Chemical Safety in the Workplace

Guidance Notes on Safe Use of Flammable Liquids

Occupational Safety and Health Branch
Labour Department

Occupational Safety & Health Council

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1 Preface

Flammable liquids are extensively used in work processes such as printing, surface finishing, paint manufacturing, furniture making and indoor decoration. They are commonly found as main components in paints, printing inks, diluents, etc. Handling and storage of flammable liquids could create hazards if safety measures are not taken.

Fire and explosion are the main hazards associated with the handling and storage of flammable liquids. In addition to physical hazards, flammable liquids can also pose health hazards to workers.

This booklet aims to provide guidance for proprietors and managers of workplaces to identify the potential hazards arising from the use and storage of flammable liquids and establish a chemical safety programme to protect the safety and health of workers using flammable liquids.

2 Introduction

2.1 Flammable liquids

2.1.1 Flammability of a liquid indicates its relative ease to start a fire. It is one of the main properties used to determine fire and explosion hazards. An important indicator of this property is the flash point[1]. Flash points[2] of some flammable liquids used in workplaces are given in Appendix 1.

2.1.2 In Hong Kong, a substance is classified as "flammable" for legislative control purpose under the Factories and industrial Undertakings (Dangerous Substances) Regulations if its flash point is below 66°C. However, liquid with flash point not within the statutory limit (i.e. 66°C) should not be regarded as totally safe because fire and explosion hazards are still imminent if the liquid is heated to temperatures above its flash point.

2.1.3 Overseas countries or territories under other jurisdiction may adopt different flash point criterion from Hong Kong for their legislative control of flammable substances. In view of the variance, user has to read the material safety data sheets of the imported chemicals carefully, since imported products not labelled as flammable may not be so under the local legislation. In case of doubt, further information should be obtained from distributor or manufacturer.

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[1] Under the Factories and Industrial Undertakings (Dangerous Substances) Regulations, flash point means, in relation to any liquid, the lowest temperature, if any, at which such liquid will give off vapour which will ignite or explode if mixed with air and exposed to a naked light.

[2] Depending on the method of test used to determine the flash point, whether close-cup or open-cup, there exist slight variations in the result. In general, the close-cup flash point is often quoted.

3 Use of Flammable Liquids

3.1 Solvents

3.1.1 Many solvents used in workplaces are flammable liquids. Besides being used on their own as cleaning solvents, diluents, etc., solvents are the main components of printing inks, varnishes, paints, lacquers, adhesives and asphalt products.

3.1.2 Commonly used solvents include chemicals such as toluene, hexane, alcohols, glycol ether, etc. and specially formulated proprietary solvent blends. Flammable solvents often pose fire or explosion risk if safety measures for their use and storage are not observed.

3.1.3 Volatile organic compounds (VOCs) such as benzene, toluene, hexane, etc. are produced during work processes in which solvents are used such as printing, cleaning with solvents, drying of paints etc. The VOCs released may cause health concern to workers.

3.2 Fuels

3.2.1 Liquid fuels are flammable substances. Most of the fuels are hydrocarbon products obtained from fractional distillation of crude oil. Hydrocarbon fuels could be gases, light oils and heavy oils depending on the carbon chain length as illustrated by the examples below:

Fraction	Carbon chain length	Distillation boiling range/℃
Gases	C1 – C4	Below 30
Petroleum ether	C5 – C6	35 - 90
Gasoline	C7 – C10	90 - 200
Kerosene	C11 – C16	200 - 300
Diesel oil	C20 & up	290 - 380
Heavy oil	C30	250 & up

3.2.2 Gasoline and diesel are mainly used for propelling engines including the aeroplane jet engines that require special grade products. Diesel is also used in firing boilers and kerosene is used as fuel in cooking stoves.

3.2.3 Methyl alcohol is frequently used as a fuel for various purposes such as heating food in catering establishments.

4 Hazards

4.1 Fire and explosion

4.1.1 Fire and explosion are the main hazards associated with the use, transport and storage of flammable liquids. For a fire to start, the following conditions are simultaneously required:

- fuel (gas, vapour or combustible dust) of concentration within the flammable range
- oxygen (sufficient supply)
- ignition source

4.1.2 The burning requirements provide a conceptual basis for establishing safety measures in handling flammable liquids. Elimination of any one or combinations of the requirements would normally prevent fire.

4.1.3 The above concept should be applied cautiously. No ignition source is needed if a flammable liquid is heated above its auto-ignition temperature[3], and no additional oxygen is required if an oxidizing agent is present or in some cases when oxygen is within the fuel molecule (e.g. ethylene oxide).

[3] "Auto-ignition temperature" refers to the minimum temperature required to initiate or cause self-sustained combustion in the absence of any external source of energy.

4.1.4 Flammable liquid burns when the vapour released from the liquid ignites and the flame propagates. The amount of flammable vapour given off has significant effect on the extent of fire or explosion hazard. Physical properties data of the liquid such as flash point, viscosity, vapour pressure, flammable range, etc. provide reference information to identify and assess potential fire hazards. Data for some flammable liquids are tabulated at Appendix I for reference.

4.1.5 A combustible mixture will burn within its flammable range, which is the range between the lower and upper flammable/explosive limits[4]. Typical values of liquid flammable range are given in Appendix I. Flammable range data shall be regarded as reference information to identify and assess potential hazards since the conditions can be different from the experimental conditions used to obtain the data.

4.1.6 Flammable liquid auto-ignition temperature can be used as a reference to evaluate the level of hazard that will be incurred when the liquid is operated in work processes at elevated temperatures. It should be noted that the auto-ignition temperature shall not be regarded as a clear cut-off point between no ignition/self-ignition conditions.

[4] "Flammable (or explosive) limits" specify the concentration range of a gas/vapour in air which will burn or explode in the presence of an ignition source. The lower explosive limit (LEL) or upper explosive limit (UEL) is the lowest or highest concentrations of the gas or vapour respectively within which the mixture will burn or explode if ignited.

