

Technical Advisory for **Flammable Hazardous Substances**



1. Introduction

Fire or explosion at work is a hazard that can cause serious injuries, deaths and damage to property. Highly flammable substances like gasoline and solvents are the most obvious sources but less apparent substances such as food, wood and metal dusts have also been known to explode and cause major fires.

This Technical Advisory (TA) aims to provide practical guidance on measures that can be taken to ensure the safety and health of workers who may be exposed to flammable hazardous substances at work. In this TA, “Flammable Hazardous Substances” refer to substances with inherent fire hazards.

2. Basic Concepts of Fire and Explosions

Fire is the process of a fuel (such as solvents or gasoline) combining with oxygen to produce heat.

Explosions are due to the violent expansion of gases, releasing large amounts of energy rapidly. The effects of explosions are fast-moving pressure waves and shock waves, which can damage equipment, destroy buildings and shatter windows.

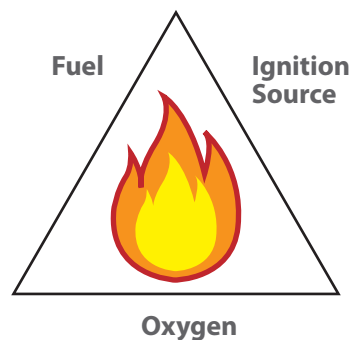
How do fire occur?

Three elements – Fuel, oxygen and an ignition source such as heat, are all needed to be present in the correct concentration for a fire to start or an explosion occur:

Oxygen is present naturally in the air around us.

Fuel keeps a fire burning.

Ignition source provides energy to initiate a fire.



Examples of Fuel

Liquids	Gasoline, acetone, pentane, ammonia, ethylene oxide
Gases	Acetylene, propane, carbon monoxide
Solids	Rubber, plastics, wood, plastic foams, packaging, textiles, sugar dust, wood dust, flour dust

Examples of Ignition Sources

Sparks, open flames, welding arc, static electricity, heat, friction, motor starter, cigarette ember, pilot light

There is no fire when any one of the three elements is eliminated or removed.

- Remove air to smother fire. Fire cannot burn without oxygen.
- Remove fuel sources. E.g. prevent build-up of combustible or flammable debris will decrease the likelihood of a fire.
- Keep sparks or other ignition sources away from fuel sources.

Case Study 1

Explosion of an oil drum when cut with a gas torch

The Incident

A drum, which was previously used for containing waste oil, exploded when a worker was cutting it with an oxy-acetylene 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 cutting operation.
- No risk assessments were conducted for hot work.

Lessons Learnt

Before carrying out any hot work, a careful assessment of the associated risks involved should be made. In the assessment, other alternative or safer methods of work such as cold cutting technique should be considered instead of hot work.

Upon ascertaining that hot work is necessary, the oil drum should first be rendered gas-free by cleaning, purging or steaming, or inerted before hot work commences. Additionally, safe work procedures must be established and implemented to ensure that hot work can be carried out safely without endangering the safety of workers and other workers in the vicinity of the hot work.



1 Damaged drum cover due to impact of the explosion



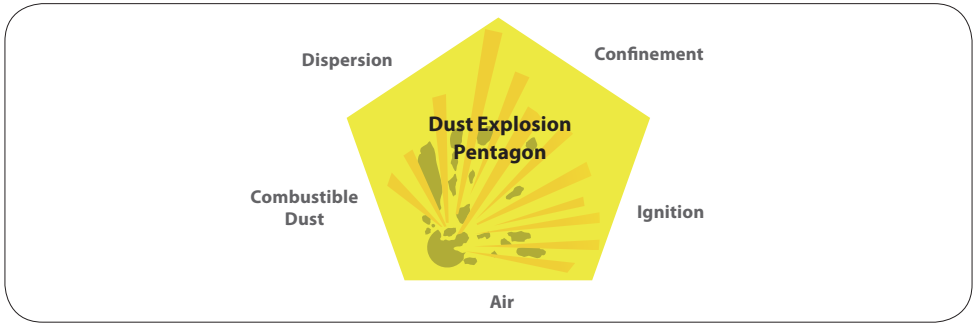
Scene of accident where the explosion took place



1 Damaged cutting torch due to impact of the explosion

3. Combustible Dust

Materials such as wood, food, metal dusts can cause explosions due to the dispersion of fine combustible particles, when in sufficient quantities and concentration and under favourable conditions, such as air, heat, fuel, dispersion and confined environment.



How do dust explosions occur?

