GUIDELINES ON SOLVENT MANAGEMENT IN DRY-CLEANING

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PUBLISHED IN JANUARY 2000

Nomenclature

cfm	cubic feet per minute
fpm	feet per minute
mg/m^3	milligrammes of the substance per cubic metre of contaminated iair
m/s	metres per second
PCE	perchloroethylene
PEL	Permissible Exposure Level. This is the maximum time weighted average concentration of a toxic substance to which persons may be exposed.
PEL (Long Term)	Permissible exposure level over an 8-hour working day and a 40-hour work week.
PEL (Short Term)	Permissible exposure level over a 15-minute period during any working day.
ppm	Parts of the substance per million parts of contaminated air by volume

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Introduction

Dry-cleaning refers to the process of cleaning garments using chemical solvents. The most commonly used solvent for dry-cleaning is perchloroethylene which is also known as tetrachloroethylene, PERC or PCE. PCE is a toxic substance that can cause adverse health effects including damage to the liver and kidneys.

The purpose of these guidelines is to provide recommendations on the work practices and control strategies for the use of perchloroethylene (PCE) as solvent in dry-cleaning. The guidelines contain information on the nature and hazards involved in PCE usage, the legal requirements of using PCE and the various alternative technologies available to substitute dry-cleaning using PCE.

1. Perchloroethylene

1.1. Physical and chemical properties

Color and form	: colorless, clear liquid
Odour	: ethereal (chloroform-like)
Boiling point	: 121 °C
Molecular weight	: 165.8
Solubility in water	: insoluble
Vapour pressure	: 14 mmHg
Relative density	: 1.62 (water=1)
Relative vapour density	: 5.7 (air=1)
Flammability	: Noncombustible liquid

Stability and reactivity

- Upon contact with hot surfaces or flames, PCE decomposes into toxic and corrosive fumes such as hydrogen chloride, phosgene, and chlorine.
- Upon contact with moisture, PCE decomposes slowly to form trichloroacetic acid and hydrochloric acid.
- PCE is reactive. It reacts with metals such as aluminium, lithium, barium and beryllium.

1.2. Health hazards

- Routes of Exposure
  - Inhalation: through breathing in the PCE vapours
  - Skin absorption: through direct contact of liquid PCE on the skin and through contact with the PCE vapours
  - Ingestion: through the mouth (oral), usually unintentional.
  - Eye contact: following a splash

- Immediate effects of massive exposure
  - Irritation of eyes, nose and throat
  - Dizziness, headache, nausea, incoordination, coma and death
- Long-term effects of exposure exceeding the permissible levels

- Headache, dizziness, fatigue, incoordination, impaired memory
- Dry and scaly skin, redness and fissures from repeated skin contact; skin burns
- Liver and kidney damage

• Potential human carcinogen
- Increased risk of urinary, pancreatic and esophageal cancer

2. Legal requirements

2.1. The Factories Act

In Singapore, any premises in which dry-cleaning is carried out is defined as a *factory* under the Factories Act. The occupier of the premises must comply with the relevant provisions of the Act and its subsidiary legislation. The more important provisions relating to the protection of employees against toxic substances are as follows:

Section 59(1)
Where, in connection with any process or work carried on in any factory, there is produced or given off any toxic, irritating or offensive dust, fume or other contaminants, all practicable measures shall be taken to protect persons employed against inhalation of the dust, fume or other contaminants and to prevent their accumulation in the workforce.

Section 59(2)
The measures to be taken under subsection (1) shall include one or more of the following where appropriate:
(a) carrying out the process or work in isolated areas where workers not connected with the process or work are prohibited;
(b) carrying out the process or work in closed vessels or systems to prevent persons employed from coming into contact with such contaminants;
(c) providing adequate ventilation to dilute the contaminants;
(d) providing local exhaust ventilation to remove the contaminants at their sources of emission

Section 59(6)
The atmosphere of any workplace in which dangerous or obnoxious substances are manufactured, handled, used or given off shall be tested by a competent person at sufficient intervals to ensure that they are not present in quantities liable to injure the health of persons employed.

Section 60(1)
Toxic substances in a factory shall be placed under the control of a competent person who has adequate knowledge of the properties of the toxic substances and their dangers.

Section 60(2)
Warning notices in languages understood by the persons employed in the factory specifying the nature of the danger of the toxic substances shall be placed at all entrances to any workroom and at appropriate locations where the toxic substances are used or present.