4.1.7 Flammable liquids of low viscosity such as thinners could be much more hazardous as the liquids could spread quickly when spilt, causing a rapid build-up of flammable vapours from the liquid surface. Furthermore, the vapour pressure[5] of a flammable liquid should also be considered in assessing hazards. The vapour from the liquid is "pushing" against the atmosphere in the evaporation process. As such, the higher the vapour pressure, the faster a liquid evaporates. When the vapour pressure comes to the atmospheric pressure, the liquid reaches its boiling point and the temperature of the liquid is the boiling point temperature. Vapour pressure and boiling point have an intimate relationship. In general, low boiling point liquid will have high vapour pressure at atmospheric condition. Flammable liquid of high vapour pressure is readily volatile and thus a high concentration of the flammable vapour could quickly form in the space above the liquid creating a hazardous environment.

4.1.8 The physical environment where flammable liquids are handled is an important factor in assessing hazards. Flammable vapour may build up in poorly ventilated areas to a concentration within its flammable range. As the vapour is heavier than air in many cases, it will therefore tend to accumulate in lower areas or in confined spaces such as pits and drains forming potential hazardous areas. Vapour can also spread away from the liquid and if ignited at some distance from the emission source, the flame could flash back to the flammable liquid and starts a fire.

[5] "Vapour pressure" is the pressure at any given temperature of a vapour in equilibrium with its liquid.

4.2 Ignition sources

4.2.1 In workplaces, various ignition or energy sources can ignite a flammable/vapour mixture but some of which may seem insidious and obscure to the unsuspecting workers. A list of ignition sources is tabulated below for reference:

Sources		Examples
1. Thermal	Flames	Pilot light, cigarette lighter, stove, blow torch, welding
	Hot surfaces	Hot plate, drying oven, molten metal or glass, electric heater, vehicle exhaust, steam pipe, refractory lining, incandescent particles from incinerator or chimney, glowing ember, hot slag, cigarette butt, electric lamp, soldering iron
2. Electrical	Electrical current	Electric motor, vehicle starter, electric switches, cable break, spark produced under short circuit or other fault conditions
	Electrostatic charge	Pneumatic conveying of solid, flow of liquid in pipeline, rubbing of plastic or rubber, liquid spray generation, powder flow, fluidized-bed drying
	Lightning	Direct strike, induced voltage
	Stray current	Arc welding
3. Mechanical	Friction heat	Abrasive wheel, bearing, jamming of material, piston movement
	Materials fracture	Cracking of metal
4. Chemical	Exothermic reactions	Vigorous oxidizing reactions, exothermic polymerization and exposing pyrophoric substance (e.g. sodium metal etc.) to air

4.3 Other hazards of flammable liquids

4.3.1 Apart from the heat released, burning of flammable liquids may also produce toxic substances e.g. carbon monoxide and hazardous smoke. As oxygen is consumed during burning, hazardous oxygen deficiency environment will develop in a confined area.

4.3.2 Flammable liquids e.g. hexane, toluene, etc. can pose health hazard if they enter into human body through inhalation, ingestion or contact with skin. Exposure to flammable liquid may cause skin irritation, sensitization or dermatitis, or damage to the central nervous system and organs such as liver, etc. Some flammable liquids are also known to be carcinogenic. For detailed hazard information, users may have to consult Material Safety Data Sheets or the supplier.

4.4 Incidents involving flammable liquids

4.4.1 Improper handling of the liquids often leads to fire and explosion incidents. In general, the incidents may occur during the following operations:

- transporting flammable liquids;
- decanting or dispensing flammable liquids;
- using flammable liquids in processes such as mixing and spraying;
- dealing with flammable liquids spillages;
- disposing of flammable liquids;
- emptying tanks containing flammable liquid residue;
- cutting/welding of containers/tanks that contain flammable liquid residue/vapour.

4.4.2 There are many causes of incidents in work processes. It is not unusual that the occurrence of incidents is a result of random combination of the various causes. The following are some causes of incidents involving flammable liquids:

- lack of information and alertness of the hazardous properties of the flammable liquids;
- operator error due to inadequate supervision or lack of training;
- inadequate control of ignition sources;
- use of inappropriate equipment in work process involving flammable liquids;
- occurrence of electrostatic discharges.

5 Chemical Safety Programme

5.1 Overview

5.1.1 To ensure the safety and health of employees engaged in the use and storage of flammable liquids, a carefully planned chemical safety programme is essential. In the programme, the chemical hazards of flammable liquids should be firstly identified. The risks arising from these hazards are assessed taking account of the work situations and personnel involved. Appropriate preventive and/or control measures are then set up to eliminate or mitigate the risks, with their effectiveness being regularly monitored and reviewed. The associated hazard information and protective measures should be communicated to all affected employees. The chemical safety programme should also include other elements like planning of emergency responses and training of employees.

5.1.2 The chemical safety programme should be organized and integrated into the overall safety management system of the workplace to facilitate its effective implementation. Employers should deploy adequate manpower and resources for the development, implementation and maintenance of the programme.

5.1.3 The advantages of establishing a chemical safety programme at work are as follows:

(a) to avoid possible problems or failure due to oversight of hazards that may be caused when any of the interrelated processing steps is changed;

(b) to provide management with a systematic overview about the entire processing work, allowing easy detection of warning signs of potential incidents; and

(c) to render a safer operation consistent with increased efficiency and productivity.

5.2 Major elements

5.2.1 A chemical safety programme should include the following major elements:

(a) risk assessment -- to identify the potential hazards arising from the materials and processes involving the use of flammable liquids and to assess their associated risks taking into account the adequacy and effectiveness of existing control measures;

(b) safety measures -- to adopt and maintain preventive and/or control measures to eliminate the risks or minimize them to acceptable levels;

(c) emergency preparedness -- to establish plans and procedures for emergency response;

(d) hazard communication -- to establish appropriate and effective means to disseminate the safety and health information on the materials and processes to employees via adequate instruction and training; and

(e) monitoring and review -- to monitor the effectiveness of the adopted safety measures with regular review and revision which may also be required for any new requirements or significant changes in the materials or processes.

5.2.2 Depending on individual situation of the workplace, employers may find it beneficial to include other elements such as inspection, accident investigation and health surveillance in the chemical safety programme.