A dust explosion can occur when the following conditions exist at the same time:

1. Fuel, i.e. combustible dust of sufficiently small particle size;
2. Air;
3. Dispersion of the dust into the air;
4. A confined environment (e.g. a silo); and
5. An ignition source (e.g. heat).

Examples of combustible dusts are:

- Wood dust.
- Rubber dust.
- Plastic dust and additives (e.g. polyethylene, resin dust).
- Metal dust (e.g. aluminium, chromium, iron, magnesium, zinc).
- Food and grain dust (e.g. sugar, spice, starch, flour, animal feedstock).

Implement dust control measures:

- Establish effective dust control measures to prevent and reduce the escape of dust from processing equipment to the environment, e.g. dust collecting system.
- Replace combustible dust with safer alternatives e.g. ready-to-use materials.
- Establish and implement good housekeeping practices to keep work places clean and safe, such as cleaning at regular intervals to prevent the accumulation of dust.
- Design building elements and arrange equipment to reduce dust accumulation. Use features such as smooth, easy-to-clean walls and sloped surfaces.

Case Study 2

Combustible dust explosion in a food manufacturing company

The Incident

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

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

Lessons Learnt

- Tapioca flour is a combustible material. A flash fire can be triggered in the presence of an ignition source, for example, the flame of the cutting torch.
- A safe work procedure was not implemented for the process

Materials such as wood, food, metal dust can cause explosions when dispersed in air, in sufficient quantities and concentration and under favourable conditions, such as air, heat, fuel, dispersion and confined environment.

4. Risk Assessment

Before starting work, a risk assessment should be carried out to identify hazards associated with it.

1. Assess risks based on:
 - the likelihood of accidents occurring as a result of hazards and
 - the severity of the consequences, should the accident occur.
2. Take appropriate measures to eliminate the hazards or to reduce the risk, and implement safe work procedures.
3. Adopt appropriate risk control measures by following the hierarchy of control.
4. Review risk assessments periodically.
5. Communicate these risks to all persons involved.

See Pg 17 for Example on Risk Assessment. For more information on Risk Assessment, please refer to the Guidelines on Risk Assessment available on MOM's website.

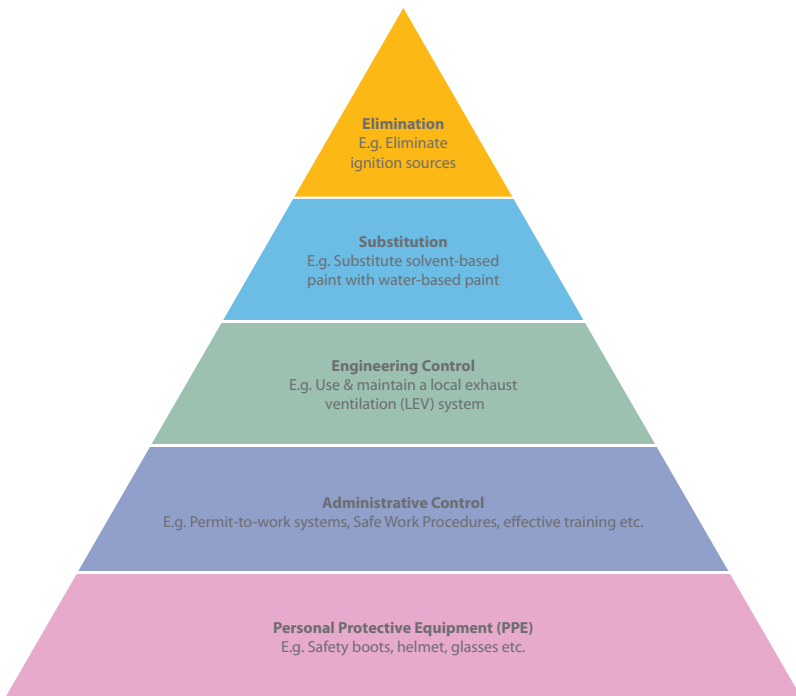
Communication



5. Prevent Fire/Explosions Through The Hierarchy of Control

The following are examples of control measures associated with the handling of flammable and combustible substances.

Care must be exercised when selecting the measures to ensure that they are appropriate for the setup of your facilities.



Elimination

The first priority of control is to eliminate the risk at source. If the work or the process can be carried out without the need for the use of flammable or combustible substances, the risk of fire or explosion arising from the ignition of such substances will be eliminated.

Eliminate oxygen:

- Pipelines intended for carrying flammable substances should be purged to eliminate the presence of oxygen before use.

Eliminate fuel:

- Do not use oil or grease for lubricating valves, gauge connection or other parts of an oxygen system.

