Chemical Safety in the Workplace

Guidance Notes on Paint Spraying and Related Coating Processes

Occupational Safety and Health Branch
Labour Department

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This Guidance Notes is prepared by the
Occupational Safety and Health Branch
Labour Department

First edition February 2003

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1 Preface

People employed in paint spraying industry are potentially exposed to a variety of hazardous substances at work. These substances include organic solvents (thinner or diluent), resins, pigments and those for or emanated during surface preparation, such as degreasing agents, rust removers and dusts from grinding. Exposure to these substances, either through inhalation of vapours, aerosols or mists, or absorption through the skin, may cause injury or ill-health. As many of them are also flammable, improper handling or use may also incur fire or explosion. The risks associated with the use and handling of such substances in the paint spraying industry are generally high unless suitable safety measures are adopted.

With safety management in mind, a vehicle of ensuring chemical safety at the workplace, namely, the chemical safety programme, can be developed, implemented and maintained in conjunction with other elements of the safety management system of the organisation. The chemical safety programme comprises, in its core, such elements as hazard communication programme, risk assessment of chemicals and chemical processes and suitable preventive measures, personal protective equipment (PPE) programme and training. Details of the chemical safety programme will be elaborated in this Guidance Notes.

This Guidance Notes is intended to provide employers, management personnel, professionals, safety personnel, supervisors and employees engaged in paint spraying and related coating processes with detailed information on the development of a systematic programme for chemical safety of paint spraying and related operations. As every workplace has its own uniqueness, employers should make use of this book to develop their own chemical safety programme that best suits the conditions of their workplaces with consideration of the training and experience of their employees.

Readers' attention is also drawn to the relevant requirements under the provisions and subsidiary legislation of the *Occupational Safety and Health Ordinance (Cap 509)* and *Factories and Industrial Undertakings Ordinance (Cap 59)*, in particular the specific requirements of the *Factories and Industrial Undertakings (Spraying of Flammable Liquids) Regulations.*

2 Hazards of Paint Spraying and Related Coating Processes

2.1 Paint spraying processes

2.1.1 Paint spraying means the processes in which the paint is atomised to form mists or aerosols for deposit on surface to be coated to produce a smooth and even film.

2.1.2 Paints are mainly composed of solvents (or thinner, diluent), resins and pigments. Other additives may include hardeners, driers, thickeners, extenders, and mollusc killers. Most solvents used in paints, except water, are highly volatile organic compounds.

2.1.3 Related coating processes in this Guidance Notes are those spraying processes in which the paints are replaced by varnishes, lacquer or other finishes. Unless otherwise indicated, the term “paint spraying” in this Guidance Notes also covers the related coating processes.

2.1.4 Paint spraying is usually carried out by one of the following methods:

(a) Airless spraying – The paint liquid is dispersed by being forced through a small orifice under high pressure. The hydraulic pressure is usually produced by small piston pumps powered by compressed air. The overspray and ricochet may reach 20% as the velocity of the paint droplets drops rapidly after leaving the nozzle of the gun. The method is primarily applied to produce viscous high-solid heavy-duty coatings.

(b) Compressed air spraying – It is the commonest spraying method in which paint liquid is atomised in either internal- or external-mix nozzles by low pressure compressed air. In internal-mix nozzles, liquid and compressed air are combined in a chamber inside the nozzle, whereas in external-mix nozzles, liquid and compressed air are ejected through separate orifices to combine outside the nozzle. In this method, losses of the paint liquid are typically over 50% because of failure to reach the object or reflection from the surface.

(c) Electrostatic – liquid droplets (or solid particles) are given an electrical charge causing them to be attracted to an earthed conductive work piece. The charge is applied either to the liquid stream before its release or to atomised droplets by passing them through an ionising field. Up to 90% of the finish can be deposited on the surface.

(d) Any combination of the above processes.

2.2 Fire and explosion hazards

2.2.1 The use of flammable substances in paint spraying increases the fire and explosion hazards. In paint spraying, the paint mists spread and rapidly fill the airspace, and when they come into contact with potential sources of ignition, such as static electricity, sparks and flames, fire or explosion can occur.

2.2.2 In spraying processes, not all liquid sprayed is deposited on the work piece. Some may fall onto other surfaces such as walls, floors and clothing, and leave flammable deposits. These deposits can cause serious fire if ignited.

2.2.3 The release of flammable vapours during the drying process also creates serious fire and explosion hazards. Some finishes, particularly lacquer, may contain up to 80% of volatile solvents that evaporate on drying.

2.3 Health hazards

2.3.1 Chemicals hazardous to health enter human body via three main routes:

(a) ingestion;

(b) inhalation; and

(c) skin absorption.

2.3.2 Various health hazards are associated with paint spraying. These mainly come from the hazardous constituents of the paint such as solvents, resins and pigments. Some pigments (e.g. yellow and red chrome pigments) and primers containing lead or other heavy metals may pose adverse health effects. Besides, prior surface preparation like cleaning, degreasing, paint-removal or rust-removal may be necessary. Such treatment would entail the use of toxic solvents, corrosive chemicals, or if grinding is conducted, possible generation of harmful dusts.

2.3.3 The exposure of workers to the hazardous substances in paint spraying may cause acute or chronic health effects.

2.3.4 Long-term (chronic) health effects may include:

(a) chronic obstructive airway disease;

(b) chronic dermatitis;

(c) lung cancer;

(d) ‘painter’s syndrome’ which results from long term exposure to organic solvents and affects the brain; and

(e) damage to the reproductive system, haemopoietic system, kidneys and liver.

2.3.5 Short-term (acute) health effects may include:

(a) occupational contact dermatitis;

(b) burns to the skin or eyes;

(c) vomiting and diarrhoea;

(d) irritation to the nose, throat and lungs;

(e) headache, dizziness, nausea and fatigue; and

(f) occupational asthma.

3 Chemical Safety Programme

3.1 Introduction

3.1.1 To ensure safety and health at work of employees working with hazardous paint substances and spraying processes, a carefully planned chemical safety programme is essential. In the programme, the hazards of the materials and processes used in the workplace should be known and communicated to all affected employees. The risks arising from the hazards have to be assessed and responsive controls set up with their effectiveness monitored. The chemical safety programme also includes other elements, such as personal protective equipment (PPE), emergency planning and training for employees.