6 Risk Assessment

6.1 Overview

6.1.1 Risk assessment is a process to estimate the level of risk and decide whether the risk is tolerable or acceptable. Before risks can be assessed, the hazards related to the process and associated chemicals have to be identified. The risks are then estimated in terms of the people who might be involved and their exposure, the likelihood and potential consequences of the identified hazards. Suitable safety measures will then be developed and implemented with periodic monitoring and reviews.

6.1.2 It should be noted that many of the materials used in industries are proprietary prepared formulations and their chemical components may not be shown in detail on their original containers. It is advisable to be acquainted with the specific functions of the product since these will often throw some light on their chemical natures. In all cases, employers who use chemicals should enquire from the supplier detailed hazard information and user safety precautions of their products.

6.1.3 Reference should be made to relevant legislation, codes of practice, guidelines and best trade practices in order to decide on the need and adequacy of safety measures. Employers should keep an inventory of all substances in the workplace, identify whether they are hazardous and ensure that they are handled and stored safely. It is also essential to obtain the Material Safety Data Sheet (MSDS) of the chemicals from the supplier, as it contains a wealth of information indispensable for risk assessment, stipulation of safety measures and emergency planning.

6.1.4 The risk assessment should be reviewed regularly and whenever there is any indication to suspect that it is no longer valid or when there has been a significant change in the operation to which the assessment relates. In particular, the risks associated with the processes and chemicals should be re-assessed when:

(a) there are changes to any of the processes or their scales;

(b) there are changes in the materials used; or

(c) safer procedures or improved preventive measures become available or reasonably practicable in light of recent technological advancement.

6.1.5 When health risk is assessed, the occupational exposure limits (OELs) of the chemicals concerned should be consulted. OELs refer to the airborne concentrations of individual chemicals below which no adverse health effects would be imposed on nearly all workers upon exposures by the route of inhalation. More information on OELs can be found in the *Code of Practice on Control of Air Impurities (Chemical Substances) in the Workplace* issued by the Labour Department.

6.1.6 As OELs do not represent 'no effect' levels at which every employee can be guaranteed protection, employers should:

(a) ensure the workplace exposure standards are not exceeded under normal operational conditions; and

(b) keep the level of exposure as low as reasonably practicable.

6.1.7 Risk assessment should be performed by competent persons who are well knowledgeable about the hazards associated with the chemicals and related processes including the physical and chemical changes at each stage of the processing work. Specialist or expert advice should be consulted whenever needed.

6.1.8 The *Chemical Safety in the Workplace: Guidance Notes on Risk Assessment and Fundamentals of Establishing Safety Measures* published by the Labour Department provides detailed information about the systematic approaches for conducting risk assessment related to chemical hazards.

6.2 Factors for consideration in the risk assessment

6.2.1 Various factors discussed in paragraph 6.1.4 should be taken into consideration in assessing the risks associated with the use of flammable liquids. In addition, the following aspects are relevant.

6.2.2 Physical form of flammable liquids

The physical form of flammable liquids has pronounced effect on the extent of the hazards. Flammable liquids in the form of a mist or froth would increase the risk of fire and explosion. The risk of entering into the human body also increases.

6.2.3 Chemical changes

If chemical changes occur in the process involving the use of flammable liquids, the chemical reactions and products should be studied, and the associated hazards should be identified. Incompatibility of flammable liquids with other chemicals, such as oxidizing agents, should be evaluated to avoid accidental contact, which would further increase the fire/explosion risk. Attention should also be paid to any possible side reactions and by-products for example combustion of flammable liquid may produce carbon monoxide and degradation of high molecular compounds to produce volatile fractions that may increase fire risk.

6.2.4 Temperature changes

Increase in temperature will accelerate liquid vapourization. Many of the exothermic chemical changes generate heat spontaneously resulting in the following effects:

- causing evolution of hazardous vapours.
- increase of pressure in the container causing explosion.
- rapid bubbling causing splashes of flammable liquids.
- increase in reaction rate generating more heat.

The above effects due to temperature changes will be intensified if there is no effective means to dissipate the heat evolved, causing localised heating or superheating of the flammable liquids leading to a violent sudden expansion.

6.2.5 Scale of the process

Scale of the process generally determines the amount of hazardous flammable liquids involved. The larger the amount of hazardous liquids is used, the greater is the likelihood of occupational exposure and risk.

6.2.6 Extent of exposure

The extent of exposure of employees to hazardous chemical liquids and vapour associated with the use of flammable liquid is affected by:

(a) frequency and duration of exposure;

(b) rate of generation and concentration of the hazardous vapour in the atmosphere; and

(c) effectiveness of safety measures in minimizing the exposure.

6.2.7 Working environment and facilities

Many workplaces are temperature and humidity controlled environment to ensure the quality of products, e.g. printing workshops. The working environment may cause accumulation of hazardous chemicals in the atmosphere if the ventilation is inadequate. Employers should therefore pay due attention, but not limited, to the following when conducting the risk assessment:

(a) any nearby ignition sources when flammable liquids are handled, transferred or mixed;

(b) adequate ventilation of the workplace;

(c) any accumulation of flammable vapours at locations;

(d) whether the flammable liquids, when used, transferred or stored is sensitive to air, moisture or light, and whether it is compatible with others when stored; and

(e) proper design of the containers for flammable liquids.

7 Safety Measures

7.1 Overall strategy in establishing safety measures

7.1.1 The primary consideration is to adopt appropriate preventive measures such as by elimination or substitution in order to directly remove the hazards at source. On many occasions, flammable liquids, equipment or process can be replaced by a safer one that eliminates or minimizes the risks to acceptable level. If such measures are not possible, segregation of the flammable liquids or the processes or other control measures should be taken. The use of personal protective equipment should only be considered a supplementary means or as the last resort to minimize workers' exposure to the hazards.

7.1.2 Safety measures can be realised by engineering and administrative controls. Engineering control measures such as installation of suitable types of ventilation can eliminate or lower the level of flammable vapours at source. Administrative control measures such as by implementation of safe work practices and scheduling of breaks or rotating shifts can limit worker's time spent near the hazard thus reducing their exposure. The adoption of good housekeeping practices could not be more emphasized when flammable liquids are concerned.