Substitution

Substitute flammable and combustible substances with safer alternatives:

- Use water-based substances or any non-flammable process instead of solvent-based substances.
- Use high flash point* substances instead of low flash point substances.
- Replace powders with materials in paste or pellet form.
- Use safer technologies or methods of work such as brush or roller application instead of spraying.

* Flash points of substances can be found from this TA's Glossary or from Safety Data Sheets (SDSs).

Engineering Controls

Design safety into the process:

- Use spark-proof/explosion-proof, intrinsically safe or double insulated equipment.
- Use electrical devices that are enclosed in explosion-proof housings, which are designed to withstand an internal explosion and prevent the combustion from spreading beyond the enclosure.
- Bond and ground to minimise static electricity build-up when:
 - Carrying nonconductive liquids through metallic pipes, vessels, containers.
 - Pneumatically-carried solids.
 - Mixing immiscible liquids.

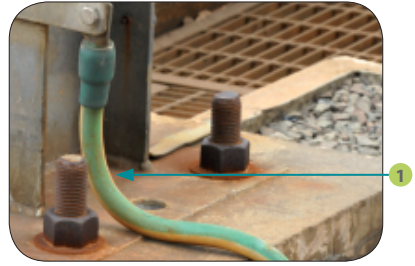


1 Explosion proof light fittings



1 Spark arrestor mounted on exhaust pipe of vehicle

- Fireproof vessels, pipes, structures with insulation to minimise damage due to fires.
- Segregate flammable storage from the process areas. Dike vessels to contain and carry away spills.
- Design controls to fail safe. Add safeguards for safe shutdown during emergencies.
- Install ventilation and extraction systems to dilute flammable vapours with air to prevent fire/explosions.
- Apply local and/or dilution ventilation for works that cannot be carried out in the open, such as using a blower to supply fresh air to dilute the concentration of flammable substances.
- Install and maintain explosion vents of tanks or compartments, where appropriate.
- Install and maintain pressure relief vents for pressurised equipment.
- Ensure that construction material for tanks, piping, containers and vessels are suitable for flammable substances.



1 Chemical tank grounding



1 Grounding equipment and spring-loaded clip at loading/unloading bay for earthing of static electricity



1 Tank farm with bund wall for secondary containment



1 Pressure relief valve

Administrative Controls

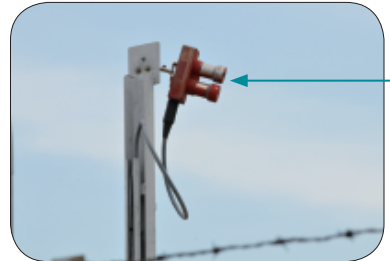
- Establish safe work procedures for work involving the storage, use, handling and disposal of flammable substances.
 - Instil good housekeeping practices such as regular cleaning of any contamination or spills.
 - Implement a safe storage and proper disposal system and store flammable substances away from heat or ignition sources.
 - Keep lids on containers of flammable substances when not in use.
 - Prohibit or control smoking.
 - Do not allow naked flames in areas where flammable vapour is likely to be present.
- Implement a permit-to-work (PTW) system for hot work, or work involving flammable substances, such as spray painting in confined space.
- Institute an effective preventive maintenance programme for process equipment and protective equipment such as safety valves and alarms.
- Manage changes in processes, technologies and equipment to ensure operation integrity and safety.
- Use suitable electrical installations and equipment.
- Do not overload electric circuits and promptly report signs of electrical malfunction.



1 No smoking sign

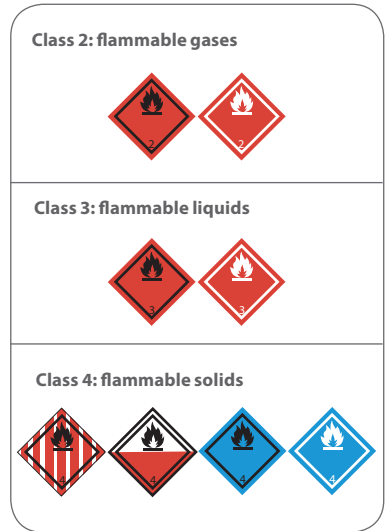


1 Intrinsically safe lighting



1 Install gas monitors to detect leaks

- Maintain and monitor equipment to prevent any possible defects that can lead to fire or explosions.
- Identify clearly the contents of containers, packaging, intermediate bulk containers (IBCs), portable tanks, multiple-element gas containers (MEGCs) and bulk containers containing flammable substances with the United Nations Recommendations on the Transport of Dangerous Goods (UNRTDG) flammable symbols.
- Obtain, use and disseminate information found in SDSs for flammable substances.
- Provide training on:
 - How to recognise the Globally Harmonised System of Classification and Labeling of Chemicals (GHS) pictogram for flammable substances.
 - Implementing the health and safety measures required for flammable substances, including storage, safe use and emergency procedures.
 - The appropriate use and maintenance of PPE.