Section 60A (1)
Where any toxic, corrosive or inflammable substance is used, handled or stored in a factory, the occupier shall
(a) obtain a material safety data sheet of the substance;
(b) assess the information in the material safety data sheet and take precautionary measures to ensure the safe use of the substance; and
(c) make available the material safety data sheet to all persons employed in the factory who are liable to be exposed to the substance.

Section 61 (1)
Where in any room any toxic or otherwise injurious substance is so used as to give rise to any dust or fume, a person shall not be permitted to partake of food or drinks in that room or to remain in that room during the intervals allowed to him for meals or rest and no food or drinks shall be kept in or conveyed through that room at any time.

Section 62(1)
Where, in any factory, workers are employed in any process involving exposure to … any toxic or offensive substance, suitable protective clothing and appliances, including where necessary suitable gloves, footwear, goggles, ... and respirators, shall be provided and maintained for the use of such workers.

Section 65(1)
The occupier of a factory shall wherever possible substitute harmless or less harmful substances, processes or techniques for harmful substances, processes or techniques.

Section 65(2)
Hazardous processes shall be carried out in separate rooms, buildings, or premises occupied by a minimum number of workers.

Section 65(3)
Effective means shall be taken to prevent the liberation of harmful substances and for the protection of workers against inhalation, skin absorption or ingestion of the harmful substances.

Section 65(5)
Warning notices shall be placed where there are special risks to which workers are exposed and the workers shall be warned of the precautions to be taken to avoid such risks.

Section 65(7)
No person shall enter or remain in, and no other person shall require, permit or direct any person to enter or remain in, any room, building or premises in which any hazardous process is carried out unless he or that person is employed in the process.

Section 67(3)
Written notice of every case of any of the diseases specified in the Sixth Schedule occurring in a factory shall be sent by the occupier in the form set out in the Eleventh Schedule and accompanied by the prescribed particulars to the Chief Inspector; and section 51 with respect to the notification of dangerous occurrences shall apply to any such case in like manner as to any such dangerous occurrence as is mentioned in those provisions.

2.2. The Factories (Permissible Exposure Levels of Toxic Substances) Order

The permissible exposure levels of PCE are:

PEL (Long term): 25 ppm (170 mg/m^3)
PEL (Short term): 100 ppm (685 mg/m^3)

Employees are not allowed to be exposed to PCE vapor above these limits.

2.3. The Factories (Medical Examinations) Regulations

All persons employed in factories in any occupation involving the use or handling of or exposure to PCE shall be subject to the following requirements:

- Medical examinations are to be conducted by a registered designated factory doctor and will determine fitness for work with PCE
- The pre-employment medical examination shall be conducted not later than 3 months after commencement of employment.
- The pre-employment medical examination shall consist of the following investigations:
  - (i) Clinical examination for signs and symptoms of PCE poisoning
  - (ii) Urine trichloroacetic acid estimation (using mid-week end-of-shift urine sample)
  - (iii) Liver function tests including serum bilirubin, alkaline phosphatase, gamma glutamyl transpeptidase, alanine and aspartate aminotransferase estimations (Workers should abstain from alcohol for one week before the test).
- The frequency of subsequent examinations is once in every twelve months or at intervals specified by the Chief Inspector of Factories. These medical examinations shall consist of the following investigations:
  - (i) Clinical examination for signs and symptoms of PCE poisoning
  - (ii) Urine trichloroacetic acid estimation (using mid-week end-of-shift urine sample). The results of the medical examination shall be kept for at least 5 years.
- The employer shall bear the expenses incurred for the medical examinations required under these Regulations.
- The exposed workers shall submit themselves for the examination and shall be granted paid leave of absence for the purpose.
- The employer shall maintain a register of all persons who are employed in the hazardous occupation.

- If the worker's health is likely to be or has been affected injuriously by his employment, the designated factory doctor shall certify the worker to be unfit for further exposure, either for a period or permanently.

3. Dry-cleaning Process

Garments are first inspected and tagged for identification. They are then sorted according to weight, color and finish. Garments with visible stains are usually treated at the spotting section. Spotting involves the use of selective chemicals (eg. trichloroethylene and steam to remove specific stains).

Garments are then manually loaded into the machine where three main stages occur, namely washing/cleaning, extracting, and drying.

During the washing cycle, garments and PCE solvent are agitated for a period of time to allow the solvent to remove dirt/soil.