7.1.3 It is desirable to consider safety and health aspects of the materials, processes and equipment at the design or purchase stage. This will save additional expenses and often reduce practical difficulty in subsequent adjustments to accommodate the safety features. Management should also keep abreast of the up-coming safety alternatives or devices that are available on the market.

7.1.4 All safety measures should be documented, for example, in the standard operating procedures (SOP), and should be made known to the workers concerned. The effectiveness of such measures should be constantly monitored and reviewed to ensure adequacy of the adopted safety measures. If any changes are made to the SOP in respect of the use of flammable liquids, a fresh risk assessment should be conducted and any amended protective measures should be documented in the SOP accordingly.

7.2 Elimination/Substitution

7.2.1 Elimination/Substitution of flammable liquids

The three conditions needed simultaneously for the burning of flammable vapour are fuel (concentration within the flammable range), ignition source and oxygen. Eliminating any one of the above elements can stop burning and prevent the outbreak of fire. Substituting with other liquids, which are either non-flammable or have a higher flash point, could be suitable alternatives, but care must be exercised in choosing one that does not pose a risk to health or the environment. In any case, the use and storage of flammable liquids should be kept to the minimum required.

7.2.2 Elimination of ignition sources

The elimination of another condition, ignition sources, can prevent the outbreak of fire. Paragraph 4.2 tabulates some common sources of ignition that should be avoided as far as possible. In paragraph 7.8, precautions related to elimination of ignition sources will be discussed in more details.

7.2.3 Elimination of oxygen

In some cases, it is possible to replace oxygen by inert gases such as carbon dioxide or nitrogen that does not support combustion in order to reduce fire hazard. Flammable solvents used in batch processes in the industries could be rendered safe by operating in an inert gas environment. However, appropriate control measures should be implemented since inert gas may cause asphyxiation.

7.3 Segregation

7.3.1 Segregation by fire-resisting partitions to isolate areas where flammable liquids are used, handled or stored from other parts of the workroom could be adopted to mitigate fire hazard. However, excessive amount of flammable liquids should not be stored in the workplace. In case of such need, Fire Services Department has to be consulted for construction of a dangerous goods store in accordance with the licensing requirements and related guidance.

7.4 Engineering control measures

7.4.1 The primary objective of adopting engineering control is to eliminate or lower the risks at source. With working processes, the main engineering control method against hazards of accumulation of flammable vapours is exhaust ventilation, which provides an effective means of preventing their accumulation in the atmosphere. There are four major types of ventilation, namely, general dilution ventilation, booth ventilation, local exhaust ventilation and push-pull ventilation. The system should be designed and constructed to take account of the flammable hazard of the chemicals extracted and discharged.

7.4.2 Practically the ventilation methods to control inhalation and fire/explosion hazards are combined. Factors related to the materials used, such as the quantity, frequency of use, volatility, flash point, explosive limits and exposure limit should be considered. Effective engineering set-up should not only ensure that the workplace is safe regarding the physical hazards such as fire or explosion, but also safeguard workers' health.

Ventilation – General dilution ventilation

7.4.3 In general dilution ventilation, fresh air is supplied to work area by using suitable equipment such as fans to dilute the air containing flammable vapour. Alternatively, the contaminated air could be drawn out by exhaust fan. Natural airflow through doors, windows or other openings such as relief openings could also be means to dilute the contaminated air in work area.

7.4.4 This method only replenishes fresh air supply for the whole work area. It should therefore be used in conjunction with other means of ventilation in order to remove airborne contaminants from source.

Ventilation – Booth ventilation

7.4.5 Booth ventilation is the most effective in the control of flammable vapour. A carefully planned and designed ventilation system in a booth restricts the hazardous activity to a designated area to contain hazards.

Ventilation – Local exhaust ventilation

7.4.6 Local exhaust ventilation (LEV) allows vapours be captured and removed by forced air current through a duct near the emission point before the flammable vapour can be dispersed into the work area. It is generally applied to the equipment that cannot be readily enclosed. LEV may not be suitable for working with large pieces of equipment.

7.4.7 When LEV is adopted it is important to ensure that the exhaust current does not pass through the worker's breathing zone. The extraction hoods should be positioned as close as practicable to the point of generation of vapour and should enclose the source to the greatest practicable extent.

7.4.8 The ducting should be of adequate diameter, and as short and as straight as practicable. Bends should be of gentle radius while 'T' section junctions should be avoided.

7.4.9 The system should vent to a safe place in the open air in such a manner that neighbours are not subjected to nuisance. If vents are poorly sited, discharged vapour may re-enter buildings through doors, windows, roof spaces or intakes to air conditioning system. In some cases the air may need to be cleaned before it is discharged to the outside atmosphere.

Ventilation – Push-pull ventilation

7.4.10 Push-pull ventilation system is suitable for large work pieces, in which fans are used to blow vapours away from the worker's breathing zone towards an extraction system. Again, the design of the system should ensure that the flow of contaminated air is not within the worker's breathing zone.

7.5 Administrative control measures

7.5.1 Administrative control measures include arrangement of work schedules and stipulation of safe work practices so that the risk of exposure of individual employees to flammable liquids can be reduced. Employers should ensure that these are incorporated into the management system as far as practicable. Typical safe work procedures that reduce the worker's exposure to flammable liquids should include the following:

(a) ensuring the time spent near the hazard is kept to minimum. Workers should not stay between the work piece and the extraction system during operation;

(b) keeping pots or bottles of flammable liquids closed when not in use;

(c) avoiding skin contact with flammable liquids;

(d) keeping minimum amount of flammable liquid for use in the workplace, usually no more than a half-day’s or one shift’s supply; and

(e) adopting of general practices of good housekeeping.

7.6 Personal protective equipment (PPE)

7.6.1 The primary objective of using PPE is to supplement control measures by minimizing worker’s risks of exposure to flammable liquids through inhalation or skin contact. Being only passive protective measures PPE should not replace preventive measures and in general, it should be considered as the last resort in respect of the safety measures outlined in this section.