UNRTDG Flammable Symbols



GHS Pictogram for Flammable Substances

Personal Protective Equipment (PPE)

Suitable PPE can be used to protect persons against fires and explosions. However, PPE should not be used as the only means of protection; it should be used in conjunction with the other risk control measures mentioned earlier.

- Selection of PPE:
The selection of PPE should be suitable and compatible to the work, substances used and the work environment.
- Use of PPE:
Workers should be familiar with the correct way of wearing and removing PPE.
- Maintenance of PPE:
PPE should be properly maintained and stored to retain its protection efficacy.

6. Mitigate Consequences of Fire or Explosion with An Emergency Response Plan

Emergency response planning

A written emergency response plan should be established. Emergency response equipment should be kept on site, made readily available and accessible.

Keep updated information on flammable substances and processes including:

- Location, types and quantities of flammable and combustible substances.
- Possible accidents and emergency scenarios, with considerations to neighbouring buildings and installations.
- Protocols on activation of key personnel to oversee and direct the management of accidents, inclusive of chain of command and communication protocols.
- Suitable media for fire fighting, commensurate with the types of flammable substances involved and operational resources.
- Recovery procedures inclusive of clean-up and decontamination operations.

Fire protection and fire fighting systems:

- Maintain fire protection and fire fighting systems (e.g. PPE, fire extinguishers).
- Institute an inspection programme for emergency equipment and systems.
- Install, use and maintain fixed and mobile fire fighting equipment (e.g. hydrants, fire monitors, deluge systems, sprinkler systems, water curtains etc).
- Ensure good supply and drainage of fire-fighting water.
- Ensure access to extinguishers, hoses, alarms, fire exits and other emergency equipment and sprinkler heads are free from obstruction.



1 Chemical spill kit



1 Deluge system

Training:

- Train and educate employees on fire fighting, safety-related operations and procedures (e.g. evacuation, location and use of emergency equipment, activation of alarms and communicator system).

Drills:

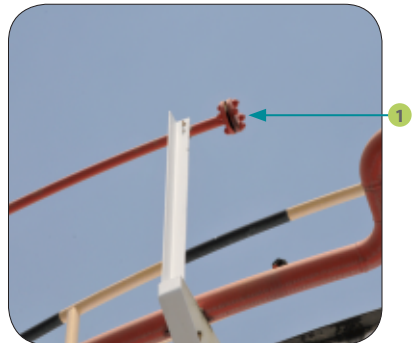
- Regularly review emergency action plans to ensure its continual relevance and currency.
- Conduct emergency drills at regular intervals, involving all persons at site to thoroughly validate and test the effectiveness and robustness of the plans.



1 Fire hydrant monitor



1 Sprinkler system (bulb and nozzle type)

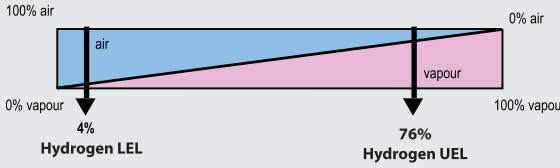


1 Sprinkler located on top of a tank

7. Example of Risk Assessment

RISK ASSESSMENT FORM									
Company:		ABC Chemical Company		Conducted by: Teo Ai Ling, Operator					
Process / Location:		Chemical mixing / Mixing Dept		Mohd Samat, Operator					
Approved by:		Sim Bee Heong Manager		Approved on: 3 Jul 2008					
(Name, designation)		Last Review Date: 3 Jul 2008		Next Review Date: 3 Jul 2011					
No	Work Activity	Hazard	Possible Accidents / Ill Health & Persons-at-Risk	Existing Risk Control (if any)	Likelihood	Severity	Risk Level	Additional Risk Controls	Action Officer, Designation (Date)
1				Hazards and control measures listed are not exhaustive					
2	Mix chemicals D and E	Flammable vapour-air mixture in the flammable range with presence of ignition source	Fire and/or explosion leading to deaths, severe injuries, burns (Workers, visitors, sub-contractors, members of public)	<ul style="list-style-type: none"> Fugitive flammable vapours from processes and ventilation are controlled by using enclosures, collection systems and equipment design. Explosion venting is constructed within work area. 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 flammables substances. Training provided on the use and maintenance of safety control measures 	Occasional	Major	High	To separate mixing operations from other work areas by explosion-resistant barriers.	Sim Bee Heong Manager (Jan 2009)

