the appropriate GHS hazard pictogram. At minimum, the label should state the:
  - waste type (e.g., highly flammable liquid);
  - volume of the waste;
  - its key chemical constituents;
  - purity of the waste (if available);
  - date of disposal;
  - associated safety and health hazards; and
  - the recommended PPE if necessary.
- If the waste container is already partially filled, conduct a RA and check for chemical compatibility before pouring in more waste. Never mix one type of waste with another waste in the same container unless the constituents in both waste sources are known. If necessary, conduct laboratory testing to ascertain the hazardous substances in each source before combining waste from different sources.
- Contact your TIW collector once the minimum quantity required for a collection has been reached so that only the minimum amount of flammable materials (a fire hazard) is stored on your premises.
- Use waste bins with self-closing lids for disposal of cloth (including rags), paper and other solid materials contaminated with a flammable material. These bins are designed to remain closed when not in use, thereby isolating its contents from any external ignition source. The lid also serves to block air from entering and this helps to smother any fire that may start inside the bin. The use of waste bins with lids that are opened with a foot pedal are

recommended. It is good practice not to overfill these bins and to empty them at the end of each workday.

- Return all unused and partially/ fully depleted flammable gas cylinders to the industrial gas supplier/ distributor/ vendor.
- Record the details of the waste disposal (e.g., description of the waste, volume or weight of the waste, date of disposal, TIW contractor responsible for the disposal) in the waste register.

Caution!

- **Treat flammable waste as you would for all flammables**

  There is a tendency for people to be more careless with unwanted/ discarded materials than with new materials. When flammable materials are handled with such an attitude, a fire is bound to happen sooner or later.

- **Treat mixtures of flammable and combustible liquids as flammable**

  For example, if a metal drum filled with waste kerosene (a combustible liquid) is topped off with a few litres of waste naphtha (a flammable liquid), the mixture should be considered as hazardous as a full drum of naphtha. This is because the vapours of the flammable liquid can readily form an ignitable mixture with air, and any fire in the mixture would result in the immediate generation of vapours from the combustible liquid as well.

- **Be careful with "empty" flammable and combustible liquid containers**

  "Empty" containers may contain enough liquid to cause a fire. Only a small amount (as low as a few millilitres) of flammable liquid may generate sufficient vapours to form a flammable atmosphere within the container. This amount of liquid can easily be trapped in a seam within the container or be present as a very thin film on the inner surface of the container. It is therefore important not to perform any work (e.g., welding, cutting, drilling, soldering) on an "empty" liquid container until all liquid and vapours have been cleaned out. Contact the chemical manufacturer or supplier for the best way to do this.

Further Information

- SS 603: 2014 Code of Practice for Hazardous Waste Management

8. Emergency Response

Emergencies can happen anywhere and at anytime. Accidents involving flammable materials often result in fires, which if uncontrolled, may result in death or injury of a large number of persons or cause extensive damage to equipment, property and the environment. As being prepared helps to minimise injury and reduce the extent of damage, it is important for companies to put in place an emergency response plan.

8.1 Emergency Response Plan

An Emergency Response Plan (ERP) details the various mitigation measures and operational actions that need to be taken immediately by a company in the event of fire or other emergencies (e.g., a major chemical spill). To be ready for emergencies involving a fire, the ERP typically includes information on the types of fire safety measures provided in the designated work area as well as the floor layout plans and fire evacuation route.

Key aspects of an ERP include:

- Overview of the premises, site operations and occupancy load.
- Risk assessment and information on site-specific hazards (e.g., pertaining to storage of P&FM and hazardous substances).
- Procedure to notify SCDF, Police, relevant authorities and neighbouring companies.
- Procedure for emergency evacuation.
- Procedure for emergency action to contain the emergency (e.g., emergency shutdown procedure, firefighting and rescue procedure, procedure for in-place protection).
- Procedure for decontamination and restoration to normal operations.
- Emergency contact numbers (for both during and after office hours).
- Information on fire protection facilities and equipment (e.g., sprinkler system, fire extinguishers) and safety/ first aid equipment (e.g., breathing apparatus, stretcher, resuscitators, first aid kit).
- Information on incident command centre, command structure and coordination with SCDF.
- Plans for employee communication, table-top exercise and emergency drills.

Visit SCDF website at www.scdf.gov.sg to download the template entitled "General Guidelines for Emergency Response Plan" which may be used to assist in the development of an ERP.

Further Information

- SCDF Guidelines for Emergency Response Plan
- SCDF Civil Defence Emergency Handbook

8.2 Fire Evacuation

In a serious emergency involving a fire, the premises must be vacated as quickly as possible. Urgent evacuation is necessary so that all persons are moved away from the hazard area to a safe location. Evacuation also clears the way for the Company Emergency Response Team (CERT) and SCDF personnel who will be handling the emergency.

There are 3 models of evacuation depending on the height of the building:

A. Low-rise buildings (less than 8 storeys)

- one-stage alarm and total evacuation
- occupants to effect immediate evacuation on hearing the fire alarm

Note:
Two-stage alarm evacuation may also be considered for low-rise buildings depending on the design complexity and occupancy load of the building.

B. Medium-rise buildings (8 to 30 storeys)

- two-stage alarm and total evacuation
- first fire alarm serves as an alert and occupants should standby for evacuation
- second alarm is sounded once the fire situation is confirmed followed by total evacuation.

C. High-rise buildings (above 30 storeys)

- two-stage alarm and phased evacuation
- first fire alarm serves as an alert and occupants should standby for evacuation
- second alarm is sounded once the fire situation is confirmed followed by phased evacuation

Phased Evacuation

Phase 1: "Fire floor" plus two floors above and two floors below
Phase 2: All floors above the "fire floor"
Phase 3: All floors below the "fire floor"

Evacuation is usually to a clear outdoor assembly area on the ground level located at a safe distance away from the affected building.

Further Information

- SCDF Evacuation Planning Guidelines

8.3 Company Emergency Response Team

The Company Emergency Response Team (CERT) is a group of in-house first responders identified by a company to be trained in preventing any emergency from escalating into a major disaster. The main objective of CERT is to mitigate and control an emergency situation during its initial stages prior to SCDF's arrival and also to ensure operational synergy between the CERT and SCDF.

A minimum CERT configuration of at least 6 members (comprising 1 Site Main Controller, 1 Site Incident Controller and 4 Emergency Response Team members) is recommended so as to sufficiently handle the worst credible scenario.