7.6.2 Appropriate PPE should be chosen with regard to the hazards and physical nature of the chemicals and their routes of entry into the human body. The MSDS information and risk assessment will help determine the PPE requirements. Before and after use, PPE should be inspected for any signs of damage. It should be regularly cleaned and stored in good condition. Contaminated PPE should be properly treated or disposed of as appropriate, and replacement sets kept readily available. Moreover, as no PPE will give long-term protection, a programme should be in place for its regular replacement.

7.6.3 Wrongly selected, improperly used or maintained PPE may do more harm than good as the user may have a false sense of security. Readers should refer to *Chemical Safety in the Workplace: Guidance Notes on Personal Protective Equipment for Use and Handling of Chemicals* for details.

Protective clothing

7.6.4 Protective clothing protects the skin or personal clothing from contact with flammable liquids and prevents spread of contamination. When handling flammable liquids, such as dispensing and storage, or conducting work processes involving flammable liquids, employees should always wear suitable protective clothing. Employers should also provide their employees with special clothing for use in emergencies.

7.6.5 Protective clothing includes gloves, aprons, gowns and overalls. It is important to choose protective clothing made of materials that resist penetration or damage by the chemicals used.

7.6.6 As workers frequently have to handle many flammable liquids by hands, chemical resistant gloves have to be used. It should be noted that natural rubber gloves are not effective against hydrocarbon-type solvents as they can penetrate the rubber and physically degrade it. Nitrile or neoprene gloves, though more expensive, should be used against hydrocarbon-type solvents. It is prudent to always check with the supplier and consult the MSDS of the chemicals involved.

Face and eye protection

7.6.7 Where there is a reasonably foreseeable risk of eye injury, suitable eye protectors or face shields should be worn. Safety spectacles can be fitted with prescription lenses if required, while clear plastic safety goggles that completely enclose the eyes provide superior eye protection. If protection to the whole face including mouth, nose and eyes is required or there is a risk of splashing, face shield should be used.

Respiratory protective equipment

7.6.8 Respiratory protective equipment (RPE) protects workers against exposure to dusts, gases, fumes and vapours, but exposure duration should be kept short.

7.6.9 RPE should be used to protect the workers where engineering control is not reasonably practicable such as during maintenance work, cleaning, or emergencies where hazardous vapour is generated from chemical spillages or inadvertent mixing of incompatible chemicals.

7.6.10 The choice of RPE depends on the vapour concentration, duration of exposure and physical and chemical nature of the flammable liquids. For fire and other major emergencies where asphyxiation or inhalation of toxic gases at levels immediately dangerous to health or life is possible, self-contained breathing apparatus (SCBA) should be used.

7.6.11 The following RPE can protect against airborne chemical contaminants:

(a) air purifying respirators – when fitted correctly, most half-face respirators and full-face equipped with appropriate filters could reduce the exposure to air contaminants by 90% and 98% respectively; many powered air-purifying respirators that use battery-operated motor blower to draws air through filters have similar efficiency.

(b) airline respirators – airline respirators supply clean air to the mask, helmet or hood using an airline, and the device could reduce the exposure to air contaminants by 96% to 99.9%, depending on the type of covering.

7.7 Monitoring

7.7.1 Monitoring provides a means to ensure the effectiveness of safety measures taken. Air monitoring generally involves measuring the concentration of chemical vapour at strategic locations in the work area or at the worker's breathing zone. The monitoring can be continuous or periodic sampling and analysis using sensors (with alarm device), direct-reading meters, static samplers and personal samplers.

7.7.2 Based on the work activities and the result of risk assessment, the management should establish and implement appropriate monitoring programme to ensure that the levels of chemical vapour do not exceed the acceptable hazard limits, such as the lower explosive limit (LEL) or the occupational exposure limit (OEL) of the chemicals. The monitoring programme should include:

(a) monitoring parameters such as concentrations;

(b) frequency of monitoring;

(c) location and method of monitoring;

(d) alarm levels based on the acceptable limits; and

(e) follow-up actions.

7.7.3 Investigation of serious accident or dangerous occurrence involving flammable liquids is a reactive means of monitoring after the event. All such events should be investigated and be taken as a 'learn-from-mistake' exercise. The investigation should be led by a line manager or professional having adequate knowledge about the operation.

7.7.4 Biological monitoring can be used to provide additional information for the assessment of chemical exposure by measuring the level of the chemical or its metabolites (what it breaks down into in the body) in the worker's urine and/or blood. Biological monitoring should be used only to complement, rather than replace, air monitoring. It can be incorporated into the health surveillance programme where appropriate.

7.7.5 Health surveillance is a means of early monitoring for adverse health effects resulted from chemical exposure. It provides clues on the need of workplace and practical interventions, thereby preventing further harm to the health, especially for employees who have regular exposure to flammable liquids. It usually takes the form of pre-employment and periodic medical examinations. Where appropriate, medical examination should also be conducted upon and after termination of work and upon resumption of work after prolonged sickness absence. Health surveillance should be conducted by registered medical practitioner, preferably one who has received formal training in occupational medicine.

7.7.6 If monitoring reveals over-exposure to flammable liquids, the process should be suspended and the causes be investigated. The management should also put in place suitable control measures and ensure that such measures are operating effectively before allowing resumption of the process. The lesson learnt is also useful in reviewing the chemical safety programme.

7.8 Some practical safety measures

7.8.1 The systematic management approach of establishing measures to ensure safety in the use of flammable liquids has been discussed in other paragraphs of this section. Some practical precautions will be suggested in the following paragraphs. It should be noted that these precautions are only exemplary, as the hazards dealt with may vary from workplace to workplace. The systematic management approach should always be adopted to establish suitable safety measures.

Control of ignition source

7.8.2 With respect to the ignition sources discussed in paragraph 4.2, practical measures can be adopted to avoid them. Some of the sources are discussed in the following paragraphs.