The clothes are then spun at a high speed during the extraction stage. Extraction reduces solvent losses and eliminates dripping of solvent.

After solvent extraction, garments are then tumbled dry using hot air. This drying process ensures that any remaining solvent is removed. Once the drying cycle is complete, garments are unloaded from the machine and pressed to remove wrinkles.

The schematic diagram of dry-cleaning process is shown in Appendix 1.

4. Work Practices

4.1. PCE storage

- PCE storage tanks should be stored in a dry and cool place.
- The storage tank should be made of galvanised mild steel or the appropriate grade of stainless steel. Plain mild steel tanks are not suitable. For small quantities, pigmented high-density polyethylene containers can be used to store PCE.
- Do not store PCE storage tanks near a heat source.
- PCE storage tanks should remain sealed whenever they are not used in order to prevent evaporation and spillage.
- PCE storage tanks should be checked for any corrosion, mechanical damage or leakage.
- PCE storage tanks should be properly labeled identifying the contents, amount, hazards involved and precautionary measures.
- A spillage tray should be provided underneath the PCE storage tanks so as to minimise workers' exposure in the event of a leakage or spillage.

- Adequate ventilation should be present if the PCE storage tanks are to be located indoors to ensure exposure is limited in the event of a leakage or spillage.

4.2. Machine operation

- The guidelines as set out in the manufacturer's manual book should be strictly followed during start-up, operation and shut-down of the dry-cleaning machine.
- No worker shall be left alone during the operation of the dry-cleaning machine. This is to minimise the health and safety risk involved in the event of excessive exposure to PCE due to spillage or leakage.
- Before starting the operation of the machine, ensure that the water-cooling system or refrigeration system and the ventilation are switched on.
- Check if the water-cooling or refrigeration system is working properly.
- During operation of the dry-cleaning machine, all outlets/doors (eg. loading/unloading door, button strainer, lint filter, and sludge port) should be properly closed or sealed.
- Check if process parameters (eg. steam pressure, air temperatures, etc.) are set at the required values.
- Check if solvent supply in the tank is sufficient.
- Button strainer and lint filter should be properly cleaned before operating the machine.
- The drying cycle should not be shortened for the purpose of unloading the items at an earlier time.

4.3. Loading/Unloading

- A de-odorisation cycle should be completed prior to the loading of garments for dry-cleaning. This is to ensure that any accumulation of the PCE vapour inside the drum will be condensed.
- Take the load to the machine before opening the loading/unloading door.
- Avoid overloading the machine. Overloading results in inefficient drying and as such leaves excess PCE on garments and reduces PCE recovered.
- Avoid unnecessary underloading of the machine as this will result in less efficient use of the solvent.
- Underload the machine only when heavy items such as quilts, carpets, and blankets are cleaned. This will ensure efficient cleaning and drying and effective PCE recovery.
- Items should not be unloaded from the dry-cleaning machine before the whole cleaning cycle is completed.
- Do not attempt to interrupt the machine by putting additional items into the machine during the dry-cleaning process.
- Keep one’s head out of the machine during the loading and unloading. A long stick or handle should be used to retrieve garments at the back of the drum.
- An interlock system should be fitted to the loading/unloading door to prevent it from opening before a cleaning cycle is completed or throughout a dry-cleaning process.

- Once the cleaning cycle is completed, workers are to wait as long as possible before opening the loading/unloading door to unload the garments. This is to ensure minimal release of PCE.

4.4. Solvent charging/transfer

- The charging process should only be done when the dry-cleaning machine is not operating.
- A machine built-in pump should be used for charging fresh PCE into the machine.
- The number of charging should be minimised where possible in order to reduce exposure to PCE.
- Avoid manual pouring of PCE from the storage tank into the machine.
- PCE should be added into the dry-cleaning machine directly from the storage tank. The use of an intermediary container should be avoided where possible in order to limit the exposure to PCE.
- Avoid using an open container or bucket during the charging process since an unsealed container or bucket can lead to spillage and exposure.
- Charging process must not be left unattended.
- During the charging process, the level of PCE in the tank should be monitored to avoid the tank from overfilling.

4.5. Spillage handling procedures

- Collect PCE in the spillage tray and pump the PCE back into the machine.
- In the absence of any spillage tray, PCE should be recovered by using a suitable absorbent cloth. This cloth should be laundered in the dry-cleaning machine so as to recover the PCE.