CERT Member	Roles and Responsibilities
Site Main Controller (SMC)	• Responsible for the overall management of the CERT. • Assumes overall authority and responsibility in managing the in-house emergency situation and liaises with officers from government agencies such as SCDF, SPF, MOM, NEA, etc. • He/ She is also the company representative to link up with the SCDF Incident Manager.
Site Incident Controller (SIC)	• Leader of the Emergency Response Team members. • Assumes command and control of the emergency response incident scene and co-ordinates the activities of the company emergency responders, providing on-site support to SCDF.
Emergency Response Team (ERT)	• Carries out basic emergency response such as firefighting, rescue and HAZMAT mitigation under the command of the SIC. • Assists in emergency notification and taking action to protect the public and accounting for personnel.

Table 18: Roles and responsibilities of CERT members

Further Information

- SCDF Guideline for Company Emergency Response Team

8.4 Flammable Material Spill Control

For a spill or leak situation involving the release of a flammable chemical, emergency procedures need to be established so that the source of the release can be promptly rectified, and the contaminated area contained and properly decontaminated.

Responding to a Flammable Material Spill

- Act quickly and alert others in the vicinity that a spill has occurred. Initiate evacuation so that all persons are moved away from the hazard area.
- Do not touch or walk through the spilled material.
- Remove all ignition sources including any equipment capable of generating sparks.
- Put on eye and skin protection. Put on gloves that are compatible with solvents. Avoid breathing in the vapours and use a suitable personal respirator when necessary.
- Dike or soak up the spilled liquid. Cover with a sheet of plastic or plastic-backed absorbent pad to suppress vapour if absorbent is not immediately available. Note that:
  - spill pillows, pads, or a general absorbent material may be used but these do not reduce vapour formation; and
  - activated charcoal or absorbent meant for solvents are good for soaking up flammable materials with a low flash point since they can reduce vapour formation as well as absorb the spill.
- Use non-sparking tools (plastic scoop, plastic shovel, plastic dustpan) to:
  - mix the absorbent with the spilled material until it appears dry; and
  - transfer the cleanup material into a plastic or glass container with a sealable lid.
- Never use a vacuum cleaner to clean up flammable material spills or debris, as the hot surface of a motor can be a potential ignition source.
- Close the container tightly and label it for subsequent collection by a TIW collector.
- Thoroughly ventilate the area after the cleanup.
- Clean the area with detergent and water.

8.5 Body Decontamination

Should there be skin contact with a flammable material, remove any contaminated clothing, and immediately flush the contaminated skin with clean water for at least 15 minutes. Similarly, for eye exposures, immediately flush the eyes with water for at least 15 minutes.

The use of a safety shower and emergency eyewash is recommended, but in the event that these are not available, rush the affected person to the nearest water tap (affix hose as necessary) or to the nearest restroom with showering facility.

After decontamination, consult the SDS of the flammable material for guidance on recommended first aid (see Chapter 9 on first aid for burn injuries). Where medical attention is required, always provide the SDS to the attending medical personnel as this will facilitate accurate diagnosis and quick determination of the appropriate treatment.

8.6 MOM Incident Reporting Requirements

Under the WSH (Incident Reporting) Regulations, employers and occupiers are required to report workplace accidents, dangerous occurrences (including those involving fires and/ or explosions), and occupational diseases to the Ministry of Manpower (MOM) at www.mom.gov.sg/ ireport. This will help the Occupational Safety and Health Division (OSHD) of MOM to monitor national WSH trends, identify where the risks are and channel resources in partnership with the relevant stakeholders to prevent the recurrence of similar accidents and reduce workplace injuries and diseases. Reporting will also facilitate insurance claims as well as claims under the Work Injury Compensation Act.

9. Burn Injuries and First Aid

Fires can kill. They can also cause severe injuries. Typical injuries due to fire include skin burns (due to direct contact with flames or exposure to intense heat) and lung disorders (due to smoke inhalation and/ or exposure to toxic gases released as a result of combustion).

The problem with smoke is that it can quickly overcome a person and prevent him/ her from reaching the nearest emergency exit. In addition to producing smoke, fire can incapacitate or kill by reducing the oxygen level (by directly consuming the oxygen or by displacing it with combustion gases) in the immediate atmosphere. The heat generated by the fire also creates a respiratory hazard, as superheated air can cause severe burns to the respiratory tract.

The focus of this chapter is on burn injuries (due to fire) characterised by the depth and extent of the damage caused to body tissues.

9.1 Depth and Extent of Burn

The skin serves as a protective barrier against physical and thermal injury as well as hazardous substances.

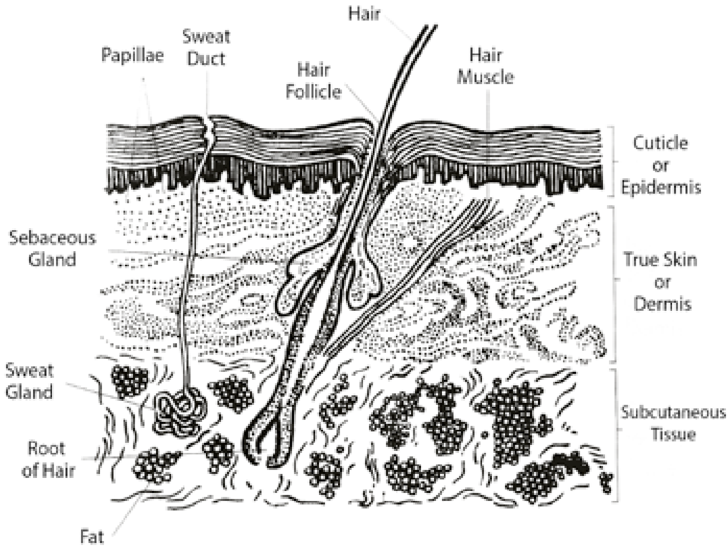


Figure 25: Cross-section of the skin (human body)
(Image Source: Occupational First Aid Manual by National First Aid Council and Ministry of Manpower)

There are three layers in the structure of the human skin (see Figure 25):

- epidermis – outer layer, also known as the cuticle layer;
- dermis – inner layer with sebaceous glands, blood vessels and nerve endings; and
- subcutaneous tissue – layer under the dermis with sweat glands, hair roots, blood vessels and fat.