Electrostatic charge

7.8.3 Electrostatic charge can build up due to liquid movement in work process, for example, during pumping, emptying, filling and spraying; and the movement of other materials, such as powders. Incidentally, non-conducting footwear and clothing made of synthetic fibres could also generate electrostatic sparks that could be potential ignition source.

7.8.4 In a work environment with potential fire or explosion hazards, all metal (or other conducting) components should be adequately earthed in order to protect against electrostatic charge build-up. All fixed equipment used to handle flammable liquids should be electrically bonded together and earthed.

7.8.5 Pumping of flammable liquids should restrict to appropriate speeds in order to reduce possibility of generating electrostatic charge.

Friction sparks

7.8.6 Tools and work process involving rubbing or impact can generate sparks. It is recommended to use spark-proof tools and remove all flammable liquids or residues before carrying out operations that may generate spark.

Hot work

7.8.7 Welding, cutting or similar hot work operations can be a potential source of ignition for flammable liquids. In many incidents, hot work causes fire or explosion. The hot work should only be carried out under strictly controlled manner with safety measures in place.

7.8.8 Before hot work is carried out, flammable liquids in the vicinity should be removed. When working on containers that have been used to contain flammable liquids, any remaining liquids should be drained off and residues should be cleared. Flammable vapour inside containers should be removed by flushing with air. Accumulation of the flammable vapour in the workplace should be avoided.

Electrical equipment

7.8.9 Electrical devices should be avoided as far as possible inside a flammable atmosphere since any spark given off would set off a fire or explosion. However, if the situation so requires, special types of protection, for example explosion proof[6], intrinsically safe[7], enclosed type equipment[8], etc. can be considered. However, to ensure that these equipment live up to their expected functions, they have to fulfill recognized international or national standards, such as the BS EN 60079:2004 series.

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[6] This is the equipment that is housed in an enclosure capable of containing an internal explosion without allowing flames or hot gases to escape to trigger an explosion in a flammable atmosphere.

[7] This is the equipment that does not release sufficient electrical or thermal energy to cause ignition of flammable vapour in a hazardous area.

[8] The equipment has electrical components that are fully encapsulated in an approved material so as to exclude the flammable atmosphere.

Explosion venting/relief

7.8.10 Flammable vapour may explode when ignited. Explosion venting/relief is a passive protection measure whereby the drastic pressure build-up in a closed vessel or system is released through a setup without causing the vessel or system to rupture by the force in flammable vapour explosion accident.

7.8.11 One such application is the installation of explosion relief panel in solvent evaporating oven. The relief panel is designed and constructed such that the explosion pressure is absorbed and discharged by the rupture of the panel.

7.8.12 Adequate ventilation is also required to ensure that no excessive flammable vapour accumulates to dangerous level arising from the venting process. Explosion venting should be taken as a complementary measure and prior consideration is to eliminate the possibility of occurrence of explosion by adopting other safety measures.

Precaution during dispensing and decanting

7.8.13 Dispensing and decanting of flammable liquids should be carried out in such a way to avoid liquid spill and release of vapour. Workers should be aware of the potential hazards and assess the risk before dispensing and decanting. The use of enclosed transfer system is preferable and in circumstances where the enclosed system is inapplicable, appropriate containers that are designed to minimize spill and release of vapour, and to prevent fire should be used. The containers should possess the following safety features:

- metal or heavy-duty plastic construction. Plastic containers need to be compatible with the liquid that they are intended to contain;
- the containers should incorporate anti-static features so that any metal components in the transfer system would not build up electrostatic charge.
- pouring and/or filling apertures sealed with self-closing spring loaded caps; and fitted with flame arresters;
- hoses or other aids when dispensing into small openings;
- carrying handles for containers with a capacity approximately greater than 2.5 litres as a general guideline.

7.8.14 Open-topped cans and buckets are not suitable for handling or storing flammable liquids. Drums for flammable liquids should have secure closures that can withstand the expected handling conditions without leaking. Drums with large removable ends are not normally suitable for flammable liquids. Open-ended drums or receptacles with fitting lids or covers may be adequate for viscous liquids such as paints, provided the container is not easily tipped over. Drums and cans should always be opened easily and closed securely but not by punching holes in the cap or on the drum wall.

7.8.15 Transfer of flammable liquid to containers from bulk quantity should preferably be conducted in open air or designated area with adequate ventilation to reduce hazard in case of any spillage. Spill trays or other means to contain spillages should be provided where decanting or dispensing is carried out. Containers should be properly earthed.

Precaution during handling and storage

7.8.16 Incompatible chemicals such as flammable liquids, oxidising agents and combustible materials, etc. should be clearly labelled and stored separately from one another away from direct sunlight and other heating sources and preferably, in a cool, well-ventilated store constructed of fire-resisting materials.

7.8.17 Small quantities of flammable liquids should be stored in a fire-resisting cupboard or bin with clear marking outside the container. Larger quantities of flammable liquids should be stored in a separate fire-resisting room constructed in accordance with the requirements of the *Dangerous Goods Ordinance (Chapter 295)*.

7.8.18 Spillages should be avoided wherever possible by the provision and use of non-spill containers.

7.8.19 When spillages or leakages do occur they should be dealt with quickly in the way as recommended by the supplier.

8 Emergency Preparedness

8.1 Overview

8.1.1 Emergency preparedness is vital to provide quick and effective response to industrial incidents that may result in injuries, loss of life and damages of property. During the use of flammable liquids, emergency situations mainly arise from chemical spillages, and on some occasions from fire and explosion.

8.1.2 In regard to chemical safety and health in the use of flammable liquid, the employer or management should:

(a) identify and list out all possible emergency situations in the workplace;

(b) assess the effects and impacts of the emergency situations;

(c) develop and implement an emergency response plan, which may include procedures to handle minor leaks and spills, and an evacuation plan ;

(d) provide and maintain emergency equipment and other necessary resources; and

(e) ensure that staff are familiarised with the arrangements in case of emergencies by providing procedural instructions and employee training and organising drills.

8.1.3 Appropriate first aid facilities and adequate numbers of trained first-aiders as required by the *Occupational Safety and Health Regulation* should be provided.