3.1.2 The above aspects of the chemical safety programme should be well organized and integrated into the safety management system of the workplace. In other words, the company should have its safety policy, responsible personnel and resources on the development, implementation and maintenance of the chemical safety programme.

3.2 Essential components

3.2.1 The major elements of a chemical safety programme on paint spraying processes should include:

(a) Hazard communication — to establish appropriate means to transmit the safety and health information about the chemicals and processes in paint spraying to employees;

(b) Risk assessment — to assess the risks in the undertaking;

(c) Safety measures — to adopt and maintain preventive and control measures;

(d) Emergency preparedness — to establish plan and procedure for emergency response;

(e) Information, instruction and training — to enable employees to do their jobs safely; and

(f) Monitoring and review of the chemical safety programme — to monitor the effectiveness of the safety measures and review and revise them at regular intervals to cope with new requirements or significant changes in the paint spraying industry.

3.2.2 Depending on individual situation of the workplace, employers may find it beneficial to include other elements into the chemical safety programme, such as the inspection programme, health assurance programme, or incorporating the chemical safety programme to other safety programmes.

4 Hazard Communication

4.1 Introduction

4.1.1 Under the provisions of *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. The hazard communication programme is intended to transfer such information about the concerned substances and processes to the employees.

4.1.2 Employers should first identify and list out all the hazardous chemicals used or liberated in the paint spraying processes in their workplace. The list should be exhaustive and be checked against the availability of material safety data sheets (MSDS) or equivalent information, from the suppliers of the chemical products or other sources. They should also ensure that such information about the chemicals, labels and standard operation procedures are effectively communicated to their employees through proper training programmes or other means as appropriate.

4.2 Sources of hazard information

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

4.2.2 The quality of hazard communication programme depends on the adequacy and accuracy of the risk assessment in the workplace. Employers should therefore endeavour to obtain sufficient and up-to-date information about the hazardous substances from the suppliers when assessing the risks of the substances.

4.3 Means of hazard communication

4.3.1 Employers should ensure that their employees know and understand the hazards of the chemicals involved in the paint spraying. Typical means of hazard communication include labels, MSDS, standard operating procedures and training. Employers may also find placards, notices and signboards useful for their workplaces.

Labels

4.3.2 Labelling the container holding the hazardous substance is the most direct means of providing hazard information. The label should include the following hazard information:

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

(b) hazard classification and hazard symbol;

(c) particular risks inherent in the substance; and

(d) required safety precautions.

4.3.3 If it is not reasonably practicable for a container holding a hazardous substance to be labeled, a notice in respect of that substance with the following information should be displayed:

(a) in English and Chinese;

(b) identifying the container or containers holding that substance;

(c) setting out clearly and indelibly the particulars as required by the *Factories and Industrial Undertakings (Dangerous Substances) Regulations*;

(d) in a conspicuous place near the hazardous substance; and

(e) with the symbol or symbols required to be shown not less than one-tenth of the area of the notice.

Detailed requirements on labelling dangerous substances are prescribed in *the Factories and Industrial Undertakings (Dangerous Substances) Regulations*.

Material safety data sheets (MSDS)

4.3.4 MSDS gives detailed hazard information. A standard format of MSDS (e.g. complying with ISO 11014-1) should contain the following information, most of which are essential for risk assessment purpose:

(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.

4.3.5 A copy of the MSDS of each hazardous substance should be kept in the workplace and readily accessible by the employees. These safety data sheets are vital in the risk assessment of the hazards associated with the use and handling of the substances.

Standard operation procedures

4.3.6 The hazard information on paint spraying should be stated clearly in the standard operation procedures to be followed by the employees.

Training (see also Section 8.3)

4.3.7 Training on how the hazard communication programme is implemented should be provided. Employees should also be trained to ensure they know how to access the available hazard information and understand the information on the labels and MSDS of the chemicals.

5 Risk Assessment

5.1 Overview

5.1.1 Risk assessment is a process to evaluate what chemicals or processes in the concern would cause harm at work in terms of its likelihood and severity, and to adopt suitable control measures to reduce the risks.

5.1.2 The Guidance Notes *Chemical Safety in the Workplace: Guidance Notes on Risk Assessment and Fundamentals of Establishing Safety Measures* issued by the Labour Department sets out some principles and systematic approaches for conducting risk assessment pertaining to chemical hazards.

5.1.3 Risk assessment should be performed by competent persons with suitable experience and training in the work activities of paint spraying. The persons should have adequate understanding of the chemicals and processes of paint spraying being assessed as well as a good knowledge of the required safe practices. They may also consult specialists for expert advice if needed.

5.2 Risk assessment

5.2.1 Employers should ensure that a risk assessment is conducted on all paint spraying works pertinent to potential exposure to the hazardous substances and processes.

5.2.2 When considering the potential health effects, exposure to airborne hazardous substances should be kept below the relevant Occupational Exposure Limits (OELs) stipulated in the *Code of Practice on Control of Air Impurities (Chemical Substances) in the Workplace* issued by the Labour Department. The values of the OELs refer to the airborne concentrations of individual chemicals below which no adverse health effects would impose on nearly all workers upon exposures by the route of inhalation. Air monitoring may be needed for this purpose.

5.2.3 As OELs do not represent 'no effect' levels at which every employee can be guaranteed protection, employers should also consider how to:

(a) ensure exposure standards are not exceeded under any circumstances;

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

(c) eliminate or further reduce exposure in the future whenever reasonably practicable.

5.2.4 A practical way to conduct risk assessment on paint spraying processes includes the following steps.

Step 1

5.2.5 The first step is to list all the substances *used* or *produced* in the paint spraying process, for example, paints, solvents, resins, powders and the surface preparation substances, such as adhesives, paint removers, rust converters, rust removers and dusts produced in grinding.

Step 2

5.2.6 The second step is to obtain and examine the information about their hazards from the label on the container and the material safety data sheet (MSDS).