Depth of Burn

Burns can be classified according to the depth (degree) of burn, based on the severity of the damage to the skin tissue incurred:

1st degree (superficial) burn	– burn injury that affects only the epidermis
2nd degree (partial-thickness) burn	– burn injury that extends into the dermis
3rd degree (full-thickness) burn	– burn injury that extends into the subcutaneous tissue

Extent of Burn

Burns can also be classified according to the extent which it has occurred, expressed as a percentage (%) of the total surface area of the body.

The "rule-of-nines", which divides the body surface area into areas of approximately 9%, may be used to estimate the extent of a burn (see Figure 26) for persons over 16 years of age.

Note that a 1st degree burn involving over 50% of the body surface area may turn out to more serious than a 3rd degree burn involving 3% of the body surface area.

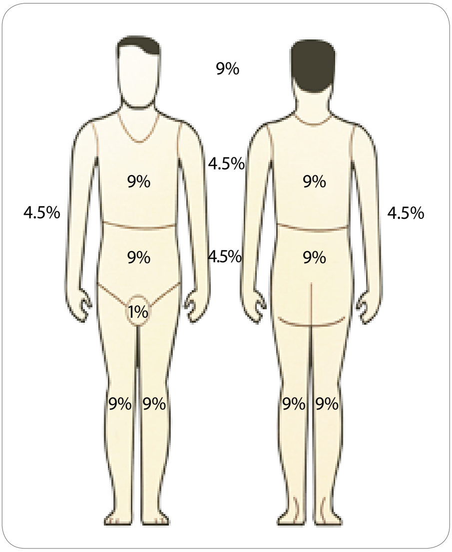


Figure 26: : Extent of burn based on the "rule-of-nines"

(Image Source: Occupational First Aid Manual by National First Aid Council and Ministry of Manpower)

9.2 First Aid for Burn Injuries

A first aider must always ensure his/ her own safety (e.g., by rendering first aid in a safe area away from the location of fire) before attempting to treat a casualty. The table provides recommendations on the first aid to be rendered:

Depth of Burn	Recognition	Suggested First Aid
1st degree burn (superficial)	Skin is red (or pink), tender and dry with no blistering. Swelling may occur. Painful when touched.	• Flush with cool water for at least 10 mins to prevent further tissue damage, reduce swelling and minimise pain. • Cover the affected area with a sterile dressing • Seek medical attention
2nd degree burn (partial thickness)	Skin is cherry red (or pearl-pink) and moist. May have small to large blisters. Very painful when touched or exposed to air.	• Flush with cool water for at least 10 mins, blot dry and cover with a clean cloth for protection • Treat the casualty for shock (if present) • Seek medical attention immediately • Do not break blisters as this may cause infection to set in
3rd degree burn (full-thickness)	Skin appears dry, waxy, leathery, white to dark brown (or charred) and may be sunk below surrounding tissue. Relatively pain-free except at edges of the burn.	• Do not immerse large burns in cold water as this can cause a drop in body temperature (hypothermia) and deterioration of blood pressure and circulation (shock) • Cover with a clean cloth for protection • Treat the casualty for shock (if present) • Check for breathing difficulties • Call for an ambulance (dial 995) immediately

In general, for all burns:		• Do not apply ice • Do not apply lotions, ointments or creams to the affected area • Do not use antiseptics, ointment sprays or home remedies • Do not remove anything stuck to the burn as this may cause further damage and infection • Do not use adhesive dressings

Table 19: Suggested first aid depending on the degree of burn
Source: Occupational First Aid Manual by National First Aid Council and Ministry of Manpower

If you are unsure on what to do or if the burn injuries are more severe than what you have been trained to handle, call for an ambulance (dial 995) immediately, specifying that you have a burn casualty at hand and urgent medical assistance is required.

Further Information

- Workplace Safety and Health (First-Aid) Regulations
- Occupational First Aid Manual by National First Aid Council and Ministry of Manpower

10. Fire Case Studies

This chapter offers insight to past fire cases that have taken place in Singapore so that everyone can learn from past accidents to prevent a recurrence. The case studies not only highlight the lessons learnt but jointly remind all employers and employees of the need to actively review current practices and continually find ways to make workplaces safer.

Case Study 1: Oil Drum Explosion During Gas Cutting

Incident Description

An oil drum, previously used for containing waste oil, exploded when a worker was cutting it with an oxyacetylene gas torch. The worker suffered serious head injuries from the explosion and died two days after the accident.

Findings

- The explosion was due to the ignition of the remnant waste oil in the drum by the oxy-acetylene gas torch.
- Risk assessment was not conducted for the hot work.

Figure 27: Scene of accident where the explosion took place

Figure 28: Damaged drum cover due to impact of the explosion

Figure 29: Damaged cutting torch due to impact of the explosion

Lessons Learnt

Before carrying out hot work, a careful assessment of the specific WSH risks involved should be made. In this case, safer methods of work such as cold cutting technique could be considered in place of hot work.

If hot work is necessary, the oil drum must first be rendered safe by cleaning, purging or steaming, or adequately inerted before commencing hot work. Additionally, safe work procedures (e.g. a hot work permit system) must be established and implemented to ensure that the hot work can be carried out safely without endangering the safety of workers and others in the vicinity.

Further Information

- SS 510: 2005 Code of Practice on Safety in Welding and Cutting (and Other Operations involving the Use of Heat)

Case Study 2: Combustible Dust Fire in a Food Manufacturing Company

Incident Description

A worker was cutting the support of an old conveyor pipe system with a cutting torch when flour poured out from the bottom opening of the silo. When the flour dust mixed with the surrounding air, a flash fire was triggered and an explosion followed thereafter. The worker immediately switched off the cutting torch.

The injured worker suffered burns on his arms, face and parts of the body, while the co-worker who came to his rescue suffered minor burns. The platform of the silo and electrical wiring were also damaged.

Findings

- The flash fire involving tapioca flour (a combustible material) was triggered by the flame of the cutting torch (ignition source).
- A safe work procedure was not implemented for the cutting operation.

Lessons Learnt

Finely divided materials such as wood, food and metal dust can cause flash fires and explosions when dispersed in air, in sufficient quantities and concentration under favourable conditions involving air, heat, fuel and extent of dispersion in a confined environment. A permit-to-work system needs to be established for any activity involving hot work.