4.6. First-aid measures

- In the event where a person inhales excessive amount of PCE vapour, transfer the person to a place with fresh air immediately. If breathing has stopped, perform mouth-to-mouth resuscitation. Keep the affected person warm and at rest. Get medical attention as soon as possible.
- If PCE contacts the skin, cwash the contaminated skin with soap and water immediately. Get medical attention promptly.
- If PCE contacts the eyes, wash the eyes with a large amount of water and lift the lower and upper eyelids occasionally. Get medical attention immediately.
- A Material Safety Data Sheet for PCE can be referred to for further details on emergency procedures.

4.7. Personal protective appliances

- Personal protective appliances which include impervious gloves, chemical

splash goggles, footwear, and a respirator with organic vapour cartridges should be worn during the following procedures: cleaning of lint trap and button strainer, sludge disposal, charging of PCE, spillage handling, loading and unloading of garments, spotting and maintenance of machine.
- Workers should undergo a respirator fit test to ensure the individual fit of the organic-vapour cartridge respirators.
- During the fit test, a positive and/or negative-pressure fit check should be conducted to determine if the respirator is properly sealed to the face of the user. This check should also be performed by the user each time the respirator is worn.
- Personal protective appliances should be properly maintained. Maintenance of respirators shall include regular cleaning, inspection for defects and replacement of cartridges.

4.8. Consumption of food and drink

- No food or drink shall be consumed in the dry-cleaning area.
- Hands should be washed thoroughly with soap and water before eating, drinking or smoking.

5. Spotting

Chemical agents used for spotting (before/after the dry-cleaning process) may contain PCE or other toxic solvents. The following procedures should be followed.

5.1. Process isolation

- The spotting process should be isolated to prevent exposures of workers who are not involved in the process.

5.2. Work practices

- Workers who are required to conduct spotting should be trained in the safe use of the spotting chemicals. They should know how to selectively apply suitable spotting chemicals and the proper technique of removing stain.
- The use of PCE in spotting should be eliminated whenever possible or otherwise used in limited quantity.

6. Maintenance of dry-cleaning machine

To ensure the effective and efficient operation of the dry-cleaning machine, a planned maintenance program should be implemented. It serves the following purposes:
- to detect any PCE leakage and release associated with wear and tear of machine components or parts

- to minimise operating cost due to a reduced consumption of PCE arising from leakage and energy consumption
- to achieve optimum operation of the machine.

The maintenance program should include the following:

- Check for any leakage arising from openings (loading/unloading door gasket, button trap, still doors), seals, piping, flanges, joints, valves, etc. Leak can be detected by smell (PCE odour), visual observation of pools or droplets in the vicinity of the machine, or using a gas detector.
- Monitoring of PCE usage to indicate any leak.
- Cleaning of the button strainer and lint trap.
- Regular maintenance of solvent pump, filter, recovery condenser, still, carbon adsorption unit, and other major parts of the dry-cleaning machine.

In addition, the maintenance program should include frequency of maintenance. A competent person should be employed to carry out the maintenance. Table 1 gives the common maintenance activities and their recommended frequencies. Manufacturer's maintenance recommendations should be consulted if available.

Table1. Recommended Maintenance Schedule for Dry-cleaning Machines[i]

Component	***Maintenance Activities***	***Frequency***
Machine cylinder	Check for leaks at door seals and gaskets	Weekly
	Check for leaks at exhaust damper (vented)	Monthly
Heating/condensing coils	Check for lint build-up	Monthly
	Clean coils	Annually
Button trap	Clean strainer	Daily
	Check for lid leaks	Weekly
Lint trap	Clean lint bag	Daily
	Launder lint bag	Weekly
	Check ductwork for leaks	Monthly
	Check lint build-up on temperature probe	Monthly
Filters	Clean and change	As required
Distillation unit	Rake out still	Daily/weekly
	Check for leaks at seals/gaskets	Weekly
Muck cooker	Clean steam and condensation coils	Semi-annually
Water separator	Dispose of contaminated water	Daily
	Clean separator tank	Weekly
	Check vent	Monthly
Refrigerated condenser	Measure exhaust temperature	Weekly
	Check for leaks at seals, gaskets and valves	Weekly
	Check coils for lint build-up	Monthly
	Clean refrigerant coils	Annually
Carbon adsorber	Desorb	Daily
	Measure PCE in exhaust stream	Weekly
	Check for leaks at gaskets and ducts	Monthly

During maintenance, a localised release of PCE vapour may arise. Adequate ventilation must therefore be provided. Personal protective appliances which include impervious gloves, chemical splash goggles, footwear, and a respirator with organic vapour cartridges should be worn during maintenance.