5.2.7 The hazardous substances can be classified into the following three hazard categories, namely *high, medium and low*, as follows:

(a) *High hazard:* includes substances that contain or are:

(i) cancer-causing chemicals, for example, coal tar;

(ii) skin or respiratory sensitisers, for example, isocyanates in polyurethane paints;

(iii) mutagens or reproductive hazards, for example, ethoxyethyl acetate;

(iv) substances which cause severe effects after repeated or prolonged exposure, for example, styrene;

(v) metallic hazardous substances, for example, cadmium;

(vi) substances which cause acute lethal or non-lethal irreversible effects after a single exposure;

(vii) substances which cause acute irritant effects;

(viii) classified as toxic substances;

(ix) classified as corrosive substances;

(x) classified as strong supporters of combustion; or

(xi) two (or more) pack paints, for example, a polyurethane paint and its hardener.

(b) *Medium hazard:* includes any substance that contains organic solvents or is a flammable liquid not listed in *high hazard* category.

(c) *Low hazard:* includes any other substances not listed above.

Step 3

5.2.8 The third step is to inspect the workplace and procedures to find out who are being exposed to the hazards. This involves:

(a) discussion with employees about their work practices, procedures and environment;

(b) determining whether any hazardous substances are being released into the work area, with particular attention to (i) evidence of contamination; and (ii) employee's experience or symptoms of exposure;

(c) consideration of other potentially exposed persons including passers-by, cleaners and maintenance workers;

(d) consideration of the effects of any unusual or special circumstances;

(e) consideration of the combined effects of two or more hazardous substances;

(f) estimation of the extent of the exposure, such as the level, frequency, duration of the exposure and the different routes of entry; and

(g) consideration of the existing control measures to find out whether:

(i) suitable controls are already in place and effectively maintained; and

(ii) employees have been trained in the adoption of such controls.

Step 4

5.2.9 The fourth step is to rate the risks associated with hazardous substances and processes of paint spraying, i.e., how great the risks are. The ratings of risks depend on the estimated likelihood and the potential severity of the hazards. On the other hand, the severity of a hazard, or its harm, depends on various factors such as its hazard category (high, medium or low) and the quantity of the chemical to be used. Typically the ratings of risks can be summarized in the following table:

	Slightly harmful	Harmful	Extremely harmful
Highly unlikely	*Low Risk*	*Medium to Low Risk*	*Medium Risk*
Unlikely	*Medium Risk*	*Medium to High Risk*	*High Risk*
Likely	*Medium to High Risk*	*High Risk*	*High Risk*

5.2.10 Risks associated with hazardous substances and processes can be classified as high, medium or low, as exemplified below:

(a) Risk is high — The potential harm is serious and the likelihood of exposure is high. For example, the substances or processes are of high hazard; dusts, mists or fumes are visible in the air; there are widespread complaints of illness, discomfort and irritation; splashes are present; and employees have not been trained.

(b) Risk is medium — The substances or processes are of medium hazard and there are a number of employees who could be affected on a daily basis, use of the substance is strictly controlled in accordance with the MSDS and through effective engineering controls.

(c) Risk is low and is unlikely to increase:

(i) There is hardly any risk, for example, because the amounts of the substance used are too small to cause much harm, even if controls fail.

(ii) The substances or processes can cause minor effects, but its use is being strictly controlled in accordance with the MSDS or appropriate hygiene requirements, and employees have been trained.

5.2.11 After completing the above steps of assessment, decisions will then be made to:

(a) plan, establish and adopt suitable control measures as to meet the requirements stipulated in (i) local legislation and related Codes of Practice (ii) guidance books issued by the Labour Department or other reputable organisations, and (iii) the best trade practice and performance;

(b) ensure adequate control measures are properly implemented and maintained;

(c) arrange induction and training for the employees;

(d) decide if monitoring or health surveillance is required;

(e) provide suitable first-aid and emergency procedures; and

(f) review or develop standard operating procedures as appropriate.

5.2.12 If the risk is concluded to be high, the necessary control measures must be identified, adopted and implemented *before* hazardous chemicals are used or hazardous procedures are carried out. Monitoring and health surveillance should also be required to ascertain the effectiveness of such measures. A long-term control requirement should be determined.

5.2.13 If the risk is concluded to be medium, remedial safety measures should be taken in appropriate time.

5.2.14 Only when the risk is concluded to be low, can it be considered tolerable with pace of further improvement being discretionary.

5.3 Record of findings

5.3.1 Employers should keep the record of findings of the risk assessment. The record can assist tracing back the rationale of conclusions made before, and provide important information for future review of the assessment.

5.4 Review of assessment

5.4.1 The risk assessment should be reviewed regularly and whenever there is any evidence to suspect that it is no longer valid or where there has been a significant change in the relevant operation.

5.4.2 The following information should provide hints that the risk assessment might be no longer valid:

(a) results of regular performance check of equipment;

(b) results of atmospheric contaminant monitoring conducted in the workplaces;

(c) occurrence of significant incident or accident;

(d) results of health surveillance; and

(e) new information on relevant health hazards.

5.4.3 Significant changes in the paint spraying processes may include

(a) change in the hazardous substances used including both the physical forms and source of the substances;

(b) plant modification including the equipment used in the control measures;

(c) change in the method or working procedure; and

(d) change in the scale of the process.

6 Safety Measures

6.1 Overall strategy

6.1.1 In selecting the appropriate safety measures, primary consideration should be given to the following in that order of priority:

(a) elimination of hazards;

(b) substitution with less hazardous alternatives;

(c) isolation of the paint spraying process;

(d) engineering controls;

(e) administrative controls; and

(f) use of personal protective equipment (PPE).

6.1.2 Complete elimination of the hazards should be the first choice. If it is not practicable, the second measure in the hierarchy - substitution should be considered and so on. Being a last resort, the use of PPE should only be considered when higher levels of safety measures are not practicable or are inadequate.

6.1.3 In some circumstances, it is appropriate to use a combination of two or more safety measures to ensure that risks are eliminated or reduced to the lowest level.

6.1.4 Employers should strive to adopt the safety measures in the upper part of the hierarchy in the long run. For instance, elimination or substitution of a hazardous substance may not be practicable now, but may become practicable in future with the advancement in science and technology.

6.2 Elimination

6.2.1 This is the most effective safety measure. It is achieved by ceasing to use the substances or plant that have been assessed as a moderate risk or higher.