Case Study 3: Flash Fire in Oven Due to Gas Leak

Incident Description

A flash fire occurred when a worker tried to ignite the pilot flame of an oven using a handheld spark generator. The worker suffered burns on the face and left hand, and was given 4 days of medical leave.

Findings

- Town gas was leaking overnight from a valve within the oven compartment.
- The flash fire was due to ignition of accumulated town gas inside the oven.

Figure 30: Lighting of pilot flame using a handheld spark generator

Lessons Learnt

Inspection and maintenance of gas ovens (including piping, hoses, pipe fittings and valves) should be carried out periodically.

If the smell of gas is detected, workers should immediately (i) turn off the gas supply, (ii) isolate all possible sources of ignition in the vicinity, and (iii) ventilate the area before calling in a professional to check for leak sources and carry out rectification.

Consider equipping gas ovens with the following safety devices:

exhaust fan	to remove any accumulation of flammable gas as well as products of combustion. This will effectively reduce the risk of creating a flammable atmosphere within the oven compartment.
flame sensing device	to detect the presence of a pilot flame before the main gas supply valve can be opened. This will prevent accumulation of flammable gas within the oven compartment prior to ignition of the burner.

Case Study 4: Laundry Fire Caused by Auto-Ignition

Incident Description

A fire broke out at a laundry facility after midnight, when no one was present.

Findings

The fire was suspected to have been the result of an auto-ignition (i.e. spontaneous ignition) due to exothermic reaction of chemical residue on the cloth and poor dissipation of heat.

Lessons Learnt

Cloth is a combustible material. Laundry facilities are exposed to fire risk due to the presence of large quantities of cloth, a hot environment (due to hot washing, machine drying and ironing), and unknown residues on the laundry.

The residue on soiled clothing could include chemicals or oils encountered at workplaces. Inadequate washing (e.g. due to insufficient detergent or faster wash cycles) may also result in the chemicals or oils being retained on the cloth after a normal wash.

The storage of washed laundry with residual chemicals or oils is also a concern as they are often stacked up after the drying process without sufficient cooling time. Poor dissipation of heat (e.g. from the drying or ironing process) and any generated heat (due to reaction of unknown residue) could lead to auto-ignition.

It is therefore critical that:

- soiled clothing are properly washed with the correct detergent;
- dryers are programmed (i) not to overheat the laundry and (ii) to include a cool down cycle to lower the laundry temperature prior to removal from the dryer;
- sufficient time be given for the laundry to cool to near room temperature before folding or bundling; and
- bundled or folded laundry are stored away from hot environments including boiler rooms, next to water heaters, behind dryers, etc.

Case Study 5: Gas Blast Triggers Fire at Eatery

Incident Description

A flash fire occurred at a local eatery. The incident resulted in 11 persons (2 workers and 9 patrons) sustaining burn injuries.

Findings

The fire occurred at the kitchen area of the eatery. Severe burn marks were observed along the aisle from the kitchen to the dining area (see Figure 31). A leaking 50 kg liquefied petroleum gas (LPG) cylinder was found to be the fuel source for the fire. The LPG cylinder had been shifted from the gas cylinder manifold assembly located outside the rear exit of the eatery into the indoor aisle next to the kitchen area for connection to a portable stove. Subsequent ignition of the gas leaking from the cylinder resulted in the flash fire.

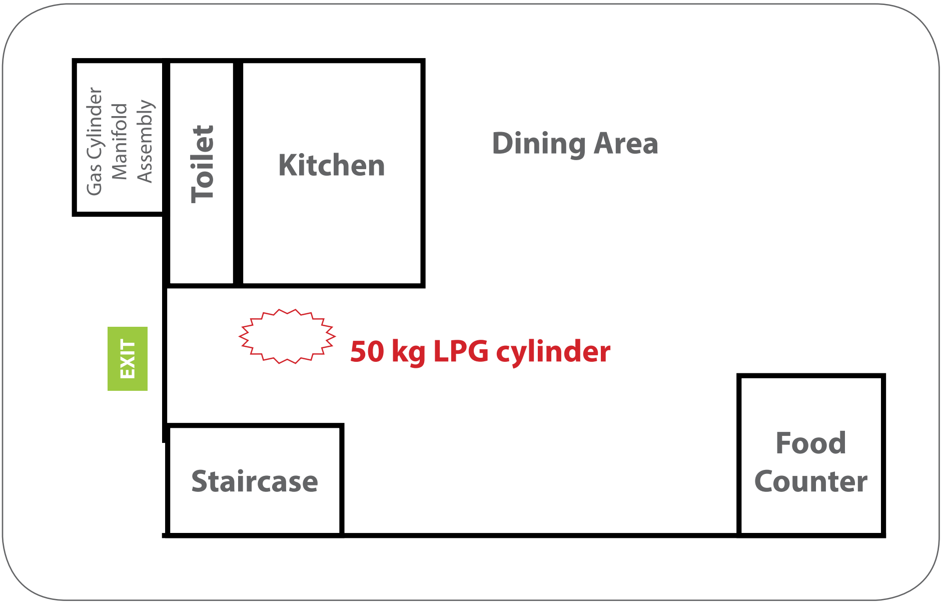


Figure 31: Floor plan of the eatery showing the location of the 50 kg LPG cylinder which caught fire

Lessons Learnt

- Keep stocks of LPG gas cylinders to a minimum. This will minimise the extent and duration of the fire should one occur.
- Do not shift 50 kg LPG cylinders indoors or near a kitchen. They should be stored outdoors on the ground floor and in a cool and well-ventilated area away from ignition sources. LPG can be piped into the kitchen area as required via a flammable gas distribution system. Place LPG cylinders in a steel cabinet and keep it locked to protect against physical damage and tampering.
- To minimise the potential for leaks, all gas tubing, connectors and regulators should be regularly inspected and replaced as necessary.
- Strongly recommended is the installation of an on-site gas leak detector with the capability to automatically shut-off the LPG supply.
- Evacuation routes (including aisles and exits) should be kept unobstructed at all times. For LPG installations placed next to a fire exit route of a building having only one exit, a minimum clearance of 3 m between the LPG cylinders and the exit is recommended.

Further Information

- SCDF Fire Code 2013 Appendix 13: Fire Safety Requirements for Liquefied Petroleum Gas (LPG) Cylinder Installations.