8.1.4 The MSDS in respect of handling accidental release of flammable liquids and disposal of waste should be consulted.

8.2 Emergency response plan

8.2.1 An emergency response plan should be established for handling various foreseeable emergency situations in the workplace. It should provide the following:

(a) assignment of responsibilities;

(b) alarm systems;

(c) emergency response procedures; and

(d) schedule for emergency drills.

8.2.2 Assignment of responsibilities -- It is extremely important that all employees understand their own roles during any emergency situations as assigned in the overall safety plan. In particular, the head of the emergency response team should be charged with the following duties:

(a) assessing the emergency situation and taking necessary actions;

(b) overseeing the implementation of the emergency response plan;

(c) organising regular drills; and

(d) ensuring all emergency equipment is well maintained.

8.2.3 Emergency response procedures -- Emergency response procedures are operating instructions for employees to follow in case of emergency situations. Appropriate procedures should be established for each type of emergency situations and cover the following:

(a) reporting, declaring and clearing off emergencies;

(b) handling of emergency situations;

(c) evacuation; and

(d) deployment of employees to perform critical operations before they evacuate.

8.2.4 The emergency response plan and related information should be documented and communicated to all employees: evacuation routes, names and locations of first aid team members, locations of safety equipment, telephone numbers of key personnel and emergency services. The documents should be kept or posted in prominent places in the workplace for easy access by all staff.

8.2.5 Handling of spillages of hazardous chemicals and other emergencies should be included in the chemical safety programme.

8.3 Emergency equipment

8.3.1 Appropriate emergency equipment should include but not limited to:

(a) fire alarm;

(b) fire-fighting equipment, such as fire hoses, fire extinguishers and fire blankets;

(c) emergency lights and backup for fume extraction in case of power failure;

(d) emergency showers and eyewashes;

(e) first aid facilities, such as first aid kit; and

(f) absorbent material for cleanup of minor chemical spills.

8.3.2 All emergency equipment should be properly maintained and regularly inspected for proper performance. Expired items should be replaced. Locations of emergency equipment in the workplace should be made known to all staff.

9 Hazard Communication

9.1 Overview

9.1.1 Under *the Occupational Safety and Health Ordinance*, employers are obliged to provide such information as is necessary to ensure the safety and health of their employees at work.

9.1.2 The information is indispensable in the identification of potential hazards related to the use and handling of workplace chemicals during risk assessment and preparation of emergency response plans.

9.2 Sources of hazard information

9.2.1 Limited but essential hazard information can be found on the label of the container of the substances, whereas detailed information can be obtained from the suppliers (chemical manufacturers, importers or distributors) of the chemicals. Other information sources include chemicals catalogues, chemistry journals, chemical handbooks and online databases.

9.3 Means of hazard communication

9.3.1 Typical means of hazard communication include labels, MSDS, standard operating procedures and employee training. Employers may also find placards, notices and signboards useful for their workplaces.

Labels

9.3.2 Labelling each container containing hazardous substance is the most direct means of hazard communication. The label should include the following information:

(a) identity of the substance -- chemical name(s) or common name(s);

(b) hazard classification and symbol(s);

(c) indication of the particular risks inherent in the substance; and

(d) indication of the required safety precautions.

9.3.3 If it is not reasonably practicable to put full information on a container, the container should at least be labelled with the identity of the chemical and the hazard group(s) and symbol(s). Other required information can be given in an information sheet placed in the close vicinity. Statutory requirements for labelling of dangerous substances are prescribed in *the Factories and Industrial Undertakings (Dangerous Substances) Regulations*.

Material Safety Data Sheet (MSDS)

9.3.4 An MSDS provides important source of information about a specific chemical used in the processing work, especially when the chemical is used for the first time. The information includes safe handling and storage of the chemical, first-aid procedures, potential effects of contact and measures to take in the event of a spill or leak. ISO 11014-1 recommends a standard format for the MSDS, which contains the following sixteen sections or headings of information:

(i) product and company identification;

(ii) composition/information on ingredients;

(iii) hazards identification;

(iv) first-aid measures;

(v) fire-fighting measures;

(vi) accidental release measures;

(vii) handling and storage;

(viii) exposure controls/personal protection;

(ix) physical and chemical properties;

(x) stability and reactivity;

(xi) toxicological information;

(xii) ecological information;

(xiii) disposal considerations;

(xiv) transport information;

(xv) regulatory information; and

(xvi) other information.

Standard operating procedures (SOP)

9.3.5 Hazard information can also be communicated via SOP, which refer to a set of systematic step-by-step written procedures to be followed for completing a process or operation. The SOP should describe the tasks to be performed, data to be recorded, operating conditions to be applied with associated safety and health precautions.

9.3.6 The inclusion of appropriate hazard information in SOP relies very much on how thorough and thoughtful the risk assessment is undertaken, so as to effectively eliminate or control the risks in the entire process.

10 Information, Instruction and Training

10.1 Overview

10.1.1 After assessing the risks in the workplace and adopting appropriate preventive measures, employers should make sure that their employees fully understand the risks at work, and that the work practices can help them perform their jobs safely. To achieve this, employees should be provided with adequate safety information, instruction and training.

10.2 Information and instruction

10.2.1 Employees should be informed of the following:

(a) safety information about the flammable liquids regarding the risks that they could probably be exposed to, including the nature of hazards, exposure standards, possible routes of entry into the body and risks to health;

(b) correct labelling of flammable liquids and the significance of label details;

(c) content and significance of MSDS;

(d) measures to reduce the risks of exposure to flammable liquids, including practice of personal hygiene;

(e) safe work procedures on the use, handling, storage, transportation, cleaning up and disposal of flammable liquids;

(f) information on the safe handling of plant and equipment;

(g) emergency response procedures, including locating and using emergency equipment and facilities for first aid, decontamination and fire-fighting;

(h) procedures for reporting faults and incidents, including spills; and

(i) proper selection, use and maintenance of PPE.

10.2.2 Information and instruction should be provided to employees by:

(a) SOP, safety manual, and emergency procedures being located in prominent locations in the workplace easily accessible by employees;

(b) others such as notice, poster and video show arousing the safety awareness of everyone on handling flammable liquids and relating processes.