6.3 Substitution

6.3.1 Substitution means using a less hazardous substance, plant or process to do the same job.

6.3.2 Substitution measures include:

(a) replacing hazardous substances or procedures with less hazardous ones. For example, substitute flammable paint liquids by less flammable or water-based liquids, or substitute the spraying process by rollers, brushes and dipping; or

(b) replacing hazardous item of plant with the less hazardous ones.

6.4 Isolation

6.4.1 Isolation is separation of employees from hazards by physical barriers, distance or time. It can be achieved by automation or segregation.

Automation of the process

6.4.2 The paint spraying process should be totally enclosed if it is fully automated. This is the most effective form of isolation because the process is fully contained and everyone is isolated from the hazards.

Segregation of the process

6.4.3 Spraying process using flammable liquid could be carried out in a spraying room constructed of fire resistant materials. The construction materials require a fire resisting period of 1 hour for floors, walls and ceiling and 1/2 hour for windows and doors.

6.4.4 If it is not practicable to provide a segregated spraying room, the spraying process should be carried out in a spraying area set aside for the purpose, and in which spraying is done inside a totally enclosed booth or cabinet. Openings of suitable size in the booth or cabinet are provided for working or ventilation purposes.

6.4.5 The spraying room or spraying area including both booth and cabinet within such area, should be efficiently ventilated to open air by mechanical means adequate to remove from any such area, booth, or cabinet any flammable or hazardous vapour mist arising from the spraying process.

6.5 Engineering controls

6.5.1 Engineering controls involve the use of engineering principles and practice to reduce risks. Engineering controls for paint spraying include:

(a) ventilation;

(b) electrical safety; and

(c) location and design of high pressure hoses and lines.

6.5.2 Engineering controls can minimize, suppress or contain the generation of hazardous substances during the spraying operation, and limit the area of contamination in the event of spills and leaks.

Ventilation

6.5.3 Ventilation helps reduce the risks from vapours and aerosols created during paint spraying and prevent inhalation of hazardous substances. It is also an important means to reduce skin or eye contact with hazardous substances, and to control fire or explosion hazards. Besides, ventilation can draw overspray away from the operator and filter or wash the air before it is discharged.

6.5.4 The types of ventilation for paint spraying are:

(a) spray booth;

(b) local exhaust ventilation; and

(c) dilution ventilation.

Ventilation -- spray booths

6.5.5 Spray booth is the most effective form of ventilation for paint spraying. Therefore, paint spraying should always be carried out in a spray booth as far as practicable.

6.5.6 Two common types of spray booth are as follows:

(a) Side-draught booth – The inside airflow of this type is horizontal. It can be used in spraying small and medium articles and the ones that can be rotated on turntables. The degree of enclosure can vary but the greater the enclosure the easier it will be to control the spread of the paint.

(b) Down-draught booth – With downward ventilation, it is used in the spraying of large articles where all-round access is necessary and the use of a turntable is not appropriate. It allows free movement around the article and the operator is never downstream of the aerosol. Air enters the booth through either an open roof or an air replacement system, and is extracted through the floor usually to washing chambers along the sides of the booth.

6.5.7 The spray booth should be designed, constructed, installed and maintained to national or international standards. The spray booth contains an exhaust ventilation system, thus providing a continuous, uniform and evenly distributed supply of airflow throughout the paint spraying area to the exhaust outlets.

6.5.8 The spraying worker should never be positioned between the spraying gun and the exhaust air outlet when working in any type of spray booths.

6.5.9 Fresh air should be drawn from an uncontaminated source and the contaminated air exhausted to a location that will not pose a hazard or further contamination to the work area.

Ventilation -- local exhaust ventilation

6.5.10 Local exhaust ventilation systems are normally used for contaminant control during paint spraying activities, capturing overspray and solvent vapour as close to the source of release as possible. The systems should be fitted with particulate filtration device to filter overspray.

6.5.11 Local exhaust ventilation captures overspray and solvent vapour by drawing the contaminants into a capture hood. Since there are various designs of capture hoods, employers should select the most effective and suitable hoods for the work processes concerned.

6.5.12 Local exhaust ventilation should be used for indoor paint spraying when a spray booth cannot be used. Moreover, it can be combined with other control measures such as isolation for external paint spraying.

Ventilation -- dilution ventilation

6.5.13 Dilution ventilation is the dilution and displacement of contaminated air by fresh air. The fresh air is supplied to the work area by mechanical supply fans or natural air currents through doors, windows or other openings in the workplace. The contaminated air is forced out through relief openings or drawn out by an exhaust fan.

6.5.14 This method is only suitable for replenishing stale air and should be used in conjunction with other effective means of ventilation in order to remove airborne contaminants emitted from paint spraying process. Dilution ventilation can also supplement local exhaust ventilation for controlling the fire and hazardous substances risks of paint spraying vapours and aerosols when the use of a spray booth is not practical.

6.5.15 The dilution ventilation system should be designed, constructed, installed and maintained to maximise its effectiveness.

Electrical safety

6.5.16 Airless paint spraying using high fluid pressures can produce static electricity that may cause a spark. Therefore, the airless spray gun and any conductive article that is being sprayed, including containers into which the flow from the gun is directed, should be electrically earthed.

Location and design of high pressure hoses and lines

6.5.17 Employers should ensure that hoses and lines are located so that:

(a) they are protected from a leak or rupture; and

(b) in the event of a leak or rupture, flammable material is not discharged into an area where there is a source of ignition.

6.6 Administrative controls

6.6.1 Administrative controls are means of organizing work so as to make it safer by, for example, reducing exposure of employees to hazardous substances or spraying processes through administrative arrangement such as rotating shifts, scheduling breaks, etc. Details of safe work practices will be discussed in Chapter 7.

6.7 Electrical equipment

6.7.1 Electrical equipment in a paint spraying workplace includes fans, turntables, drying lamps, fixed lighting and switches, heating equipment, appliances used for cleaning and repairing operations and appliances used to mix paint formulations.

6.7.2 All electrical equipment is potentially exposed to a flammable atmosphere arising from the paint spraying process. The equipment should therefore be constructed, designed, installed and maintained to prevent the ignition of the flammable atmosphere.