11. WSH Checklist for Working with Flammable Materials

Workplace inspections play a critical role in preventing accidents and injuries by providing an opportunity to identify hazards on-site and confirm that risk control measures are in-place and effectively implemented. It is recommended that company managers and their staff teams or WSH personnel conduct routine inspections of their work areas on a frequent basis (e.g. fortnightly or monthly) so that unsafe conditions may be readily identified and promptly remedied.

The use of a checklist can help bring focus to an inspection and ensure that key WSH aspects are looked into. A generic WSH inspection checklist for working with flammable materials is provided below. The checklist provided is non-exhaustive and company managers are encouraged to insert new entries and customize the checklist as necessary to fit the specific circumstances of each workplace to be inspected.

Generic WSH Inspection Checklist for Working with Flammable Materials

	Purchasing a Flammable Material	Yes	No
1	Purchase of flammable materials is carried out by or under the advisement of a competent person with adequate knowledge of the material and its hazards.		
2	Flammable materials are evaluated for short- and long-term risks prior to purchase.		
3	Less- or non-flammable materials are procured whenever safer alternatives exist.		
4	Minimum quantity of flammable materials is procured in line with expected rate of use.		
5	SCDF licence has been obtained for the import and transport of the P&FM being purchased.		
6	Employees are trained to safely receive the flammable material(s) being delivered.		
7	SDS is obtained for each flammable material being delivered.		

	Storing a Flammable Material	Yes	No
1	SCDF licence has been obtained for the storage of the P&FM being purchased.		
2	Risk assessment (RA) has been carried out prior to storing the flammable material.		
3	Flammable materials are stored a safe distance away from process areas.		
4	Flammable materials are stored in a location that is cool, dry, well-ventilated and free of ignition sources.		
5	Flammable materials are stored in an area accessible by firefighters. (Note: Flammable materials should not be stored in the basement.)		
6	Storage containers are affixed with GHS labels indicating the flammable property of the material being stored.		
7	Safety data sheets are readily available at the location of storage.		
8	Storage containers are always kept closed when not in use.		
9	Storage containers are placed on spill control pallets or within a dike for spill containment.		
10	Small quantities of flammable materials are kept in fire-rated storage cabinets specially designed for storage of flammable materials.		
11	Flammable liquids with flash points lower than room temperature are stored under appropriate conditions (e.g., in a laboratory-safe or explosion-proof refrigerator).		
12	Flammable gas detectors are sited at locations where loss of containment is possible.		
13	Only trained and authorised personnel are allowed into storage areas containing flammable materials.		

	Storing a Flammable Material	Yes	No
14	Electrical and communication devices (e.g., ceiling lamps, radio handsets) used in flammable material storage areas are of intrinsically safe construction.		
15	Smoking is banned in all areas where flammable materials are stored.		
16	Good housekeeping is practiced at all times such that spills are immediately cleaned-up and all routes for access and egress are kept free from obstruction.		
17	Firefighting equipment and facilities (e.g., fire extinguishers, water sprinkler system) are available on-site and ready for use.		
18	Spill clean-up equipment (e.g., non-sparking tools, absorbents, sealable containers) are available on-site and ready for use.		
19	Warning placard is posted at each entrance to the store (for indoor storage of flammable materials) or prominently displayed at the storage area (for outdoor storage of flammable materials).		
	Handling a Flammable Material	**Yes**	**No**
1	Users are familiar with the SDS of the flammable material being handled and understand its flammability characteristics.		
2	Risk assessment is carried out prior to any work involving a flammable material.		
3	Safe work procedures are developed for work involving flammable materials.		
4	A permit-to-work system is implemented for hot works.		
5	Work area is well-ventilated and free from ignition sources (e.g., open flames, hot surfaces) and combustible materials (e.g., wood, paper, cloth).		
6	Appropriate PPE (e.g., fire-retardant coveralls and gloves) are worn prior to any work activity involving flammables.		

7	Work is carried out behind a splash guard or face shield when handling a machine or process that ejects flammable materials.		
8	Containers (those currently in use as well as new) of flammable material are affixed with GHS labels featuring the appropriate hazard pictogram(s).		
9	Metal containers are electrically bonded and grounded before a flammable material is transferred.		
10	Transfer of flammable materials (e.g., from a large container to a smaller container) is carried out under local exhaust ventilation wherever practicable.		
11	Containers of flammable material are kept closed when not in use.		
12	Unused flammable materials are returned to the proper storage area or cabinet at the end of each work day.		
13	Work area is adequately equipped with the following emergency response equipment and facilities: fire extinguisher, first aid box, spill control kit, eye wash and safety shower.		
14	Users are familiar with the emergency response plan for their specific work area(s).		
	Disposing a Flammable Material	**Yes**	**No**
1	The flammable material cannot be used for other applications.		
2	The flammable material cannot be recycled, refined or regenerated for reuse.		
3	There are no high value components in the flammable material that can be recovered.		
4	Risk assessment has been carried out prior to disposing the flammable material.		
5	Flammable materials are not disposed together with general waste.		

6	Flammable liquids are not poured into the sewerage system (e.g., by pouring down the sink) or into storm water drains.		
7	Appropriate PPE (e.g., fire-retardant coveralls and gloves) are worn prior to handling flammable waste materials.		
8	Wastes from different sources are never mixed unless a compatibility check has been carried out and the results show that it is safe to proceed.		
9	Flammable waste materials are stored in the same way as all other flammable materials. (Refer to checklist on “Storing a Flammable Material”)		
10	Waste bins with self-closing lids are used for disposal of cloth, paper and other solid materials contaminated with a flammable material.		
11	Flammable gas cylinders are returned to the industrial gas supplier/ distributor/ vendor.		
12	TIW Collector is contacted for assistance with flammable waste disposal once the minimum quantity required for a collection has been reached.		