7. PCE-in-air monitoring

PCE concentration in air shall be tested by a competent person at sufficient intervals to ensure that it is not present in significant quantity hazardous to the workers. The frequency of air monitoring depends on the exposure level. The following serves as a guide:

Exposure level	***Frequency of monitoring***
10-50% of PEL	Once a year
> 50-100% of PEL	Once every 6 months
> PEL	Once every 3 months until the exposure is reduced to below the PEL by appropriate control measures.

The results of PCE monitoring should be kept for at least 5 years.

8. Control Strategies

8.1. Substitution

There are a number of alternative technologies that could substitute dry-cleaning using PCE. These are:

- Petroleum-based dry-cleaning
- Wet-cleaning (Aqua cleaning)
- Liquid carbon dioxide cleaning

A brief description of each technology is given in Table 2.

Table 2. Comparison of various alternative technologies to dry-cleaning using PCE

Substitution	***Advantage***	***Disadvantage***
Petroleum-based dry-cleaning	Generally considered less - toxic than PCE Exposures due to inhalation are generally lower than PCE - Generally less costly than PCE Effective in cleaning all	Flammable - Longer drying process - than using PCE Less effective at removing oil and grease stains than using PCE - Provide a more conducive environment for bacterial

	types of garments - - 	growth which leads to unpleasant odors -
Wet-cleaning (Aqua cleaning)	Fewer health and safety - hazards Elimination of air pollutants Some soils are easier to - remove using water (eg. drink stains, salts, sugars) Comparable cost to dry-cleaning using PCE - Reduced concerns for compliance with health, safety and environment regulations More pleasant smell than - solvent - -	Not a complete - replacement for cleaning with PCE Potential risk for fabric deterioration, loss of shape, dye transfer or color - change Certain garments are more prone to fibre shrinkage or bleeding of dyes Generate contaminated wastewater - Some soils are more difficult to remove (eg. oils, greases) - -
Liquid carbon dioxide cleaning	Relatively high PEL of - 5,000 ppm Shorter expected cycle time than conventional dry-cleaning - Eliminate environmental concerns such as soil contamination and air pollution Potentially more effective - in cleaning leather and fur than conventional dry-cleaning	Potential safety hazards - associated with high pressure process. New technology, commercial viability unknown - Possible difficulty to remove protein stains More costly than dry-cleaning machines using PCE - -

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8.2. Process isolation

- Workers who are not directly involved in dry-cleaning should be isolated from the process by either time or space.
- Since PCE release by and large originates at the dry-cleaning machines, isolating the workers from the machines will reduce exposure. A physical barrier or wall can be built to separate the dry-cleaning machines from other machines or equipment or work areas (garment collection area, pressing section, wet-cleaning area).
- Maintenance work and transfer of fresh solvent should as far as possible, be carried out after working hours to minimise the number of persons exposed to PCE.

8.3. Ventilation

Ventilation is commonly used to control PCE exposure in dry-cleaning. There are 3 types of ventilation that can be used to control the exposure of PCE in dry-cleaning:

- *Built-in (integral) exhaust ventilation.*
  This is usually part of a vented dry-cleaning machine. This ventilation system within the dry-cleaning machine prevents the release of PCE vapour into the environment through the loading/unloading door by providing a draft of clean air that passes over the load inside the machine cylinder/drum prior to removal of the load. Integral exhaust ventilation system is usually activated by a door interlocking switch.

  Dry-cleaning machines that use built-in exhaust ventilation should have an inward air velocity of 0.5 m/s (100 fpm) through the loading/unloading door (This is also known as the door's face velocity). In addition, the blower should be ducted to a point 1.5 m (5 ft) above the roof to ensure that the exhaust will not re-enter the work environment.[ii,iii]

- *Local exhaust ventilation*
  This type of ventilation can be used for non-vented dry-cleaning machines. An external ventilation hood is usually installed outside the dry-cleaning machine door.

  The airflow rate through this hood should not be less than 0.5 m^3/s times the door opening area in square meter (100 cfm times the door opening area in square feet).[iv] The exhaust hood should be isolated from any cross drafts caused by general ventilation, fans, or areas of high human traffic.