6.7.3 All portable electrically powered equipment, such as electrical hand-held power tools, should require earth leakage current protection by means of a residual current device.

6.8 Personal protective equipment (PPE)

6.8.1 PPE provides a barrier to shield workers from exposure to chemical hazards. However, the use of PPE as a safety measure should be limited to situations where all the other safety measures are not practicable or where PPE is used in conjunction with other measures to increase the level of protection, e.g., for paint spraying where overspray cannot be totally eliminated, the use of PPE (respirators and protective clothing) to supplement the engineering controls is necessary.

6.8.2 The use of PPE is a passive way of protecting employees. Given thoughtful safety management in developing an effective PPE programme, this passive safety measure can be turned into a proactive one. Readers can refer to the Labour Department's *Chemical Safety in the Workplace: Guidance Notes on Personal Protective Equipment for Use and Handling of Chemicals* for details.

6.8.3 PPE should be:

(a) suitably selected and fitted for the work site and the task;

(b) clean, functional and readily available;

(c) properly stored and not left in a spray work area;

(d) correctly used and regularly maintained in accordance with the manufacturer’s instructions;

(e) on personal issue and marked with the name of the individual to whom it has been allocated; and

(f) accompanied by adequate training prior to use.

6.8.4 Employees should wear, store and maintain their PPE as trained and instructed.

6.8.5 When choosing PPE and planning work processes involving the use of PPE, consideration should also be given to the limitations of the PPE as well as to controlling any risks that could be caused by the PPE, such as heat stress, restricted vision, mobility and communication.

6.8.6 For paint spraying, the selection of respiratory protective equipment would depend on:

(a) the OELs for the different paint components;

(b) the manufacturer's safety data sheets, or MSDS for the chemical products encountered;

(c) ventilation in the areas where the paint is to be applied;

(d) the level and duration of exposure;

(e) the protection factor of the respirator; and

(f) relevant international and national standards pertinent to the use of the PPE.

6.8.7 In general, a combined particulate/organic vapour respirator is the minimum requirement for protection against the paint mists and organic solvents. If a half-face mask is used, additional eye and face protection should be considered.

6.8.8 For spraying of large articles in a spray booth, e.g., the spraying of automobiles, large amount of overspray is expected. Thus air-line respirators should be used in addition to other ventilation requirements.

6.8.9 The selection of PPE for paint spraying in respect of skin protection depends mainly on the required chemical resistance. Reference should be made to the information on the chemical resistance properties and physical characteristics of the PPE provided by the manufacturer.

6.9 Monitoring and health surveillance

6.9.1 Monitoring provides a means of ensuring that the adopted safety measures in paint spraying are adequate and effective in protecting employees from injuries or illness caused by the hazards of the chemicals and the process. In paint spraying, monitoring of the working environment involves measuring the concentration of the air contaminants at strategic locations in the work area or at the breathing zones of workers. The monitoring can be continuous or intermittent and be conducted with proper detecting equipment including sensor with alarm device, direct-reading meter, static sampler and personal sampler.

6.9.2 Based on the work activities and risk assessment results, employers should establish and implement a monitoring programme to check the effectiveness of the control of the airborne contaminants as regards their lower explosion limits or occupational exposure limits. The monitoring programme should include:

(a) monitoring parameters;

(b) frequency of monitoring;

(c) location and method of monitoring;

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

(e) follow-up actions.

6.9.3 If monitoring reveals that the acceptable limits are exceeded, the process concerned should be suspended and the causes investigated. Remedial actions should then be taken, which include reviewing the corresponding standard operating procedures and safety measures, and making appropriate amendments. Under no circumstances should employees be exposed to airborne contaminants exceeding the acceptable limits.

6.9.4 In the paint spraying work area, all accidents or dangerous occurrences involving chemicals and related processes should be investigated and taken as a 'learn-from-mistake' exercise. The investigation should be led by a line manager, safety personnel, or professional having adequate knowledge about the operation. The investigation should identify:

(a) cause(s) of the accidents or dangerous occurrences;

(b) reason(s) for any substandard performance; and

(c) underlying causes of the failures.

The investigator should also recommend measures to prevent recurrence, and the management should ensure that the recommendations are implemented.

6.9.5 For employees who are liable to be regularly exposed to hazardous chemicals at work, health surveillance can be an effective means to detect adverse health effects at an early stage and prevent further harm. In addition, the results of health surveillance can help:

(a) check the effectiveness of the safety measures;

(b) provide feedback on the accuracy of the risk assessment; and

(c) identify and protect affected employees who are at increased risk.

6.9.6 Health surveillance includes, where appropriate, biological monitoring, pre-assignment and regular medical examinations, as well as medical examinations upon resumption of work after prolonged absence for health reasons, and upon and after termination of work involving hazardous chemicals.

6.9.7 If cases or suspected cases of illness are discovered due to exposure to hazardous chemicals, the operation should be suspended and the causes investigated. Remedial actions should then be taken, which include reviewing the relevant operation procedure, control and protective measures, and making appropriate amendments.

6.10 Review of the safety measures

6.10.1 All safety measures should be reviewed to ensure that they are working effectively and to find out where they could be further improved. In the course of reviewing, opportunities to eliminate hazards should always be sought.

6.10.2 Employers should check that implementation of the measures has not created further hazards. Employees should report promptly to their employers or supervisors any defects that they notice in the safety measures, equipment, machinery, facilities and labelling.

6.10.3 Long-term plans should be made to improve safety and health at work by gradually incorporating preventive measures into management systems, and by adopting higher order controls.

7 Safe Work Practices

7.1 Overview

7.1.1 Employers should design safe work practices to minimize any hazards which their employees would encounter in paint spraying. The design should include the following considerations:

(a) mixing and pouring;

(b) storage and handling;

(c) maintenance and cleaning;

(d) general operations;

(e) emergency procedures; and

(f) amenities and personal hygiene.

7.2 Mixing and pouring

7.2.1 When undertaking paint mixing and pouring, employers should ensure:

(a) good ventilation is maintained;

(b) all containers are properly earthed;

(c) appropriate protective equipment is worn; and

(d) all spills, if any, are cleaned up immediately, especially those on personnel.