12. References

Workplace Safety and Health Act

- *Workplace Safety and Health (Risk Management) Regulations*
- *Workplace Safety and Health (General Provisions) Regulations*
- *Workplace Safety and Health (First-Aid) Regulations*
- *Workplace Safety and Health (Incident Reporting) Regulations*
- *Workplace Safety and Health (Construction) Regulations 2007*
- *Workplace Safety and Health (Shipbuilding and Ship-repairing) Regulations 2008*
- *Workplace Safety and Health (Confined Spaces) Regulations 2009*

Fire Safety Act

- *Fire Safety (Petroleum and Flammable Materials) Regulations*

Environmental Public Health Act

- *Environmental Public Health (Toxic Industrial Waste) Regulations*

Code of Practice on Workplace Safety and Health Risk Management
CP 10: 2005 Code of Practice for Installation and Servicing of Electrical Fire Alarm Systems
CP 52: 2004 Code of Practice for Automatic Fire Sprinkler System

Globally Harmonised System of Classification and Labelling of Chemicals (GHS)
www.wshc.sg/ghs

Guidance on the Application of GHS Criteria to Petroleum Substances by IPIECA (2010)
ILO International Chemical Safety Cards
National Fire Prevention Council's Fire Risk Assessment Guide
NIOSH Pocket Guide to Chemical Hazards
National First Aid Council and Ministry of Manpower's Occupational First Aid Manual
SCDF Civil Defence Emergency Handbook
SCDF Evacuation Planning Guidelines
SCDF Guidelines for Emergency Response Plan

SCDF Fire Code 2013 (also known as the Code of Practice for Fire Precautions in Buildings)
– Appendix 13: Fire Safety Requirements for Liquefied Petroleum Gas Cylinder Installations

SCDF Fire Safety Guidelines for Open Plant Structures in Oil, Chemical and Process Industries

SCDF Guideline for Company Emergency Response Team

SCDF Guidelines for Emergency Response Plan

SCIC's Guidebook on Transport & Handling of Dangerous Goods

SS EN 3: 2012 Portable Fire Extinguishers (EN 3 Series)

SS 510: 2005 Code of Practice on Safety in Welding and Cutting (and Other Operations involving the Use of Heat)

SS 532: 2007 Code of Practice for The Storage of Flammable Liquids

SS 575: 2012 Code of Practice for Fire Hydrant, Rising Mains and Hose Reel Systems

SS 578: 2012 Code of Practice for Use and Maintenance of Portable Fire Extinguishers

SS 586: 2014 Specification for Hazard Communication for Hazardous Chemicals and Dangerous Goods – Part 1: Transport and Storage of Dangerous Goods

SS 586: 2014 – Specification for hazard communication for hazardous chemicals and dangerous goods – Part 2: Globally harmonised system of classification and labelling of chemicals

SS 586: 2008 (2014) – Specification for hazard communication for hazardous chemicals and dangerous goods – Part 3: Preparation of safety data sheets.

SS 603: 2014 Code of Practice for Hazardous Waste Management

United Nations' Recommendations on the Transport of Dangerous Goods (UNRTDG) (Volumes I and II)

Workplace Safety and Health Guidelines on Safe Loading on Vehicles

Workplace Safety and Health Guidelines on Safe Operation of Forklift Trucks

Suggested References for Specific Storage Situations

Hazardous Material (HAZMAT) Warehouses

- SCDF Fire Code 2013 Appendix 2: Fire Safety Requirements for Chemical/ HAZMAT Warehouses
- SS 532: 2007 Code of Practice for The Storage of Flammable Liquids
- NFPA 55: Compressed Gases and Cryogenic Fluids Code

Liquefied Petroleum Gas (LPG) Cylinder Installations

- SCDF Fire Code 2013 Appendix 13: Fire Safety Requirements for LPG Cylinder Installations
- SS 99: 1998 Specification for Welded Low Carbon Steel Cylinders for Storage and Transportation of Compressed Liquefiable Gases
- SS 233: 2013 Specification for Flexible Rubber Tubing, Rubber Hose and Rubber Hose Assemblies for use in LPG Vapour Phase Installations
- SS 281: 1984 Specification for Pressure Regulators for LPG
- SS 294: 1998 Specifications for Valves for use with Domestic and Industrial LPG Cylinders
- British Standard BS EN 60079-14:2008 Explosive Atmospheres. Electrical Installations Design, Selection and Erection.
- NFPA 58: 2014 Liquefied Petroleum Gas Code
- Workplace Safety and Health Guidelines for Hospitality and Entertainment Industries

Laboratories

- SCDF Guidelines and Fire Safety Requirements for Laboratories Handling Chemicals
- NFPA 45: 2011 Standard on Fire Protection for Laboratories Using Chemicals
- WSH Guidelines on Management of Hazardous Chemicals Programme
- WSH Guidelines for Laboratories Handling Chemicals

Advice for Readers:

Always refer to the latest version of the above references for up-to-date information.

13. Acknowledgements

Supporting Organisations	Contributor
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14. Annex

Annex A: List of Flammable Materials

In general, flammable materials include petroleum products and the following:

1	Acetal	16	Aluminium alkyl halides
2	Acetaldehyde diethylacetal	17	Aluminium alkyl hydrides
3	Acetoin (3-Hydroxybutanone)	18	Aluminium alkyls
4	Acetone	19	Aluminium borohydride
5	Acetyl chloride	20	Aluminium carbide
6	Acetyl methyl carbinol (Butanolone)	21	Aluminium ferrosilicon powder
7	Acetylene	22	Aluminium hydride
8	Acryloyl chloride	23	Aluminium powders, uncoated
9	Aldehydes	24	Amines
10	Allyl acetate	25	2-Amino-4, 6-Dinitrophenol, wetted [with not less than 20% water, by mass]
11	Allyl bromide	26	Ammonium picrate
12	Allyl chloride	27	Amyl acetate
13	Allyl formate	28	Amyl butyrate
14	Allyl iodide	29	Amyl chlorides
15	Allyl methacrylate	30	Amyl mercaptan

31	Amyl nitrites	51	Butene
32	Azobis (dimethylvaleronitrile)	52	Butyl acetate
33	Azobis (methylpropionitrile), Azobis-isobutyronitrile	53	n-Butyl formate
34	Azodi (methylbutyronitrile)	54	Butyl acrylate
35	Azodicarbonamide	55	Tert-butylamine
36	Barium	56	Butyl butyrate
37	Barium azide, wetted [with not less than 50% water, by mass]	57	Tert-butyl hypochlorite
38	Benzotrifluoride	58	Butyl isobutyrate
39	Bis-cyclopentadienyl iron (Ferrocene)	59	Butyl isovalerate (Butyl 3-Methylbutanoate)
40	Boron trifluoride dimethyl etherate	60	Butyl nitrites
41	1-Bromobutane	61	1,2-Butylene oxide
42	Bromomethylpropane	62	Butyryl chloride
43	2-Bromopentane	63	Calcium
44	Bromopropanes	64	Calcium carbide
45	3-Bromopropyne	65	Calcium dithionite (Calcium hydrosulfite)
46	Bromotrifluoroethylene	66	Calcium hydride
47	Butadienes	67	Calcium or Calcium alloys
48	Butanedione	68	Calcium silicide
49	Butane	69	Carbon disulfide
50	Butanol (Butyl alcohol)	70	Carbonyl iron powder