- *General ventilation*
  General ventilation serves to dilute the concentration of PCE in the air prior to reaching the worker's breathing zone. This ventilation system supplies fresh air

into the working environment and exhausts contaminated air from the working area. A complete air change for every 5 minutes is recommended [v,vi] with a minimum supply of 0.85 m^3/min (30 cfm) of outside air per person [vii].

Diagrams of different types of ventilation are shown in Appendix 2.

8.4. Dry-cleaning machine technology

There are two systems that are available to recover PCE vapor:

1. Refrigeration system
   PCE vapor can be recovered using refrigerated condenser where a refrigerant will cool down the air containing PCE below the dew point of the PCE vapor.
2. Carbon adsorption system
   In this system, air contaminated with PCE passes through an activated carbon bed where PCE vapours are adsorbed.

The latest (*fifth generation*) dry-cleaning machines use state-of-the-art technology. The machine incorporates both the refrigeration system and the carbon adsorption system to recover PCE. In addition, it has an interlock system which ensures that the loading/unloading door cannot be open until the PCE concentration in the cylinder reaches below 290 ppm. It has been shown that the *fifth generation* machines can reduce worker exposure to PCE to below 5 ppm[viii, ix]

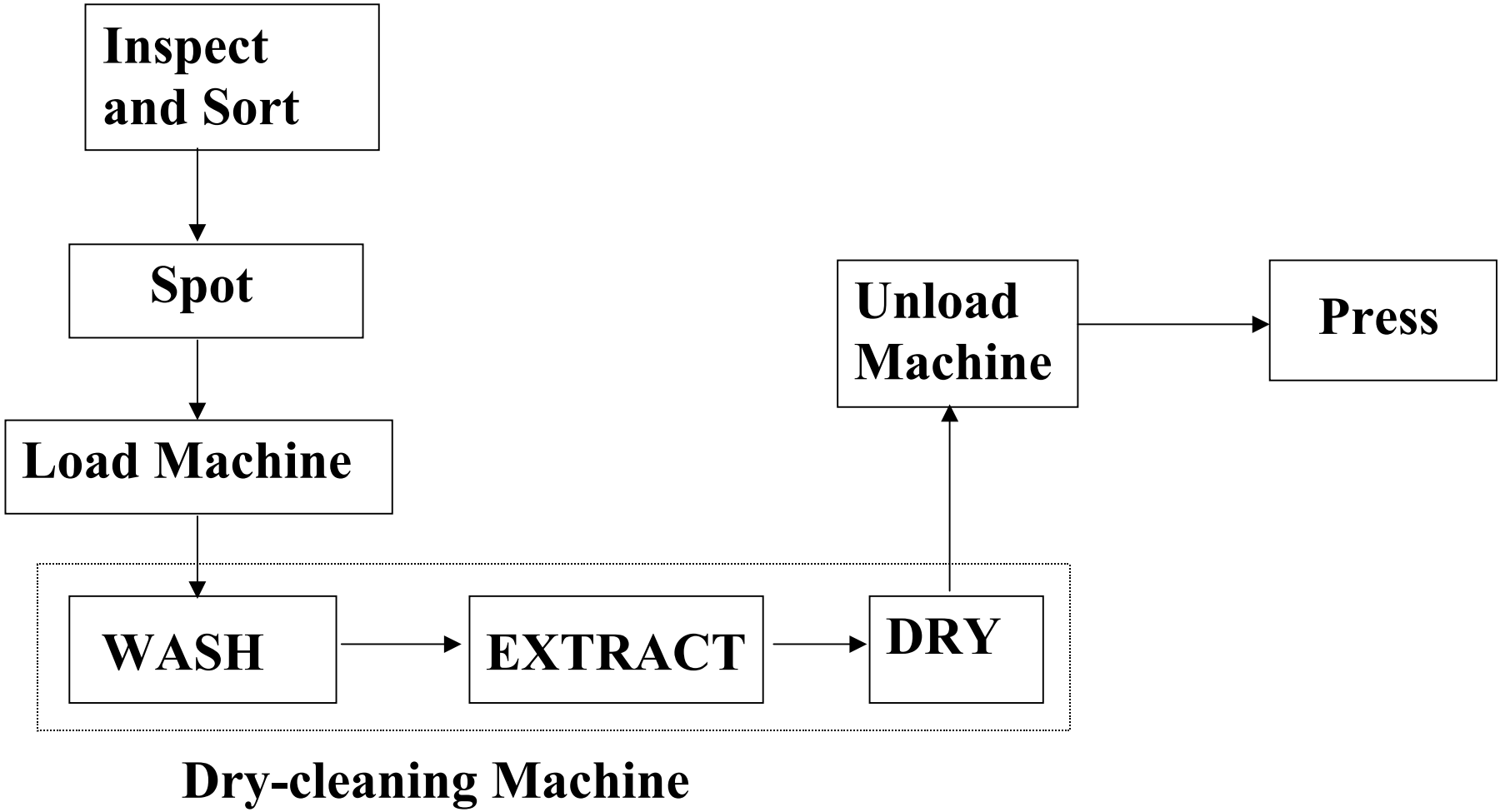
Ideally, the *fifth generation* machines should be used for dry-cleaning.