7.2.2 If the paint spraying substances are splashed on clothing or the body, the contaminated clothing should be immediately removed and the skin thoroughly cleaned with soap and water. No organic solvents should be used to clean the skin.

7.2.3 Unused or surplus liquid should always be returned to the designated container. The unnecessary or accidental mixing of different liquids should be avoided.

7.2.4 Empty containers or cans may still contain vapour or residual solvent that could explode under certain circumstances. They should therefore be decontaminated or closed and removed to a safe place before disposal.

7.3 Storage and handling of hazardous substances

7.3.1 Safe working practices for storage and handling of hazardous substances in coating industry should include:

(a) lids of containers are replaced after each use;

(b) storage area for flammable substances is well ventilated;

(c) containers are properly earthed whilst flammable solvents are being decanted in order to control static electricity;

(d) paint spraying substances in the spray area are kept to a minimum as far as practicable;

(e) flammable liquids are stored in designated containers with proper labelling;

(f) containers of flammable liquid are not left in direct sunlight or near any sources of heat or ignition;

(g) small containers should be stored in flammable storage cabinets; and

(h) warning signs are placed on storage cabinets and outside storage areas to draw attention to the hazardous nature of the stored materials.

7.3.2 Paint spraying substances should not be stored or kept other than in their original containers. This does not apply to a container in actual use in paint spraying or coating, or to a container used for mixing paint for immediate use.

7.3.3 Unnecessary plant and equipment should not be kept in spray room or spraying area.

7.4 Maintenance and cleaning

7.4.1 A maintenance programme should be in place to allow early detection of any defects of the control measures that may jeopardize the protection. When working with hazardous substances, proper housekeeping is essential.

7.4.2 All spraying equipment including hoses and lines should be regularly inspected to maintain good condition. Any defects in equipment or control measures should be rectified immediately.

7.4.3 All spraying equipment should be regularly cleaned and maintained in accordance with the manufacturer's instruction to safeguard the operator's safety and health. Cleaning process should be performed in a well-ventilated environment.

7.4.4 Any areas subject to the build-up of combustible residues including walls, floors and work surfaces should be cleaned frequently. Dusts generated by sanding or grinding should be removed using water-wetted rags, wet vacuum cleaners or other wetted cleaning equipment.

7.4.5 Workplaces should be kept clean and tidy to avoid additional hazards. Moreover, washing facilities, changing rooms and eating areas should be located away from hazards and well maintained.

7.4.6 To facilitate the removal of residues from inner surface of spray booths, the surface may be coated with coatings which can be readily peeled away together with the residues.

7.4.7 To reduce the risk of spontaneous combustion of inter-reacting residues of some materials, booths, trunking etc. should be cleaned out and dry filters replaced before changing-over to another material.

7.5 Paint spraying operations

7.5.1 During paint spraying operations, the object to be sprayed should always be located between the operator and the exhaust air outlet so that a continuous supply of uncontaminated air is flowing through the operator's breathing zone and past the object to the exhaust air outlet. Whenever possible, the spray should be directed towards the exhaust air outlet of a booth.

7.5.2 Special care should be taken to prevent spray guns from pointing towards other workers and to ensure that they are not exposed to the spray.

7.5.3 Unnecessary equipment should be kept out of the booths and proper care should be taken when handling and using pressurized equipment.

7.5.4 Where compressed air spraying is used, the correct balance of air and liquid is important to minimise the formation of very small droplets that are not deposited on the article and to minimise deflection of droplets with the "bounce back" air stream.

7.5.5 No smoking or the presence of any naked flame or other means likely to ignite vapour from a flammable liquid should be permitted inside any spraying room, spraying area including spray booth or within 6 meters of any spraying area.

7.6 Emergency procedures

7.6.1 Even with all practicable control measures in place, an emergency situation could still occur. For example, there could be a leak, spill or uncontrolled release of a hazardous substance causing a fire. Therefore, an emergency response plan should be established for handling all foreseeable emergency situations. The plan should include:

(a) assignment of responsibilities and notification procedure;

(b) alarm system;

(c) emergency response procedures; and

(d) emergency drills to test readiness.

7.6.2 For a leak or spill of hazardous substances, the emergency procedures should include:

(a) access to suitable PPE for the person(s) assigned to identify the source of the release and do repairs if it is safe to do so;

(b) exclusion of all persons not concerned with the emergency from the contaminated area; and

(c) safe disposal of the substances.

The labels and MSDS of all hazardous substances in the workplaces should be referred to when planning emergency procedures.

7.6.3 For a fire incident, the emergency procedures that should be established include:

(a) raising the alarm;

(b) if necessary, request Government Departments such as the Police and the Fire Services Department to assist;

(c) in safe condition, tackling the fire with suitable fire-fighting equipment; and

(d) evacuating the premises safely.

Fire-fighting equipment includes fire hoses, fire extinguishers, fire blankets and sprinkler systems. For tackling fires involving flammable liquids, the dry powder or foam extinguisher is recommended.

7.6.4 All emergency procedures should be documented and copies strategically located in the workplace and readily accessible by all personnel.

7.6.5 Other emergency equipment includes emergency lights and backup for fume extraction in case of power failure, shower and eyewash station, first aid facilities and absorptive material for cleanup of minor chemical spills.

7.6.6 All emergency equipment should be properly maintained and regularly checked for proper performance. Expired items should be disposed of and should be replaced whenever necessary. Locations of emergency equipment in the workplaces should be made known to all personnel.

7.7 Amenities and personal hygiene

7.7.1 Hand washing facilities and other amenities should be provided. Amenity rooms should be kept free of contaminants and noise arising from the paint spraying work.

7.7.2 If hazardous substances are splashed onto clothing or the body, the contaminated clothing should be removed immediately and the skin thoroughly cleansed with water, or water-based cleanser.

7.7.3 Most organic solvents can be absorbed through the skin into the body and therefore should not be used to clean the skin.

7.7.4 Employers should ensure that food and drink are not kept, prepared or consumed in any spray room or area, paint spraying mixing or pouring area, or any area which may become contaminated with paint spraying substances. Paint spraying workers should remove any PPE used, and wash their hands and face before drinking and eating.