71	Cerium	90	1,1-Dichloroethane
72	Cesium (Caesium)	91	1,2-Dichloroethylene
73	Chlorobutane	92	1,2-Dichloropropane
74	Chloroprene	93	Dichloropropene
75	2-Chloropropane	94	Dicyclohexylammonium nitrite
76	2-Chloropropene	95	Diethoxymethane
77	Chlorosilanes, except Hexachlorodisilane, Phenyltrichlorosilane and Tetrachlorosilane	96	3,3-Diethoxypropene
78	1-Chloro-1, 1-difluoroethane	97	Diethyl carbonate
79	Compressed Natural Gas (CNG)	98	Diethyl ketone
80	Crestyl methyl ether para (1-methoxy-4-methylbenzene)	99	Diethyl sulfide
81	Cyclobutane	100	Diethylhydroxylamine 85%
82	Cyclohexanone	101	Diethylzinc
83	Cyclohexyl acetate	102	Diethynyltertramethyldisiloxane (1,3-Diethynyl -1,1,3,3-tetramethyldisiloxane)
84	Cyclopentanone	103	Difluoroethane
85	Cyclopropane	104	1,1-Difluoroethylene
86	Decaborane	105	Difluoromethane
87	Deuterium	106	2,3-Dihydropyran
88	1,2-Di-(dimethylamino)ethane	107	Diisobutyl ketone
89	Diacetone alcohol	108	1,2-Dimethoxyethane

109	1,1-Dimethoxyethane	129	Esters
110	Dimethyl carbonate	130	Ethane
111	Dimethyl disulfide	131	Ethanol
112	Dimethyl ether	132	Ethers
113	Dimethyl hexynol	133	Ethoxy propanol
114	Dimethyl sulfide	134	Ethyl 3-ethoxypropionate
115	Dimethyl trisulfide	135	Ethyl acetate
116	2,3-Dimethylbutane	136	Ethyl acrylate
117	Dimethylcyclohexane	137	Ethyl borate
118	Dimethyldiethoxysilane	138	Ethyl butyrate
119	Dimethyldioxane	139	Ethyl caproate (Ethyl hexanoate)
120	Dimethylformamide	140	Ethyl chloride
121	2,2-Dimethylpropane	141	Ethyl crotonate
122	Dimethylzinc	142	Ethyl formate
123	Dinitrophenol, wetted [with not less than 15% water, by mass]	143	Ethyl isobutyrate
124	Dinitrophenolates, wetted [with not less than 15% water, by mass]	144	Ethyl isocyanate
125	Dinitroresorcinol, wetted [with not less than 15% water, by mass]	145	Ethyl isovalerate
126	Dioxane	146	Ethyl lactate
127	Dioxolane	147	Ethyl methacrylate
128	Dipicryl sulfide	148	Ethyl methyl butanoate

149	Ethyl methyl butyrate	170	Hexadiene
150	Ethyl nitrite	171	Hexamethyldisiloxane
151	Ethyl propionate	172	Hexamethyleneimine
152	Ethyl silicate	173	Hexenyl formate
153	Ethylacetylene	174	Hexyl acetate
154	Ethylbenzene	175	Hydrogen
155	Ethyldichlorosilane	176	2-Iodobutane
156	Ethylene	177	Iodomethylpropane
157	Ethylene glycol diethyl ether	178	Isoamyl acetate
158	Ethylene glycol dimethyl ether	179	Isoamyl alcohol
159	Ethylene glycol monoethyl ether acetate	180	Isoamyl butyrate
160	Ethyloxypropanoic acid, ethyl ester	181	Isoamyl propionate
161	1-Ethylpiperidine	182	Isobutane
162	Eucalyptol (1,8-Cineol)	183	Isobutyl acetate
163	Ferrocerium	184	Isobutyl formate
164	Fluorobenzene	185	Isobutyl isobutyrate
165	Fluorotoluene	186	Isobutyl isocyanate
166	Furan	187	Isobutyl isovalerate
167	Hafnium powder	188	Isobutylene
168	Heptaldehyde (Aldehyde C7)	189	Isobutyryl chloride
169	Heptanone	190	Isopentyl formate

191	Isopentyrate	212	Magnesium diamide
192	Isoprene	213	Magnesium diphenyl
193	Isopropanol (Isopropyl alcohol)	214	Magnesium hydride
194	Isopropenoxytrimethyl silane	215	Magnesium or Magnesium alloys
195	Isopropenyl acetate	216	Magnesium silicide
196	Isopropyl acetate	217	Methane
197	Isopropyl isobutyrate	218	Methanol
198	Isopropyl isocyanate	219	Methoxy acetoxypropane
199	Isopropyl nitrate	220	Methoxy methylethly acetate
200	Isopropyl propionate	221	Methoxy propanol acetate (1-methoxy-2-propanol)
201	Lead phosphite, dibasic	222	Methoxy propyl acetate
202	Lithium	223	Methoxybutanol
203	Lithium alkyls	224	Methoxymethyl isocyanate
204	Lithium aluminum hydride	225	Methoxypropanol
205	Lithium borohydride	226	Methyl acetate
206	Lithium ferrosilicon	227	Methyl acetylene
207	Lithium hydride	228	Methyl acrylate
208	Lithium nitride	229	Methyl allyl chloride
209	Lithium silicon	230	Methyl amyl ketone
210	Lutidine	231	Methyl butanol
211	Magnesium alkyls	232	Methyl butane