8. Glossary

Auto-ignition Temperature (AIT)	The lowest temperature at which a flammable gas- or vapour-air mixture is capable of extracting enough energy from the environment to self-ignite.
Flammability Limits	<p>The range of flammable vapour or gas-air mixture between the upper and lower flammable limits. 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 burn; concentrations above the upper flammable limit (UFL) are too rich to burn.</p>  <p>The diagram illustrates the flammability limits for hydrogen. It shows a horizontal bar representing a mixture of air and hydrogen vapour. The left end is labeled '100% air' and '0% vapour'. The right end is labeled '0% air' and '100% vapour'. A vertical line at 4% vapour is labeled 'Hydrogen LEL'. A vertical line at 76% vapour is labeled 'Hydrogen UEL'. The area between these two lines is shaded: light blue for 'air' and light pink for 'vapour'.</p>
Flash Point (FP)	Minimum temperature at which a liquid gives off enough vapour to form an ignitable mixture with air.

9. Flammability Characteristics of Liquids and Gases

Compound	FP (°C)	LFL (vol% in air)	UFL (vol% in air)	AIT (°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
Ethylene oxide	-28.9	3%	100%	429
Hydrogen	NA (Gas)	4%	76%	500 to 571
LPG	NA (Gas)	1.6% (Butane) 2.1% (Propane)	8.4% (Butane) 9.5% (Propane)	-
Methane	NA (Gas)	5%	15%	537
Methanol	12	5.5%	44%	464
Pentane	-49	1.5%	7.8%	309
Petrol	< -21	1.3%	7.1%	250
Propane	-104	2.1%	9.5%	450
Toluene	4	1.1%	7.1%	480
Turpentine	30 to 46	0.8%	6%	220 to 255

This table is extracted from

- NIOSH Pocket Guide to Chemical Hazards
- ILO International Chemical Safety Cards

10. Useful References

- Chemical Process Safety: Fundamentals with Applications, Daniel A. Crowl / Joseph F. Louvar
- Safe Working with Flammable Substances, HSE
www.hse.gov.uk/pubns/indg227.pdf
- NIOSH Pocket Guide to Chemical Hazards
www.cdc.gov/niosh/npg
- ILO International Chemical Safety Cards
www.ilo.org/public/english/protection/safework/cis/products/icsc/dtasht/index.html
- FM Global Property Loss Prevention Data Sheets 7-0, Causes and Effects of Fires and Explosions
- FM Global Property Loss Prevention Data Sheets 7-76, Prevention and Mitigation of Combustible Dust Explosions and Fire
- Combustible Dust in Industry: Preventing and Mitigating the Effects of Fire and Explosions, OSHA
www.osha.gov/dts/shib/shib073105.html
- Emergency Response Program, EPA
www.epa.gov/OEM/docs/chem/W-Chap-08.pdf
- Fact Sheet on Personal Protective Equipment, OSHA
www.osha.gov/OshDoc/data_General_Facts/ppe-factsheet.pdf
- Globally Harmonised System of Classification and Labelling of Chemicals (GHS)
www.unece.org/trans/danger/publi/ghs/ghs_rev02/02files_e.html
- The following legislations:
 - Workplace Safety and Health Act
 - Workplace Safety and Health (General Provisions) Regulations
 - Workplace Safety and Health (Risk Management) Regulations
 - Workplace Safety and Health (Shipbuilding and Ship-repairing) Regulations 2008
at www.mom.gov.sg/legislation/wsh.html
- More information and guidelines on Risk Assessment:
www.mom.gov.sg/wsh/risk_management
- The Fire Safety Act and Fire Code:
www.scdf.gov.sg/Building_Professionals/Publications/index.html

- Information on Fire Safety Licensing and Enforcement:
www.scdf.gov.sg/Building_Professionals/Fire_Safety_Licensing_and_Enforcement/index.html
- Guidelines on Emergency Response Planning:
www.mom.gov.sg/publish/etc/medialib/mom_library/Workplace_Safety/bc_safety.Par.18438.File.tmp/Emergency%20Response%20Planning.pdf

Singapore Standards

SS 510 : 2005(formerly CP 50) 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

CP 55 : 1991 Code of practice for use and maintenance of portable fire extinguishers

Singapore Standards can be obtained from:

SNP Corporation (Legal) Ltd
 Legal Publication Retail Outlet
 1 Kim Seng Promenade #18-01/06
 Great World City East Tower S(237994)
 Tel: (65) 6826 9691
<http://www.snpcorp.com/webshop>

11. Acknowledgements

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