8 Information, Instruction and Training

8.1 Overview

8.1.1 After assessing the risks and adopting appropriate safety measures in the workplace, employers should make sure their employees know and understand the hazards that exist at their work sites and the adopted safe work practices. To achieve this, employees should be provided with necessary safety information, instruction and training.

8.1.2 Information, instruction and training have to deal with many factors related to human behaviour. Employers should, after consulting their employees, develop an effective plan for the following:

(a) devising in-house safety rules and instructions for paint spraying;

(b) providing access to necessary safety information for employees, e.g. hazardous properties of chemicals used in the workplace and their safety precautions;

(c) devising training policy for their employees; and

(d) reinforcing information, instruction and training for the employees by

- observation, supervision and inspection of employees in doing their jobs; and
- promotional activities to increase their safety awareness.

8.2 Information and instruction

8.2.1 Information and instruction should be provided to employees so that they know and understand:

(a) the information about hazardous substances that employees could be exposed to, such as nature of the hazards, risks to health, exposure standards and routes of entry into the body, etc.;

(b) the nature of the hazards from the plant and systems of work, and the availability and use of such information;

(c) the correct labelling of hazardous substances;

(d) the availability of MSDS for the substances;

(e) the measures used to control exposure to hazardous substances and risks from plant;

(f) the emergency procedures;

(g) first aid and incident reporting procedures; and

(h) keeping and maintenance of the PPE by employees.

8.2.2 Information and instruction can be provided to the employees by the following means:

(a) issuance of safety manual, working procedures and emergency procedures is the primary means, and the concerned documents should be placed in prominent locations in the workplaces easily accessible by the employees; and

(b) notices, posters and video shows are used as appropriate in arousing worker's safety awareness of the handling of hazardous substances and paint spraying processes.

8.3 Training for employees

8.3.1 Training helps employees acquire the necessary skills and knowledge to apply safety measures, use protective equipment and follow emergency procedures. Training should also enable employees to participate in decision making relevant to workplace safety and health.

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8.3.2 Employers should ensure that all persons directly or indirectly engaged in paint spraying processes are adequately trained prior to commencing their job.

8.3.3 Training should include:

(a) the reasons for, and the nature of, control measures which are in use or are planned;

(b) the work practices and procedures to be followed in the use, handling, storage, transportation, cleaning up and disposal of any hazardous substances;

(c) safe work practices in operating the paint spraying plant and carrying out paint spraying processes;

(d) reporting of faults and incidents;

(e) the selection, use and maintenance of PPE; and

(f) the use of emergency equipment.

8.3.4 Training should be an ongoing process so that employees learn about new development, and their knowledge and skills continue to improve. Refresher training should be provided, especially to the employees who return from extended leave or returning to a work process after an extended period of absence and changes in the workplace rendering previous training obsolete.

8.3.5 Training should be reviewed to make sure that employees are gaining up-to-date skills and knowledge they need. Employers should also ensure that their employees, after undergoing the training, understand what they have been taught.

8.3.6 The employers should keep the training record which should include:

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

(b) an outline of the course contents; and

(c) the names and credentials of persons providing the training.

9 Special Topics

9.1 Organic solvents

9.1.1 With the exception of water, all solvents (thinner and diluent) used in paint spraying are volatile organic compounds. The most common ones include toluene, xylene, methyl ethyl ketone, acetone, benzene, ethylene glycol derivatives, turpentine and white spirit.

9.1.2 Organic solvents may enter the body by inhalation in form of solvent vapour or spray mist. They may also enter the body by skin absorption through direct contact with the worker's hands and arms.

9.1.3 Short-term exposure to organic solvents can cause a wide range of symptoms, such as irritation to eyes, throat, lungs and stomach. Headache, nausea, a drunken feeling, and altered sensation may be experienced. If exposure is extremely severe, unconsciousness and even death may occur. Long-term exposure may affect the blood forming function of the body, liver, kidneys and nervous system. Repeated skin contact may also lead to defatting of the skin and chronic dermatitis.

9.1.4 Appropriate PPE such as gloves, boots, sleeves and aprons should be provided for the employees who handle the solvents. The MSDS of each solvent used in the workplace should also be obtained from the suppliers to get detailed safety and health information including the selection of suitable PPE.

9.1.5 When engineering controls are not immediately feasible, appropriate respiratory protection may be temporarily adopted. The use of half-face or full-face respirators with suitable adsorbing medium for organic vapours should be considered.

9.1.6 Organic solvents should never be used for hand cleaning. Skin areas coming into contact with the solvents should be washed immediately with soap and water.

9.2 Lead

9.2.1 Spraying with lead-based paint may result in significant exposure to lead, which can enter into the body through inhalation, ingestion and skin absorption.

9.2.2 Workers who employ conventional compressed-air spraying equipment may be exposed to the overspray and rebound of the lead-based paint spray, which will increase the inhalation hazards.

9.2.3 The acute health effects of lead may include:

(a) anaemia;

(b) skin irritation;

(c) gastrointestinal upset;

(d) eye irritation;

(e) irritation to mucous membranes and upper respiratory tract; and

(f) nervous system disturbances.

9.2.4 The chronic health effects of lead may include:

(a) reproductive disorders;

(b) anaemia; and

(c) damage to the nervous system and kidneys.

9.2.5 The Occupational Exposure Limit (Time-Weighted Average) of lead and inorganic lead compounds is 0.05 mg/m^3 (as lead). Employers should adopt necessary measures to ensure that the amount of lead in air in the breathing zone of any worker is below this level.

9.2.6 The following measures will reduce or eliminate workers' exposure to lead during paint spraying and related coating processes:

(a) applying lead-free paints;

(b) replacing lead chromate with zinc;

(c) applying lead-based paint by brush or roller coating methods rather than by spraying methods; and

(d) using local exhaust ventilation with proper filtration.

9.2.7 Appropriate PPE should be provided to the workers engaged in the paint spraying and related coating processes.

9.2.8 Employees should be given adequate information and training about the hazards of lead poisoning and the preventive means. They should use the equipment and facilities provided and co-operate with their employers in restricting the spread of lead contamination.

9.3 Two-part (or two-pack) paints

9.3.1 Two-part (or two-pack) paints, which include various types of polyurethane, epoxy and acrylic systems, involves a base (part A) and a hardener or catalyst (part B). For example, polyurethane, is complex cellular polymers, formed by the reaction of a diisocyanate with a polyol.