233	Methyl butyraldehyde	249	Methyl propyl ketone
234	Methyl butyrate	250	Methylal
235	Methyl caproate (Methyl hexanoate)	251	3-Methylbutan-2-one
236	Methyl Ethyl Ketone (MEK)	252	Methyldichlorosilane
237	Methyl formate	253	Methylfluoride (Fluoromethane)
238	Methyl heptenone	254	2-Methylfuran
239	Methyl hexanone (Methyl isoamyl ketone)	255	n-methylmorpholine
240	Methyl isobutyl carbinol	256	Methylpentadiene
241	Methyl isobutyl ketone (Methyl pentanone)	257	1-Methylpiperidine
242	Methyl isopropenyl ketone	258	Methyltetrahydrofuran
243	Methyl isovalerate	259	Methyltriethyloxysilane
244	Methyl magnesium bromide	260	Methyltrimethoxysilane
245	Methyl methacrylate monomer	261	Nitriles
246	Methyl methoxypropionate	262	Nitrocellulose, wetted [with not less than 25% water, by mass]
247	Methyl methylbutyrate	263	Nitroglycerin mixture, desensitized, liquid, with not more than 30% nitroglycerin, by mass
248	Methyl propionate	264	Nitroglycerin mixture, desensitized, solid, with more than 2% but not more than 10% nitroglycerin, by mass

265	Nitroglycerin solution in alcohol, more than 1% but not more than 5% nitroglycerin	283	Potassium or Potassium alloys
266	Nitroglycerin solution in alcohol, not more than 1% nitroglycerin	284	Potassium borohydride
267	Nitroguanidine, wetted [with not less than 20% water, by mass]	285	Potassium dithionite (Potassium hydrosulfite)
268	Nitromethane	286	Potassium sodium alloys
269	1-Nitropropane (Nitropropane)	287	Potassium sulfide
270	p-Nitrosodimethylaniline	288	Prenyl acetate
271	Nitrostarch, wetted [with not less than 20% water, by mass]	289	Propadiene
272	Octamethyltrisiloxane	290	Propane
273	Octanal (Aldehyhe C8)	291	Propanethiol
274	Pentaborane	292	n-Propanol
275	Pentanol	293	Propionyl chloride
276	Pentyl acetate	294	n-Propyl acetate
277	1,1,1,3,3-pentafluorobutane (Pentafluorobutane)	295	Propyl butyrate
278	Phosphorus heptasulfide	296	Propyl chloride
279	Phosphorus pentasulfide	297	Propyl formate
280	Phosphorus sesquisulfide	298	Propylene
281	Phosphorus trisulfide	299	Propylene glycol monoethyl ether
282	Phosphorus	300	Propylene glycol monomethyl ether

301	Propylene glycol monomethyl ether acetate	320	Sodium sulfide
302	n-Propyl nitrate	321	Strontium
303	Propylene oxide	322	Terpineol
304	Propyleneimine	323	Tetraethyl orthosilicate
305	Pyridine	324	Tetraethylsilicate
306	Pyrrolidine	325	Tetrafluoroethylene
307	Rubidium	326	Tetrahydrofuran
308	Silanes	327	1,2,3,6-Tetrahydropyridine
309	Silver picrate	328	Tetrahydrothiophene
310	Sodium	329	Tetrakis (dimethylamino) hafnium
311	Sodium aluminum hydride	330	Tetrakis (dimethylamino) titanium
312	Sodium borohydride	331	Tetramethylsilane
313	Sodium dinitro-o-cresolate, wetted [with not less than 15% water, by mass]	332	Thioacetic acid
314	Sodium dithionite (Sodium hydrosulfite)	333	Thiophene
315	Sodium ethylate	334	Thiourea dioxide
316	Sodium hydride	335	Tifluoromethyl propanol
317	Sodium hydrosulfide	336	Titanium hydride
318	Sodium methylate	337	Titanium powder
319	Sodium picramate, wetted [with not less than 20% water, by mass]	338	Titanium trichloride

339	Tributylphosphane	353	Urea nitrate, wetted [with not less than 20% water, by mass]
340	Triethylboron	354	Vinyl acetate
341	Triethyl borate	355	Vinyl acetylene
342	Triethyl silane	356	Vinyl bromide
343	1,1,1-Trifluoroethane	357	Vinyl butyrate
344	Triisopropyl borate	358	Vinyl chloride
345	Trimethyl gallium	359	Vinyl fluoride
346	Trimethyl borate	360	Vinylidene chloride
347	Trimethyl silane	361	Vinyltrimethoxysilane
348	Trinitrobenzene, wetted [with not less than 30% water, by mass]	362	Xanthates
349	Trinitrobenzoic acid, wetted [with not less than 30% water, by mass]	363	Zinc powder or Zinc dust
350	Trinitrophenol, wetted [with not less than 30% water, by mass]	364	Zirconium hydride
351	Trinitrotoluene, wetted [with not less than 30% water, by mass]	365	Zirconium picramate, wetted [with not less than 20% water, by mass]
352	Tris(isopropylcyclopentadienyl) Lanthanum	366	Zirconium powder

Source: Fourth Schedule of Fire Safety (Petroleum and Flammable Materials) Regulations

Annex B: Flammability Characteristics of Liquids and Gases

Compound	Flash Point (°C)	Lower Flammability Limit (vol% in air)	Upper Flammability Limit (vol% in air)	Auto-ignition Temperature (°C)
Acetone	- 17.8	2.5%	12.8%	465
Acetylene	NA (Gas)	2.5%	100%	305
Ammonia	NA (Gas)	15%	28%	651
Benzene	- 11.1	1.2%	7.8%	498
Butane	NA (Gas)	1.6%	8.4%	365
Carbon monoxide	NA (Gas)	12.5%	74%	605
Diesel	52	0.6%	6.5%	254 to 285
Ethanol	13	3.3%	19%	363
Ethylene oxide	- 28.9	3%	100%	429
Hydrogen	NA (Gas)	4%	76%	500 to 571
Isopropyl Alcohol	12	2%	12.7%	456
Kerosene	38 to 72	0.7%	5%	220
LPG	NA (Gas)	1.9% (Butane) 2.1% (Propane	8.5% (Butane) 9.5% (Propane)	-
Methane	NA (Gas)	5%	15%	537
Methanol	11.1	6%	36%	464

Pentane	- 49	1.5%	7.8%	309
Petrol (Gasoline)	< - 21	1.3%	7.1%	~ 250
Propane	NA (Gas)	2.1%	9.5%	450
Toluene	4	1.1%	7.1%	480
Turpentine	30 to 46	0.8%	6%	220 to 255

The data in this table is extracted from: (i) NIOSH Pocket Guide to Chemical Hazards
(ii) ILO International Chemical Safety Cards