8.5. Solvent Usage Management

The use of PCE as solvent should be monitored regularly by keeping a weekly record of PCE usage for dry-cleaning. A simple form as given in Appendix 3 can be followed. The PCE usage indicator depends on several factors such as types of garment cleaned, machine load, and conditions of the machine. Any changes in the PCE usage indicator may indicate leaks in the dry-cleaning machines.

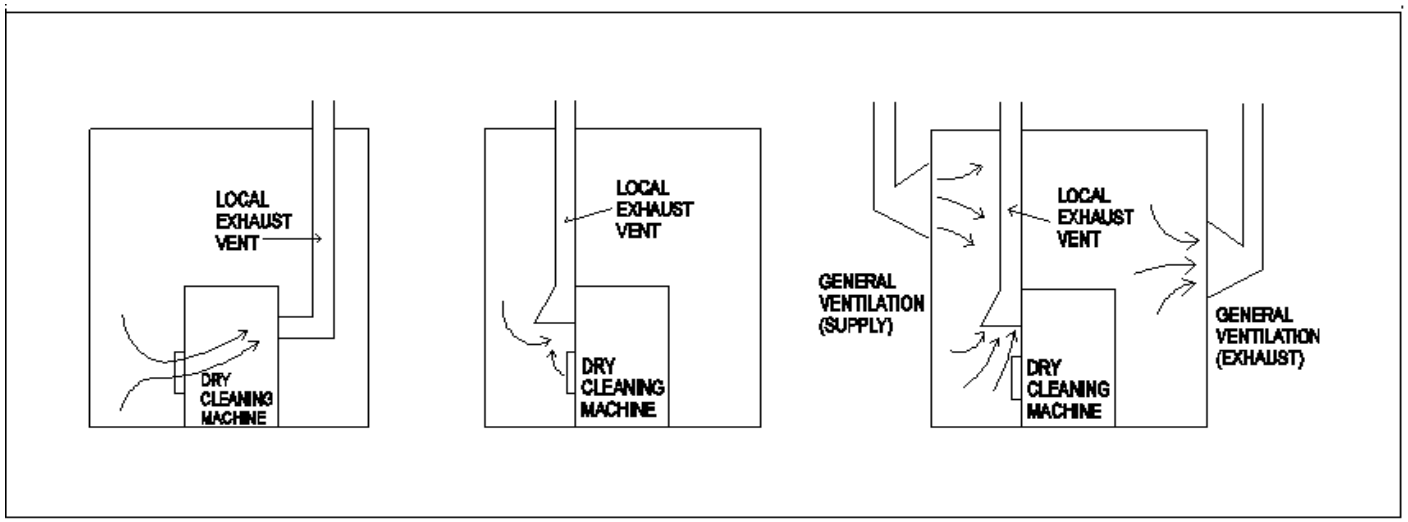
Appendix 1

Schematic Diagram of Dry-cleaning Process



Appendix 2

Diagram of Ventilation Systems



Appendix 3

SOLVENT USAGE MANAGEMENT

Period of assessment	Amount of PCE in machine at beginning of period (litres) (X)	Amount of PCE added to machine during the period (litres) (Y)	Amount of PCE in machine at end of period (litres) (Z)	Amount of PCE used during the period (litres) (C=X+Y-Z)	Weight of load processed during the period (kg) (W) *	PCE usage indicator for the period (kg/litre) (I=W/C)

Note:
For PCE solvent, 1 litre of PCE = 1.6 kg of PCE

* The weight of load processed during the period can be estimated as:

W (kg) = Number of loads processed during the period of assessment * Nominal load capacity of machine (kg)

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