9.3.2 Two-pack paints or lacquers containing diisocyanate are often used in the form of sprays to achieve hard, durable, easy-to-clean finishes, in which diisocyanate is added to the liquid resins and pigments to produce a polyurethane film. Vapours and spray mists containing isocyanates are highly irritant to the eyes and respiratory tract, and can cause occupational asthma.

9.3.3 Full protective clothing, such as disposable coveralls, should be worn. Nitrile gloves should also be worn to prevent skin absorption. Any remaining exposed skin should be coated with barrier cream, as these paints stick very well. For applying two-pack polyurethane, a full-face air-line respirator is required. For epoxy or acrylics, if an air-line respirator is not available, a full-face respirator fitted with organic vapour cartridges with a pre-filter, should be used but for short periods only.

9.3.4 Two-pack paints systems should only be applied by trained and authorized persons.

9.3.5 Two-pack paints spraying should be carried out within a spray booth. Otherwise, it should only be applied by brush or roller.

9.4 Spraying in confined spaces

9.4.1 The spraying method is often used to apply coatings in confined spaces, e.g., the inside of storage tanks or enclosed rooms and spaces. In an unventilated enclosure, a harmful vapour concentration may be built up within a few seconds from the start of spraying, and a flammable atmosphere within a few minutes.

9.4.2 Spraying in a confined space in an industrial undertaking is regulated by the *Factories and Industrial Undertakings (Confined Spaces) Regulation*. The *Code of Practice: Safety and Health at Work in Confined Spaces* offers practical guidance and technical information for proprietors, contractors and other persons of any industrial undertakings to ensure the safety and health of all persons who would enter or work in confined spaces.

9.4.3 It is essential that employees engaged in paint spraying in confined spaces should receive specific safety training and recognise the hazards involved. A formal written entry permit or permit-to-work should be required for entry into confined spaces.

9.4.4 Mechanical exhaust ventilation should be provided to ensure that the concentration of hazardous materials in all parts of the confined space is at a safe level. As vapours from spraying are likely to accumulate at floor level, extraction at this level is essential. The discharge point should be situated in a safe place away from any building, work area or source of ignition. When there are changes in spraying conditions such as when the number of sprayers is increased or a more volatile coating substance is used, reassessment of the effectiveness of the ventilation may be necessary.

9.4.5 Continuous atmospheric monitoring is essential to detect any increase in the flammable vapour level above the specified limit throughout the spraying process. The instrument normally used is a gas detector or explosimeter preferably with alarm function.

9.4.6 Sources of ignition inside a confined space should be strictly prohibited and any lighting used should be protected. Any unprotected equipment used, such as fan motors, compressor, switches and alarms, should be located in a safe area outside the confined space where they will not be exposed to flammable vapour.

9.4.7 It is important to maintain the ventilation within the confined space until the coating is dry and there is no further risk of a flammable atmosphere. Any accumulation of flammable vapours inside the confined space could be ignited by hot work performed outside.

9.5 Ignition dangers in electrostatic spraying

9.5.1 In an electrostatic spraying system, atomized droplets from the spray gun are electrically attracted towards a component. This has the advantage of reducing the amount of ricochet and overspray.

9.5.2 The ignition of solvent vapour by an electrical discharge constitutes a specific hazard to electrostatic spraying. Generally speaking, ignition may be caused either by a direct electrical discharge from the gun to the component, or by discharge of an unearthed object that has been charged by induction or contact. There is hence a risk of electric spark ignition both at the spray gun nozzle and at the wetted surface of the component.

9.5.3 In view of the ignition hazard, the following precautions should be taken:

(a) The spray equipment should only be operated by trained personnel.

(b) Electrostatic spraying should be carried out in a spraying room or spraying area exclusively reserved for such work. All possible sources of ignition of both the solvent vapours and the solid residues should be removed from the vicinity of the work.

(c) Booths and similar enclosures should be fire-resistant and have adequate ventilation.

(d) Only the spray gun and the cables connected to it should be in the spraying room or spraying area. All the other associated electrical apparatus, for example, power pack, motor-driven compressor and mains connections, should be located outside the room or area, or be enclosed separately in a fire-resistant structure, unless the equipment is suitably certified for use in a hazard zone.

(e) All equipment and metal surfaces within a radius of 3 metres from the charged head of the spray gun should be earthed to avoid the build-up of static charges that could cause ignition.

(f) Any persons in the spraying room or spraying area who could attain a charge in the course of their work should not wear metal articles and care should also be taken in the choice of clothing to avoid the generation and accumulation of static electricity.

(g) Workers should wear antistatic and conductive footwear to prevent the accumulation of electrostatic charge in the body.

(h) No drums of paint or cleaning solvent should be allowed in the spraying room or spraying area while spraying is in progress.

(i) The cleaning solvent for spray gun should have a flash point not less that $23^{o}C$ and preferably above the ambient temperature. Only properly earthed metallic solvent containers should be used and the gun should not be cleaned with the high voltage supply being switched on.

Appendix I
References

1. Code of Practice on Safety Management, 2002
2. Code of Practice on Control of Air Impurities (Chemical Substances) in the Workplace, 2002
3. Chemical Safety in the Workplace: Guidance Notes on Risk Assessment and Fundamentals of Establishing Safety Measures, 2001
4. Chemical Safety in the Workplace: Guidance Notes on Personal Protective Equipment for Use and Handling of Chemicals, 2002
5. ISO 11014-1 "Safety Data Sheet for Chemical Products", 1994, Geneva, Switzerland
6. Five Steps to Risk Assessment, 1999, HSE, UK
7. The Spraying of Flammable Liquids, 1998, HSG178, HSE, UK
8. Spraying of Highly Flammable Liquids, 1987, Guidance Note EH9, HSE, UK
9. National Guidance Material for Paint Spraying, 1999, NOHSC, Australia
10. Code of Practice: Spray Painting, 2000, WorkSafe Western Australia Commission, Australia

Useful Information

If you wish to enquire about this Guidance Notes 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.info.gov.hk/labour.

Occupational Safety and Health Branch
Labour Department

3/2003-1-B123