10.3 Employee training

10.3.1 Employees should be informed of the hazards arising from the use of flammable liquids and the need to eliminate ignition and heat sources from work area. Training on proper handling and storage of flammable liquids should be provided. The training should also include emergency procedures for dealing with incident. Periodic refresh training should be arranged. Content of the training programme should include those information and instruction aspects as detailed in paragraph 10.2.1.

10.3.2 Training helps employees to acquire the necessary skills and knowledge that enable them to follow safe working procedures, take appropriate control measures, use appropriate personal protective equipment and follow emergency procedures. Training should also enable employees to participate in decision-making relevant to workplace safety and health.

10.3.3 Employers should ensure that all persons involving in use of flammable liquids, including workers, supervisors, store staff, emergency personnel and safety and health representatives are adequately trained.

10.3.4 Training should be an ongoing process so that employees can learn about the new developments of workplace safety and continue to improve their relevant knowledge and skills. Refresher training is useful and should be provided, especially to employees returning from an extended leave of absence or when there are changes of work procedures that may render previous training obsolete.

10.3.5 The training programme should be reviewed periodically to make sure that employees are gaining the skills and knowledge they need. Employers should also ensure that their employees, after undergoing appropriate training, understand what they have been taught.

10.3.6 Employers should keep the training record, which should include at least the following:

(a) names of employees receiving training, and dates of attendance;

(b) outline of the course content; and

(c) names and credentials of trainers.

Appendix I

Fire/explosion Data of Some Flammable Liquids Used in Workplace

Chemical	[9]Flash point (℃)	Auto-ignition temperature (℃)	Flammable range (% volume)	Boiling point (℃)
Acetaldehyde	-38	185	4 – 60	20.2
Acetic Acid	39	427	5.4 – 16	118
Acetic Anhydride	49	316	2.7 – 10.3	139
Acetone	-18	465	2.2 – 13	56
n-Amyl Acetate	25	360	1.1 – 7.5	149
iso-Amyl Acetate	25	360	1 – 7.5	142
sec-Amyl acetate	32	380	1 – 7.5	121
n-Amyl Alcohol	33	300	1.2 – 10.5	138
iso-Amyl Alcohol	45	350	1.2 – 9	132
sec-n-Amyl alcohol	34	360	1.2 – 9	116
Benzaldehyde	62	190	1.4 – 13.5	179
Benzene	-11	498	1.2 – 8	80
Benzyl Chloride	67	585	1.1 – 14	179
n-Butyl Acetate	22	420	1.2 – 7.6	126
Butyl Alcohol	29	345	1.4 – 11.3	117
Carbon Disulphide	-30	90	1 – 50	46
Chlorobenzene	27	590	1.3 – 11	132
Cumene	31	420	0.9 – 6.5	152
Cyclohexane	-18	260	1.3 – 8.4	81

[9] Unless otherwise stated, flash points relate to closed cup measurements.

Chemical	[9]Flash point (℃)	Auto-ignition temperature (℃)	Flammable range (% volume)	Boiling point (℃)
Cyclohexanone	44	420	1.1 – 9.4	156
1, 1-Dichloroethane	-6	458	5.6 – 11.4	57
Diethyl Ketone	13*	452	1.6 – 3	102
1,4-Dioxan	12	180	2 – 22.5	101
Ethyl Acetate	-4	427	2.2 – 11.5	77
Ethyl Alcohol	13	363	3.3 – 19	79
Ethylbenzene	18	432	1 – 6.7	136
n-Heptane	-4	285	1.1 – 6.7	98
n-Hexane	-22	225	1.1 – 7.5	69
Isoprene	-54	220	1.5 – 8.9	34
Kerosene	37 – 65	220	0.7 – 5	150 – 300
Methyl Acetate	-13	455	3.1 – 16	57
Methyl Acrylate	-2.8	468	2.8 – 25	80.5
Methyl Alcohol	12	464	5.5 – 44	65
Methyl Ethyl Ketone (MEK)	-9	505	1.8 – 11.5	80
Methyl Isobutyl Ketone	14	460	1.4 – 7.5	117 – 118
Methyl Methacrylate	10*	421	1.7 – 12.5	100.5
Octane	13	220	1.0 – 6.5	126
n-Propanol	15	371	2.1 – 13.5	97
Isopropyl alcohol (IPA)	11.7	456	2 – 12	83
n-Propyl Acetate	14	450	2 – 8	101.6
Isopropyl acetate	2	460	1.8 – 7.8	89
Styrene	31	490	0.9 – 6.8	145

* Flash points relate to open cup measurements.

Chemical	[9]Flash point (°C)	Auto-ignition temperature (°C)	Flammable range (% volume)	Boiling point (°C)
Thinner	4.5	300	Dependent on product formulation	98 – 105
Toluene	4	480	1.1 – 7.1	111
Turpentine	30 – 46	220 – 255	0.8 – 6	149 – 180
m-Xylene	27	527	1.1 – 7.0	139
o-Xylene	32	463	0.9 – 6.7	144
p-Xylene	27	528	1.1 – 7.0	138

Source of data: International Chemical Safety Cards (ICSC), prepared in the context of cooperation between the *International Programme on Chemical Safety and the European Commission*

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8. BS EN 60079 series on Electrical apparatus for explosive gas atmospheres.

9. Safety data sheet for chemical products, ISO 11014-1:1994, International Organization for Standardization, Geneva, Switzerland.

Enquiries

If you wish to obtain further information about this guide or require advice on occupational safety and health, please contact the Occupational Safety and Health Branch of the Labour Department through:

Telephone	:	2559 2297 (auto-recording after office hours)
Fax	:	2915 1410
E-mail	:	enquiry@labour.gov.hk

Information on the services offered by the Labour Department and on major labour legislation can also be found by visiting our Home Page at http://www.labour.gov.hk.

You can also obtain information on the various services provided by the Occupational Safety and Health Council through its telephone hotline at 2739 9000.

Complaints

If you have any complaints about unsafe workplaces and practices, please call the Labour Department's occupational safety and health complaint hotline at 2542 2172.